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EFFECTS OF HYDROPOWER POTENTIAL ON LONG-TERM ECONOMIC GROWTH IN BRAZIL

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Environmental limitations are about to cause increasing economic costs as human actions affect climatic conditions around the world. Those costs can be mitigated cost-efficiently within appropriate institutional framework.

Deforestation in tropical rainforest regions can be a significant factor altering the climate in those particular regions. In Brazil it reduces rainfall, thus affecting hydrological conditions which are critical for hydropower generation. The country relies heavily on hydropower in its electricity production, and therefore this study considers a possibility of that hydroelectricity supply issues would negatively affect Brazil's long-term economic growth.

A literature review combines different aspects of development in Brazil in order to form a picture of how country's institutional structure inflicts the transmission of issues in hydropower sector into the economy. The review is complemented by a sensitivity analysis to a growth projection which aptly reflects some characteristics of development in Brazil. Thereby the analysis demonstrates how more comprehensive evaluation of different aspects than what in general has been done so far could change the conception of country's growth potential.

If current state of institutional affairs persists, there is an obvious threat of that electricity supply side issues will have increasing economic costs. Historical factors and currently prevailing international political economy orientation may hamper realization of institutional change that is essential in mitigating these possible costs.
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1 INTRODUCTION

Economic growth has been receiving significant weight in economic policy discussions in different forums. At the same time it has been noticed that human actions tend to change climatic conditions in various parts of the globe including Brazil, so that environmental limitations are about to induce notable economic costs that are likely to be greater in the long-run, if actions taken to prevent them are further from sufficient in shorter perspective. Interestingly, this issue has not been given much attention when it comes to projections, e.g. by International Monetary Fund (IMF), and assumptions considering Brazil's growth potential. Stern Review on the Economics of Climate Change focuses on the mentioned relation between environmental limitations and economic costs. An aspect of the review that is relevant to Brazil, home to a large part of one of the largest remaining rainforest areas, is deforestation. According to the review efforts led by the nation, where a particular forest subject to deforestation is located, could within appropriate institutional structures and with right policies effectively mitigate related economic costs. The review names, for instance, clarifying rights and responsibilities that locals have to the forestland and enforcement of them, and encouraging alternative ways of using land resources as means to provide economic incentives to restrain deforestation, in addition to which these individual efforts should be integrated to other policies and market contexts with whom they have interrelations.

Even though Stern Review refers mainly to that deforestation affects climate through increased carbon dioxide content in the atmosphere, in Brazil there can also be another way through which decreasing rainforest cover may similarly have negative economic effects. Production of hydroelectricity in the country is dependent on river discharge. Reduced rainfall resulting from the loss of forests decreases river flow and thereby hydropower potential as well (Stickler et al. 2013). An analysis done from a hydropower operator's perspective indicates that lower amounts of water would be the most severe single threat to its business profitability (Andrade et al. 2012). Andrade and others link that profitability to public accounts, to which public energy generation companies are said to have contributed significantly, which refers to that the state could have an economic incentive to try to improve operational environment of the sector in question. Stickler and others' observations of deforestation being a
major factor behind hydropower potential indicates that forest conservation could be a way of doing that. Andrade and others also note that possible changes in climatic conditions are still not explicitly considered in national long-term energy planning.

Could more comprehensive evaluation of factors that can have economic impacts make any difference? This study intends to find out if hydropower potential could be another channel through which deforestation can have negative impacts in the long-run. That is from the point of view of Brazil's economic growth potential, considering that the country derives around 80 per cent of its electricity from hydropower\(^1\), and that electricity plays an important role in productive activities. Existence of that particular channel would also denote that there could be additional matter having real significance regarding state actions that direct economic activities, and which has not received attention that is equivalent to its relevancy. Possible implications of taking these environmental limitations into account in relevant growth forecasts and project calculations in hydropower sector development planning, and also prospects of the state taking a role in which it would effectively mitigate possible deforestation-related economic costs are discussed.

An institutional point of view is taken to the economic development in Brazil, characteristics of which are then reflected to the structure of the economy in order to demonstrate a threat of hydropower supply side issues having long-term economic costs. A mechanism of those costs to occur could be slower growth in total factor productivity (TFP). Sensitivity analysis done to a growth projection, in which TFP is given relatively lot of weight, complements the review of literature.

Chapter 2 starts the review with the development of the Brazilian economy from Portuguese colonial times to the present, thus providing some historical aspect behind Brazil's current institutional structures and how the role of state has been seen in the development process. Chapter 3 connects hydropower to the overall development process, observes development within the sector from the perspective of evaluation of different aspects and then deals with hydropower potential's

\(^1\) Figures from EIA and EPE state the share in 2010.
interrelation with deforestation. Electricity's role in productivity and conceivable effects of issues in hydroelectricity supply within structural composition of the Brazilian economy are the subject of chapter 4. Chapter 5 introduces reference projection to which the sensitivity analysis is done and evaluates required assumptions from this study's point of view. Chapter 6 contains the sensitivity analysis and its results followed by discussion. Finally, chapter 7 concludes.
2 DEVELOPMENT OF THE BRAZILIAN ECONOMY

2.1 Colonial era and pre-industrial 19th century

Brazil was a colony of Portugal from 1500 to 1822. Before that any kind of complex social arrangements had not been developed in the country, so Portuguese had a major influence on the institutional development. Trade policy was determined in Lisbon and it was based on demand patterns in Europe and production opportunities offered by Brazil. Economic production established by Portuguese was characterized by extraction of raw materials and making use of land resources and slave labor from different colonies. Sugar cane cultivation and gold mining were among the most important commercial activities that shaped institutional foundations. Local elite had the control over agricultural land, but the political power remained within the Portuguese state. This may have led to the persistence of local elite's strong position, especially in terms of land ownership, in the agricultural sector, that is based on the elite running given institutions. The state was interested in a share of income the gold mining sector was generating and imposed a tax on it. To make sure that the tax was paid on all the production Portuguese created a system to monitor all stages of production. Inefficiency of the system and significant repatriation of tax revenue to Portugal ended up in a culture of detachment between the state and population, when what mattered to colonial power was the aggregate net benefit received from all colonies as a whole. To some extent the influence of this may be seen in lower public good provision today. (Alves Carrara 2010; Mattos et al. 2012; Naritomi et al. 2012.)

In spite, or because, of distrust in the state private-order institutional arrangements developed around growing trade between Brazil and Portugal. Small amount of key players, who were able to cope with uncertain conditions, had an important role in this reputation-based system. Parties with connections to those key players could have benefited from these connections. (Costa et al. 2010.)

This social capital perspective can help understanding the development of power structures. State not being an effective party in promoting institutional development from the whole society's point of view may have been a way of persistence of certain
smaller groups' strong position in the society. According to Baer and Sirohi (2013) colonialism resulted in lopsided distribution of political power and disenfranchisement amongst the masses, and after Brazil became independent in 1822 the pre-industrial time in 19th century also witnessed fragmented occurrence of economic expansion that hampered development of internal markets. In that time gold industry had already declined, so that relative importance of agriculture increased significantly (Cardoso & Teles 2010). The focus of economic policy was on integrating Brazil's agriculture export sector into international markets as a supplier of primary goods, when Britain that had guaranteed the independence strongly influenced different policies (Baer & Sirohi 2013). This way resources for coming industrialization were provided, but also dissatisfaction towards the role of state remained (Baer & Sirohi 2013).

2.2 Industrialization

2.2.1 Early industrialization

Brazil relied on foreign capital and technology in its industrialization process that started in late 1800s. In the beginning the British still had a strong position as a supplier of capital and financier of public sector. Their presence, however, was characterized by an aim to make the most of advantageous situation that they had achieved earlier. Competition from continental Europe and North America in the form of investments in new and more dynamic industrial sectors instead of primary goods exporting facilities began reducing relative potential gains of those activities, in which the British had mostly been engaged. Thus the British started to concentrate more on banking sector activities and acquiring firms that had come from other foreign countries. With contracts working for their advantage they lent money to Brazilian federal government, so that it could buy public infrastructure facilities, for example. Gradually competition undermined British dominance in financial intermediation too. (Abreu 2000.)

Large foreign firms with easy access to finance and advanced technology targeted to underdeveloped markets with growing demand for modernization in Brazil, and the tendency among those firms to merge instead of compete against each other led to
that they were able to gain remarkable market power (Macchione Saes 2013). Following earlier trends economic growth concentrated mostly in clear clusters that were largely disconnected from one another, and domestic business elite had to rely on their connections within institutional setting lacking conducive interaction with the state from their point of view (Musacchio & Read 2007). In the end of 1800s economic growth was slowed by inflation caused by loose monetary policy when there was no central bank regulating it, and exchange rate depreciation that made investments less profitable in foreign currencies, which reduced foreign capital inflow (Abreu 2000; Cardoso & Teles 2010). Introduction of gold standard in the beginning of 1900s helped stabilizing the exchange rate, and foreign capital inflow increased until the World War I limited available resources (Abreu 2000). In the 1920s the Brazilian federal government was able to practice more independent economic policies (Cardoso & Teles 2010). According to the Oxford Latin American Economic History Database estimates the real economy grew annually by around 2.9 per cent on average between 1900 and 1930.

All in all, this period from late 19th century to start of economic depression in economically influential country markets in early 1930s affected public attitude towards the role of foreign investments in Brazil, and the role of state in economic affairs continued being criticized because of not serving broader domestic interests sufficiently (Abreu 2000). That time also meant new opportunities and responsibilities for Brazilian political and economic elite when it comes to country's development, which in underdeveloped institutional context evolved in an uneven way from whole society's perspective, thereby reinforcing inheritance of inequality (Macchione Saes 2013).

2.2.2 Import substituting industrialization and the following military regime

There were institutional changes in 1930s that altered economic context in Brazil. Gradual weakening of the British influence allowed, and international economic slowdown compared with rising nationalist sentiment drove the federal government to adopt policies that aimed at making foreign investments serve national interests better than before (Abreu 2000; Baer & Sirohi 2013). In short, the adopted development strategy, that is also called import substituting industrialization (ISI), is
about protecting domestic industries from foreign competition, so that they can produce goods that would otherwise be imported, thus helping domestic firms to develop and making markets more self-contained. ISI, as it is referred to in Brazilian context, can be a combination of different policies and country specific arrangements.

Steps towards ISI policies had been taken already during the 1920s, when companies were founded with government incentives after the World War I had reduced foreign competition in manufacturing. Brazil's economy was still mainly agriculture-based and the country had a dominant position in the world markets of coffee, which was its main export commodity. Difficulties in the world economy in the end of the decade triggered an export crisis that led to policy changes in favor of domestic industrialization. (Cardoso & Teles 2010.)

Foreign investments were seen as an essential contributor to industrial development because of availability of domestic resources and expertise was limited, and therefore new government regulations were designed to direct investments in manufacturing by making other sectors less attractive to invest in (Baer & Sirohi 2013). In some sectors, such as mining, requirements of the share of domestic employment and ownership in companies were imposed and, for example, foreign banks and insurance companies were to be nationalized (Abreu 2000). Earlier separately and relatively independently by elite groups ruled regions began to be subject to centralized policy-making with a trend of more systematic state involvement in economic affairs authorized by new constitutions, two of which were introduced in the 1930s (Todorov & Torres Filho 2012).

Public attention focused on economic and political costs of foreign investments and net balance of payments of foreign firms received more attention. The government started to control the distribution of foreign exchange, which made remittances of profits and interests more difficult. Also antitrust decrees were brought into use. At first they were of an authoritarian nature; business practices that were contradictory with nationalist intentions were criminalized. Later the antitrust legislation began to refer to companies using their market power to eliminate competition or to arbitrarily raise profits. However, the government was heavily involved in business and not
willing to execute the antitrust legislation consistently before the first fully functioning competition authority was set up in 1962. Initially the new development strategy caused difficulties between companies and the government, and reduced willingness to participate in Brazilian markets, but companies that participated in the markets often improved their profitability after initial challenges in doing business. (Abreu 2000; Todorov & Torres Filho 2012.)

The Oxford Latin American Economic History Database estimates deliver around 1,9 per cent average real economic growth rate for years 1930-1950. The period is characterized by mostly higher than mentioned average growth, up to two-digit rates, and slower and occasionally negative growth during the early 1930s crisis and the World War II. Structural change occurred in the way that, according to Library of Congress Country Studies, by 1950 the share of agriculture in GDP had declined and the equivalent share of industry had increased so that each accounted for close to one fourth.

After that the following three decades were time of rapid economic growth except time in the first half of the 1960s, when Brazilian political regime that had developed into multi-party democracy faced a political crisis, to which earlier ISI policies had led. Distributing the benefits of development that had through certain policies favored specific groups in more democratic way was not in line with the nature of the ongoing industrialization. Besides, concerns related to the dependence on foreign capital and financing grew, causing political uncertainties, which increased risks for foreign investments that were crucial for growth. Politicians had issues in dealing with the crisis and a military government came to power in 1964. It introduced a program including structural reforms, which was seen to improve country's growth potential, realizing in so-called economic miracle starting from 1967 and eventually slowed by the oil shocks in the 1970s. The average annual GDP growth was about 7,5% from the beginning of the 1950s until the end of the 1970s. (Cardoso & Teles 2010; Markoff & Baretta 1990.)

The military government intervened extensively in the economy. Newly established technocrats, for instance in the new central bank, implemented policies coordinating the expansion and concentration of state-led industries, that was also promoted by
different laws. The government altered its development strategy from ISI to export subsidizing with a focus on promoting industrial exports by tax incentives and simplified administrative procedures. Policy implementation was financed by high levels of external debt, disregarding inflation. Incurred structural and financial imbalances of the economy were to bring along challenges in changing world economic environment, and high growth rates in the period of the economic miracle may have been to large extent due to delayed effects of the reforms done by the military government. (Todorov & Torres Filho 2012; Cardoso & Teles 2010; Veloso et al. 2008.)

2.3 Debt crisis and neo-liberal political economy on the way to the present

The way of industrialization the military government had promoted distorted the composition of production so that, for example, agriculture sector was hit and the country became more dependent on oil imports (Todorov & Torres Filho 2012). The oil shocks in the 1970s started to slow growth, and worsened current account balance was financed with increased external debt, but rising foreign interest rates eventually made it difficult for the government to serve the debt, which was then financed with inflation in the early 1980s increasing the unpopularity of the government (Cardoso & Teles 2010). The focus of economic policy turned onto stability instead of growth, but the stabilization of the economy wasn't properly achieved before the 1990s (Cimoli et al. 2011).

The debt crisis necessitated new arrangements with foreign debtors and financiers, and Brazil was persuaded to adopt neo-liberal policies that made the country more open to trade and investments as well as limited state intervention in the economy giving more opportunities to foreign private firms. This resulted in increased foreign direct investment (FDI) flows in public utilities and natural resource exploitation that tended to be acquisitions of existing firms and facilities instead of new capacity generating, so-called greenfield investments. (Baer & Sirohi 2013.)

Forms of FDI that increased in Brazil can have ambiguous effects on local economy. Growth and employment generating potential of primary sector FDI is often limited because of lack of linkages with local economy (Baer & Sirohi 2013). Domestic
firms being acquired by foreigners, in turn, is often associated with the use of intermediate products supplied within their own organizational network, when local suppliers' position may worsen, thus making spillover effects even negative (Mencinger 2003). The spillover effects have been considered the main FDI related contributor to growth in investment-receiving country, but the way they affect growth is also dependent on local institutions (Mencinger 2003). The military government that remained in power until 1985 was not interested in enforcing regulations considering economic activities, and actual political deals between public sector and business community were conducted so that in practice regulating agencies didn't have real means to affect the deals (Todorov & Torres Filho 2012). Transition to democracy was led by a president who had been a supporter of military dictatorship, and some political and economic practices were maintained until new institutional environment inevitably led to changes (Todorov & Torres Filho 2012). The adoption of neo-liberal policies meant that the state didn't have the same possibility to control financial in- and outflows as earlier. In addition to Astorga's (2010) findings about negative correlation between overall openness and long-term economic growth considering the whole 20th century Seabra and Lach (2005) find a unidirectional causality between FDI inflows and profit outflows, indicating that the former has been a driving factor behind remarkable increase in the latter after financial liberalization in Brazil in the 1990s.

![Graph](image-url)

**Figure 1.** Contribution of net capital stock to GDP per worker growth (Adapted from Cardoso & Teles 2010)
Figure 1 demonstrates contribution of capital stock growth to GDP per worker growth from 1951 to 2008. The change measured in percentages at annual basis is on the Y-axis, and time is on the X-axis. Until 1980 the growth in net capital stock and the consequential effect on output per worker growth were quite stable with an exception of transition period from democracy to military regime. After 1980 there has been hardly any positive growth in the net capital stock, but at the same time according to United Nations Conference on Trade and Development FDI inward stock seven-folded between 1980 and 2000, from which it grew to almost 5 times bigger by 2012. In other respects GDP per worker growth mainly reflects fluctuations in TFP (Cardoso & Teles 2010). Cimoli and others (2011) argue that after the debt crisis in early 1980s the structure of the Brazilian economy moved towards less technology intensive sectors, which may have affected growth negatively minding the indications of higher technology intensities leading to higher growth rates through increased productivity in other countries.

This perspective refers to that TFP has played a central role in Brazil's economic growth, especially in industrial time. Average TFP growth was negative between 1980 and 2008, and the aggregate output growth averaged less than 2.5%, which is one third of the corresponding figure of preceding three decades during which TFP growth was clearly positive (Cardoso & Teles 2010). Another growth determining factor has been investment rate according to Astorga, who also stresses the significance of interrelations between different determinants of growth in the way that the effect of a single factor by itself may be different from its effect in combination with other factors. So, taken as a whole the Brazilian experience can be seen to reflect the importance of not only amount, but also quality and sectoral composition of investments on growth, and the corresponding importance of institutions in these matters as well as in determining who benefits from the development and on whose expense. The question about who benefits considers, for example, domestic economy in relation to foreign parties.

After democratization and the liberalization of economic policies Brazil's institutional framework seems to have been in a transition guided by past development and globalization forces, and in which the state's role is essential. The
legislation and policy guidelines, for example considering regulations, have become up-to-date in many respects, but their enforcement still remains inadequate in international pressure and when appropriateness of earlier ways of dealing with different issues is not questioned because of power that some stakeholders have in current processes (Todorov & Torres Filho 2012; Victorino 2012). Regulatory agencies often have the technical ability to control their area of responsibility, but the valuation of the issues they are dealing with as well as the effort of related actions taken by them is challenging, and thus they easily face difficulties in competition for public resources (Coimbra Borges et al. 2012; Todorov & Torres Filho 2012). Besides, true influence of certain regulatory agencies is still limited to giving recommendations or similarly influential proceedings, and for these reasons the credibility of sanctioning for unwanted actions may not be sufficient to affect economic behavior (Sousa Júnior & Reid 2010; Todorov & Torres Filho 2012). This in combination with perception of certain level of public power misuse for private benefit may foster the conception, presumably inherited from previous centuries, of not getting fair value for taxes paid among the people.

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2 General definition of prevalence of corruption in Transparency International's Corruption Perceptions Index (see CPI 2010: Long Methodological Brief), in which Brazil's score was 42/100 and country ranking 72/177 in 2013.
3 HYDROPOWER IN BRAZIL

3.1 Importance for growth

As the country's history partly reveals Brazil has abundant natural resources, use of which has contributed to country's economic development, especially in terms of GDP growth. Hydropower as a form of making use of natural resources has more than a century long history in the country. It was enabling industrialization-based modernization of earlier mostly agrarian society by forming development-leading urban agglomerations, such as Sao Paulo, that attracted foreign investments in hydropower-exploiting activities, thus building foundations of the importance of hydropower (Victorino 2012). The country can be thought of having a comparative advantage in hydroelectric generation, which has been taken into account in the implementation of productive activities.

In addition to attracting productivity-enhancing physical investments hydropower can have had positive long-term effects on human capital accumulation, for example, since the potential of public infrastructure investments on productivity was given more attention, when the government started to control the expansion of hydropower grid more systematically in the 1960s. Libscomb and others (2013) studied long-term development effects of the grid expansion using data from years 1960-2000. Their results indicate that higher incomes and better educational attainment could be found in locations with access to hydropower than in those left without it, which they explain to be possible due to firms' better ability to provide employment opportunities that, in turn, allowed gaining more work experience as well as higher expenditures in post-secondary education. Experience and education can raise labor productivity, which is known to be important in terms of modern economic growth as part of TFP.

The importance of hydropower is also demonstrated by Pao and Fu's (2013) findings about long-term equilibrium relationship between hydropower use and real GDP from data over years 1980-2009. This positive unidirectional causality suggests that limiting hydroelectric use would hamper economic growth in Brazil. Pao and Fu
refer to unfavorable policy as a limiting factor, which in their conclusions means policies directly affecting the use of hydropower rather than unintentionally through insufficiently evaluated growth-affecting factors like environment, though the possibility of which is not ruled out. The early history of larger-scale hydropower use was characterized by very little or non-existing regulation, which allowed prioritizing hydroelectric generation over all other aspects of water use (Victorino 2012). And later, when water use legislation was updated, the environmental regulation still lagged behind (Coimbra Borges et al. 2012). This kind of operational environment may not be ideal in providing incentives to consider environmental and other relevant aspects sufficiently when it comes to suggestions of hydropower projects to be implemented. In addition to that Pao and Tsai (2010) remind of the importance of improving energy efficiency, considering wasteful energy consumption in Brazil among other BRIC (Brazil, Russia, India and China) countries, in order to maintain economic growth performance nowadays and in the future, when environmental limitations are about to become more and more binding.

In fact, according to Nazmi and Revilla (2011) Brazil's production has been continuously less efficient than that of China and India's for more than 25 years starting from 1980, which may be associated with Cimoli and others' findings of the way of structural change and partly explain Brazil's weaker than its potential growth record. China and India have done much better in that respect, even though in general the recognition of long-term growth affecting factors in those countries is not necessarily more comprehensive than in Brazil. China and India don't rely on hydropower to same extent as Brazil. Nazmi and Revilla emphasize the role of TFP in the form of labor productivity, hydropower's impact on which is already discussed, and investments in physical capital. They argue that public expenditures, that in Brazil have consisted largely of consumption instead of growth promoting investments such as those in infrastructure, have crowded out private investments through high taxation and high interest rates. Oreiro and others (2012) show by econometric testing that Brazil's economic growth between 1990 – 2005 was almost exclusively demand-led and mainly based on exports and public sector consumption. They say that in the circumstances of high public debt, high taxes and low public investments in infrastructure, like in Brazil, long-term growth cannot be based on increasing government consumption.
All these perspectives from labor input dynamics to efficiency and composition of GDP together imply that, like earlier, TFP and its growth may play relatively important role if Brazil is about to perform according to its growth potential in upcoming decades. Since remarkably reduced reliance on hydropower is not in prospect\(^3\), it is important that resources directed to the development of that particular sector will be used in a way that does not weaken the foundations of growth. For the most part so far, institutional structures and policies that affect behavior of economic agents in the sector seem not to have effectively worked on ensuring that, especially with respect to possibly relevant interrelations between growth-affecting factors. To some extent this is reflected from development planning and project implementation.

### 3.2 Characteristics of planning and project implementation

#### 3.2.1 Reasoning, parties involved and related power asymmetry

In the beginning of commercial hydropower use in Brazil licenses were granted with tax exemptions to firms who were able and willing to harness the potential of water basins, which then happened in a way desired by, for example, companies from more developed countries, where they didn't really have that kind of opportunity anymore (Victorino 2012). In the early 1960s a national electricity company was created to coordinate the hydropower grid expansion at national level, that seemed to be based on government's development goals and projected GDP growth (Libscomb et al. 2013). Partial privatization of electricity markets in the 1990s led majority of distribution to end up in the control of private companies, while the state remained 80% ownership of generating capacity (Gall 2002). This combined with continuous restructuring of regulatory agencies, that McCormick (2007) mentions to have transferred power from those agencies to private companies as well, may facilitate capturing private financial interests in hydropower development projects. Still and all, energy demand growth calculations based on GDP projections have continued to

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\(^3\) According to Andrade and others (2012) it is estimated in the National Energy Plan that hydropower would account for approximately 77% of total energy demand by 2030.
be the driver of hydropower sector development planning (Sousa Júnior & Reid 2010; Andrade et al. 2012). This is also supported from small hydropower plants' point of view by Tiago Filho and others' (2012) observations about strong correlation between GDP and installed capacity. Assuming that projected GDP growth continues to be a driver of energy development planning, altered projections could have an impact on plans about new capacity that is seen to be needed, if taking more aspects than earlier into account changes expectations of future growth. Paying attention on resource use will probably be more important in the future than what it may have been earlier.

More comprehensive consideration of different aspects has been pursued by coalition that based on environmental and social arguments has tried to remove large-scale energy development projects from government agenda, on which those projects have been placed by dominating coalition with better connections to core government agencies (Carvalho 2006). In addition to different government bodies public generation companies and electricity research institutions as well as certain regulatory agencies form the core group that makes decisions about hydropower development (Sousa Júnior & Reid 2010). The dominating coalition consists of private and some public sector actors that have financial interests related to public infrastructure projects (Carvalho 2006). Another coalition, in turn, is more fragmented set of, for example, Brazilian and international non-governmental organizations, indigenous communities representing activists and more independent experts⁴, that has less resources and more limited possibilities to affect hydropower sector development (McCormick 2007).

This power asymmetry between coalitions becomes apparent in such a way that public hearings are held within tight schedules, which makes it difficult for any project opposing party to gather credible argumentation material on time, and at too late a stage of implementation process for democracy-ensuring consensus building (McCormick 2007; Bermann 2007). Besides, the agency that is responsible for the interaction with the public does not have any formal way to bring those views into

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⁴ Sometimes experts have supported less influential coalition because projects have affected their residential zone (McCormick 2007), which may have an influence on objectivity.
decision-making process (McCormick 2007). All this makes the procedures of hearing citizens' opinion seem like a formality that is done only because that particular right is in the constitution, and according to Carvalho there has been an attempt to alter the constitution to make execution of hydroelectric projects easier regarding to required formalities. The less influential coalition has also not been able to achieve permanent resolutions through court system, since its opponent has been able to take planned projects forward at every turn (Carvalho 2006).

As a result of the power asymmetry, for instance in some cases, acknowledgement of affected people's rights can be ignored with a justification of majority's will, which is derived from a forum whose composition already reveals that it favors the party that wants to implement a project (Bermann 2007). This kind of issues can also be applied to information about projects' interrelations with different factors like environment. The majority mentioned is said to want to avoid power blackouts, and thus project implementations are reasoned by referring to the ones experienced because of drought in the early 2000s, not considering low power generation during dry season, that can make projects unsustainable (Carvalho 2006). Adding depleting rainforest cover's impact on rainfall, which affects rainy season too, more of which later in this chapter, consideration of relevant information can appear to be even more important from the point of view of using resources in a way that is beneficial for reliable energy supply.

3.2.2 Acknowledgement of information

The information used as argumentation for hydropower project planning is based on expert assessment, often done by engineers that project implementing party has hired, and then due to purely engineering's perspective of the assessment expected costs of environmental preservation are low (McCormick 2007). This way it's possible that the assessments are just as comprehensive as the financier wants, and only reflect the facts that are in line with financier's interests. McCormick mentions that sometimes engineers flying over the river can be sufficient basis for report, and argues that indigenous peoples' knowledge should be treated as legitimate, because they are the only ones to know the real local effects of hydropower projects. In Brazil it is well known that those effects are likely to be significant, but because of mostly
informal characteristics of the knowledge about the effects, it only has a marginal change to make any difference. More or less biased valuation of information can be observable also when it comes to taking cognizance of international aspect. The government agency that represents Brazil in international forums guiding more sustainable use of water resources, such as World Commission on Dams, is left without effective means to participate in actual decision-making concerning hydropower sector's development (Sousa Júnior & Reid 2010).

Maybe institutional structures have not sufficiently promoted the consideration of different aspects, noting both that certain groups may have had disproportionate influence on decisions in relation to all affected sides and that arguments for certain projects can have been characterized by observation from seemingly narrow perspective. This can also have something to do with that climatic conditions are still not explicitly considered in national long-term energy planning. However, scientific publications are also used to assess environmental and social impacts, and some experts in cooperation with grassroots level actors have been able to achieve some, though relatively modest, recognition of the information which otherwise would not have been considered as legitimate in development project planning (McCormick 2007). So, if current academic discussion around Brazil's hydropower development reflects social preferences, considering it in decision-making could mean that more comprehensive perspective would be represented. Indication of this making a change is offered by a change in project implementation procedures in small-scale dimension of hydropower sector.

3.2.3 Evaluation of small-scale projects

Legislation and regulation guiding the development of small hydropower plant (SHP) network has moved in the direction of tighter environmental requirements and more comprehensive consideration of multiple use of water resources. New procedures have been introduced in order to increase project operator's responsibility of environmental compensation. For instance, to receive a license for an SHP more precise environmental assessment than required earlier must be submitted before a given deadline, after completion of which a compulsory cash deposit can be returned. Local citizens' voices have also been better heard, which has revealed SHP
implementation opposing atmosphere among them, because expected benefits are seen to be lower than costs to be beared by them. In addition to these factors limiting SHP network expansion new proposed requirements are making it less attractive to invest in project implementation, thus making the realization of the expansion projected in 2010-2019 energy plan provided by an organization involved in planning less likely. (Tiago Filho et al. 2011; Tiago Filho et al. 2012.)

SHP dimension of Brazil's hydropower sector can be seen as an example of how taking environmental and democratic aspects better into account can affect the operating environment in the sector through acknowledgement of today's realities. If there is an inconsistency between energy development planning and amount of actually feasible projects, alternative options to cover expected growth in energy demand need to be found. Referring again to Pao and Tsai, energy efficiency has not been highly prioritized, and combining this to institutional circumstances in electricity sector which haven't worked for efficiency either, it can be costly to the economy in a case finding those options turns out being problematic to an extent that it already induces electricity supply issues. More of the functioning of electricity markets and possible electricity supply issues in chapter 4. Noting that once ready the SHPs under construction in 2009 added to those in operation at that time account around half the total amount of hydropower plants, but less than 5% of the country's aggregate hydroelectric generation (Tiago Filho et al. 2011), the importance of accuracy in calculations from the viewpoint of avoiding electricity supply issues comes into play in more pronounced way when it comes to larger-scale projects. There can be quite a sharp contrast between implementation procedures of those projects and the direction in which SHP sector appears to be heading.

3.2.4 Current example of implementation of a large-scale project

Belo Monte hydropower complex (BMHC) in the Amazon, representing large-scale projects, planning of which this chapter has mainly dealt with, is probably the most controversial hydropower project under construction in Brazil at the moment. It's supposed to become the 3rd biggest dam in the world and its implementation process aptly demonstrates the contrast against those related to SHPs. The complex was first proposed in the 1970s, and in the late 1980s it was cancelled when its opponents
succeeded to lobby the World Bank to withdraw its funding for the project, but in the late 1990s the project returned onto government agenda with new design (Carvalho 2006). However, technical critique and a law suit halted the project again few years later (McCormick 2007). Then suddenly in 2005 the National Congress approved the construction of the dam again with virtually no debate (Fearnside 2006). In spite of all the opposition BMHC is still moving forward as some 20 000 workers are building the dam around the clock\(^5\), and it seems like the implementation is not going to be cancelled at this point.

BMHC's implementation's continuing has been possible partly because the main project executing company with its powerful support including a ministry, for example, has remained fairly isolated from outside pressure, so that ways to finance the project can have been found (Carvalho 2006). Eventually, Chinese and Brazilian aluminum industries have got interested in electricity produced by BMHC among other large-scale hydropower dams and possibly the multi-dam system planned to complement Belo Monte, all of which can be carried out more securely with help of foreign capital (Fearnside 2006; Bermann 2007; McCormick 2007). Based on Sousa Júnior & Reid's (2010) analysis, that underestimates social and environmental impacts due to lack of specific information, there is 72 % likelihood that BMHC results in negative net benefits assuming 50 years of operating. According to Sousa Júnior and Reid two large private construction companies didn't participate in Belo Monte public bid after addressing feasibility and environmental studies, and those who ended up in the project receive subsidized loans and tax exemptions worth billions of US dollars in total. Bermann and Carvalho also point out that there are more cost-efficient alternatives in providing the amount of energy expected to be provided by new large-scale hydropower projects. These standpoints signal that BMHC is implemented for a specific purpose that is not necessarily optimal for the whole economy in the long-run. This, in turn, can have happened as a result of political and other institutional processes with their consequences, about which in more detail in chapter 4.

3.2.5 Possible implications on growth potential

In sum, Brazil's hydropower sector development seems to have been going along with country's overall institutional development in that sense the economy as a whole may not have received attention in development planning that would have ensured optimal growth prospects for it in the long-run. However, growing awareness of hydropower projects' interrelations with different aspects may rationalize more comprehensive project evaluation, which may have been hampered by seemingly to some extent prevailing culture of detachment between public sector and the people. If planning and project implementation continue the same way as so far, environmental limitations can be transmitted to future long-term growth conditions in more accentuated way than in the past. Affecting this could be possible, if up-to-date evidence was used in order to make economic growth projections as realistic as possible, assuming that energy demand projections continue being based on them. If these projections, in turn, were as realistic as possible according to current knowledge, it could affect the conception of what kind of projects would be needed to meet expected energy demand. And if the interrelations with environment were considered in project evaluations as well, it could help in choosing investment alternatives that are more likely to be optimal for long-term growth conditions.

Indication of more comprehensive assessment's effects on realization of a current plan can already be found in SHP sector, thus revealing that adding some relevant aspects into planning could make a difference. The relative importance of SHPs, though, indicates that changes in their implementation only have a marginal impact on aggregate energy supply. Figure 2 demonstrates relative shares of hydropower plants of different scales in terms of total quantity and total power generation. The relative shares of micro (MHP), small (SHP) and large (LHP) hydropower plants are shown in the shades of grey from lightest to darkest respectively in the figure. As it can be seen in the figure the significance of what is done in SHP sector could be concretized mainly as a large amount of project experiences that could be made use of in more comprehensive consideration of relevant factors among larger projects, where true influences on growth prospects may occur. MHPs only account for 0.1% of the power generation (Tiago Filho et al. 2011).
3.3 Dependence on rainforest cover

3.3.1 Deforestation trend and its implications on river discharge and rainfall

Considering relatively recent evidence of deforestation's indirect effects on rainfall in relation to hydropower potential in energy development planning could make a difference in comparing cost efficiency of different actions in mitigating possible deforestation-related economic costs. Brazilian power grid is highly dependent on water availability for reliable energy generation, and thus uncertainty about future's hydrological conditions in areas considered to have high hydroelectric potential can cause remarkable challenges (Soito & Freitas 2011). Reduced rainforest cover can directly increase river flow regionally by leaving more water to rivers when less evapotranspiration through trees occurs (Nepstad et al. 1994). This has often been
taken into account in hydropower potential calculations unlike indirect effects of reduced rainfall resulting from decreased evapotranspiration, which in the long-run can be markedly more significant in terms of hydropower potential than the direct effects mentioned, if current trends in land use continue (Stickler et al. 2013).

Converting land to other uses, such as agriculture, is the main force behind deforestation in Brazil, that appears to be happening even faster than theoretically expected, and is partly a result of government's colonization programs (Aldrich et al. 2006). If the interaction between those programs and hydropower potential has been considered, it is more likely to have been done in the way of assuming that the potential would increase instead of decreasing, which highlights the importance of up-to-date information. Forests are cleared in remote frontiers, were land rents are low, by smallholders in order to reside and practice subsistence cultivation there, while large farm owners often tend to provide external resources for shorter period of cattle ranching, after which the land can be used for soy production, whose importance is increasing (Aldrich et al. 2006; Walker et al. 2000). Institutional factors such as government-promoted land-intensive way of doing business have been directing local economic life on the edge of the rainforests (Walker et al. 2000). In addition to that Mendes (2009) argues that information asymmetries between local and central government levels enables collusion between land owners and low rank officials leading to increased illegal deforestation.

Most of Brazil's remaining pristine rainforests and untapped hydropower potential are located in the Amazon. Therefore it's subject to intensive forest clearing and new infrastructure projects in relation to other regions. Removal of millions of square kilometers of forests that are endangered is likely to have climatic impacts that alter hydrological conditions in the region. Soares-Filho and others' (2006) conservative estimates of deforestation in the Amazon based on current trends state that more than 40 % of the region's total forest cover will be eliminated by 2050, and up to 85 % in some unprotected areas. These estimates focus on agriculture expansion and infrastructure construction such as highway paving, and only include already existing and planned highways. Logging and forest fires, that according to Nepstad and others (1999) may double the annual amount of deforestation in the Amazon, in addition to global warming related substitution of forests to other types of natural
landscape are excluded. According to Soares-Filho and others government's land use policy and questionable enforcement of insufficient formal preservation are important factors allowing current unsustainable land use trends to continue, though consumption habits in advanced countries also contribute to the issue. The effective change in those habits in favor of environment in developing countries has been modest so far, and more and more people around developing world are adopting similar habits. Hence, making Brazil's land use sustainable enough to prevent possibly remarkable negative impacts on hydrological conditions can be challenging and slow, and there would presumably have to be a change in the role of state too.

Figure 3 illustrates possible trend of deforestation in the Amazon basin. In pictures on top and bottom of the figure there are approximations of situation with no deforestation and the result of current trends of deforestation in 2050 respectively. In
these two pictures the Amazon basin is separately marked out and inside the outline darker grey represents rainforest area, lighter grey other natural landscapes and white is land used in agriculture. In the middle there is a picture based on NASA's satellite images showing the area of remaining rainforests in early 2000s. Forests are displayed in darker grey around the Amazon River that can be seen in white in the picture.

Figure 4 shows development on the edge of the Amazon. Each NASA satellite image in the figure covers the same area of tens of thousands of square kilometers, and the darker color indicates remaining and the lighter color cleared forests in years 2001, 2005 and 2010 from the top to the bottom respectively.

3.3.2 Reduced rainfall and hydropower potential

Costa and Foley (1997) find a strong dependence of evapotranspiration on vegetation cover, especially during rainy season. Spracklen and others (2012) estimate the resulting reduction of rainfall across the Amazon basin to be 12 % in rainy and 21 % in dry season by 2050 based on Soares-Filho and others' estimation of current trends of deforestation. Döll and Müller Schmied (2012) observe that climate change induced changes in river flow are relatively higher in locations where natural river discharge is significantly restricted by human actions than in rivers that are in natural state. Deforestation is a substantial contributor to CO$_2$ emissions that are the main factor in anthropogenic global warming. For instance, without preventing actions carbon emissions in the Amazon by 2050 may equal to several times current annual emissions worldwide (Soares-Filho et al. 2006). This is to say that climate change may amplify the effects of deforestation on river flow in Amazonian rivers with large hydropower dams.

Assuming 40 % deforestation in the Amazon basin, where controversial Belo Monte complex is being built, the reduction in river flow can cause even bigger reduction in hydropower potential. Stickler and others show in their study that in these assumed conditions BMHC's mean annual power generation potential is likely to be only 33-38 % of its maximum capacity, when official projections that don't include future deforestation assure minimum generation potential to be 40 % of the maximum.
According to the study monthly energy generation potential can be more than halved in 10 months a year even when global climate change induced expected lengthening of the dry season is not considered, and as a whole the total generation potential could decline almost 40% of what is projected.

Stickler and others also refer to that the Amazon is not the only region vulnerable to such issues related to hydropower potential. Despite better assessment required by tightened legislation almost half the SHPs monitored at least five years by authorities haven't been able to produce 80% of assured energy, including performances of just 13%, indicating that hydrology was overestimated (Tiago Filho et al. 2011). Bermann (2007) also points out that there are already other bigger hydropower plants that cannot run at their projected potential, of which operators accuse insufficient amounts of water. The issues in question seemingly occurring from small- to large-scale hydropower plants in different parts of the country makes the relevancy to include deforestation's indirect effects on hydropower potential in projections considering the whole hydroelectric sector more plausible, especially noting that the analyzes have been conservative. Stickler and others conclude that by regarding this that particular sector could have an incentive to use its considerable political influence to promote forest conservation.

Table 1 presents possible implications on Brazil's energy sector and economy, if current unsustainable land use ended up decreasing hydropower potential by 40%. Total annual hydroelectricity generation could drop by 170 TWh from 2011 value, which would account for more than 30% of total electricity generation in the country. This, in turn, could have substantial impact on productivity of businesses, or alternatively it could mean a need for several additional hydropower plants with capacity of BMHC. The presumable amount of those new plants required and thus the costs of dam construction and transmission investments in these estimates depend on that if reduced hydropower potential is taken into account in the project calculations or not. If it is, true costs of patching up the reduction might better be detected. For more details, see Appendix 1.
Brief calculation results in Table 1 are based on an assumption of hydropower potential being reduced by 40% immediately, which is presumably not the case yet. Still, any other costs than construction related ones, such as environmental and social costs, are not considered. And the absolute reduction of annual electricity generation may increase along new installed capacity, if it's implemented like so far, thereby also acting as a counterbalancing force in relation to the assumption. Altogether, intention is to roughly demonstrate how the use of up-to-date information might affect the conception of how public resources are used from the point of view of cost efficiency in a situation, where it can have real significance regarding climate-induced economic costs.

### 3.4 Other factors to be considered

In addition to depleting rainforest cover's impacts on hydropower potential there are other hydropower related factors possibly affecting long-term productivity in Brazil. Including them in development planning data may become more topical when more precise studies about their effects have been conducted, which can be expected to happen considering the growing awareness and concerns about those effects. However, this kind of scientific uncertainty should be already addressed with the principle of caution at all stages of hydropower development processes (Soito & Freitas 2011).
Less forest cover is associated with higher costs of water treatment by Reis (2012), which in the article is referred to water contamination that is evident especially in Sao Paulo region, where prioritizing the use of water resources for energy generation has resulted in that water must be supplied from outside the region, whose own abundant water reserves cannot be used by citizens anymore (Victorino 2012). People can be continually, and emphatically during repeated events of flooding, exposed to health risks, about which Pao and Tsai (2010) raise a concern as a negative externality lowering productivity in the long-run. Libscomb and others (2013) suspect that health was the only aspect of United Nations Human Development Index, in which there were no long-term gains in areas with access to hydropower due to worsened environmental quality following the implementation of hydropower plants. Stagnant water in reservoirs formed by dams that can easily get contaminated is a major factor behind the problem, and reservoirs themselves also cause several other kinds of environmental and social problems.

Population growth and people moving to new areas to work in dam constructions, for instance, tends to increase the amount of individuals affected by the projects (Soito & Freitas 2011). Amazonia is already an area, where tension over land tenure and access to natural resources have caused violence, like assassinations of local grassroots leaders, and growing migration is not about to ease the situation (Carvalho 2006). This is an example of possibly growing instability that makes areas in need of infrastructure investments less attractive from investors' point of view, which may eventually show in productivity.

The relevance of these matters for this study is mainly focused on the evaluation of results of the sensitivity analysis, in which they can't be assumed to be given as fixed by earlier studies. They may also act as productivity growth slowing factors in the long-run, which would make the distinction between their and reducing hydropower potential's effects on TFP growth more complicated.

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6 Human Development Index includes income, education and health.

7 See Bermann (2007) for more detailed description of these issues.
4 ELECTRICITY CONSUMPTION AND PRODUCTIVITY IN BRAZIL

4.1 Users of electricity and their contribution to GDP

Hydropower's share of final energy consumption in Brazil has tripled from 1970 to 2010. Main function of hydropower is electricity generation and of total energy consumption in the country hydroelectricity accounts nowadays for approximately 14%. Other forms of hydropower use, such as cooling buildings, are more or less parallel to electricity use, and when though that way hydropower is responsible for more than 90% of electricity and equivalent energy forms in total energy consumption. Agriculture sector's share of electricity and hydropower consumption is around 4%, while share of households is close to 24%. Transportation and energy sectors together only use less than 5% of the energy forms in question, leaving two thirds of total to the rest of service sector and industry that is the biggest consumer with almost 45% share of the total. This last mentioned part of service sector relies on electricity with nearly 90 per cent portion of its energy consumption, while industrial sector gets one fifth of its energy in the form of electricity. (EPE; Soito & Freitas 2011.)

Most of the industrial production is concentrated in large metropolitan regions, such as Sao Paulo and Rio de Janeiro, located in southeastern and southern parts of the country, where firms can benefit from positive externalities of agglomeration as well as technological change due to better scientific and educational infrastructure, and thereby also productivity gains and higher economic growth tend to concentrate there (Markusen & Diniz 2005). This has concretized, for instance, in that more than 80% of country's exports, that like earlier mentioned have recently been one of the engines of growth, are coming from those particular areas after liberalization of economic policies in the 1990s (Markusen & Diniz 2005). Again, most of the biggest companies operating in Brazil are located in these regions. Cravo and others (2012) argue that Brazil's institutional arrangements form an operational environment, in which it is difficult for small and medium-sized businesses to operate efficiently, and therefore their relative importance is negatively correlated with economic growth in manufacturing, commerce and services. Inversely, this refers to that large companies
are major contributors to growth, and thus also supports above-mentioned concentration of growth in the Southeast and South Brazil.

Largest firms consist mainly of energy companies, banks, telecommunication enterprises, retailers and wholesalers, and industrial conglomerates. Many of them, except the energy companies, fall either into the segment of industry or electricity relying services. Combining the estimates from Central Intelligence Agency's World Fact Book, World Bank and International Labour Organization indicates that industrial sector currently generates around 26-27 %, agriculture together with transportation and energy services roughly 12-13 % and the rest of the service sector the remainder of GDP. So, one can say that as a whole electricity is closely associated with more than half of production and additionally to lesser, but still significant extent to one fourth. Hence, electricity supply shocks can affect most parts of the economy that are effectively contributing to growth.

4.2 Effects of electricity supply shocks on productivity

Given the concentration of growth in south and most of untapped hydropower potential thousands of kilometers away in the Amazon, if that untapped potential must be utilized, power transmission inevitably comes into play. The partial privatization of electricity markets in the 1990s with institutional framework characterized by little experience in electricity regulation provided private firms incentives to use lower-quality materials and equipment in transmission lines, and increased fragmentation of transmission system, so that the functioning of it as a whole suffered (Gall 2002). The system had losses of 15 % of transported energy in mid-2000s that is two and a half times internationally acceptable level, achieving of which would induce remarkable energy savings (Carvalho 2006). Progress towards better efficiency, though, has not been made referring to that according to Empresa de Pesquisa Energética (EPE), a national energy research company, in 2010 distribution losses related to all hydropower and electricity consumption were more than 20 %. EIA statistics imply the same, though with a bit more optimistic figure. Just to mention, in addition to Carvalho Andrade and others as well as Pao and Tsai have raised up investments targeted in existing electricity transmission facilities as an option of developing the aggregate energy supply in the country. These investments
represent an example of alternatives that could turn out helping to mitigate climate-induced economic costs better than, for instance, building new large-scale dams in the Amazon, from where the energy produced would have to be transferred through existing system to the locations of consumption.

Public investments in new generating capacity that are not based on market incentives together with related subsidies lessen private incentives to invest in the long-run if similar support payments are not provided (Joskow 2008). Joskow notes that poorly implemented reform in Brazil also adds to the malfunctioning of electricity markets and makes politicians more cautious about trying to find new solutions to tackle market imperfections. Maybe this kind of institutional and political factors are somehow associated with the implementation of BMHC, dealt with in chapter 3. Anyhow, the current state of affairs implies that remarkable changes in the direction of electricity supply side development may not be happening soon. In the long-run that is possible, though whether the changes, that are sufficient to prevent electricity supply issues possibly affecting aggregate economy, will take place soon enough or not is uncertain. Decreasing hydropower potential by itself can be a threat and especially together with deteriorating transmission network it may increase the frequency of blackouts that have been an issue in Brazil.

Exact economic costs of blackouts can be difficult to evaluate and they depend on the extent and length of the blackouts, so that short ones happening more often tend to be more costly than longer ones that take place less often according to LaCommare and Eto (2006). Already earlier, when electricity as an energy source was probably not as important as today, some industrial firms in Brazil could lose at least a day's production because of an outage during peak hours of electricity consumption (Gall 2002). Some sort of other implication of the costs is available too. Fisher-Vanden and others (2012) opine that in China energy-intensive industrial producers might have responded to more frequent blackouts in early 2000s by substituting other inputs for energy, resulting in lower productivity due to higher production costs. Applicability of this to Brazilian economy may be limited mainly to relatively energy-intensive characteristics of production there, but lagging production efficiency compared to China also suggests that Brazilian companies could well face at least comparable issues in similar situations. Service sector is estimated being far more severely hit by
blackouts than manufacturing in the Netherlands (de Nooij et al. 2007). Like mentioned above, the importance of that particular sector for the economy is significant in Brazil too. Based on LaCommare and Eto's analysis\(^8\) annual costs of power interruptions to US electricity customers are 79 billion US dollars, business and industry's share of which is 98 %, and that is equivalent to 0.74 % of US GDP (World Bank) in 2001. In that same year Brazil experienced an electricity crisis because of a drought, and a temporary Energy Crisis Commission together with electricity consumers carried out a 20 % rationing of electricity use compared to previous year, obviously to prevent a worse-case scenario, thereby causing a corresponding reduction of 24 % in the consumers' projected income (Gall 2002). Altogether, electricity shortages can cause noteworthy costs to the economy, and in Brazil they would presumably be beared by sectors that generate most of economic growth.

One could think of improving reliability of electricity supply by importing energy from neighboring countries. Brazil has interconnections in electricity functions with neighboring countries and processes going on in order to establish agreements on new ones (Soito & Freitas 2011). Noting the concentration of electricity demand in the South and Southeast Brazil, there are considerable distances between those regions and the countries that could export electricity to Brazil if necessary. From those countries Paraguay and part of Argentina that are closest to Brazil's big metropolises are roughly thousand kilometers away from Sao Paulo, for instance, while countries like Peru and Venezuela are even further away than Brazilian Amazon. Due to the long distance that electricity has to be transferred through inefficient Brazilian system electricity market integration with neighbors alone may not overcome energy security issues in the long-run. Besides, it doesn't stop Amazon deforestation, and hydropower potential in the countries around Amazon may not completely escape from similar effects that the deforestation is about to cause in Brazil. According to U.S. Energy Information Administration hydropower accounts for around half of total electricity generation in Latin America excluding Brazil.

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\(^8\) Costs in the analysis according to the year 2001, measured in consumer price index weighted 2002 U.S. dollars.
Figure 5 displays where most of the biggest metropolitan areas and a major part of electricity consumption are concentrated in Brazil, and distances between the concentration and a city in the middle of the Amazon as well as neighboring countries.

Rising electricity prices constitute another way through which environmental challenges might be transmitted to productive activities in the form of higher input prices that depress productivity, when other things are left unchanged. For example, costs of building and maintaining excessively massive capacity considering

Figure 5. Location of 4 major cities in Brazil (Adapted from Gaffney 2010)
hydrological conditions must be covered somehow. Likely way of doing this is including the costs in the price of electricity, amount of which produced in relation to generation capacity is about to get gradually smaller and smaller. Balbina dam that has been operating in the Amazon since late 1980s provides nearby city of Manaus most expensive energy in the country due to its costs in relation to production, and it may not remain the only similar case with the current way of energy sector development (Victorino 2012).

Cardoso and Teles (2010) describe the rise in the oil prices caused by the oil shocks in the 1970s as a production tax that negatively affected Brazil's growth potential. According to the Oxford Latin American Economic History Database estimates industrial value added as a share of GPD was somewhat more than 30 % throughout the 1970s and early 1980s, being higher than currently. The share of energy derived from oil products in final energy consumption had, in turn, moved from around 38 % in 1970 to one half in 1980 (EPE). Recalling the shift from fossil fuels towards renewable electricity consumption, increased share of strongly on electricity relying service sector in GDP and considerable use of electricity in industry, reducing hydropower potential could possibly act in a similar way nowadays and in the future as did the price of oil earlier. That is with an assumption of that the ongoing long-term trend from industrialization towards service society is not going to be reversed. A difference, though, is that as an energy supply shock the nature of reducing hydropower potential would be long-, when in the case of oil shocks it was more like short- to medium-term.

The conception of electricity supply side issues having real significance regarding growth potential is indicated by current president's plan in 2012 to force electricity prices down by 20 % in order to boost the economy. Political manipulation of electricity prices in Brazil has happened earlier too, and the costs are eventually paid in taxes, directly in the form of high tax rates at electricity retail level or indirectly through inflation like in certain periods of 20th century Brazil (Gall 2002). This kind of state intervention probably just increases market distortions, and even though the recent policy would not contain public expenditures that would have to be paid in taxes, the disincentives it causes from the point of view of needed investments imply that the costs are just postponed into the future.
All things considered, reliable supply of reasonably priced electricity can play an important role in long-term economic development, and therefore a combination of different electricity supply shocks can affect it through productivity. Although physical and human capital as individual factors may be more important with respect to productivity, assuming that using capital requires electricity and that higher levels of human capital are partly associated with the knowledge of using this physical capital in the form of new technology, it means that these three factors are essentially interrelated. These two points, the conception and the assumption, seem to be applicable to relatively significant share of the Brazilian economy, that is reliant on foreign capital and know-how as well as hydroelectricity, to an extent of that environmental issues can be thought to slow TFP growth in the long-run unless remarkable institutional changes occur soon enough.
5 REFERENCE PROJECTION AND ITS MODELING

5.1 Reference projection

5.1.1 Introduction

The reference projection used in the sensitivity analysis of this study is forecast considering Brazil in Purushothaman and Wilson's (2006) gross-country growth projections in their paper Dreaming with BRICs: the path to 2050. BRIC-countries include Brazil, Russia, India and China, respectively, and South Africa has been added to the concept later, changing the name of it to BRICS. These countries have been seen possessing high economic growth potential compared to advanced industrial nations and their influence on world economy is likely to increase in coming decades. Thus, Purushothaman and Wilson's paper demonstrates possible world aggregate demand patterns in the future.

In addition to the theoretical growth potential BRICS-countries don't have much in common. The whole concept was introduced mainly in order to advertise the countries to large institutional investors (Bell 2011). Formal interaction between the countries within the concept has been more or less rhetorical. For instance, BRICS Development Bank, that in principle is supposed to compensate the lack of corresponding authority in IMF and the World Bank that these countries' relative share in the world economy could already represent, reflects this kind of interaction between political leaders that is observable in international media. The implementation of proposed bank faces such challenges related to heterogeneity of the countries and most of their interests that very little of concrete product, in terms of how the bank would actualize infrastructure projects among other affairs on its agenda, has come up in the meetings. Still, most of BRICS are in need of foreign investments, so an international forum promoting them seems to have been an attractive option.

Investing point of view is apparent in Purushothaman and Wilson's paper. The authors worked as economists in an investment bank Goldman Sachs to write the
paper as a product of the bank's research unit, and it was published in a book compiled by a professor of international marketing, who was also representing an institute funded by a large multinational corporation. This perspective may lack the recognition of comprehensive evaluation of possible factors and related development issues affecting growth prospects, and it's said in the article that the countries face significant, mainly political, challenges in meeting the growth projections. In Brazil's case this is highlighted because of lower than expected growth performance in recent decades and existing obstacles to sustained growth. Macro level stability, appropriate institutions, growth promoting public policies, the amount of external debt in relation to the size of export sector and other structural features of the economy are emphasized, all of which can be important from investor's point of view. Environmental issues, that may already affect business profitability in Brazil as well, however, are only mentioned without any further addressing last in the list of additional possible growth constraints in Kedia and others' (2006) complementing article that takes a closer look at earlier and expected growth slowing factors. Energy security as itself does not receive any attention.

Although the reference projection relies on heavy assumptions in meeting the projected growth, the Brazilian government's Ten-Year National Energy Plan for years 2010-2019 assumes slightly more optimistic growth according to Andrade and others (2012). The plan's assumptions regarding economic environment include more of different possibly growth limiting aspects than those of the reference projection, but maybe the assessment of each individual factor has been more superficial and/or the interrelations between different factors has not been taken into account sufficiently. Purushothaman and Wilson compare their results to IMF's assumptions of potential growth at that time and run another projection using the method of Levine and Renelt's (1992) econometric model, with former of which the reference projection is about in line, but to some extent more optimistic than the latter. Though IMF has recently adjusted expectations about Brazil's growth downward, still providing similar growth potential forecasts as assumed in electricity sector development planning the reference projection fits in the context of this study.
5.1.2 Context and assumptions

The development of BRICs in the reference projection is reflected from long-term estimates of G6, a group of industrial countries including United States, United Kingdom, Germany, France, Italy and Japan. BRICs' growth potential is derived from growth in employment and capital stock, and catch up process with the developed world in terms of productivity growth. The U.S. Census Bureau projections are used with the first and historical data about investment rates with the second factor. Third one comes from lower initial capital per labor unit levels, meaning higher return on capital, that lead to increasing capital stock, and availability of latest technology from advanced countries, thus decreasing productivity gap. The focus of the projection is on potential growth and therefore economic cycles are ignored, as is also inflation by measuring change in real terms using 2003 U.S. dollars and 2003 local currency. More or less standard simplification by excluding economic cycles is reasonable considering the difficulty of predicting them, especially in developing world. This is evident, for example, in Purushothaman and Wilson's own comparison between actual trend growth from 1960 to 2000 and corresponding one derived with the method used in their future projections. In the comparison realized and projected growth rates differed from each other more in the case of developing than developed economies.

Changing the assumed trends of the factors behind Brazil's growth potential in the reference projection could alter the results because favorable political and other conditions are so essential for the potential to be realized. Changing working population growth rate from U.S. Census Bureau's estimates would require further evaluation of Brazil's employment policies, among other possible determinants of labor market participation, that can be hard to predict in the long-run, and which is not meaningful considering this study. Brazil's case in the reference projection has been observed from structural perspective by Nazmi and Revilla (2011). They study determinants of relatively low levels of investment in the country and point out what could be done regarding economic and trade policies to make the use of production factors more efficient. Albeit alone without broader institutional change these policies are not necessarily enough to provide economic incentives that through investments enable sustained long-term growth rates of the reference projection,
investment rates remaining at historical levels in Brazil can be assumed to be given for this study like in the reference projection.

Pao and Tsai (2010), in turn, discuss energy efficiency's role in ensuring the potential long-term growth in the reference projection. They argue that after a shock hitting the economy adjustments back to long-term equilibrium happen through energy consumption, thereby clarifying energy security as a factor of sustained TFP growth from energy efficiency's point of view. Their paper together with Nazmi and Revilla's also justify the assumption of investments taking place where they are needed to overcome growth limiting infrastructure conditions by 2020, although it may be a bit optimistic to assume so minding the electricity infrastructure, for example. Low levels of education similarly fixed by the same year is taken as given for simplicity in this study. Assuming these dimensions of development to be like they are in the reference projection, with these arguments, the impacts of slower TFP growth in the projections of this study can better reflect the significance of falling hydropower potential.

5.2 Structure of the growth model and its assumptions

The growth model used to generate the reference projection is an application of Cobb-Douglas production function. It assumes GDP \((Y)\) to be a function of labor \((L)\), capital stock \((K)\) and total factor productivity \((A)\) in the following fashion:

\[
Y = AK^\alpha L^{1-\alpha},
\]  

(1)

where \(\alpha\) denotes capital's share of income. The value of \(\alpha\) is assumed to be 1/3. That assumption may better apply to advanced countries, where labor rights are better enforced and labor markets as well as other institutional arrangements more developed in the sense of not letting capital owners to make profit at the expense of cheap labor to same extent as in less developed countries. According to United Nations Trade and Development Report (2012) the income share of capital in Brazil has been close to 50 % from the beginning of the 1990s until the start of recent global economic crisis. Whether or not the model incorporates the effects of functional income distribution onto growth as it really happens in Brazil is not
directly an issue for this study’s analysis. On the other hand, most of capital income is often earned by higher income groups, especially in countries with high income inequalities, like Brazil. And lower income groups, in turn, easily tend to have higher marginal propensity to consume, so higher labor’s share of aggregate income could mean higher aggregate demand. Besides, relatively low investment rates in Brazil don’t indicate that all income left after consumption would necessarily be invested in growth-enhancing productive capital. Therefore the assumed value of $\alpha$ might act in a way of making growth prospects more optimistic than what reality would imply, if it makes a difference in the model.

Change in $L$ over the years is based on U.S. Census Bureau's projections as mentioned earlier. The variables of the growth in $K$ are investment rate $(I / Y)$ as a share of GDP and a depreciation rate $\delta$. The development of $K$ is expressed in an equation:

$$K_{t+1} = K_t(1 - \delta) + \left(\frac{I}{Y_t}\right)Y_t.$$ (2)

Investment rate is 19% for Brazil. Growth in capital stock over time resulting from this given rate is simply based on assumption of higher return on capital that comes from lower capital per worker level in relation to advanced countries. The process itself is not described more explicitly, so that, for example, real interest rate would be brought into play to determine required marginal rate of return on capital, as it could be done in this model that fits the framework of neoclassical Solow growth model and its extensions. The level of investments is not tied solely to domestic savings, even though it's measured in terms of domestic GDP. Thereby it can be thought to allow also foreign investments in the spirit of the BRICS concept, but any specific assumptions regarding domestic or foreign contribution to the level of investments are not made. The depreciation rate is 4% as in the World Bank capital stock estimates. These types of depreciation rate estimates have been based on analyzing service lives of capital goods and their shares in gross domestic fixed investments due to lack of developing country data (Nehru & Dhareshwar 1993). This also makes the difficulty of forecasting developing country progress evident.
Change in $A$, that is convergence-based TFP growth or in other words technical progress, depends largely on income per capita level ($y$), so that the bigger the gap between two countries faster the convergence. The U.S. acts as a country to which each developing country (DC) is related in that matter, and therefore both income levels are in 2003 U.S. dollars. The process of TFP growth obeys the following pattern:

$$\frac{A_t}{A_{t-1}} = 0.013 - \beta \ln \left( \frac{y_{DC}^{t-1}}{y_{US}^{t-1}} \right),$$  \tag{3}

where $\beta$, that is the given speed of convergence, is in addition to the per capita income level gap is determining the level of TFP growth. The value of $\beta$ can be altered in order to test how different factors affecting TFP may influence economic growth. This is how the sensitivity analysis in this study is conducted, based on the assumption of that electricity supply issues will have negative impact on TFP growth. Assumed long-term U.S. TFP growth is 0.013 to which the convergence factor is added, as the natural logarithm of a figure within the range of [0,1] is negative, thereby reversing the negative sign in front of $\beta$.

Growth rates in U.S. dollars are converted into growth rates in local currency with an exchange rate model assuming that equilibrium real exchange rates in the long-run are determined only by productivity differences and that the exchange rates change in proportion with productivity convergence. Thereby exchange rate appreciation is determined by the difference between labor productivity growth rates in a developing country and the U.S. The former is derived from levels of GDP and employment in the developing country, and the latter is assumed to be constant 2%.

Though according to the model developing economies are not in such a steady state in which growth would only depend on the progress in TFP, it is still given relatively lot of weight in the context of emerging economies catching up with advanced countries. This is because, especially in Brazil's case, the growth in employment is expected to be comparatively modest in the long-run.\footnote{See Purushothaman & Wilson (2006): Figure 1.11, page 16, Figure 1.13, page 21.} Increases in capital per labor unit ratio are also constrained to some extent, if investment rate remains low.
Besides, Brazil's per capita income level is significantly lower than the level in the U.S. This emphasizes assumed convergence between these two countries. Big role of TFP growth can, to certain extent, be thought to reflect the assumption of it being important in today's economic growth. In development stage classification of the World Economic Forum (2010) Brazil ranks in transition from efficiency driven to innovation driven stage, in which factor productivity plays more important role in economic growth compared to earlier stages.

The assumption of TFP convergence is so simplified that its realization is subject to several uncertainties, which are related to the strong dependence of Purushothaman and Wilson's (2006) growth projections on structural and institutional factors. In that sense during the first years of the reference projection, before the recent global economic crisis other types of convergence between BRICs and G6 than the one of economic freedom were to be seen possibly later, and the crisis could trigger some sort of additional protectionism, thus slowing the convergence already started to occur (Bell 2011). If the preconditions for income growth differ, the convergence in per capita income levels may also differ from predicted. And this is just one example that highlights the role of different assumptions in realization of growth projected in the reference projection.

The U.S. is probably the most robust benchmark economy to compare other countries with, because of existing research in relevant fields, even though all the assumptions based on the U.S. economy may not apply to less developed countries with same accuracy. Since real growth rates with respect to local purchasing power matter, converting growth in U.S. dollars to local currency is necessary because of assumed income growth that is faster in BRICs than in the U.S. If Purushothaman and Wilson's own estimates of 129 % appreciation of Brazilian real against U.S. dollar by 2050 happens, it will make a difference between growth rates measured in those two different currencies respectively.

As a whole the reference projection can be considered being mainly indicative, and therefore the simplicity of the sensitivity analysis is also justified. As simple as the analysis is, it can still be seen demonstrating how taking additional aspects into account can make a difference.
6 ANALYSIS

6.1 Changing different factors in the projection

In the reference projection Purushothaman and Wilson (2006) use slower speed of TFP convergence for Brazil until the year 2020 due to lower levels of education and poor infrastructure. After that the value of $\beta$ is assumed to be 1.5. With the growth model in use that means one and a half times the natural logarithm of Brazilian per capita income divided by corresponding level in the U.S. in percentage points of annual TFP growth rate difference. As indicated earlier lowering that particular value of $\beta$ results in slower TFP growth, and in this sensitivity analysis it is done due to the assumed electricity supply issues caused by lower than expected hydropower provision in order to generate alternative long-term growth projections for years 2020-2050. The starting year 2020 allows assumed policy changes supposed to be needed to take place and possible economic crisis caused protectionism to break away. Assuming that the Ten-Year National Energy Plan for years 2010-2019 is not going to be replaced by another one before expiring, next plan starts from the year 2020. The next plan may include large-scale energy sector development projects following Belo Monte complex that is expected to be ready in 2019.10

The analysis starts with the income levels of 2020 in the reference projection, so that the initial relative weight of TFP convergence is not changed. Given all other growth trends and parameter values, except $\beta$ and thus TFP growth, that are not changed from what they are in the reference projection, convergence's importance increases with lower projected Brazilian GDP levels in relation to the U.S. On the other hand, slower convergence speed works in the opposite direction in one sense, because the relative share of other factors in generating growth presumably increases. That kind of opposition between the effects of slowed TFP growth-induced changes in different factors also appears with capital stock growth and conversion of U.S. dollar growth rates into rates in local currency. Since capital stock grows according to

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10 Constructor estimates according to The Economist. May 4th, 2013.
investment rate that is a fixed share of GDP, lower GDP levels would also slow capital stock growth and again that way slow GDP growth as well. The difference between growth rates measured in different currencies, in turn, is affected by lower productivity growth in Brazil so that its currency appreciates less against U.S. dollar, which in this case would mean higher growth in local standards. Altogether the talk is about effects whose significance would be very slight, because they are combinations of already marginal changes. Therefore they are not taken into account, which is done by using the given trends. Considering an indicative nature of the sensitivity analysis this simplification can be done confidently. On the other hand, though, it's interesting to notice how changing value of a single parameter affects several other variables too already in this kind of relatively simple model, a simplification of the growth process in real world.

Constant reductions in the value of $\beta$ in the analysis are first used to demonstrate possible scale of reduced TFP growth's impacts. Then reductions are changed to happen gradually, so that also gradually depleting rainforest cover's influence would be better reflected, assuming that discounting environment's value continues as it has been so far. Calculating alternative projections is done by trying different values of $\beta$ because estimating an exact reduction based on electricity's actual contribution to TFP might require extensively complicated examination in relation to the amount of other factors that depend on assumptions in the reference projection.

### 6.2 Breaking down the growth

The growth in the model that is used comes from the multiplication of growth in TFP, capital stock and employment. Before altering the speed of TFP convergence changes in all these factors are derived from estimates of the reference projection. All the information needed to do that is provided in the form of time series and figures by Purushothaman and Wilson's article. First, dividing projected GDP by GDP/capita gives total population, multiplying which by estimated share of working age population gives the number of workforce for each year. The share of working age population is taken from Figure 1.11 in Purushothaman and Wilson's article. The share is projected to decline steadily all the way from 2020 to 2050, and when combined with relatively modest projected changes in total population over the years
the contribution of employment growth to GDP growth turns out being minor in relation to other factors. Therefore taking the share that way is accurate enough, so that final results of the sensitivity analysis are not biased because of that. Original TFP growth can be calculated with its own formula, and thereby knowing it in addition to employment levels and annual GDP growth the change in capital stock can be calculated for each year. That is, dividing GDP growth by the change in TFP and employment, applying the format of equation (1) in chapter 5 in the following way:

\[ \Delta Y = \Delta A \times \Delta K \times \Delta L, \]  

which gives the change in any single factor, once the change in all other factors is known. This way growth in capital stock and employment can be taken as given in the analysis.

Calculating trends in growth generating factors this way reveals that Brazilian total population is projected to grow at decelerating speed until mid-2040s after which it stays roughly constant until the end of the time span of the analysis. The decreasing share of working age population, however, is projected to offset the effect of the increase in total population, so that annual growth in employment averages about a quarter of percentage negative for the whole analysis period. Annual capital stock growth is predicted to increase quite steadily from less than one per cent in early 2020s to somewhat more than two per cent in late 2040s, while TFP growth is gradually slowing along assumed convergence all the way from 2020 to 2050, but its growth rate still clearly exceeds those of other factors every year. Hence, according to the reference projection Brazil is expected to experience more or less similar development as many of advanced countries; declining section of population is about to be responsible for well-being of the whole society, and thereby their productivity plays a crucial role when it comes to economic growth.

6.3 Alternative projections

Once the changes in factors determining growth are known the speed of TFP convergence can be slowed in order to make alternative projections. Equation (3)
from chapter 5 comes into play at this point, but as new values for TFP growth calculated with it are just multiplied with given values of growth in other factors in the way indicated by equation (1), there is no need to use equation (2). Conducting the sensitivity analysis this way is possible, since the focus is on growth rates, and therefore exact value of capital stock does not have to be known.

Constant reductions in $\beta$ differentiating from its value in the reference projection and each other by 0,1 percentage point, so that the value of $\beta$ is between 1,4-1,1, are respectively equal to 0,2-0,8 percentage point reductions in TFP growth rate compared to the initial value of $\beta = 1,5$. With assumed speed of convergence it means 4,6-18,8 % slower TFP growth in the beginning, from which over time that particular difference gets halved by the end as the convergence process goes on. In the projection with $\beta$ reducing gradually from 1,3 to 1,0 the slowdown in TFP growth starts from 9,4 % and ends up being 14,7 % in the last year of analysis period. Lower value of $\beta$ in a given period lowers GDP in the next period and thus also GDP/capita level which in its part determines the level of TFP growth in that period, though difference the change in the latter variable makes is rather marginal.

U.S. dollar growth rates of alternative projections are converted into growth rates in local currency (BRL) by using following equation of projections:

$$\frac{USD^R}{BRL^R} = \frac{USD^A}{BRL^A},$$

rearranging of which gives:

$$BRL^A = \frac{USD^A \ast BRL^R}{USD^R},$$

where superscript R refers to the reference and A to alternative projections. This conversion means taking currency appreciation as it is in the reference projection.
6.4 Results

According to the reference projection the Brazilian economy grows at moderately accelerating rate throughout the 2020s. In the 2030s the annual growth rate peaks at almost 4 %, staying at that level for the first half of the decade, after which it starts to slow down incrementally. The alternative projections with constant reductions in $\beta$, in turn, yield slower annual growth rates all the way from 2020 to 2050, the difference between them and the reference projection varying from a few tenths of a percentage point to almost one in the first years of the analysis period. Then the difference gradually gets smaller along the convergence process and increasingly positive growth in capital stock over time. This is a result of the equilibrium in which developing economies are assumed to be, and where capital stock growth together with TFP growth contribute the most to GDP growth. In the end the difference is very small with smaller reductions in $\beta$ and less than half a percentage point with the biggest slowing in the speed of TFP convergence.

Figure 6 displays progression of above-mentioned projections. On the X-axis there are years within the time span of the analysis, and corresponding real economic growth rates in local standards, measured in percentages on the Y-axis. Highest line in the figure represents the reference projection and lines below it indicate alternative growth rates based on slower TFP growth respectively according to the value of $\beta$. 
Figure 6. Projected real growth rates including constant reductions in speed of TFP convergence (Sources: own calculations, Purushothaman & Wilson 2006)

Figure 7. Projected real growth rates including gradually reduced speed of TFP convergence (Sources: own calculations, Purushothaman & Wilson 2006)
Unlike other alternative projections the one with gradual reductions in the speed of TFP convergence results in more or less constant difference of close to half a percentage point in the growth rates in relation to the reference projection, when the influence of continually slowing TFP growth offsets the gains in capital stock growth as time goes by. That is shown in the Figure 7 similarly as in the previous figure; line of the reference projection being above the alternative one. Again, there is time on the X- and the percentage growth rate on the Y-axis.

Table 2 presents projected 5-year average growth rates in the course of analysis period. Each 5-year sub-period is in the first column from the left, followed by projected average percentage growth rates according to the reference projection, alternative projections with constant and then with gradual reductions in the value of $\beta$ towards right respectively. As it can be seen in the table, modest slowing of TFP growth generates growth rates very close to the ones in the reference projection. Bigger as well as gradual reductions, in turn, already show remarkable differences.

<table>
<thead>
<tr>
<th>Years</th>
<th>Reference</th>
<th>$\beta = [1,4;1,1]$</th>
<th>$\beta = [1,3;1,0]$</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020-2025</td>
<td>3,7</td>
<td>3,5 – 3,0</td>
<td>3,3</td>
</tr>
<tr>
<td>2025-2030</td>
<td>3,8</td>
<td>3,7 – 3,1</td>
<td>3,4</td>
</tr>
<tr>
<td>2030-2035</td>
<td>3,9</td>
<td>3,8 – 3,3</td>
<td>3,4</td>
</tr>
<tr>
<td>2035-2040</td>
<td>3,8</td>
<td>3,6 – 3,3</td>
<td>3,3</td>
</tr>
<tr>
<td>2040-2045</td>
<td>3,6</td>
<td>3,4 – 3,1</td>
<td>3,1</td>
</tr>
<tr>
<td>2045-2050</td>
<td>3,4</td>
<td>3,3 – 3,0</td>
<td>2,9</td>
</tr>
</tbody>
</table>

Table 2. Projected 5-year average real growth rates
(Sources: own calculations, Purushothaman & Wilson 2006)

6.5 Discussion

The sensitivity analysis was not based on electricity being responsible for a certain proportion of TFP that would have been known exactly. Therefore the results are only indicative. Threat of reducing hydropower potential negatively affecting long-term growth, if current state of institutional and structural conditions in the economy
prevail also in the future, has been made evident in other parts of this study, so the role of the sensitivity analysis is mainly to demonstrate possible scale of its impact. Development in the mentioned conditions can alter magnitude of the threat, and thus results derived using constant reductions in the value of $\beta$ could be parallel to how institutional development in Brazil in its part determines realization of growth potential of the country. Instead of assumed growth potential, that has been derived with insufficient evaluation of environmental and energy security issues, potential growth rates might be, for example, somewhere between the highest and the lowest line drawn in the Figure 6 depending on how institutions direct behavior of economic agents towards preserving rainforest cover, assuming that at least some development in that sense occurs. Alternative projection with gradually lowering value of $\beta$, in turn, could represent an example of how growth potential may be reduced if there is no institutional development in that particular sense and the depletion of the rainforest cover continues like so far.

Reasoning for simplicity of the sensitivity analysis comes from the reliance on heavy assumptions and non-comprehensive consideration of different aspects that characterize the reference projection, but it inevitably leaves remarkable uncertainty in the results of the analysis. Given the assumptions made in the analysis, choice of development in the value of $\beta$, that is not based on any exact estimation in the projection with gradually reducing $\beta$, it naturally means that there is no guarantee that the difference in the growth rates displayed in the Figure 7 could not be smaller. This is not an issue with the other set of alternative projections. On the other hand the difference can be larger as well, which is the case in both types of alternative projections. It may be so that the loss of rainforests turns out being greater than expected resulting in even lower hydropower potential, and social instability and health risks associated with effects of hydropower projects on people's livelihood and deteriorating water quality in addition to other uncertain environmental and social costs will have their negative impact on TFP growth.

Hence, these uncertainties also make it more complicated to evaluate appropriateness of the reductions in $\beta$ behind the analysis results. Still, the results can be seen indicating that there is a threat of economic growth rates being lower than assumed in the reference projection or similarly in current energy demand growth forecasts.
due to environmental issues negatively affecting TFP. Thus the analysis reaches its main objective by complementing other arguments, which it also does considering the relevance of taking these issues into account in development planning. Therefore need for the exact appropriateness of the reductions is not that binding. Assumptions related to the analysis also have their impact on the order of reasonableness of the reductions in the way that leaving room for them not to be fully realized makes the reductions more conservative.

Assuming that different economic policies enable sufficient level and growth potential optimizing composition of investments, like in the analysis, conditions in the sense of being able to mitigate the effects of environmental issues on economic growth would apparently be better than otherwise. In that case relevance of including these issues in different growth as well as project calculations could be related to efficiency of resource use. The Ten Year National Energy Plan assumes energy demand to grow faster than in proportion to economic growth, so the impact of lower rates in the latter would presumably be no less-significant in the forecasts of the former, when other things left unchanged. Whether those lower rates would make a real difference in hydropower sector development planning or not, though, probably also depends on how much attention these issues receive and how they are included in growth forecasting. But, for instance, if the situation is like that reducing hydropower potential is not considered and therefore over-optimistic growth projections direct the implementation of new generation capacity so that actual energy demand growth is covered with "suitably excessive" capacity that provides enough energy in lower than estimated stage of hydrological conditions, there is an obvious possibility to make the use of resources more efficient.

When public resources are involved, more efficient use of them could at its best change the conception of how public institutions serve social preferences, thereby promoting broader institutional change, just about what Stickler and others' conclusion in the case of politically powerful hydropower sector could be seen referring to. Chang (2002) argues that public institutions including the state can also constitute individual motivations instead of just constraining behavior, as it is commonly seen in neo-liberal view that emphasizes individual's logical and temporal position ahead of public institutions. Thus, according to Chang neo-liberal discourse
has shortcomings in its view of mutual interrelations between markets, the state and politics. Brazil has been subject to pressure of adopting neo-liberal policies that advocate minimum role of state after the early 80s' debt crisis, and since then country's average growth has been below its potential, indicating that perhaps some essential interrelations have been undetected. In the Brazilian context, though, change towards more active role of the state may be difficult because of historical reasons that have made it hard for people to trust in public institutions.

One currently ongoing process offers a chance to observe how the state altering institutional circumstances could make above-mentioned change. Olympic Games 2016 are going to take place in Rio de Janeiro, and slums of the city have become subject to intentions to, for example, make the streets safer. The slums can be seen reflecting Brazilian history of institutional arrangements in that sense the government has for long been largely absent from these areas and unofficial institutional structures have evolved instead, which has been concretized so that different criminal groups have attained a strong position in controlling people's everyday life. And now the police is replacing them in taking control. Gaffney (2010) and Freeman (2012) claim that this process represents neo-liberal way of state facilitating private capital accumulation in areas that have new market potential, but whose residents' view is excluded from the process implementation. If it is so, to trust in public institutions is not likely to be any easier for people in general, though that also depends on the role the state takes after the sport event, which remains yet to be seen. Anyhow, the process can provide relevant indication of economic effects of state-led institutional change, which has to start from somewhere, like people's conception of the functioning of their public institutions, for example, if it is about to happen.

The role of the state is presumably important also if the assumptions made on investments are not realized. In that case ability of different economic actors to adapt to changing environmental conditions is presumably inferior, and thereby impacts of issues in electricity provision may turn out being more challenging. Then the acknowledgement of environmental limitations on hydropower potential is probably more urgent than possible fine-tuning of the system that may come into play at higher stages of institutional development. Thereby the conception of those possibly more optimal types of investments for growth, mentioned in earlier chapters, could
help in finding alternatives that could improve the resilience of the system against these issues. One could think this to be achieved most effectively in cooperation between public and private sectors. Hence in sum, the role and importance of taking reducing hydropower potential into account in all relevant aspects of energy sector development is obviously linked to the level of institutional development. And it can be reasonable to do so at all of those levels as far as the main factor behind reducing hydropower potential is effective.
7 CONCLUSIONS

This study has taken a look at how environmental limitations may affect long-term economic growth through hydropower sector development in Brazil. The country has a long history of significant foreign influence on its institutional development. In one sense it seems to have resulted in lack of state playing pro-development role that would be optimal from whole society's perspective, which has obviously been seen in people's attitudes towards authorities in a negative way. Different institutional settings, shaped largely by the state, have been a major factor determining economic processes and thereby affecting the quality and rates of growth, to which also hydropower has been contributing from the early days of industrialization. Hydropower sector development has exhibited characteristics being such as to easily turn public opinion against public sector institutions in addition to lacking comprehensive evaluation of different relevant aspects, which may consequently affect long-term development of the country.

Brazil's institutional framework in general is apparently not promoting sustainable use of land resources sufficiently, which is being concretized in extensive loss of rainforest cover. Correspondingly, in hydropower sector preparedness to face decreasing rainforest cover's negative effects on hydropower potential could be managed better. If current state of these affairs persists, Brazil's long-term economic growth rates may turn out being at lower than their potential level due to electricity supply issues negatively affecting TFP growth, assuming that TFP is going to play an essential role in growth like before and indicated by country's current development level. Future growth being possibly lower than potential was illustrated by sensitivity analysis done to a growth projection that leaves some aspects potentially affecting growth out of consideration, and generates similar growth rates as currently assumed in official energy development planning.

The state is in a crucial position when mitigating the threat to long-term economic growth caused by environmental issues. It has the means to affect behavior of economic actors. To begin with, enforcement of relevant laws is important in preventing unwanted activities. This requires presence, instead of historically typical
absence, in areas where those activities are suspected to occur, and effective flow of information as well as cooperation between local and higher level authorities. These alone, though, are likely to be either insufficient or so costly that achieving results, that would make a real difference to preconditions for sustained long-term growth potential, could be more efficient with a combination of different actions. Therefore providing incentives to more sustainable land use, such as promoting alternative ways to make a living from forests rather than clearing them, as brought up in Stern review, could complement those other efforts. Private institutions alone presumably have more limited ability to alter prevailing circumstances, to which in Brazil they traditionally have more like had to adapt, so active state involvement is also of the essence.

This kind of institutional change towards more cooperative operational environment between private and public sectors may, however, be challenging and slow considering the long history of trust in public institutions being an issue. And this, in turn, may still be upheld by internationally prevailing neo-liberal political economy that seems not to foster sufficient consideration of all relevant development aspects and their interrelations. Hence, from state-led institutional point of view the occurrence of sufficient changes to prevent environmental limitations negatively affecting long-term growth is uncertain. In that sense this study does not address other factors, such as corruption or impact of growing middle class on demands regarding public policies, that may also have their role in the process. However, acknowledgement of environmental limitations and consideration of them in hydropower development planning could help adapting to changing environmental conditions by affecting efficiency of resource use, and also provide a rationale to pursue mentioned kind of institutional change, probably depending on the attention that approaching issues this way receives.

By combining different aspects of development into a broader perspective this study contributes to earlier findings about that environmental limitations can have economic costs at some point. Observing the issue in a specific country context a possibility of deforestation inducing those costs also through another channel than increasing carbon dioxide content in the atmosphere is detected. Findings of this study are also in line with the conception of that the costs can be greater in the long-
run, if less effort directed by public institutions is made in order to take care of related issues in a shorter time span, even though denoting the threat of it to be evident does not mean unambiguous causality. Because of geographical, historical and institutional characteristics of chosen country context the findings can hardly be generalized, but they can help understanding that development process comes fundamentally from within local circumstances, considering of which is crucial when designing policies to tackle issues in the process.

A potential topic for further study could be related to state-led operations that break well-established institutional patterns, such as in Rio. Information about how a given role of state functions in these operations could be gathered through a survey in which local people would be asked about how they think the state affects their everyday life, for example, after the Olympic Games. And this information, in turn, could turn out to be relevant from the point of view of broader institutional change that can affect Brazil’s growth potential or realization of it, when compared to earlier studies in order to find out what kind of progress in people’s attitudes towards public institutions would have occurred.
REFERENCES


http://earthobservatory.nasa.gov/IOTD/view.php?id=4385 (retrieved on 17 Dec 2013)


APPENDICES

Appendix 1.

Figures in Table 1 obtained as follow:

Reduction in total annual hydroelectricity generation, 170 TWh, calculated from total of 424 TWh hydroelectricity generated in 2011 (EIA) using average annual generation per GW of installed capacity derived from 2009 values of hydroelectricity produced with existing capacity (Soito & Freitas 2011), and assuming 40 % reduction in the capacity.

Share of total electricity generation, 32 %, from the assumption of hydroelectricity's share of total electricity production being 80 % (EIA).

Times of annual electricity generation of BMHC, 3 and 5, calculated from estimated reduction in total generation, 170 TWh, divided by projected capacity of the complex, 11 GW (Sousa Júnior and Reid 2010), times calculated average annual generation, assuming full and 40 reduced generation capacity respectively. Figures are approximated to integers.

Possible costs estimated using USD 15 billion per complex from the range of professional estimates up to USD 17 billion, mentioned by Sousa Júnior and Reid (2010).