Analyzing the Brazilian Higher Education System using System Dynamics

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Abstract

Higher education in Brazil has experienced a rapid expansion since the publication of the Directives and Bases Law (LDB) in 1996 and the pliability of the Government for the launching of new programs and educational institutions, mainly driven by the private sector. Despite this expansion, Brazil has not yet reached the aim expected in the Education National Plan: 30% of young people from 18 to 24 years old in higher education in 2010. Moreover, the demand for undergraduate programs presents signs of retraction, characterizing a system with fast initial growth followed by stagnation. This work proposes to understand the dynamics of this system by developing a model in System Dynamics, analyzing the undergraduate higher education. The model considers regulation, aims, demand, supply and especially the balance between public and private sectors. The methodology consists in the stages of problem definition, formulation of the dynamic hypothesis, development of the simulation model and in the validation and scenario testing. This step resulted in an analysis of alternative scenarios for the Brazilian undergraduate higher education. As a result, this model allows one to analyze the possible behavior of key variables in each scenario and to make observations on the variables that are not defined in the real system.

Key words: System Dynamics, Modelling, Higher Education, Brazil.

1. Introduction

Higher education can be seen as a public asset, insofar as it benefits the society as a whole (Mizrahi & Mehrez, 2002). Dias Sobrinho & Brito (2008), Dalvi *et al.* (2005), Porto & Régnier (2003) highlights that access to education is necessary for economic growth, indicative of social justice, and, especially in Brazil, an aspiration of young people seeking social ascension. According to Carneiro (1998), access to quality education is one of the aspects needed to achieve equality among people. Given its importance, higher education access was considered by the legislator as a social right guaranteed by the Brazilian Constitution.

Taking into consideration several aspects such as: the strategic role of higher education, the regulatory policies and legislation, and the coexistence of public and private institutions acting in this field, this paper aims to answer the following question: "How to help managers involved in higher education in better understanding the dynamics of the undergraduate education system in Brazil, in view of regulatory and political issues, budget constraints, different curves of supply and demand, fluctuations in enrollment, different levels of quality, goals, and socioeconomic status?".

The main objective of this paper is to describe the system dynamics model developed to address this research question. The model was implemented in iThink© and is able to evaluate the dynamic behaviour of the undergraduate education system considering several different scenarios, regulatory policies, and strategies from the several actors involved.

This paper is organized as follows. The next section briefly describes major aspects related to the higher education system in Brazil. Section 3 introduces the developed systems dynamics model and how the model was partially validated. The final section presents the conclusions, limitations and further developments.

2 The Undergraduate Brazilian System

In Brazil, education, at all levels, can be provided both by the public and the private sector, according to the 1988 Federal Constitution and Law 9.394/1996, the Law of Directives and Bases of Education. Aiming to expand the system and access to higher education, the government relaxed in 1995 the rules for opening new courses and higher education institutions (Dias Sobrinho & Brito, 2008, Dalvi *et al*. 2005). The response was the rapid growth of higher education as a whole, driven primarily by the private sector. According to McCowan (2007), private institutions have grown in number and size worldwide, and Latin America has changed from a small and elitist public system to a diversified system in which the private sector has an important role, since it represents a viable solution for expansion. This view is shared by Schwartzman and Schwartzman (2002), for which private enterprise is no longer seen as a "necessary evil". Beyond Latin America, other countries such as Israel (Mizrahi & Mehrez, 2002, Shoham & Perry, 2009), Taiwan (Ka-Ho Mok, 2002) and Romania (Niculescu, 2006), the participation of private enterprise in education is significant and had an important role in the expansion of the sector.

The rapid expansion of private initiative has created a situation of competition between institutions. Higher education is now seen also as an economic sector, a business area (Dalvi *et al*. 2005, Porto & Régnier, 2003, Schwartzman & Schwartzman, 2002). The coexistence of the public education, aiming at quality, and a private sector, motivated by profit, is one of the main topics of this research work.

In 2009, there were 2,250 public and 244 private higher education institutions in Brazil. The private sector accounts for around 75% of all undergraduate enrollments. The rapid growth of this sector was due to the supply due to a better economic situation of the population, a more affordable private sector, and finally by the existence of a pent-up demand, e.g., people already in the labor market and wanted to return to studies (Dalvi *et al*., 2005) to enhance their competitiveness in the market. Fig. 1 shows the evolution of the number of students enrolled in undergraduate courses in Brazil, from 1980 to 2008. There is an accelerated growth from the approval of the LDB in 1996, being the private sector the major participant. It took 20 years, from 1980 to 2000 for doubling the number of enrolled students, but only eight years, 2000 to 2008, for that number to double again.
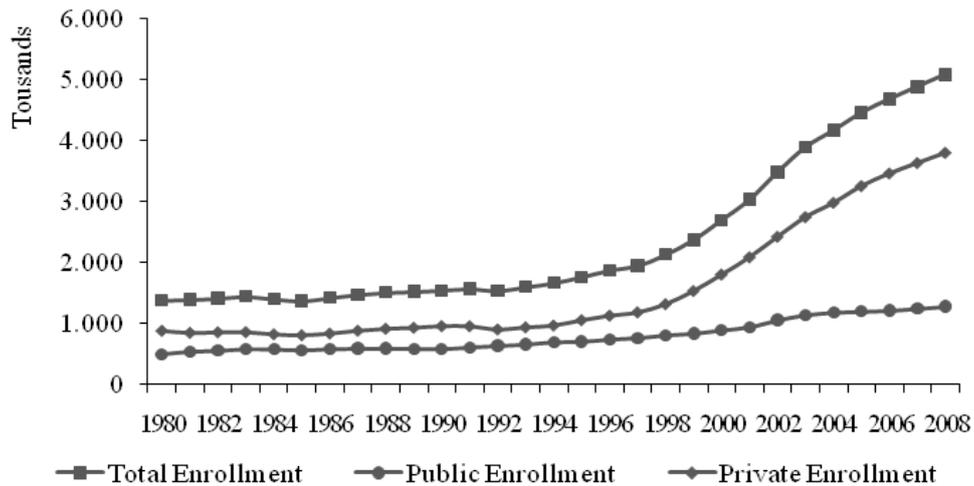
Figure 1 – Higher Education Enrollment

3. System Dynamics Model

System Dynamics is a method to enhance learning in complex systems. The main application of SD is in the dynamic behavior of complex systems, for which mathematical models are of little use due to the strong and complex interaction among the several variables involved.

The higher education system in Brazil has experienced rapid growth since 1995. Such growth, though desired, was very fast and therefore did not come without its problems. Senge (2004) warns that "when growth becomes excessive [...] the system itself will seek to compensate him". In this case, the expansion was a result of legislation and government policy. However, when the government started to note that the private sector growth was chaotic, it took some steps to halt this situation. As a consequence, several investments in the private sector did not fulfill their potential, establishing a half-crisis situation.

The major objective to the development of the SD model is to evaluate the behavior of the system, given that the involved agents, government and private sector, can play several different strategies, and the environment in general, such as the macroeconomic and demographic aspects of the country, can have a sensible effect over the system.

The model was developed following the methodology presented by Sterman (2000). The causal loop diagram emphasizes the balance between the public and the private sectors and sought to establish the dynamics between them under government and market constraints and regulations. The elements presented in the causal loop diagram were converted into stock and flows, whose relationships were modeled using the data collected in the Ministry of Education site and expert opinions. The defined structures were then used to build a simulation model that allowed us to analyze the dynamic behavior of the involved variables. The outputs were compared with actual data, indicating that the model, albeit with some caveats, is a satisfactory representation of the system. The last step of the methodology was the analysis of scenarios, not presented in this article for the sake of economy. This analysis aimed to assess the potential of the model as a learning tool. Next, the two first steps are briefly described.

3.1 Causal Loop Diagram

Fig. 2 shows the causal loop diagram developed for the addressed problem. The diagram emphasizes the coexistence of public and private education and their main

elements as follows: (i) demand for higher education, (ii) the regulatory policies; (iii) the public sector, (iv) the private sector, and (v) the attractiveness between the two sectors.
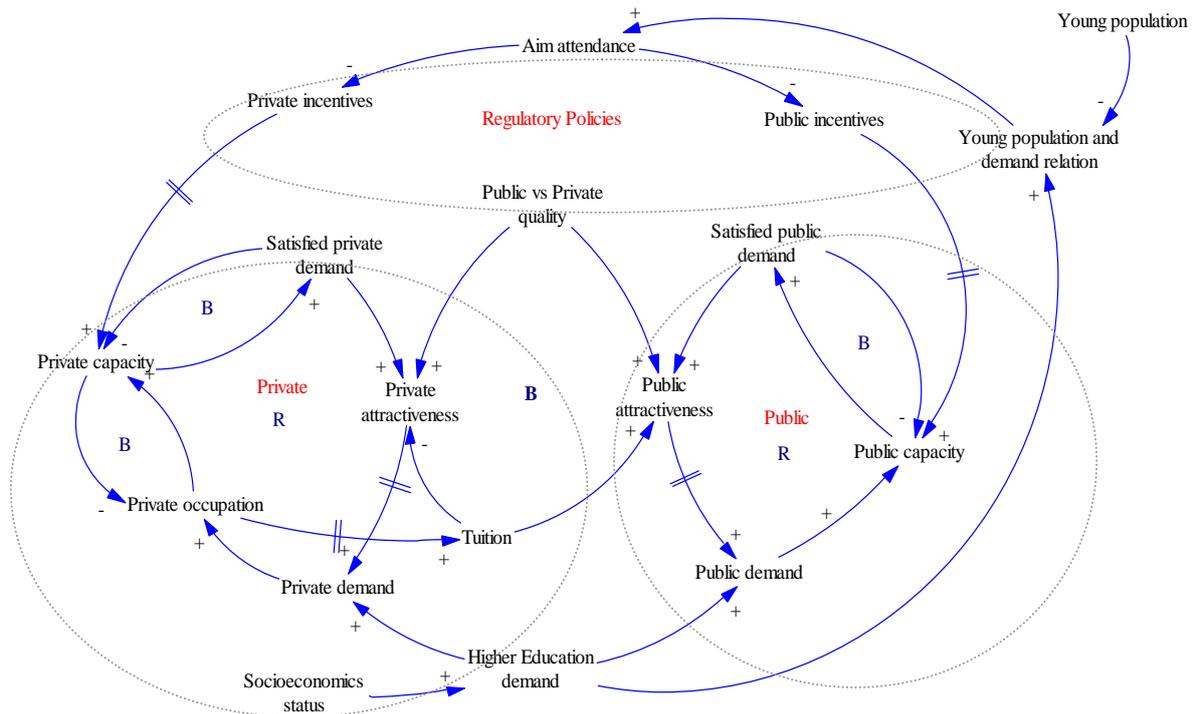

Figure 2 – Causal Loop Diagram

The demand for higher education is influenced by socioeconomic status. Policies for higher education are set by the Ministry of Education. The combination of policies in the model is translated into incentives to create new openings for graduate students in both the public and the private sectors.

The loops that represent the public and private sectors include the service capacity of each sector. They present reinforcement loops, where the growth in capacity is driven by the demand and the perceived incentives by the government; and balance loops to limit the exponential growth of the system, as demand is limited. In the private sector, there is the additional issue of pricing: tuition increases with the demand. If the capacity starts to idle, the tuition tends to fall. The balance between the two sectors is given by the attractiveness of the private sector in relation to public sector, which takes into account the quality (computed by the Ministry of Education), competition (relation candidates/places), and tuitions (inspired by the model developed by Carvalho (2001)).

3.2 Stock and Flow Diagrams

The stock and flow diagrams were developed with iThink 9.1.2. We divided the model into smaller units, all intertwined, in an attempt to facilitate its understanding. These units were nominated as follows: (i) demand for higher education, (ii) policies for higher education, (iii) the public sector, (iv) distance learning in the public sector, (v) the private sector, (vi) distance learning in the private sector, (vi) pricing; and (vii) attractiveness of the private sector in relation to the public sector.

The demand for higher education is based on the number of students graduating from the high school system (prerequisite for entrance in the higher education), pent-up demand, and the socioeconomic conditions of the population. The high school system is represented by a structure of stock (Enrolled) where entering students stays a predetermined period of time and then exits (Finished). The abandonment rate (high in

Brazilian higher education system) is represented as an exhaust flow (Escape). The outflow of the high school system and the pent-up demand generate the demand for higher education, highly influenced by socioeconomic aspects (represented in the model by GDP per capita) and the attractiveness of the private sector in relation to the public one. Finally, it is considered that distance learning allows an increase in the demand for higher education.

Policies for higher education can be regarded as intangible and abstract, and therefore very difficult to be directly represented in the model. The solution adopted was to model incentives as auxiliary variable that varies from 0 to 1. The coexistence of public and private sectors is represented by means of auxiliary variables *Private* and *Public*, combined with other auxiliary variables that represent changes in the regulation policies. The main goal for higher education defined by the Ministry of Education is to enroll 30% of the young population aged 20 to 24 years in an undergraduate course in the period of 2001 to 2010. The comparison between the number of enrolled students by the age-adjusted series with the target is verified by the discrepancy variable, as shown in the equation below.

$$Discrepancy = Min\ (1,\ ((Enrollment\_Pv + Enrollment\_Pb + Enrollment\_Pv\_DL + Enrolled\_Pb\_DL)\ *\ Age\_distortion)\ /\ Target))$$

where *Enrollment_** is the number of students enrolled in the private sector (Pv) or public sector (Pb) or distance learning (DL), *Age_distortion* represents the proportion of students enrolled, but out of the range 20 to 24 years old, and *Target* is the objective defined by the regulator. The discrepancy from the target increases or decreases the amplitude of government's incentives to open new places in higher education.

Fig. 3 shows the complete modeling of policies for higher education. The budget allocated to education is also considered.

The public sector, the private sector, and the distance learning within the public and private sectors units follow a similar structure. Each sector contains two stock structures: *Places* and *Enrollment*. The *Places* inventories are obtained from the adjustments in the flows of opening and closing places, resulting from government control and incentives, as well as entrance, fusions and bankruptcy of private institutions. The main difference between the public and private sectors is the insertion of the variable price (representing tuitions) in the modeling of the latter sector.

Stocks related to student enrollment include one in-flow of fresher students and two out-flows related with graduates and drop outs, respectively. They are modeled differently in the two sectors. In the public sector, a function computes the occupation of places as an average of the collected data in the Census of Higher Education, annually defined by the Ministry of Education. In the private sector, this relationship has suffered a decline since 2003, and in recent years, is around 50% (INEP, 2008). Therefore, the entrance flow is also linked to the economic situation of the population. Fig. 4 shows the structure of the public sector unit.

The Price Definition unit was modeled based on Sterman (2000), introducing some adaptations. Finally, the attractiveness unit considers three criteria: entrance requisites for both sectors, tuitions, and education quality. Strauss (2010) describes with details these two units.

3.3 Model Validation

Model validation occurred through analysis of extreme situations (tests included in borderline situations of the real system), sensitivity analysis (to check for discrepancies between the expected behavior and the simulation result), and especially comparisons with actual data observed.

Comparisons between real and simulated output data were performed in a qualitative way, focusing on trends rather on a rigorous statistical analysis. Several comparisons were carried out, mainly for variables for which historical data were available such as students' enrollment and graduating from high school, freshmen enrollment in higher education and graduating, places offered, and applicants in higher education. To illustrate the carried out analysis, Fig. 5 shows the comparison made for the number of places for each sector since 1990. This indicator influences all variables in the system. The model has captured the growth observed for both sectors. The real data for the private sector have faster growth than the simulated ones, but the simulation has captured the fairly captured the verified behavior, and therefore was considered adequate.
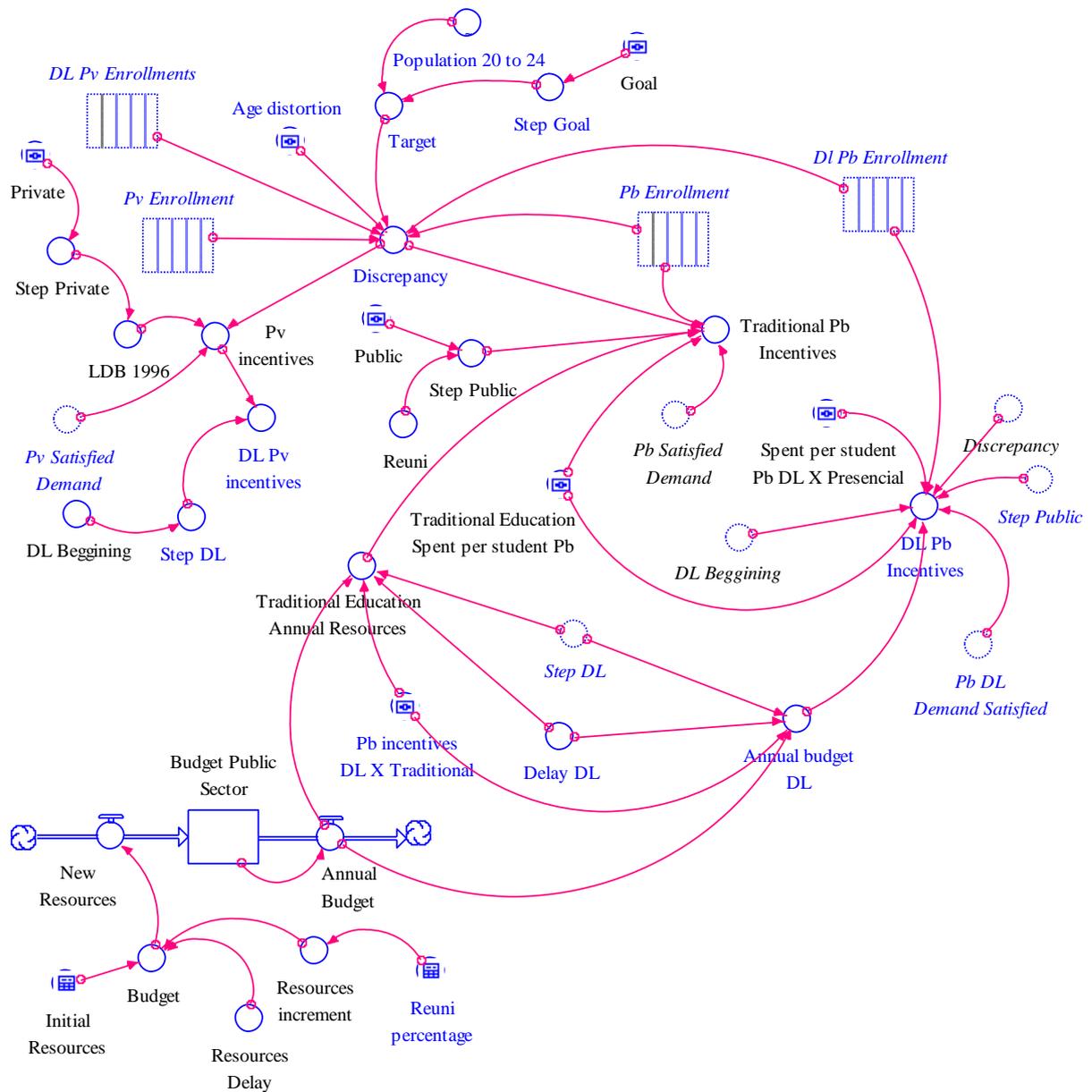

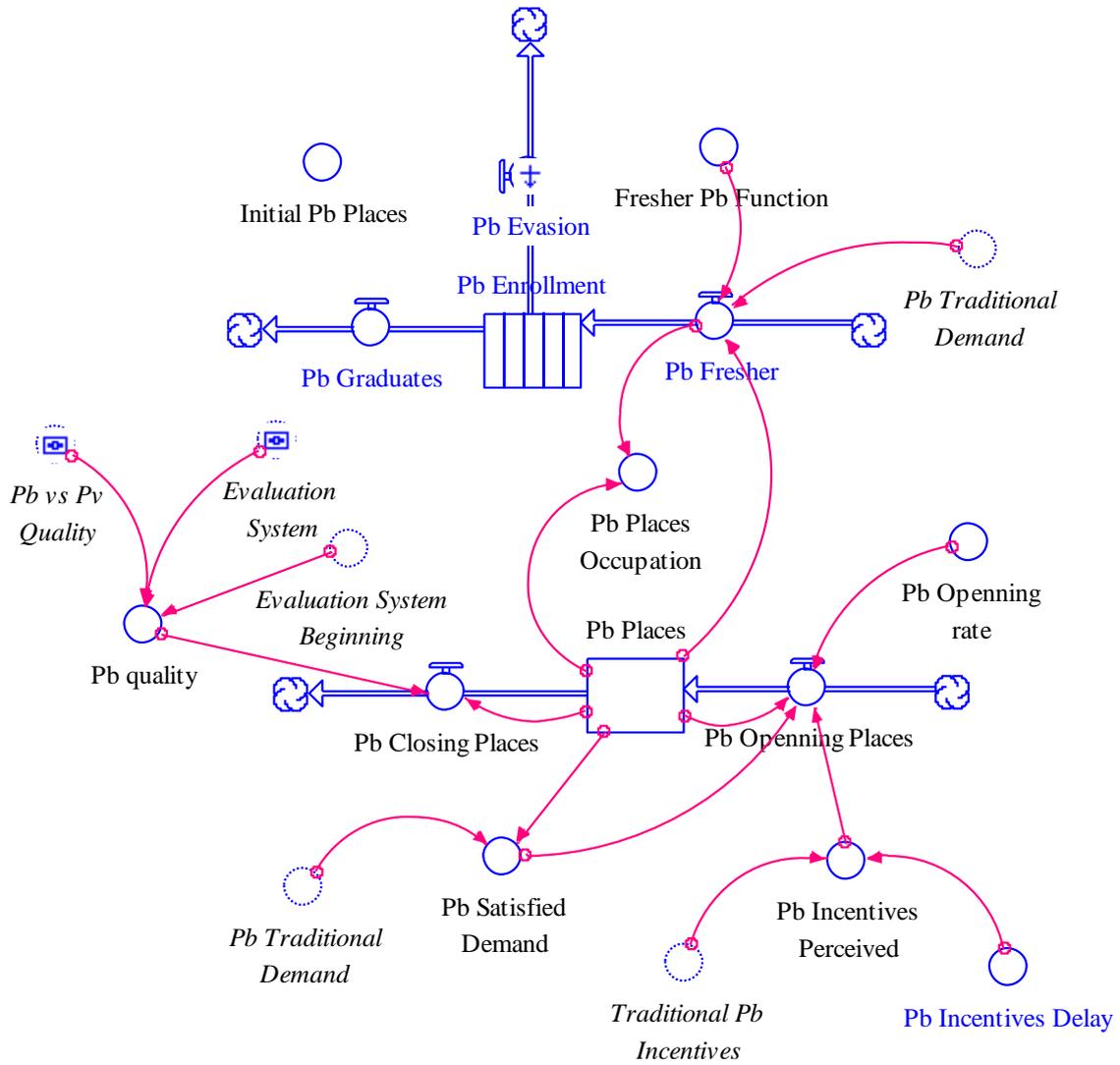Figure 3 – Policies for Higher Education
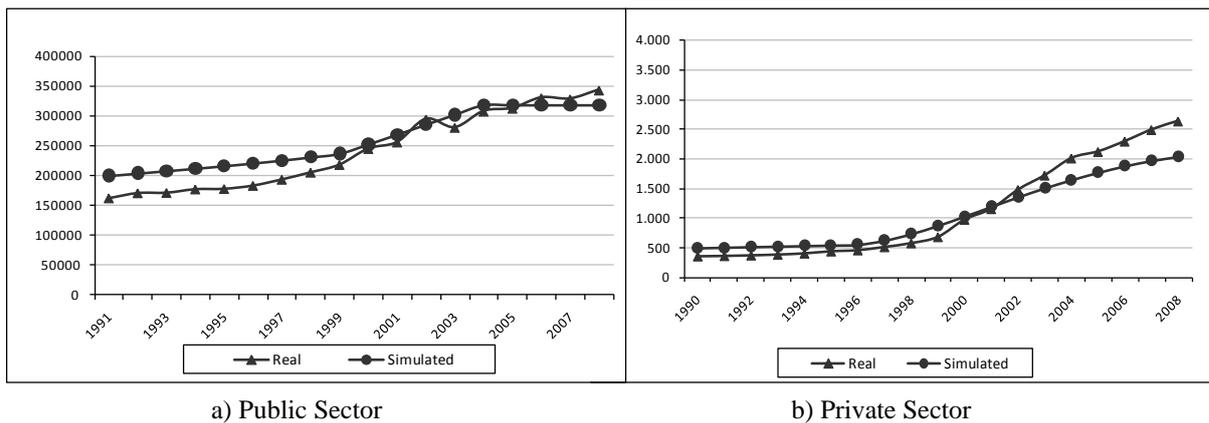
Figure 4 – Public Sector

a) Public Sector
b) Private Sector

Figure 5 – Comparison and real data and simulation results - enrolments

4. CONCLUSIONS

The major motivation for this study was related to the importance that education has for the economic and social development of a country and the difficulties faced by Brazil in achieving its goals in the higher education system. The objective was to develop a

learning model using system dynamics, which could help managers of higher education to analyze and understand the dynamics of undergraduate higher education.

The simulation developed in iThink© is mainly a prototype. Several elements, for the sake of simplification were not incorporated in the model. Some are due to the inability to establish all the relationships and links between variables in the real system. Others deal with the lack of formal measurement of several indicators, such as pent-up demand, prices charged by the private sector and the attraction between the public and private sector. At the moment, the model is in validation process after being totally verified. However, it is possible to confirm that the use of system dynamics has offered a useful and flexible learning tool to understand the very complex dynamic behavior of the Brazilian higher education system.

Future research will be directed towards the expansion of the model through the refinement of some assumptions and limitations, particularly to investigate and implement: pent-up demand, perceived attractiveness of the public sector compared to the private, tuition prices in the private sector, perceived attractiveness of distance education the classroom, and the encouragement of distance learning in the public sector. It is also suggested to expand the model to incorporate internal efficiency performance indicators, such as spending per student, tax evasion and other quality indicators established by the Ministry of Education. Finally, it would be interesting to differentiate between different types of high education institutions such as universities, colleges, and polytechnics.

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