The Impact of Career and Funding Policies on the Academic Workforce in The Netherlands: A System Dynamics based Promotion Chain Study

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Abstract

The Dutch government bears part of the costs of scientific research conducted at Dutch universities with public funds. The government supports the science system by implementing policies, in the hope of developing a robust academic workforce. However, it is difficult for policy makers to determine the consequences the policies can have on the science system. In this paper, a model is developed that describes the influence of funding regimes and career policies on the workforce development and research output over time. The model is used to conduct policy experiments to analyse the effect of different policies on workforce development and research output. The model results show that an increased focus on indirect governmental funding would eventually lead to a larger temporary workforce, but it also suggests that this change does not necessarily lead to more research output. Results also show that contract policies for temporary researchers do not have the intended effect. Changing contract structures could lead to a different balance but does not decrease the uncertainties in contract accumulation and turnover.

Keywords

Academic Workforce Development, Public Research Funding, Science System Policies

1. Introduction

Academic research and scientific development are some of the main drivers for continued economic growth (Chiong Meza, 2012; Elk *et al.*, 2015; Ghaffarzadegan *et al.*, 2014a). In the Netherlands, the Dutch government bears part of the costs of scientific research conducted at Dutch universities with public funds, through the Ministry of Education, Culture and Science, and the Ministry of Economic Affairs, with the goal of producing research that is useful for society (Versleijen & van der Meulen, 2007). Over the past years the financial support for scientific research and education has been stagnating, even though the number of new students and scientific articles are rising (OCW, 2014). Simultaneously, policies with regard to contract and funding regimes have been enacted to strengthen the research staff in producing high impact research. It is unknown what the effects of these policies and the stagnating funds are on the development of the academic workforce.

Traditionally, academic research was mainly conducted autonomously within public research organisations (AWT, 1999) such as universities. The government provided direct institutional funding to research organisations, on the assumption that funds would be allocated effectively. As

governmental regulation would no longer be detailed, the emerging autonomy gave universities the opportunity to self-direct while being responsible for quality and productivity.

However, academic research is conducted in a growing international and multidisciplinary environment. The necessary funds that enable researchers to conduct their work are obtained from a variety of sources, both public and private, and is increasingly international. The multitude of funding regimes makes it difficult for universities to manage and direct their research body. Additionally, the multitude of funding regimes and career policies makes it increasingly complex to govern the research workforce and provide the right incentives.

This study tries to examine and understand the dynamics of the research workforce development in universities in The Netherlands over time and explores the consequences of changes in funding and policies. One of the main purposes of this research is to clarify the interrelation between funding schemes/policies on the one hand and workforce development and research output in academia on the other. The analysis is directed toward understanding the evolution of academic careers; therefore modelling the dynamics of change in numbers of staff over time is key to this purpose.

The outline of the paper is as follows. Section 2 describes the main mechanisms in the science system that influence the development of the academic workforce. Section 3 describes the use of system dynamics for analysing the science system. Section 4 introduces the main concepts that have been included in the model. Then, in Section 5, the base run simulation and the policy experiments will be shown. Conclusions and recommendations are presented in Section 6.

2. Academic Workforce Development – Population, Funding and Performance

2.1 Workforce Characteristics and Career Progression

Advancing mobility between academic positions is considered as one of the ways to create room for new academic staff (De-Jonge-Akademie, 2010). In The Netherlands, mobility between academic positions is based on a hierarchical structure (Goede, Belder & Jonge, 2014). Especially in the lower positions of the academic career there is a significant amount of mobility. The majority of these people finally find employment outside of Dutch universities, suggesting that there is limited space for a permanent position in academia. Figure 1 shows that the number of PhD degrees have doubled over the past 15 years, which is a remarkable trend when compared to other academic positions which have stayed relatively stable (OCW, 2014).

Academic positions have a specific role in the promotion chain. The postdoc position, which is classified under Other Academic Staff (OAS), is the link between the PhD-researcher and a more independent research position at the university. Within the OAS category, a distinction is made between staff focusing on education, research or secondary tasks. The OAS position is the main gateway to a more permanent faculty position. However, only a small percentage successfully navigates the hurdles of the academic world and acquires a permanent position (De-Jonge-Akademie, 2010; van Balen, van Arensbergen, van der Weijden, & van den Besselaar, 2012). The next stage in the academic career is the one of the independent researcher; the assistant professor. After the assistant professor, the associate is the next stage in the academic career, which is also the most

closed, as only a small percentage moves every year (Goede et al., 2014). The function of the full professor is the highest rank in the academic career ladder and the leader of the research group.

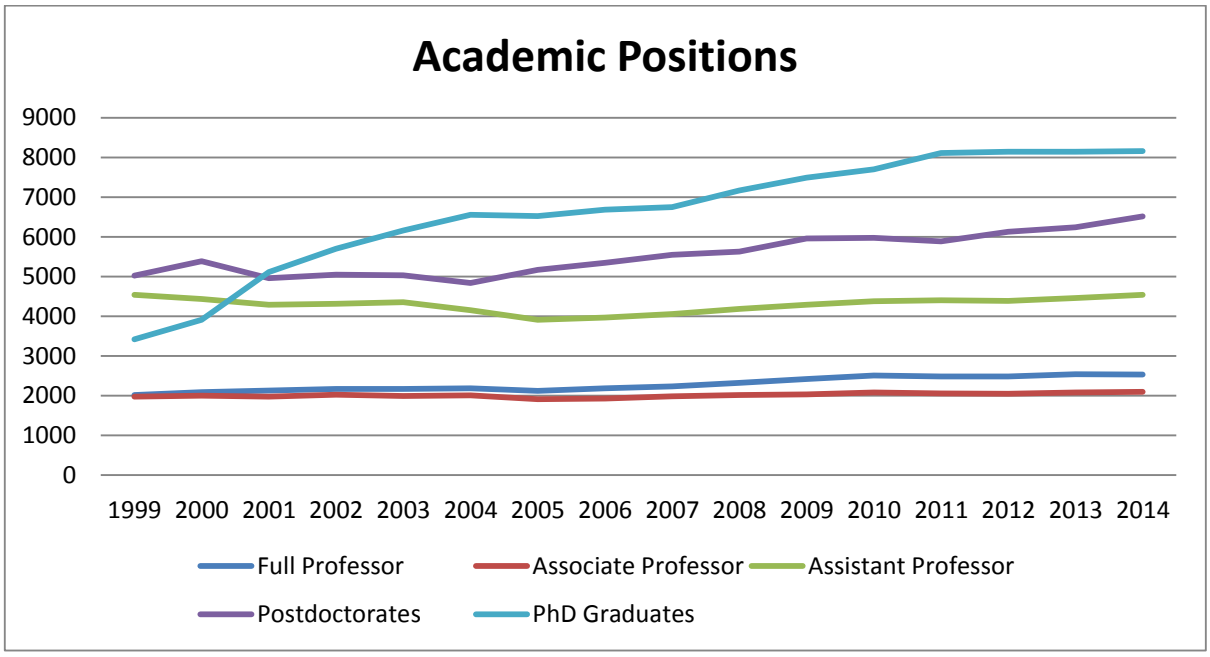


Figure 1 Academic Research Positions in The Netherlands, 1999-2014 (Biomedical researchers are omitted from this graph for consistency reasons and data limitations) (VSNU, 2015)

2.2 Public Research Funding

Important factors in the organisation of the science system are the size, form and organisation of research funding (Benner & Sandström, 2000; van Dalen *et al.*, 2014; Versleijen & van der Meulen, 2007). Universities, as well as individual researchers, base their behaviour in research activities on the availability of funds. Traditionally, public research funds were allocated to universities based on student numbers, as it was deemed sufficient that researchers would allocate the funds themselves, in the hope that it was in the best interests of society (Versleijen & van der Meulen, 2007).

In recent years, a growing part of the public research funds have been allocated via competition by the Netherlands Organisation for Scientific Research (NWO), with the aim of increasing the quality of research and stimulating the research in promising fields. While competition can lead to better research, it could also lead to the underdevelopment of potential research fields (van Dalen *et al.*, 2014).

Presently, four types of funding allocation schemes can be distinguished in the Netherlands: institutional funding (funding that is allocated directly on a lump sum and is calculated based on a number of indicators), competitive funding (funding that is allocated through NOW based on project proposals) contract funding (allocated through public or private parties such as the European Union (EU)), and biomedical funding. These four funding schemes are the backbone of the research funding in the Netherlands.

Figure 2 shows the different funding types until 2019. Note that tertiary funding includes funding from private organisations and that biomedical funding, as biomedical researchers, are not included

in this graph due to consistency reasons and data limitations. This graph shows that, while the total amount of public research funding has remained stable, institutional funding has decreased while competitive funding has increased, which shows a shift of focus.

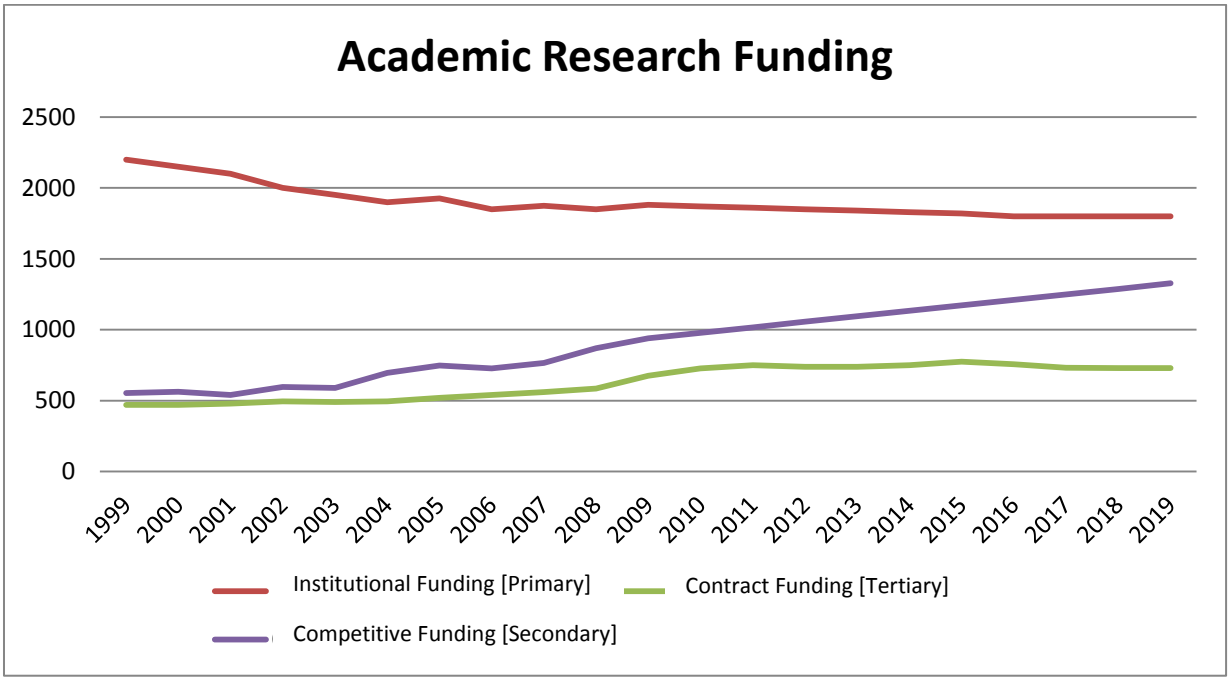


Figure 2 Academic research funding, 1999-2014 (realisation), 2015-2019 (prognoses of primary and secondary funding by the Ministry of Education, Culture and Science) and 2009-2019 (prognoses of tertiary funding by the Association of Universities in the Netherlands), at constant prices (2014), euro*1,000,000 (OCW, 2014; VSNU, 2015).

3. System Dynamics and the Science System

Various SD models on related topics have been developed over the years, mostly covering managerial issues at academic institutions (Kennedy, 1998, 2011; Kennedy & Clare, 1999). Only few of those have covered growth and age structures within universities. Sterman describes a model of academic promotion within universities based on the different stages of the academic career (Sterman, 2000). His work is based on the promotion and exit rates of scientific staff at MIT between 1930 and 1993, in a modelling example of how aging chains within organisations can be used to describe the distribution of persons within a hierarchical system.

Oyo *et al.* (2008) have extended that model by including funding, quality and policy aspects. They assume a causal link between the amount of funding and educational activities, the strategic direction of the research organisation and the produced output. This feedback system, where funding influences the amount of human capital, human capital influences the amount of research output and the level of research output creates the necessary incentives for public and private organisations to invest in research by funding is also one of the main assumptions for this paper. However, their study describes the science system in a developing country with the emphasis on competitive funds which is noteworthy different from the Dutch system (van Dalen *et al.*, 2014).

In a study by Larson and Gomez Diaz (2012), an aggregated SD model was created to analyse the recruitment process within universities based on a non-fixed retirement age. A follow-up study by

Gomez Diaz (2012) described the transition between young researchers and established researchers based on public research funding. This model demonstrated that in dynamic social systems intuitive cause and effect assumptions are not always correct: the public research funding budget increase did not lead to the desired workforce development.

A study by Ghaffarzadegan *et al.* (2014a) shows the workforce distribution among national and international postdocs for biomedical research in the US. The model suggests that international temporary postdocs benefit the most from the increase in research funding. International temporary researchers could move abroad after the contract ends and the accumulated tacit knowledge could be lost. Another study from the same author suggests that graduate diplomas will become less valuable with the increase of PhD candidates (Ghaffarzadegan *et al.*, 2014b).

This paper focuses on the workforce development of researchers at universities in The Netherlands. Data from the Association of Universities in the Netherlands (VSNU) has been used to develop a system dynamics model of the workforce development. The aim of the model is to represent the flows of researchers into and out of the different stages of the academic career, and perceive the effects of career and funding policies on the population and output of the research workforce.

Model simulations are used to conduct what-if analyses of policy alternatives. These include: (1) testing the effects of funding mechanisms, (2) testing the effects of changing the mandatory retirement age and (3) testing the change in temporary contract structure. These tests were identified through discussions with system experts and the examination of the policy note: vision on science published by the Ministry of Education, Culture and Science (OCW) (OCW, 2014).

4. Model Building

Figure 3 represents the different stages of the academic career in The Netherlands. Individuals enter the science system as they are admitted as PhD candidates and move towards a permanent faculty position directly or through a postdoctoral stage. Applicants from outside academia can also be admitted to an academic position. Through this path, a proportion of researchers drop out, while others graduate and find work outside academia. In this study, we will analyse the influence of funding and career policies on inflow, throughput, and outflow of the academic researchers and the effects on research output over time. The time horizon of this study is 1999-2029. In the following sections, the feedback structure and main concepts of the model will be presented.

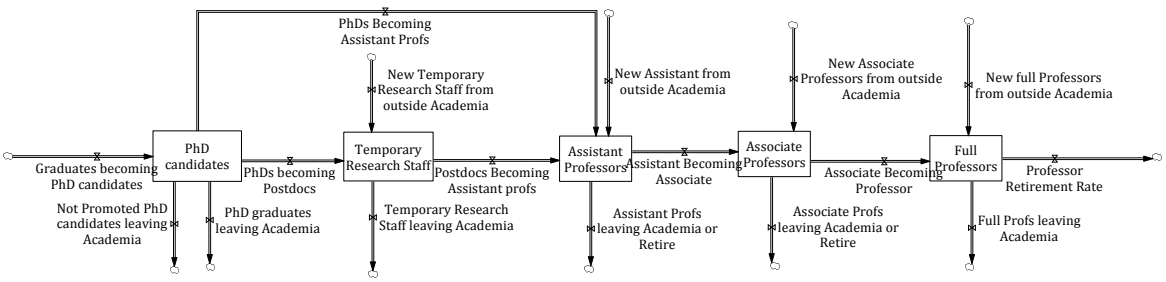


Figure 3 Academic Workforce Development Promotion Chain

4.1 Feedback Behaviour

Figure 4 shows the simplified causal loop model for academic researchers in The Netherlands. Six main feedback loops can be distinguished, which will be explained further below:

Loop 1: Reproduction [growing action]

Academic Staff -> [+] promotion and hiring rate [reproduction rate] -> [+] Academic staff

Loop 2: Funds Availability [slowing action]

Academic Staff -> [-] capacity to hire [amount of funding as the limiting condition] -> [+] Academic Staff

Loop 3: Research Funding Stabilisation [goal seeking action]

Academic staff -> [+] Research output -> [-] Availability of Funds [given Desired Level of Research Output] -> [+] Appointment capacity -> [+] Academic Staff

Loop 4: Demotivation

Academic staff -> [+] Temporary Staff -> [+] Residence Time in Academic Career -> [-] Attractiveness of Academic Career -> [+] Academic Staff

Loop 5: Competition for Funds

Availability of Funds -> [+] Project funds -> [+] Competition -> [-] Research Output [more time applying for funds] -> [-] Availability of Funds

Loop 6: PhD provision

Promotion -> [+] Funds -> [+] Appointment Capacity -> [+] Academic Staff -> [+] Promotions

Feedback loop 1 represents, in combination with loop 2, a limits to growth archetype. Full professors have the opportunity to promote or hire external, non-permanent, members of academia. It is known that this promotion rate in academia is very high, leading to unprecedented growth if there is no system limitation (Ghaffarzadegan, Hawley, Larson & Xue, 2014). In a steady state system this would lead to system saturation; there is no room to absorb new research staff. This loop therefore grows until the system reaches its peak, after which it is halted by external limits of the system: the availability of funds and the capacity to hire which is loop 2.

Feedback loop 3 represents a goal seeking archetype: fostering research and scientific discoveries are the main motivations for the government and private parties to support the science system with funding. The government therefore responds to the call for scientific progress, when there is significant political pressure, by investing in research (Gomez Diaz, 2012; Oyo et al., 2008). If the research budget increases, universities can hire additional staff and expand their overall amount of research activity. If the amount of research output is satisfactory, governments and private parties are less likely to increase the amount of funding that is needed for research (Oyo et al., 2008). However, if the amount of research output is unsatisfactory, a discrepancy between the desired research output and the actual research output fuels the need for additional funds. In this situation these parties will have the incentive to increase their investments. When the discrepancy decreases, the desire for increasing the governmental budget decreases which, over time, stabilises the goal seeking behaviour.

Feedback loop 4 represents the workforce development of temporary research staff and the attractiveness of the academic career. It is the psychological, legal or economic pressure after residing for some time in this position to leave for a position outside academia (Ghaffarzadegan et al., 2014). Temporary researchers cannot stay in academia forever, as these are low paid jobs and do not provide long-term stability. When the residence time of researchers in this position increases they are more likely to face the pressure to leave.

Feedback loop 5 represents the increased competition between researchers when the share of competitive funding will increase. If more funding becomes available through contract or competition structures, more researchers will compete in order to acquire these funds. To secure these funds, researchers will invest more time to apply for these grants. More applications for the same funds will lead to more time writing proposals. As such, researchers find themselves busy with writing research proposals while they refrain from their core research activities.

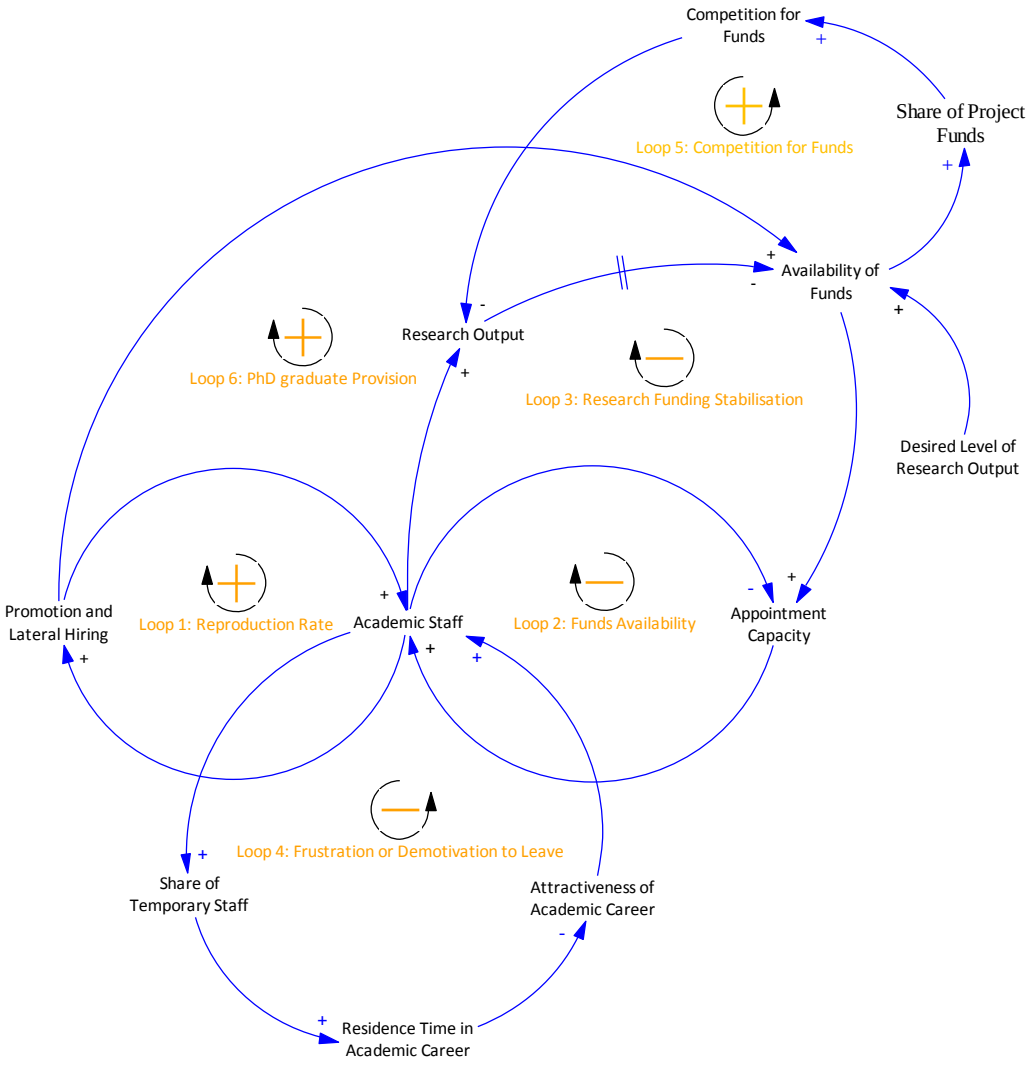


Figure 4 Causal Loop Diagram of Academic Workforce Development

Feedback loop 6 represents the reinforced growth of public research funding through the promotion of PhD candidates. When additional PhD candidates are hired, universities obtain additional funds. This growth is halted by the total amount of funding that is available for researchers. This is one of the main mechanisms causing the increase in PhD staff from 1994 onwards (van Dalen *et al.*, 2014).

4.2 Model Mechanisms

Through system analysis, expert interviews and a comparative analysis of earlier publications on academic workforce development, model mechanisms were formulated that determine the inflow, outflow and promotion of academic staff.

To determine the number of openings for temporary and permanent researchers, a capacity mechanism has been formulated. For the PhD candidates and temporary research staff (TRS), hiring is determined by the openings available due to the exit rate of staff and limited by the capacity. The yearly amount of public research funds, divided by the average researcher costs and corrected by an infrastructure fraction, determines this capacity. The discrepancy between the staff capacity and the number of present staff can be accommodated with new workforce openings.

After the PhD period, some researchers continue in academia. It is reasonable to assume that PhD candidates prefer to acquire a permanent faculty position rather than a temporary position. Based on the likeliness of acquiring a permanent position after a PhD is obtained, some researchers will become permanent researchers.

For the permanent positions the same formulation method is used. The main difference is that now not just the TRS and hires from outside academia compete to get a faculty position but new PhD graduates can also compete for a permanent position. Three groups compete, who all have a different level of competitiveness. While staying longer in academia improves one's curriculum vitae by producing more papers and gaining more knowledge, it will also lead to more uncertainty in promotion opportunity making it more likely for researchers to leave academia (Ghaffarzadegan *et al.*, 2014; Hur, Ghaffarzadegan & Hawley, 2015). To model this uncertainty, researchers within the TRS position will go through three distinct phases to represent the temporary contract accumulation and the effect of coincidence, demotivation and quality on the promotion flow of these phases. The three phases represent the three temporary contracts a researcher goes through hoping to acquire a permanent faculty position. Until 2015, the maximum duration of TRS was six years in The Netherlands. This has recently been changed to 4.5 years. The influence of this new situation will be analysed when we discuss the policy experiments in Section 5.2.

Details of the model formulation, model verification and validation and the behavioural analysis results can be found in Van Kersbergen (2015). The public research funding parameters are considered to be exogenous. Longitudinal data from the Association of Universities in the Netherlands (VSNU) have been used to simulate these variables. While it is better to simulate these variables endogenously, the main objective is to see the effects of funding on the evolution of the academic workforce. This allows focusing on the different stages of the academic career. The model has been developed in Vensim PRO. Observed historical behaviour has been used to test the behaviour of the model. Uncertain parameter values have been calibrated across a reasonable range to obtain a model fit. While the model does not replicate the historical data accurately it does show the same patterns of behaviour (van Kersbergen, 2015).

5. Model Analysis

5.1 Base Run Simulation

The base run simulation results are shown in Figure 5. Figure 5 (a) shows the increase of academic staff and the distribution between temporary and permanent staff over time. It shows that temporary staff increases significantly over time, in comparison to permanent staff, which is relatively stable. This is caused by the focus on competitive research funds, which are more uncertain to obtain. Therefore universities tend to prefer temporary over permanent staff. Additionally, the

amount of institutional funding is declining in favour of private research funds. Figure 5 (b) shows the ratio of this change of focus. Figure 5 (c) shows the turnover of academic staff, which is a representation how often the total research body is renewed. Figure 5 (d) shows the amount of research publications that increases significantly over the years under the influence of the increasing temporary workforce, who conduct research at lower costs. The stagnation towards 2029 is caused by the stagnation of expected private research funds.

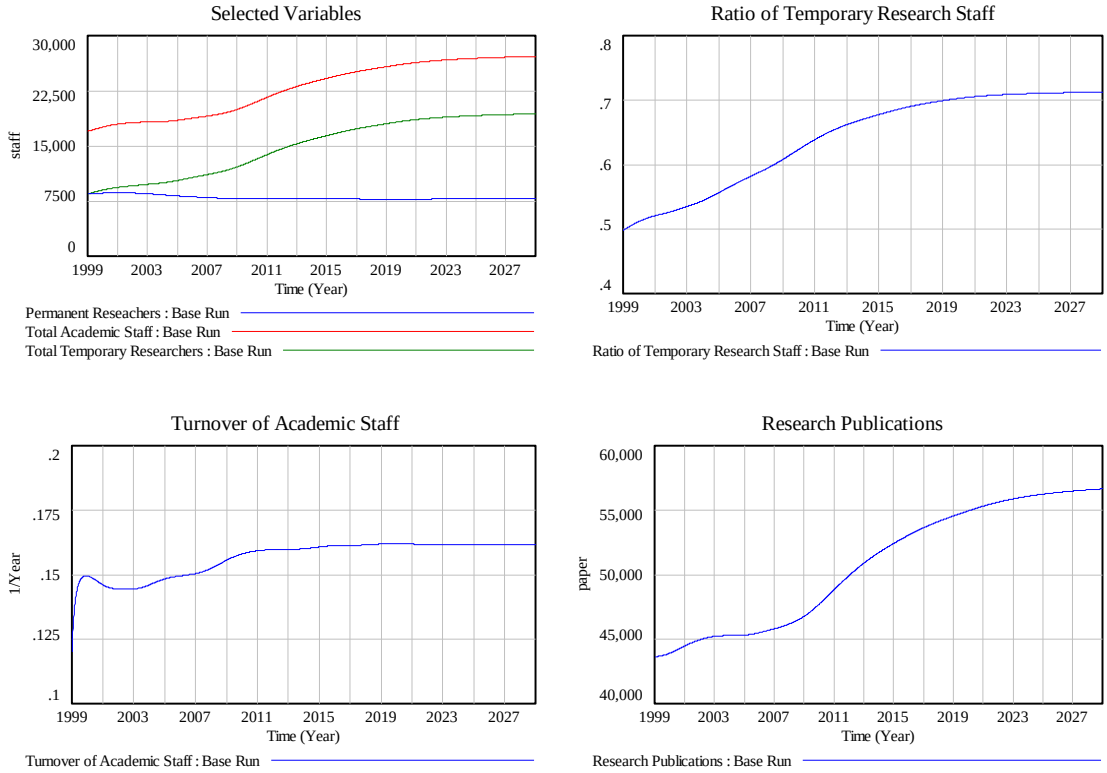


Figure 5 Base Run Simulation Results: (a) Academic Staff, Temporary Staff, Permanent Staff and (b) Ratio of Temporary to Total Staff (c) Turnover of Academic Staff and (d) Research Publications

5.2 Policy Experiments

The model is used to examine the effects of three different policies as shown in Table 1:
(1) focus on competitive funding
(2) the implications of a non-fixed retirement age
(3) capping the duration of contracts of Temporary Research Staff
The + and - signs refer to the variable going up or down. It does not suggest any positive or negative value judgement, which would be dependent on the perception of the system observer.

These tests have been implemented as factual tests, and a comparison is made between the base case and what-if situations if different policies are implemented. Table 1 also summarises the simulation results of the model run, which will be discussed in this section. The operationalisation of the simulation experiments can be found in Kersbergen (2015).

Focus on Competitive Funding

Traditionally the science system in The Netherlands was focused on institutional funding. Nowadays the different funding regimes are distributed over the science system and no form is dominant (van

Dalen *et al.*, 2014). Other academic funding systems, such as the one existing in the US, work primarily with competitive research funding. There, the amount of funding is predetermined and allocated based on research proposals. If the focus of the Dutch government would be in favour of this regime, it could have a substantial impact on the workforce development and research output.

Simulation Experiments	Policy measures				
	Temporary Staff	Permanent Staff	Ratio of Temporary to Permanent	Staff Turnover	Research Output
(1): Focus on competitive funding	+	--	+	+	0
(2): Non-Fixed retirement age	0	0	0	-	0
(3): Capping duration of TRS-phase at 4.5 years	+	0	+	++	0

Table 1 Three simulation experiments and directions of their effects on different policy measures

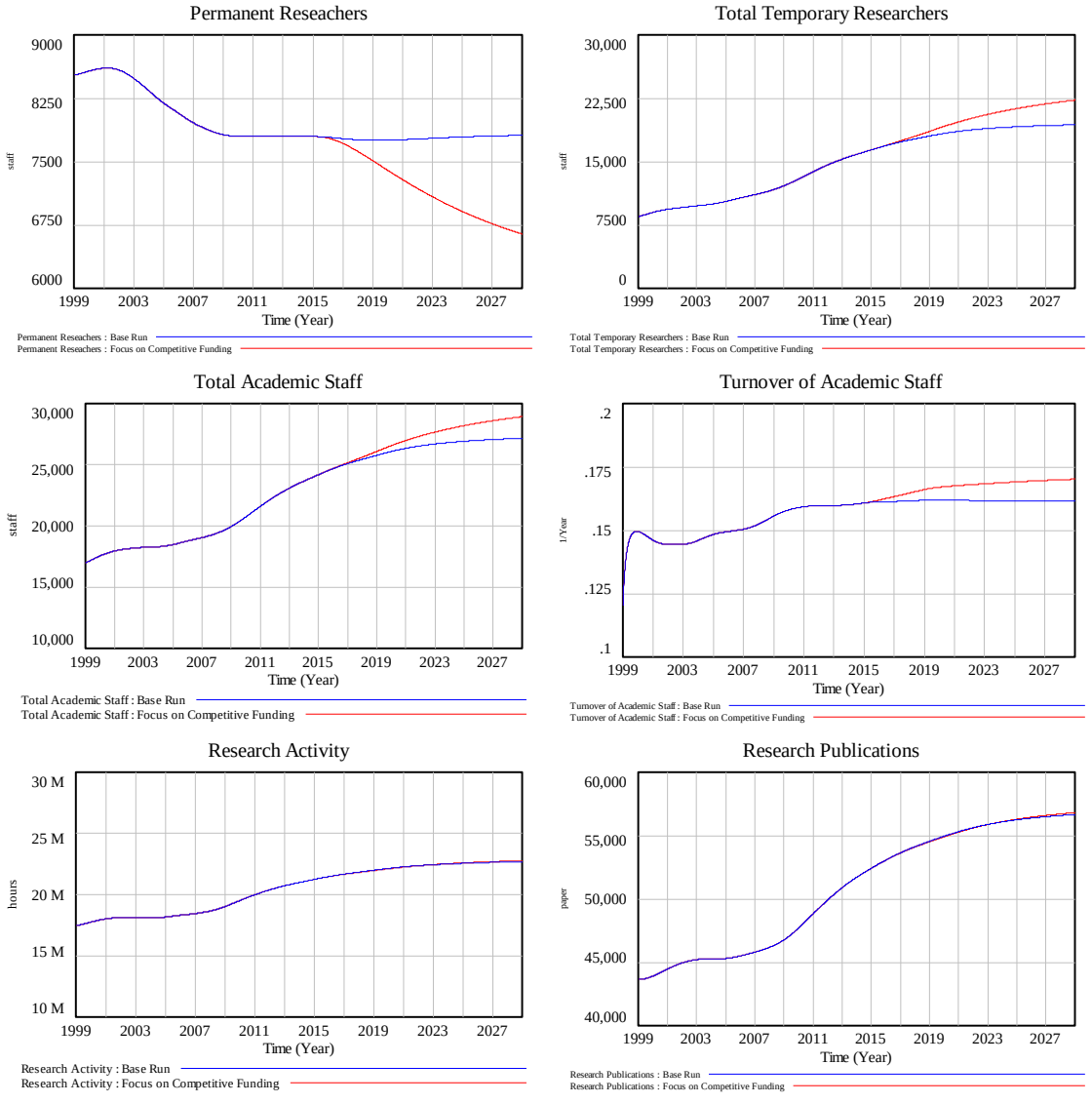


Figure 6 Simulation Results Competition Focus: (a) decrease in permanent researchers (b) increase of temporary researchers (c) increase in total academic staff (d) increase in turnover in academic staff (e) insignificant increase in research activity and (f) insignificant increase in research publications

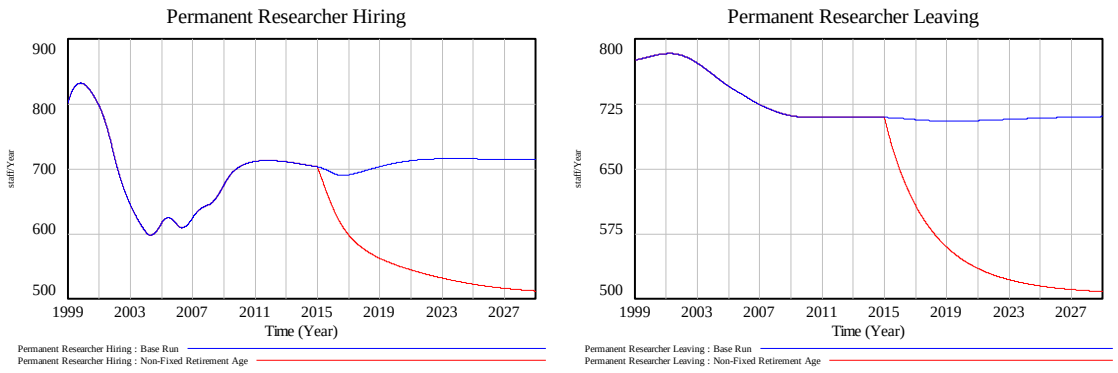
Figure 6 shows the simulation outcomes for this policy experiment. It was expected that more competitive funding leads to an increased focus on temporary staff. Because stipends are lower in temporary staff positions, the total amount of academic staff is increasing. Because temporary staff often works on temporary positions the turnover of staff, the fraction that is renewed on a yearly basis, increases consequentially. However, while this was expected, the increase in staff does not necessarily lead to more research activity of the workforce, which has two reasons. First, temporary research staff is expected to be less efficient in producing research due to inexperience and other obligations (van Drooge & de Jong, 2008). Second, the increase of competitive funds has consequences for the research productivity (Gomez Diaz, 2012). As there are more project funds available, more researchers will compete with each other to acquire these funds. This will lead to a decrease in productivity of researchers as more time is consumed for writing research proposals.

The results suggest that having a more competitive funding structure does not necessarily lead to more output. However, the model is not suitable for testing the quality of the newly produced work.

Non-Fixed Retirement Age

Many permanent faculty members at universities enjoy the rare job benefit of having a contract for life (Larson & Gomez Diaz, 2012). If temporary researchers successfully become a permanent researcher they enjoy job security until their retirement. The only way to leave academia is voluntarily or to retire at the age of 65. However, in many countries the mandatory retirement age has been abolished all together. While this is not the case in The Netherlands, it is wise to explore this effect of a later retirement age, as this is expected in the upcoming years.

The results show that the number of permanent researcher hires start declining in 2010 from around 700 until reaching a new equilibrium around 500. The hiring behaviour reflects the faculty exit rate, which also decreases over time. The number of years researchers stay in a permanent position increases from 24 in 2010 until finding a new equilibrium around 34, a decade after the policy change is initiated. And most importantly, the number of permanent researchers starts to increase once the policy is initiated and then starts to decrease gradually until it returns to the target permanent capacity.



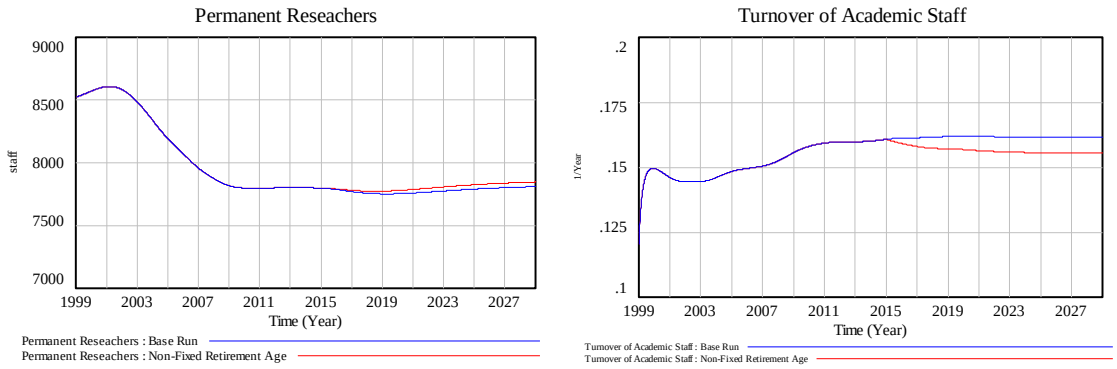


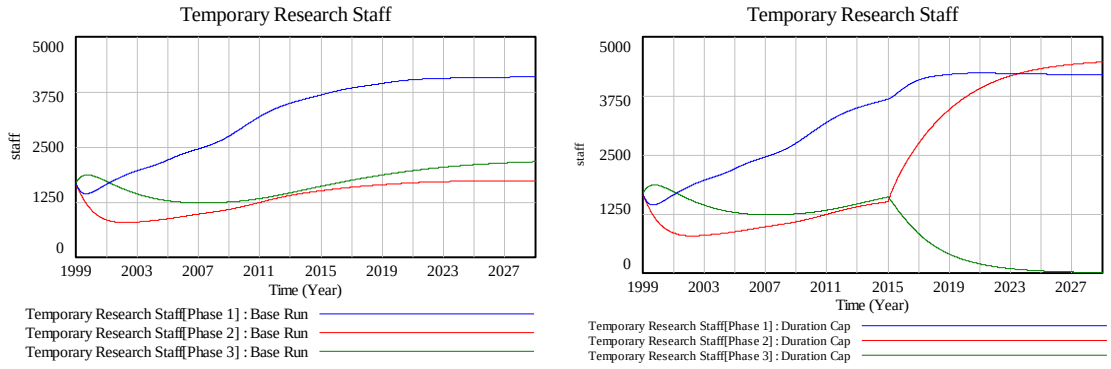
Figure 7 Simulation Results Non-Fixed Age: (a) decrease in permanent researcher hiring (b) decrease in permanent researchers leaving, (c) number of permanent researchers and (d) the decrease in turnover of academic staff

The results suggest that, due to the elimination of the mandatory retirement age, in 2029 an additional 200 positions a year become unavailable for temporary researchers or other individuals outside academia. Percentage wise this is a decrease of nearly one third of the total of 700 a year.

Capping the Temporary Research Staff (TRS) phase

With the emergence of more rigid temporary research funds, there has been an increase in temporary research staff at universities. Professors often apply for these project funds through a process of competition. Their stipends are often paid, so the project funds are used to acquired additional staff to aid the research. However, with the increase of temporary funding a different behaviour can emerge (Ghaffarzadegan *et al.*, 2014). As project funds are often only used for a short duration it is often more interesting to hire temporary staff on short contracts. This has increased the turnover of temporary research staff. The government wants to reduce this behaviour by allowing fewer contract accumulations; from six years on three temporary contracts to 4.5 years on two temporary projects.

The results suggest that the change in contract terms does not decrease the number of temporary research staff in academia. To the contrary, with the decrease in contract terms the inflow and outflow of temporary staff will further increase. It leads to an additional flow of newcomers that are often less qualified as contracts of qualified staff cannot be renewed.



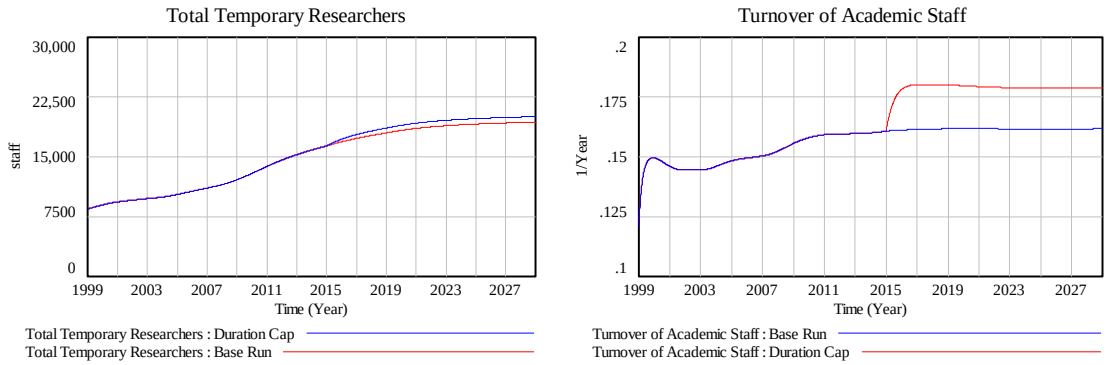


Figure 8 Simulation Results Contract Terms (a) base run temporary research staff, (b) temporary research staff with duration cap, (c) total temporary researchers, (d) turnover of temporary research staff

6. Conclusions and Discussion

A system dynamics model has been developed to understand and explore the effects of policies on the academic workforce and research output in The Netherlands. The simulation results suggest that a link exists between the increased focus on competitive funding schemes and the increased focus on staff on temporary contracts. When it is uncertain whether funds will be obtained, universities are more likely to hire temporary research staff, who are flexible, interchangeable and less expensive. Additionally, the focus on competitive funding could lead to productivity losses, as researchers spend more time on the acquisition of funds. Because a quality concept was not included in the system dynamics model, the effects of competition on the quality of the research could not be analysed.

As the Dutch population is aging, and researchers have to continue working for a prolonged period, it is vital to understand what the dynamics are if the mandatory-retirement age is changed. When this age cap is extended, the number of years professors remain in the academic world increases, which has its effect on the temporary research staff. The number of professors starts to increase when this cap is lifted and then starts to converge back to its target size. Due to the elimination of the retirement age, one third of the total yearly positions may become unavailable for temporary researchers or other individuals outside academia.

To prevent the accumulation of temporary contracts and turn them into permanent contracts, the Dutch government proposed to limit the amount of temporary contracts a researcher can obtain. However, the simulation results suggest that this does not lead to the desired effect: the decrease in career uncertainty due to contract accumulation and the decrease of academic staff turnover. Capping the contract terms leads to an increased turnover of temporary research staff: a higher inflow and outflow of staff. This suggests that vacancies are more likely to be filled by less qualified staff, as it becomes impossible to retain staff or promote them towards a faculty position. Additionally, it could lead to strategic behaviour as researchers will temporarily change position to become eligible for a temporary position again.

The policy experiments show that changing the balance in the system between temporary and permanent researchers and between institutional and competitive funds could influence the workforce performance and career development.

The chosen methodology is a promising way to capture the dynamics of the science system, but it faces some limitations as all modelling studies do. The boundary of the model is set around the career of academic staff with the focus on how different variables within that system interact. It does not include the upstream effect of students at earlier phases in the university or the interaction with research positions outside the university. However, the preparatory education for an academic career seems to play a crucial role in the academic workforce development (Hur *et al.*, 2015). It also does not include the entire market competition for potential academic staff, and the notion of quality and excellence. The expertise and quality of a researcher does however have a significant influence on the chance of promotion.

In addition, there are other feedback systems to consider that could improve the overall validity of the system but could also make the model unnecessarily complicated. For example, the inflow of hires from outside the university could be influenced by their academic qualifications. Currently the inflow is modelled with inflow fractions to define the distribution between academic and lateral hires. The quality per group of hires can change however, due to economic change, educational change or the quality of international staff. Adding more detail to the characteristics of the academic staff such as age, gender, academic background or extending the model with intra-national differences between universities would enhance the model but could make the model unnecessarily detailed.

While relevant conclusions can be drawn from this modelling study, there may be other methodologies that could equally describe this system in a consistent manner while drawing robust conclusions. A top-down strategic perspective is chosen to analyse this system. In a follow-up study the model could be extended, a bottom-up perspective could be integrated, other model methods could be used and uncertainties could be further explored. Including the Agent Based Modelling methodology could enhance knowledge of actions and interactions of researchers and other actors within the system. Additionally, the Exploratory Modelling and Analysis approach could be adopted to analyse the uncertainties in a more comprehensive way. In light of these uncertainties, robust decisions could be made. More analysis is also needed into the perceptions of certain system characteristics, such as the desirability of temporary research staff and competitive funding regimes. Further research is therefore needed to create a more comprehensive image of the academic workforce development in The Netherlands and the factors influencing it.

References

AWT (1999). Hoofdlijnen Wetenschapsbeleid. *Adviesraad voor het Wetenschaps en Technologiebeleid*.

Balen, B. van, van Arensbergen, P., van der Weijden, I., & van den Besselaar, P. (2012). Determinants of Success in Academic Careers. *Higher Education Policy, 25*(3), 313-334.

Benner, M. & Sandström, U. (2000). Institutionalizing the Triple Helix: Research Funding and Norms in the Academic System. *Research Policy, 29*(2), 291-301. doi: http://dx.doi.org/10.1016/S0048-7333(99)00067-0

Chiong Meza, C. (2012). *Feiten en Cijfers - De Nederlandse Universiteiten*, Rathenau Instituut. Den Haag.

Dalen, R. van, Mehmood, S. & Verstraten, P. (2014). *Public Funding of Science*.

De-Jonge-Akademie. (2010). Rendement van Talent - Aanbevelingen voor Motiverend en Stimulerend Loopbaanbeleid. In E. Bouma (Ed.). Amsterdam: De Jonge Akademie.

Drooge, L. van, & de Jong, S. (2008). *Feiten & Cijfers: 20 jaar onderzoeksevaluatie*.

Elk R. van, Weel, B.T., Wiel, K. van der, Wouterse, B. & Verspagen, B. (2015). *A Macroeconomic Analysis of the Returns to Public R&D Investments.* CPB Netherlands Bureau for Economic Policy Analysis.

Ghaffarzadegan, N., Hawley & Desai, A. (2014a). Research Workforce Diversity: The Case of Balancing National versus International Postdocs in US Biomedical Research. *Systems Research and Behavioral Science, 31*(2), 301-315.

Ghaffarzadegan, N., Hawley, J., Larson, R. & Xue, Y. (2014b). A Note on PhD Population Growth in Biomedical Sciences. *Systems Research and Behavioral Science, 32(3), 402-405*.

Ghaffarzadegan, N., Xue, Y. & Larson, R. (2014). Hiring College Graduates to Flip Hamburgers: An Endogenous Theory of Professionalization: MIT ESD Working Paper Series.

Goede, M., Belder, R, & Jonge, J. (2014). Academische carrières en loopbaanbeleid/Academic careers in the Netherlands.

Gomez Diaz, M. (2012). *Unintended effects of changes in NIH appropriations: Challenges for biomedical research workforce development.* Massachusetts Institute of Technology.

Hur H., Ghaffarzadegan N., Hawley J. (2015). Effects of Government Spending on Research Workforce Development: Evidence from Biomedical Postdoctoral Researchers. *PLoS ONE,* 10(5): e0124928. doi:10.1371/journal.pone.0124928

Kennedy, M. (1998). A Pilot System Dynamics Model to Capture and Monitor Quality Issues in Higher Education Institutions: Experiences Gained. *Proceedings of the 16th International Conference of the System Dynamics Conference*, Quebec City, Canada.

Kennedy, M. (2011). A Review of System Dynamics Models of Educational Policy Issues. *Proceedings of 29th International Conference of System Dynamics Society*, Washington DC, USA.

Kennedy, M., & Clare, C. (1999). Some Issues in Building System Dynamics Models for Improving the Resource Management Process in Higher Education. *Proceedings of the 17th international Conference of the System Dynamics Society*, Wellington, New Zealand.

Kersbergen, R.J. van (2015). *Academic Workforce Development: A System Dynamics based Promotion Chain Study into the Effects of Career and Funding Policies.* (MSc degree thesis), Delft, University of Technology, Repository, TU Delft.

Larson, R. C., & Gomez Diaz, M. (2012). Nonfixed Retirement Age for University Professors: Modeling its Effects on New Faculty hires. *Service science, 4*(1), 69-78.

OCW, M. v. (2014). Wetenschapsvisie 2025 - Keuzes voor de toekomst [Press release]

Oyo, B., Williams, D., & Barendsen, E. (2008). A System Dynamics Tool for Higher Education Funding and Quality Policy Analysis. *Proceedings of the 26th International Conference of the System Dynamics Society*, Athens, Greece.

Sterman, J. D. (2000). *Business dynamics: systems thinking and modeling for a complex world*. Irwin/McGraw-Hill Boston.

Versleijen, A., & van der Meulen, B. (2007). *Dertig jaar publieke onderzoeksfinanciering in Nederland 1975-2005.* Den Haag, Rathenau Instituut.

VSNU (2015). Personeelsinformatiedata & geldstromen. Retrieved 01-09, 2015, from http://www.vsnu.nl/nl_NL/feiten-en-cijfers.html