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

Ruben Johannes van Kersbergen

Technology, Policy and Management
Delft University of Technology
The Netherlands

December 2015

Abstract – The Dutch government supports the academic research workforce through public research funding. However, while this support is needed for continued economic growth, current trends suggest that present funding and career policies have a transitory effect on the workforce of which mainly permanent researchers benefit. In this paper a model is created that describes the influence of funding regimes and career policies on the workforce development and research output over time. The model has been validated and is successful in replicating the observed historical behaviour. The model is then used to conduct several policy experiments to analyse the effect of different policies on the workforce development and research output. The model shows that the increased focus on indirect governmental funding and a temporary workforce, could have a negative impact on the workforce development and research output at public research organisations. The analysis suggest that competitive funding favours permanent staff member over temporary staff members while not inducing more research output. However, further research is needed to incorporate multiple perceptions and analyse the complex interaction between funding, workforce development and research performance.

Keywords – Academic Workforce Development; Public Research Funding; System Dynamics; Simulation Modelling; Science System Policies

1 Introduction

Academic research and scientific development are some of the main drivers for continued economic growth (Chiong-Meza, 2012; Rathenau-Institute, 2015). In the Netherlands, the academic workforce is supported by the Dutch government, through the ministry of Education, Culture and Science (OCW) and Economic Affairs (EZ), with the goal of inducing research that is useful for society (Versleijen & van der Meulen, 2007). However, over the past years the financial support for the academic workforce has been stagnating, even though the number of new students is rising (OCW, 2014). Simultaneously, policies with regard to contract and funding regimes have been enacted to strengthen the research body in the pursuit of continued high impact research. It is however 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 (PRO) (AWT, 1999). The government provided direct institutional funding to research organisations, with the assumption that funds would be allocated efficiently. 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, with the increasing complexities over the years regarding funding mechanisms and governmental policies, it is increasingly difficult to manage the science workforce from a bottom-up perspective.

Today academic research is conducted in a growing international and multidisciplinary environment. The necessary funds that enable researchers to 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 PROs to manage and direct their research body. Additionally, the multitude of funding regimes and career policies make it increasingly complex to govern the research workforce and provide the right incentives.

This study tries to examine and understand the dynamics in the research workforce development over time and explores the consequences of changes in funding and policies. For this, a modelling method is proposed. One of the main purposes of this research is to address a question raised by the stakeholder, the Rathenau Institute, to clarify the interrelation between funding and policies and the workforce development and research output in academia. The analyses here is directed toward understanding the flows into and out of the academic careers and modelling the dynamics of change in number of staff over time. A model will be used to conduct these simulation-based analysis of the effects of different policies.

The following outline is followed in this paper. Section 2 describes the main mechanisms in the science system that influences the development of the academic workforce. Section 3 describes the method that is used to analyse 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. Based on the outcomes, this paper will be concluded and discussed.

2 Academic Workforce Development – Population, Funding and Performance

Workforce Characteristics and Career Progression

Advancing mobility between positions is considered as one of the ways to create room for the new talented 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 lot of movement. The majority of these positions find work outside of Dutch universities suggesting that there is limited space for a permanent positions in academia. One of the reasons for this change is the increasing interests by policy makers and academic institutions for PhD-graduates and other temporary researchers. 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 stayed relatively stable (Rathenau-Institute, 2015). A knowledge economy is not only in need of a professional workforce but also of specific knowledge coming from PhD-graduates.

![Academic Positions](image_url)

Figure 1: Academic positions, without HOOP area Health, 1999-2014

Academic research positions all have a specific role in the promotion chain. The postdoc position, which falls within the Other Academic Staff (OAS), is the link between the PhD-program and a more independent research position at the university. Within the OAS category a distinction is made between staff focussing on education, research or secondary tasks. OAS positions are becoming increasingly temporary as of 2010 every year one third of the whole batch changes position (Goede et al., 2014). The largest part of this change is from outside academia, almost all foreign or PhD-graduates taking an
academic sabbatical. The OAS position is the main gateway to more permanent faculty positions. 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, only a small percentage moves every year (Goede et al., 2014). The function of the professor is the highest rank in the academic career ladder and the face of the research section.

Public Research Funding
One main factor in the organisation of the science system is the size, form and organisation of research funding (Benner & Sandström, 2000; van Dalen, Mehmood, & Verstraten, 2012; Versleijen & van der Meulen, 2007). Public research organisations, 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 reasonable part of the public research funds was allocated via competition by the Netherlands Organisation for Scientific Research (NWO), with the aim of increasing quality of research and stimulating research in promising fields. While competition can lead to better research, it could also be detrimental for specific research (van Dalen et al., 2012).

Presently, four types of funding allocation schemes can be distinguished in the Netherlands: direct governmental funding, which is the traditional form of funding, indirect governmental funding, which is the funding allocated through NWO, contract funding, which is allocated through public or private parties such as the EU and medical funding. These four funding schemes, which are described as money stream, are the backbone of the research funding in the Netherlands.

![Figure 2: Academic Research Funding, 1999-2019](image)

Figure 2 shows the different funding types till 2019, which are based on fair values and their estimates. Note that tertiary funding includes funding from private organisations. 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 focus shift.

3 Method
Data from the Association of Universities in the Netherlands (VSNU) is used to develop a system dynamics model (Forrester, 1994; Sterman, 2000) of the workforce development in public research organisations (PRO) in the Netherlands. The aim of the model is to represent the flows of researchers in-
and out of the different stages of the academic career, and perceive the effects of career- and funding policies on the population and productivity of the research workforce.

Many education related SD models have been created 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 PRO’s. In his book Business Dynamics Sterman develops a model of academic promotion within universities based on the different stages of the academic career (Sterman, 2000). His research is based on the promotion and exit rates of scientific staff at the Massachusetts Institute of Technology (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 seems to be the first one to extend that model by including funding, quality and policy aspects (Oyo, Williams, & Barendsen, 2008). His initial assumption about the direct link between educational activities, its strategic directions and the produced quality form one of the main assumptions for this paper. However, this study focusses on educational literature and concepts in a developing world country with the emphasis of funds acquisition.

In a study by Larson and Gomez, an aggregated SD model was created to analyse the recruitment process within universities based on a non-fixed retirement age (Larson & Gomez Diaz, 2012). A follow-up study by Gomez described the transition between young researchers and established researchers based on public research funding (PRF) (Gomez Diaz, 2012). This model demonstrated that in dynamic social systems intuitive cause and effect assumptions are not always correct: the PRF budget increase did not lead to the desired workforce development. A study by Ghaffarzadegan shows the workforce distribution among national and international postdocs for biomedical research in the US (Ghaffarzadegan, Hawley, & Desai, 2014). The model suggests that international temporary postdocs benefit the most from the increase in research funding. So while an investment is made, many international temporary researchers could move abroad after the contract 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 (N Ghaffarzadegan, Xue, & Larson, 2014). Overall, none of these studies have specifically focussed on the influence of career and financial policies on the workforce development within public research organisations in the Netherlands. More importantly, none have dealt with the notion of uncertainty within the constructed models. This paper addressed that gap and focusses on the workforce development of researchers in the Netherlands.

The data that are used for three purposes: Input for the model, calibration of the uncertain model parameters and testing the fidelity of model results to the observed data. Model simulations are used to conduct what-if analyses through the testing of policy alternatives. These policy experiments include testing effects of a change the use of PRF, the effect of removing the mandatory retirement age and changing the temporary contract structure. These tests were found through discussions with system experts and the examination of Vision on Science governmental policy note (OCW, 2014).

The following modelling structure will be followed: first the simulation model is made that follows the problem articulation, then the model will be calibrated with the use of VSNU data. After examining the models ability to reproduce the historical data, the policy experiments will be performed.

4 Model building

Figure 3 represents the different stages of the academic career in the Netherlands. Individuals enter as they are admitted to a PhD degree programme and move towards a permanent faculty position directly or through a postdoctoral stage. Applicants from outside academia are also admitted to academic positions. Through this path, a considerable proportion of researchers drop out, graduate and find work outside academia. The focus of this research is the influence of funding and career policies on in-throughput- and outflow of the academic researchers over time and the implications for research performance.

The focus of this study will be on the determining factors that influence the promotion of researchers and the workforce development in addressing the stakeholders problem of interest. 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.
4.1 Feedback behaviour

Figure 4 shows the simplified causal loop model for academic researchers in the Netherlands. There are six major feedback loops in this system.

Feedback loop 1 represents, in combination with loop 2, a limits to growth archetype. Full professors have the opportunity to promote or hire external, nonpermanent, members of academia. It is known that reproduction rate in academia is very high, leading to unprecedented growth if there is no system limitation (Navid Ghafrarzadegan, Hawley, Larson, & Xue, 2014). In a steady state system this would lead to system saturation; there is no room to absorb new academic staff. This loop therefore grows until the system reaches its peak, after is halted by external limits of the system: the availability of funds and the capacity to hire which is loop 2.
additional staff and expand their overall amount of research activity. If the amount of research output is satisfactory, no additional funds are needed. However if the amount of research output is unsatisfactory, a discrepancy between the desired research output and the actual research output arises that incentivise the need for additional funds. As the discrepancy falls, 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 positions to leave for an application outside academia (Ghaffarzadegan et al., 2014). Temporary researchers cannot stay in academia forever, as these jobs are low paid and don’t provide long term stability. When the residence time of researchers in this position increases they are more likely to face pressure to leave.

Feedback loop 5 represents the increased competition between researchers to acquire funds. If there are more grants available, competition among researchers to acquire these funds will increase. Researchers will increase their application time to produce more quality, to secure these grants. However, more applications for the same grant leads to more time spent by researchers on writing funding applications. As such, researchers find themselves busy with writing proposals while they refrain from their core activity: research.

Feedback loop 6 represents a reinforcing growth in funding based on the funding allocation mechanism and the number of new PhD staff. When additional PhD candidate is hired, public research organisations get an additional amount of funds. This growth is halted by the total amount of funding that is available for researchers. This was one of the main mechanisms why researchers started to hire additional amounts of PhD staff from 1994 onwards (van Dalen et al., 2012).

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 in- and outflow and promotion of academic staff.

To determine the number of openings for temporary and permanent researchers, a capacity mechanism is formulated. For the temporary researchers, PhD and TRS staff, hiring is determined by the openings available due to the exit rate of staff and limited by the capacity within the stock. The amount of yearly public research funds (PRF), 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 that prefer to acquire a permanent faculty positions above a temporary position. Based on the likeliness of acquiring a permanent positions after a PhD is obtained, some researchers will become permanent researchers.

For the hiring for faculty positions the same formulation method is used. The main difference is that now not just the TRS and lateral hires 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 increases ones 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 for industry (Ghaffarzadegan et al., 2014; Hur, Ghaffarzadehgan, & Hawley, 2015). To model this uncertainty, researchers within the TRS phase go through 3 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 2 year temporary contract the researcher goes through hoping to acquire a permanent faculty position. The maximum duration of OAS is six years in the Netherlands.

Details of the model formulation and the results can be found in the thesis work by the author. The PRF parameters are considered exogenous. Longitudinal data from the VSNU are used to simulate these variables. While it is better to simulate these variables endogenously, the main stakeholder interest is to see the effects of funding on the development of the academic workforce. This allows for a concentration on the different stages of the academic career. For validity reasons, it is important to replicate the historical data by calibrating the uncertain parameter values across an reasonable uncertainty range. For the modelling purpose the software package VENSIM Professional is used.
5 Model Analysis

5.1 Base Run Simulation
Observed historical behaviour of the model is used to validate the behaviour of the model. Uncertain parameter values are calibrated across a reasonable range to obtain a model fit. By using two behavioural pattern tests, the MAPE and $R^2$ metric, the model can be validated. It has been found that the model is useful to model the academic workforce in the Netherlands.

The simulation results between 1999 and 2029, with the focus on workforce development and research output, can be found in Figure 5. Figure 5 (a) shows the increase of academic staff and the distribution between temporary and permanent staff over time. It shows the increased focus on temporary staff, which 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 PRO’s 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 focus change. Figure 5 (c) shows the turnover of academic staff, which is a representation how often the total research body is renewed, that increases over time suggesting that staff leave academia at an increasing rate. This is caused by the increasing residence time of TRS that want to acquire a permanent position, but wait and leave due to capacity issues. Figure 5 (c) shows the amount of research publications that increases significantly over the years under the influence of the increasing temporary workforce, that conducts research for less 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 Permanent 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 and (3) capping the duration of contracts of TRS. The + and - signs refer to the variable going up or down and does not suggest any connotation, which is dependent on the perception of the system observer.

These tests are implemented as factual tests and compare the differences in reality and with what can happen if the policies are implemented. Table 1 also summarises the simulations results of the model run, which will be discussed in this section. The operationalization of the simulation experiments can be found in the authors thesis work (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. 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.

<table>
<thead>
<tr>
<th>Policy measures</th>
<th>Temporary Staff</th>
<th>Permanent Staff</th>
<th>Ratio of Temporary to Permanent</th>
<th>Staff Turnover</th>
<th>Research Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1): Focus on competitive funding</td>
<td>+</td>
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<td>+</td>
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<td>+</td>
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<tr>
<td>(2): Non-Fixed retirement age</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>-</td>
<td>0</td>
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<tr>
<td>(3): Capping duration of TRS-phase at 4.5 years</td>
<td>+</td>
<td>0</td>
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<td>+</td>
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</tbody>
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Table 1: Three simulation experiments and directions of their effects on different policy measures

Figure 6 shows the simulation outcomes for this policy experiment. The result are counter intuitive and contrary to initial expectations. 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, is increasing 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 project proposals.

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

**Non-Fixed Retirement Age**

Many permanent faculty member at universities enjoy the rare job benefit of having a contract for life (Larson & Gomez Diaz, 2012). If temporary researchers successfully navigate the hurdles of reappointment and promotion, and become a permanent researcher they enjoy job security until the retire. 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 prohibited all together. While this is not the case in the Netherlands, it is wise to explore this effect of an later retirement age, as this is expected in the upcoming years.

The results show that the number of permanent researcher hiring starts declining in 2010 from around 1500 until reaching a new equilibrium around 900. The hiring behaviour reflect the faculty exit rate, which is also decreasing over time. The number of years that 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](image)

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 TRS phase**

With the emergence of more rigid temporary project 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 in the project work. However, with the increase of funding perverse behaviour emerged (Ghaffarzadegan et al., 2014). As project funds are often only used for a short duration it was often more interesting to hire temporary staff on short contracts. This has increased the turnover of temporary research staff. The government want to reduce this behaviour by allowing only little contract
accumulations; from six year on 3 temporary contracts to 4.5 years on 2 temporary project. In the model the contract term is analysed and adjusted.

The results suggest that the change in contract terms does not decrease the number of temporary research staff in Academia, more the contrary. With the decrease in contract terms the in- and outflow of temporary staff will further increase. Not only does the system become unbalanced, it also leads to an additional flow of newcomers that are often less qualified as contracts of qualified staff cannot be renewed.

![Graph showing the effect of contract terms on temporary research staff](image)

Figure 8: Simulation Results Contract Terms (a) base run temporary research staff and (b) temporary research staff with duration cap, (c) aging in contract phases and (d) turnover of temporary research staff

5 Conclusions and Discussions

A SD model has been created to understand and explore the effects of policies on the workforce development and research output in the Netherlands. The model has been tested for errors and uncertain parameters were calibrated across an reasonable uncertainty range to fit the observed historical data. Following this, a number of policies have been tested on the model. From the simulation results, the following conclusions can be drawn:

The simulation results suggest that a link exists between the increased focus for competitive funding and the increased focus on a temporary workforce. When it is uncertain whether funds will be obtained, PRO’s are more likely to hire temporary research staff, who are flexible, interchangeable and inexpensive. Additionally, the focus on competitive funding could lead to productivity losses, as more researchers spend more time on the acquisition of funds. Because a quality concept was not included in the SD 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 longer period, it is vital to understand what the dynamics are if the mandatory retirement age of 65 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 TRS. The number of professors starts to increase when this cap is lifted and then starts to decline back to its target size. Due to the elimination of the retirement age, on third of the total yearly positions may become unavailable for temporary researchers or other individuals outside academia.

To prevent the contract accumulation of temporary research staff, the government proposed to limit the amount of temporary contracts a researcher could obtain. However, the simulation results suggest that it 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 a reinforced turnover of temporary research staff: a higher in- 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 let
them promote towards a faculty position. Additionally, it could lead to perverse behaviour as researchers will temporarily change position to become eligible for a temporary position again.

All these tests show that changing the balance in the system between temporary and permanent researchers and between institutional and competitive funds could have a negative effect on the workforce performance and career certainties.

The chosen methodology is a promising way to capture the dynamics of the science system, but also, as all modelling studies, faces its own limitations. The boundary of the model is set around the promotion 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. However the education preparation 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 side competition for potential academic staff, and the notion of quality and excellence. The expertise and quality of researcher does however have a significant influence on the choice for promotion.

Then there are other feedback systems to consider that could improve the overall validity of the system but could make the model unnecessarily complicated. For example, the inflow of lateral hires could be influenced by their academic qualifications. Now 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 difference between universities would enhance the model but would make the model unnecessarily detailed. Now the scope is chosen from the stakeholders perspective and serves that purpose.

While relevant conclusions can be drawn from this modelling study, there might 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 the system. In a follow-up study the model could be extended, a bottom-up perspective could be integrated within other model approaches and uncertainties could be mitigated. Including the Agent Based Methodology could enhance knowledge of actions and interactions of researchers and other actors within the system. Additionally, the Exploratory Modelling and Analysis methodology could be adopted to analyse the uncertainties in a more comprehensive way. In light of these uncertainties, robust decisions could be made. Traditional System Dynamics modelling could be used to extend the model beyond the chosen boundaries to increase overall robustness of the model results. 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 workforce development in academia and the factors influencing it.
References


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