A System Dynamics Tool for Higher Education Funding and Quality Policy Analysis

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Abstract

Conceptually, the level of funding of higher education activities is directly proportional to its strategic directions/implementations and hence quality. In developing countries, these dependencies are far from straightforward due to ad-hoc reactions to reduced funding. This paper contributes to the development of tools for this management challenge. We investigate the dynamics of higher education funding and ensuing impact on part-time teaching, staff to student ratios, staff development, research productivity, and hence the perceived quality, using a system dynamics simulation model. The model developed is based on higher education literature in the developing world in general and Uganda in particular. We use the resulting model to review policies on funding and quality in higher education, and ultimately envisage that the model can easily be adapted to higher education in other environments.

Keywords: system dynamics; higher education; funding; quality; model

1. Introduction

Quantitative approaches such as public accountability, unit cost budgeting, performance based funding, and research based teaching alongside new theories (economic theory, management theory) and other classic paradigms of management (total quality management, quality assurance, strategic planning) have recently been espoused in higher education management practices. Research literature, however, is relatively silent on whether improved academic standards have occurred as a result of these ongoing trends. On the other hand, the literature maintains that most of the present problems in higher education worldwide are linked directly or indirectly to financial constraints (Srikanthan and Dalrymple, 2007; Mamdani, 2007; National Council for Higher Education, 2006). Narrowing down to the developing countries, the 1990 World Conference on Education for All, held in Jomtien (Thailand) escalated the shifts in allocation of funds from higher education to primary education creating new avenues for policy changes in these countries (Salmi, 1992). About the same time, higher education (HE) in the developing countries was evolving in reaction to

pressures of excessively rapid growth of enrolment, deteriorating physical facilities, poor library resources, insufficient scientific equipment, and inadequate yet underpaid staff (Court, 1999; Salmi, 1992).

While enrolment growth should match staff capacity and basic educational resources, Chapman and Austin (2002) find that the sharp increase in demand for higher education across the developing world occurred not because of actions taken by colleges and universities, but largely as a result of demographic, political, and economic changes at the national level. They add that these changes triggered a complex set of interconnected pressures on government and higher education leaders to accommodate larger enrolments while encouraging more diversity in student populations, raising the quality of instruction, and either doing these things at a lower unit cost. In the case of Uganda, initial expansion of HE manifested as rise in private universities on the one hand and admission of private students in public universities on the other hand. The public universities since 1992 therefore, concurrently run programs for self sponsored (private) and government funded students. The aim of partial privatisation of the Ugandan public universities was to increase enrolment given high demands for limited university places while subsequently improving staff welfare through new allowances from private students (Court, 1999). A major set back vis-à-vis quality over the enrolment reforms in the Ugandan public universities was the culture of tying departmental budget allocations to student enrolment leading to excessive student numbers without regard to quality.

A number of funding mechanisms including: negotiated allocations (historical criteria based, input based), performance based, and purpose based funding are used in HE funding worldwide. Public universities in the developing countries in general and Uganda in particular use the negotiated funding mechanism. In this mechanism, funding is based on activity plans and budget proposals. The budget allocations, however, are based on the previous year's allocation of specific budget items. Annual changes or increases in each budget item are treated individually on the basis on cost projections. The budget items usually include staff salaries, students' allowances, material requirements, building maintenance costs, and investment. Since, more than 60 percent of students in Ugandan public universities are privately funded, it is observed that both the negotiated allocations and demand-supply funding are adopted by these universities. The latter implies that funding also depends on demand for HE placements and availability of places in these institutions.

Considering therefore, that more than one funding mechanism may be adopted in a university, the basic funding system for higher education seems defined by three interconnected stages: funding mechanism, institutional strategies, and institutional outcomes. Such a system as summarised in Figure 1, demonstrates that funding mechanisms influence institutional strategies which in turn determine institutional outcomes.

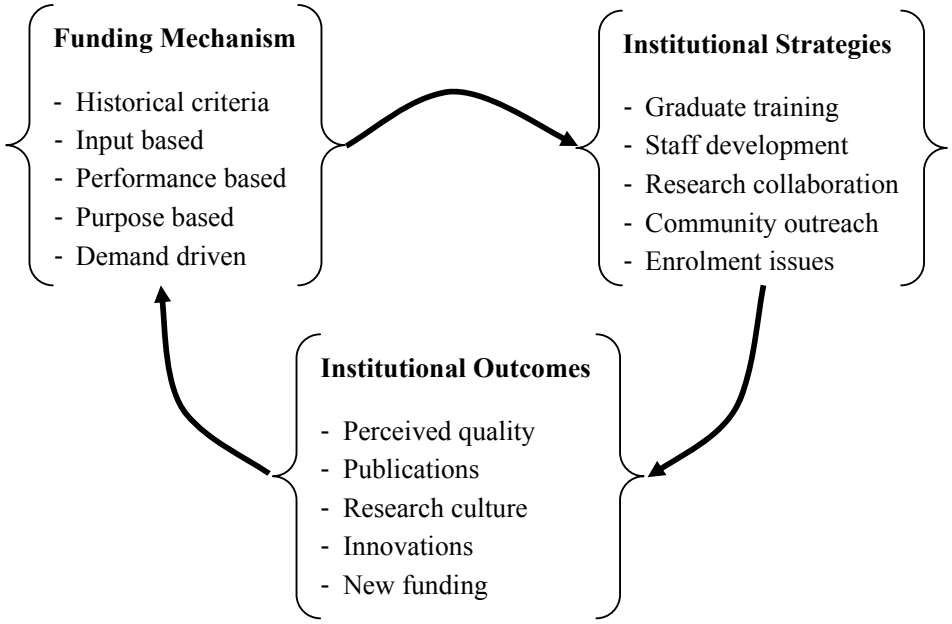


Figure 1: A Simplified Funding System: Mechanism, Strategies and Outcomes

The dependencies in Figure 1 are supported by literature in two perspectives: first, funding practice influences institutional strategies (Frølich and Klitkou, 2006; Wabrire, 2007), and secondly, institutional strategies enhance quality (Srikanthan and Dalrymple, 2007; Mamdani, 2007; Try and Grgaard, 2003). The underlying feedback mechanisms implied by Figure 1 are further explored in the later sections of this paper.

The complex dynamics underpinning funding and quality relationship as partially depicted in Figure 1, cannot be addressed by linear methods. For instance, it is observed that as funding (public and/or donor) continues to reduce in developing countries, universities become desperate, resorting to tuition from increased enrolment (Teferra and Altbach, 2004). As such, enrolment outstrips local capacity to generate commensurate numbers of qualified academic staff. At the same time, expenditure on academic staff is minimised through part-time staff who are employed on the basis of available teaching loads rather than the established staff to students' ratios. Thus, in addressing such complexity, HE managers need to precise define the problems scope. Apparently, this scope can be categorised into three, namely: quantitative issues (e.g., funding demand versus funding allocations, student enrolment, dropout/graduation rates, student grades, and student-lecturer ratio); qualitative concerns (e.g., student satisfaction, staff quality, and teaching quality); and the mixed type, comprising of quantitative and qualitative (e.g, academic staff competence, staff experience, and university reputation). Furthermore, in order to avoid the scenario where the gap between problem solved and the solution of the problem is significant (Vinnik and Scholl, 2005; Luna-Reyes and Anderson, 2003), the system dynamics approach that transcends the quantitative -to- qualitative problem area is adopted in this paper.

In the remaining sections of this paper, first, the relevance of system dynamics in addressing HE funding and quality problems is outlined. Next, the challenges of Ugandan universities are given, from which reference modes and dynamic hypothesis are derived and discussed. Thereafter, the model and ensuing simulation results viz. policy analysis are presented. Finally, a concluding discussion including implications of findings is made. Throughout this paper, university and higher education are synonymous.

2. The Relevance of System Dynamics

System dynamics (SD) is a computer-aided approach for analysing and solving complex problems through policy design and analysis. The problems addressed by SD are based on the premise that the structure of a system, that is, the way essential system components are connected, generates its behaviour (Luna-Reyes and Anderson, 2003). These problems have at least two features in common. First, they are dynamic (involve quantities which change over time). Secondly they involve the notion of feedback where, item x affects another item y and y in turn affects x perhaps through a chain of causes and effects (Forrester, 1998). Forrester further suggests that studying a link between x and y, independent of the other links between y and x cannot predict how the system will behave; only the study of the whole system as a feedback system can lead to correct results.

Specific to HE issues is Kennedy's (2002) taxonomy for system dynamics models that include topics such as: external forces, corporate governance, planning, resources and budgeting, human resource management, teaching quality, teaching practice, micro worlds, and enrolment demand. Apart from this taxonomy, recent studies acknowledge complex interactions in modelling higher education issues, but use methods that don't capture non-linearity and feedbacks in their inquiry.

For instance, Try and Grøgaard (2003) measured the relationship between resources and outcomes in higher education in Norway using hierarchical linear modelling (HLM) but restricted institutional resources to student composition, financial and staff resources, and staff priorities. Ho et al. (2006) suggest three groups of resources: manpower (human resources), hardware (infrastructure type), and software (intangible effects e.g., conference facilitation) that can be prioritised and budgeted for using analytic hierarchy process concurrently with goal programming approach. Although Ho and colleagues incorporate a large section of resources, their approach is linear and therefore sacrificing non-linear dependency. For example, computing resources facilitate teaching, learning and research which in turn affect perceived quality of graduates. By using data warehousing approach, Vinnik and Scholl (2005) explore the relationship between university's educational capacity and resource management but they do not suggest quality implications.

This paper adopts the SD approach to investigate the dynamics of higher education funding and ensuing impact on part-time teaching, staff to student ratios, staff development, research productivity, and ultimately the perceived quality. The relevance of SD in this inquiry therefore is in its ability to:

- Model feedbacks or interactive views in dynamic systems like higher education

- Incorporate non-linear relationships inherent in higher educational quality issues
- Address complexity situations while experimenting their behaviour over time
- Accommodate soft factors such as effectiveness of students' projects supervision, staff competence, quality of staff, quality of research, and quality of teaching that underpin higher education quality issues
- Model time delays that underpin certain policies on quality, e.g., time to recruit new staff, durations of study programmes, staff on training, executing research projects, and investment in new students' capacity.

Since the research process begins with correct articulation of problem(s), the salient issues of concern to HE funding and quality from the current practice in the Ugandan universities are presented next.

3. The Challenges of Ugandan Universities

Enrolment in the Ugandan universities over the last decade (1997-2006) has grown by about 62,000, down from about 31,000 in 1997 (National Council for Higher Education, 2006). In the same period, the numbers of licensed universities have increased from five to twenty, and two to five, respectively for private and public universities. These figures imply that the growth rate of students is 6,200 per year while the numbers of universities are rising at a rate of approximately 2 per year. Although these figures suggest that demand and supply are balancing, the preference of historical universities (mainly public) by students due to quality perceptions has resulted into excessive enrolment in the public universities. It is further observed that graduate training (Maters and PhD) falls in the range of 2 percent to l2 percent of total enrolment in the universities with both undergraduate and graduate training. Worse still, none of the graduate training universities emphasises 'thesis publication index' (Badri and Abdulla, 2004) as a measure of quality of Masters and in some cases PhD degrees. On the other hand, full time academic staff constitute on average 60 percent of the total academic staff across all these universities (Kasozi, 2006), thereby creating ground for part-time staff who are contracted on the basis of available teaching loads rather than staff to student ratio. As a result, the total staff numbers are less than required staff numbers that matches students' enrolment, and ultimately quality of teaching, students' research projects supervision, and students' academic evaluations are low.

In a recent survey of publication trends, out of 216 academic staff from two leading public and private universities, we find that 44 percent submitted at least one publication (conference paper, journal, book chapter or book) in the period 2004-2007. Narrowing down to the individual universities changes the general picture significantly as depicted in Figure 2. For instance out of 69 academic staff of Makerere, 65 percent had at least one publication in the same period. While these findings may not represent the actual publications output, they can be used as threshold for future publications analysis. Figure 2 summarises publications on a per university basis. The acronyms in Figure 2 are:

MUK - Makerere University
MUST - Mbarara University
UCU - Uganda Christian University
UMU - Uganda Martyrs University

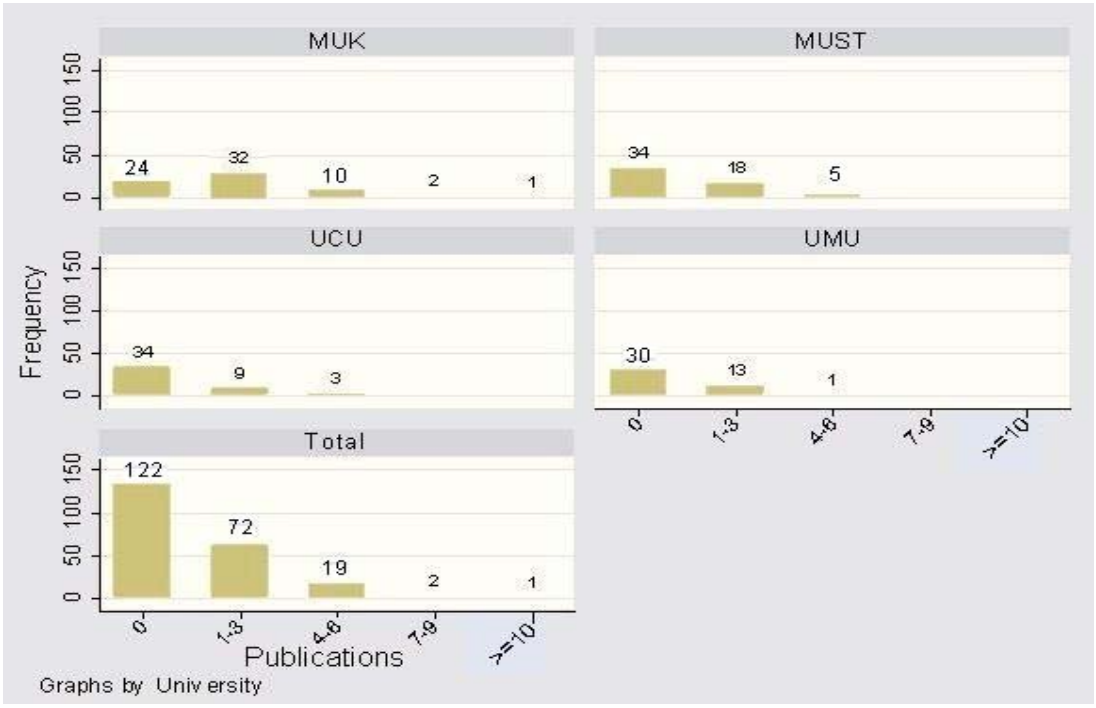
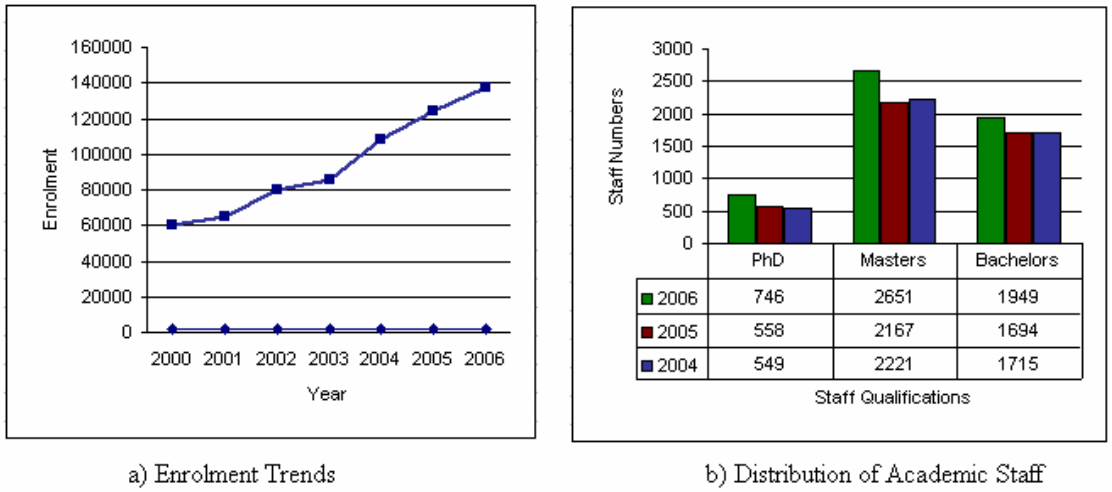


Figure 2: Publications by Selected Ugandan Universities

Judging by the publications grouping in Figure 2, it is clear that a large section of academic staff in leading Ugandan universities does not consistently publish. This observation is in the context of 216 surveyed academic staff out of which 13.5% hold PhD, 67% hold Masters and 19.5% Bachelors. These percentages are comparable with staff numbers by qualifications in Figure 3b and hence the survey distribution is justified.

The low quality indicators as already presented are escalated by recurrent funding deficits, prompting the universities to increase enrolment even under a vacuum of local capacity to generate commensurate numbers of qualified academic staff. This is demonstrated by Figures 3a and 3b corresponding with student enrolment trends and distribution of academic staff in Uganda's tertiary institutions.



a) Enrolment Trends

b) Distribution of Academic Staff

Figure 3: Enrolment versus academic staff distribution (Source: National Council for Higher Education, 2006)

Since tertiary institutions span beyond universities, enrolment in universities over the period 2004-2006 constituted 58.9 percent to 67.5 percent of the values in Figure 3a, while staff with PhD and Masters qualifications in universities were respectively in the range of 92%-93% and 80-81% of the values in Figure 3b in the same period. Considering the large numbers of staff with Masters and Bachelors qualifications as in Figure 3b, it is imperative that universities in Uganda prioritise staff development in order to improve quality of staff.

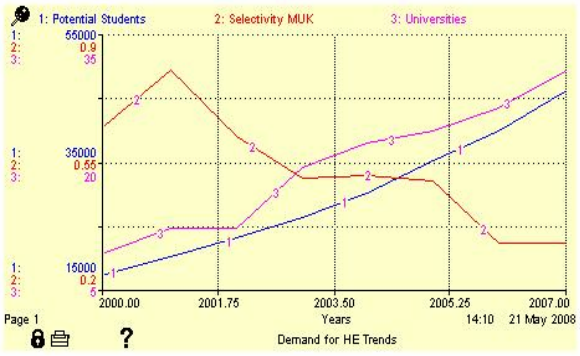
In view of the challenges as discussed, it is necessary to investigate the long term effect these challenges pause on quality as well as test policies aimed at offsetting them. This line of argument is further explored in this paper, by presenting the problematic behaviour as reference modes, from which a dynamic hypothesis is conceptualised and subsequently the model is built.

3.1 Reference Modes

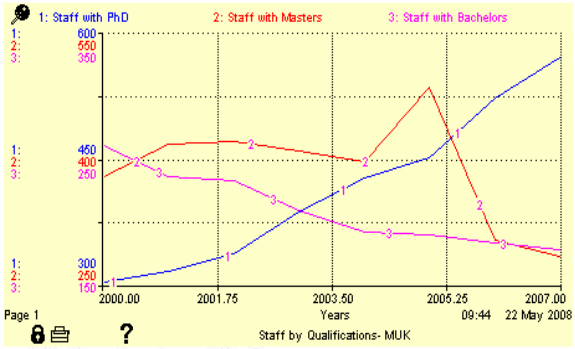
Real data on problematic issues in the Ugandan universities was used to construct graphs of historical behaviour or reference modes. At national level, data was obtained from National Council for Higher Education (2004, 2006) and Kasozi (2006). Other sources used to complete the required data included: our survey as described in the previous section, and Makerere University (Wabwire, 2007; Makerere quality assurance framework, 2006: Musisi and Muwanga, 2003). Funding and quality concerns deemed problematic in this research include:

- Rising students' enrolment amidst irregular staff training and development as well recruitment of new full-time academic staff.
- Inadequate public funding compounded by the politics of fees, donor policies and insufficient national income.
- Low research productivity escalated by a vacuum of research funding and research staff
- Poor supervision of students' dissertations and projects due to low qualified academic staff in some cases or overloaded though highly qualified staff in other cases.
- Lack of feedback mechanisms for evaluation of teaching and available resources.

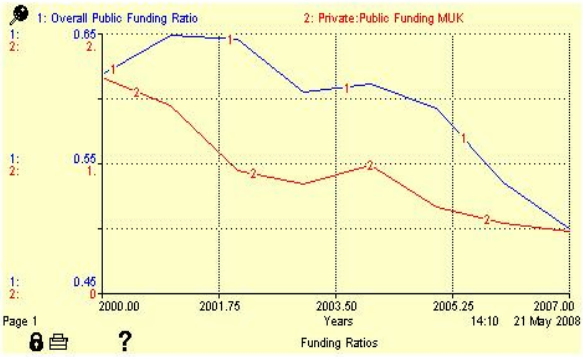
The reference modes in Figures 4a to 4d show behaviours of problematic issues underpinning HE funding and quality including: (a) growth in potential students versus growth of universities and ensuing university's absorption capacity (Figure 4a), (b) public funding trends and impact on private funding in public universities funding policy (Figure 4b), (c) trends in staff qualifications as an indicator of staff training (Figure 4c), and (d) research publications ratios as indicators of research productivity (Figure 4d).



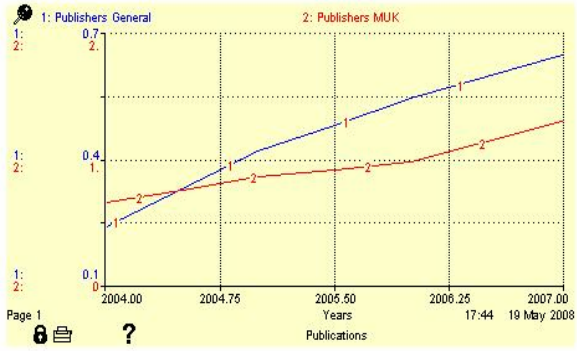
a) Trends in potential students, selectivity and number of universities



c) Staff numbers by qualifications



b) Funding trends in public universities by allocated ratios



d) Ratio of publications in a year to total publications

Figure 4: Dynamic Behaviour for Reference Modes

Figure 4a depicts that the growth in universities correspond with demand for new places (graph 4a-1 and graph 4a-3). Considering selectivity for Makerere University, the ratio of available places to qualified applicants (graph 4a-2) is falling, this implies on one hand that demand for university admission in Makerere is increasingly higher than available places. On the other hand, it implies that demand for university training is not uniform in all Ugandan universities. Moving on to Figure 4b, graph 4b-1 shows a general fall in funding allocations to public universities. The ratios used in graph 4b-1 are based on the recommended percentage allocations by the National Council for Higher Education versus actual allocations by government (Kasozi, 2006). Graph 4b-2 narrows down to Makerere University's ratio between public to private funding. It confirms that prior to 2002, public funding was higher than private funding (ratio is greater or equal to one) and thereafter the trend changes. Figure 4c shows staff qualification trends for Makerere University, in which staff with PhD generally increase in number while those with Masters and Bachelors decrease. Finally, Figure 4d shows trends in publications ratios for the four universities combined (graph 4d-1) and Makerere independently (graph 4d-2).

Comparisons of model behaviour with references behaviour are made in section 5. Since the reference behaviour depicts prevailing theories in practice, propositions for the dynamic hypothesis are conceptualised from the reference modes.

3.2 Dynamic Hypothesis

The interactions in Figure 5 show the effect of HE funding on staff quality, research performance, and basic operational costs provisions. Williams (2002) emphasises that a test of a good theory lies in its ability to predict, shape or change the surrounding world. Figure 5 offers a useful basis for research in HE funding and quality issues since it provides a theoretical analysis of the factors that determine this relationship. The feedback structure in Figure 5 contains seven dominant feedback loops, of which four are reinforcing loops (R), and the other three are balancing loops (B).

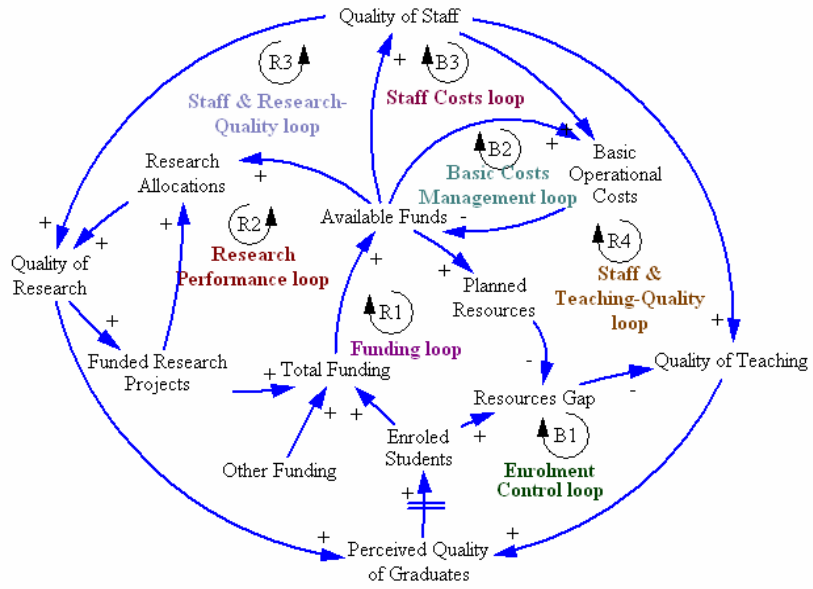


Figure 5: Dynamic Hypothesis for Funding and Quality System

The dynamics in Figure 5 reflect two categories of feedback loops, namely: -

- Funding and performance loops (R2, R3, R4 and B1)
- Funding and costs management loops (R1, R2, B2, B3)

Funding and performance loops (R2, R3, R4 and B1)

Both loops R2 and R3 associate quality of research with research allocations and quality of staff. Specifically, loop R2 articulates that: an increase in available funds increases research allocations in turn impacts on quality of research. Further increase in quality of research increases funded research projects which results into increases in total funding and ultimately available funds. The loops R3 and R4 are longer but their causal explanations are similar to R2. The theory depicted by B1 follows that an increase in quality of teaching increases perceived quality of programmes which over time attracts more enrolment. However, increase in enrolments reduces quality of teaching.

Funding and cost management loops (R1, B2 and B3)

The balancing effects of loops B2 and B3 show the effects of basic costs on available funds. Considering loop B3, an increase in available funds increases quality of staff. A subsequent increases quality of staff increases basic operational costs which in turn decreases available funds. Loop R1 purely focuses on funding issues. It depicts that an increase in total funding increases available funds (after some cost deductions). Subsequently and increase in available funds over time increases enrolled students and when more students are enrolled then more total funding is achieved.

The policies implied by the dynamic hypothesis are further explored using stocks and flows diagrams in the next section. Influence diagrams are not, however, discussed independently as they are consolidated in the stocks and flows.

4. The Model

Following a preliminary survey over quality management issues from two leading Ugandan public universities (Makerere and Mbarara) and two private universities (Uganda Martyrs and Uganda Christian) as the basis for the model in this paper, the authors established that; an academic unit or faculty's functions are generally defined by the following characteristics:

- Offering degree programmes ranging from undergraduate to PhD, but in a manner that Masters and PhD programmes start in the later years when necessary human and other resources to support these programmes are available;
- Generating income from internal activities like short courses, consultancy, and hire of premises on addition to tuition from students;
- Prospecting for funding in the areas of staff training and research projects;
- Having full time academic staff in the categories of teaching assistants to professors, whereby, the subsequent full time staff recruitment ratios, follow a pattern that depends on graduate students' graduation rates;
- Operating under a fixed strategically planned students capacity but with provisions for growth or fall in actual capacity with respect to the planned capacity depending on the dynamics of the factors that influence capacity growth;

In addition to these characteristics, the model is underpinned by the following assumptions:

1. A minimum number of publication(s) is mandatory for research students (Masters and PhD) prior to their graduation (Badri and Abdulla, 2004). A publication is a journal or its equivalent;
2. Tuition from students contribute only a small fraction of funds needed for research (Mamdani, 2007; National Council for Higher Education, 2006). This is also supported by the fact that universities generally operate under budget deficits and thus research thrives only when it is funded through a separate channel.

3. Faculty's academic staff with PhD qualifications together with research students constitute research groups. Every research group in turn manages at least one research project at a time, and the maximum number of research groups a faculty can have is fixed.

Basing on the dynamic hypothesis in Figure 5, the overall model's sectors as shown in Figure 6 are five. These include: students' enrolment, funding and strategic planning, research and publication, academic staff, and teaching.

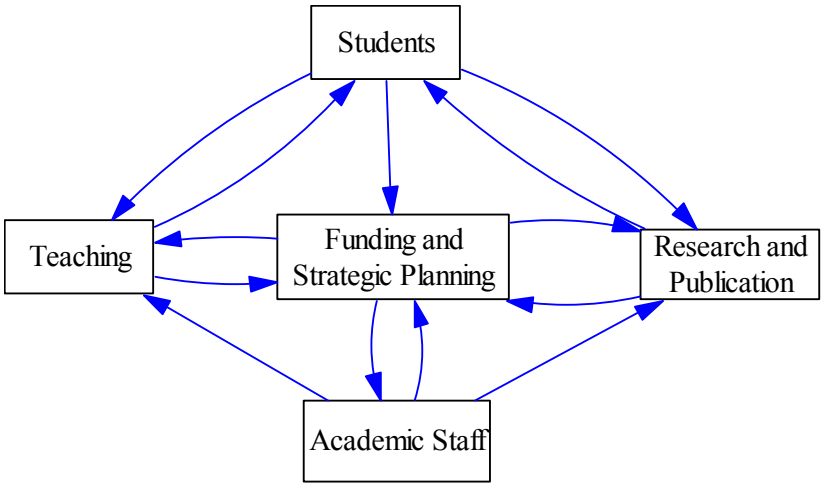


Figure 6: The Main Model's Sectors

Each sector has defined influence factors, representing the real HE environment. Influence diagrams based on Figure 6 are not discussed, but are compensated by a detailed presentation of the model's stocks and flows on a per sector basis.

4.1 Funding and Strategic Planning Sector

This sector links with all the others since issues of funding and/or planned students' capacity directly determine the existence of a higher education institution. Although demand for courses is computed from the students sector, its effect on funding decisions and subsequently required students' capacity underlie the link between this sector and the student sector. Try and Grøgaard (2003) define selectivity or demand for courses as the ratio between number of applicants and number of admitted students at each faculty. Whereas this ratio can be used as an indicator of initial student body quality, in this paper, it doubles as a measure of "rate of demands for courses" and a determinant for faculty's decision in implementing desired students' capacity growth policy. In the same vein, demand for courses together with two other variables (capacity ratio and total revenue) as shown in Figure 7 influence "capacity funding decision". "Capacity funding decision" is the fraction of tuition revenue that can be invested in new capacity or additional places for extra students' admission. The decision in turn influences "capacity investment" rate that accumulates the "New Capacity" stock. Thus "new capacity" is modelled as an oven allowing capacity investment accumulation equivalent of Ω students, then incrementing "Total Capacity" stock by Ω over a cook time or delay of σ years. The Ω and σ values are appropriately varied by the decision maker. The term total capacity implies the overall required students' enrolment, while

specific capacity is the actual required students' numbers in their respective categories, i.e., undergraduate to PhD students. One scenario for specific capacity values is having 90% of the total capacity corresponding with undergraduate students and the remaining 10% shared among the rest (Post Graduate Diploma-PGD, Masters, and PhD). Therefore, specific capacity is modelled as an array with the student categories as its elements.

Reflecting on funding issues, this sector depicts that revenue from tuition supports several activities including: full-time staff salaries, extra load allowances for full-time academic staff (denoted by specific FT Staff Extra Load Costs), part-time staff allowances (denoted by PT Staff Costs), staff training/development, student costs (includes costs for basic academic resources per student), and other funding needs (included all other categories of faculty expenditure). The rest of the outflows from tuition revenue stock are shown in Figure 7. Since full-time staff salaries in public universities are not paid from tuition revenue, the "nature of university constant" whose value is [0- for public universities or 1- private universities], is used to compute the full-time staff's salary allocation out-flow (denoted by FT staff salary allocation).

Another issue of concern to this sector is internal revenue sources, which include: short courses, consultancies, and other (e.g., hiring of premises or laboratories). Profits from internal revenue are mainly invested in new capacity depending on established demand for courses. Other than savings from tuition revenue and other internal income for investment in new capacity or additional capacity, new capacity can also be achieved through donations. Although donations towards new capacity are highly unpredictable, the model caters for such donations through the "courses increment effect on capacity" rate. This rate is computed from the teaching sector and is discussed in section 4.4.

Figure 7 therefore demonstrates major determinants that underpin growth in a faculty's students' capacity, and dynamics in tuition revenue allocations for overlapping funding needs. The rest of the influencing factors in this sector can be conceptualised in Figure 7.

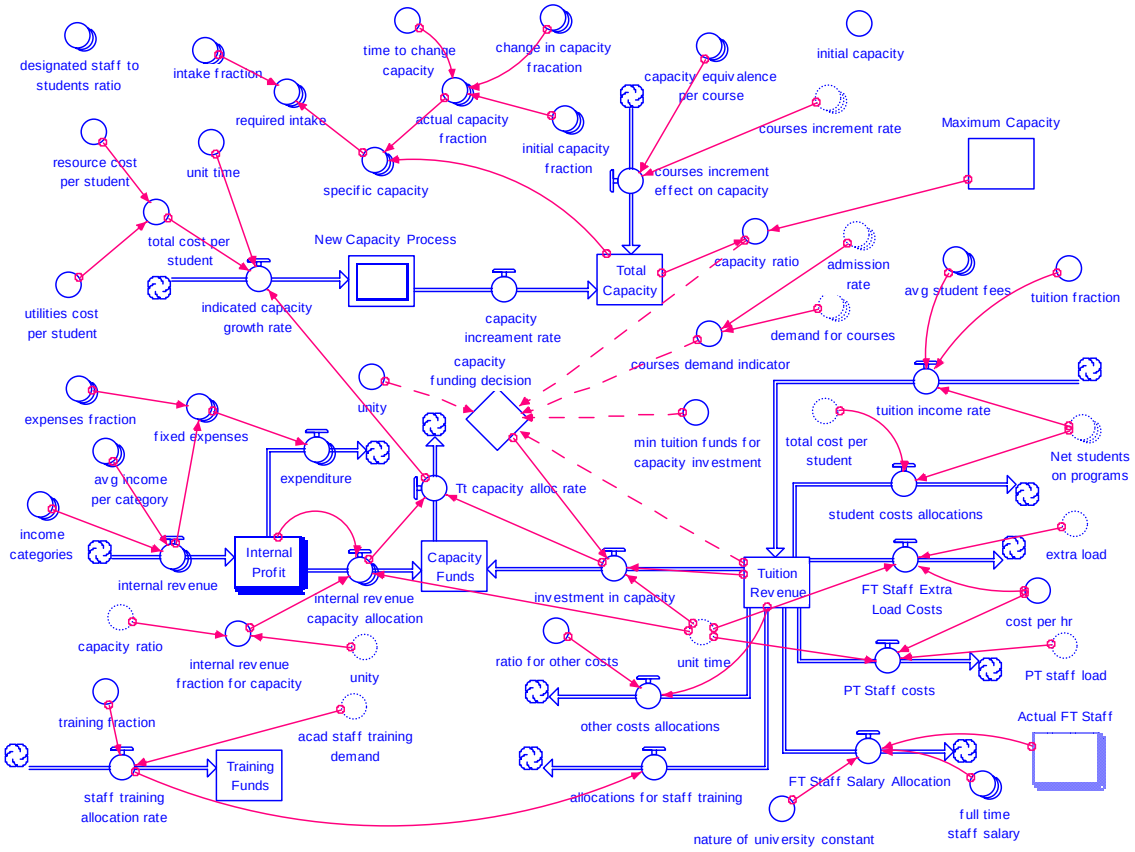


Figure 7: Funding and Capacity Planning Sector Stocks and Flows

4.2 Students Sector

This sector consists of five major stocks namely, potential applicants, admitted students, students on programmes, graduating students and students on retake. Potential applicants stock is accumulated by "demand for courses" rate. This rate is influenced by three factors including: required intake, initial applicants per place, and perceived quality of research. The "students on programmes" conveyor keeps students for specific periods depending on their programme of study. Undergraduate students take three years, Post Graduate Diploma (PGD) take one year, Masters take two years, and PhD take three years, while in this conveyor. At the end of these periods, students flow into "graduating students" stock, from which, the fraction that fails to graduate because of retakes (papers that must be redone) remain in the system through the "students on retake" conveyor, and graduate a year later. The required intake is determined from the administration sector as the product of admission fraction and corresponding specific capacity of students, where admission fraction is the reciprocal of the respective programme durations. University reputation and market share are determined from quality standards and community sectors respectively. The details of this sector are shown in Figure 8.

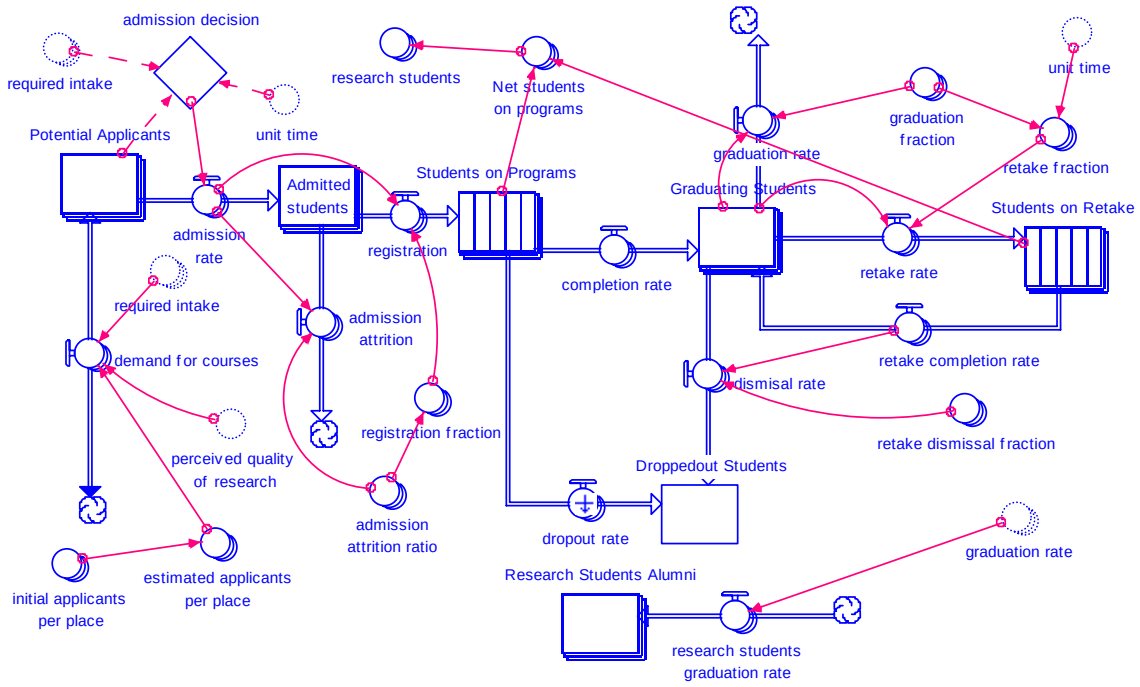


Figure 8: Students Sector's Stock and Flows Diagram

4.3 Research and Publications Sector

Internationally, research is measured in terms of: staff publications, PhD completions, PhD thesis publication index and Masters thesis publication index, research income, prestigious awards, and research-based infrastructure (Williams and Van Dyke, 2007; Badri and Abdulla, 2004; Kennedy and Clare, 1999). The current model considers these measures except prestigious awards that lack even distribution within university research output. Furthermore, research can be evaluated both in terms of quantity and quality.

Research quantity and quality

With respect to quantity, "stocks" for PhD completions, faculty publications, research resources capacity or research based income can be conceptualised from Figure 9. On the other hand, quality relates to publications per PhD and Masters Thesis (Badri and Abdulla, 2004), publications per faculty staff (Williams and Van Dyke, 2007), quality of staff and research resources availability (Kennedy and Clare, 1999). Quality of staff is discussed under academic staff sector, but the rest of the research issues are presented this subsection.

As indicated in Figure 9, "research students' publications" stock is accumulated by "research students' publications" rate. This rate is obtained as the product of "indicated publications per thesis" and "research students' graduation rate". The "indicated publications per thesis" is further determined as:

*Mean(staff commitment to students supervision, staff publications indicator)*upper quartile publications per research students*……..i

The upper quartile publications are determined from historical publications trends of research students. It is assumed that a university sets a minimum number of journal publications or its equivalent as graduation requirements for the research degrees. Following from equation (i) and since upper quartile publications are considered as "ideal publications per thesis" (refer to Figure 9), indicated publications per thesis ≤ ideal publications per thesis. Furthermore, "expected students' publications" is derived from ideal publications per thesis, and subsequently "quality of students' thesis" computed as the ratio between "research students' publications" and "expected students' publications". Similar arguments are used to determine staff publications indicator in Figure 9. In the same line, SPI is an acronym for staff publications index. Regarding SPI, a publication is considered to be a journal and book chapter. Conference papers are excluded as publications since these papers are usually transformed into journals.

Another set of interrelated stocks and flows in this sector correspond with funded research projects. These transcend incoming projects rate, to executed projects stock through executing projects stock. Starting from executed projects stock, research resources capacity stock is derived. Subsequently, research growth factor is computed as:

$$\frac{INIT(Research\_Resources\_Capacity)}{Research\ Resources\ Capacity} \quad \text{……ii}$$

Consider the result of equation (ii) to be β, and since "Research Resources Capacity" is a stock that accumulates with number of projects executed, then β decreases over time. Research resource availability which is determined from β as $\mathbf{e}^{-\beta}$, undergoes exponential growth in the range [0, 1]. The "research project publications" stock and "projects income" stock are similarly derived from "projects executed" stock.

The overall stock and flow structure in this sector is presented in Figure 9.

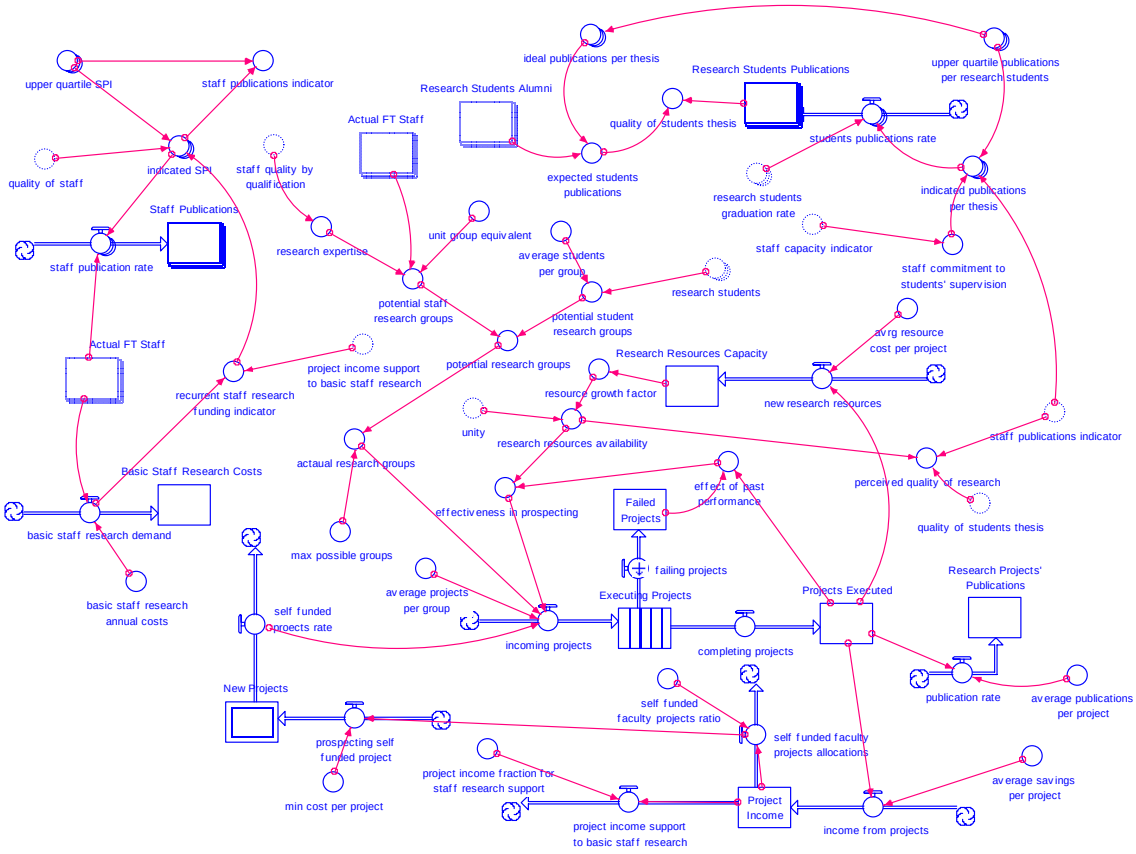


Figure 9: Research and Publications Sector's Stock and Flows Structure

4.4 Teaching Sector

Quality of teaching is derived from quality of staff, resources availability (Patrick and Stanley, 1998), class size (Krueger, 2003), and students rating of teaching. This sector contains mainly computations for teaching load distributions between full-time and part-time academic staff. The assumption made is that part-time academic staff are only employed when the full-time staff have been allocated teaching hours corresponding to their maximum load (nominal load + extra load). The only stock in this sector keeps track on number of current courses. It is observed that faculties with increasing students' capacity also increase courses they offer. Since courses change (increase) in a non continuous form, this trend is best modelled using a delay process (an oven), whereby the 'oven's inflow rate arises from the difference between maximum planned courses and current courses.

Referring to Figure 10, planned load per year is influenced by four factors. These include: current courses, credit units per course (60 hours or 45 hours a semester), type of programmes (day only or day and evening or evening only), nature of courses (core or elective), and course durations in terms of years of teaching (3 years, 2 years or 1.5 and 1 year). To clarify on these factors: 'day only' programme refers to a category of courses run during the day, while 'day and evening' programme refers to two groups of the same courses with one group running during the day and the other in the evening. The 'evening only' programme just like 'day only' programme is offered in evening. Provided the planned load

is known, extra hours are computed by subtracting nominal load for full time staff from it. Extra load for full time staff is subtracted from extra hours and any excess hours after this subtraction is considered as load for part time staff. The extra load for full time staff is paid as allowance for over time and corresponds with "specific FT staff costs" highlighted on in the finance sector. The rest of the influencing factors in this sector are shown in Figure 10.

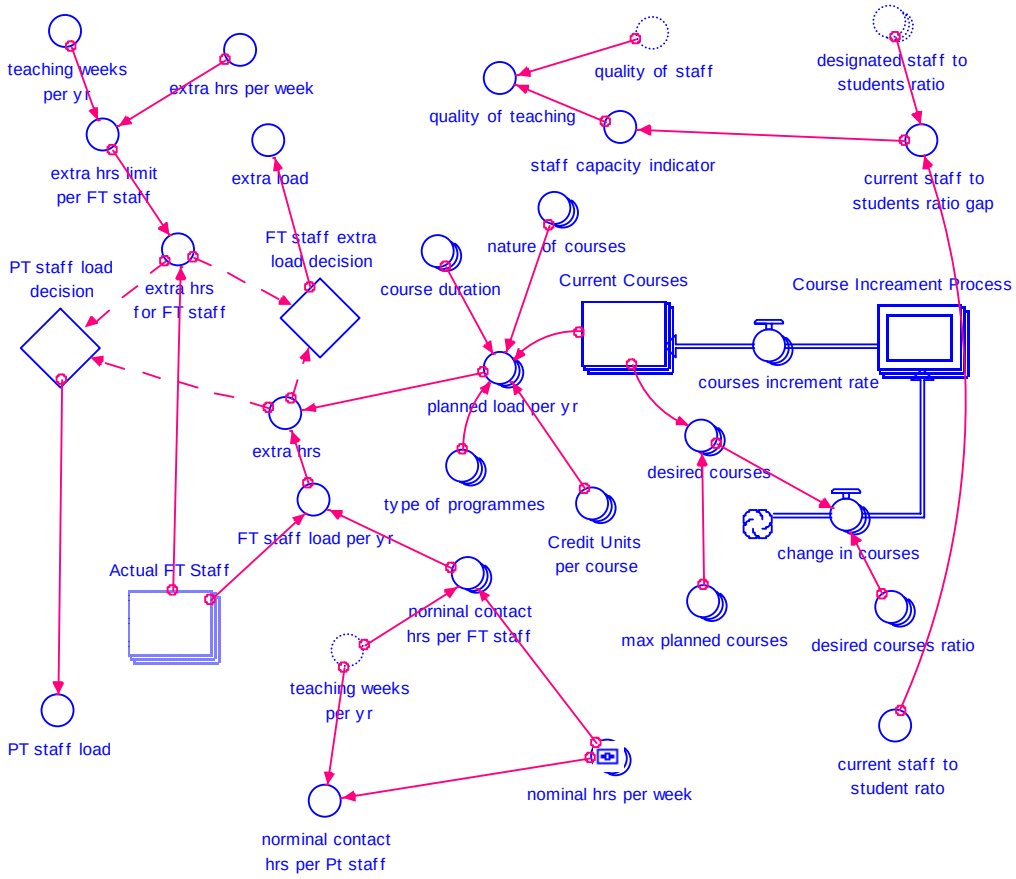


Figure 10: Teaching Sector Stock and Flows Structure

Quality of teaching is computed from resources availability, quality of staff, and staff capacity indicator. The "staff capacity indicator" is envisioned in this paper due to the fact that both part time and full time academic staff constitute the 'current staff to students' ratio', yet part time staff are contracted only when teaching needs arise. On this note, the 'current staff to students ratio' is an underestimation of the 'designated staff to students ratio' **(say r),** creating a gap in staff to students ratio. Following from Figure 10 and considering μ to be current staff to students' ratio gap, "staff capacity indicator" is given by:

$e^{-10\mu}$ ……..iii

for $0 \leq |\mu| \leq r$. Therefore, values corresponding with equation (iii) lie in the range [0,1]. Since all factors affecting quality of teaching in this case have values in the range [0,1], quality of teaching is thus obtained as their mean value.

4.5 Academic Staff Sector

This sector includes stocks for full time academic staff and part time staff. The full time staff stock is further broken down into other stocks to track training progress of staff members without PhD qualifications (teaching assistant and assistant lecturers). Staff training is in two forms: first, through demand for training versus availability of training funds, and secondly, through executing faculty research projects. In the first scenario, all staff requiring PhD training or Masters training are considered while in the second scenario, only PhD training is catered for. This is based on the assumption that each funded research project run by a faculty has provision for a PhD training position of which staff members have top priority.

The status of staff degree as an indicator of quality of staff (ideal minimum required qualification is PhD) is computed as a ratio of staff with PhD or its equivalent qualifications to the total staff capacity. Other indicators for quality of staff include staff competency and staff experience. The former is the measure of current performance of academic staff in terms of research output, peer recognition, supervision of research students and Academy membership (Williams and Van Dyke, 2007). It is an exogenous variable computed from staff appraisal data in the scale of [0,1] using inbuilt and logical functions in MS Excel and linked to STELLA® through the dynamic data exchange (DDE) option. Staff experience on the other hand is obtained as ratio between current experience level and desired experience level. i.e., staff experience is modelled as a stock that is accumulated by gain in experience rate based on staff retention trends, and reduced by loss in staff experience rate derived from staff attrition trends.

Staff recruitments are modelled differently for full-time and part-time as shown in Figure 11. Focusing on full-time staff, an "oven" is used to accumulate required full-time staff until a fixed number is obtained before the actual recruitment is effected. Since both private and public Ugandan universities only recruit a fraction of desired full-time staff, the model uses the "employable fraction" ratio to cater for this practice. Part-time staff on the other hand, are recruited when teaching hours exceed maximum teaching load provisions for full time academic staff. Computations for teaching loads are done in the teaching sector and converted into part time staff values by preset average teaching load per part time staff. Since part time staff capacity influences total staff capacity, the part time stock is regulated by an out flow rate using "if-then-elseif-else" conditions based on teaching load calculations from the teaching sector. The details of this sector are shown in Figure 11.

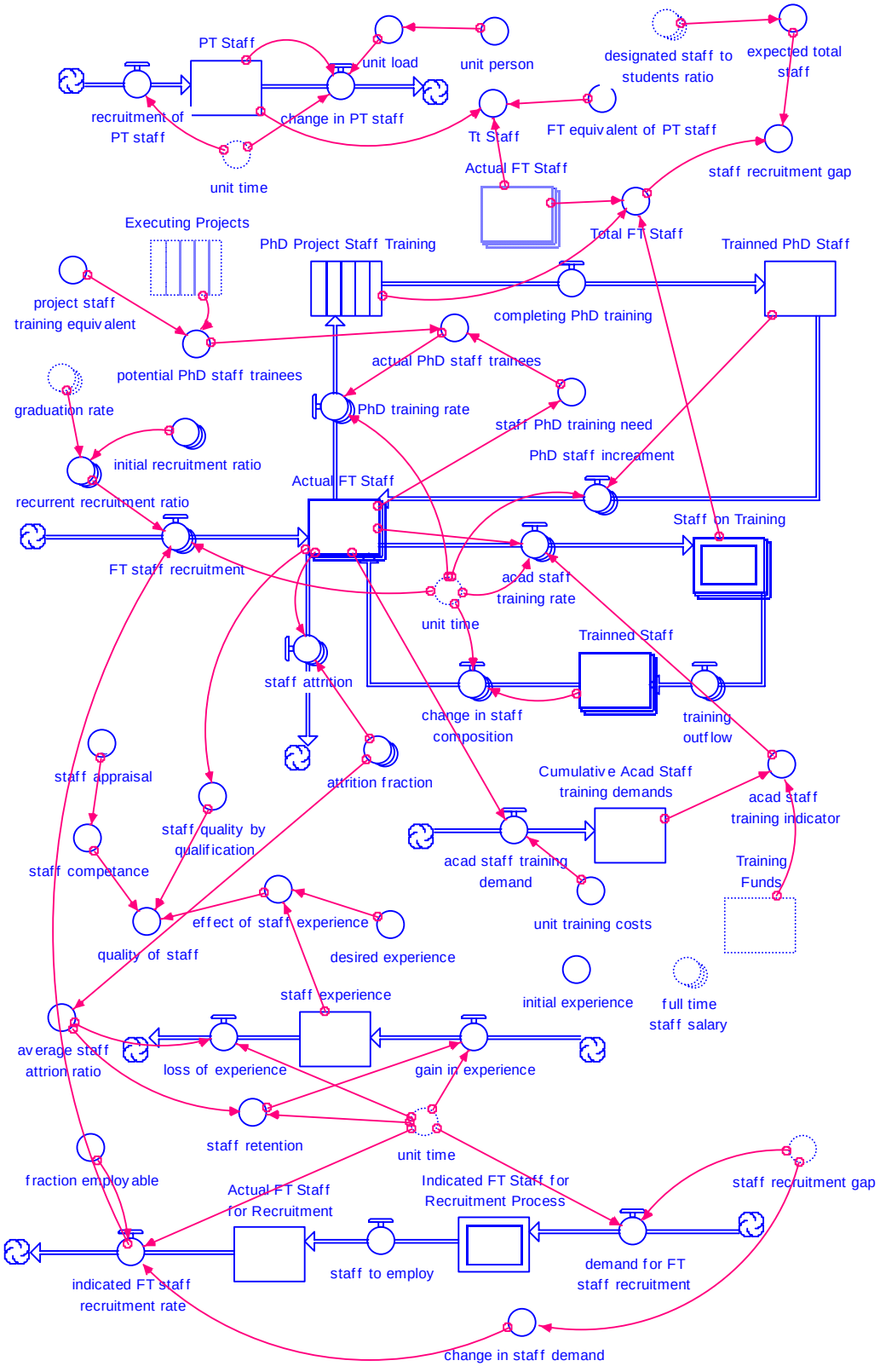


Figure 11: Academic Staff Sector's Stock and Flows Diagram

5. Simulation Results

As stated initially, this paper aims to investigate the dynamics of higher education funding and ensuing impact on part-time teaching, staff to student ratios, staff development, research productivity, and ultimately the perceived quality. Given the resulting complexity of the model, different simulations may be of interest to different decision makers. The simulation results discussed under this section, however, are based on policies implied by the dynamic hypothesis in Figure 5.

5.1 Students' Enrolment Trends

The dynamics of enrolment has been elaborated in the "students sector". As depicted by Figure 12, actual enrolment trends of undergraduates begin in the year 2000, while those of research students (Masters and PhDs), take effect in 2002. The overall behaviours in Figure 12 are comparable with the general reference mode (Figure 4a-graph1). Specifically, Figure 12 shows that growth in total capacity (graph 5) is stepwise; arising from accumulation of funds equivalent to eight hundred students at each growth.

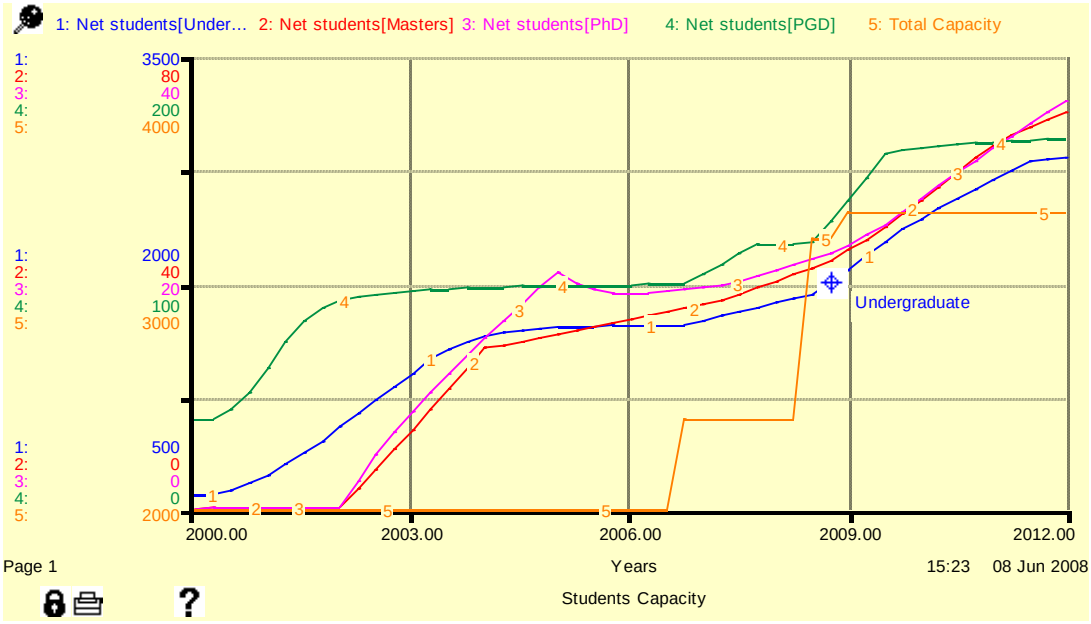


Figure 12: Actual Students Enrolment vs. Capacity Growth

The total capacity is depicted to stabilise in 2009 yet the same trend is only replicated by the specific students' categories towards 2012. This is because for every increase in total capacity, the corresponding increase in a specific category (e.g., undergraduates) must be spread over the years it takes a student to graduate. In other words, an increase in say, undergraduate students must be distributed sequentially through increase in admission which then spreads over into increase in first year, then second year and finally third year students.

5.2 Staff establishment

Staff establishment is influenced by several factors including recruitment policies (how fast should it be done if the need arises), staff development policies, level of students' enrolment, and nature of graduate training. The resultant effect of these factors creates avenue for part-time staff and full-time staff recruitment choices. Full-time staff are recruited based on established ratios of staff in the categories of teaching assistants to professors. As depicted by Figure 13, full-time staff with PhD (lecturer) follows stable growth which is comparable with reference mode (Figure 4c-graph1). This behavioural trend is supported by two factors in the model, first, the fact that assistant lecturers (graph2) who complete training become lecturers (compare with rise in graph1 between 2003 and 2006). Secondly, the number of lecturers grows due to recruitment of new full-time staff (Figure 15-graph1). The behaviours of graph2 and graph3 correspond respectively with reference modes Figure 4c-graph2 and Figure 4c-graph3.

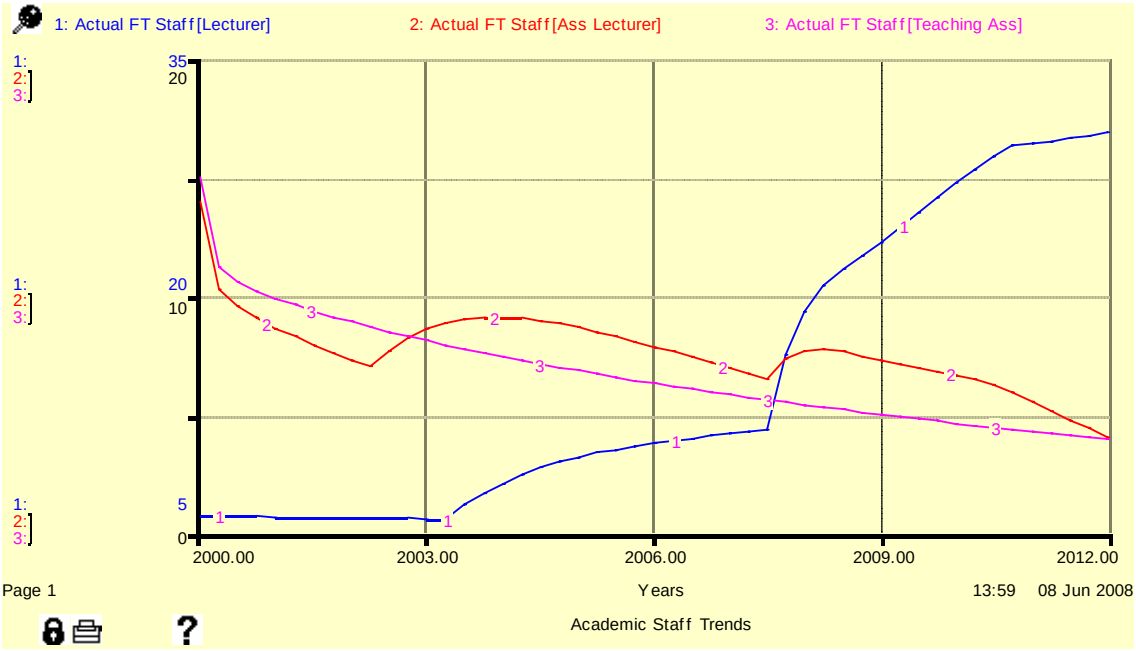


Figure 13: Staff Establishment Trends

As depicted by Figure 13, graph2 and graph3 are generally falling because they correspond to the category of staff that still need further training. As such, depending on the availability of training funds, the total capacity of these staff decreases dynamically. It is specifically noticed that as graph3 falls steadily, graph2 follows a different pattern, which is justified by the scenario of teaching assistants (graph3) becoming assistant lecturers (graph2) after training.

5. 3 Research and Publications

Research output in terms of publications is generally low partly due to un-favourable funding policy where the highest allocations for research are 1.1% and 0.4% for public and private

universities respectively. Therefore for research to thrive, it must have a separate channel of funding, as depicted in the dynamic hypothesis (Figure 5). Specifically, low publications arise from few research projects run by a faculty or an academic unit irrespective of the quality/qualifications of academic staff. Considering publications from a section of staff (Assistant lecturers to senior lecturers) against ongoing projects as shown in Figure 14, it is observed that the actual staff publications of academic staff can be boosted by publications due to executing projects (graph 4).

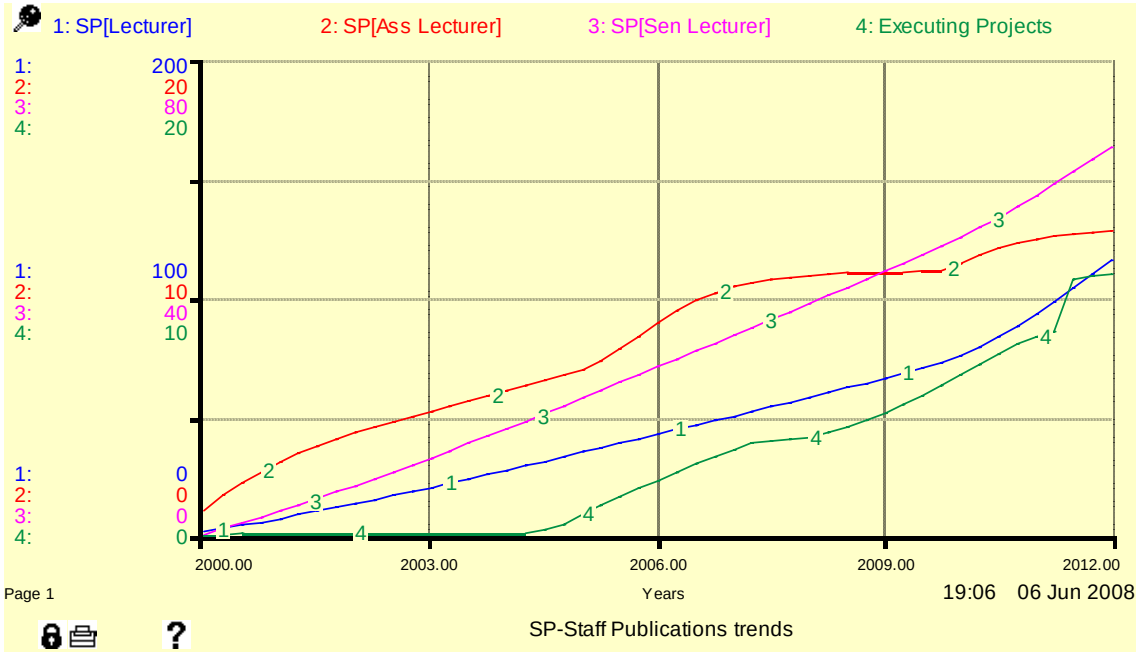


Figure 14: Research Publications Analysis

It shouldn't be unrealistic to argue that more research funding be allocated from tuition which is claimed to be constrained by overlapping high priority demands since research is equally top priority. Furthermore, for research and publishing to be strengthened, governments, major donor institutions, NGO's, and bilateral organisations should and must demonstrate their willingness to invest in research that meets the needs of the immediate society. In return the universities need to develop a culture of aggressive research prospecting while strengthening graduate training base. Only then will the graphs in Figure 15 have a larger positive gradient and hence greater research performance.

6. Policy Analysis

Exploring the effects of policy changes and experimenting with alternative policy formulations is not feasible in the real world. On the other hand, the relationship between funding and quality in HE is difficult to delineate since no ideal funding system exists yet determinants and manifestations of quality are diverse and complex. The tool (simulation model) described in this paper, however, integrates the main sectors that underlie this relationship thereby offering ways to test policies in the context of quality improvement

through explicit income and allocations system. Three fundamental policy experimentations are discussed in this section:

First: Achieving optimal academic staff numbers

The interplay between part-time and full-time staff as elaborated in section 4.5 creates a gap between the desired and the actual staff to students' ratios. This gap arises because of policies aimed at reducing expenditure on staff emoluments. As such, recruitment of part-time staff which is on the basis of available teaching load rather than the established staff to student ratios alongside fewer full-time academic staff is favoured. As a result, effective teaching, evaluation of students performance, and students' research projects supervision are compromised. While it is not possible to accurately measure attributes in the latter statement, focusing on specific indicators is a viable starting point. Equation (iii) as given in the previous section suggests that this gap in staff numbers, also referred to as "staff capacity indicator" in this paper, can be explored using an exponential function. The resulting behaviour of staff capacity indicator with its dependencies is shown in Figure 15.

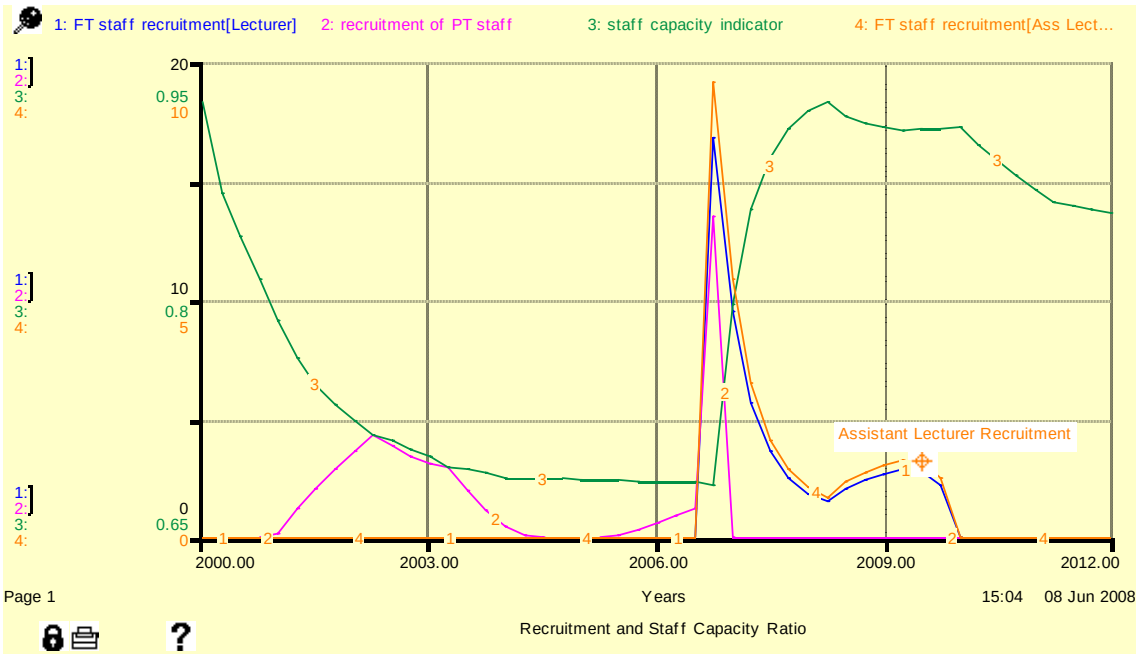


Figure 15: Dynamics of staff capacity indicator and its basic dependencies

It is observed that as enrolment of students rises (Figure 12) and a fraction of full-time staff without PhD qualification enrol for further training (Figure 13-graph2 and graph3), new staff to match the increasing student numbers must be recruited. However, due to cost minimisation issues, part-time staff are employed (Figure 15-graph2) resulting into gap in staff numbers as depicted by graph3-Figure 15. When new full-time academic staff are employed in the seventh year (graph1 and graph4 in Figure 15) subsequently part-time staff recruitment becomes zero and staff capacity indicator rises. The slight fall in staff capacity indicator after 2010 is due to further staff development (Figure 13-graph2 and graph3)

leading to overloading of available full-time staff, in this case without recruitment of part-time staff.

If staff capacity indicator is a good measure for optimal staff numbers given available students' capacity, then paying attention to its dynamics enhances quality of service provision (teaching, students' assessment and projects supervision) by a university's academic unit. Although recruiting full-time staff boosts staff capacity indicator and should yield optimal academic staff capacity, this only applies when the recruited staff all hold at least a PhD. On the other hand, if a fraction of the recruited full-time staff lack the minimum qualification of a PhD, subsequent pursuit for further training definitely lowers full-time staff numbers rendering optimal staff capacity unattainable even at ideal budgeted allocations.

Second: Enhancing students' outcomes

Measuring students' outcomes quantitatively is risky and only ignites unending debate. However, devising new logical approximations to quality of students' outcomes should not be hindered in the interest of consensus. Along this perspective, we attempt to measure quality of students outcomes as the mean effect of undergraduate quality and graduate quality or quality of students thesis. Graduate quality is approximated from students' publications index as already discussed, while undergraduate quality is obtained as the product of staff capacity indicator and observed undergraduate quality (Q_u). The latter is computed from the available percentage grading of undergraduate scores as follows:

$$Q_u = P_u(1+P_p) + \frac{P_l}{(1+P_l)} \quad \text{iv}$$

Where

Q_u is the indicated quality of undergraduate
P_u is percentage of students with first class and second upper degree
P_l is percentage of students with second lower degree
P_p is percentage of students with pass degree

The behavioural outcomes for the quality considerations are given in Figure 16.

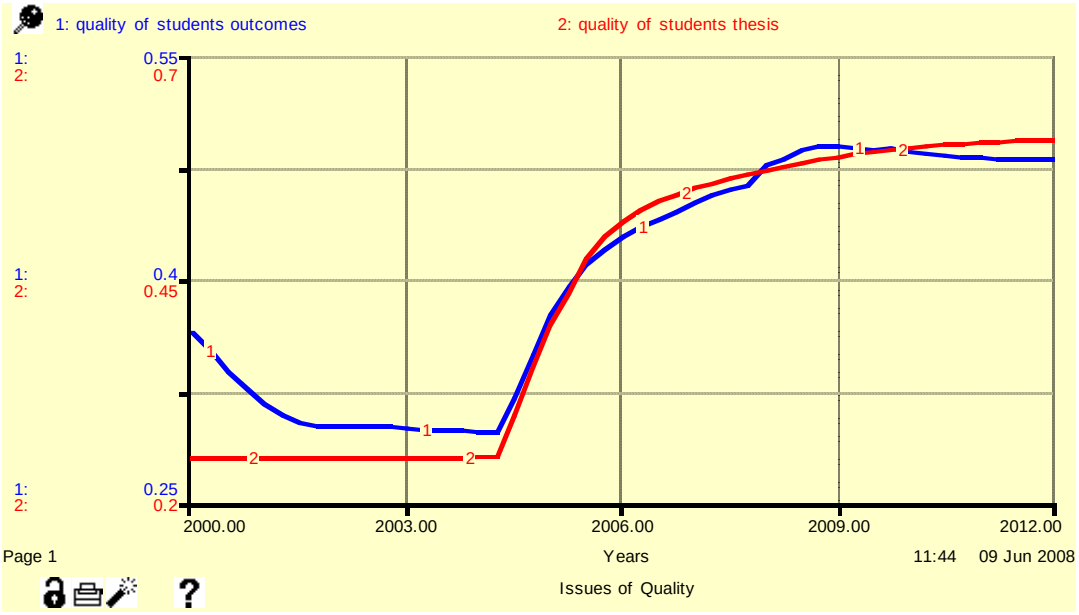
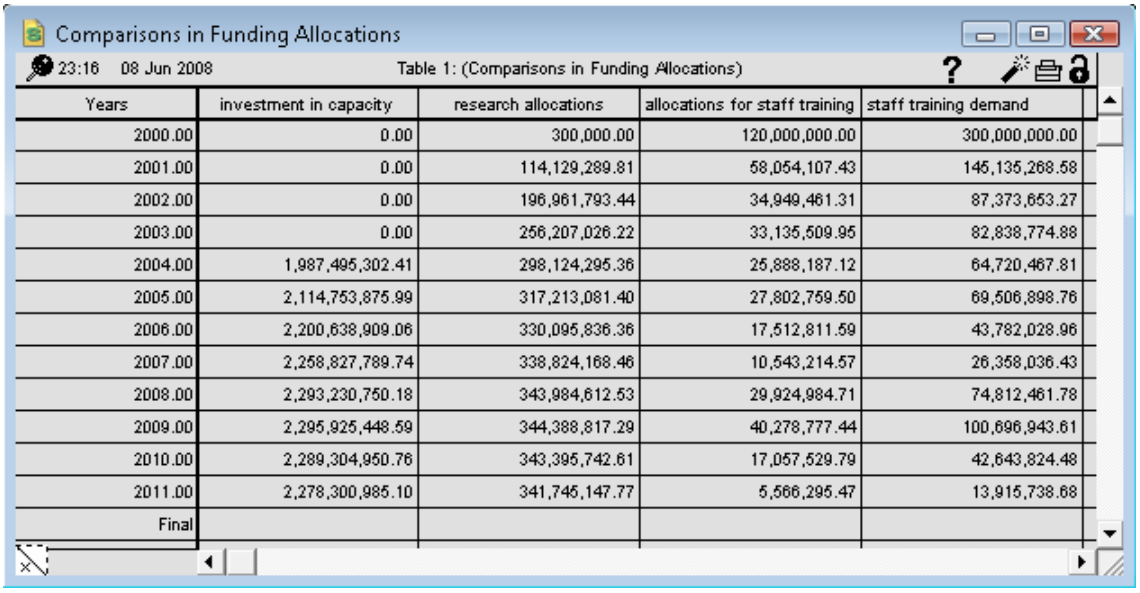


Figure 16: An estimation of quality of students' outcomes

As observed in Figure 16, the quality of students' thesis before 2004 is constant, corresponding with graduate students training as given in Figure 12 (graph2 and graph3). If the graduate students' admission ratio is raised while keeping other parameters constant, then several positive effects on different quality dimensions arise. These include: improved research output in terms of publications, higher quality of staff recruited (cf. section 4.5), increased availability of funds since tuition fees for graduate training is higher, and ultimately quality of students' outcomes in Figure 16 will be higher.

Third: Seeking improvements in allocations of available funds

Prioritisation of available funds is a major problem in the Ugandan universities. Due to high demand for HE training, budget allocations on paper do not match the outcomes as allocations for expansion implicitly have top priority. Table 1 compares simulated funds allocated to expansion with those allocated to staff training/development and research. The allocations to staff training and research are calibrated ratios from our survey and National Council for Higher Education (2006) figures. From both sources, no explicit ratios are attached to expansion (investment in capacity) yet evidence of expansion is the norm in all universities. The results depicted in Table 1 arise from model parameter in which expansion is 4% of tuition revenue above eight hundred million Uganda Shillings and hence zero investment before 2004. Despite these restrictions, the investment in capacity shows greater preference over staff development and research combined. This arises because training allocation is 40 percent of training demand while research allocation is 0.6 percent of tuition revenue as per the operational budget allocations.



Comparisons in Funding Allocations

23:16 08 Jun 2008 Table 1: (Comparisons in Funding Allocations)

Years	investment in capacity	research allocations	allocations for staff training	staff training demand
2000.00	0.00	300,000.00	120,000,000.00	300,000,000.00
2001.00	0.00	114,129,289.81	58,054,107.43	145,135,268.58
2002.00	0.00	196,961,793.44	34,949,461.31	87,373,653.27
2003.00	0.00	256,207,026.22	33,135,509.95	82,838,774.88
2004.00	1,987,495,302.41	298,124,295.36	25,888,187.12	64,720,467.81
2005.00	2,114,753,875.99	317,213,081.40	27,802,759.50	69,506,898.76
2006.00	2,200,638,909.06	330,095,836.36	17,512,811.59	43,782,028.96
2007.00	2,258,827,789.74	338,824,168.46	10,543,214.57	26,358,036.43
2008.00	2,293,230,750.18	343,984,612.53	29,924,984.71	74,812,461.78
2009.00	2,295,925,448.59	344,388,817.29	40,278,777.44	100,696,943.61
2010.00	2,289,304,950.76	343,395,742.61	17,057,529.79	42,643,824.48
2011.00	2,278,300,985.10	341,745,147.77	5,566,295.47	13,915,738.68
Final				

It clear from Table 1 that if staff development and research are prioritised over expansion, then income from tuition can significantly improve these sectors. On the basis of these revelations, although funding in the Ugandan universities viz. universities in developing countries may be perceived as inadequate, the priorities placed on the available funds deter the impact these funds should have on quality.

7. Concluding Discussion

The relationship between funding and quality in HE which is the focus of this paper is difficult to delineate since no ideal funding system exists yet determinants and manifestations of quality are diverse and complex. By all measures, this paper has demonstrated that the dynamics of HE funding and quality issues, escalated by the nature of quality in terms of its non-linearity, complexity and feedbacks, can be appropriately studied using system dynamics. In presenting the system dynamics tool (simulation model) in this paper, we concur with Sterman (2002) who maintains that simulation is essential for effective systems thinking even when faced with a "mess" rather than a well-structured problem. Quality itself is not structured since it is influenced by factors across the structured to unstructured problem spectrum. While only a few behavioural outcomes are discussed, more comparative analysis of simulation results for different scenarios e.g. faculties with undergraduate training only, those without other internal sources of income, those with the lowest research funding priority, those with high part-time academic staff, etcetera, can be done. As such, more policies for quality improvements can be tested.

The findings in this research are not specific to Uganda or the developing countries as the interactions between funding and quality are widely generalisable. In summary, two policy lessons can be derived:

First, how can exponential growth in student numbers as depicted by model's results and reference behaviour be controlled? Although exponential growth is justified by the fact that universities are inadequately funded and hence large enrolments compensate funding needs,

the rise in enrolment undermines any university's capacity to maintain quality. Whereas there may be no immediate solutions to high enrolments, however, prioritising incomes from sources other than tuition to research and staff development obviously increases quality of staff, and volume and quality of research while reducing funding allocations to new students' capacity and hence the rate of growth in enrolment irrespective of the demand levels. Furthermore, seeking optimal students' enrolment at improved quality and cost of increased but justifiable tuition is self sustaining due to globalisation. This is confirmed by Williams and Van Dyke (2007) who assert that: due to globalisation, today's students, employers, and academics demand for indicators of international academic standing of universities in order to make decisions about where to study, whom to employ, or where to seek professional expertise.

Secondly, it shouldn't be unrealistic to argue that more research funding be allocated from tuition which already is constrained by overlapping high priority demands since research is equally top priority. On the other hand, for research and publishing to be strengthened, governments, major donor institutions, and bilateral organisations should and must demonstrate their willingness to invest in research that meets the needs of the immediate society while addressing relevance of university training. Only then will universities be empowered to develop the culture of aggressive research prospecting while strengthening graduate training base and ultimately achieving the dual aim of teaching and research.

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