EVALUATION OF PUBLIC PRIVATE PARTNERSHIP FOR INFRASTRUCTURE PROVISION

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By

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Certified that the Thesis entitled

"Evaluation of Public-Private Partnership for the infrastructure provision" submitted by me for the award of the Degree of Doctor of Philosophy in Arts at Jadavpur University is based upon my work carried out under the supervision of Professor Bidisha Chakraborty, Department of Economics, Jadavpur University. And that neither this thesis nor any part of it has been submitted before for any degree or diploma anywhere / elsewhere.

(Professor Bidisha Chakraborty)	(Bara Aman Appolinus)
Countersigned by the Supervisor	Candidate
Dated:	Dated:

Dedicated to

My spouse Vishal

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Chapter 1

Introduction and Literature Survey

Infrastructure is a pivotal wheel without which an economy cannot function. It promotes growth through the formation of capital, improves access to health care and education, accelerates regional and international trade and affects the demand and supply of every other sector of the economy by stimulating multiplier effects. According to Helm (2009), infrastructure is an indispensable part of our lives because it is not just the route to market through transport and communications but also the route for key factor inputs in the production process. A well-functioning network of infrastructure that includes, roadways, railways, airports, water, sewerage and sanitation, energy and electricity etc is the backbone for the economic functionality of an economy, therefore, an inadequate supply of infrastructure may lead the economies to decelerate in growth and development.

In the past, conventional public provision was the sole mode of the provision in the infrastructure and the government either made a direct state investment or chose a private player to build the infrastructure while procured it and retained the ownership. However, several inefficiencies were reported in the traditional provision, such as incidents of white elephants and corruption, congestion, deterioration of bad quality built infrastructure, scanty perennial underinvestment in maintenance, out-of-date technology used for the manufacturing and construction delays of infrastructure projects. Although the problem of short supply and poor quality of infrastructure is found to be severe in low-income countries, it is sizable in most middle-income countries (Briceno-Garmendia et al. (2004)). But, while the economies struggled with the infrastructure bottlenecks, the need for adequate good quality infrastructure for both the developed and developing nations never stopped growing.

To meet such enormous demand became impossible for the financing capacities of many governments. The governments then started to concentrate on pure public good and looked into the alternative ways in which impure public goods could be provided. The private players were also asked and encouraged to participate in the provision of infrastructure. Hence, the role of the state changed from producer to subsidy provider to the financier of the partial cost of production. The complete privatization and Public-Private Partnership (PPP) were increasingly adopted by the nations around the world and their nature of investment differed based on the characteristic such as ownership entitlement, bundling/unbundling of public goods and the interaction between private players and public entities. But, private decision-making does not fully reflect the entire benefit of infrastructure projects since the private sector is known to under provide non-rival services. Here, comes the role of government intervention in the provision of infrastructure, which is also true for the PPP mode of provision. Though the role of the government has shrunk from being the producer to being the financier of partial cost of the infrastructure in the case of PPP mode of provision, the shrunken role of the government does not mean that role of government in the infrastructure provision has become any less important. Infrastructure is a genuine public-policy issue, which requires long-term planning regardless of how it is ultimately financed.

1.1 Public private partnership (PPP) in the infrastructure provision

A PPP is defined by Maskin and Tirole (2008) as a long-term development and service contract between the government and a private partner. In a PPP, the government typically engages its private partner both to develop the project and to operate and service it. The partner may bear the substantial risk and even raise private finance. The revenue of the project comes from some combination of government payments and user fees. In real life, there are several PPP contracts such as Build-Operate-Transfer (BOT), Build-Own-Operate-

Transfer (BOOT), Design-Build-Finance-Operate (DBFO) and Design-Construct-Maintain-Finance (DCMF) etc. In a PPP project some form of subsidy or monetary support is provided to the private infrastructure firm by the government, also known as Viability Gap Funding and the Special Purpose Vehicle. VGF is a special form of government's capital grant to the infrastructure–manufacturing firm for the construction of the infrastructure projects. According to Bagal (2008), the mechanism of VGF (Viability Gap Funding) seeks to fill the gap between the expected rate of return and actual return of the investors through a capital grant and ensures a reasonable rate of return for the project. It is plausible that VGF could be an important fiscal policy instrument in the infrastructure sector influencing the growth rates for the nations adopting PPP projects. In a PPP, when the franchise ends after the revenue generated by the private firm in 20-30 years, the infrastructure capital reverts to the government. In the case of the PPP mode of provision, the government remains the important decision-maker in infrastructure finance, long-term planning, generation of infrastructure-related investment climate, and the role of public and international players in developing countries. Sometimes, a private firm partakes in a PPP only if it receives a guarantee from the government (in form of subsidy or advance payment) that their investment will pay off. Such support from the government provides a shield to a private firm against lower than expected demand of the project use and higher than anticipated costs of the contract due to project delay, inflation, white elephants, etc. Many instances of project cancellations and renegotiations have been reported in the PPP. When this happens, the advantages of PPP disappear because they are usually detrimental to the taxpayers and the users who pay for it.

1.2Literature in the infrastructure provision by PPP mode

Very few papers have studied the PPP mode of the provision in the literature of infrastructure provision. To name a few, Sadka (2007) highlights the advantages and disadvantages of PPPs from the public economic perspective in his paper. He discussed the role of Pigouvian taxes and found that toll (the price of public services) is set at a higher than the efficient level upon the transfer of the infrastructure facility to the government at the end of the partnership and according to him, the price of public services under PPP covers more than all the economic costs of the project. Murphy (2008) gives the 'for and against views' regarding the applicability of PPP. He concludes, the PPP are neither inherently good nor bad but the key to performance lies in effective implementation and accountability of public objectives. It was also noted in Murphy (2008) that not all the projects are ideally suited to a PPP but if it does, then key threshold levels are met and it argues strongly for the efficiency and effectiveness of the PPP model. According to Engel et al. (2013), the PPPs should be favoured only when they lead to efficiency gains. And they noted that PPPs are more close to traditional pure public provision than to private provision because the public funds are not released due to the subsidy or cash transfer (also known as VGF) to the infrastructure manufacturing firm even when a PPP project is financed by the user fees.

A comparative study between the PPP mode and traditional mode in the infrastructure provision was made by a few authors. For example, Bennett and Iossa (2006) compared private ownership with bundling contracts (known as the Private Finance Initiative) and unbundling of contracts (known as the traditional procurement) in their paper. In the United Kingdom, Private Finance Initiative (PFI) is a form of PPP. Bennet and Iossa (2006) found that PFI may not be optimal if the externality is negative and weak, then rather TP should be preferred. They also point out that the mere existence of market failure does not necessarily justify TP. According to them, the bundled provision is more likely to be preferred with the positive externality if stronger is the effects that innovations in bundling bring on the residual market value of facilities and also if it is higher than the benefits from the provision of the public service. According to Besley and Ghatak (2001), for the optimal provision of public goods, the party who values the benefits of it most highly should hold the ownership right and the mere existence of market failure does not necessarily justify the government provision of a public good. For that matter, NGOs would deliver high-quality facilities with cost-efficient projects because of their religious or ideological orientation. According to Iossa and Martimort (2015), innate quality of the infrastructure can be provided through the PPP mode through the bundling of different phases of the infrastructure provision because PPP incentivizes investors to invest more in the asset quality as compared to the traditional procurement. Also, Lee et al. (2018) gave credit to the structural and functional features of the PPP mode of provision for attaining high-quality infrastructure services and efficiency gains over the traditional procurement. According to them, the infrastructure-growth link becomes stronger due to the better maintenance and delivery of infrastructure services on time and within budget in the case of PPP projects. Engel et al. (2013) noted in their paper that PPP is closer to the conventional public provision of infrastructure than it is to the privatization because the government's exchequer is not completely relieved even with the participation of private investors for the provision of infrastructure. But, the paper discussed above analysed the PPP mode of provision through the microeconomic framework and none of them analysed the macroeconomic problems encountered in the PPP provision of infrastructure.

1.3Excludability of public good

A pure public good is non-rival and non-excludable by its nature and is provided free of charge by the government. But, the public good provided under the PPP mode is an impure public good that is excludable by its nature. The provision of non-rival but excludable impure public goods has garnered the attention of the authors with mixed reactions. According to

Sanchez-Robles (1998), the imposition of user fees in highways could endow public officials with quasi-market guidance on how a particular facility is valued by the citizens, hence contributing to higher levels of efficiency. According to Patel and Bhattacharya (2010), toll rates should be charged at marginal costs, so that usage of infrastructure services from PPP provision can be encouraged. Although they considered tolls to be a proxy of congestion charge but were unconvinced about the commercial viability of the PPP project because of the user charges. Dasgupta (1999) pointed out that the pricing of infrastructural services may be inefficient. Thus, according to him, the dilemma may arise for the developing countries who would like to recast the public provision of infrastructure in the mould of a privately supplied good. Further, he elaborated that the non-competitive behaviour by the conventional provision of public goods does not satisfy the marginal conditions and in a market economy, Samuelsonian conditions necessary for an efficient allocation of public goods cannot be fulfilled. Dasgupta (2001) modelled the optimal infrastructure pricing in a growing economy, such that under certain conditions, any pareto-optimal allocation of resources is achievable as a Lindahl equilibrium, rather than a competitive equilibrium. According to him, the pricing scheme not only leads to an optimal valuation of infrastructure and private capital but also leads to the optimal allocation of resources. The paper also addressed the question of Lindahl prices and well-defined subsidies that induces the agents to satisfy the right marginal conditions based on their private optimization exercises, thereby leading the economy to its socially optimal steady growth path. Thus, he analysed the allocation efficiency in a price-subsidy scheme of a competitive economy that gave first best growth path and also computed the rate of return to the government from its investment in infrastructure at the chosen prices which is found to be the same as the rate of return on private capital, suggesting necessary (sine qua non) condition for the social optimality of investment project. However, market-friendly policies in the provision of infrastructure have been adopted enthusiastically by developed and developing nations, both, and therefore it is important to study the excludable impure public goods.

A rich literature has been found that explains the infrastructure-growth nexus in the endogenous growth theory dealing with the traditional public provision, starting with the celebrated paper, Barro (1990).

1.4 Infrastructure-growth nexus and public provision in the endogenous growth theories

In Barro (1990), it is assumed that the government does not own capital; rather, it buys a flow of output (e.g. services of highways, sewers, etc) from the private sector, and these types of public goods were paid for and were made available to households. He showed how the presence of a flow of public services as an input in the production of the final good can affect long-run growth and welfare. Barro (1990) showed in his model that growth and welfare maximization were equivalent goals and the growth-maximizing tax rate was equal to the elasticity of output to public capital. Barro's main theoretical prediction showed that an increase in government expenditures on infrastructure was associated with higher long-run growth rates and an increase in resources devoted to non-productive government consumption was associated with lower per-capita growth. On contrary, Greiner and Hanusch (1998) found different results than Barro (1990). In Greiner and Hanusch (1998), the maximization of economic growth was not equivalent to welfare maximization and an income tax rate exceeding to growth maximizing tax rate yielded higher welfare. According to the latter, a fiscal policy that involves a reallocation of public resources from non-productive to productive uses or a reallocation of private resources from consumption to investment always raises the balanced growth rate. Barro (1990) has been extended by several authors in the literature of public provision and endogenous growth theories, like

Mourmouras and Lee (1999). According to them, an increase in the government spending on infrastructure are associated with higher long-run growth rates; however, this rise in the growth rate is reversed after a point (the hump-shaped Barro curve), showing that there is an optimum value for public investment. Thus, in Mourmouras and Lee (1999), the growth maximizing level of government expenditure was given by the Barro rule. It was noted by Turnvosky and Fischer (1995) that a permanent increase in government expenditure gives rise to an increasing level of instantaneous utility over time and the long-run accumulation of infrastructure capital leading to welfare gains through the output growth. According to Engen and Skinner (1992), the government plays a central role in economic development by providing public goods and infrastructure. They integrated the effects of government spending and the distortionary effects of taxation in a model of output growth and found that government spending has a strong negative effect on private productivity.

However, maximizing the country's economic growth does not necessarily maximize the welfare of the people therefore comparison of the growth-maximizing tax rate with the welfare-maximizing tax rate has been dealt with, in the growth literature extensively and it is also important for a social planner for policy prescription. In Dasgupta (1999), the command economy growth rate was found to be higher than the market economy growth rate for all values of the tax rate. In Futagami et al. (1993), the welfare-maximizing tax rate was found to be lower than the growth-maximizing tax rate and a decrease in the tax rate that maximized economic growth improved social welfare but, they included the investment subsidy and lump-sum transfers in their study. In sharp contrast to the above papers, it was found in Turnovsky (1996) and Tsoukis and Miller (2003) that the growth-maximizing level of public expenditure was higher than the welfare-maximizing growth rate. In Turnovsky (1996) it was noted that, as long as government adjustment costs are responsive to productive government expenditure, the welfare-maximizing level would be less than the growth-maximizing level. And in Tsoukis and Miller (2003) it was found that the fiscal policy had a growth-promoting effect and the growth-maximising rate of tax and/or public expenditure was non-zero. Since the welfare-maximizing tax rate was found to be lower than the growth-maximizing tax rate, the growth-maximising level of government expenditure exceeded the welfare-maximising level. A similar result was found for Ghosh and Mourmouras (2002) upon extension of Barro (1990) model to the finite horizon in a two-country framework. Greiner (1998) also extended Barro (1990) with income taxation and integrated lump-sum transfers and found that on setting the lump-sum transfer ratio, the growth rate of the competitive economy equalled the growth rate of the social optimum.

Some literature has focused mainly on the resource allocation between the productive public goods, the public consumption goods (also known as unproductive public goods) and the private components which affect the growth of the economy in the long run. According to Khan and Kumar (1997), public investment in infrastructure may increase the productivity of private capital or may also crowd out private investment and may hurt growth. They suggested that for the policymakers, the total level of investment should not only matter but on how it is split between its public and private components. According to Devarajan et al. (1996), the composition of public expenditure affects a country's growth rate. While the size of government is a public-choice issue, its composition of public expenditure between the 'productive public spending' and 'unproductive public spending' is open to policy discussion, because it can improve its economic performance and growth by changing the mix between the two. They found that higher distortionary taxes are needed to finance a higher level of government spending and the steady-state growth rate will increase only if the productivity of government expenditure exceeds the deadweight loss associated with the taxes required for its' financing. According to Ghosh and Roy (2004), the growth rate depends on the apportionment of tax revenues between the accumulation of public capital and the provision of public services. Public capital means roads, railways, airports etc which are non-rival and non-excludable but involves time lag and can be accumulated. In their paper, public services mean maintenance of infrastructure networks, maintenance of law and order, etc which has an immediate effect and cannot be accumulated. However, the literature highlights the 'public goods-growth nexus' and not the impure public goods that are a reality today in infrastructure provision. The relationship between infrastructure and growth depends on the production structure of the public good. In the next section, we'll discuss the production structure of infrastructure as a public good.

1.5 Production structure of infrastructure as a public good

In the endogenous growth literature concerning the provision of infrastructure, different authors have considered the different relationships between public capital and private capital when infrastructure production requires both kinds of capital. The relationship between private goods and public goods may be complementary or substitutes in nature as reflected in some of the pioneering works such as Turnovsky and Fischer (1995), Blejer and Khan (1984), Irmen and Kuehnel (2008), Khan and Kumar (1997), Tsoukis and Miller (2003), Bucci and Bo (2012), Fischer and Turnovsky (1998) etc. The production structure may also differ according to the assumed nature of the infrastructure goods. And infrastructure goods may have been assumed to be a stock variable or a flow variable.

1.5.1 Varying degree of substitutability between public capital and private capital

Most of the papers in the endogenous growth theory dealing with infrastructure as public goods are of the view that complementary relation between public goods and private goods may generate better growth performance as compared to the substitute case. Complementarity between the public and private investment in infrastructure can be viewed as the positive effect on the decision of private agents to increase their stock of physical capital to supply more public infrastructure capital. According to Blejer and Khan (1984), if the provision of public goods is complementary to private investment then it raises the productivity of capital and demand for inputs. They noted that the complementarity implies a faster response of private investment but if public and private investment are substitutes then the coefficient of adjustment of private investment becomes smaller as the rate of public investment increases. Khan and Kumar (1997) are of the view that some components of public investment may be complementary to private investment and so would be beneficial for growth, while others may be substitutes and may have a less positive, or even negative effect on growth. They also noted that complementarity may arise in the case of public investment in infrastructure which increases the marginal product of private capital, which is most likely to be true for the capital goods industries and for those developing countries where the existing stock of infrastructure capital is inadequate. If public goods and services compete directly with the private sector, the two forms of investment become substitutes. While, Serven and Solimavo (1992), Erden and Holcombe (2006) specifically argue that private goods and public goods are complementary in the production function and complementarity crowds-out private investment. Mourmouras and Lee (1999) argue that private inputs cannot be a close substitute for public inputs.

Some authors have studied the relationship between private and public capital by including the effect of a change in the degree of complementarity/substitutability between private and public capital investments on the growth rate of real per capita income, congestion and subsidy, etc. Bucci and Bo (2012) find that technological parameter measuring the degree of complementarity/substitutability between private and public investments has no effect on the growth but influences the fraction of public capital that is used in the production of the final output. According to them, the greater the complementarity between private and public capital investments, the larger and more positive the effect that an increase in private capital accumulation has on public capital investment and, hence, on the optimal growth rate of the economy. With the exogenous allocation of public capital to final output-production, they found that irrespective of the shape of the aggregate technology for goods production, the main determinant of optimal growth is the level of complementarity/substitutability between private and public capital investments (with a higher complementarity being conducive to higher growth). According to Fischer and Turnovsky (1998), in the absence of congestion a higher stock of public capital will lead to a higher stock of private capital if and only if the two factors are complements. In the presence of congestion, the effect involves a trade-off between the degree of substitution between private and public capital in production and the degree of congestion. According to Erden and Holcombe (2006), public investment may increase productivity indirectly by enhancing the productivity of private capital, because public infrastructure expenditures may be complementary to private investment. Public investment may also be a substitute for private investment when they both produce goods and services that are in direct competition in a marketplace and especially if public production is subsidized by the government. However, none of these papers studied the command economy problem or the optimality of the PPP mode of provision and the transitional dynamics of the complementary case and the substitute case.

1.5.2 Public goods are stock or flow within the production function

According to Irmen and Kuehnel (2008), government activity in the production of infrastructure can be treated either as a flow or as a stock. When the production of public goods is treated as stock or flow they might have a different outcome on the growth rate of the economy. Barro (1990) was the earliest of the papers that considered the public good to be a flow within the production function. Barro (1990) developed a model in which public services affected the long-run performance of an economy by entering into the production function of the final output, along with private capital. In Barro (1990), the public provision of infrastructure services included roads, airports, harbours, and sewer systems; or public expenditures on law and order, education, R&D etc. Futagami et al. (1993) extended Barro's (1990) paper, by treating public good to be a stock. They found that Barro (1990) result about optimal fiscal policy remained valid in the steady-state equilibrium even in the case of government services being proportional to the stock of public capital (rather than capital expenditure flows), but not in the development transition phase. Barro (1990) was also extended by Tanaka (2002) to the framework of an overlapping generation model while retreating the public services as flow variable then the growth-maximizing income tax rate was found to maximize utilities of not only the current generation but for all future generations. Tanaka (2002) concluded that changing the income tax rate according to the Barro rule would be Pareto-improving. Others have considered public goods to be a stock and the role of public capital accumulation in economic growth. By specifying public capital as a flow variable within the production function, the endogenous growth model considers only the newly established infrastructure capital such as roads or ports, which raise the level of private production, however, it does not include the previously accumulated infrastructure capital. Barro (1990) and Tanaka (2002) have considered the public services as a flow variable within the production function. While others, like, Futagami et al. (1993), Turnvosky and Fischer (1995), Cashin (1995), Dasgupta (1999) and Buci and Bo (2012) etc have considered the public capital to be a stock variable within the production function.

Cashin (1995), used the stock concept in the production of public capital in an endogenous growth setting to examine the influence of public finance variables, rather than the flow of government services. Dasgupta (1999) treated the infrastructure under the public provision as an accumulable stock. The non-rival and non-excludable public goods together with the help of privately supplied inputs were used for further accumulation of infrastructure. In a paper by Calderon and Serven (2010), robust evidence was found for an increase in the better quality and stock of infrastructure services, had a positive impact on the long-term growth and a negative impact on income inequality. Bucci and Bo (2012) also examined the role of productive government activity in the form of a stock variable on the long-run optimal growth.

Some papers have analysed both the stock and flow concept of public goods within the production function of the public goods. For example, Ghosh and Roy (2004) studied productive public spending through a production function that includes public capital and public services. According to them, the government's effect on an economy depends not only on the tax rate but also on the apportionment of tax revenues between the provision of public services and the accumulation of public capital. In Jones and Manuelli (1997), a composite factor was part stock and part flow affecting the optimal taxation. The optimal tax rate on capital income-a stock-was found to be zero in the long run, while the optimal tax rate on labour-a pure flow-was found to be positive. Tsoukis and Miller (2003) examined the optimal tax/spending rate and its allocation between flow expenditures (such as payment of salaries in education, health and justice) and public investment as a stock to boost infrastructure in the same sector. They used the Barro rule (optimal tax rate is equal to the output elasticity of public capital) to maximize steady-state growth and also applied it in a framework where public services are derived from both public capital and flow services. Yet another paper by Turnvosky and Fischer (1995) makes a clear distinction between stock and flow. According to them, the current flows of government consumption and infrastructure expenditure, rather than the services of the existing stocks of government consumption and infrastructure generates additions to utility and production. But, many utility-enhancing public goods such as national parks and production-enhancing public goods such as roads are likely to affect the economy through their accumulated stocks, rather than their current flows.

To boost infrastructure investment, the government has relied on public debt along with tax because the infrastructure is so important for growth. Traditionally the government has been the sole financier under the traditional public provision of infrastructure. In the past, the developing countries have also asked for external assistance from foreign funding institutions, such as IMF and the world bank or external borrowing from the developed countries to build their infrastructure capital. Several papers study the balanced budget and deficit financing for the pure public provision in the endogenous growth literature. Given the mode of financing, the government has to tailor its budgetary and fiscal policy, so that a balanced budget or sustainable deficit financing is availed. Since the public fund is not released completely even with the PPP mode of provision, the study of a balanced budget and deficit financing in the case of PPP is all the more important.

1.6 Financing of public provision of infrastructure

The infrastructure investment, no matter the mode in which it is provided, is a costly affair because it involves heavy sunk cost at the initial stage of inception and during the entire life of the infrastructure project maintenance and operational cost is required. Given this, designing the best policy for financing the infrastructure is a challenge for the government.

1.6.1 Balanced budget in the provision of infrastructure

There are many papers, which have analysed the balanced budget. Barro (1990) assumed that the optimal tax rate was constant over time in an AK model, such that he was able to obtain a result of maximizing the growth rate of the economy to be equivalent to maximizing social welfare. In Futagami et al. (1993) public investment was financed by a flat-rate income tax in a balanced budget. They found that when the tax rate was time-variant, the welfare-maximizing policy was not equivalent to maximizing the growth rate of the economy. In Dasgupta (1999), the public sector accumulated the infrastructure and charged user fees for its services not to maximize profit but to provide the infrastructure. The infrastructure capital is publicly provided with the help of taxation from capital income and user fees received for infrastructure services. He found that the equilibrium value of the infrastructure price falls as the tax rate rises and there exists a tax rate for which the market equilibrium rate of growth is the same as that of the command economy and the latter attains higher welfare than the market economy for all values of the tax rate. According to Angen and Skinner (1992), by following a balanced budget fiscal policy with the distortionary effect of taxation and inefficient government spending, the government suffocated the dynamic economic growth because of the negative impact on the output growth. In Greiner and Hanusch (1998), the government ran a balanced budget at any point in time, such that income tax collected was equal to the public investment in infrastructure, investment subsidy and transfer payments. If the government chose an investment subsidy smaller than the growth maximizing rate, then a reallocation of private resources from investment to consumption would lead to a higher level of initial consumption tending to increase welfare. It was also found that the rise in the transfer payments reduced the balanced growth rate and a reallocation of public resources from non-productive to productive uses raised the balanced growth rate.

However, in reality, the public expenditure is financed mainly by fiscal deficit and not tax revenue. Several papers have analysed the fiscal deficit and infrastructure investment in the endogenous growth models.

1.6.2 Fiscal deficit in the provision of infrastructure

Public debt is a basic instrument to raise funds for public investment. Compared with balanced budget rules, borrowing rules transfer the burden of the public debt to future generations because the provision of public goods can be temporally dissociated from the taxation process required to fund it. Government borrowing is potentially popular because they allow higher levels of government spending and lower levels of taxation. Substantial pieces of literature have extensively analysed fiscal deficit financing for the public provision of infrastructure. There are some studies, which shows that the fiscal deficit and growth are self-reinforcing. In Futagami et al. (2008), if the government increases the debt financing for productive input, then the growth rate reduces the high-growth equilibrium but increases the low-growth equilibrium. And if the government increases the tax rate then the growth rate decreases in the low-growth equilibrium but maximizes the growth rate in the high-growth equilibrium like Barro (1990). It was suggested that less developed countries would do better by borrowing rather than tax finance to raise the growth rate and on the contrary, the developed countries should use tax finance rather than bond financing. In Ueshina (2018), public investment was fully financed by public debt and the tax revenue of the government was used only for the payment of interest because government expenditure consisted of public investment and the payment of interest on public debt. The growth-maximizing tax rate was found to be equal to the elasticity of output to public capital and exceeded the welfare-maximizing tax rate, even when the debt-financed public investment took place. Therefore, the tax rate maximizing the economic growth was the same regardless of the means of finance. And an increase in tax rate yielded a higher ratio of public debt to private capital, and so the consumption ratio may rise even when the tax rate exceeds the elasticity of output to public capital. According to Groneck (2010), a positive fixed deficit regime does not affect the growth rate but the golden rule of public finance has a positive effect on the growth rate and the highest welfare. According to him, the welfare effects were found to be highly dependent on the intertemporal elasticity of substitution and economies with households having a strong tendency to smooth consumption should maintain a balanced budget from a welfare point of view.

Some authors while discussing the financing of public investment by public debt asserted the importance of well-defined budgetary regimes to which the government must stick. Ghosh and Mourmouras (2004(a)) extended Barro's paper by including deficit financing. They found that the rate of interest was lower under the golden rule of public finance (GRPF) as compared to standard dynamic government budget constraint (DGBC) where public borrowing was allowed for all kinds of public spending, therefore, the welfare-maximizing ratio of public spending to GDP in the GRPF regime was lower than standard DGBC. According to Ghosh and Mourmouras (2004(b)), the inefficiency associated with over-investment in public capital was lower under the GRPF than under the DGBC, because of the constraint imposed on minimum productive public spending. But the welfare-maximizing ratio of public capital to private capital in the GRPF regime was found to be lower than in the DGBC regime because a higher ratio of current spending (including interest payments) to total taxes was associated with higher taxes and crowded out productive investment by more than with a lower ratio. A less strict budgetary policy lowers the steady-state welfare because of the smaller ratio of public capital to private capital and a lower interest rate. Brauninger (2005) analyzed the effect of the fixed deficit ratio or the tax rate on the growth in an overlapping generation model. According to him, capital growth and public debt growth, both, depended on the deficit ratio and the debt-capital ratio. Both capital growth and public debt growth stayed constant if the debt-capital ratio was constant. Also, there was a critical deficit ratio below which the debt-capital ratio reached the stable steady-state but capital growth and public growth rate were found to be lower. When the deficit ratio exceeded the critical level, then no steady state was obtained and the debt-capital ratio increased continuously. As a result, capital and output growth declined continuously and after some point in time became negative, resulting in zero capital and output in the long run. Therefore, an increase in deficit financing led to lower growth and a higher debt-capital ratio. However, a stable steady-state growth rate was found for a fixed deficit regime and a fixed deficit ratio was feasible but a fixed tax rate was not sustainable. Greiner and Semmler (2000) highlighted the feedback effects of the higher level of public debt. According to them, the government could generate positive growth effects of a deficit-financed public investment by following a less restrictive budgetary policy but it may have caused a higher ratio of public debt to private capital which probably would compensate for the positive direct effect of lesser interest payments to be financed out of the tax revenue so that the economy may end up with lower but positive economic growth. Hence, a less restrictive budgetary regime implied a lower part of tax revenue that goes towards the payment of debt interest held only if the ratio of public debt to private capital was held constant. Also, it was noted by them that applying a less restrictive budgetary regime for a positive balanced growth rate to the GRPF required that only a certain part of debt payments for productive government spending must be financed out of the tax revenue and when a less restrictive budgetary regime was applied to a regime where a certain part of the interest payment on public debt was paid out by both tax revenue and by issuing new bonds, then either a higher or lower balanced growth rate may be obtained. However, for the non-productive government spending such as public consumption and transfer payments to households when financed only from tax revenue and when productive public spending is financed from public debt then a positive balanced growth rate is obtained only for extremely high values of the instantaneous elasticity of substitution.

If the volume of the debt relative to GDP becomes too large after some point in time, then the country may find itself on a path to insolvency. If the present value of future non-interest government outlays exceeds the present value of future tax receipts, then the debt cannot be repaid. If the levels of public debt are persistently high then it will not only drive down capital accumulation, productivity growth and long-term potential growth but also the mobilization of government revenues for new investment projects may become difficult. Further, if the borrowing is pushed beyond the carrying capacity of an economy, it may create problems of intergenerational equity undermining growth. Some authors have discussed the problem of the sustainability of public debt. American Economist, Martin S. Feldstein made a remark on fiscal deficits, comparing it with obesity at L.K. Jha Memorial Lecture, Reserve Bank of India in Mumbai, India held on 12 January 2004. While addressing a public lecture he said, “You can see your weight rising on the scale and notice that your clothing size is increasing, but there is no sense of urgency in dealing with the problem. That is, so even though the long-term consequences of being overweight include an increased risk of a sudden heart attack as well as of various chronic conditions like diabetes. Like obesity, government deficits are the result of too much self-indulgent living as the government spends more than it collects taxes. The appropriate size of the national debt, like the ideal weight for an individual, is a complex question, but basic common sense tells us that the ratio of debt to GDP should not be allowed to rise year after year." Yet, no matter what the purpose for which the borrowing has to be done to finance the public expenditure to increase social welfare and to promote economic growth. The issue of macro-economic stability is linked to the sustainability of fiscal deficit in terms of its implications for debt burden, interest rate, etc and debt accumulation has a detrimental and causal effect on GDP growth. Reducing non-interest outlays or non-productive public spending is always politically difficult but it is not impossible. Fortunately, what matters is not the absolute level of government outlays but the ratio of outlays to GDP. Reducing the interest rate on the government debt is another way to reduce the budget deficit and the equilibrium ratio of debt to GDP. Growth makes deficit less harmful and therefore good fiscal management is one of the strongest arguments for a policy of low and stable fiscal deficits. In recent years, governments have been employing a greater degree of various fiscal rules to limit deficits or debt accumulation for the public expenditure for infrastructure provision.

Greiner has extensively discussed the issue of the sustainability of public debt. In Greiner (2007), it was noted that high debt ratios of the Euro-area countries were corrected by increasing the primary surplus ratios, which was achieved by a decline in public spending. Greiner assumed that the primary surplus of the government was a positive linear function of the ratio of public debt to GDP, which guaranteed that the intertemporal budget constraint of the government is fulfilled and guaranteed the sustainability of public debt because of the increase in primary surplus with the public debt growth. Greiner (2008) made a comparative study of a balanced budget scenario, a scenario where public debt grew at a smaller rate than other variables and a scenario where public debt grew at the same rate as all the other variables. It was found that for the scenario when public debt grew at a smaller rate than consumption, capital and output growth rate, the welfare was higher as compared to the balanced budget and also a scenario when public debt grew at the same rate as capital and output yielded smallest growth and welfare as compared to the other two scenarios. Also, it was noted by Greiner (2008) that if debt ratios declined over time instead of remaining constant, it would benefit the economies. Greiner (2008) was further extended by Greiner (2010). It was found in Greiner (2010) that the public deficit is saddle-point stable if and only if the reaction of the government was sufficiently strong for higher public debt. It implies that the government must increase its' primary surplus sufficiently as public debt rises, otherwise, the economy would be unstable implying that the government could not fulfil its inter-temporal budget constraint. According to him, a fiscal policy where the debt ratio increases less than the GDP growth will reduce the debt to GDP ratio and it may lead to higher welfare than any other budget rule like the balanced budget or a situation where the debt grows at the same rate as GDP. According to Greiner (2012), a guarantee for solvency to higher public debt today must be accompanied by an increase of future primary surpluses of the government. The primary surplus could be achieved by either higher taxes, reduction of public spending resulting from a rise in GDP. But, they found a crucial difference in the balanced growth rate due to the adoption of these two methods for obtaining primary surplus. When the government reduces the public spending in response to large public debt, the long-run growth rate is smaller, but when the government reduces the lump-sum transfer, which acts as a lump-sum tax, it does not affect the balanced growth rate. Fincke and Greiner (2012) applied the Bohn test and found in an empirical result that Netherlands, Germany, Portugal, Austria, France and Italy have either followed a sustainable debt policy, such that rising debt ratios led to higher primary surplus relative to GDP exerting a tendency towards mean reversion. In Greiner (2014), the primary surplus does not depend on the current period but on the past public debt that has accumulated over the years with exponentially declining weights put on debt further back in time. According to him, the history of government debt results in a continuous rise in public debt or decline of public debt in the past is a decisive factor for government's budget plans. It was found that balanced budget rule gives a stable balanced growth path (BGP) only if the reaction of the government to higher public debt is sufficiently strong but for the permanent deficit case, the existence of a BGP cannot be guaranteed and if it exists, then it depends on whether the government puts high weight on the stabilization of the past cumulated public debt or the reaction of the primary surplus to higher public debt is sufficiently strong or not. In Greiner (2015), a balanced budget scenario gave a higher balanced growth compared to a permanent deficit scenario because public resources were not required for the unproductive interest payments and debt service. And with an increase in public debt, the primary surplus rose such that multiple balanced growth rates occurred, giving rise to an underdevelopment trap and the economy converged to a low growth path in the long run if the initial debt to GDP ratio exceeded a certain critical threshold. And a deficit-financed rise of productive public spending under the golden rule of public finance led to higher long-run growth if and only if the balanced growth rate was smaller than a certain critical value.

Other than Greiner, there are few others, who have dealt with the issue of sustainability of public debt, namely, Kamiguchi and Tamai (2012) and Ostry et al. (2015). According to Kamaiguchi and Tamai (2012), the government imposes a flat income tax and issues public debt under the assumption of the primary surplus rule. They use a subjective discount rate to set the debt to GDP ratio to maximize the balanced growth rate. When the feedback effect of public debt is higher than the discount rate, the growth-maximizing long-run debt to GDP is set to zero and the growth maximizing tax rate is set to the output elasticity of public input, such that Barro's rule holds. But when the feedback effect of public debt is lower than the discount rate then the growth-maximizing policy differs from Barro's tax rule and in such a case the balanced growth path cannot be attained. According to Ostry et al. (2015), high public debt must be reduced and the methods adopted to reduce high public debt depends very much on the availability of fiscal space, therefore no one-size-fits-all method is applicable for all economies. According to them, when an economy runs out of fiscal space (means the sources of public financing is exhausted), the optimal policy would be to pay down the debt immediately but it will come with a cost of high taxation, for the economy which has ample fiscal space, the debt should be paid gradually and should be reduced organically through growth. Lastly, for the economy with positive fiscal space but salient sovereign risk, it will be optimal for the economy to live forever with high debt. Yet, none of these papers analysed the fiscal problems in the context of PPP provision of infrastructure.

Over the years, the governments have relied heavily on taxation and deficit financing, yet they have not been able to settle the shortage in the infrastructure capital of their countries. In response to deficiency of infrastructure capital, mounting interest payment on public debt and the need for more infrastructure for the growth and development, the governments have been forced to seek foreign assistance, such as foreign aid, foreign debt and foreign direct investment and public-private partnership for the provision of infrastructure.

1.7 Foreign assistance in the provision of infrastructure

According to Lin and Sosin (2001), foreign debt has both cost and benefit. The debtor country which has foreign borrowing can raise the efficiency of the production process because of the diffusion of the superior technology from developed countries to the developing countries and thus debtor country may increase public spending and stimulate economic growth if the interest rate on foreign debt is not high. On the contrary, if the foreign debt is high then the debt repayment will take a toll on the future capital stock and economic growth. According to Germaschewski (2016), if the government of the developing country borrows from the international capital market to finance the infrastructure provision, then it might temporarily resolve the government's financing difficulty in the infrastructure investment. But, if the accumulation of foreign debt increases, then a large portion of the domestic output gains may be required to repay the interest on foreign borrowing, thus leading to a smaller increase in consumption and a decrease in the demand for domestic currency. Thus, Germaschewski (2016) also agrees with Lin and Sosin (2001) that if a larger portion of accumulated foreign capital is used for external debt servicing, then investment and growth will be adversely affected. However, barring Germaschewski (2016) the above-mentioned papers focused mainly on foreign debt and not FDI received in the infrastructure sector.

In recent years, FDI has been increasingly welcomed by the governments in the infrastructure sector of both developed and developing countries. FDI was defined by Luiz R. de Mello Jr. (1997) as a composite bundle of capital stocks, know-how and technology. Authors have different views regarding the effect of FDI on growth. According to Mello Jr. (1997), FDI was expected to have a growth-enhancing effect due to productivity spillovers to domestic firms and if the foreign investment had complementarity with the domestic investment of the developing countries, then FDI was sure to have a positive effect on growth. As it was noted by him that the complementarity between old and new FDI-related technologies in developing countries depend on the productivity and plant size differential in the host country. However, for the technologically advanced countries, rapid absorption of new FDI-embodied innovations takes place with faster obsolescence of older capital stocks and because of this substitution effect, the efficient firms replace inefficient firms and the degree of competition increases in the recipient country. Also, it was shown by Mello Jr. (1997) that countries that pursued export promotion policies had higher growth rates as compared to countries that promoted import substitution policies. Dasgupta and Shimomura (2006) studied the effect of free trade on the sustainable growth rate of a small open economy in the presence of infrastructure that acted as a vital input into the production process. They found that a policy of free trade with FDI was unambiguously superior to autarky or trade without FDI. Also, they found that the unique balanced growth equilibrium was saddle point stable and there was an unconditional rise in the rates of growth of aggregate private and aggregate public capital stocks, both, in the FDI recipient country. However, there are others, who have pointed out the negative effect of FDI on growth. According to Reis (2001), FDI increases growth but decreases welfare due to the transfer of capital returns to the foreign investors and foreign investment may crowd out a domestic investment with the degree of substitutability between foreign capital and domestic capital leading to immiserizing growth due to distortions. The foreign investment will increase welfare only if an increase in the productivity of the FDI-recipient country is greater than the profit forgone to the foreign investors. According to Samborskyi et al. (2020), foreign investment inflows are not always accompanied by advanced know-how. They argue that economic growth is reduced when part of the revenue from the production of infrastructure capital by foreign investors is repatriated and when foreign capital and domestic capital are substitutes to each other, displacement of domestic investment and increased dependence on foreign financing may take place. According to them, repatriation does not affect the stock of domestic capital and the level of consumption in the current period but reduces output and the level of consumption in the next period. But, they could not refuse to agree in line with the previous authors that FDI-induced growth is higher than domestic investment-induced growth when a comparison between domestic and foreign investment in infrastructure is made.

Germaschewski (2016) extends FDI in the infrastructure and growth literature, by including the case of public-private partnership for infrastructure provision in a dynamic general equilibrium open economy model. The paper by Germaschewski stands out remarkably different from the previous studies because when a foreign firm produces the infrastructure capital in the host country in a PPP framework, the government of the host country is not only eased off the financial burden but is also able to earn partial direct rent revenues, therefore leading to a crowding-in of the domestic private investment as a result. Also, in this paper, it was found that the growth and welfare outcome of FDI in infrastructure through joint PPP with domestic private firms exceeds growth and welfare outcomes of all other domestic financing instruments such as lump-sum taxation, internal debt financing and external borrowing. In line with the previous studies, the efficiency and superior quality of foreign capital inflow yielded higher growth and welfare outcome and if production efficiency and quality of domestic firm were the same as the foreign firm then it resulted in inefficient outcomes, such as a significant rise in inflation and deterioration of fiscal imbalance. In the model, a foreign firm manufactured the entire infrastructure project, such that it made a positive profit and the domestic government covered the cost of maintenance of the depreciated capital and earned a partial percentage of rental revenues. It was noted that the distribution of the rental revenue also depended on the partner's bargaining power and low-income countries (LICs) suffered from weak bargaining power. This being the case, a larger portion of the rental revenue was captured by the foreign firm and LICs were able to retain only indirect revenues from the investment VATs, making inefficient concessions by giving up all the rents to the foreign firms.

Of all the efforts being taken to bridge the demand and supply gap of infrastructure and the financing issues in the infrastructure sector, the existence of corruption in the infrastructure sector makes infrastructure provision more problematic. According to Banerjee et al. (2006), a higher level of corruption is uniquely associated with infrastructure projects. Corruption is usually defined as the misuse of public office for the self-benefit and to use of the misappropriated public fund which had entered in the corrupt government officials' pocket for personal benefit. When corruption takes place in an infrastructure project funded by public money, it reduces productive public spending and allows for more illegal public spending by corrupt government officials and politicians. Corruption in the infrastructure sector may lead to a high tax rate, low private investment and low economic growth.

1.8 Corruption and the infrastructure provision

Corruption in infrastructure projects leads to a negative effect on growth due to the wasteful leakage of public funds and reduction of physical capital accumulation. Rioja (2003) studied the long-run consequences of ineffective infrastructure in a general-equilibrium framework. Loss of potential output in the case of infrastructure is critical for the countries with sufficiently low infrastructure and growth and welfare both decrease for these economies. He identified neglect of operation and maintenance and corruption at various levels of government as the main cause for inefficient infrastructure. Aghion et al. (2016) analyzed how corruption and government efficiency affect the relationship between taxation and growth. If corruption is high, then the government can attain a lower equilibrium and if both tax rate and corruption are high then it weakens any positive effect of taxation causing more distortions in an economy. According to them, the tax rate that maximizes economic growth also maximizes innovation for a given corruption level, but initial taxation benefits entrant firms more than the incumbent firms. But the tax rate that maximizes the entrant share is lower than the tax rate that maximizes growth. If corruption is salient or is further reduced, then the entrant share is maximized at all tax rates. D'agostino et al. (2016) studied the effect of corruption on military spending and public investment spending in an endogenous growth model and a strong negative effect of corruption on growth was found due to the budgetary distortions. According to Monte and Papagni (2001), the efficiency of public spending decreased due to bureaucratic corruption in a growth model. The public good is purchased by the government from the private producer and corruption arises from the asymmetric information between the government and private agent, who may provide the low-quality goods at the market price or may acquire the public good at a higher price thus lowering the amount and quality of the public infrastructure services supplied to the private sector. Thus, corruption has a direct negative effect on the long-run growth rate. In the theoretical model of Coppier et al. (2013), a nonlinear U-shaped relationship between the level of state monitoring and growth was found. They found that at the low level of state monitoring, the economy experienced widespread corruption and medium growth rate but surprisingly at the intermediate monitoring level with no corruption, the firms invested in the traditional sector and attained a lower profit and lower accumulation of capital leading to a slower growth rate. At high monitoring level, no corruption took place and high growth rates were observed. Tarhan (2008) studied the choice of the public spending behaviour of the government influenced by corruption in an endogenous growth model. A non-benevolent government chooses how much of the tax revenue is to be spent on the public goods and how much of it is to be expropriated depending on the weighted average of consumer's welfare and its own welfare from the expropriation of tax revenue. The benevolence of the government was determined by the weight on consumers' welfare. It was found that the non-benevolent government chose a higher public-to-private capital ratio as compared to a benevolent government. According to Tarhan, corruption cost the economy with high tax rates, lower investment by the private firms, high recorded public spending including corrupt spending and high public-to-private capital ratio. Mauro (2004) gave the concept of strategic complementarity in the corruption which implied that if one agent does something it becomes more profitable for another agent to follow suit. According to Mauro, the models involving strategic complementarity led to multiple equilibria such as a good equilibrium characterized by absolute no corruption, high investment rate, high growth rate and a bad equilibrium characterized by pervasive corruption, low investment, slow growth, unproductive transfer of resources and the low marginal product of capital. When people steal from the government, they base their decision not on the marginal product of working in legal activities but on the marginal product of stealing, thus it becomes more profitable for an individual to allocate more time in the rent-seeking than in the productive legal activities. And when the government steals from the people, an individual politician sets a higher bribe rate that shortens the other politicians time frame to remain in power, thus they will be more willing to obtain a bigger slice of cake today rather than waiting for tomorrow and thus this type of illegal activities involves grand corruption and not petty corruption. Barro (1990) also studied the self-interested government that had no electoral constraint and who maximized its utility and earned the net revenue but not by automatically balancing the budget. However, these literatures have not analysed the problem of corruption in the PPP mode of provision even though the corruption incentives are much stronger in the case of PPP projects.

Governments of the developing economies have tried to reduce wasteful public spending by inviting private players for the provision of infrastructure. However, to reap the benefit from the participation of private investors in the infrastructure sector, the role of institutions is of paramount importance. Banerjee et al. (2006) examined the role of the institutional environment which affected the infrastructure provided by a private entity in a developing country. An institutional power of good quality and strong regulatory capacity of the government used for controlling corruption is known to play an important role in attracting investment by private players. But, on the contrary, it was found in their papers that corrupt markets with higher levels of corruption led to more private participation of investors in the infrastructure. Valero (2015) studied the impact of corruption in a contractual arrangement of PPP provision of infrastructure in a microeconomic framework. He made a comparative study of the cost efficiency of PPP and the cost efficiency of traditional procurement. In traditional procurement, the building of public infrastructure and delivery of the infrastructure services are contracted differently, but in the PPP, a single contract takes care of both, through bundling. Bundling of both activities lowers the cost of service provision and thus it increases the efficiency of infrastructure provision. Thus, PPP can deliver better results in terms of cost-efficiency than traditional procurement, but the government's opportunism diminishes the cost-benefit efficiency of PPP because of the weak institutional framework. It was noted by Valero that the benefit of long-term management of PPP would be fully realized only if the government commitment to the long-term contractual agreement in part of the government was high and it did not behave opportunistically. It might also happen that an inefficient firm would win the franchise by underbidding their competitors. However, Valero (2015) did not study the open economy problem and it analysed the problem of corruption in the PPP in a microeconomic framework.

The infrastructure sector has been receiving a lot of foreign inflow of capital through the PPP infrastructure projects. It would be interesting to analyze the impact of corruption in the infrastructure sector, where foreign direct investment is brought in by the public-private partnership. In the next sub-section, we'll discuss the literature on corruption and FDI inflow in general and FDI inflow in the infrastructure sector.

1.8.1 Impact of corruption on FDI inflow

According to Habib and Zurawicki (2002), the difference in the corruption level in the host country and source country plays an important role in the decision for foreign direct investment to take place. More and more interaction between the less corrupt and more corrupt countries have intensified the corruption even more and a change in the level of corruption due to institutional improvement may have the same impact on FDI as a change in the tax rate on earned income. In Fredriksson et al. (2003), both environmental policy and the capital stock were endogenised and corruption affected the foreign capital inflow through its impact on the environmental policy stringency and due to greater theft of the public funds earmarked for public spending. If weaker environmental policy led to the capital inflow, then the effect of corruption was said to be positive and if stricter environmental policy led to the capital outflow then the effect of corruption was said to be negative, however, they could not find the measurable effect of corruption on FDI inflows due to environmental regulation. However, some papers highlight the distortions corruption brings in for the FDI inflow in the infrastructure sector. Cieslik and Goczek (2018) studied the effect of corruption using an open economy version of the endogenous growth model with international capital mobility. Corruption affects the FDI negatively due to the direct effect on reduction in the expected return from investment and indirectly by increasing the uncertainty. According to them, the increased uncertainty and instability in some countries due to higher corruption are the less-invested countries and if international investors are sufficiently diversified, they will never invest in such corruption risk countries. Hence differences in the level of corruption across countries bring about differences in the FDI thus leading to the differences in the level of development across countries. Belgibayeva and Plekhanov (2015) highlight the differential impact of reduction of corruption on the FDI from less corrupt and more corrupt partner countries by studying the complementarity between corruption and FDI inflow in the origin and destination countries. According to them, the control of corruption in the source country is not sufficient to encourage FDI in the host country, because corruption must also decrease in the host country. Also, it may not happen that investors are deterred by corruption because some investors see corruption as an opportunity to get around the rules and regulations. Hence, the marginal impact may be positive or may be negative.

Abotsi (2016) gave the reason for such an outcome by citing a corruption tolerable level of investment (CTLI)-the level of corruption which is tolerable by foreign investors and beyond that level, it is not tolerable. Investors enter a foreign market only if they have a comparative advantage over the domestic investors and these domestic investors have comparative disadvantages in the foreign market. In a game-theoretic model, quality of institution mattered for the choice of FDI decision by the foreign investor, which implied that for the low level of institutional quality, the firms had to pay more bribes for low marginal returns, discouraging investors to invest in such corrupt countries but for a comparatively high level of quality of the institution, the firms had to pay a lesser bribe for higher marginal returns, hence investors were not deterred from investing in these countries. It was suggested by Abotsi that since corruption cannot be completely eradicated reducing the level of corruption to CTLI must be the goal for the government that wants to attract FDI in infrastructure. Also, it was noted by Abotsi (2016) that arbitrary corruption increases the uncertainty and risk of investment because bribes may not be asked and their investors are not able to factor the choice of bribe to be paid in their maximization problem. Whereas, in the case of pervasive corruption, investors factor the bribe asked by corrupt public officials of the host country in their profit maximization problem. According to Cuervo-Cazurra (2008), pervasive corruption leads to a reduction in FDI and has a larger negative influence on FDI because the increase in the cost of FDI investment in the foreign country is known to be certain. On the other hand, arbitrary corruption had a smaller negative influence on FDI because corruption may be asked or may not be asked and it does not have a deterring influence on corruption. Given the problem of corruption in PPP, it becomes all the more important to analyze the small open economy case for the PPP provision.

1.9 The outline of the present thesis

Infrastructure provision by the PPP model has received much criticism and advocacy. Despite the criticism faced as an imperfect mode of provision of infrastructure, PPP still serves as the flagship model of infrastructure provision and complements public spending, even if it does not replace the traditional provision of infrastructure completely. There are many successful real-life examples for PPP projects in the public utilities such as metro railway service, electricity, airports and ports, etc around the world. Metro rail system- New Delhi of India, roads in Chile- Argentina, United States of America, Hong Kong, Hungary and Italy, water system of Singapore, Airports of New Delhi and Mumbai of India, rural electrification of Guatemala, port expansion in Colombo, Sri Lanka, etc. There are various types of PPP contracts in real life, for example, Build-Operate-Transfer (BOT), Build-Own-Operate-Transfer (BOOT), Design-Build-Finance-Operate (DBFO), Design-Construct-Maintain-Finance (DCMF), etc. The PPP mode of provision is generally justified by the government because the traditional model of provision or the pure public provision has landed the government into budgetary problems, making them incompetent to build new assets and to bear the maintenance and operation costs. Since PPP releases the excess strain from the public purse it is chosen by most of the governments around the world. In the case of PPP, the governments can also easily transfer the risk associated with the provision of infrastructure to private provision.

We focus our study mainly on the evaluation of PPP of infrastructure provision and deal with the supply-side economics of the infrastructure provision in the endogenous growth models in this thesis. By designing models in an endogenous growth framework, we will be able to capture the infrastructure-growth nexus and the productivity effects of government spending on the infrastructure, especially concerning PPP. This thesis excludes labour from its study because infrastructure is capital-intensive and inclusion of labour would unnecessarily complicate the models and we would not be able to draw any conclusion from our models.

In chapter 2 of this thesis, we study the respective role of private capital and public capital in a complementary relationship between the two and when they are perfect substitutes. Evaluation of a comparative study of both complementary case and substitute case for growth-maximizing fiscal policy and optimal fiscal policy in a balanced budget framework is important from the view of policy prescription. Chapter 2 examines whether the financing of infrastructure provision through the PPP mode is optimal or not. In section 2.2, we present the competitive economy and the command economy problem for the complementary relationship between private capital and public capital in the production of infrastructure capital in an endogenous growth framework. This section also analyses the transitional dynamics of the complementary case. In Section 2.3, we include the perfect substitute relationship between private capital and public capital as a special case in the endogenous growth model. Also, the transitional growth paths have been found for the perfect substitute case as well.

Finding the right mode of infrastructure provision is a difficult task for the governments of most countries. Therefore, the evaluation of optimal mode of provision of infrastructure among purely private, pure public and PPP, could be an important subject of study to close the gap between the demand and supply of infrastructure. In Chapter 3, we find whether the PPP mode of infrastructure provision is better as compared to other modes of provision of infrastructure thus in this chapter a comparative study is done to find the optimal model of provision and the optimal participation of investment by the private firms in the PPP projects for financing the infrastructure provision. Chapter 3 also incorporates the deficit financing along with the balanced budget case and therefore makes a comparative study of the different budgetary regimes for different modes of provisions. A comparative study of pure private provision, public provision and PPP mode of provision has been done in section 3.2.1, 3.2.2

and 3.2.3 respectively and also the steady-state balanced growth rates, user fees and equilibrium values of the fraction of private physical capital used for the production of finished goods under different budgetary regimes have been illustrated. We also find whether the imposition of tax financing or charging of user fees or a mix of all is optimal for the financing of infrastructure. In section 3.3 and section 3.4 we analyse the balanced budget case and the permanent deficit case respectively with the help of calibration exercises.

We discuss the problem of corruption in an otherwise FDI recipient economy which might have different growth outcomes due to the negative effect on growth from corruption and positive effect on growth from FDI inflow in the infrastructure sector in chapter 4. In chapter 4, we find out if the developing countries can reap the benefits from the PPP projects in the joint venture between the domestic investment because of the corruption. The small open economy model receives foreign investment for the production of infrastructure. We assume that in the presence of corruption, the infrastructure provided by the foreign firm is of inferior quality. We also assume that a bribe is charged by the corrupt government officials for the issuance of a license or permit to enter into the infrastructure industry of the host country, such that investor compromises on the quality of the infrastructure to cut down the cost of production. Here we assume that instead of being benevolent the government is self-motivated. We find in chapter 4 that corruption discourages the inflow of foreign capital in the infrastructure but host country's aggregate output relative to the foreign capital increases with increase in corruption.

We conclude in chapter 5.

Chapter 2

Is Public-Private Partnership an optimal mode of provision of infrastructure?

2.1 Introduction

Infrastructure is one of the most important determinants of economic growth. The mode of infrastructure financing is considered to be an important issue in economic theories. Traditionally, infrastructure has been provided by the government in most countries. However, the infrastructure bottleneck is an important concern for the government. One solution to this problem is the market provision of infrastructure. Privately provided infrastructure which includes road, power, water, transportation, irrigation and communications are quite common in the developed world (Chatterjee and Morshed, 2011). But, governments of both developed and developing nations are now considering the Public-Private Partnership (PPP) mode in the provision of infrastructure. PPP is the collaboration of public and private investments which take place together. According to Kateja (2012), BRIC countries have benefitted a lot from the implementation of the PPP model. Partnership with private entities in infrastructure provision is gaining popularity because it offers significant advantages regarding enhancing efficiency through competition in the provision of services to users.

In this chapter, we developed an endogenous growth model with private and public capital to study the respective role in the infrastructure provision and consequently their impact on growth. We extended Barro (1990) by including private capital in the infrastructure sector, however considering the private capital and public capital as stock variables. Bucci and Bo

(2012) have studied the impact of the change in the degree of complementarity and substitutability between private capital and public capital investments on the growth rate, but they considered infrastructure as a stock variable. It is well known that private investments and public investments are not independent of each other. Sometimes there is a crowding-out effect of private investment and public investment displaces private investment when public investments and private investments are substitutes to each other. But, when public capital and private capital are complementary to each other, there may be a crowding-in effect. According to Rashid and Ahmad (2005), public investment improves the productivity of private capital in production. In the present chapter, we have considered both, the cases of a substitute and complementary relationship between public investment and private investment. Following Barro (1990), infrastructure is a flow variable in this chapter. Here in this chapter, the government partially finances public investment by imposing output tax and the private sector finances a part of it. If the optimal tax rate to be imposed by the government or the optimal private capital to be employed in infrastructure is found to be zero then public-private partnership (PPP) is not desirable, otherwise, it is.

We studied the steady-state growth paths for competitive and command economies for both complementary and substitute cases under the balanced budget fiscal rule assumption. We also analyzed the transitional dynamics for both substitute and complementary cases. Bom and Ligthart (2014), Chen and Guo (2016) also studied the dynamic macroeconomic effects of public infrastructure investment under a balanced budget fiscal rule. However, previous works have not considered the possibility of PPP investment for infrastructure provision. The present chapter discusses the complementary relationship between public investment and private investment first and then proceeds to compare the results with a case where public investment and private investments are perfect substitutes in the infrastructure provision. In public policy analysis, it is important to find a growth-maximizing tax rate and optimal tax rate. The private agent takes tax rate and public investment as given and accordingly makes its investment decision and the government takes into account its budgetary restriction and maximizes the welfare with respect to the tax rate along with other choice variables. Several papers focused on public investment and private investment in infrastructure but, public-private partnership investment in infrastructure has been rarely studied in the endogenous growth literature. Chatterjee and Morshed (2011) compared the impact of the private provision of infrastructure and government provision of infrastructure, both separately on the economy's aggregate performance. Barro and Sala-i-Martin (1992) studied the effects of alternative fiscal policies in case of a publicly provided private good (rival and excludable), publicly provided public good (non-rival and non-excludable) and publicly provided goods subject to congestion (rival and non-excludable). Several papers which have considered private and public capital in the production of final output namely, Barro (1990), Futagami et al. (1993), Fisher and Turnovsky (1998) and Devarajan et al. (1998). According to Bucci and Bo (2012), a change in the degree of complementarity/substitutability between public and private capital stock affect the optimal growth rate of the economy. However, they have not found the growth maximizing tax rate and optimal tax rate in a command economy and have not compared the competitive and command economies. Besley and Ghatak (1999) discussed the responsibility of public and private entities especially NGOs in the infrastructure provision in a microeconomic framework. But, their paper was not the evaluation of PPP from the macroeconomic perspective.

In real life, there are many instances where PPP is being successfully implemented, for example, metro rail system- New Delhi of India, roads in Chile- Argentina, United States of America, Hong Kong, Hungary and Italy, water system of Singapore, Airports of New Delhi and Mumbai of India, rural electrification of Guatemala, port expansion in Colombo, Sri Lanka, etc; are some examples of successful PPP projects. Though most of the infrastructure services may be non-rival, most of these are excludable at least to some extent; for example, metro railway service, electricity, telephone service, etc. So the desirability of the PPP model is relevant for all these infrastructure services. This chapter considers infrastructure as an impure public good and examines whether the financing of a public-private partnership in infrastructure service is optimal or not. Comparison between the growth-maximizing and welfare-maximizing fiscal policy has been a central issue in the literature of public finance and growth, which is also important from policy-making. This chapter attempts to find out growth-maximizing and optimal policies in the context of PPP in infrastructure provision.

Similar to Dasgupta (1999), we found that the command economy growth rate may be less than that of a competitive economy for the complementary relation between private and public capital. But, in the case of a perfect substitute relationship between public and private investment, the command economy growth rate is always higher than the competitive economy growth rate. However, when private capital and public capital are the perfect substitutes for each other, the growth-maximizing tax rate is zero. Erden and Holcombe (2006) found empirically that, in most of the developing countries private investment and public investments are complementary to each other, also to be true in the case of Pakistan (Rashid and Ahmad, 2005). We found that there exists a unique, interior growth-maximizing tax rate and an optimal tax rate for the complementary relationship between private investment and public investment.

The structure of the chapter is organized in the following manner. Section 2.2 describes the base model, where public capital and private capital are complementary to each other.

Section 2.3 discuss the special case when public capital and private capital are the perfect substitutes. Lastly concluding remarks are made in Section 2.4.

2.2 The model

We consider a closed economy model. The output is produced using private capital and infrastructure service. Following Barro (1990), infrastructure service enters into the production function as a flow variable. Production of infrastructure service requires physical capital. The labour is not considered as a factor of production in our model, because we focus only on the physical capital investment in the infrastructure sector and precisely would like to find out whether PPP investment is an optimal solution in the long run or not. Usually, the construction of infrastructure requires a lot more physical capital as an input compared to labour. In this model, we consider only the physical infrastructure and not the social infrastructure (like education and health). Therefore, the inclusion of labour will not contribute much to the findings of the study. There are several other works on infrastructure investment in an endogenous growth framework where labour is not considered as an input. To mention a few of them are, Greiner and Hanusch (1998), Dasgupta (1999), Mourmouras and Lee (1999), Devarajan et al. (1998), Dasgupta (2001), Chatterjee and Ghosh (2011) etc. Also, the omission of labour makes our model algebraically simple to deal with. The infrastructure services may be provided privately (by the representative agent), or publicly (by the government) or by a public-private partnership (by a collaboration of both). Initially, it is assumed that private capital and public capital are complements in producing infrastructure services. Government accumulates public capital by imposing a tax on output. It is also assumed that the government runs a balanced budget. The economy is populated by a large number of infinitely lived households having perfect foresight.

An infinitely lived representative agent maximizes the present discounted value of utility from consumption. The utility function of the representative agent is given by

$$U = \int_0^\infty \frac{C^\gamma}{\gamma} e^{-\beta t} dt, \ -\infty < \gamma \le 1, \beta > 0, \tag{1}$$

Infrastructure service is produced using capital provided partly by the government denoted by k_g and also by a fraction of private capital denoted by k. The production function of infrastructure service is assumed to take the Cobb-Douglas form,[1]

$$k_I^S = B(\theta k)^\alpha k_g^{1-\alpha}, \tag{2}$$

Where k_g and k complement each other and θ is the fraction of privately owned physical capital allocated to infrastructure service production. The product exhaustion theorem states that in a competitive factor market since factors of production are paid a price equal to their value of the marginal product, the payments to the factors will exhaust the value of the total product. Here, we assume perfect competition in the product and the factor markets. So, in the absence of any external effect, the assumption of the constant returns to scale is necessary for product exhaustion and zero economic profits in the long run. Increasing returns to scale is not compatible with the perfect competition, because the value of the marginal product cannot be distributed among the factors because that will over exhaust the total product. If there are diminishing returns to scale, then even after payments to the factors at a competitive rate, there will be excess total product indicating super-normal profit in the economy which is compatible only with the imperfect competition in the product market. Though imperfect competition may be widely prevalent in the factor market and the infrastructure provision, for simplicity, we have assumed perfect competition and consequently constant returns to scale. In the existing literature, Dasgupta (1999), Tsoukis and Miller (2003), Bucci and Bo (2012) also have considered constant returns to scale in the infrastructure production function.

[1] According to Dasgupta (1999), under the Cobb-Douglas framework assumed, there is a restriction on the model; this arises from the fact that the share of each factor in the Y-sector output must be constant under competitive conditions. (page. 367)

The final output (Y) is produced using the remaining fraction of private capital (k) and infrastructure service (k_I^S). The production function of the final output is given by,

$$Y = A\{(1-\theta)k\}^{\eta} (k_I^s)^{1-\eta}, 0< \eta < 1, A > 0. \quad (3)$$

In equation (3), $(1-\theta)$ is the fraction of privately owned physical capital allocated to the production of final goods. Tax revenue over depreciation is accumulated as publicly owned physical capital. The rate of accumulation of private capital and public capital is governed by the following equations:

$$\dot{k} = (1-\tau)Y - C - \delta_k k, \quad (4)$$

$$\dot{k}_g = \tau Y - \delta_g k_g, \quad (5)$$

Where a dot over its variable indicates its time derivative. $\dot{k}$ is the change in the private physical capital stock per unit of time and $\dot{k}_g$ is the change in the public capital stock per unit of time, τ is the constant marginal tax rate on output used to finance the provision of infrastructure when private and public capital are complements to each other, δ_k and δ_g denote their corresponding depreciation rates, $(1-\tau)Y - C$ and τY measure the flow of new investments into the two capital goods, k and k_g respectively. We assume that the depreciation rates of both private capital and public capital are positive.

2.2.1 Decentralized economy

The representative agent maximizes the present discounted value of inter-temporal utility over an infinite time horizon subject to the resource constraints given by equation (3) and (4) and with respect to control variables C and θ_d. The subscripts d represent a decentralized economy in the model. Private agents (households and firms) take fiscal policies as given while making optimal private decisions. The current-valued Hamiltonian of the representative agent is given by,

$$H_c = \frac{C^{\gamma}}{\gamma} + \lambda\left[(1-\tau_d)Y - C - \delta_k k\right] \tag{6}$$

While maximizing their instantaneous inter-temporal utility function, the representative agent considers k_g to be given. The first-order conditions necessary for this optimization problem with respect to control variables C, θ_d are:

$$C^{\gamma-1} = \lambda \tag{7}$$

$$\theta_d = \frac{\alpha(1-\eta)}{\eta+\alpha(1-\eta)} \tag{8}$$

In a decentralized economy, θ_d is the fraction of privately owned physical capital allocated to the infrastructure service production. Please note that θ_d is the output elasticity of private physical capital in the infrastructure production and has a negative relationship with η and positive relationship with α.

Time derivatives of the co-state variables satisfying the optimum growth path are:

$$\frac{\dot{\lambda}}{\lambda} = \beta - (1-\tau_d)A(1-\theta_d)^{\eta}(B\theta_d^{\alpha}u_d^{1-\alpha})^{1-\eta}[\eta + (1-\eta)\alpha] + \delta_k \tag{9}$$

Where u_d denotes (k_g/k) or the ratio of public capital to private capital. The interior value of u_d is also necessary for the public-private partnership in the infrastructure provision. Taking the log and derivative of equation (7), we have,

$$(\gamma-1)\frac{\dot{C}}{C} = \frac{\dot{\lambda}}{\lambda} \tag{10}$$

From equations (9) and (10), we obtain the growth rate of consumption.

$$\frac{\dot{C}}{C} = \frac{(1-\tau_d)A(1-\theta_d)^{\eta}B^{1-\eta}\theta_d^{\alpha(1-\eta)}u_d^{(1-\alpha)(1-\eta)}[\eta+\alpha(1-\eta)]-\delta_k-\beta}{(1-\gamma)} = g_d \tag{11}$$

We find that the growth rate of consumption depends on the ratio of public capital to private capital, u_d.

2.2.1.1 Steady-state growth for the decentralized economy

A steady-state growth path is defined as a path along which consumption, public physical capital, and private physical capital grow at a constant rate and the fraction of private capital devoted to infrastructure production is constant. For the existence of steady-state balanced growth equilibrium, $\dot{c}/c$ must be constant. We also assume, τ_d, θ_d and g_d to be constant along the steady state. If g_d is constant, then u_d must also be constant. If u_d and $\dot{k}/k$ are constant then c/k is also constant. Therefore, in steady-state balanced growth, $\dot{c}/c = \dot{k}/k = \dot{k_g}/k_g = g_d$.

$$\frac{\dot{k}}{k} = (1-\tau_d)A(1-\theta_d)^{\eta}B^{1-\eta}{\theta_d}^{\alpha(1-\eta)}u_d^{(1-\alpha)(1-\eta)} - \frac{c}{k} - \delta_k \qquad (12)$$

$$\frac{\dot{k_g}}{k_g} = \tau_d A\,(1-\theta_d)^{\eta}B^{1-\eta}\theta_d^{\alpha(1-\eta)}u_d^{-\alpha(1-\eta)-\eta} - \delta_g \qquad (13)$$

Now equating demand-side growth rate given by equation (11) and supply-side growth rate given by equation (13), we have

$$(1-\gamma)\tau_d A(1-\theta_d)^{\eta}B^{1-\eta}\theta_d^{\alpha(1-\eta)}u_d^{-\alpha(1-\eta)-\eta}$$
$$= (1-\tau_d)A(1-\theta_d)^{\eta}B^{1-\eta}\theta_d^{\alpha(1-\eta)}u_d^{(1-\alpha)(1-\eta)}[\eta+\alpha(1-\eta)] - \delta_k - \beta + \delta_g(1-\gamma) \qquad (14)$$

In the above equation, the only unknown variable is, u_d.We can solve for the equilibrium rate of u_d^* graphically. Let left-hand side of equation (14) be $f_1(u_d)$ and right-hand side of the equation be $f_2(u_d)$. For the existence and uniqueness of the equilibrium solution u_d^*, we differentiate f_1 and f_2 with respect to u_d and we find an interior solution in figure 2.1.

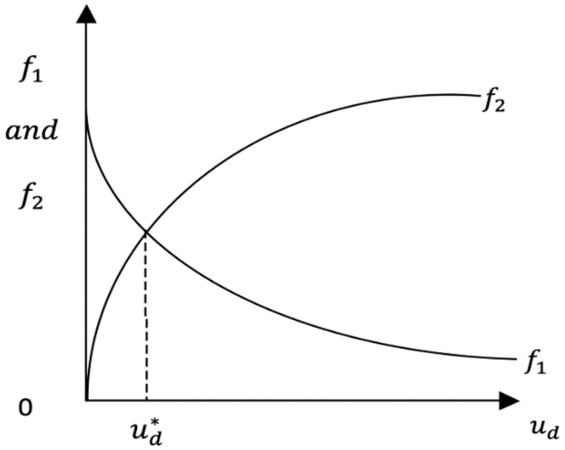


Figure 2.1 Existence of Unique u_d

Figure 2.1 shows that there exists a unique equilibrium u_d^* under the competitive economy for the case, when the public capital and private capital are complementary goods.

Proposition 1. *There exists a unique steady state balanced growth rate in the decentralized economy, when public and private capital complements each other. The growth maximizing tax rate is positive for financing of infrastructure services.*

2.2.1.2 Transitional dynamics for the complementary case

To study the dynamic behaviour of the model, for the complementary case, we analyze the transitional dynamics in this section. Before we analyze the model around the steady-state, we define new variables, $x = c/k$ and $u = k_g/k$. From equation (8) we find that θ_d is always a constant. Differentiating these variables with respect to time leads to a two-dimensional system of differential equations. Therefore, the first-order differential equation system in two variables in the general form is given as,

$$\frac{\dot{x}}{x} = \frac{\dot{c}}{c} - \frac{\dot{k}}{k} = f(x, u) \tag{15}$$

$$\frac{\dot{u}}{u} = \frac{\dot{k}_g}{k_g} - \frac{\dot{k}}{k} = g(x, u) \tag{16}$$

From equation (15) – (16), we have,

$$\frac{\dot{x}}{x} = \frac{\left[(1-\tau)A(1-\theta)^{\eta}\{B\theta^{\alpha}u^{1-\alpha}\}^{1-\eta}\{[\eta+(1-\eta)\alpha]-(1-\gamma)\}-\delta_k\gamma-\beta+x(1-\gamma)\right]}{(1-\gamma)} \quad (17)$$

$$\frac{\dot{u}}{u} = A(1-\theta)^{\eta}B^{1-\eta}\theta^{\alpha(1-\eta)}u^{-\alpha(1-\eta)-\eta}[\tau-(1-\tau)u]-\delta_g+\delta_k+x \quad (18)$$

At steady state, $\dot{x}/x = 0$ and $\dot{u}/u = 0$. The relationship between x and u are given by equations (17) and (18) respectively,

$$x^{*} = \frac{\delta_k\gamma+\beta}{(1-\gamma)} - \frac{(1-\tau)}{(1-\gamma)}A(1-\theta)^{\eta}\{B\theta^{\eta}\mathrm{u}^{1-\alpha}\}^{1-\eta}\{\eta+\gamma+(1-\eta)\alpha-1\} \quad (19)$$

$$x^{*} = \delta_g-\delta_k-A(1-\theta)^{\eta}B^{1-\eta}\theta^{\alpha(1-\eta)}u^{-\alpha(1-\eta)-\eta}[\tau-(1-\tau)u] \quad (20)$$

We show the qualitative transitional dynamic analysis with the help of phase diagram using equations (19) – (20).

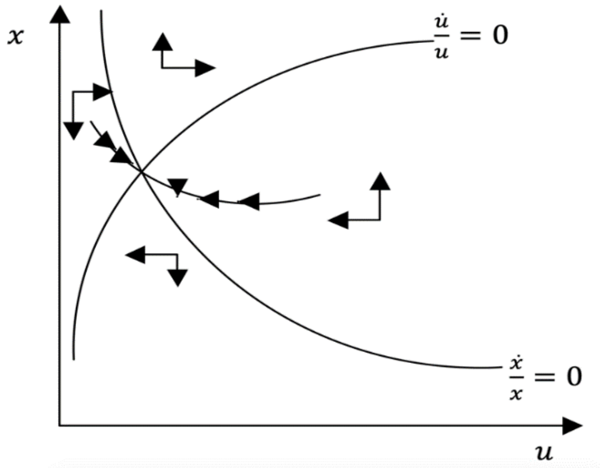


Figure 2.2 Saddle path stability when the private and public capital are complementary goods

To determine the local behaviour around the steady-state, we linearize the dynamic system. The characteristic equation is given by,

$$J_E = \begin{bmatrix} 1-\lambda & M \\ 1 & N-\lambda \end{bmatrix} = 0, \quad (21)$$

where, $M = \left(\frac{(1-\tau)A(1-\theta)^{\eta}\{B\theta^{\alpha}\}^{1-\eta}(1-\eta)(1-\alpha)u^{(1-\alpha)(1-\eta)-1}\{[\eta+(1-\eta)\alpha]-(1-\gamma)\}}{(1-\gamma)}\right)$, $N = -A(1-\theta)^{\eta}B^{1-\eta}\theta^{\alpha(1-\eta)}u^{-\alpha(1-\eta)-\eta}(1-\tau)\left[\frac{\{\alpha(1-\eta)+\eta\}\tau}{u(1-\tau)+2}\right]$, λ is the characteristic root of the dynamic system. From the matrix given in equation (21), we obtain the characteristic equation,

$$\lambda^2 - \lambda(1+N) - (M-N) = 0. \tag{22}$$

The characteristic roots depend critically on the expression $(1+N)$ and $(N-M)$. Where, $(1+N)$ is the sum of the principal – diagonal elements of the Jacobian (or trace of Jacobian) and $(N-M)$ is the determinant of Jacobian. Now, the characteristic roots can be expressed as,

$$r_1, r_2 = \frac{trJ_E \pm\sqrt{(trJ_E)^2-4|J_E|}}{2} \tag{23}$$

Thus, for this dynamic system to be stable, there must be at least one stable eigen-value or characteristic root. The trace of the Jacobian is given by

$$trJ_E = 1 - A(1-\theta)^{\eta}B^{1-\eta}\theta^{\alpha(1-\eta)}u^{-\alpha(1-\eta)-\eta}(1-\tau)\left[\frac{\{\alpha(1-\eta)+\eta\}\tau}{u(1-\tau)} + 2\right] \tag{24}$$

The trJ_E is positive, implying sum of the roots are positive. So, for the dynamic system to be stable $detJ_E$ must be negative.

$$detJ_E = -[(1-\tau)A(1-\theta)^{\eta}B^{1-\eta}\theta^{\alpha(1-\eta)}u^{-\alpha(1-\eta)-\eta}$$

$$\{\frac{(1-\eta)(1-\tau)\big([\eta+(1-\eta)\alpha](1-\alpha\gamma)-(1-\gamma)\big)}{(1-\gamma)} + \frac{[\eta+(1-\eta)\alpha]\tau}{u(1-\tau)} + 2\}] \tag{25}$$

Since $[\eta + (1-\eta)\alpha] > 0$, $detJ_E$ is negative. Hence the dynamic system is saddle path stable when the private physical capital and public capital are complementary to each other in the infrastructure provision.

Proposition 2. *The dynamic system is saddle path stable.*

2.2.1.3 Growth maximizing tax rate

From equation (14), we have,

$$A(1-\theta_d)^{\eta}B^{1-\eta}\theta_d^{\alpha(1-\eta)}u_d^{-\alpha+\alpha\eta-\eta}\left[\frac{(1-\tau_d)}{(1-\gamma)}\{\eta+\alpha(1-\eta)\}u_d - \tau_d\right] = \frac{\delta_k+\beta}{(1-\gamma)} - \delta_g \tag{26}$$

Differentiating equation (26) with respect to τ_d, we find that,

$$\left(\frac{\partial u_d}{\partial \tau_d}\right) = \frac{(1-\gamma)+\{\eta+\alpha(1-\eta)\}u_d}{\{\eta+\alpha(1-\eta)\}\left[(1-\gamma)\frac{\tau_d}{u_d}+(1-\tau_d)(1-\eta)(1-\alpha)\right]} > 0 \quad (27)$$

$(\partial^2 u_d/\partial \tau_d^2)$ is given in equation (28) of the Appendix A1.

Now for the existence of growth maximizing tax rate, the first order condition and second order condition must be positive, given by equation (27) and (28), respectively. To find the growth- maximizing tax rate, we maximize equation (11) with respect to τ_d. Therefore, setting $\partial g_d/\partial \tau_d = 0$.

$$\frac{\partial g_d}{\partial \tau_d} = AB^{1-\eta}\{\eta+\alpha(1-\eta)\}(1-\theta_d)^\eta \theta_d^{\alpha(1-\eta)} u_d^{(1-\alpha)(1-\eta)-1}[-u_d + (1-\tau_d)(1-\eta)(1-\alpha)\frac{\partial u_d}{\partial \tau_d}] = 0 \quad (29)$$

From equation (29), we obtain the value of $u_d = \left[\frac{(1-\tau_d)(1-\eta)(1-\alpha)\partial u_d}{\partial \tau_d}\right]$.The growth-maximizing tax rate, τ_d^* for the decentralized economy is obtained after substituting the value of $\partial u_d/\partial \tau_d$ in u_d. Hence, the growth maximizing tax rate for the decentralized economy is a function of the marginal productivity of public capital and the output elasticity of the public capital in the production of infrastructure services.

$$\tau_d^* = (1-\eta)(1-\alpha) \quad (30)$$

Now, the second order condition must be negative for the existence of growth maximizing tax rate.

$$\frac{\partial^2 g_d}{\partial \tau_d^2} = N u_d^{(1-\alpha)(1-\eta)-2}[(1-\alpha)(1-\eta)\{-2u_d\frac{\partial u_d}{\partial \tau_d} + (1-\tau_d)\{(1-\alpha)(1-\eta) - 1\}(\frac{\partial u_d}{\partial \tau_d})^2 + (1-\tau_d)\frac{\partial^2 u_d}{\partial \tau_d^2}\}] < 0 \quad (31)$$

Where, $N = (AB^{1-\gamma}/(1-\gamma))\{\eta+\alpha(1-\eta)\}(1-\theta_d)^\eta \theta_d^{\alpha(1-\eta)}$ and it is positive.

The interior values of θ_d and τ_d imply public-private partnership in infrastructure. While α is the parameter and the equilibrium value of θ is determined in competitive economy and τ are determined optimally in command economy problem.

Proposition 3. *When public capital and private capital complement each other, there exists a unique, positive growth-maximizing tax rate for the financing of infrastructure services.*

The main concern for the policy-makers today in the developing countries is to accelerate growth. The present research points out that maximization of the growth rate in the PPP model requires setting the tax rate equal to the marginal productivity of public capital that is the product of marginal productivity of infrastructure services in output and the output elasticity of the public capital in the production of infrastructure services.

2.2.2 Command economy

The difference between a competitive economy and a command economy is that, in competitive economy private agent consider τ and k_g to be given; but, in command economy while optimizing the present discounted value of utility, the dynamic constraint $\dot{k}_g$ is taken into consideration and tax rate (τ) is one of the choice variables of the social planner. Because of the difference in the optimization procedure, the results obtained in competitive and command economies are different.

The command economy maximizes the utility function over the infinite time horizon given by equation (1), subject to the resource constraints (4) and (5), and with respect to the control variables C, θ_c, τ_c, where the subscript c represents command economy in the model. The current value Hamiltonian is,

$$H_c = \frac{C^\gamma}{\gamma} + \lambda_1[(1-\tau_c)Y - C - \delta_k k] + \lambda_2\left[\tau_c Y - \delta_g k_g\right] \tag{32}$$

λ_1 and λ_2 are the co-state variables of k and k_g respectively, representing their shadow prices.

The first order conditions with respect to control variables, τ_c, θ_c are given by the following equations:

$$C^{\gamma-1} = \lambda_1 \tag{33}$$

$$\lambda_1 = \lambda_2 \tag{34}$$

$$\frac{\partial Y}{\partial \theta_c}[\lambda_1(1-\tau_c) + \lambda_2\tau_c] = 0 \tag{35}$$

From equation (35), we obtain the optimal value of θ_c,

$$\theta_c = \frac{\alpha(1-\eta)}{\eta+\alpha(1-\eta)} \tag{36}$$

Note that $\theta_c = \theta_d$ given by equation (36) and (8) respectively, implying that the share of private investment in the PPP mode of infrastructure provision for both, decentralized economy and command economy is same when private capital and public capital are complementary goods. The time derivatives of the co-state variables satisfying the optimum growth path are given by:

$$\frac{\dot{\lambda_1}}{\lambda_1} = \beta - \frac{\partial Y}{\partial k} + \delta_k \tag{37}$$

$$\frac{\dot{\lambda_2}}{\lambda_2} = \beta - \frac{\partial Y}{\partial k} + \delta_k \tag{38}$$

Using equation (34) and equating equations (37) and (38), we get,

$$\frac{\delta_k - \delta_g}{A(1-\theta_c)^{\eta}B^{1-\eta}\theta_c^{\alpha(1-\eta)}} = u_c^{(1-\alpha)(1-\eta)}[\{\eta + \alpha(1-\eta)\} - (1-\alpha)(1-\eta)\frac{1}{u_c}] \tag{39}$$

Taking the log and derivative of equation (33), we get,

$$(\gamma-1)\frac{\dot{C}}{C} = \frac{\dot{\lambda}_1}{\lambda_1} \tag{40}$$

Therefore, the growth rate of consumption for the command economy is given by,

$$\frac{\dot{c}}{c} = \frac{A(1-\theta_c)^{\eta}B^{1-\eta}\theta_c^{\alpha(1-\eta)}u_c^{(1-\alpha)(1-\eta)}\{\eta+\alpha(1-\eta)\}-\beta-\delta_k}{(1-\gamma)} = g_c \tag{41}$$

g_c denotes the growth rate for the command economy case.

2.2.2.1 Steady-state growth for the command economy

In steady-state balanced growth equilibrium, $\dot{c}/c$ must be constant. Since the growth rate of consumption depends on u_{c}, therefore if $\dot{c}/c$ is constant then u_c is also constant. Therefore in steady-state balanced growth, $\dot{k}_g/k_g = \dot{k}/k = \dot{c}/c = g_c$.

In equation (39), there is only one unknown variable, that is, u_c. Hence, we can solve for the equilibrium u_c graphically. On the left-hand side of equation (39), we do not have u_c. Let the left-hand side of the equation be represented as J and the right-hand side of the equation be represented as $f(u_c)$. Differentiating $f(u_c)$ with respect to u_c we find the existence and uniqueness of the equilibrium u_c^*, which is illustrated in figure 2.3 below.

$$f'(u_c) = (1-\alpha)(1-\eta)u_c^{-\eta-\alpha(1-\eta)}\left[\frac{(1+u_c)(\alpha(1-\eta)+\eta)}{u_c}\right] > 0, \quad (42)$$

$$f''(u_c) = (1-\alpha)(1-\eta)u_c^{-\eta-\alpha(1-\eta)-2}[\alpha(1-\eta)+\eta]\big[\big(-\eta-\alpha(1-\eta)\big)(1+u_c)+u_c\big] < 0 \quad (43)$$

Figure 3 shows that there exists a unique equilibrium u_c^*, under the command economy for the complementary case of public capital and private capital.

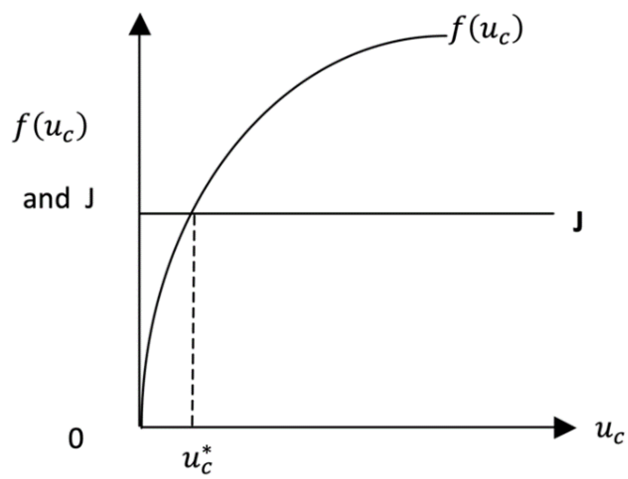


Figure 2.3 Existence of unique u_c

Proposition 4. *There exists a unique growth rate in the command economy when public and* *private capital complements each other. Also, there exists an optimal tax rate that maximizes welfare.*

2.2.2.2 Optimal tax rate

Equating (13) and (41) i.e., $\dot{k}_g/k_g = g_c$, we have,

$$\tau_c A(1-\theta_c)^{\eta} B^{1-\eta}\theta_c^{\alpha(1-\eta)} u_c^{-\alpha(1-\eta)-\eta} - \delta_g$$

$$= \frac{1}{(1-\gamma)}\left[A(1-\theta_c)^{\eta} B^{1-\eta}\theta_c^{\alpha(1-\eta)} u_c^{(1-\alpha)(1-\eta)}\{\eta+\alpha(1-\eta)\} - \beta - \delta_k\right] \quad (44)$$

From equation (44), we find the optimal tax rate, which is welfare-maximizing,

$$\tau_c = \frac{\frac{A(1-\theta_c)^{\eta}}{(1-\gamma)} B^{1-\eta}\theta_c^{\alpha(1-\eta)} u_c^{(1-\alpha)(1-\eta)}\{\eta+\alpha(1-\eta)\} - \frac{(\beta+\delta_k)}{(1-\gamma)} + \delta_g}{A(1-\theta_c)^{\eta} B^{1-\eta}\theta_c^{\alpha(1-\eta)} u_c^{-\alpha(1-\eta)-\eta}} \quad (45)$$

This is the first best solution of the optimal tax rate in the command economy. We can also achieve a command economy solution through the decentralized economy by equating steady- state growth rates obtained in the command economy as expressed in equation (41) and steady- state growth rate obtained in the market economy as expressed by equation (11) and imposing the tax rate that equals both the growth rates. Hence, the second-best tax rate is $\tau^* = 1 - (u_c/u_d)^{(1-\alpha)(1-\eta)}$. Note that, u_d must be greater than u_c for the tax rate to be positive.

2.2.2.3. Zero-depreciation rate of physical capital

In this section, we assume that the depreciation rate of both the public capital and the private physical capital is zero. In the decentralized economy, when $\delta_k = \delta_g = 0$, there is not a specific value of u_d but graphical solution shows that there will be a reduction in the value of u_d. However, in the case of a command economy, we get the value of u_c as,

$$u_c = \frac{(1-\alpha)(1-\eta)}{\{\eta+\alpha(1-\eta)\}} \quad (46)$$

When $\delta_k = \delta_g = 0$, the decentralized economy growth rate and the command economy growth rate are given respectively as,

$$g_d = \frac{(1-\tau_d)A(1-\theta_d)^\eta B^{1-\eta}\theta_d^{\alpha(1-\eta)}u_d^{(1-\alpha)(1-\eta)}[\eta+\alpha(1-\eta)]-\beta}{(1-\gamma)} \tag{47}$$

$$g_c = \frac{A(1-\theta_c)^\eta B^{1-\eta}\theta_c^{\alpha(1-\eta)}u_c^{(1-\alpha)(1-\eta)}[\eta+\alpha(1-\eta)]-\beta}{(1-\gamma)} \tag{48}$$

Therefore, comparing equation (47) and (48), we see that the growth rate of the command economy is greater than the growth rate of the decentralized economy if $u_d < \{(1-\alpha)(1-\eta)\}\{\eta+\alpha(1-\eta)\}^{-1-(1-\alpha)(1-\eta)/(1-\alpha)(1-\eta)}$.

In general case, when depreciation rates of physical capital are not zero, the command economy growth rate is greater than the growth rate of the decentralized economy, if $[\eta+\alpha(1-\eta)]u_d^{(1-\alpha)(1-\eta)} < u_c^{(1-\alpha)(1-\eta)}$.

Proposition 5. *Command economy growth rate may not be higher than the competitive economy growth rate.*

For the non-rival infrastructure Dasgupta (1999) found a similar result that the market economy grew faster than the command economy, though the latter dominated in welfare. In our chapter, if the marginal productivity of private capital in output and the output elasticity of private capital in the production of infrastructure services are higher, then the market economy would allocate more resources (even more than what is optimal) to private capital investment and thus result into faster growth rate than the command economy.

2.3. Private capital and public capital are perfect substitutes

In this section, we consider the case when private capital and public capital are perfect substitutes in producing infrastructure service.

Therefore, the production function of infrastructure service is given by,

$$k_I^S = \theta k + k_g, \tag{49}$$

θ is the fraction of privately owned physical capital allocated to infrastructure service production. k_I^S, k and k_g denote flow of infrastructure services, private capital and public capital respectively.

The final output (Y) is produced using a fraction of private capital (k) and infrastructure service (k_I^S).The public capital and private capital are perfect substitutes in the production of infrastructure services as shown in equation (49).

The production function of the final output is given by,

$$Y = A\{(1-\theta)k\}^{\eta}\left(\theta k + k_g\right)^{1-\eta},\ 0 < \eta < 1, A > 0. \tag{50}$$

In equation (50), $(1-\theta)$ is the fraction of privately owned physical capital allocated to the production of final goods.

2.3.1 Decentralized economy

The representative agent maximizes the inter-temporal utility over an infinite time horizon as given in equation (1) subject to the resource constraints given by equation (3) and (4) and with respect to control variables C and θ_d. Private agents (households and firms) take fiscal policies as given when making optimal private decisions. The current-valued Hamiltonian of the representative agent is given by,

$$H_c = \frac{C^{\gamma}}{\gamma} + \lambda\left[(1-\tau_d)\mathrm{Y} - C - \delta_k k\right] \tag{51}$$

While maximizing their instantaneous inter-temporal utility function, the representative agent considers k_g to be given. The first order conditions necessary for this optimization problem with respect to control variables C, θ_d are:

$$C^{\gamma-1} = \lambda \tag{52}$$

$$\eta\left(k_g + k\right) = (1+\theta_d)k \tag{53}$$

From equation (53), we obtain the constant value of the share of private investment in the infrastructure provision by PPP mode in this case too. Therefore, for the decentralized economy, θ_d is given as,

$$\theta_d = 1 - \eta - \eta u_d \tag{54}$$

Time derivatives of the co-state variables satisfying the optimum growth path are:

$$\frac{\dot{\lambda}}{\lambda} = \beta - (1-\tau_d)A(k-\theta_d k)^{\eta-1}\left(\theta_d k + k_g\right)^{-\eta}\left[\eta(1-\theta_d)\left(\theta_d k + k_g\right) - (1-\eta)\theta_d(k - \theta_d k)\right] + \delta_k \tag{55}$$

Dividing equation (55) by k and denoting the ratio of public to private capital by u_d, we have

$$\frac{\dot{\lambda}}{\lambda} = \beta - (1-\tau_d)A(1-\theta_d)^{\eta-1}(\theta_d + u_d)^{-\eta}[\eta(1-\theta_d)(\theta_d + u_d) - (1-\eta)\theta_d(1-\theta_d)] + \delta_k \tag{56}$$

Taking the log and derivative of equation (52), we obtain the growth rate of consumption for the substitute case under the decentralized economy.

$$\frac{\dot{c}}{c} = \frac{(1-\tau_d)A(1-\theta_d)^{\eta-1}(\theta_d+u_d)^{-\eta}[\eta(1-\theta_d)(\theta_d+u_d)+(1-\eta)\theta_d(1-\theta_d)]-\delta_k-\beta}{(1-\gamma)} \tag{57}$$

We find that the growth rate of consumption depends on the ratio of public capital to private capital.

2.3.1.1 Steady-state growth for the decentralized economy

For steady-state balanced growth equilibrium to prevail (the growth rate of consumption to be constant), the ratio of public capital (k_g) to private physical capital (k) must also remain constant. The growth rate of consumption in the decentralized economy (when private capital and physical capital are substitutes) is denoted by g_d, i.e.; $\dot{c}/c = g_d$ and the growth rate of private physical capital is denoted by g_k. If g_d is constant, then $\dot{k}/k = \dot{k}_g/k_g = g_k$ is also constant. From equation (55), we have a constant θ_d, which is the share of private investment in the PPP mode of infrastructure provision in the decentralized economy.

$\dot{k}/k$ and $\dot{k}_g/k_g$ are obtained in equation (58) and (59),

$$\frac{\dot{k}}{k} = (1-\tau_d)A(1-\theta_d)^{\eta}(\theta_d + u_d)^{1-\eta} - \frac{c}{k} - \delta_k \tag{58}$$

$$\frac{\dot{k}_g}{k_g} = \tau_d\, A(1-\theta_d)^{\eta}(u_d)^{-\eta}\left(\frac{\theta_d}{u_d}+1\right)^{1-\eta} - \delta_g \tag{59}$$

In steady-state, if $\dot{k}/k$ and u_d are constant in equation (58) then c/k must also be constant. Equating the growth rates of public capital accumulation given by equation (59) with the growth rate of consumption given by equation (57), we get, the equilibrium values of u_d and g_d respectively.

$$u_d = \frac{\tau_d A\eta^{\eta}(1-\eta)^{1-\eta}(1-\gamma)}{A\eta^{\eta}(1-\eta)^{1-\eta}(1-2\tau_d+\tau_d\gamma)-\delta_k-\beta+\delta_g(1-\gamma)} \tag{60}$$

The conditions for u_d to be positive are $\gamma \le 1$ and $\tau_d \ge \frac{(\delta_k-\delta_g+\gamma\delta_g+\beta-A\eta^{\eta}(1-\eta)^{1-\eta})}{A\eta^{\eta}(1-\eta)^{1-\eta}(2-\gamma)}$. These conditions are both necessary and sufficient for $u_d \ge 0$. The steady-state balanced growth rate of the competitive economy for the substitute case is given by,

$$g_d = \frac{1}{(1-\gamma)}[(1-\tau_d)A\eta^{\eta}(1-\eta)^{1-\eta} - \delta_k - \beta] \tag{61}$$

2.3.1.2 Transitional dynamics for the substitute case

To study the dynamic behaviour of the model for the perfect substitutes relationship between public capital and private capital, we analyze the transitional dynamics. Before we analyze the model around the steady-state, we define new variables, $x = c/k$ and $u = k_g/k$. From equation (54), we find that θ_d is always a constant. Differentiating x and u with respect to time leads to a two dimensional system of differential equations. Therefore, the first-order differential equation system in two variables in the general form is given as,

$$\frac{\dot{x}}{x} = \frac{\dot{c}}{c} - \frac{\dot{k}}{k} = f(x,u) \tag{62}$$

$$\frac{\dot{u}}{u} = \frac{\dot{k}_g}{k_g} - \frac{\dot{k}}{k} = g(x,u) \qquad (63)$$

From equation (62) -(63), we have,

$$\frac{\dot{x}}{x} = \frac{[(1-\tau)A(1-\theta)^{\eta}(\theta+u)^{-\eta}\{[\eta(\theta+u)-(1-\eta)\theta]-(\theta+u)(1-\gamma)\}-\beta-\delta_k\gamma+x(1-\gamma)]}{(1-\gamma)} \qquad (64)$$

$$\frac{\dot{u}}{u} = A(1-\theta)^{\eta}(\theta+u)^{1-\eta}\left[\frac{\tau}{u}-(1-\tau)\right]+\delta_k-\delta_g+x \qquad (65)$$

At steady-state, $\dot{x}/x = 0$ and $\dot{u}/u = 0$.The relationship between x and u are given by equations (64) and (65) respectively.

$$x^* = \frac{\delta_k\gamma+\beta}{(1-\gamma)} - \frac{(1-\tau)}{(1-\gamma)}A(1-\theta)^{\eta}(\theta+u)^{1-\eta}\left[(\eta-1+\gamma)-\frac{(1-\eta)\theta}{(\theta+u)}\right] \qquad (66)$$

$$x^* = \delta_g-\delta_k-A(1-\theta)^{\eta}(\theta+u)^{1-\eta}\left[\frac{\tau}{u}-(1-\tau)\right] \qquad (67)$$

We show the transitional dynamic analysis with the help of phase diagram using equations (66) -(67).

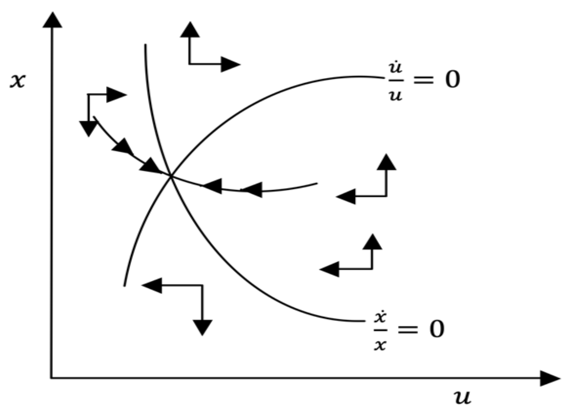


Figure 2.4 Saddle path stability when the private capital and public capital are perfect substitutes

To determine the local behaviour around the steady state, the characteristic equation of the reduced linearization is given by,

$$J_{\mathrm{E}} = \begin{bmatrix} 1-\lambda & M \\ 1 & N-\lambda \end{bmatrix} = 0, \qquad (68)$$

Where, $M = (1-\tau)A(1-\theta)^{\eta}(\theta+u)^{-\eta}\{\eta(\theta+u)[1-\gamma-\eta]+\eta(1-\eta)\theta+\eta+\gamma-1\}$, $N = A(1-\theta)^{\eta}(\theta+u)^{-\eta}\left[\frac{(1-\eta)\tau}{u}-(1-\tau)(1-\eta)-(\theta+u)\tau/u^2\right]$, λ is the characteristic root of the dynamic system. From the matrix given in equation (68), we obtain the characteristic equation,

$$\lambda^2 - \lambda(1 + N) - (M - N) = 0. \tag{69}$$

The characteristic roots depend critically on the expression $(1 + N)$ and $(N - M)$. Where, $(1 + N)$ is the sum of the principal–diagonal elements of the Jacobian (or trace of Jacobian) and $(N - M)$ is the determinant of Jacobian. Now, the characteristic roots can be expressed as,

$$r_1, r_2 = \frac{trJ_E \pm \sqrt{(trJ_E)^2 - 4|J_E|}}{2} \tag{70}$$

Thus, for this dynamic system to be saddle path stable, there must be two stable and one unstable eigen-value.

$$trJ_E = 1 + A(1 - \theta)^{\eta}(\theta + u)^{-\eta}\left[(1 - \eta)\frac{\tau}{u} - (1 - \tau)(1 - \eta) - \frac{(\theta + u)\tau}{u^2}\right] \tag{71}$$

The trJ_E is positive and now for the BGP (balanced growth path) to be stable $detJ_E$ must be negative.

$$detJ_E = -[A(1 - \theta)^{\eta}(\theta + u)^{-\eta}(1 - \tau)$$
$$\{\frac{\tau}{u(1 - \tau)}(\frac{\theta}{u} + \eta) + \gamma + \eta(\theta + u)(1 - \gamma - \eta) + \eta(1 - \eta)\theta\}] \tag{72}$$

$detJ_E$ is negative if $1 - \gamma - \eta > 0$ holds, hence this condition is sufficient for the saddle path stability.

Proposition 6. *If $\gamma + \eta < 1$ implying high output elasticity of infrastructure in final goods production, the dynamic system in substitute case is saddle path stable.*

2.3.1.3 Growth maximizing tax rate

Differentiating (61) with respect to τ_d, we find that the growth-maximizing tax rate is zero in the case of a decentralized economy, when public and private capitals are perfect substitutes. The following figure depicts the relationship between growth rate (g_d) and tax rate (τ_d) in the decentralized economy.

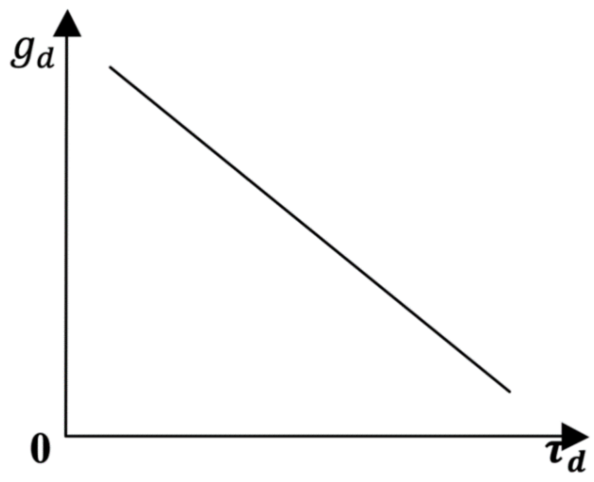


Figure 2.5 Growth maximizing tax rate (τ_d) is zero

Proposition 7. *When private capital and public capital are perfect substitutes, there exists a unique steady-state balanced growth rate in the decentralized economy. There exists a feasible range of tax rates for which growth rate is positive and public-private partnership in infrastructure investment happens. However, the unique steady-state growth falls with a rise in the tax rate. Hence in the decentralized equilibrium, the growth-maximizing income tax is zero, and this suggests complete privatization.*

The reason is quite obvious. As public capital and private capitals are perfect substitutes and usage of public capital requires taxation that creates a distortionary effect, we obtained the result that the growth-maximizing tax rate is zero. Our result is similar to the results obtained by Dasgupta (1999), Fischer and Hof (2000) where they find the growth-maximizing tax rate to be zero too.

2.3.2 Command Economy

The command economy maximizes the present discounted value of utility by taking into account the equation of motion of both private physical capital and public capital with respect to the choice variables including the tax rate.

The command economy maximizes the present discounted value of utility over the infinite time horizon given by equation (1), subject to the resource constraints (4) and (5), and with respect to the control variables C, θ_c, τ_c, where the subscript c stands for a command economy. The current value Hamiltonian is,

$$H_c = \frac{C^\gamma}{\gamma} + \lambda_1[(1-\tau_c)Y - C - \delta_k k] + \lambda_2[\tau_c Y - \delta_g k_g] \tag{73}$$

λ_1 and λ_2 are the co-state variables of k and k_g respectively, representing their shadow prices.

The first order conditions with respect to control variables, τ_c, θ_c are given by the following equations:

$$C^{\gamma-1} = \lambda_1 \tag{74}$$

$$\lambda_1 = \lambda_2 \tag{75}$$

$$\frac{\partial Y}{\partial \theta_c}[\lambda_1(1-\tau_c) + \lambda_2\tau_c] = 0 \tag{76}$$

From equation (76), we obtain the optimal value of θ_c in terms of u_c. Therefore,

$$\theta_c = 1 - \eta - \eta u_c \tag{77}$$

Note that the above-mentioned θ_c is equal to θ_d for the perfect substitute case as well, implying that the share of private investment in the infrastructure provision in the PPP model for both decentralized economy and command economy is same.

Time derivatives of the co-state variables satisfying the optimum growth path are given by following,

$$\frac{\dot{\lambda}_1}{\lambda_1} = \beta - \frac{\partial Y}{\partial k} + \delta_k \tag{78}$$

$$\frac{\dot{\lambda}_2}{\lambda_2} = \beta - \frac{\partial Y}{\partial k_g} + \delta_g \tag{79}$$

From equations (78) and (79), we get the equilibrium value of u_c,

$$u_c = \frac{(\delta_k - \delta_g) - A\eta^{\eta}(1-\eta)^{2-\eta}}{A\eta^{\eta}(1-\eta)^{2-\eta}} \tag{80}$$

Note that for u_c to be positive, the condition $(\delta_k - \delta_g) \geq A\eta^{\eta}(1-\eta)^{2-\eta}$ must hold true.

From the condition that $u_c \geq 0$ and $\theta_c \geq 0$, we find $1 \leq \frac{\delta_k - \delta_g}{A\eta^{\eta}(1-\eta)^{2-\eta}} \leq \frac{1}{\eta}$.

Taking the log and derivative of equation (74), we get,

$$(\gamma - 1)\frac{\dot{C}}{C} = \frac{\dot{\lambda}_1}{\lambda_1} \tag{81}$$

Using equation (78) and equation (81), the growth rate of consumption for command economy for the substitute case is given by,

$$\frac{\dot{C}}{C} = \frac{A\eta^{\eta}(1+u_c)^{\eta}(\theta_c+u_c)^{-\eta}[\eta(\theta_c+u_c)-(1-\eta)(1-\eta-\eta u_c)]-\delta_k-\beta}{(1-\gamma)} = g_c \tag{82}$$

Also, the growth rate of consumption, g_c depends on the ratio of public capital to private capital, u_c.

2.3.2.1 Steady-state balanced growth for the command economy

In steady-state balanced growth, the growth rate of consumption, $\dot{c}/c$ must be constant. In steady-state $\dot{k}_g/k_g = \dot{k}/k = \dot{c}/c = g_c$. Now equating $\dot{k}_g/k_g = \dot{k}/k$, we obtain the equilibrium tax rate in the command economy, which is the optimal tax rate.

$$\tau_c = \frac{A\eta^{\eta}(1-\eta)^{1-\eta} + \delta_g(1-\gamma) - \delta_k - \beta}{(1-\gamma)A\,\eta^{\eta}(1-\eta)^{1-\eta}\frac{(1+u_c)}{u_c}} \tag{83}$$

The optimal tax rate τ_c, which maximizes the welfare of the economy, must lie between 0 and 1 (i.e, $0 < \tau_c < 1$). Since, u_c is positive, $\frac{1+u_c}{u_c} > 0$. Also, since we have assumed $-\infty \leq \gamma \leq 1$ and $0 < \eta < 1$ therefore, the denominator of equation (83) is positive. So the sufficient condition for $\tau_c \geq 0$, the numerator of τ_c must also be ≥ 0. Therefore, $A\eta^{\eta}(1-\eta)^{1-\eta} + \delta_g(1-\gamma) - \delta_k - 0\beta \geq 0$ holds if $A\eta^{\eta}(1-\eta)^{1-\eta} \geq \delta_k + \beta - \delta_g(1-\gamma)$.

The condition for τ_c to be less than one is shown in the Appendix A2. The steady-state balanced growth rate of the command economy is,

$$g_c = \frac{A\eta^{\eta}(1-\eta)^{1-\eta}-\beta-0\delta_k}{1-\gamma} \tag{84}$$

For steady-state growth rate to be positive or $g_c \geq 0$, we require the condition $A\eta^{\eta}(1-\eta)^{1-\eta} \geq \beta + \delta_k$. Note that, if this condition is satisfied, the condition for $\tau_c \geq 0$ is also satisfied.

Proposition 8. *There exists a unique growth rate in the command economy when public and private capital are treated as perfect substitutes and also there exists a positive optimal tax rate to be imposed on output for financing infrastructure service.*

From (61) and (84) we find that the steady-state command economy growth rate is higher than the competitive economy growth rate. When no tax is imposed on the competitive economy, (which implies complete financing by privatization) then the competitive economy growth rate is equal to the command economy growth rate.

Proposition 9. *Command economy growth rate is higher than the competitive economy growth rate.*

Barro (1990) finds a similar result where the command economy grows faster. In a command economy, the social planner can internalize the social productivity of infrastructure by public provision and determines tax rate optimally. Whereas, in a market economy the private marginal product of capital is only taken into account and the tax rate is considered exogenously given while optimizing the present discounted value of utility. Therefore, in the present chapter, the competitive economy growth rate is less than the command economy growth rate for all positive tax rates.

Now, let us assume that the depreciation rate of both public capital and private capital is zero. In the decentralized economy, when $\delta_k = \delta_g = 0$, then, $u_d = \frac{(\tau_d A\eta^{\eta}(1-\eta)^{1-\eta}(1-\gamma))}{(A\eta^{\eta}(1-\eta)^{1-\eta}(1-2\tau_d+\tau_d\gamma)-\beta)}$. However, in the command economy, when $\delta_k = \delta_g = 0$, any solution of positive optimal u_c is not possible. Therefore, the command economy solution suggests that no public capital should be used if public capital and private capital are perfect substitutes in infrastructure production and the depreciation rates of both types of capital are the same. This is simply because an accumulation of public capital is financed by tax revenue and imposition of taxation creates distortion. The comparative static effects on growth rates and optimal tax rates of the decentralized economy with public and private goods being complementary/substitute are compared and summarized in a table given below:

Table 2.1 Comparative static table for both complementary and substitute case

	When private capital and public capital are complements in the PPP model$\left[K_I^s = B(\theta K)^{\alpha} K_g^{1-\alpha}\right]$	When private capital and public capital are substitutes in the PPP model $\left[K_I^s = \theta K + K_g\right]$
Decentralized Economy (Where, d denotes decentralized economy)	(1) There exists unique steady state growth rate (2) There exists a unique, interior growth-maximizing tax rate given by, $\tau_d = (1-\eta)(1-\alpha)$	(1) There exists unique steady state growth rate. There also exists a range of feasible tax rates for which growth rate is positive. (2) The impact of a tax rate on growth is negative. Hence, the growth-maximizing tax rate is zero. It suggests that the complete privatization rather than PPP would maximize the growth rate.
Command Economy (Where, c denotes command economy)	(1) There exists unique steady state growth rate (2) The unique, optimal tax rate is found out. (3) The command economy growth rate may not be higher than the competitive economy growth rate.	(1) There exists unique steady state growth rate. (2) The unique, optimal tax rate is found out. (3) The command economy growth rate is higher than the competitive economy growth rate.

2.4 Conclusion

In this chapter, we developed an endogenous growth model with an infrastructure service that is an impure public good. The infrastructure sector uses private capital and public capital as factors of production. Private investment and public investment are not independent of each other. There is a crowding-out effect in case of substitute relationship between private capital and public capital and crowding in effect in case of a complementary case. This chapter studied both the substitutes and complementary relationship in a public-private partnership model and found the equilibrium as well as the optimal public policy in this context.

The transitional dynamics result shows saddle-path stability of the dynamic system for both the complementary and substitute cases. The government is assumed to impose output tax to finance the expenditure on public capital and if the optimal tax rate is found to be zero, Public-Private Partnership (PPP) is not desirable, otherwise, it is. The main objective of this chapter is to inquire whether PPP in infrastructure is feasible and optimal or not. The results obtained in this chapter suggests that the public-private partnership (PPP) model is optimal in the provision of infrastructure because we obtain an interior optimal solution of the tax rate in a command economy, no matter public and private capitals are substitutes or complements. When depreciation rates of physical capital are assumed to be zero, we find that PPP is an equilibrium outcome for the complementary case and complete privatization emerges as an equilibrium solution for the perfect substitutes case.

While comparing the growth rate of command economy and growth rate of competitive economy, we found that in the case of substitute, command economy growth rate is higher than the competitive economy growth rate but in the case of complementary relationship, command economy growth rate may not be higher than the competitive economy growth rate. This implies that the public-private partnership is always an optimal solution for financing infrastructure no matter the relationship between private capital and public capital are substitutes or complements. But, the PPP solution is not growth maximizing in the case when the public capital and private capital are perfect substitutes.

This chapter is subject to some limitations. We have assumed that the government runs a balanced budget. But, most of the time, the government of an economy, especially a developing economy, faces a deficit budget. It would be interesting to analyze how debt financing of public investment affects growth rates and welfare in comparison to the tax-financed one. We abstract from any kind of subsidy given by the government which is an important variable affecting the investment decision of the private sector and especially for the infrastructure sector in the real world. Further, for simplicity, we have not considered labour as a factors of production in our model. We agree that a perfectly competitive product and factor market and consequently constant returns to scale in the production of infrastructure may not be too realistic. But, considering market imperfection and more general production functions (with non-constant returns to scale) are beyond the time and scope of this present chapter. Though usually, infrastructure service generates a positive external effect on other sectors of the economy, we have ignored the presence of an external effect in the present chapter. This chapter attempts to find out whether PPP is an optimal policy when the government runs a balanced budget and the result shows that it is an optimal policy in the provision of infrastructure, but may not be a growth-maximizing one.

APPENDIX

Appendix A1. The second order condition is,

$$\left(\frac{\partial^2 u_d}{\partial \tau_d^2}\right) = \frac{1}{[\{\eta + \alpha(1-\eta)\}[(1-\gamma)\frac{\tau_d}{u_d} + (1-\tau)(1-\eta)(1-\alpha)]]^2}[\{\eta + \alpha(1-\eta)\}\big((1-\gamma)$$

$$+ \{\eta + \alpha(1-\eta)\}u_d\big) - \left(\frac{(1-\gamma)}{u_d} + \{\eta + \alpha(1-\eta)\}\right)\{\eta + \alpha(1-\eta)\}(1-\gamma)[1$$

$$- \frac{(1-\gamma) + \{\eta + \alpha(1-\eta)\}u_d}{\{\eta + \alpha(1-\eta)\}[(1-\gamma)\frac{\tau_d}{u_d} + (1-\tau_d)(1-\eta)(1-\alpha)]}\frac{\tau_d}{u_d} - \frac{(1-\eta)(1-\alpha)u_d}{(1-\gamma)}]]$$

For $\left(\partial^2 \mathrm{u_d}/\,\partial \tau_\mathrm{d}^2\right)$ to be positive, $[1-((1-\gamma)+\{\eta+\alpha(1-\eta)\}u_d)/(\{\eta+\alpha(1-\eta)\}[(1-\gamma)\tau_d/u_d+(1-\tau_d)(1-\eta)(1-\alpha)])(\tau_d/u_d)-((1-\eta)(1-\alpha)u_d)/(1-\gamma)]$ must be less than zero. Therefore,

$$[1 - \frac{(1-\gamma)+\{\eta+\alpha(1-\eta)\}u_d}{\{\eta+\alpha(1-\eta)\}[(1-\gamma)\frac{\tau_d}{u_d}+(1-\tau_d)(1-\eta)(1-\alpha)]}\frac{\tau_d}{u_d} - \frac{(1-\eta)(1-\alpha)u_d}{(1-\gamma)}] < 0,$$

Since,$((1-\gamma)+\{\eta+\alpha(1-\eta)\}u_d)/(\{\eta+\alpha(1-\eta)\}[(1-\gamma)\tau_d/u_d+(1-\tau_d)(1-\eta)(1-\alpha)]) = \partial u_d/\partial\tau_d$. Therefore, substituting it in the above equation, we obtain,

$$\frac{\partial u_d}{\partial \tau_d}\frac{\tau_d}{u_d} + \frac{(1-\eta)(1-\alpha)u_d}{(1-\gamma)} > 1. \tag{28}$$

Equation is a sufficient condition for $(\partial^2 u_d/\partial \tau_d^2)$ to be positive and $(\partial^2 g_d/\partial \tau_d^2)$ to be negative. In other words, equation (28) is a sufficient condition for the existence of growth maximizing tax rate.

Appendix A2. For τ_c to be less than one, In equation (64), $\left[A\eta^\eta(1-\eta)^{1-\eta}+\delta_g(1-\gamma)-\beta-\delta_k\right]/[A(1-\gamma)\eta^\eta(1-\eta)^{1-\eta}] \times \left[\delta_k-\delta_g-A\eta^\eta(1-\eta)^{2-\eta}\right]/\left(\delta_k-\delta_g\right) < 1, \quad u_c/(1+u_c) < 1$. Therefore, $\left[\delta_k-\delta_g-A\eta^{\eta+1}(1-\eta)^{2-\eta}\right]/\left(\delta_k-\delta_g\right) < 1$.

So the sufficient condition for τ_c to be less than 1 is $\left[A\eta^\eta(1-\eta)^{1-\eta}+\delta_g(1-\gamma)-\beta-\delta_k\right]/[A(1-\gamma)\eta^\eta(1-\eta)^{1-\eta}]$ must be less than 1.

Therefore, $A\eta^\eta(1-\eta)^{1-\eta}+\delta_g(1-\gamma)-\beta-\delta_k < A(1-\gamma)\eta^\eta(1-\eta)^{1-\eta}\delta_g(1-\gamma)-\beta-$

$$\delta_k < A\eta^{\eta}(1-\eta)^{1-\eta}[(1-\gamma)-1]$$

$$A\eta^{\eta}(1-\eta)^{1-\eta}\gamma < \delta_k + \beta - \delta_g(1-\gamma).$$

Chapter 3

Why should the government provide the infrastructure through the Public-Private Partnership mode?

3.1 Introduction

Infrastructure service is an important development tool that catalyses growth in the long run. Traditionally, the government has been the unique provider of public goods and services in most developing nations. Though the provision of infrastructure service is crucial for growth and development, the challenge faced by the government was to bear the enormous financial cost required for infrastructure investments and at the same time to deliver high-quality public services at low cost to the consumers and to obtain a high growth rate. To tackle this challenge some of the governments started charging user fees (example: tolls on highways and bridges) for availing infrastructure services that are non-rival yet excludable in nature and also started giving the contract to private firms who did the same. There had been a growing consensus that private provision of public goods and services is often a viable option, if not a superior alternative to public provision (Buiter (2001)). Mostly privately provided roads, power, water, transportation, communication and irrigation became common in the developed nations (OECD countries) to reduce the financial burden of the governments and to ensure that those who benefit pay a greater portion of the costs (Oxley and Martin (1991)). According to Kateja (2012), there was a widespread shift from public provision to private provision and it happened much more quickly than had been anticipated. He also agreed to the point that with the help of the private sector much was achieved for the infrastructure development, which could not have been possible with the traditional mode of provision. However, it was asserted in a report by the Public-Private-Partnership Legal

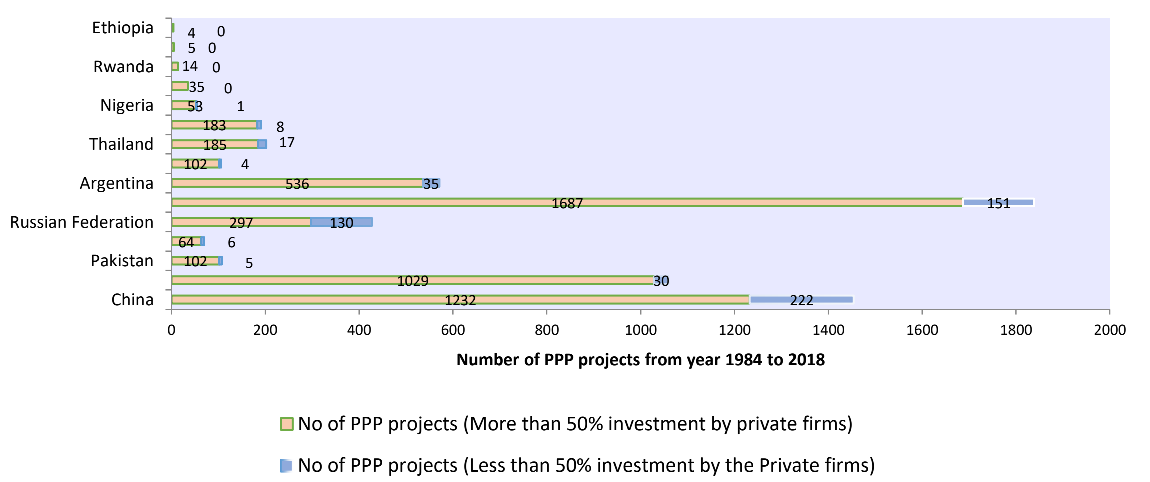
Resource Centre, World Bank Group that very few PPP projects are viable without some form of government support. Without any government intervention, private provision of infrastructure may also lead to the under-provision of the infrastructure capital. Hence, Public-Private Partnership (PPP) became a feasible and efficient solution to the problem of infrastructure provision. According to Maskin and Tirole (2008), a PPP is defined as a long-term development and service contract between the government and a private partner. The government typically engages its private partner both to develop the project and to operate and service it. The partner may bear the substantial risk and even raise private finance. The revenue of the project comes from some combination of government payments and user fees. The PPP provision reduces the huge financial cost on the part of the government, improves the current budgetary position and lowers the government deficit. After witnessing the success of PPP infrastructure projects in the developed nations the developing nations started adopting the Public-Private Partnership (PPP) projects at an increasing rate. There has been a significant increase in the number of PPP projects adopted by the developing countries after the year 1991.

The literature on infrastructure and endogenous growth theory such as Barro (1990), Dasgupta (1999), Futagami et al. (1993), Turnovsky and Pintea (2006) concentrated more on the non-rival and non-excludable pure public goods in a balanced budget framework. However, in reality, the governments of many countries have relied upon the partnership with private entities and public debt along with tax to reverse the declining trend in infrastructure investment. Developed countries are known to have accumulated extensive debt in the past and borrower-lender cycles have often stretched over many decades. Many major borrowers like the UK and the USA have taken a long time to turn into lenders (Ueshina (2018), Wijnbergen (1989)). Therefore, the study of a deficit budget in the infrastructure and growth literature is imperative. The public debt temporarily provides the fiscal stimulus for public investment shifting the cost of the debt burden to the future tax-payers. Hence, public borrowing distributes the heavy cost of capital formation over the years during which infrastructure capital will be used. However, the choice of debt policy and the growth performance of nations are very much related. In this context, it is important to know the effects of public debt and deficit budget strategy on economic growth.

The concept of sustainability is associated with long-term fiscal policy and it means the capacity to keep a balance between costs of additional borrowing and the returns from such borrowing in the form of higher growth, resulting in higher government revenues, which again can be used for the servicing of additional borrowing. To study the sustainability of public debt of the government, certain fiscal rules such as Ricardian equivalence, Golden rule of public finance (GRPF) and Primary surplus rule; are popular in the academic circle. The primary surplus rule has novelty over the Ricardian equivalence and the GRPF because it makes sure that the tax revenue must exceed the government spending so that sustainability of public debt can be obtained. The higher public debt today must go along with a corresponding increase of future primary surpluses of the government. Here, in this chapter, following Greiner (2008, 2012) and Kamiguchi and Tamai (2012) we apply the primary surplus rule. We assume that while the government runs a deficit budget, it must set the primary surplus as a positive linear function of public debt, which guarantees that the public debt is sustainable. As a consequence, the primary surplus becomes a positive function of public debt (Greiner (2014)). In other words, if a government raises the primary surplus as public debt increases, it takes corrective action which stabilizes the debt ratio. Kamaiguchi and Tamai (2012) analysed the conditions on which the ongoing balanced growth and sustainability of public debt were simultaneously achievable. They found that when the debt ratio was smaller, higher was the growth rate. Greiner (2014) also found a similar result. He also found that a balanced budget yields a higher long-run growth rate than an accumulating debt budget policy and higher values of coefficient determining the reaction of the primary surplus to higher debt tended to stabilize the economy. However, none of these papers studied the sustainability of public debt from the impure public good provision or the PPP provision of infrastructure point of view in an endogenous growth framework. The present chapter attempts to fill this gap.

Figure 3.1 depicts the PPP projects undertaken in different middle and low-income countries during the years 1984-2018. In Figure 3.1, we observe that the number of PPP projects undertaken by Brazil, China, India, Argentina and Russia are quite high. It is also noted in figure 1 that the percentage of investment by the private firms varies in the PPP projects, which are broadly classified into more than 50% investment by the private firms and less than 50% investment by the private firms.

Figure 3.1 : Public -Private Partnership projects in the middle and low income Countries



Source: Authors' compilation from Private participation in Infrastructure Database, World Bank.

We see in figure 3.1 that most of the countries have adopted PPP projects with more than 50% investment by private firms rather than less than 50% investment by private firms. These differences in the percentage of private participation in the infrastructure sector are due to the difference in public spending in the PPP projects which is called Viability Gap Funding (VGF). VGF is the special form of government's capital grants to the infrastructure–manufacturing firm for the construction of the infrastructure projects. According to Bagal (2008), the mechanism of VGF (Viability Gap Funding) seeks to fill the gap between the expected rate of return and actual return of the investors through a capital grant and ensures a reasonable rate of return for the project. It is plausible that VGF could be an important fiscal policy instrument in the infrastructure sector influencing the growth rates for the nations adopting PPP projects. Our model tries to find if there is a difference in the growth rates of the nations because of the degree of participation of private firms in terms of the percentage of investment by the public entities (more than 50% or less than 50%) in the PPP projects.

We address several public policy questions in this chapter. Is the PPP mode of infrastructure provision a better option compared to the purely private provision or public mode of provision? Bara and Chakraborty (2019) studied the optimality of PPP in an endogenous growth model. However, their paper dealt only with the balanced budget regime and not the debt-financing regime. In the present chapter, we investigate the reason why the government needs the help of a private firm for the manufacturing of infrastructure. We attempt to find out whether the imposition of a tax, bond financing or charging of a user fee or mix of these instruments is the optimal method of financing in these different provisions of infrastructure. If the government chooses the PPP mode of provision, then what should be the optimal participation or optimal percentage of investment by the private firms in the PPP projects?

We built a closed economy model of infrastructure provision to answer these questions. In this chapter, infrastructure may be provided by the pure private firm, pure public entity or through the partnership of private firm and public entity. We are considering different budgetary regimes of the government in providing the infrastructure: the government may opt for a balanced budget or may opt for a budget deficit. Following, Greiner (2008, 2012) and Kamiguchi and Tamai (2012), we assume that while the government runs a deficit budget, it must set the primary surplus as a positive linear function of public debt, which guarantees that the public debt is sustainable.

In this chapter, we find that the growth rate under the pure private provision is higher compared to that in pure public provision. We also find that under the balanced budget when the government charges user fees and imposes tax to finance the infrastructure cost, the growth maximizing tax rate is zero. However, under the accumulating debt regime, the growth maximizing tax rate is positive. It is also found that the maximum growth rate in the public provision of infrastructure under the accumulating debt regime is greater than the growth rate in the pure private provision or pure public provision of infrastructure under the balanced budget regime if primary surplus does not react to changes in GDP and changes in public debt strongly. This result contradicts the result found by Greiner (2014) that says the growth rate obtained under a balanced budget is always greater than that obtained under a deficit budget. We also find that PPP yields a higher growth rate compared to public provision of infrastructure both under a balanced budget and accumulating debt. PPP under accumulating debt yields a higher growth rate than the growth rate under PPP in a balanced budget only if primary surplus decreases as the GDP increases and vice versa. In the numerical example, we find that the PPP projects with more than 50% of investment by the private firm yield the highest growth rate.

The structure of the chapter is organized in the following manner: Section 3.2 describes the models of pure private, pure public and the PPP provisions of infrastructure. We also find the steady-state balanced growth rates, user fees and equilibrium value of the fraction of private physical capital used for the production of finished goods for all the three provisions of infrastructure in different budgetary regimes respectively. In Section 3.3 and section 3.4, we see the numerical example of the balanced budget and permanent deficit regime for different provisions of infrastructure respectively. Finally, we conclude with section 3.5.

3.2 The model

We consider a closed competitive economy with three agents - the representative household and two profit-making firms. It is assumed that the infinitely lived representative household derives utility from the direct consumption of final goods. The utility function of the representative household is given by equation (1).

$$U = \int_0^\infty (\gamma \ln C)\, e^{-\rho t} dt \qquad (1)$$

ρ is constant and denotes the positive discount rate at which future utility is discounted. We assume that there are two profit-making firms in the economy. Firm 1 produces final goods for consumption and capital accumulation. Firm 2 produces infrastructure services. Following Barro (1990), we assume that infrastructure services are flow in nature. Both firms are run by profit-maximizing private entities. Infrastructure is used for final goods production.

The household supplies private physical capital (K) required for the production of both final goods (Y) and infrastructure (G). The production function of final goods is given by equation (2).

$$Y = A(uK)^{1-\alpha} G^{\alpha} \quad , \qquad 0 < \alpha < 1 \qquad (2)$$

Y is used for consumption as well as capital accumulation. u fraction of private physical capital and flow of infrastructure good at time t denoted by G enter as intermediate goods for the production of Y. A is the technology parameter of the production of Y. $1-\alpha$ and α are output elasticities with respect to uK and G respectively. The final good is assumed to be a numeraire commodity. Hence, the price of Y is considered to be unity.

The production function of infrastructure service is given as,

$$G = \delta(1-u)K \tag{3}$$

Where, $(1-u)K$ denotes the remaining part of private physical capital that is used to produce infrastructure. δ is the technology parameter of infrastructure services production, which is a constant. We obtain the ratio of infrastructure to private physical capital from (3).

$$\frac{G}{K} = \delta(1-u) \tag{4}$$

The profit function of firm 1 producing the final goods is given by (5).

$$\Pi^1 = A(uK)^{1-\alpha}G^{\alpha} - ruK - \mu G \tag{5}$$

μ is the user fees paid by firm 1 for availing infrastructure services. Firm 1 takes input prices as given and choose input quantities to maximize its' profit. Differentiating the profit function of firm 1 with respect to uK and G, we obtain the infrastructure demanded by firm 1 in (6) and after substituting the value of $\left(\frac{G}{K}\right)$, we express the first-order conditions as (7) and (8) respectively.

$$G = \left[\frac{\mu}{Au^{1-\alpha}\alpha}\right]^{\frac{1}{\alpha-1}} K \tag{6}$$

$$r = A(1-\alpha)\delta^{\alpha}\left(\frac{1-u}{u}\right)^{\alpha} \tag{7}$$

$$\mu = A\alpha\delta^{\alpha-1}\left(\frac{1-u}{u}\right)^{\alpha-1} \tag{8}$$

3.2.1 Pure private provision of infrastructure

The pure private provision is a laissez-faire provision and hence the government does not play any role in the provision of infrastructure. The profit-making private firm manufactures the entire infrastructure and charges user fees for providing the infrastructure services. The profit function of infrastructure producing firm 2 is given by (9).

$$\Pi^2 = \mu G - r(1-u)K \tag{9}$$

Where, μ is the user fee charged by firm 2 for the infrastructure services (e.g. toll fees charged for the usage of roads). As a competitive firm, firm 2 also takes input prices as given and chooses input quantities to maximize its' profit. Differentiating the profit function of firm 2 with respect to $(1-u)K$, we obtain the first-order condition.

$$r = \mu\delta \tag{10}$$

Using the no-arbitrage condition, we equate the rate of interest of firm 1 and firm 2 and find the equilibrium value of u under the pure private provision of infrastructure. The superscript 'P' denotes pure private provision of infrastructure.

$$u^P = 1-\alpha \tag{11}$$

Now substituting the value of u in (8), the user fee to be charged under the pure private provision is given by equation (12).

$$\mu^P = A\delta^{\alpha-1}\alpha^{\alpha}(1-\alpha)^{1-\alpha} \tag{12}$$

3.2.1.1 The household sector

The utility function of the representative household is given in (1). It is assumed that the households accumulate disposable income over expenditure as wealth. The total wealth/ asset (W) of the households is equal to the total private physical capital (K) in the economy. The rate of accumulation of private physical capital is given by (13).

$$\dot{K} = rK - C \tag{13}$$

And, the rate of growth of private physical capital is given by (14).

$$\frac{\dot{K}}{K} = r - \frac{C}{K} \tag{14}$$

In a competitive economy, the representative household's problem is expressed in the current-value Hamiltonian as $H_c = \gamma \ln C + \eta[rK - C]$, which delivers the growth rate equation under the purely private provision.

$$\frac{\dot{C}}{C} = r - \rho = g^P \tag{15}$$

3.2.1.2 Steady-state balanced growth

At steady-state balanced growth rate under the pure private provision of infrastructure, $\frac{\dot{C}}{C} = \frac{\dot{K}}{K} = g^P$. If $\frac{\dot{K}}{K}$ is constant, it follows that $\frac{C}{K} = \rho$ is also constant. The steady-state growth rate, g^P is constant and positive. Now setting $\frac{\dot{C}}{C} = \frac{\dot{K}}{K}$, we get equation (16).

$$\frac{C}{K} = \rho \tag{16}$$

Substituting the value of r from equation (10) and the user fees from equation (12) in the growth rate equation (15), we obtain the steady-state balanced growth rate of the pure private provision of infrastructure.

$$g^P = A\alpha^{\alpha}(1-\alpha)^{1-\alpha}\delta^{\alpha} - \rho \tag{17}$$

Proposition 1: *Under the pure private provision of infrastructure, there exists a unique steady-state balanced growth rate.*

3.2.2 Public provision of infrastructure

In this section, we assume that the government charges the user fees to the firms for the usage of infrastructure, not to maximize its profit but to meet the expenses of producing infrastructure. This is contrary to the traditional pure public provision where the government do not charge the user fees for the public services. Here, we assume that the government solely renders the infrastructure services. There are two agents namely; the representative household and the government. In addition to charging user fees, the government also imposes a tax on the capital income to finance the cost of producing infrastructure. We also consider the case where the government does not charge the user fee but charges only the capital income tax to finance the infrastructure cost, which is the conventional traditional way of financing public goods.

3.2.2.1 The government

The benevolent government is mainly engaged in 3 activities in connection with the impure public provision: (i) it provides the infrastructure goods and charges user fees for the usage of infrastructure; (ii) it imposes capital income tax to finance its cost; (iii) it also issues government bonds. We, therefore, evaluate balanced budget, constant debt and accumulating debt budgetary policies of the government.

The interest payment on the bonds adds to the debt burden of the government while tax revenue reduces the government debt. The bond accumulation function is given by (18).

$$\dot{B} = (1-\tau)rB - (T - E) \tag{18}$$

T is the tax revenue at time t and E is the public expenditure at time t. The total revenue of the government is comprised of tax revenue and the user fees which is presented in (19) and the public expenditure is given by (20) respectively.

$$T = \tau\, r\, uK + \mu G \tag{19}$$

$$E = r\,(1-u)K \tag{20}$$

Substituting the value of T, E and G in (18), we obtain the rate of growth of bond accumulation function.

$$\frac{\dot{B}}{B} = (1-\tau)r - \frac{K}{B}[\tau r u + \mu\delta(1-u) - r(1-u)] \tag{21}$$

3.2.2.2 The household sector

The utility function of the representative household is given in (1). However, the wealth/asset of the household now also includes bond holding (B) other than the capital holding (K) under the pure public provision. The total disposable wealth of a household over consumption expenditure is accumulated as wealth. The representative household maximizes the present discounted value of utility, subject to the rate of accumulation of wealth.

$$\dot{W} = (1-\tau)rW - C \tag{22}$$

Where, τ is the tax on capital income, r is the interest rate, C is consumption at time t.

From the first order conditions we have,

$$-\frac{\dot{C}}{C} = \rho - (1-\tau)r \tag{23}$$

Since $W = B + K, \frac{\dot{W}}{W} = g$, therefore, the growth rate under the pure public provision implies,

$$\frac{\dot{C}}{C} = \frac{\dot{G}}{G} = \frac{\dot{W}}{W} = (1-\tau)r - \rho = g^T \tag{24}$$

The superscript 'T' denotes traditional pure public provision of infrastructure. Using equation (24) and equation (22), we obtain the ratio of consumption to private physical capital.

$$\frac{C}{K} = \left(1 + \frac{K}{B}\right)[(1-\tau)r - g] \tag{25}$$

3.2.2.3 Steady-State balanced growth

The steady-state balanced growth equilibrium is defined as a situation when consumption, private physical capital and infrastructure capital grow at the same strictly positive constant growth rate, i.e.; $\frac{\dot{C}}{C} = \frac{\dot{K}}{K} = \frac{\dot{G}}{G} = \frac{\dot{B}}{B} = \frac{\dot{Y}}{Y} = g^T$. If $\frac{\dot{B}}{B}$ is constant, then $\frac{B}{K}$ is also constant. We obtain the value of $\frac{B}{K}$ by setting $\frac{\dot{C}}{C} = \frac{\dot{B}}{B}$.

$$\frac{B}{K} = \frac{\tau r u + \mu\delta(1-u) - r(1-u)}{\rho} \tag{26}$$

3.2.2.4 Zero debt regime

In the zero debt regime or under the balanced budget policy of the government, the government's tax revenue is equal to the total expenditure of the government and public debt is zero. A zero debt to GDP ratio implies that the primary surplus relative to GDP also equals zero so that the government does not have to use public resources for unproductive interest payments and debt services. Here, in our model, the steady-state balanced growth rate of the impure public provision in the zero debt regime is denoted by $g^T_{(B=0)}$. Subscript $(B = 0)$ denotes zero debt regime. The balanced budget constraint of the government is obtained by equating (19) with (20).

$$r[1 - u(1 + \tau)] = \mu\delta(1 - u) \tag{27}$$

Now resorting to (7) and (8), we obtain the equilibrium value of u, user fees and the growth rate under the impure public provision of infrastructure in the zero-debt policy of the government.

$$u^T_{(B=0)} = \frac{(1-\alpha)}{\alpha+(1-\alpha)(1+\tau)} \tag{28}$$

The user fees under the impure public provision in the balanced budget policy of the government is given by (29).

$$\mu^T_{(B=0)} = A\delta^{\alpha-1}\alpha\left[\frac{\alpha+(1-\alpha)\tau}{(1-\alpha)}\right]^{\alpha-1} \tag{29}$$

The growth rate equation under the impure public provision in the zero-debt regime is given by (30).

$$g^T_{(B=0)} = (1-\tau)A(1-\alpha)\delta^{\alpha}\left[\frac{\alpha+(1-\alpha)\tau}{(1-\alpha)}\right]^{\alpha} - \rho \tag{30}$$

Differentiating equation (30) with respect to τ, we find from the first-order condition that the growth maximizing tax rate is zero. If the government does not impose a tax and finance the infrastructure cost solely by charging user fees, the government is doing the same job as a private firm. Therefore, in the zero debt regime, the growth rate when the government charges user fees without imposing a tax is equal to the growth rate of the pure private provision of infrastructure. $g^T_{\hat{\tau}(B=0)}$ denotes the maximum growth rate under the traditional provision of infrastructure.

$$g^T_{\hat{\tau}(B=0)} = A\alpha^{\alpha}(1-\alpha)^{1-\alpha}\delta^{\alpha} - \rho \tag{31}$$

Proposition 2: *When the government charges user fees and imposes tax to finance the infrastructure cost, the growth maximizing tax rate is zero. It is optimal for the government to charge only user fees instead of imposing a tax for financing the infrastructure in the balanced budget regime.*

3.2.2.5 Constant Debt regime

We assume that at a steady-state, the government opts for the constant debt regime for the impure public goods, such that $\dot{B} = 0$ and also $\frac{\dot{C}}{C} = \frac{\dot{K}}{K} = \frac{\dot{G}}{G} = g^T_{(\dot{B}=0)}$ is constant and positive. The subscript ($\dot{B} = 0$) denotes debt accumulation is zero or a constant debt regime. The steady-state growth rate under the impure public provision in the constant debt budgetary policy of the government is denoted by $g^T_{(\dot{B}=0)}$. When $\dot{B}$ is equal to zero, it does not necessarily imply that public debt is zero. The debt to GDP ratio and the debt to capital ratio are both positive because the level of initial debt is positive, however, both declines over time and asymptotically converge to zero in the long run, since the public debt is constant and the capital and output are growing. By following Aizenman et al. (2007), we assume in our model that the interest rate on public debt is equal to the rate of return to capital.

When setting $\dot{B} = 0$, the results are found to be the same as the zero debt budgetary policy of the government and this is because the debt capital ratio converges to zero in the long run.

The proofs of this have been illustrated in Appendix A1 which shows the user fee, growth rate, optimal tax rate and the optimal growth rate in the constant debt regime.

Proposition 3: *The growth maximizing tax rate, the user fee and the growth rate are the same in the constant debt and zero debt regimes.*

Proof: The proof for proposition 3 is shown in Appendix A1.

3.2.2.6 Public expenditure is financed only by taxation

In this section, we assume that the government does not charge any user fee and infrastructure cost is financed only by tax revenue and thus this mode of financing can be termed as the pure traditional provision of infrastructure.

$$T = \tau r u K_g \qquad (32)$$

$$E = r(1-u)K_g \qquad (33)$$

Under the balanced budget, the government's tax revenue is set equal to the total public expenditure of the government and public debt is zero. We find the equilibrium value of u in equation (34).

$$u^{PT} = \frac{1}{\tau+1} \qquad (34)$$

The superscript PT denotes the pure traditional form of infrastructure provision. The growth rate equation when the government charges only tax for the financing of infrastructure is given by (35).

$$g^{PT}_{(\dot{B}=0)} = (1-\tau)A(1-\alpha)\delta^{\alpha}\tau^{\alpha} - \rho \qquad (35)$$

Differentiating (35) with respect to τ, the first-order condition gives the optimal tax rate under the traditional pure public provision.

$$\tau^{PT} = \frac{\alpha}{1+\alpha} \qquad (36)$$

From the second-order condition, we find that,

$A(1-\alpha)\delta^{\alpha}\alpha^{\alpha}(1+\alpha)^{1-\alpha}\left[-2+\frac{\alpha-1}{\alpha}\right]<0$

The optimal growth rate under the traditional pure public provision by substituting the optimal tax rate in the growth rate equation. $g^{PT}_{\hat{\tau}(\dot{B}=0)}$ denotes the maximum growth rate under the pure traditional provision of infrastructure.

$$g^{PT}_{\hat{\tau}(\dot{B}=0)}=\frac{A(1-\alpha)\delta^{\alpha}\alpha^{\alpha}}{(1+\alpha)^{1+\alpha}}-\rho \tag{37}$$

Comparing equation (31) and equation (37) we see that the growth rate obtained when infrastructure is financed solely by taxation is always smaller than the growth rate when infrastructure is sponsored by charging user fees. But, the latter is the same as the growth rate obtained under the pure private provision.

Proposition 4: *Financing the infrastructure solely by taxation yields lower growth compared to financing it by user fees under a balanced budget. Hence, the growth rate under a pure private provision of infrastructure is higher than that under a pure public provision of infrastructure.*

3.2.2.7 Permanent deficit regime

In this section, we assume that the government is accumulating debt for financing infrastructure costs. The permanent deficit case is characterized by the public deficit, where the government debt grows at the same rate as all other endogenous variables in the long run such that the inter-temporal budget constraint is fulfilled. The steady-state balanced growth rate under this accumulating debt regime is denoted by $g^{T}_{(\dot{B}>0)}$. The subscript ($\dot{B}>0$) denotes the accumulating debt or permanent debt regime. Along the steady-state, all the variables grow at the same constant rate, such that $\frac{\dot{C}}{C}=\frac{\dot{G}}{G}=\frac{\dot{K}}{K}=\frac{\dot{W}}{W}=\frac{\dot{B}}{B}=g^{T}_{(\dot{B}>0)}$.

Substituting the value of T and E from equation (32) and equation (33) in equation (18), we obtain the bond accumulation function.

$$\dot{B} = (1-\tau)rB - \tau ruK_g + r(1-u)K_g \quad (38)$$

The rate of growth of bond is given by,

$$\frac{\dot{B}}{B} = (1-\tau)r - \frac{K_g}{B}[\tau ru - r(1-u)] \quad (39)$$

At the steady-state balanced growth by setting $\frac{\dot{C}}{C} = \frac{\dot{B}}{B}$, we obtain the value of $\frac{B}{K_g}$.

$$\frac{B}{K_g} = \frac{\tau ru - r(1-u)}{\rho} \quad (40)$$

Primary surplus rule

For the sustainability of public debt in our model, we apply the primary surplus rule in this chapter. The empirical evidence also reveals that some of the governments follow such a rule of the primary surplus. For example, using OLS estimations Bohn (1998) and Greiner et al. (2007) have shown that this rule holds for the USA and selected European countries. Fincke and Greiner (2012) find that the reaction-coefficient determining the response of the primary surplus to public debt is not a constant but time-varying with the average of that coefficient being strictly positive for some euro area countries. Following Kamiguchi and Tamai (2012) and Greiner (2008), we assume that the ratio of the primary surplus to gross domestic income ratio is a positive linear function of the debt to gross domestic income ratio with an intercept. Hence, the primary surplus ratio can be written as,

$$\frac{T-E}{Y} = \xi + \beta \frac{B}{Y} \quad (41)$$

According to Greiner (2008), ξ, β are the real numbers and are constant. β determines how strongly the primary surplus reacts to changes in public debt. When $\beta > 0$, the government pursues a rule-based policy in the sense that it raises the primary surplus as public debt grows, relative to GDP respectively. However, it does not mean that the government has no discretionary scope at all. Rather, it can determine public spending by the choice of the parameter ξ to a certain degree. ξ determines whether the level of the primary surplus rises or falls with an increase in gross domestic income. If $\xi < 0$, it implies that primary surplus decreases as the GDP increases and the government puts a large weight on stabilizing public debt. In this case of negative ξ, β must be sufficiently large. If β is sufficiently low, then the government must be a creditor for the economy to achieve sustained growth. If $\xi > 0$ implies that the primary surplus rises as GDP increases which means that the government prefers to raise productive public spending as GDP grows, rather than to reduce the accumulation of public debt. Therefore, the government runs into debt to finance public investment and interest payments. In this case, β must not be too large. A high β implies that the government does not invest sufficiently and it must be a creditor to finance its investment and to achieve sustained growth. (ibid)

$$T - E = \xi \, Y + \beta \, B \tag{42}$$

Substituting the values of T, E and Y in the above equation, we obtain the value of $\frac{B}{K}$.

$$\frac{B}{K} = \frac{\tau \, r \, u - \xi \, A \, u^{1-\alpha}\delta^{\alpha}(1-u)^{\alpha} - (1-u)(r-\mu\delta)}{\beta} \tag{43}$$

The bond accumulation function for the sustainability of public debt is,

$$\dot{B} = (1-\tau)rB - (\xi \, Y + \beta \, B) \tag{44}$$

The rate of growth of bond is,

$$\frac{\dot{B}}{B} = (1-\tau)r - \frac{\xi \, A u^{1-\alpha}[\delta(1-u)]^{\alpha}\beta}{\tau \, r \, u - \xi \, A \, u^{1-\alpha}\delta^{\alpha}(1-u)^{\alpha} - (1-u)(r-\mu\delta)} - \beta \tag{45}$$

We set $\frac{\dot{C}}{C} = \frac{\dot{B}}{B}$ to find the equilibrium value of u under the impure public provision in the permanent deficit budgetary policy of the government.

$$u^{T}_{(\dot{B}>0)} = \frac{(\rho-\beta)(1-\alpha)}{(\rho-\beta)[(1-\alpha)(\tau+1)-\alpha]-\xi\rho} \tag{46}$$

Substituting this value of u in (8), we obtain the user fee to be charged by the government in the accumulating debt regime.

$$\mu^{T}_{(\dot{B}>0)} = A\alpha\delta^{\alpha-1}\left[\frac{(\rho-\beta)[\tau(1-\alpha)-\alpha]-\xi\rho}{(\rho-\beta)(1-\alpha)}\right]^{\alpha-1} \tag{47}$$

Substituting the value of the rate of interest from (7) in (24), we obtain the growth rate equation in the permanent deficit regime.

$$g^T_{(\dot{B}>0)} = (1-\tau)A(1-\alpha)^{1-\alpha}\delta^{\alpha}\left[\frac{(\rho-\beta)[\tau(1-\alpha)-\alpha]-\xi\rho}{(\rho-\beta)}\right]^{\alpha} - \rho \qquad (48)$$

Differentiating (48) with respect to τ, the value of the growth maximizing tax rate in the accumulating debt regime is found out.

$$\tau^T_{(\dot{B}>0)} = \frac{\xi\rho+\alpha(\rho-\beta)(2-\alpha)}{(\rho-\beta)(1-\alpha)(1+\alpha)} \qquad (49)$$

The necessary and sufficient condition for the tax rate to be positive is $\frac{\xi\rho}{(\beta-\rho)} < \alpha(1-2\alpha)$. Note that this condition is always satisfied if $\xi > 0$ and $\rho > \beta$ or $\xi < 0$ and $\beta > \rho$. The tax rate given by equation (49) is less than 1 if $\xi > 0$ and $\rho > \beta$ and $\alpha > 0.5$, but the growth rate is not real when the second-order condition is negative.

$$\frac{\partial^2 g}{\partial \tau^2} = -\tau^* A(1-\alpha)^{2-\alpha}\delta^{\alpha}\alpha\left[\frac{\alpha\{(\rho-\beta)(1-2\alpha)-\xi\rho\}}{(\rho-\beta)(1+\alpha)}\right]^{\alpha-1} < 0 \qquad (50)$$

For the growth rate given by the equation (50) evaluated at growth maximizing tax rate to be positive real number should always be positive. Please note that, unlike the balanced budget case and constant debt case, the growth maximizing tax rate is not zero. We obtain the optimal growth rate in the permanent deficit regime by substituting the value of the growth maximizing tax rate in the growth rate equation.

$$g^T_{\tau(\dot{B}>0)} = A(1-\alpha)^{-\alpha}\delta^{\alpha}\alpha^{\alpha}\left(\frac{(\rho-\beta)(1-2\alpha)-\xi\rho}{(\rho-\beta)(1+\alpha)}\right)^{1+\alpha} - \rho \qquad (51)$$

The condition for the growth maximizing tax rate (τ^*) given by equation (49) to be less than 1, the second-order condition for growth maximization to be negative and the necessary condition for the growth rate evaluated at τ^* to be positive and real, if $[\frac{\alpha\{(\rho-\beta)(1-2\alpha)-\xi\rho\}}{(\rho-\beta)(1+\alpha)}]$ is positive. This happens if and only if $(1-2\alpha) > \frac{\xi\rho}{(\rho-\beta)}$. Hence, if $(1-2\alpha) > \frac{\xi\rho}{(\rho-\beta)} > \alpha(1-2\alpha)$ all the conditions are satisfied.

The maximum growth rate in the public provision of infrastructure when the government is charging user fee and imposing a tax under the accumulating debt regime is greater than the growth rate in the pure private provision under the balanced budget regime of infrastructure if $(1-2\alpha)-(1-\alpha)^{\frac{1}{1+\alpha}}(1+\alpha)>\frac{\xi\rho}{\rho-\beta}$ and it is greater than pure public provision under balanced budget regime if $(1-2\alpha)-(1-\alpha)^{\frac{\alpha}{1+\alpha}}>\frac{\xi\rho}{\rho-\beta}$ when β and ξ are low, this condition is easily satisfied. This result contradicts the result found by Greiner (2014) that says the growth rate obtained under a balanced budget is always greater than that obtained under a deficit budget.

Proposition 5: *The maximum growth rate in the public provision of infrastructure under the accumulating debt regime is greater than the growth rate in the pure private provision or pure public provision of infrastructure under the balanced budget regime if primary surplus does not react to changes in GDP and changes in public debt strongly.*

3.2.3. Public-Private Partnership provision of infrastructure

In the Public-Private Partnership (PPP) provision of infrastructure, the government in partnership with the private firm provides the infrastructure services. In real life, there are several PPP contracts such as Build-Operate-Transfer (BOT), Build-Own-Operate-Transfer (BOOT), Design-Build-Finance-Operate (DBFO), and Design-Construct-Maintain-Finance (DCMF) etc. Hence, whatever may be the type of PPP contract, the basic nature of PPP is the collaboration between the government and the private firm for rendering the infrastructure services. In this section, we construct a model where the government makes a partial investment in the private firm. Therefore, following the real-life examples of VGF in the PPP infrastructure projects, it is assumed that the government bears $(1-\phi)$ fraction of the total cost of manufacturing infrastructure. In this PPP provision, the government does not get any revenue because the ownership of the infrastructure project belongs to the private firm, which enjoys revenue from the projects. We have four agents namely; two firms, the government and the representative household.

Like the pure private provision case, here also we assume that firm 1 produces final goods for consumption and capital accumulation using physical capital and infrastructure. Therefore, the production function of final goods is the same as (2). The profit function of firm 1 is given by (5). But, here in the PPP provision of infrastructure, firm 2 produces the infrastructure services, charges user fees for it and bears the partial cost of manufacturing. The government bears the partial cost of infrastructure because infrastructure is essential for final goods production and welfare enhancement. The production function of infrastructure services is the same as equation (3) but the profit function of firm 2 producing the flow of infrastructure service is different, given by (52).

$$\Pi^2 = \mu G - \phi r (1-u)K \tag{52}$$

In (52), μ is the user fee and ϕ is the share of the cost borne by firm 2 for manufacturing infrastructure. Substituting the value of G in the above equation, we obtain (53).

$$\Pi^2 = \mu\delta(1-u)K - \phi r (1-u)K \tag{53}$$

In PPP provision of infrastructure as well, both firms take input prices as given and choose input quantities to maximize their profit. Differentiating the profit function of firm 2 with respect to $(1-u)K$, we obtain the rate of interest under the PPP provision.

$$r = \frac{\mu\delta}{\phi} \tag{54}$$

By no-arbitrage condition, equating the rate of interest of firm 1 and firm 2, we obtain the equilibrium value of u under the PPP provision.

$$u = \frac{(1-\alpha)\phi}{\alpha + (1-\alpha)\phi} \tag{55}$$

Substituting this value of u in equation (8), we get the user fees under the PPP provision of infrastructure.

$$\mu = A\alpha^{\alpha}\delta^{\alpha-1}(1-\alpha)^{1-\alpha}\phi^{1-\alpha} \quad (56)$$

3.2.3.1 The government

The government under the PPP provision is involved in three activities: (1) bearing the partial cost of manufacturing infrastructure, (2) imposing capital income tax to finance its cost, and (3) issuing government bonds. However, in the PPP provision, the government does not earn the profit from the user fee but the private firm charges the user fee and earns revenue. Therefore, the tax revenue and public expenditure are different from that of public provision of infrastructure.

$$T = \tau\, r\, uK \quad (57)$$

$$E = (1-\phi)r\,(1-u)K \quad (58)$$

$(1-\phi)$ in the above equation is the share of infrastructure manufacturing cost borne by the government. Using equations (57) and (58), the bond accumulation function and the rate of growth of bond under the PPP provision are given by (59) and (60) respectively.

$$\dot{B} = (1-\tau)rB - \tau ruK + (1-\phi)r(1-u)K \quad (59)$$

$$\frac{\dot{B}}{B} = (1-\tau)r - \frac{K}{B}[\tau ruK - (1-\phi)r(1-u)K] \quad (60)$$

3.2.3.2 The household sector

The utility function of the representative household is given by equation (1). The wealth/asset of the household under the PPP provision is the sum of bond holding and private physical capital and therefore, the rate of accumulation of wealth is the same as (22). The representative household agent maximizes the present discounted value of utility, subject to the wealth accumulation function given by (22). Using the first-order maximization condition, the time-derivative of the co-state variable and taking the log and differentiating (24), we obtain the growth rate equation under the PPP provision of the infrastructure.

$$\frac{\dot{C}}{C} = \frac{\dot{G}}{G} = \frac{\dot{W}}{W} = (1-\tau)r - \rho = g \tag{61}$$

3.2.3.3 Steady-state balanced growth

The steady-state balanced growth equilibrium in the accumulating debt regime is defined as a situation when consumption, private physical capital and infrastructure capital grow at the same strictly positive constant growth rate, i.e; $\frac{\dot{C}}{C} = \frac{\dot{K}}{K} = \frac{\dot{G}}{G} = \frac{\dot{B}}{B} = \frac{\dot{Y}}{Y} = g^{PPP}$. Where g^{PPP} is positive and constant. The superscript PPP denotes the Public-Private Partnership provision of infrastructure. If $\frac{\dot{B}}{B}$ is constant then $\frac{B}{K}$ is also constant. We obtain the ratio of public debt to private physical capital under the PPP provision by setting $\frac{\dot{C}}{C} = \frac{\dot{B}}{B}$.

$$\frac{B}{K} = \frac{\tau r u - (1-\phi) r (1-u)}{\rho} \tag{62}$$

3.2.3.4 Zero debt regime

In the zero debt regime under the PPP provision, we set $T = E$. From (57) and (58), we obtain the equilibrium value of u under the PPP provision in the zero debt regime.

$$u_{(\dot{B}=0)}^{PPP} = \frac{(1-\phi)}{\tau + (1-\phi)} \tag{63}$$

Substituting this value of u in equation (8), we obtain the user fee under the PPP provision in the zero debt regime.

$$\mu_{(\dot{B}=0)}^{PPP} = A\alpha\delta^{\alpha-1}\tau^{\alpha-1}(1-\phi)^{1-\alpha} \tag{64}$$

The growth rate under the PPP provision in the zero debt regime is obtained by substituting the value of the rate of interest and u in (64).

$$g_{(\dot{B}=0)}^{PPP} = (1-\tau)A(1-\alpha)\delta^{\alpha}\left(\frac{\tau}{1-\phi}\right)^{\alpha} - \rho \tag{65}$$

Differentiating equation (65) with respect to τ, the first-order condition gives the value of an optimal tax rate under the PPP provision in the zero debt regime.

$$\tau_{(\dot{B}=0)}^{PPP} = \frac{\alpha}{(1+\alpha)} \tag{66}$$

From the second-order condition we find that it is negative.

$$\frac{\partial^2 g}{\partial \tau^2} = A(1-\alpha)\delta^{\alpha}\alpha\left(\frac{\tau}{1-\phi}\right)^{\alpha-1}\left(\frac{1}{1-\phi}\right)\left[-2+\frac{(1-\tau)(\alpha-1)}{\tau}\right] < 0 \tag{67}$$

The optimal growth rate under the PPP provision in the zero debt budgetary policy of the government is obtained by substituting the value of the optimal tax rate from (66) into equation (65).

$$g_{(\dot{B}=0)}^{PPP} = \frac{A(1-\alpha)\alpha^{\alpha}\delta^{\alpha}}{(1+\alpha)^{1+\alpha}(1-\phi)^{\alpha}} - \rho \tag{68}$$

Comparing the growth rates given by equations (68) and (31), we find growth rate is higher under the PPP provision compared to pure public provision when the government runs the balanced budget.

Proposition 6: *When public infrastructure is financed solely by income tax in the balanced budget regime, the growth maximizing tax rate is equal to that under the PPP provision in the balanced budget but the growth rate is higher in PPP compared to pure public provision.*

PPP yields a higher growth rate compared to pure public provision of infrastructure under a balanced budget since a part of the cost of infrastructure production is borne by a private firm. But, the consumers of infrastructure (in this model, the finished goods-producing firms) have to pay both user fees and tax for infrastructure under PPP while having to pay only tax under the pure public provision of infrastructure. So, though the burden on consumers is higher in PPP provision, it yields a higher growth rate compared to pure public provision.

3.2.3.5 Constant debt regime

We also look at the constant debt budgetary policy of the government under the PPP provision. By setting $\dot{B} = 0$, we find that the equilibrium fractional value of private physical capital used for the finished goods production, the user fees, the growth rate equation, optimal tax rate and the optimal growth rate are the same as the zero debt regime under the PPP provision.

Proposition 7: *Under the PPP provision, the user fee charged for infrastructure services, the growth rates, the optimal tax rate and the optimal growth rates under both the constant debt and the balanced budget regimes are the same.*

Proof: The proof for proposition 6 is shown in Appendix A2.

3.2.3.6 Permanent deficit regime

We evaluate PPP provision under the budgetary rule where public debt accumulates over the years. The steady-state balanced growth rate under the PPP provision in the accumulating debt regime, denoted by $g_{(\dot{B}>0)}^{PPP}$ is positive and constant. All the variables grow at the same strictly positive constant rate, such that $\frac{\dot{C}}{C} = \frac{\dot{G}}{G} = \frac{\dot{K}}{K} = \frac{\dot{Y}}{Y} = \frac{\dot{W}}{W} = \frac{\dot{B}}{B} = g_{(\dot{B}>0)}^{PPP}$. By applying the primary surplus rule, the government does not play the Ponzi game, but instead fulfils the inter-temporal budget constraint. The value of $\frac{B}{K}$ under the PPP provision in the permanent deficit or accumulating debt budgetary policy of the government is given by (69).

$$\frac{B}{K} = \frac{\tau\, r\, u - \xi\, A\, u^{1-\alpha}\delta^{\alpha}(1-u)^{\alpha} - (1-\phi)\, r(1-u)}{\beta} \tag{69}$$

For the sustainability of public debt, we obtain the rate of growth of bond accumulation under the PPP provision in the permanent deficit regime by resorting to the primary surplus rule.

$$\frac{\dot{B}}{B} = (1-\tau)r - \frac{\xi\, A u^{1-\alpha}[\delta(1-u)]^{\alpha}\beta}{\tau\, r\, u - \xi\, A\, u^{1-\alpha}\delta^{\alpha}(1-u)^{\alpha} - (1-\phi)\, r(1-u)} - \beta \tag{70}$$

By setting $\frac{\dot{C}}{C} = \frac{\dot{B}}{B}$, we obtain the value of u under the PPP provision in the permanent deficit regime.

$$u_{(\dot{B}>0)}^{PPP} = \frac{(\rho-\beta)(1-\alpha)(1-\phi)}{(\rho-\beta)(1-\alpha)[\tau+(1-\phi)]-\xi\rho} \tag{71}$$

Substituting the value of $u_{(\dot{B}>0)}^{PPP}$ in (8), we obtain the user fees under the PPP provision in the permanent deficit budgetary policy of the government.

$$\mu_{(\dot{B}>0)}^{PPP} = A\alpha\delta^{\alpha-1}\left[\frac{\tau(\rho-\beta)(1-\alpha)-\xi\rho}{(\rho-\beta)(1-\alpha)(1-\phi)}\right]^{\alpha-1} \tag{72}$$

The growth rate under the PPP provision in the accumulating debt regime is obtained by substituting the rate of interest by (7) and $u_{(\dot{B}>0)}^{PPP}$ in (65).

$$g_{(\dot{B}>0)}^{PPP} = (1-\tau)A(1-\alpha)\delta^{\alpha}\left(\frac{\tau(\rho-\beta)(1-\alpha)-\xi\rho}{(\rho-\beta)(1-\alpha)(1-\phi)}\right)^{\alpha} - \rho \tag{73}$$

Differentiating (73) with respect to τ, the first-order condition gives the value of an optimal tax rate under the PPP provision in the accumulating debt regime.

$$\tau_{(\dot{B}>0)}^{PPP} = \frac{\xi\rho+\alpha(\rho-\beta)(1-\alpha)}{(\rho-\beta)(1-\alpha)(1+\alpha)} \tag{74}$$

For the optimal tax rate to be positive and less than 1, the condition $-(1-\alpha) < \frac{\xi\rho}{(\rho-\beta)} < \alpha(1-\alpha)$ must be satisfied. The second-order differentiation of (73) with respect to τ evaluated at growth maximizing τ gives (75).

$$\frac{\partial^2 g}{\partial\tau^2} = -A(1-\alpha)\delta^{\alpha}(1+\alpha)\left(\frac{\tau(\rho-\beta)(1-\alpha)-\xi\rho}{(\rho-\beta)(1-\alpha)(1-\phi)}\right)^{\alpha-1}\left(\frac{1}{1-\phi}\right) < 0 \tag{75}$$

We obtain the optimal growth rate under the PPP provision in the permanent deficit regime by substituting the value of $\tau_{(PPP)}^{\dot{B}>0}$ in the growth rate equation.

$$g_{\tau(\dot{B}>0)}^{PPP} = \frac{A\delta^{\alpha}\alpha^{\alpha}}{(1-\alpha)^{\alpha}(1-\phi)^{\alpha}}\left(\frac{(\rho-\beta)(1-\alpha)-\xi\rho}{(\rho-\beta)(1+\alpha)}\right)^{1+\alpha} - \rho \tag{76}$$

Comparing the growth rates given by equation (76) and (68) we can say that PPP under balanced budget yields higher growth than that under accumulating debt if $\xi > 0$. Also, comparing the growth rates given by equations (76) and (51) we have the result that PPP under accumulating debt yields a higher growth rate compared to the public provision under accumulating debt even when the government charges user fees and imposes the tax.

Proposition 8: *PPP under accumulating debt yields a higher growth rate compared to the public provision under accumulating debt even when the government charges user fees and imposes the tax. Also, PPP under accumulating debt yields a higher growth rate than the growth rate under PPP in a balanced budget only if primary surplus decreases as the GDP increases and vice versa.*

3.3 Numerical example of balanced budget case

We do a calibration exercise to find the desirable way to finance the balanced budget policy of the government. For this calibration exercise, we use the following parameter values: A = 0.33 (as taken in Ghosh and Mourmouras, 2004); α = 0.2, δ =1, ρ = 0.15 (as taken in Greiner, 2008). Following Greiner (2008), in the simulation exercise, we assume a one-time period is comprised of several years because of the long gestation period of infrastructure capital formation, justifying such a high rate of time preference.

Table 3.1: Simulation results for the balanced budget regime

Pure private provision			(a) Publicly provided private goods			(b) Traditionally provided public goods		
u	μ	g	u	μ	g	u	g	τ
0.8	0.2	0.05	0.8	0.2	0.05	0.85	0.003	0.17

PPP provision with less than 50% private investment (suppose 70% VGF)				PPP provision with more than 50% private investment (suppose 30% VGF)			
u	μ	g	τ	u	μ	g	τ
0.81	0.21	0.015	0.17	0.64	0.1	0.05	0.17

The calibration exercise in Table 1 shows that the purely private provision, provision by the government charging a user fee for accessing public goods and PPP provision with 30% VGF finance or more than 50% private investment under the balanced budget regime yield the same growth rate (i.e; 0.05). But under pure private provision user fees charged is double of what is charged by the PPP provision with 30% VGF support from the government. We find the traditional provision of pure public goods with only tax financing giving a comparatively lower growth rate (i.e 0.003) compared to the PPP investment with 30% VGF despite having the same tax rate. But, in PPP consumers have to pay user fees while in pure public provision infrastructure usage is free. We also find that the optimal tax rate in the traditional pure public provision and the optimal tax rate under the PPP provision in the balanced budget policy of the government is the same (i.e 0.17), but the growth rates are different as mentioned in proposition 5.

3.4 Calibration exercise of permanent deficit regimes for different modes of infrastructure provision

We again resort to calibration exercises to analyse the permanent deficit budgetary policy of the government while applying the primary surplus rule for the sustainability of public debt in the impure public and PPP provisions of infrastructure. Here, we consider the same values taken in Greiner (2008) to study the impact of the deficit-financed increase in the investment of the government. For the other parametric values such as A, α, δ and ρ we stick to the same benchmark values as table 1. In table 2, we report results when β is small (i.e; $\beta < \rho$) for (a) impure public provision (public provision with user fee), (b) PPP provision with 70% VGF (i.e less than 50% private investment) and (c) PPP provision with 30% VGF (i.e, more than 50% private investment). In table 3, we report results when β is large (i.e; $\beta > \rho$) for the cases (a), (b) and (c) respectively. Table 2 and table 3 present the results for different values of primary surplus (ξ). In the numerical example, we show how the government can have different growth rates, different tax rates, different user fees when it makes adjustments in the primary surplus and its reaction to the changes in public debt and GDP. In the simulation exercise of both table 2 and 3 for $\beta < \rho$ and $\beta > \rho$ respectively, we observe that the government imposes high taxes, charges high user fees, has a high debt capital ratio, but experiences low (mostly negative) growth rates under the impure public provision compared to other regimes.

When the government provides infrastructure charging user fees, imposing tax and also issuing the bond, the steady-state equilibrium involves high public debt. The interest payment of the past accumulated public debt has a positive effect on the growth of public debt and has a negative effect on the GDP growth rate. Apparently, in the presence of such high debt, when only the government is solely responsible for providing the infrastructure, it is not successful in attaining positive growth rates. The high debt ratio under the impure public provision, even when the response of the primary surplus to changes in public debt is large, do not lead to sustained positive GDP growth. We couldn't agree less to what Futagami et al. (2008) have to say, 'the countries with significantly higher debt should not go on a borrowing spree, no matter how large is their need for public investment in infrastructure.' Falling into such a debt trap should not be an option for the government. This unsustainable public debt under the impure public provision justifies the adoption of PPP for the provision of infrastructure.

Table 3.2: Simulation results (a), (b) and (c) for $\boldsymbol{\beta < \rho}$

(a) Impure public provision										
$\beta < \rho$	$\beta = 0.05$					$\beta = 0.10$				
	u	μ	τ	B/K	g	u	μ	τ	B/K	g
$\xi = 0.005$	0.88	0.40	0.39	0.92	-0.043	0.88	0.33	0.40	0.79	-0.044
$\xi = 0.0025$	0.89	0.41	0.38	0.92	-0.042	0.89	0.36	0.38	0.79	-0.043
$\xi = -0.0025$	0.87	0.37	0.37	0.91	-0.042	0.89	0.36	0.37	0.78	-0.039
$\xi = -0.005$	0.89	0.43	0.36	0.89	-0.038	0.88	0.34	0.36	0.77	-0.038

(b) PPP provision with less than 50% private investment (suppose 70% VGF)										
$\beta < \rho$	$\beta = 0.05$					$\beta = 0.10$				
	u	μ	τ	B/K	g	u	μ	τ	B/K	g
$\xi = 0.005$	0.81	0.21	0.17	0.05	0.013	0.81	0.23	0.18	0.02	0.011
$\xi = 0.0025$	0.81	0.21	0.17	0.01	0.014	0.82	0.23	0.17	0.015	0.013
$\xi = -0.0025$	0.81	0.21	0.16	-0.01	0.016	0.81	0.22	0.16	-0.004	0.016
$\xi = -0.005$	0.80	0.21	0.16	-0.027	0.017	0.81	0.22	0.15	-0.02	0.019

(c) PPP provision with more than 50% private investment (suppose 30% VGF)										
$\beta < \rho$	$\beta = 0.05$					$\beta = 0.10$				
	u	μ	τ	B/K	g	u	μ	τ	B/K	g
$\xi = 0.005$	0.65	0.11	0.17	0.07	0.043	0.65	0.11	0.18	0.03	0.041
$\xi = 0.0025$	0.65	0.11	0.17	0.05	0.044	0.65	0.11	0.17	0.05	0.043
$\xi = -0.0025$	0.65	0.11	0.16	-0.006	0.046	0.64	0.10	0.16	-0.005	0.048
$\xi = -0.005$	0.64	0.10	0.16	-0.009	0.048	0.64	0.10	0.15	-0.011	0.050

Table 3.3: Simulation results (a), (b) and (c) for $\beta > \rho$

(a) Impure public provision										
$\beta > \rho$	$\beta = 0.25$					$\beta = 0.30$				
	u	μ	τ	B/K	g	u	μ	τ	B/K	g
$\xi = 0.005$	0.89	0.37	0.36	0.31	-0.039	0.89	0.38	0.37	0.26	-0.05
$\xi = 0.0025$	0.89	0.35	0.37	0.30	-0.04	0.88	0.33	0.38	0.26	-0.05
$\xi = -0.0025$	0.89	0.35	0.38	0.32	-0.042	0.88	0.35	0.38	0.26	-0.046
$\xi = -0.005$	0.89	0.36	0.38	0.32	-0.043	0.89	0.35	0.38	0.14	-0.047

(b) PPP provision with less than 50% private investment (suppose 70% VGF)										
$\beta > \rho$	$\beta = 0.25$					$\beta = 0.30$				
	u	μ	τ	B/K	g	u	μ	τ	B/K	g
$\xi = 0.005$	0.81	0.22	0.16	-0.005	0.017	0.81	0.21	0.16	-0.006	0.017
$\xi = 0.0025$	0.81	0.21	0.16	-0.003	0.016	0.81	0.21	0.16	-0.005	0.016
$\xi = -0.0025$	0.81	0.21	0.17	0.006	0.014	0.81	0.21	0.17	0.005	0.014
$\xi = -0.005$	0.81	0.21	0.17	0.008	0.013	0.81	0.21	0.17	0.006	0.013

(c) PPP provision with more than 50% private investment (suppose 30% VGF)										
$\beta > \rho$	$\beta = 0.25$					$\beta = 0.30$				
	u	μ	τ	B/K	g	u	μ	τ	B/K	g
$\xi = 0.005$	0.64	0.103	0.16	-0.009	0.05	0.64	0.11	0.16	-0.006	0.05
$\xi = 0.0025$	0.65	0.105	0.16	-0.004	0.047	0.64	0.12	0.16	-0.005	0.046
$\xi = -0.0025$	0.65	0.105	0.17	0.007	0.044	0.64	0.11	0.17	0.005	0.045
$\xi = -0.005$	0.65	0.107	0.17	0.009	0.043	0.64	0.12	0.17	0.006	0.044

Most of the developing nations are indebted heavily and they must reduce the $\frac{debt}{GDP}$ ratio. $\frac{B}{K}$ is an endogenous variable in the model and its' positive value implies that the government is a debtor and negative value implies that the government is a creditor. Through calibration exercise of table 2 ((b), (c)) for $\beta < \rho$ and table 3((b), (c)) for $\beta > \rho$, we can see how a sustainable public debt can be obtained in PPP, with the choice of the parameters ξ and β. Since β is relatively small in table 2 (b) and 2(c) for PPP provisions with 70% and 30% VGF respectively, when $\xi > 0$, the GDP rises faster than public debt because the government does not put a large weight on stabilizing the public debt. The accumulated debt declines naturally with the increase in the higher growth rate. Therefore, debt financing is sustainable. When $\xi < 0$ and β is small, it means again that the government puts a small weight on stabilizing the public debt. But, as GDP rises, the government imposes higher taxes and reduces public spending and be a creditor to make the growth sustainable. Now, β is relatively large in table 3 (b) and 3(c) for PPP provisions with 70% and 30% VGF respectively. When $\xi > 0$, the government puts a large weight on stabilizing the public debt, and the sustained growth is achieved at a negative public debt which implies the government is a creditor. When $\xi < 0$, the public debt rises faster than GDP and the government runs into accumulated debt for the financing of VGF investment but the high value of β guarantees that sustained growth is attained.

In table 2 (b) and (c), when $\beta < \rho$, choosing smaller ξ by the government is desirable ($\xi = 0.0025$ over ξ= 0.005), as it yields lower debt capital ratio and higher growth rate. However, when $\beta > \rho$, from table 3 (b) and (c) we observe that choosing higher ξ by the government is desirable ($\xi = 0.005 \; or \; \xi = 0.0025$) as it yields lower debt ratio and higher GDP. For both the PPP provision of infrastructure with 70% and 30% VGF, we see that the debt ratio and the growth rate have a negative monotonic relationship. This result is similar to the finding of Kamaiguchi and Tamai (2012) and Greiner (2014). No matter β is small or high, PPP with 30% VGF (lower government intervention) yields higher growth rate compared to 70% VGF.

3.5 Conclusion

This chapter presents a closed economy model in an endogenous growth framework with non-rival yet excludable public goods that are used as an intermediate input for the production of final goods. We consider different options for financing the infrastructure production: a purely private venture, a government initiative charging user fees called impure public provision and a PPP provision under the balanced budget and deficit budget regimes. This chapter attempts to find the mode of the provision of infrastructure in a closed economy that can generate the highest growth. We find some interesting results in this chapter. We find that the growth rate under the pure private provision is higher compared to that in pure public provision. We also find that under the balanced budget when the government charges user fees and imposes tax to finance the infrastructure cost, the growth maximizing tax rate is zero. However, under the accumulating debt regime, the growth maximizing tax rate is positive. It is also found that the maximum growth rate in the public provision of infrastructure under the accumulating debt regime is greater than the growth rate in the pure private provision or pure public provision of infrastructure under the balanced budget regime if primary surplus does not react to changes in GDP and changes in public debt strongly. This result contradicts the result found by Greiner (2014) that says the growth rate obtained under a balanced budget is always greater than that obtained under a deficit budget. PPP yields a higher growth rate compared to public provision of infrastructure both under a balanced budget and accumulating debt. Also, PPP under accumulating debt yields a higher growth rate than the growth rate under PPP in a balanced budget only if primary surplus decreases as the GDP increases and vice versa. From the numerical example, we find that the PPP projects with more than 50% of investment by the private firm yield the highest growth rate.

However, like any other theoretical model, this model also has limitations. Here, we have considered an AK production function and infrastructure as a flow variable. Infrastructure services may be included in the utility function. This chapter could be further extended by including infrastructure as a stock variable for future research. However, this chapter contributes to the literature being the first one to incorporate the PPP in the endogenous growth model with debt financing.

APPENDIX

Appendix A1. Under the pure public provision in the constant debt, $\dot{B} = 0$. Therefore, from (18), we have,

$T - E = (1 - \tau)rB.$

Substituting the value of T and E equations (19) and (20) respectively in the above equation, we obtain the budget constraint of the government.

$\tau\,[\tau uK - (1 - u)K - (1 - \tau)B] = -\mu G$

Substituting the value of r and μ in the budget constraint of the government,

$\tau u - (1 - u) - (1 - \tau)\frac{B}{K} = \frac{-\alpha}{(1-\alpha)}u$

Since $\frac{B}{K}$ converges to zero in the long run, therefore from the above equation we obtain the equilibrium value of u under the pure public provision in the constant debt regime, which is exactly equal to the zero debt regime.

$u^{T}_{(\dot{B}=0)} = \frac{(1-\alpha)}{\alpha+(1-\alpha)(1+\tau)}$

A1.1

Now substituting A1.1 in (8), we obtain the user fees under the pure public provision in the constant debt regime, which is same as the balanced budget regime.

$\mu^{T}_{(\dot{B}=0)} = A\delta^{\alpha-1}\alpha\left[\frac{\alpha+(1-\alpha)\tau}{(1-\alpha)}\right]^{\alpha-1}$

A1.2

Substituting the rate of interest from (7) in (30), we obtain the growth rate equation under pure public provision in a constant debt regime, which is again the same as zero debt regime.

$g^{T}_{(\dot{B}=0)} = (1 - \tau)A(1 - \alpha)\delta^{\alpha}\left[\frac{\alpha+(1-\alpha)\tau}{(1-\alpha)}\right]^{\alpha} - \rho$

A1.3

Differentiating the growth rate equation with respect to τ, we find from the first order condition that growth maximizing tax rate is zero under pure public provision in the constant debt regime as well. Also, the optimal growth under the pure public provision in the constant debt regime is equal to the pure private provision growth rate.

$$g^{T}_{\hat{\tau}(\dot{B}=0)} = A\alpha^{\alpha}(1-\alpha)^{1-\alpha}\delta^{\alpha} - \rho$$

A1.4

Appendix A2.

In the constant debt regime, under the PPP provision, we set $\dot{B} = 0$. Therefore, from equation (59), we have, $\tau\, u - (1-\phi)(1-u) = (1-\tau)\frac{B}{K}$

Since $\frac{B}{K}$ converges to zero in the long run, therefore from the above equation we have,

$$u^{PPP}_{(\dot{B}=0)} = \frac{(1-\phi)}{\tau+(1-\phi)} \quad \text{A2.1}$$

Substituting the value of u from A2.1 in (8), we obtain the user fees under the PPP provision in the constant debt regime.

$$\mu^{PPP}_{(\dot{B}=0)} = A\alpha\delta^{\alpha-1}\tau^{\alpha-1}(1-\phi)^{1-\alpha} \quad \text{A2.2}$$

The growth rate under the PPP provision in the constant-debt regime is obtained by substituting the value of rate of interest and u in (61).

$$g^{PPP}_{(\dot{B}=0)} = (1-\tau)A(1-\alpha)\delta^{\alpha}\left(\frac{\tau}{1-\phi}\right)^{\alpha} - \rho \quad \text{A2.3}$$

Differentiating the growth rate equation (A2.3) with respect to τ, the first- order condition gives the optimal tax rate under the PPP provision in the constant debt regime.

$$\tau^{PPP}_{(\dot{B}=0)} = \frac{\alpha}{(1+\alpha)} \quad \text{A2.4}$$

Now, from the second order condition, we have,

$$A(1-\alpha)\delta^{\alpha}\alpha\left(\frac{\tau}{1-\phi}\right)^{\alpha-1}\left(\frac{1}{1-\phi}\right)\left[-2+\frac{(1-\tau)(\alpha-1)}{\tau}\right] < 0 \quad \text{A2.5}$$

We obtain the optimal growth rate under the PPP provision in the constant debt regime by substituting the value of optimal tax rate in (A2.3).

$$g^{PPP}_{\hat{\tau}(\dot{B}=0)} = \frac{A\,(1-\alpha)\alpha^{\alpha}\delta^{\alpha}}{(1+\alpha)^{1+\alpha}(1-\phi)^{\alpha}} - \rho$$

A2.6

Comparing (63) -(68) with (A2.1) -(A2.6), we find that endogenous variables for both the balanced budget and constant debt regimes are exactly same for the PPP provision of infrastructure.

Chapter 4

Does corruption affect the inflow of foreign capital in the Public-Private Partnership provision of infrastructure in a small open economy?

4.1 Introduction

The infrastructure services increase the productivity of private capital, therefore, has a strong growth-promoting effect on the economy. Since the early 1990s, a new paradigm shift has been witnessed in the role of government from being the sole producer of public services to being a regulator and financial supporter with the inception of public-private partnership (PPP) in the infrastructure sector of the developing countries. The PPP mode of infrastructure provision in the developing nations was intended for quality improvement and cost reduction in the construction and maintenance of the infrastructure projects and reduction in demand risk (Iossa and Martimort (2015)). The service quality of infrastructure under the PPPs has the potential to increase welfare in the presence of government contributions. To remove infrastructure bottlenecks, along with PPP provision, the developing countries have also relied on foreign borrowing and foreign debt as well from time to time.

It was noted by Ramamurti and Doh (2004) that developing countries welcomed foreign investors with much enthusiasm since the early 1990s so that they can have efficient and good quality infrastructure. The PPI database published by World Bank confirms this trend and data shows clearly that the foreign capital and domestic private capital are indeed complementary goods in the infrastructure sector in the developing nations. According to Germaschewski (2016), to build infrastructure, domestic private firms lack the financial and technical resources in sharp contrast to foreign firms. Dasgupta and Shimomura (2007) find in their study that the presence of FDI in the infrastructure sector for pure public goods results in an unconditional rise in the rates of growth.

However, it has been observed that often the inflow of foreign capital in PPP provision of infrastructure cannot generate the desired positive effect on the long-run growth rate of the economy. This is because corruption plays a miscreants' role in infrastructure production. A higher level of corruption is uniquely associated with infrastructure projects (Banerjee, et al. (2006)). The highly capital-intensive nature of the infrastructure projects and the absence of public disclosure of information regarding funding, project costs and financial transactions, issue of license etc; which are pertinent to the infrastructure sector give ample opportunity for corruption (Ferrari et al. (2016)). There is no doubt that FDI in infrastructure has an inherent productivity spillover effect from superior foreign technology and better-quality infrastructure capital but the real question is whether the foreign investment would be welfare improving. It is obvious that due to corruption, the quality of infrastructure may deteriorate.

There is substantial literature on corruption, growth and foreign investment. According to Lin and Sosin (2001), if the funds from foreign debt are largely wasted due to corruption and the high-interest rate then it is most likely to reduce economic growth. According to Rioja (2003), an inefficient infrastructure network is costly to a country in terms of loss of potential output. Chatterjee et al. (2003) find that if the economy is relatively well endowed with public capital, a tied transfer which is a form of developmental assistance or external financing is welfare deteriorating and is particularly harmful if it involves domestic co-financing. It is noted by D'agostino et al. (2016) that corruption has a negative effect on growth and Cieslik & Goczek (2018) show that the uncertainty caused by corruption has a detrimental effect on the stock of international investment in the host country in an endogenous growth framework. The theft of the public fund reduces the amount spent on productivity-enhancing public goods and also weakens investors’ confidence in the market systems. This leads to impeding of capital inflow in the host country (Fredriksson et al. (2003)). However, contrary to all these studies a surprising phenomenon was witnessed by Banerjee et al. (2006), Habib and Zurawicki (2002) and Alemu (2012). They found that India, China, Brazil, Philippines, Thailand, Nigeria and Mexico, which were perceived as highly corrupt countries, were performing very well in attracting FDI in infrastructure and corruption does not seem to deter FDI inflow in absolute terms. However, it was also noted by them that, if the corruption level of these countries were low, they would have doubled their FDI inflow (ibid). According to Belgibayeva and Plekhanov (2015), most investors view corruption as an obstacle, but some see it as a helpful tool for getting around the rules and regulations. According to Abotsi (2016), in a most common transaction, a foreign firm makes a payment to a government official in return for a benefit up to a level that can be accommodated by them, so beyond that level, the investment may be unattractive. Therefore, as long as revenue earned exceeds the cost of production including the bribe paid by the foreign firms, they will invest. According to Cuervo-Cazurra (2008), if revenue effects outweigh the cost effects, corruption may stimulate FDI, which is particularly the case in some developing countries. A World Bank study (1999) also revealed that corruption is a frequent occurrence for international investors. It was found in the survey that more than 85% of polled multinational companies “always’’ or “mostly” encountered corruption while dealing with public sectors. According to Germaschewski (2016), in terms of better technical and financial accessibility, the foreign firms were considered more competitive than the domestic firms but not immunized from corruption. However, this corruption tolerable level of investment has a quality-adjustment (or quality-compromise) effect on the infrastructure capital of the host country, if not an entry deterring effect on the foreign investors.

The cynicism of government officials and infrastructure manufacturing firms may render the infrastructure project inefficient or may even lead to the complete failure of the project. Not only the opportunistic behaviour of the government is responsible for the reduction of benefits from the bundling of PPP contracts but also private firms who entertain corrupt practices such as bribe payment for permits, licenses etc; for advancing their own interests are also equally responsible. According to Valero (2015), the cost-efficiency of PPP is damaged by the governments' opportunism and the lack of commitment to long-term contractual agreements. According to Monte and Papagni (2001), the PPP model can spawn corruption when both corrupt parties in the PPP model benefit but in the process the economy is harmed. The productivity loss due to the inferior quality of infrastructure capital is the loss to the government for the cynicism of its officials. When a large part of public expenditure is leaked into the pockets of bureaucrats, the substandard infrastructure projects increase taxation because more funds are needed towards repair and maintenance costs. We find in the works of Coppier et. al (2013) and Monte and Papagni (2001) that the presence of bureaucratic corruption lowers the quantity, quality and efficiency of public capital. According to Lin and Zhang (2009), corruption reduces capital accumulation by leaking away a part of productive infrastructure investment into the pockets of corrupt government officials. Monte and Papagni (2001) make a comparison between the inefficiently performing lower quality public-provided services with the FDI financed infrastructure and find that growth and output due to corruption are lower than the FDI regime. Without any demurral we recognize, the end result of corruption is the inferior quality of the infrastructure which has a negative effect on growth, whereas FDI inflow could have a positive effect on the growth even in the presence of corruption. Had the construction of infrastructure been done with a high standard in the absence of corruption, there is bound to have a higher growth rate. Therefore, we assume in our model that when a bribe is paid to the bureaucrats for permits or licenses, the project owner compromises on the quality of infrastructure to cut down the cost of production. According to Iossa and Martimort (2015), operating costs also depends on the quality of the infrastructure and improving the quality of the infrastructure increases operational costs due to increased maintenance cost.

In the endogenous growth framework, few pieces of literature deal with corruption, public capital and growth. To name a few, Chakraborty and Dabla-Norris (2011) study the distortions in the quality of public capital due to intermediation by corruptible bureaucrats which discourage specialization, rate of return to private investment and growth in a simple general equilibrium framework. Lin and Zhang (2009) study the effect of corruption on infrastructure, capital market and the labour market in an overlapping generation model. They find that corruption reduces capital accumulation, wage rate and worker's savings but increases the disposal income of the government's officials. According to Tarhan (2008), a non-benevolent government reduces the productivity of public capital by choosing the varying level of tax revenue to expropriate and wasteful spending on public goods depending on the degree of benevolence. Aghion et al. (2016) analyzed how corruption and the governments' efficiency affected the quality of the infrastructure and thus affected growth. According to them, the tax revenue is subject to corruption, so only a fraction of tax revenue turns into the government investment, which in turn sustains a lower infrastructure. However, these growth literatures have focused on the closed economy.

The openness and corruption in an endogenous growth setting have been discussed by Coppier, Fredriksson and others. Coppier et al. (2013) discussed the openness, corruption and government's regulation or monitoring of corruption in an endogenous growth model. They found that firms with modern technology accumulate more capital in absence of payment towards bribes and end up accumulating less when a bribe is paid by them. Fredriksson et al. (2003), studied the capital inflow influenced by corruption, environmental regulation and public expenditure in a host country. In the presence of corruption, the government officials permit incumbent industries to pollute the host country by receiving bribe money. They found that corruption reduces the amount of infrastructure provision which in turn lowers the productivity of capital. Germaschewski (2016) contributed to the literature of PPP in an endogenous growth framework by exploring the economic impact of PPP provision with foreign capital inflow and PPP with domestic financed infrastructure investment. He found that the foreign capital inflow via PPP provision not only reduced the stress on the domestic government's budget but also gave growth and welfare gains higher than the domestically financed infrastructure investment. However, he had not discussed the possibility of corruption in a PPP model which might have a possible deleterious effect on the economy.

In this context, we would like to address the research questions: Is this policy shift able to deliver the right infrastructure? Are developing countries reaping the benefits out of the excessive reliance on the PPP as the specified mode of infrastructure delivery with the joint venture of foreign and domestic investors? What role does corruption play? This chapter is an effort to bridge the gap in the previous studies in a PPP mode of infrastructure provision (in a joint venture between domestic capital and foreign capital inflow) in an endogenous growth model, which may have a high growth rate without corruption but with it, the things may not be the same. Normally in developing countries, the discretionary power is commissioned to the bureaucrats by the government for the issuance of license/permits, etc, giving them opportunistic power. We assume that a bribe is charged by the government officials for the issuance of a license/permit to enter into the infrastructure industry of the host country. Bureaucrats could extract large bribes in exchange for the award of the corruptly favoured investors and at the same time, the corrupt investors could be willing to pay a large bribe to the government officials to get the project on their table. Unlike Mauro (2004), this chapter does not focus on petty corruption such as paying a bribe to obtain a driver's license but focuses on the grand corruption which involves bribe payment to build a highway with substandard materials. Therefore, in our model when an infrastructure project contract is issued out of the corrupt deal, the foreign investor is bound to compromise on the quality of the infrastructure production. The profit motive drives the investors to lower the quality of infrastructure services. The outcome of this corrupt deal is a win-win situation for the corrupt government and the corrupt investor, but the economy suffers due to the poor-quality infrastructure services, poor maintenance and speedy wear-tear of the infrastructure capital. FDI in the infrastructure is normally thought of as a composite bundle of better capital, know-how and technology but it may not be so as it was noted by Samborskyi et al. (2020) that 'sometimes, foreign investors repatriate not only part of the income received from production but also the invested funds, which can help reduce economic growth'. However, we do not consider repatriation in this chapter. We build a theoretical model comprised of the corruption-inherent quality-adjusted or the quality-compromised investment in a PPP model with flow and stock concepts of infrastructure services. The self-interested government steals from the investors in the form of bribe money such that, it may render an infrastructure capital unproductive and may have a deleterious effect on the growth rate. But, a foreign investor still chooses to invest in the host country as long as $r_H > r_w$, that is, the cost of capital is less for the foreign investors in the host country and their profit is positive. r_H

stands for the domestic rate of interest and r_w stands for the rate of interest of the rest of the world. From this study, we highlight the adverse effect of corruption on the growth of the economy and eventually find out the role of foreign capital on the production of infrastructure capital or on the growth of the economy in general, with corruption.

4.2 The model

In a small open economy model, there are 2 countries: a 'home country' and a 'foreign country'; the latter is seen as the rest of the world. A foreign infrastructure producing firm has a joint venture with the domestic infrastructure firm in the host country and a bribe is paid by the foreign firm to the corrupt government officials to obtain a license for entry. In other words, the foreign firm receives the contract for entry in the infrastructure sector in exchange for paying a bribe. We assume that both the government and the investors are self-interested agents.

In this model, the aggregate production function of final output has 2 arguments: the private physical capital of the host country and the infrastructure capital of the host country, that is, $Y = f(uK_H, G_H)$.

The production function of final output takes Cobb-Douglas form:

$$Y_H = A\,(uK_H)^{\alpha} G_H^{1-\alpha} \qquad (1)$$

In the above equation, uK_H is the part of the private physical capital of the host country used for the production of final output and G_H is the infrastructure of the host country that enters into the production of final output as an input. α and $(1-\alpha)$ are the output elasticities with respect to uK_H and G_H respectively.

There are two profit-maximizing firms in the host country. Firm 1 produces the finished goods which could be used for consumption or investment purposes. Infrastructure is produced by a PPP venture. Here, the private entity is assumed to be a foreign firm which is firm 2 that produces the infrastructure capital. The production function of infrastructure capital (G_H) is given by equation (2). Here, the production of infrastructure capital is treated as a flow variable.

$$G_H = (1 - B)[(1 - u)K_H]^{v} K_F^{1-v} \quad (2)$$

Luiz R. de Mello Jr. (1997) argued about the complementarity relation between the FDI and domestic investment of the host country if FDI was expected to affect growth positively. Hence following him, $(1 - u)K_H$, a part of the domestic private physical capital of the host country and foreign capital inflows (K_F) considered complementary goods in the infrastructure production. v is the output elasticity with respect to $(1 - u)K_H$ and $(1 - v)$ is the output elasticity with respect to K_F. B is the fraction of the revenue paid as a bribe amount by the foreign investor to the government officials of the host country. When a government is engaged in corruption, it compromises on the quality of goods and services it delivers (Coppier et al. (2013), Monte and Papagni (2001), Aghion et al. (2016)). Therefore, here we assume, as a result of the bribe payment, the efficiency parameter of firm 2 reduced by $(1 - B)$, reflecting the deterioration of quality of infrastructure production.

Firms

The profit function of firm 1 producing the finished goods is given by,

$$\pi_H^1 = (1 - \tau)Y_H - r_H u K_H - \mu_H G_H \quad (3)$$

μ_H is the user fees paid by firm 1 for using the infrastructure services in the host country. r_H is the rate of interest of the host country. The profit function of firm 2 is given by,

$$\pi_H^2 = (1 - B)\mu_H G_H - \phi[r_H(1 - u)K_H + r_w K_F] \quad (4)$$

$(1 - B)\mu_H G_H$ is the partial user fee revenue earned by firm 2 for providing the infrastructure capital because the other part of the user fees revenue is extorted by the government officials as bribe and ϕ is the partial cost of infrastructure manufacturing borne by firm 2. Both firm 1 and firm 2 take input prices as given and choose input quantities to maximize their profit. Differentiating the profit function of firm 1 with respect to uK_H and G_H respectively, the first-order condition obtained are as follows:

$$r_H = (1-\tau)A\,\alpha\,\left(\frac{G_H}{uK_H}\right)^{1-\alpha} \tag{5}$$

$$\mu_H = (1-\tau)A\,(1-\alpha)\left(\frac{uK_H}{G_H}\right)^{\alpha} \tag{6}$$

Differentiating the profit function of firm 2 with respect to $[(1-u)K_H]$ and K_F respectively, we obtain r_H and r_w from the first-order condition are as follows:

$$r_H = \frac{(1-B)^2}{\phi}\mu_H \upsilon[(1-u)^{\upsilon-1}]\,\left(\frac{K_H}{K_F}\right)^{\upsilon-1} \tag{7}$$

$$r_w = \frac{(1-B)^2}{\phi}\mu_H(1-u)^{\upsilon}(1-\upsilon)\left(\frac{K_H}{K_F}\right)^{\upsilon} \tag{8}$$

According to the no-arbitrage condition, we equate the domestic rate of interest, r_H, of the host country given in (5) and (7) and find the ratio of infrastructure of the host country, G_H to the part of private physical capital of the host country used for the production of final output, uK_H.

$$\frac{G_H}{uK_H} = \frac{(1-B)^2\upsilon(1-\alpha)}{\alpha\phi}\left[\frac{(1-u)K_H}{K_F}\right]^{\upsilon-1} \tag{9}$$

In our model, r_w is given exogenously. Using equation (8), we find the value of $\frac{(1-u)K_H}{K_F}$.

$$\frac{(1-u)K_H}{K_F} = \left[\frac{\phi^{1-\alpha}\,r_w\,\upsilon^{\alpha}\,(1-\alpha)^{\alpha-1}(1-B)^{2(\alpha-1)}}{\alpha^{\alpha}\,A\,(1-\tau)\,(1-\upsilon)}\right]^{\frac{1}{\upsilon(1-\alpha)+\alpha}} \tag{10}$$

Replacing the value of G_H from equation (2) in equation (9), we obtain the value of u endogenously.

$$u = \frac{\alpha\,\phi}{(1-B)\,\upsilon(1-\alpha)+\alpha\,\phi} \tag{11}$$

The effect of B on u is positive, so as B increases, $(1-B)$ decreases and u increases. As corruption increases in infrastructure sector and infrastructure of inferior quality is produced, higher fraction of private capital is allocated to final output sector instead of infrastructure producing sector.

Proposition 1: *u and B are positively related when infrastructure is a flow variable. As corruption in the infrastructure sector increases, more private capital is used in corruption-free final goods sector.*

4.2.1 Non-benevolent government of the host country when infrastructure is a flow variable

Following D′agostino et al. (2016), we assume that a self-interested government and self-interested bureaucracy are subsumed into one corrupt entity; a "non-benevolent government". A benevolent government would never engage in corrupt activities and would always promote consumer's welfare but a non-benevolent government would view any infrastructure project as a 'trophy project' or an opportunity to gain illicit profit disregarding people's welfare. In this chapter, we do not intend to analyze the government's decision problem regarding the choice of VGF (viability gap funding), $(1-\phi)$. Since this variable is exogenously given in the model, we implicitly assume that it is chosen by the government already. However, we study the role of $(1-\phi)$ in the growth rate. Since the government is self-motivated, it maximizes its profit and its' opportunity cost is infrastructure capital accumulation.

According to Mauro (2004), 'when rent-seekers appropriate the government expenditure, either they consume the proceeds or invest them in their own firms. For example, funds that are earmarked for public infrastructure projects end up in the pockets of corrupt individuals or the cement that was going to be used to build a highway may be stolen and used by corrupt individuals to build their villa at the seaside instead'. The choice variables for the non-benevolent government in this model are B and τ.

The total revenue of the non-benevolent government of the host country, denoted by R, is given by,

$$R = B\mu_H G_H + \tau Y_H \quad (12)$$

In equation (12), $B\mu_H G_H$ is the bribe money extorted by the corrupt government officials from the foreign investors of the PPP projects and τ is the tax rate. The public expenditure of the non-benevolent government of the host country is given by,

$$E = (1-\phi)[r_H(1-u)K_H + r_w K_F] \quad (13)$$

In the above equation, $(1-\phi)$ is the partial cost of infrastructure manufacturing burden borne by the government (or the Viability Gap Funding (VGF)) of the host country. In Barro's paper, the self-interested government does not balance the budget but instead earns the net revenue to maximize its profit. Following Barro (1990), we assume that the government is run by an agent who has no electoral constraints and who seeks to maximize its own utility. But, it is unlikely that a government will remain in office forever, as assumed by Barro (1990). In our model, we assume that the non-benevolent government maximizes its profit not over an infinite horizon but at a point of time.

The utility function of the representative self-interested government agent is given by,

$$U(C_G) = C_G \quad (14)$$

Where, C_G is the profit or instantaneous consumption of the self-interested government. The budget constraint or the net revenue of the self-interested government is given by,

$$R - E = C_G \quad (15)$$

We replace R and E from (13) and (14) respectively in the budget equation of the self-interested government.

$$C_G = B\mu_H G_H + \tau\, Y_H - (1-\phi)[r_H(1-u)K_H + r_w K_F] \quad (16)$$

Since, government's objective is to maximize its own consumption, replacing the value of μ_H from equation (6) and Y_H from equation (1) in the above equation, we obtain the ratio of the instantaneous consumption of the non-benevolent government, C_G, to the final output of the host country, Y_H.

$$\frac{C_G}{Y_H} = [B\,(1-\tau)\,(1-\alpha)+\tau] - \frac{\frac{(1-\phi)}{A}\left(\frac{K_F}{u\,K_H}\right)}{\left(\frac{G_H}{uK_H}\right)^{1-\alpha}} \left[r_H(1-u)\frac{K_H}{K_F} + r_w\right]$$

Replacing $\frac{G_H}{uK_H}$ from equation (9) in the above equation, we have,

$$\frac{C_G}{Y_H} = [B\,(1-\tau)\,(1-\alpha)+\tau] - \frac{\frac{(1-\phi)}{A}\frac{(1-u)}{u}\left(\frac{K_F}{(1-u)\,K_H}\right)}{\left(\frac{(1-B)^2 \upsilon\,(1-\alpha)}{\alpha\,\phi}\right)^{1-\alpha}\left[\frac{(1-u)K_H}{K_F}\right]^{(\upsilon-1)(1-\alpha)}} \left[r_H(1-u)\frac{K_H}{K_F} + r_w\right] \quad (17)$$

Using equations (7), (8), (10) and (11) in equation (17), we have the value of $\frac{C_G}{Y_H}$ as,

$$\frac{C_G}{Y_H} = \frac{(1-\tau)(1-\alpha)}{\phi}(B+\phi-1)+\tau \quad (18)$$

4.2.2 Households of the host country

Taking the government's decisions on R, B and $(1-\phi)$ as given, the representative household chooses the consumption, C_H and capital, K_H to maximize their welfare at the host country. The isoelastic form of the utility function is given by,

$$U = \int_0^\infty \left(\frac{C_H^{1-\sigma}-1}{1-\sigma}\right) e^{-\rho t} dt \quad (19)$$

σ is the inverse of the intertemporal elasticity of substitution and the budget constraint of the household is given by,

$$\dot{K}_H = r_H K_H - C_H \quad (20)$$

The current-value Hamiltonian of the representative household is given by equation (21) and the control variables are C_H and K_H.

$$H_C = \frac{C_H^{1-\sigma}-1}{1-\sigma} + \lambda[r_H K_H - C_H] \quad (21)$$

From the first-order condition, we obtain the following expression:

$$C_H^{-\sigma} = \lambda \tag{22}$$

Taking the log and derivative of the above equation, we get,

$$\frac{\dot{C}_H}{C_H} = -\frac{1}{\sigma}\frac{\dot{\lambda}}{\lambda} \tag{23}$$

The time-derivative of the co-state variable is given by,

$$\frac{\dot{\lambda}}{\lambda} = \rho - r_H \tag{24}$$

Using equation (23), we obtain the growth rate of consumption of the representative households of the host country.

$$\frac{\dot{C}_H}{C_H} = \frac{r_H - \rho}{\sigma} = g^F \tag{25}$$

Superscript 'F' stands for the flow concept of infrastructure provision therefore, g^F denotes the growth rate of consumption for the flow concept of infrastructure provision in the host country. By replacing $\frac{G_H}{uK_H}$ from (9) and subsequently replacing $\frac{(1-u)K_H}{K_F}$ from (10) in equation (5), we obtain the rate of interest of the host country.

$$r_H = \left[\frac{(1-\tau)A\,\alpha^{\alpha}(1-\alpha)^{(1-\alpha)}\,\upsilon^{\upsilon(1-\alpha)}(1-B)^{2(1-\alpha)}(1-\upsilon)^{(1-\upsilon)(1-\alpha)}}{r_w^{(1-\upsilon)(1-\alpha)}\,\phi^{(1-\alpha)}}\right]^{\frac{1}{\upsilon(1-\alpha)+\alpha}} \tag{26}$$

Replacing r_H from equation (26) in growth rate equation, we obtain the growth rate as,

$$\frac{\dot{C}_H}{C_H} = \frac{1}{\sigma}\left\{\left[\frac{(1-\tau)A\,\alpha^{\alpha}(1-\alpha)^{1-\alpha}\upsilon^{\upsilon(1-\alpha)}(1-B)^{2(1-\alpha)}(1-\upsilon)^{(1-\upsilon)(1-\alpha)}}{r_w^{(1-\upsilon)(1-\alpha)}\,\phi^{1-\alpha}}\right]^{\frac{1}{\upsilon(1-\alpha)+\alpha}} - \rho\right\} = g^F \tag{27}$$

Proposition 2: *There exists a unique steady-state balanced growth rate in the host country that is positive and constant. The growth rate decreases with increase in* ϕ, r_w ,τ , ρ , B.

4.2.3 Steady-state balanced growth

At steady-state balanced growth equilibrium, the consumption of the representative household, domestic private physical capital of the host country and the final output of the host country grow at the same strictly positive growth rate, i.e; $\frac{\dot{C}_H}{C_H} = \frac{\dot{K}_H}{K_H} = \frac{\dot{Y}}{Y}$. By setting $\frac{\dot{C}_H}{C_H} = \frac{\dot{K}_H}{K_H}$, we obtain the ratio of consumption of the households of the home country to private physical capital of the host country. Using (20) and (27), we obtain the value of $\frac{C_H}{K_H}$.

$$\frac{C_H}{K_H} = \left[1 - \frac{1}{\sigma}\right] \left[\frac{(1-\tau)A\,\alpha^{\alpha}\,(1-\alpha)^{1-\alpha}\upsilon^{\upsilon(1-\alpha)}(1-B)^{2(1-\alpha)}(1-\upsilon)^{(1-\upsilon)(1-\alpha)}}{r_w^{(1-\upsilon)(1-\alpha)}\,\phi^{1-\alpha}}\right]^{\frac{1}{\upsilon(1-\alpha)+\alpha}} + \frac{\rho}{\sigma} \quad (28)$$

4.2.4 Impact of bribes on the growth rate

We differentiate the rate of interest of the host country, r_H with respect to B. From the first-order condition we have,

$$\frac{\partial r_H}{\partial B} = -\left[\frac{(1-\tau)A\alpha^{\alpha}\,(1-\alpha)^{1-\alpha}\upsilon^{\upsilon(1-\alpha)}(1-\upsilon)^{(1-\upsilon)(1-\alpha)}}{r_w^{(1-\upsilon)(1-\alpha)}\,\phi^{1-\alpha}}\right]^{\frac{1}{\upsilon(1-\alpha)+\alpha}} \left[\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}\right] (1-B)^{\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}-1} < 0 \quad (29)$$

Since, r_H is negatively related to corruption, the growth rate is also negatively related to corruption because growth rate is a function of r_H i.e; $g^F = \frac{r_H-\rho}{\sigma}$.

Proposition 3: *There exists a negative relationship between the growth rate, g^F and the fraction of bribe money charged by the corrupt government officials in an open economy under the flow concept of infrastructure provision by the PPP mode.*

4.2.5 Government consumption and bribe when infrastructure is a flow variable

When differentiating equation (18) with respect to B, the fraction of the bribe amount paid by the foreign investors to the corrupt government officials of the host country, we find that no optimal B can be obtained for the flow concept of infrastructure provision.

$$\frac{\partial(C_G/Y_H)}{\partial B} = (1-\tau)(1-\alpha)\frac{1}{\phi} \quad (30)$$

Proposition 4: *There is no optimal B found when infrastructure provision is considered to be a flow variable.*

Note that the government will never set B=1. Because then profit of foreign firm would be zero and it will not participate in infrastructure production of host country.

4.2.6 Impact of the bribe on the ratio of domestic capital to foreign capital

On maximizing equation (10) with respect to B or the fraction of bribe money paid to the corrupt government officials by the foreign investors, we find that there is a positive relationship between B and $\frac{K_H}{K_F}$.

$$\frac{\partial(K_H/K_F)}{\partial B} = \left[\frac{\phi^{1-\alpha} r_w\, \upsilon^{\alpha}}{\alpha^{\alpha} A(1-\tau)(1-\upsilon)}\right]^{\frac{1}{\upsilon(1-\alpha)+\alpha}} \left[\frac{2}{(1-u)[\upsilon(1-\alpha)+\alpha]}\right](1-\alpha)^{\frac{\upsilon(1-\alpha)+2\alpha-1}{\upsilon(1-\alpha)+\alpha}}(1-B)^{\frac{\alpha-\upsilon(1-\alpha)-2}{\upsilon(1-\alpha)+\alpha}} > 0 \quad (31)$$

Proposition 5: *There exists a positive relationship between the ratio of domestic capital to foreign capital and B, implying that corruption will discourage the foreign capital inflow in the host economy.*

This result tallies with the results obtained by Cuervo-Cazurra (2008), Fredriksson et al. (2003), Coppier et al. (2013), and Cieslik and Goczek (2018). It was also found in these mentioned papers that corruption reduces the foreign capital inflow.

4.3 Infrastructure capital as a stock variable

In this section, we consider the accumulation of infrastructure capital stock in the provision of infrastructure capital. Firm 2 produces the infrastructure capital and the law of motion for infrastructure capital stock is given by,

$$\dot{G}_H = (1-B)[(1-u)K_H]^{\upsilon} K_F^{1-\upsilon} \quad (32)$$

For the sake of simplicity, we rule out the depreciation of infrastructure capital. The profit function of firm 2 is given by,

$$\pi_H^2 = (1-B)\mu_H \dot{G}_H - \phi[r_H(1-u)K_H + r_w K_F] \quad (33)$$

On maximizing the profit function of finished goods producing firm with respect to uK_H and G_H, and profit function of infrastructure producing firm with respect to $[(1-u)K_H]$ and K_F respectively, the first order conditions are same as equations (5)-(8). Also, the ratio of infrastructure capital to the fraction of domestic physical capital used for the production of final output is given in equation (9) and $\frac{(1-u)K_H}{K_F}$ is given by equation (10).

The rate of accumulation of infrastructure capital stock is obtained from equation (32). Therefore, using equation (9) and (32), $\frac{\dot{G}_H}{G_H}$ is given by,

$$\frac{\dot{G}_H}{G_H} = \frac{\alpha\,\phi}{(1-B)\,v\,(1-\alpha)}\,\frac{(1-u)}{u} \quad (34)$$

4.3.1 Growth rate of the host country when infrastructure capital is considered as a stock variable

The growth rate equation for the stock concept of infrastructure capital is same as the flow of infrastructure capital given in equation (25). The superscript 's' stands for stock of infrastructure capital and we denote growth rate for the stock concept by g^S.

$$\frac{\dot{C}_H}{C_H} = \frac{r_H-\rho}{\sigma} = g^S \quad (35)$$

Since, $g^F = g^S = \frac{r_H-\rho}{\sigma}$ and r_H is negatively related to corruption, the growth rate for the stock of infrastructure capital, g^S is also negatively related to the fraction of bribe money paid by the foreign investors to the corrupt government officials, B.

Proposition 6: *There exists a negative relationship between the growth rate,* g^S *and the fraction of bribe money charged by the corrupt government official,* B, *in an open economy under the stock concept of infrastructure provision by the PPP mode.*

4.3.2 Steady-state balanced growth for the stock of infrastructure capital

At steady-state balanced growth equilibrium, the consumption of the representative households, domestic private physical capital stock of the host country and the infrastructure capital stock of the host country grow at the same strictly positive growth rate, that is, $\frac{\dot{C}_H}{C_H} = \frac{\dot{K}_H}{K_H} = \frac{\dot{G}_H}{G_H}$. Hence, setting $\frac{\dot{C}_H}{C_H} = \frac{\dot{G}_H}{G_H}$ by using (34) and (35), we find the value of $\left(\frac{1-u}{u}\right)$ and u endogenously.

$$\left(\frac{1-u}{u}\right) = \left(\frac{r_H-\rho}{\sigma}\right)\frac{(1-B)(1-\alpha)\upsilon}{\phi\,\alpha} \quad (36)$$

$$u = \frac{\alpha\,\phi\,\sigma}{(r_H-\rho)(1-B)\,\upsilon\,(1-\alpha)+\alpha\,\phi\,\sigma} \quad (37)$$

The effect of B on u is positive, so as B increases, r_H decreases and $(1-B)$ decreases leading to increase in u.

Proposition 7: u *and* B *are positively related to each other for the stock of the infrastructure capital just like the flow of infrastructure.*

4.3.3 Non-benevolent government of the host country for the stock of infrastructure capital

The revenue (R) of the non-benevolent government of the host country for the stock of infrastructure capital is given by,

$$R = B\mu_H\dot{G}_H + \tau Y_H \quad (38)$$

However, the public expenditure of the non-benevolent government of the host country for the stock of infrastructure is same as equation (13). From the budget constraint equation, we have the same expression as equation (17). Replacing the value of $\frac{(1-u)}{u}$ from equation (36) and $(1-u)\frac{K_H}{K_F}$ from (10) in equation (17), we have the following expression for $\frac{C_G}{Y_H}$ for the stock of infrastructure capital in the PPP mode of infrastructure provision.

$$\frac{C_G}{Y_H} = [B(1-\tau)(1-\alpha)+\tau] - \frac{(1-\phi)(1-\alpha)(1-\tau)(1-B)(r_H-\rho)}{\phi\,\sigma}$$

After replacing r_H from equation (26) in equation (39), we have,

$$\frac{C_G}{Y_H} = [B(1-\tau)(1-\alpha)+\tau] - \frac{(1-\phi)(1-\tau)(1-B)(1-\alpha)}{\sigma\phi}\left\{Q(1-B)^{\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}} - \rho\right\} \quad (39)$$

In equation (39), $Q = \left[\frac{(1-\tau)A\,\alpha^{\alpha}\,(1-\alpha)^{1-\alpha}\,\upsilon^{\upsilon(1-\alpha)}(1-\upsilon)^{\frac{(1-\upsilon)(1-\alpha)}{\upsilon(1-\alpha)+\alpha}}}{r_w^{(1-\upsilon)(1-\alpha)}\,\phi^{1-\alpha}}\right]^{\frac{1}{\upsilon(1-\alpha)+\alpha}}$.

4.3.4 Government consumption maximizing bribe when infrastructure is a stock variable in the infrastructure provision

To find the government consumption maximizing bribe or the optimal bribe, B^*, we set the first derivative of function given in equation (39) equal to zero.

$$f'(C_G/Y_H) = (1-\tau)(1-\alpha) + \frac{(1-\phi)(1-\tau)(1-\alpha)Q}{\sigma\phi}\left[\frac{(1-\alpha)(2+\upsilon)+\alpha}{\upsilon(1-\alpha)+\alpha}\right](1-B)^{\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}} - \frac{(1-\phi)(1-\tau)(1-\alpha)\rho}{\sigma\phi} = 0 \quad (40)$$

$$f''(C_G/Y_H) = -\frac{(1-\phi)(1-\tau)(1-\alpha)Q}{\sigma\phi}\left[\frac{(1-\alpha)(2+\upsilon)+\alpha}{\upsilon(1-\alpha)+\alpha}\right]\left[\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}\right](1-B)^{\frac{(1-\alpha)(2-\upsilon)-\alpha}{\upsilon(1-\alpha)+\alpha}} < 0 \quad (41)$$

The optimal value of fraction of bribe money paid by the foreign investors to the corrupt government officials of the host country, B^* is obtained from equation (40).

$$B^* = 1 - \left[\frac{\{\rho(1-\phi)-\sigma\phi\}[\upsilon(1-\alpha)+\alpha]}{(1-\phi)Q[(1-\alpha)(2+\upsilon)+\alpha]}\right]^{\frac{\upsilon(1-\alpha)+\alpha}{2(1-\alpha)}} \quad (42)$$

In equation (42), B^* is the optimal B because second derivative $f''(C_G/Y_H) < 0$ and the function $f(C_G/Y_H)$ is maximum. In equation (42), $\rho(1-\phi) > \sigma\phi$ must be positive for the feasibility of the equilibrium.

The government will be corruption free only if $\hat{B}$, the critical value of B above which aggregate output is equal to zero, is very low. $\hat{B}$ can be obtained from using equation (1) and by replacing the value of G_H from (2).

$$\frac{Y_H}{K_F} = A\, u^{\alpha}\, (1-u)^{\upsilon(1-\alpha)} \left(\frac{K_H}{K_F}\right)^{\alpha+\upsilon(1-\alpha)} (1-B)^{1-\alpha}$$

Replacing the value of u and $(1-u)$from (38) and $\frac{K_H}{K_F}$ from equation (10), we have,

$$\frac{Y_H}{K_F} = \left(\frac{\sigma}{r_H-\rho}\right)^{\alpha} \left[\frac{r_w}{(1-\tau)(1-\upsilon)(1-B)(1-\alpha)}\right]$$

We again replace the value of r_H from equation (26) in the above equation.

$$\frac{Y_H}{K_F} = \frac{P}{S}\left\{\frac{\left[T(1-B)^{\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}} - R\right]^{-\alpha}}{(1-B)}\right\} \qquad (43)$$

Where, $P = r_w\left[r_w^{(1-\upsilon)(1-\alpha)}\phi^{1-\sigma}\sigma\right]^{\alpha}$, $S = (1-\tau)(1-\upsilon)(1-\alpha)$, $R = \rho r_w^{(1-\upsilon)(1-\alpha)}\phi^{1-\alpha}$

$T = \left[(1-\tau)A\,\alpha^{\alpha}(1-\alpha)^{1-\alpha}\upsilon^{\upsilon(1-\alpha)}(1-\upsilon)^{(1-\upsilon)(1-\alpha)}\right]^{\frac{1}{\upsilon(1-\alpha)+\alpha}}$ in equation (43).

The first derivative of $f(Y_H/K_F)$ is given by,

$$\frac{\partial(Y_H/K_F)}{\partial B} = \frac{P}{S}\left\{\frac{\alpha\, T\left[\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}\right](1-B)^{\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}} + \left[T\,(1-B)^{\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}} - R\right]}{\left[T\,(1-B)^{\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}} - R\right]^{\alpha+1}(1-B)^2}\right\} > 0 \qquad (44)$$

But, for $\frac{Y_H}{K_F}$ to be positive, $T(1-B)^{\frac{2(1-\alpha)}{\upsilon(1-\alpha)+\alpha}} - R$ must be positive. So, $B < 1 - \left(\frac{R}{T}\right)^{\frac{\upsilon(1-\alpha)+\alpha}{2(1-\alpha)}} = \hat{B}$.

Proposition 8: *There exists a bribe for which the consumption of non-benevolent government relative to the host country's output is maximized. There exists a positive relationship between corruption and the host country's aggregate output relative to foreign capital inflow. However, for the domestic output to be positive, a bribe must be less than a critical level.*

4.4 Conclusion

This chapter builds a small open economy model that receives the foreign capital inflow in the infrastructure sector but foreign investors face extortions from the corrupt government officials of the host country for entry into the infrastructure sector. Both, the flow and stock concept of infrastructure production has been discussed in this chapter. This chapter studies the impact of the profit paid as bribe by the self-interested foreign investors to the self-interested government for the PPP infrastructure investment on the growth rate of the economy in the host country.

This chapter suggests that in a small open economy, there is a positive relationship between fraction of domestic capital used in corruption free final output sector and corruption in infrastructure sector. We also find that corruption in the infrastructure sector has a damaging effect on the growth rate and also on foreign capital inflow through the PPP projects in infrastructure sector for both the stock and flow concept of infrastructure provision of host country. This result is similar to the results found for the relationship between corruption and inflow of foreign capital by Cuervo-Cazurra (2008), Fredriksson et al. (2003), Coppier et al. (2013), and Cieslik and Goczek (2018).

We also obtain a bribe for which the consumption of the non-benevolent government relative to the host country's final output is maximized when infrastructure capital is a stock capital.

We also find that there exists a positive relationship between corruption and the host country's aggregate output relative to the foreign capital inflow for the PPP mode of provision of infrastructure in a small open economy. However, for the domestic output to be positive, a bribe must be less than a critical level. This chapter could be further extended by incorporating foreign debt and studying the voting outcomes in the presence of corruption in the infrastructure sector. In our future research we would like to address this issue.

Chapter 5

Summary and Conclusions

This thesis deals with the theoretical aspect of endogenous growth and evaluation of infrastructure provision through the PPP mode. Chapter 5 summarizes the crux of the thesis, main findings, the limitations of this present thesis and discusses the future research areas to be explored.

5.1 Summary of the thesis

Infrastructure service is an important development tool that catalyses growth in the long run. Governments around the world are struggling to achieve faster economic growth and development by improving their basic infrastructure sector. After seeing the success experienced by those developed countries, which had adopted the PPP projects extensively for their infrastructure provision, the developing countries too, followed suit, to remove the infrastructure bottlenecks and to provide good quality and efficient infrastructure capital in their respective countries. By the early 1990s, the PPP projects were adopted by the developing countries worldwide with much enthusiasm. However, the PPP projects invited both advocates and critics regarding its favourable effects in developing countries. But, not much has been explored in this area in the academic literature, as much as it draws criticism. Bennet and Iossa (2006), Besley and Ghatak (2001), Iossa and Martimort (2015) and others have studied the PPP mode of infrastructure provision in a microeconomic framework. But, infrastructure provision by PPP mode is not just a microeconomic problem but a macroeconomic problem as well, because the nature of PPP projects is such that the government budgets allocated for infrastructure may be curtailed but not completely released.

In a PPP project, the government has to finance the partial cost of investment in the infrastructure manufacturing, such as VGF (Viability Gap Funding) and has to share risks with the infrastructure manufacturing private firms, provide certain guarantees, laws and regulations for the smooth functioning of the PPP projects. This thesis tries to fill the gap in the literature and evaluate the performance of PPP from the macroeconomic policy point of view and thus study the functionality of PPP in the infrastructure-growth nexus in the long run. This thesis focuses on the supply-side economics of the infrastructure provision in the endogenous growth theory.

In chapter 1, we do a survey of the extensive literature on the role of infrastructure as a public good on endogenous economic growth, PPP mode of infrastructure provision in a microeconomic framework and in an open economy context, etc. Since, there is a vast literature on public goods and endogenous growth, we have limited ourselves to surveying only the theoretical works which have considered the infrastructure as a public good.

Chapter 2 is an extension of Barro (1990). A comparative study of the private capital and public capital as complementary goods and substitute goods in a growth-maximizing and optimal fiscal policy conditions in a balanced budget framework is done in two parts. In part one, for the complementary goods, we find that the command economy growth rate may be less than that of a competitive economy and a unique, interior growth-maximizing tax rate and an optimal tax rate also exists. In the second part, for the substitute goods, the command economy growth rate is always higher than the competitive economy growth rate and the growth-maximizing tax rate is zero. The interesting result found in this chapter is that a PPP is always an optimal solution for financing infrastructure no matter the relationship between the private capital and public capital are substitute or complements but PPP is not growth maximizing in the case when public capital and private capital are perfect substitutes.

In chapter 3, we make a comparative study of different modes of provision of infrastructure, such as pure private provision, pure public provision and PPP from a macroeconomic perspective. Sustainability of public debt is an issue for the governments around the world with pure public provision because of the complete dependency of infrastructure provision on the public purse and things may not be very different for the PPP mode of infrastructure provision because the government's exchequer is not released completely and a partial cost of infrastructure is borne by the government in the case of PPP projects. The sustainability issue of the intertemporal public budget of both, pure public provision and PPP mode of infrastructure provision, together, are compared with the pure private provision of infrastructure in chapter 3. We find a fascinating result that the growth rate obtained under the accumulating debt regime is higher than the balanced budget regime, which is contrary to the results found by Greiner (2014). The sustainable public debt for the provision of impure public good justifies the adoption of PPP mode for the infrastructure provision. It was also found that PPP yields a higher growth rate compared to public provision of infrastructure under both, a balanced budget and accumulating debt. If the government has to choose the optimal percentage of investment by the private firms in the PPP projects, then from the calibration exercise we find that more than 50% investment by the private firm yields the highest growth rate. However, we note that the interest payment of the past accumulating public debt has a positive effect on the growth of public debt and has a negative effect on the GDP growth rate.

In chapter 4, we discuss that impact of corruption on growth rate and the foreign capital inflow in context of foreign firm participation in the infrastructure sector of host countries through the PPP mode of infrastructure provision. Corruption is a frequent encounter for most international investors while dealing with the public sector (World Bank Study (1999)). We find some interesting results in this chapter. As expected, it is found that as corruption increases in the infrastructure sector more private physical capital is used in the corruption-free final goods sector. Corruption in the infrastructure sector has a negative effect on the growth and foreign capital inflow. Similar results are obtained by Cuervo-Cazurra (2008), Fredriksson et al. (2003), Coppier et al. (2013), and Cieslik and Goczek (2018), for the relationship between corruption and foreign capital inflow irrespective of the economic sector in which foreign investment was invited in the host country. There exists a positive relationship between corruption and the host country's aggregate output relative to the foreign capital inflow for the PPP mode of provision of infrastructure in a small open economy. However, for the domestic output to be positive, a bribe must be less than a critical level. We also obtain the bribe level for which the consumption of the non-benevolent government relative to the host country's final output is maximized when infrastructure capital is a stock capital.

5.2 Limitations and scope for the further research

Quite a few extensions of our analysis we can think of. We consider perfect competition for the analysis of our endogenous growth models for infrastructure provision, but different market structures like monopoly and monopolistic competition for the provision of infrastructure are left unexplored in our thesis. Production efficiency parameter of infrastructure sector is assumed to be independent of mode of provision of infrastructure. But switching to PPP mode may bring about enhancement in production efficiency of infrastructure sector.

Chapter 2 deals with the balanced budget regime for the infrastructure provision. Here, in the model public investment and private investment co-exist. But, partnership between private capital and public capital has not explicitly modeled. However, this limitation has been taken into account in our next chapter where the profit function of infrastructure sector through PPP mode has been explicitly modeled.

In chapter 3, we make a comparative study between the pure public, pure private and PPP mode of infrastructure provision. It will be interesting to include the case when public investment and private investment co-exist and make a comparison between this case with PPP provision. Please note that by coexistence of public and private investment we mean provision of a good by public enterprise and private firm separately but not through any partnership or collaboration unlike PPP mode. In our model, we have included only public debt financing but other modes of financing (such as borrowing from capital market) are not included. The capital market of the developing countries is underdeveloped but other types of financing cannot be ruled out.

In Chapter 4, a comparison between domestic financing and foreign capital financing in a PPP model is of interest and could be further explored. Also, chapter 4 could be further extended by studying the voting outcomes in the presence of corruption in the infrastructure sector, however, it is beyond the scope of the present thesis to study these issues.

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