What limit the research productivity of universities? A case study of a Chinese university

Zhenping Zhang[1, 4], Haiyan Yan[2], Jiayin Qi[3], Enzo Bivona[4], Jinghua Xiao[1]

1 School of Science, Beijing University of Posts and Telecommunications

2 School of Management, Shanghai University of International Business and Economics

3 Institute of AI and Change Management, Shanghai University of International Business and Economics

4 Department of Political Sciences, University of Palermo

Abstract: In the era of knowledge economy, university plays an important role in the development of community. Generally, universities are responsible for three missions, i.e. teaching, research and social service. Among them, research lies at the centre, which provides latest intellectual products for teaching on one hand, and supports social service with advanced practices on the other hand. Critical and influential as it is, after investigation we found that the research productivity of the leading research universities in China is quite stable and thus may not meet the expectation of stakeholders. To address this issue, first we conduct an unstructured interview to conclude the limiting factors and a causal loop diagram is built. Then a simulation model is developed and alternative polices are tested. It is founded that there are four limits to growth structures in the system, which help to explain the stagnant performance of research productivity. Based on sensitivity test and analysis of implementation cost and risk, we suggest university to provide trainings and supports to shorten the assimilation time and to increase maximal recruitment rate to response to the requirement of teaching and projects more promptly.

Key-words: knowledge economy, university performance, research productivity, limits to growth, policy

1. Theoretical framework

1.1. Unstructured Interview and Causal Loop Diagram

First, model boundary is set by the research mission of university. As discussed above, in this paper, we focus on research productivity, therefore the structure of the other two missions, i.e. teaching and social service, is treated as exogenous factors.

Second, we conducted an unstructured interview with faculties. Our interviews focus on three questions, i.e. what is the motivating factors? What are the difficulties? And how will you overcome that in the future? Five faculties participated in our interview and the findings are summarized in Table 3. The interviews show that, workload, time, funding and collaboration are the most critical factors for improving research productivity.

At last, we trace back through the cause and effect chain to close the loop. The number of high quality publications can be calculated by the product of number of faculties and average productivity. Begin from this, we close the loop by investigation of recruitment policy and the critical factors of research productivity. The causal loop diagram can be seen in Figure 2.

There are 4 reinforcing loops and 6 balancing loops. The links of loop and related dynamics is introduced as following:

- R1 Workforce adjustment (Faculty-Publications-Projects-Desired Workforce-Recruitment-Faculty): when number of faculty increases, publications increase, which enable more projects, more faculties are required, and recruitment is adjusted to close the gap between desired workforce and current faculties.
- R2 Funding support (Research Productivity-Publications-Projects-Funding per Faculty-research productivity): when research productivity increase, publications increases, projects increases, more funding are distributed, higher funding per faculty in turn increase research productivity.
- R3 Work input (Research Productivity-Publications-Projects-Research Workload-Research Productivity): Research productivity is driven by more research workload.

Table 1 Summary of unstructured interviews

Faculty No.	Motivation factors	Difficulties	Future Plan
1	Pressure from yearly or monthly performance evaluation, promotion, academic career development	Lack of time	More input of research time, collaborate with other researchers
2	Personal interests	Lack of innovation	More investigation and experiment
3		Too much teaching workload	
4	Personal development	Limit on publication journal list, daily things	Reduce the time for teaching and sundries
5	Performance evaluation, co-operators' achievement	Lack of collaboration and research funding	More collaboration and research time input

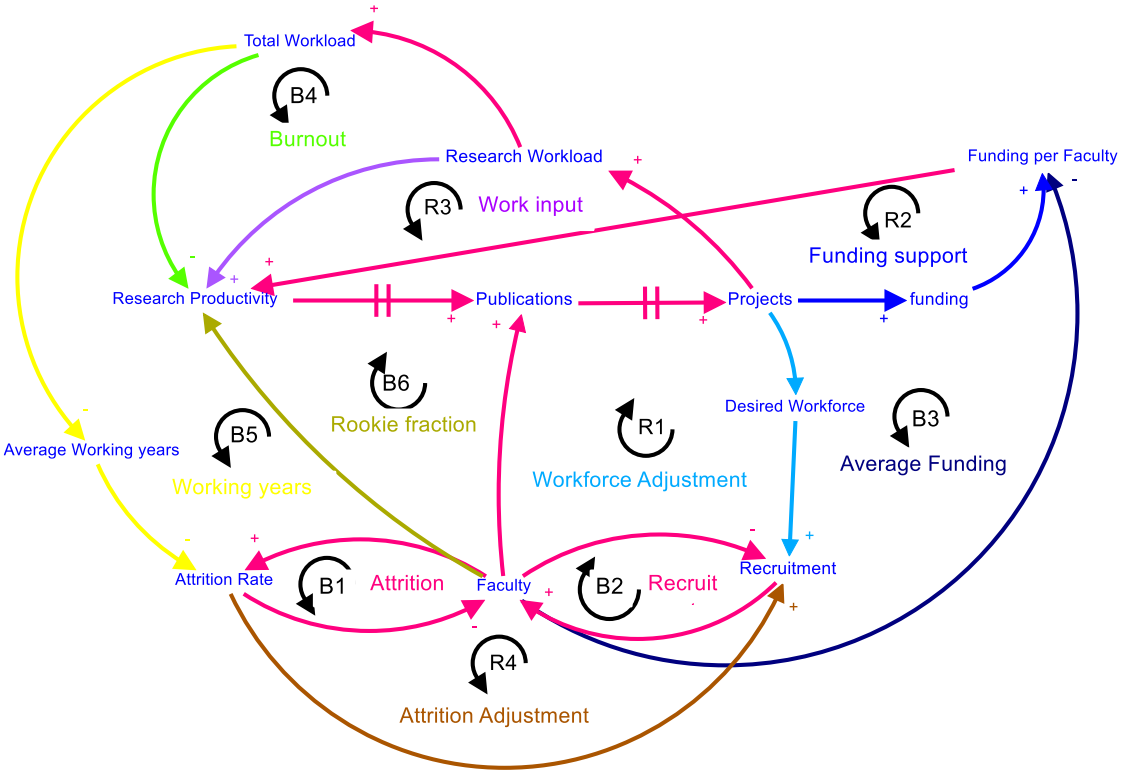

Figure 1 Causal loop diagram of research system in university

- R4 Attrition Adjustment (Faculty-Attrition Rate-Recruitment-Faculty): when attrition increase, recruitment is also increased to fill the gap, faculty increases.
- B1 Attrition (Faculty-Attrition Rate-Faculty): The higher the number of faculties, the higher attrition rate, which limits the growth of faculties.

- B2 Recruitment (Faculty-Recruitment-Faculty): when number of faculties is high, recruitment is decreased, which limit the growth of faculties.
- B3 Average funding (Research Productivity-Publications-Projects-Desired Workforce-Recruitment-Faculty-Funding per Faculty-Research Productivity): Average funding is decreased because of the recruitment of faculty, which decreases research productivity.
- B4 Burnout (Research Productivity-Publications-Projects-Research Workload-Total Workload-Research Productivity): research productivity is decreased because of high total workload.
- B5 Working years (Faculty-Publications-Projects-Research Workload-Total Workload-Average Working Years-Attrition Rate-Faculty) Limit of faculty growth because of shorter average working years, which increases attrition rate.
- B6 Rookie fraction (Research Productivity-Publications-Projects-Desired Workforce-Recruitment-Faculty-Research Productivity): Limit of research productivity because when recruitment help to increase faculty number, the rookie fraction also increase, and in turn research productivity decrease.

1.2. Stock and Flow Diagram

Our model begins from the aging chain of faculties. As Figure 3 shows, there are two kinds of stocks, rookies and professors, rookies are new recruited young faculties, and professors are experienced researchers, after some time professors retire and exist the system.

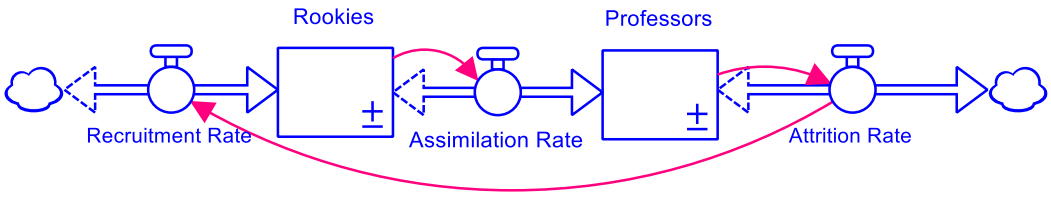

Figure 2 Aging chain of faculties

The other two stocks are actual research productivity and accumulated publications. When the funding or workload change, research productivity doesn't change immediately but take some time to adjust towards indicated research productivity. Similarly, not all of the accumulated publications can help to apply the

projects, only publications in the past few years are influential.

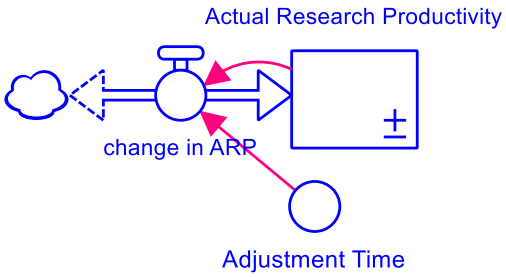

Figure 3 Actual research productivity

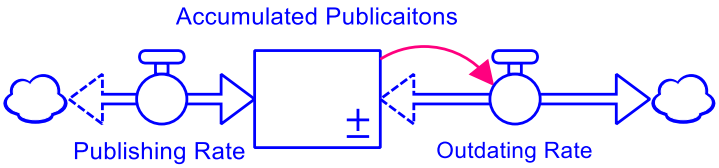

Figure 4 accumulated publications

Based on the stocks and the causal loop diagram, a stock and flow diagram is built. For example, recruitment of rookies increase the number of total researchers and then yearly publications increase, which leads to more projects. Some parameters are estimated based on historical data from the annual report of ministry of education of China. For example, the normal research productivity is estimated by average research productivity over the last ten years. And the others are calibrated based on deduction or assumption. Detailed information about the setting of model, parameter estimation and calibration can be found in model documentation in the appendix.

2. Model Analysis

2.1. Causal Loop Diagram Analysis

Limits to growth structure is very common in the social system, in which a reinforcing (amplifying) process is set in motion to produce a desired result. It creates a spiral of success but also creates inadvertent secondary effects (manifested in a balancing process) which eventually slow down the success (Senge, 1991). There are four limits to growth structure in the system. As Table 4 shows, for every reinforcing loops driving the development of university, there are some balancing loops counteracting the effect. For example, the workforce adjustment R1 can increase the number of faculties, but B6 counteracts by increasing rookies fraction which decreases research productivity.

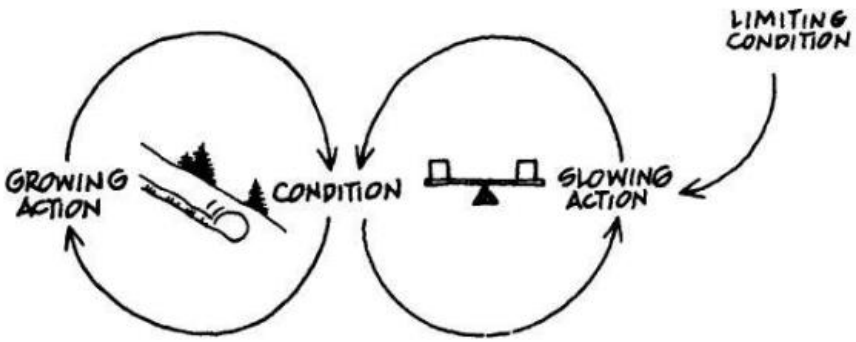

Figure 5 Limits to growth (Senge, 1991)

Table 2 Limits to growth structure in research system of university

Substructure	**Reinforcing Loops**	**Balancing Loops**
Workforce adjustment	R1 workforce adjustment	B6 rookie fraction
Funding support	R2 funding support	B3 average funding
Work input	R3 work input	B4 burnout、B5 working years
Attrition adjustment	R4 attrition adjustment	B1 attrition、B2 recruitment

To some extent, these limits to growth structures can help to explain the stability of research productivity of universities. When policies are made and implemented, the effect of balancing loops should be considered and alleviated to achieve expected policy goals. As suggested by Senge (1991), with the limits to growth structure, it is useless to push the reinforcing loop without alleviating the balancing loop, thus possible policies can be addressed to overcome the effect of balancing loops. For example, increase knowledge sharing and career development to help rookies to learn faster, which help to overcome the effect of B6. These structures also suggest some policy levers that need to be tested in the simulation model.

2.2. Stock and Flow Diagram Analysis

Base run and reference mode. Replication of reference mode can build confidence in the model. Two reference mode are compared with simulation result. As Figure 7 and Figure 8 show, the model can mimic the general trend of historical development, however, there are some randomness in the reference mode, which needs further examination. Especially in Figure 8, there is a big oscillation in the high quality publications. After investigation, we found that in 2011, an intensive incentive policy

is executed which leads to the oscillation.

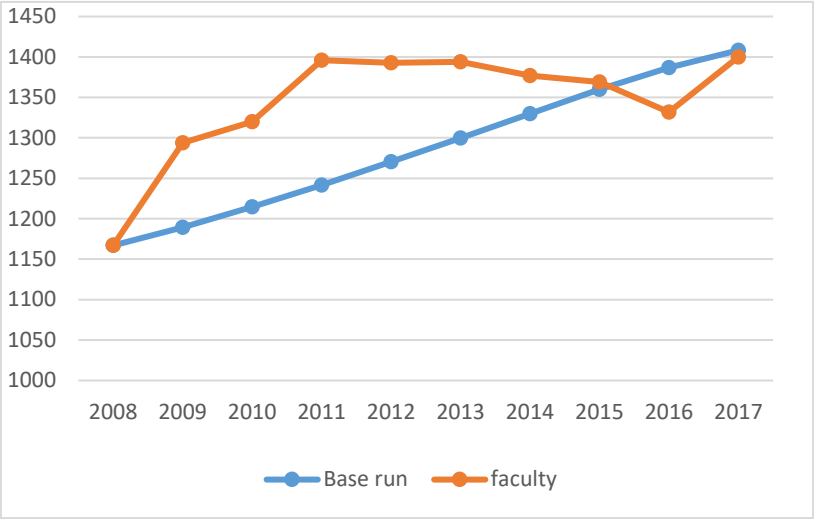

Figure 6 comparison of base run and reference mode of faculty

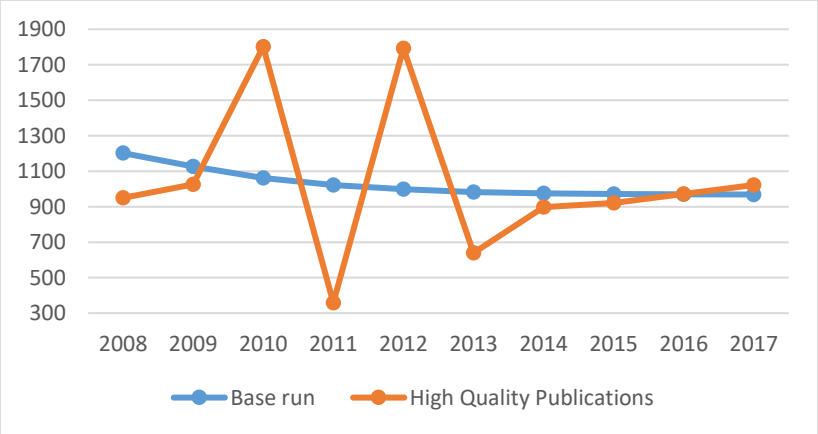

Figure 7 comparison of base run and reference mode of publications

Structure sensitivity. It is not clear whether it is the yearly publications or average publications over the previous years that contribute to the projects. Thus, we add a control structure to compare the effect of the structure. As Figure 9 shows, the simulation result of publications are almost the same. Thus the model is not sensitive to variation of this structure.

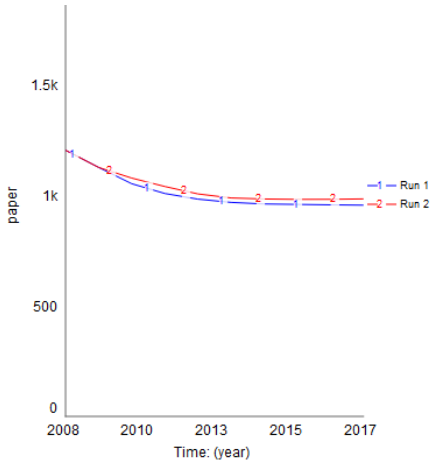

Figure 8 Switch control of yearly publications and average publications (run 1-yearly publications, run 2 average publications)

Parameter sensitivity. Parameter sensitivity analysis can help to test the stability of the model and also contribute to finding some possible policy levers. As Figure 10 shows, the behaviour modes are similar. Regarding the sensitivity, the model is sensitive to the change of teaching pressure and not sensitive to maximal recruitment and influence period of publications. The other three parameters' effect are moderate.

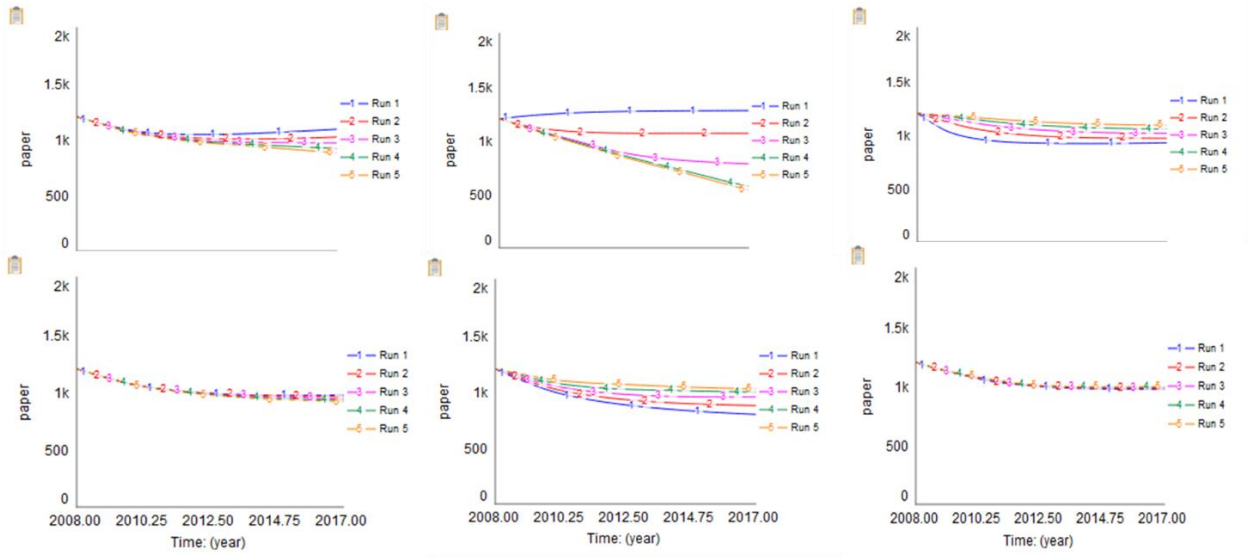

Figure 9 Sensitivity test of critical parameters (upper: Assimilation time, teaching pressure, Adjustment time of research productivity; lower: recruitment time, maximal recruitment, Influence period of publications)

3. Discussion and Conclusion

Research productivity is crucial in the evaluation of university performance, which

contributes to the development of knowledge and community. However, we found that the research productivity of the leading research universities in mainland, China, was quite stable and didn't improve overtime. Thus, it is very important to investigate the limiting factors and underlying structures.

First we conducted an unstructured interview and built a causal loop diagram. The interview showed that excessive workload, deficiency of time and lack of funding and collaboration are the main limiting factors. There are four limits to growth structure in the causal loop diagram. For every reinforcing loop there are 1 or 2 balancing loops counteracting the effect. This helps to explain the stagnant performance of research productivity in universities on one hand, and suggest possible policy levers on the other hand.

A stock and flow diagram is built based on the causal loop diagram and the historical data from the annual report of ministry of education. Behaviour and structure analysis is conducted. After that we test the sensitivity of possible policy levers. Based on the sensitivity test, we add the cost and risk to analyse the attractiveness of possible policy levers（table 5）. The cost of changing teaching pressure is high, as it is very difficult to cut courses and the cost of adjusting recruitment time is low. The others lie in the middle. Based on these two aspects, the suggested policy levers are assimilation time, maximal recruitment and adjustment time of research productivity. All of them are of high sensitivity and middle cost and risk. The others are deleted, either because of high cost or low sensitivity. Possible way to decrease the assimilation time is to provide more training and funding support for young faculties and to provide incentives for the development of research skills and experience. Increasing the maximal recruitment time helps to response to the requirement of teaching and projects in time and improve the performance. Adjustment time of research productivity depends on the efficiency of the facility and administration, which demands better academic environment and administrative service.

Table 3 Sensitivity, cost and risk of policy levers

Policy Lever	**Sensitivity**	**Cost and Risk**
Assimilation time	High	Middle
Teaching pressure	Very high	High
Recruitment time	Low	Low
Maximal recruitment	High	Middle
Adjustment time of research productivity	High	Middle
Influence period of publications	Low	Middle

However, because of the use of methods and modelling process, there are some limitations in our study. First, we focus on the research of the university, taking teaching and social service as exogenous part. Indeed these three missions are close related and there are important interplays among them (Zhang et al. 2018). Second, our simulation time is 10 years, from 2008 to 2017, which is not long enough to reveal the long term trends and dynamics. Third, we simplify the decision rules of the model, some of them needs to be examined further. Besides, our policy can only lift up the equilibrium level rather than change the behaviour mode. Future research can take the other two missions into account and extend the modelling time zone, and also test different decision rules to find possible tipping points and policies.

Please check this link for full paper:

https://www.researchgate.net/publication/336672498_What_limit_the_research_productivity_of_universities_A_case_study_of_a_Chinese