

MODELING FOR ANALYSIS ACADEMIC INBREEDING

MODELAGEM COMPUTACIONAL PARA ANÁLISE

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Roni Storti de Barros¹

Claudete Correa dos Santos²

Maria Eliana Lima dos Santos³

Erick William Pereira⁴

Rogeane Moraes Ribeiro⁵

Maria do Socorro Silva Mesquita⁶

Helena Mara Oliveira Lima⁷

Antonio Rodrigues Albuquerque Filho⁸

ABSTRACT

The present study presents the investigation into Academic Inbreeding. Defined as the hiring as a teacher of candidates who have already had some academic training at the institution. The main objective of the study was to design, develop and evaluate system dynamics model(s) capable of supporting the decision-making process regarding the hiring of teachers with different levels of Inbreeding. Levels based on the study by Horta (2013), but through this thesis, instead of investigating only the last training, links were defined from undergraduate, master's and doctorate, with No inbreeding (those who had no previous academic link with the institution investigated), inbreeding A to C, for a greater number of links. In the method, Systems Dynamics was used to evaluate the performance of the teachers in the sample through time, development, simulation and evaluation of models; as well as mapping cooperation networks in the academic production of teachers. As a result, it was found that the scenario with teachers without inbreeding (teachers with no previous academic ties at the educational institution evaluated) performed better, while inbreeding B teachers (teachers with two previous academic ties) performed worse, corroborating studies on the topic.

Keywords: Academic Inbreeding; Academic career; Systems Dynamics.

RESUMO

O presente estudo apresenta a investigação acerca do *Inbreeding* Acadêmico. Definido como a contratação como docente, de candidatos que já tiveram alguma formação acadêmica na instituição. O objetivo principal do estudo foi conceber, elaborar e avaliar modelo(s) de dinâmica de sistemas capaz(es) de apoiar o processo decisório quanto à contratação de docentes com

diferentes níveis de *Inbreeding*. Níveis baseados no estudo de Horta (2013), porém, através desta tese, ao invés de investigar apenas a última formação, foram definidos vínculos desde a graduação, mestrado e doutorado, sendo sem *inbreeding* (aquele que não teve vínculo acadêmico anterior com a instituição investigada), *inbreeding* A até C, para maior número de vínculos. No método utilizou-se a Dinâmica de Sistemas, para avaliar o desempenho dos docentes da amostra através do tempo, desenvolvimento, simulação e avaliação de modelos; assim como mapeamento de redes de cooperação na produção acadêmica dos docentes. Como resultados constatou-se que o cenário com docentes. Sem *inbreeding* (docentes sem vínculos acadêmicos anteriores na instituição de ensino avaliada) melhor desempenho, já docentes *inbreeding* B (docentes com duas vínculos acadêmicos anteriores) tiveram pior desempenho, corroborando com estudos sobre o tema.

Palavras-chave: Inbreeding Acadêmico; Carreira Acadêmica; Systems Dynamics.

1. INTRODUCTION

In Social Sciences, the concept of Inbreeding is related to immobility in the teaching staff and can affect scientific productivity, as well as excellence and innovation by limiting the exchange of ideas and the circulation of knowledge generated by collaboration networks between countries and institutions (HORTA et al., 2010). Scientific activities are unevenly distributed across geographic space (ROYAL SOCIETY, 2011) and, in this sense, Brazil presents significant heterogeneity with the concentration of activities related to the location of public university campuses – a pattern presented by developing countries (SIDONE et al., 2017).

As Pelegrini and França (2020) confirm, some characteristics of the Brazilian academic market favor Inbreeding, such as homogeneous salaries among public universities, the autonomy of institutions/departments to establish competition selection criteria and the concentration of universities in some states in the territory national. In a way, the Brazilian academic scenario is in a period of transition, after its implementation during the military regime, and inbreeding can be favorable in this transition by helping universities hire the best candidates with lower risks and information asymmetry (PELEGRINI & FRANÇA, 2020).

According to Horta (2022), studies so far have shown that academic inbreeding is difficult to mitigate because the practice leads to the creation of a political, social and cultural system within the university in which some professors exert influence over departments, faculties and, sometimes, the university itself. Due to the control that these powerful academic oligarchs have, they become the de facto leaders of the university and compete and join coalitions to exercise their power (HORTA, 2022). At universities with high rates of academic inbreeding, this leadership focuses on maintaining the status quo, emphasizing organizational identity and traditions, and perpetuating the belief that ways of doing things that have worked in the past also work in the present (BOOI et al., 2017).

Starting from the discussion proposed by Borenstein, Perlin and Imasato (2022), that “academic inbreeding” may need to be re-evaluated. Although the definition itself does not have a negative connotation, it is difficult to dissociate the use of inbreeding with problematic issues (HORTA & YUDKEVICH, 2016; MCGEE, 1960; YUDKEVICH et al., 2015).

According to a study by Balbachevsky (2019), the Brazilian experience is exemplary for understanding the tensions and contradictions produced within an emerging academic system when simultaneously facing the challenges of expanding access and strengthening its academic performance.

Inbreeding professionals, this study will seek to answer the following question: What are the differences in performance between teachers with degrees in other institutions and teachers with degrees in the same institution where they are employed? To achieve this, the general objective is to design, develop and evaluate system dynamics model(s) capable of supporting the decision-making process regarding the hiring of teachers with different levels of Inbreeding.

2. THEORETICAL FRAMEWORK

2.1. Inbreeding in Intellectual Production

It is understood that the analysis of academic Inbreeding through the quantitative assessment of scientific production in the current context in the faculty is related to the productivity and quality of research. Therefore, the following section demonstrates how Inbreeding can influence scientific research productivity.

It is recognized that, for years, Latin American journals have not been unaware of the trends of change, indexing, globalization and comparison (RÍOS GÓMEZ; HERRERO SOLANA, 2005), suggesting a transition phase from a system of dissemination and incentives that emphasizes the national publications (closed and inbreeding), to an internationally visible one that relies on knowledge networks and is measured by citation indicators (ROMERO-TORRES et al., 2013).

Inbreeding relationships between countries and journals, as a reflection of what occurs in the rest of the scientific communication system that these journals make up (GORBEA-PORTAL & SUÁREZ-BALSEIRO, 2007).

SciELO journals, the increase in the base or indexing in the Web of Science – WoS presents a sensitive growth rate. This phenomenon is accentuated by the high percentage of articles by Brazilians in national magazines as a whole. According to Collazo -Reyes (2014), in the period between 2005 and 2011, Brazilian SciELO/WoS journals presented 88.8% of Inbreeding – that is, only 10.2% articles by foreign authors – a reality that contrasts with countries such as Argentina, Chile and Mexico, whose Inbreeding percentage is close to 67%. Also according to Collazo-Reyes (2014), there is no positive correlation between all Latin American production in local journals (18.8%) and the corresponding contribution to the overall impact (4.4%) recorded in WoS. However, the Brazilian contribution to the total number of citations induced by Latin American journals in WoS is overwhelming (80.1%), with a share similar to the general Latin American production in local journals (71.4%) (COLLAZO-REYES, 2014).

Brazil then stands out as the most inbreeding country in the Latin American geographic region: 88.8% of articles published in local Brazilian journals correspond to Brazilian scientists. On the other hand, local magazines in Argentina, Chile and Mexico publish an average of 33% of their articles by foreign authors.

Colombia also has a fairly small percentage of foreign authors in its local journals. There is a group of Latin American countries (Costa Rica, Cuba, Ecuador, Jamaica and Uruguay) with a small number of

indexed journals and limited production, but their percentage of foreign authors is around 50% (COLLAZO-REYES, 2014).

According to Hirsch (2005), scientific productivity can be defined as the result of a series of research activities, such as publishing national and international articles, books and book chapters, obtaining research grants, mentoring students, production of patents, participation as a member of the editorial board, among others. However, research performance and productivity have been measured through the quantity of research products, such as the publication of articles in peer-reviewed journals (HORTA, 2013; HORTA et al., 2010).

Publications are computed over an interval of 3 years, a period of time that literature that addresses production and scientific career considers more appropriate to evaluate the behavior of recent publications (Horta, 2013), in addition to controlling the effects of teaching career length or “academic seniority” (HORTA et al., 2010). According to Fox (2005), this period of time encompasses work activities focused on research, submission and publication. The division between journals of international and national scope seeks to capture the quality or innovation of research (SIVAK & YUDKEVICH, 2015; BIRNBAUM, 2005).

According to a study by Pelegrini and França (2021), the analysis also considers a series of control variables identified in the literature that affect scientific productivity, such as gender, years since the doctorate degree was obtained, country in which the doctorate degree was obtained (classified as Brazilian/Foreign), if the professor has a research productivity grant and the allocation of

activities in the form of permanent professor and collaborating professor.

Research productivity grants are financial benefits granted to researchers who have outstanding scientific, technological and innovative production in their respective areas of knowledge with the aim of recognizing their work and encouraging increased production by researchers. The research productivity grant is organized into levels that provide increasing salary supplements: 2, 1D, 1C, 1B, 1A, with the last four levels being collectively called “levels 1” (highest) (PELEGRINI & FRANÇA, 2021).

Permanent professors carry out postgraduate and/or undergraduate teaching activities, participate in research projects, supervise master's or doctoral students and have a functional-administrative link with the institution. The category of collaborators includes other members of the teaching staff who systematically participate in the development of research projects or teaching or extension activities and/or in the guidance of students, including post-doctoral fellows, regardless of whether they have a connection with the institution or not. (CAPES, 2016).

To understand and even be able to measure teaching production, we will address teaching cooperation networks. We can find quantitative ways of measuring the performance of networks in academic literature, for example, patent generation studies. In these, the evaluation criteria are: the number of innovations (MORESCALCHI et al., 2015; SODA, 2011); number of businesses and criteria such as increasing the amount of sales (MACHLINE & AMARAL JUNIOR, 1998); economies of scale (BALESTRIN & VARGAS, 2004); in tourism, the variation in the number of visitors to the

destination (VIEIRA & HOFFMANN, 2013); and, as a consequence, the improvement of the local economy (COSTA & HOFFMANN, 2006; CROUCH & RITCHIE, 1999; DWYER & KIM, 2003; GOOROOCHURN & SUGIYARTO, 2004).

2.2. Systems Dynamics

System dynamics (DS) is an approach based on control theory and nonlinear dynamics (Hafezi et al., 2021). This approach allows analysts and modelers to account for interactions between interrelated systems that drive the dynamic behaviors of a system over time (Azadi, 2022).

It is based on the assumption that nonlinearities, system feedbacks and relationships between the elements of a system can be more significant in determining the behavior of the aggregate system than the individual components themselves (Forrester, 1970). The ability to incorporate time delays, amplifications, causal and structural relationships, and system feedbacks into the modeling procedure has made DS popular for analyzing and understanding complex temporal systems (Sterman, 2018).

Blignaut et al. (2022) highlight that System Dynamics is a method of modeling and simulating the behavior of complex systems over time, thus enabling the evaluation of changes in parts of the system so that such changes affect the behavior of the whole. Therefore, the application of the system dynamics methodology makes it possible to examine the interaction between the forces present in the system and, therefore, enable a holistic view of the process in question (Forrester, 1994).

Reddy, Rao and Krishnanand (2020) state, in their study, that Systems Dynamics is an approach to analyzing and solving complex problems with an emphasis on policy analysis and design. According to Kunc et al. (2018), DS was initially developed by control and management engineering; After this development, its applications spread across various fields and different levels of research, but with the aim of solving strategic and policy formulation issues. To Sušnik et al. (2021) Systems Dynamics modeling and simulation adopt a whole system approach and a social learning process, which is widely considered an efficient methodology for addressing a range of dynamically complex problems (Pluchinotta et al., 2018; 2021).

According to the systems dynamics modeling procedure (Sterman, 2000), modeling begins with the development of a dynamic hypothesis, generally based on a cause and consequence diagram (Zare et al., 2019). This diagram, in turn, is then converted into mathematical equations that will seek to answer the dynamic hypothesis (Zare et al., 2019).

The SD approach makes it possible to conceptualize the concerns of educational institutions and the uncertainties associated with the interface between science and society (Suprun et al., 2019). The use of DS models facilitates collaboration between researchers and managers interested in solving complex problems, in addition to integrating their local knowledge and perceptions of the problem investigated and its potential solutions (Pluchinotta et al., 2021). The use of DS is suitable for analyzing problems whose behavior is governed by feedback relationships over a long-term horizon (Sterman, 2018). For Numfor, Takahashi and Matsubae (2022) the model establishes a normal business state of the system and then generates scenarios based on specific hypothetical data, such as

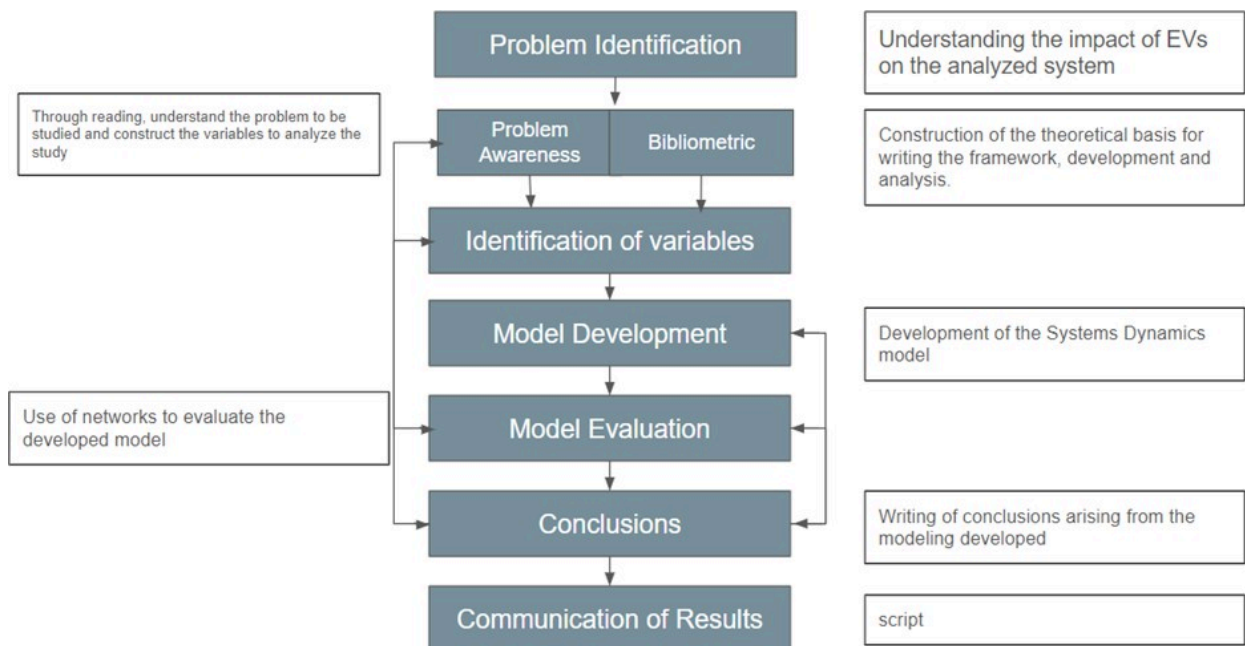
future policy interventions. The generated scenarios can provide information about changes in key system variables based on each intervention.

System dynamics models describe the behavior of complex systems over time using feedback cycles, stocks, flows and modifiers (Bertone et al., 2018). Stocks characterize the state of the system at a given time and maintain a memory of it so that its status can be described (Thompson et al., 2016). Flows affect stocks via input or output and interconnect stocks within a system. Flows correspond to the change per period of time that increases or decreases levels in the system.

3. RESEARCH METHOD

The method is a logical sequence of steps that must be followed to achieve a certain objective (Appolinário, 2016), in other words, it consists of a sequence of operations aimed at achieving a certain result (Matias-Pereira, 2019). This study employs the system dynamics method to gain a better understanding of Inbreedings faculty hiring. The use of System Dynamics helps the decision-maker to adopt and recommend policy solutions simulated in the system dynamics model(s) (Thompson et al., 2016). The model can be enriched by local knowledge from stakeholders and will also develop a detailed understanding of how the system works and evolves (Scott et al., 2016). Therefore, to achieve the objectives of this thesis, Figure 1 shows the research design with the respective steps adopted in accordance with Systems Dynamics.

Figure 1 - Research Design

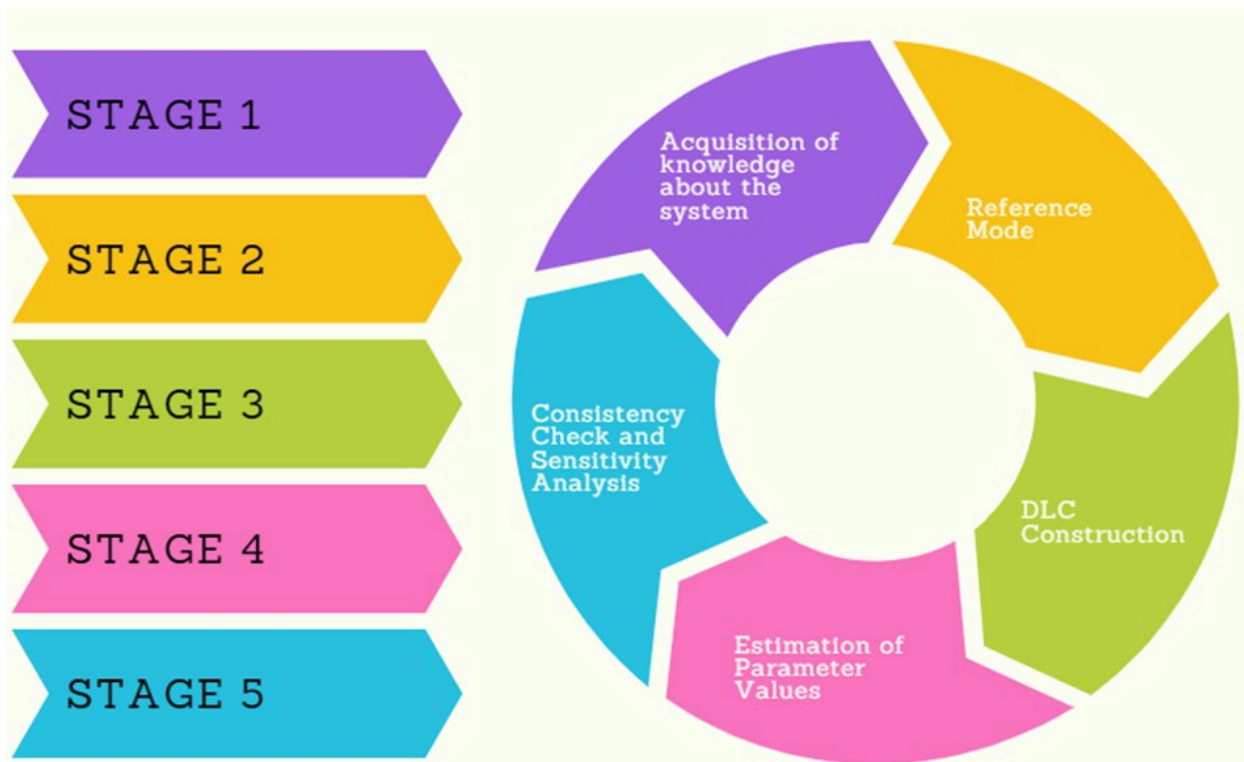


Source: Authors (2024).

Systems Dynamics is a technique that aims to analyze, model, simulate and identify implicit behaviors in complex dynamic systems over time. It serves to create models that represent systems (structures) existing in nature.

To build the model, the steps of Sterman (2018) were used. Figure 2 below includes all the steps used to develop the System Dynamics model in this Study.

Figure 2 - Design of the Steps for developing the Systems Dynamics model



Source: Adapted from Sterman (2018).

The steps used in the development of the process are described in detail in Frame 1 , providing a detailed view of the sequencing and procedures adopted throughout the study.

Frame 1 - Description of the Steps for developing the model

Stage	Description
Acquisition of knowledge about the system and formulation of the dynamic hypothesis	In this first step, it is time to identify all the relationships that govern the system, trying to discover the variables that most affect the system's behavior over time. the formulation of the dynamic hypothesis is important to explain the cause(s) of the problem.
Reference Mode	In the second step, a graph varying over time must be created with the most essential variable in the model.
DLC Construction	The third step to follow is intended to construct the DLC, with the aim of identifying the causal links between the variables and the feedback loops, making it possible to qualitatively analyze the model.

<p>Estimation of Parameter Values</p>	<p>The fourth step is about parameter confidence. Each parameter must be estimated individually, using any available reference. You can work with parameters from 100% to 10% accuracy or absolutely indefinite accuracy. Variables with undefined parameters are not removed from the model; this accuracy can be improved later.</p>
<p>Consistency Check and Sensitivity Analysis</p>	<p>In the fifth step, the model must be simulated by comparing the results with the Reference Mode. The behavior of the model is checked, if the result resembles the reference mode, it can be said that the model is consistent, to analyze sensitivity. The model parameters are changed several times to determine which variables are most important in the system. The aim is to identify whether the model is robust. To this end, the model was evaluated by experts in the field.</p>

Source: Adapted from Sterman (2018).

3.1. Inbreeding classification for the study and proposed scenarios

To define the level or degree of Inbreeding, the classification defined in Horta (2013) was used; for this, we adapted the levels according to the place of training (Undergraduate, Master's and Doctorate) of the teacher under analysis.

Based on the groups defined in the studies analyzed, we defined the criteria for segmenting the teachers in the sample, based on the Educational Institution they are currently linked to, as follows:

- Without Inbreeding – this is a teacher who does not have any training at the institution where he/she is linked;

- Inbreeding A – this is a teacher who has at least one training at the institution where he/she is linked;
- Inbreeding B – this is a teacher who has two degrees (undergraduate and master's degree, undergraduate and doctorate degree, master's degree and doctorate degree) at the institution where he/she is linked;
- Inbreeding C – this is a teacher who has three degrees (undergraduate, master's and doctorate) at the institution where he/she is linked;

Scenario planning was used to run simulations of the proposals developed, for which two blocks of scenarios were developed. In order to reproduce a diversity of groups of teachers in the postgraduate programs analyzed, thirteen scenarios were designed, each exploring different inbreeding situations. The first block is presented in Frame 2 , below.

Frame 2 - Merged scenarios

Scenario	No Inbreeding	Inbreeding A	Inbreeding B	Inbreeding C
Current	1st	2nd	4th	3rd
SI_A	1st	2nd	3rd	4th
SI_B	1st	4th	2nd	3rd
SI_C	1st	3rd	4th	2nd
IA_A	4th	1°	2°	3°
IA_B	2°	1°	3°	4°
IA_C	3°	1°	4°	2°
IB_A	4°	2°	1°	3°
IB_B	2°	3°	1°	4°
IB_C	3°	4°	1°	2°
IC_A	4°	3°	2°	1°
IC_B	3rd	2nd	4th	1st
IC_C	2nd	4th	3rd	1st

Source: Authors (2024).

Each of the thirteen scenarios divided the teaching staff between the four levels of inbreeding used in this thesis, the idea is to simulate possibilities for simpler scenarios to be executed in the teaching compositions of current programs. The behavior of the scenarios are similar, only the percentages of inbreeding level vary, for example, the current scenario is mostly made up of teachers without inbreeding and inbreeding A, while the IC_C scenario has a majority of teachers with inbreeding C.

To collect the data, a bibliographic analysis was carried out in books and scientific articles. In relation to scientific articles, studies made available in databases indexed to the Scopus and Web of portals were used. Scient. The sample of this study is made up of publications, classified in the top ten positions, in descending order of record count, available in the Main Collection, Web of Science and the Scopus database.

Finally, regarding the data collection instrument, this research uses the ProKnow -C (Knowledge Development Process – Constructivist) proposed by LabMCDA (Laboratory of Multicriteria Methodologies in Decision Support), consisting of four phases: 1) selection of the bibliographic portfolio; 2) bibliometric analysis; 3) systemic analysis; and 4) achievement of research objectives.

The production quantity was collected, using QualisCapes classification (A1, A2, A3, A4, B1, B2, B3, B4). Productions presented in the Lattes CV of each of the teachers in the sample. The production totals were arranged in a virtual spreadsheet, containing the name of the professors, the postgraduate program in which they are linked, the production totals by QualisCapes classification for the year 2023, in a way that facilitated the summation of the points in the last 5 years (2023 - 2019 - 2023). To extract data from each teacher's Lattes CV, we accessed the Lattes search page on the Lattes Platform, then downloaded each CV via XML file.

3.2. Development of the Systems Dynamics Model

The System Dynamics (SD) model has significant advantages in simulating the temporal behavior of complex systems and comparing different development scenarios, and is an effective tool for evaluating and simulating changes in the postgraduate educational system (LI et al, 2020). For Datola et al. (2022), there is a consensus that the system dynamics model focuses particularly on interactions between elements and could better examine the dynamic behaviors of a system.

Existing studies on academic inbreeding also include a large-scale discussion of the structure and practices of inbreeding, including

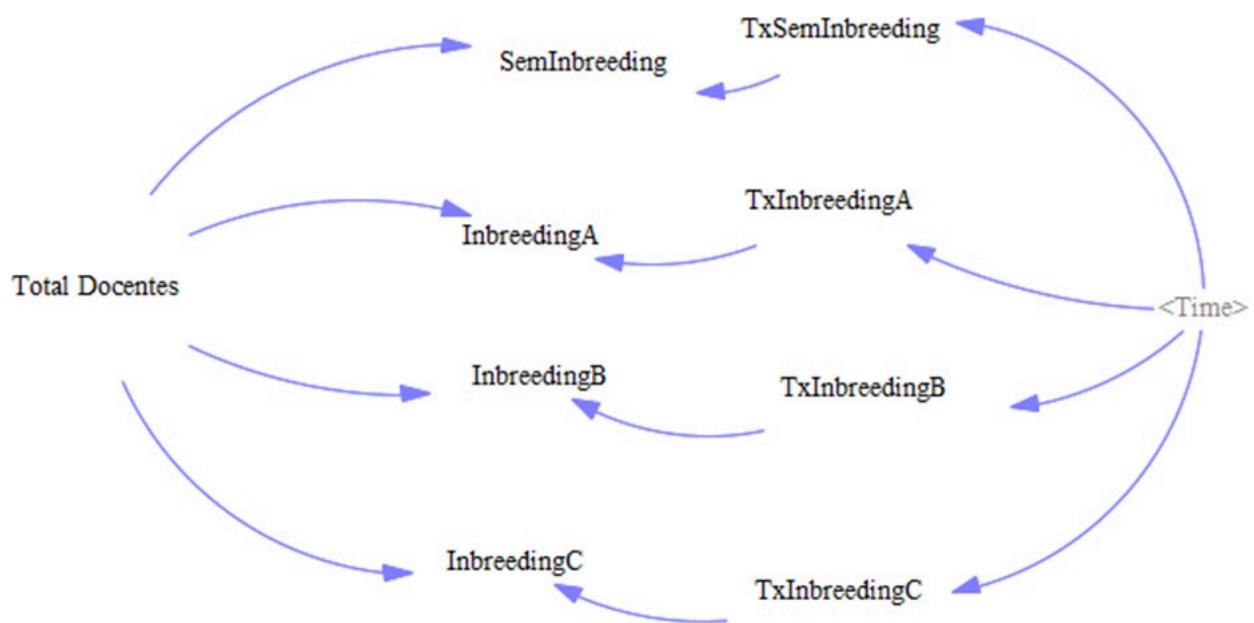
positive and negative effects within an organization (Gokturk & Yildirim-Tasti, 2020). In terms of theoretical perspectives, academic inbreeding is generally considered a negative and problematic institutional practice. For example, with regard to ethical considerations, it is related to clientelism or intra-group favoritism (Altbach et al., 2015) and is considered a practice that can compromise the legitimacy and social benefits of a university (Horta et al., 2010). Furthermore, it was highlighted that academic inbreeding makes research communities narrow-minded, as parochialism of ideas within geographic, linguistic and cultural boundaries becomes dominant (Março, 2005). The reason for this is that training academics at the same university makes them share the experiences and visions that already exist at the institution, reinforcing existing knowledge, instead of following new research paths (Pelz & Andrews, 1966).

Although the practice of academic inbreeding is considered inevitable during the early stages of the establishment of higher education systems and universities, the impact of this institutional academic inertia encourages narrow-mindedness and intellectual isolation. Furthermore, in addition to the commonly reported negative effects of academic inbreeding on research productivity and scientific performance, there is also a consensus in existing studies on the benefits and convenience of academic mobility, as it encourages both the exchange of ideas and the knowledge mobility (Horta et al., 2010). In this sense, it broadens the perspectives of academics and provides an environment that brings together the necessary conditions for innovation, academic renewal and the generation of information. Furthermore, it supports cooperation and collaboration between institutions, both nationally and internationally (Horta et al., 2010). As such, universities in some

European countries (e.g. Germany) and the United States have written or unwritten policies that prohibit or severely limit the hiring of their graduates as faculty members (Horta et al., 2011).

To calculate the number of teachers per inbreeding, the submodel shown in Figure 3 was developed.

Figure 3 - Total Teachers submodel by Inbreeding index



Source: Authors (2024).

The auxiliary variable “**TotalDocentes**” stores the number of teachers in the study database. To calculate the separation by type of inbreeding, four auxiliary variables were developed: “**TxSemInbreeding**”, “**TxInbreedingA**”, “**TxInbreedingB**” and “**TxInbreedingC**”. These variables have a rate function, they are responsible for inserting the behavior of each projected scenario, they are connected to a shadow variable called “**Time**”, this variable indicates the unit of time during the execution of the model. Finally, the variables “**SemInbreeding**”, “**InbreedingA**”, “**InbreedingB**” and “**InbreedingC**” through the interaction of the variables mentioned above are responsible for storing the value of teachers by type of inbreeding.

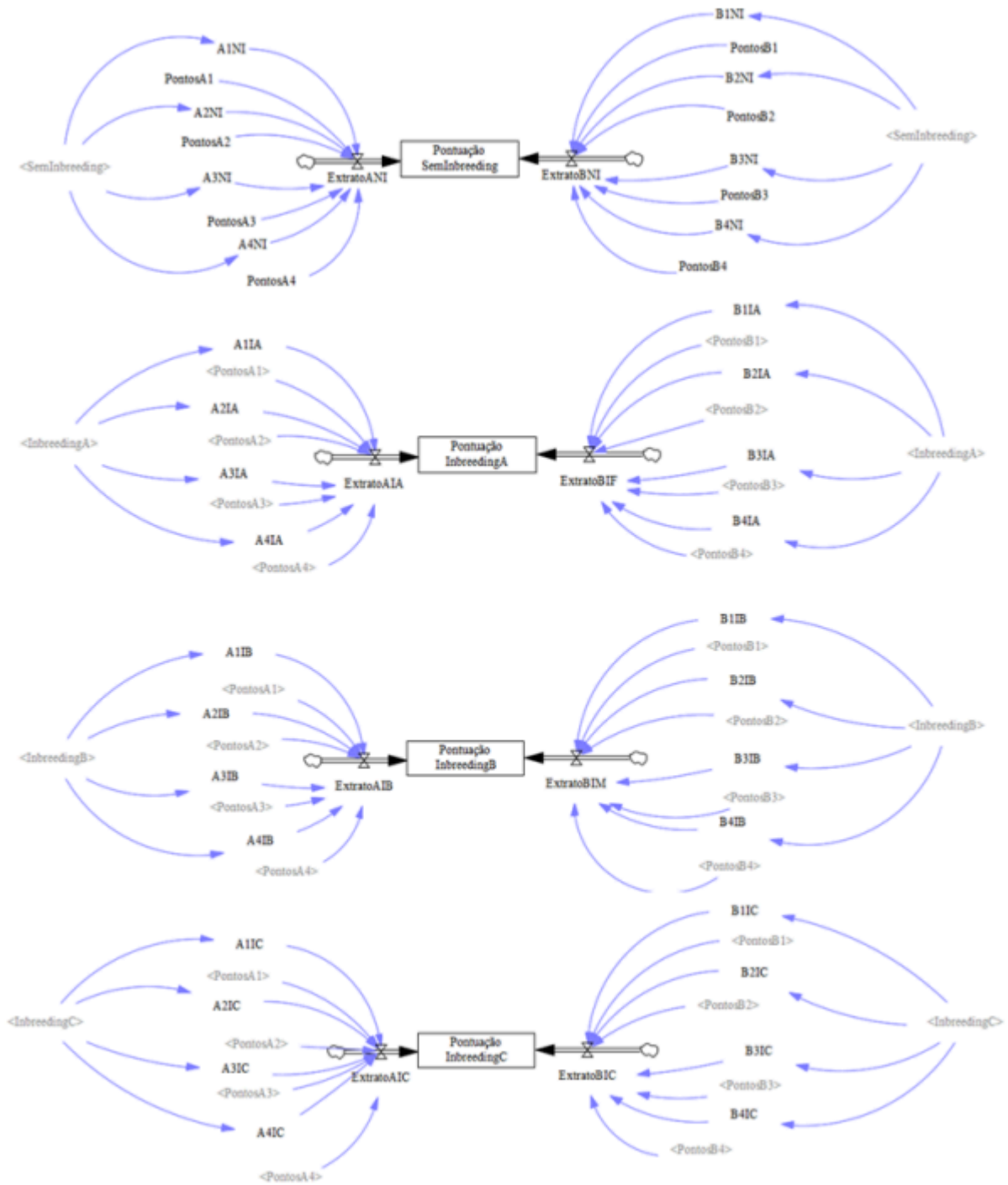
Frame 3 - Equations and Data Submodel Production By Inbreeding index

- (1) Total Teachers = RANDOM UNIFORM (252, 270, 260)
- (2) TxSemInbreeding = Time ([(0,0)-(10,10)],(2024,0.2),(2034,0.26))
- (3) SemInbreeding = Total Teachers* TxSemInbreeding
- (4) TxInbreedingA = Time ([(0,0)-(10,10)],(2024,0.08),(2034,0.14))
- (5) InbreedingA = Total Teachers* TxInbreedingA
- (6) TxInbreedingB = ([(0,0)-(10,10)],(2024,0.16),(2034,0.22))
- (7) InbreedingB = Total Teachers* TxInbreedingB
- (8) TxInbreedingC = Time ([(0,0)-(10,10)],(2024,0.2),(2034,0.26))
- (9) InbreedingC = Total Teachers* TxInbreedingC

Source: Authors (2024).

The second submodel developed aims to calculate the score at each inbreeding level. Initially, the DLC was organized to calculate this score. DLCs present cause and effect relationships between their elements. Connections are made using arrows. Every arrow has a plus or minus sign. If the sign is positive it means that the two elements are proportionally variable, while the negative sign means inversely proportional elements. Often the elements and arrows form a loop. These ties can be classified as feedback or stability. In feedback, cause and effect increase or decrease without a factor that stabilizes them. In bonds of stability or balance, cause and effect oppose each other, making the bond stagnant. Inbreeding index are presented below (Figure 4).

Figure 4 - Production Submodel By Inbreeding index



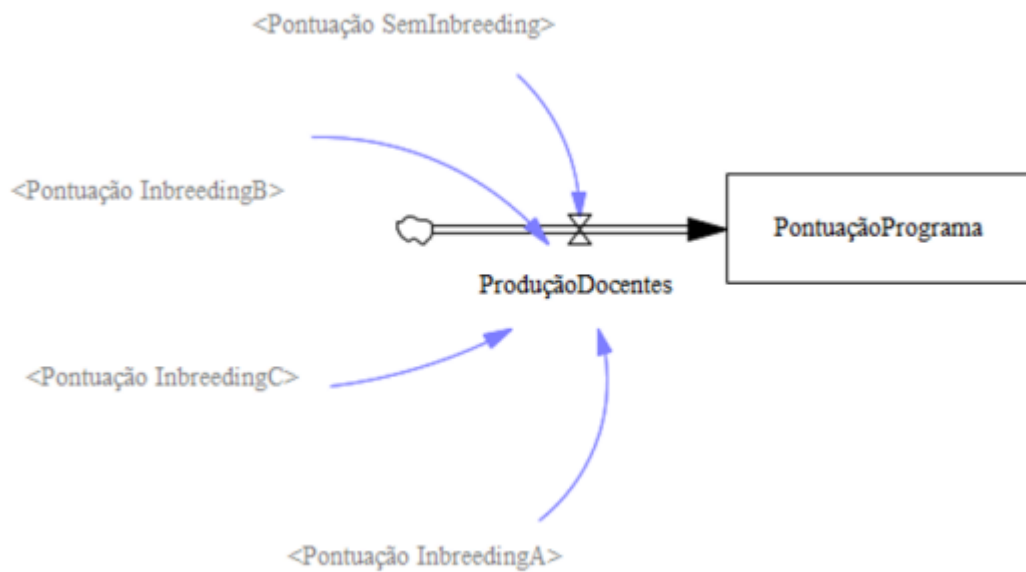
Source: Authors (2024).

In short, 4 stock-flow submodels were developed, one for each type of *inbreeding*. Both models follow the same development logic. One of the submodels will be exposed to explain the development logic of both. The stock model for calculating teacher scores without *inbreeding* has the interaction of all components of a systems dynamics model.

The last submodel will finally unite the previously calculated productions. To facilitate this, the DLC (Causal Leverage Diagram) was created. According to Sterman (2018), DLC proves useful for several purposes: Quickly capturing assumptions about the causes of dynamics; explain and represent the mental models of individuals or teams; communicate crucial feedback that may underlie a problem.

For Tavares, Sin and Nunca (2019), research productivity has attracted the attention of institutions due to a series of political initiatives that place emphasis on the scientific production of academics. Given that research productivity is crucial for the positive evaluation of academics, research units and study programs – therefore, for the good performance of institutions – and since academic inbreeding is potentially harmful to it, this article tests the hypothesis that inbreeding negatively influences research productivity, considering a number of variables related to individual academics and their teaching affiliation. The result of the developed inventory model is represented in Figure 5.

Figure 5 - Program Score Submodel



Source: Authors (2024).

This model will make it possible to calculate the developed scenarios and also to observe the differences by inbreeding score. Therefore, the system dynamics model developed is suitable for analyzing the effects of public policies relating to postgraduate programs and also for other types of analysis relating to this topic. As it allows the examination of dynamic behaviors, interactions and future trends within complex systems, offering valuable information for policy formulation and management of existing processes.

4. EXPERIMENT AND ANALYSIS OF RESULTS

Once the scenarios for carrying out the experiment using the model were defined, the simulations were carried out. As previously described, the data used in both scenarios were collected directly from the teachers' lattes composed in the study database, the other information was obtained from technical documents, as already explained in the previous section. The simulation considered a time period of 10 (ten) years, which can be changed by end users or by the model designers, aiming at projections for a shorter or longer period. The developed model will be used to simulate any educational institution higher. To execute the simulated scenarios,

the Vensim® simulator (VENSIM®, 2023) was used in a computational structure with a 2.5 Ghz Intel Core processor (i5 2450), 4 Gb of RAM memory and the simulation execution time of the three scenarios was on the order of millionths of a second.

According to the interrelationship of system components and the recognition of the behavior of key variables based on the system dynamics diagram, this model was simulated and the process of changing key criteria was determined. Based on the designed model, the behavior of the studied system was simulated over a ten-year time horizon.

Research productivity is defined in the literature as the result of various research activities, such as publishing national and international articles, books, chapters, obtaining grants, among others (TAVARES et al., 2022). Scientific efficiency and productivity were measured by the number of research results, for example among publications in professional journals. Among several factors that determine the productivity of research work, factors related to the institution and the work environment have been highlighted in the high-impact literature (KATRANIDIS et al., 2017). Working with colleagues who are active in research and publishing regularly improves research productivity, just like working at a large institution (MURRAY, 2014).

Inbreeding is most common *in* the development phase of a department, educational institution or higher education system. In new universities, inbreeding does not occur initially, as they employ researchers trained in other educational institutions (TAVARES et al., 2015). However, when they begin to grant doctorates, they tend to

recruit their own graduates to strengthen and stabilize their structures (HORTA & YUDKEVICH, 2016).

Although beneficial in the early stages of development, the negative effect of *inbreeding* increases as systems mature (TAVARES et al., 2015; HORTA & YUDKEVICH, 2016). Different studies provide conflicting results on how *inbreeding* affects research productivity. Some studies reported a negative effect of *inbreeding* on research productivity (ALTBACH et al., 2015; HORTA, 2013).

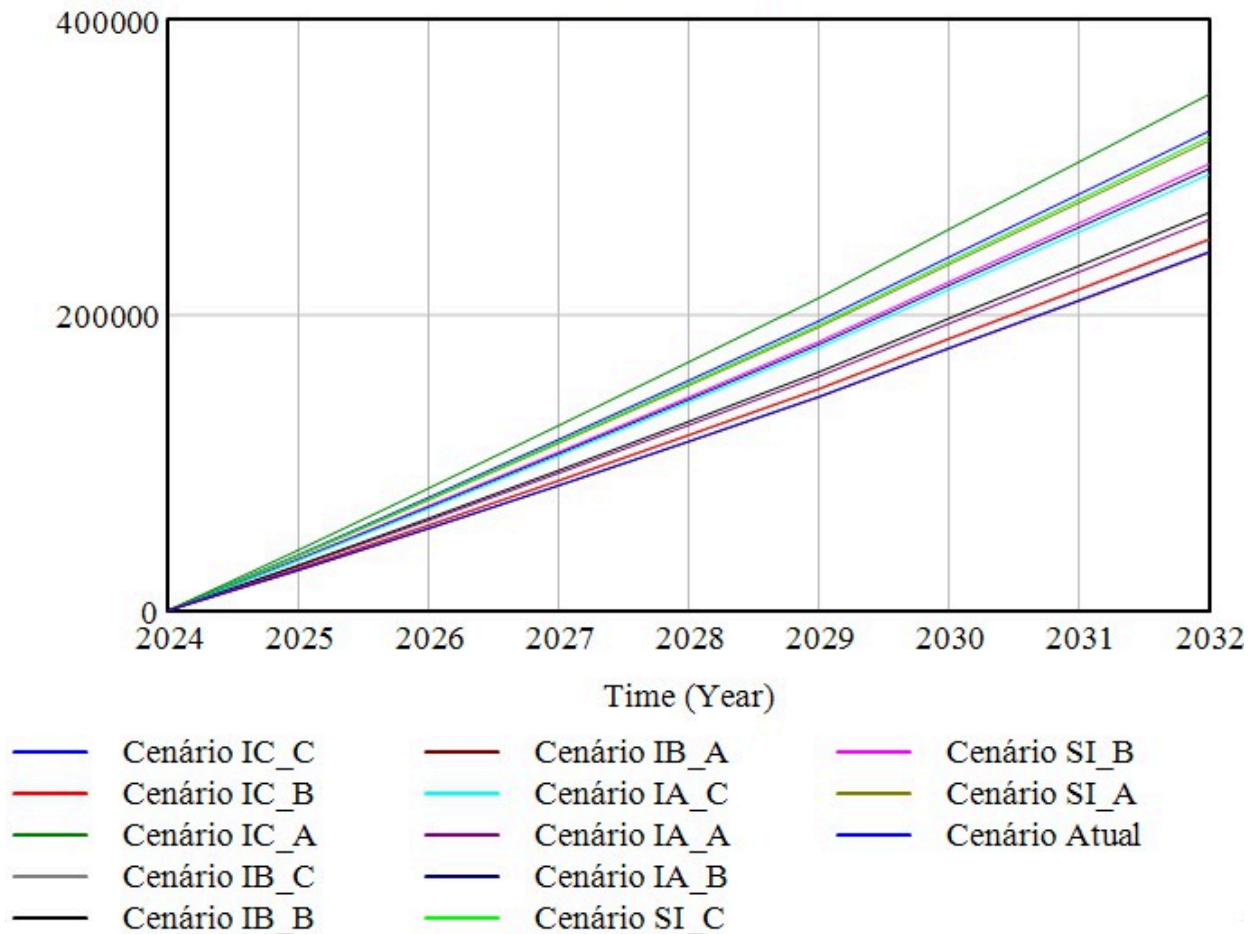
Lovakov, Yudkevich and Alipova (2019), their analysis revealed no substantial differences in productivity between inbreeds and without inbreeds. Being placed in the same academic system, both inbreeders and non- inbreeders appear to demonstrate the same editorial performance, suggesting that there is no systematic bias towards *inbreeding* at the expense of productivity, as university administration may see it.

However, we found a difference in career-wide publishing productivity between inbreeders and those without inbreeding. Non-blood relatives are more productive from a career-long perspective, which is reflected in cumulative productivity.

Given the above, the first analysis of the study sought to answer whether any level of inbreeding impacts the productivity of the programs.

Figure 6 - Performance by inbreeding mix

Pontuação Programa



Source: Authors (2024).

The initial state of Figure 6 - Performance by in the analyzes carried out is related to the output of the model based on the data entered in the variables, the production behavior in the initial state shows exponential growth with low acceleration in both scenarios analyzed. For Santos (2019), a state and flow chart is a tool that people use to build a simulation model and uses accumulation, state, auxiliary and constant variables. It requires that the user is asked to pay attention not to the form, but to the content (Forrester, 1987).

It can be seen that the IC_A scenario presented the best score, it has in its teaching staff mostly teachers with C and B inbreeding, such a point, according to Lovakov (2016) academic inbreeding can strengthen the affective and normative commitment of teachers

with their home institution, but it can also bring challenges related to innovation, external collaboration and academic mobility, which are important aspects for the development and vitality of higher education institutions.

The current scenario, where the majority of teachers do not have an inbreeding level, were the second with the highest score, corroborating the study by Pelegrini and França (2021) where the results demonstrated that those without inbreeding have a greater chance of having at least one international article and greater chances of national publications, with those without inbreeding being the most productive. According to Pelegrini and França (2021), teachers without inbreedings are more likely to publish articles in national newspapers compared to inbreedings. Just as the results indicate that those without inbreeding are also more likely to have at least one article published in international journals, although not necessarily a greater number of publications (Pelegrini & França, 2021)

The third scenario with the highest performance is the SI_C scenario where the teaching staff is made up of the two extremes, without inbreeding and with inbreeding C, the same was mentioned by De Miranda Grochocki and Cabello (2023), inbreeding can vary with the diversity and integration of research networks within universities. Collaborative networks that are predominantly made up of inbreds may not be as integrated and diverse as they could be if there were greater inclusion of Sem scholars. inbreeding (De Miranda Grochocki & Cabello, 2023). Just like González- Sauri and Rossello (2023), they highlight that in Spain they found that inbreeding academics obtained job stability earlier and with a greater number of publications than those without inbreeding.

The worst scenarios are on average where the teaching staff is composed of the majority inbreeding B and C (IB_C; IC_C and IB_A) such results in Brazilian universities can justify the arguments and findings of the study by Barbosa et al. (2018), which identified that inbreeding has a negative effect on research productivity and, consequently, has an impact on the scientific community. Inanc and Tuncer (2011) also verified the negative effect of inbreeding by identifying that there is a negative and statistically significant correlation between the productivity of an individual and the percentage of pure endogenous animals.

Neutral scenarios are those that have a majority of teachers without inbreeding or inbreeding A in predominance in the teaching staff, thus corroborating with Yudkevich and Sivak (2012), who discuss how academic inbreeding can affect the dynamics and effectiveness of universities, arguing that it can lead to less diversity of perspectives and potentially harms the innovation and openness to new ideas. This practice can have significant impacts on values, strategies and individual productivity of faculty members (Lovakov, 2016).

Frame 4 - Simulation Result

SCENARIO	POINTS	RANKING
IC_A	349666	1st
Current	324746	2nd
SI_C	320640	3rd
SI_A	318123	4th
SI_B	302495	5th

IA_B	299197	6th
IA_C	295405	7th
IB_B	269529	8th
IA_A	264642	9th
IC_B	251545	10th
IB_C	250903	11th
IC_C	243020	12th
IB_A	242391	13th

Source: Author (2023).

5. FINAL CONSIDERATIONS

Inbreeding has been linked to varying effects on research productivity and academic performance. On the one hand, some studies suggest that inbreeding may have a negative effect on scientific productivity, arguing that scholars who remain at or return to their doctoral institution tend to have fewer publications and restrictions compared to those who do not have inbreeding. This may be due to a lack of diversity of ideas and the isolation of different approaches and methodologies that are more common in more heterogeneous academic environments.

Furthermore, systems thinking, which underlies the methodological approach of the study, offers a holistic perspective that is essential for understanding the interrelationships and patterns within the system under analysis. This is particularly important when considering the complexity of knowledge networks and the dynamics of Higher Education Institutions (HEIs), where

performance is often assessed based on quantitative indicators, such as the number of publications.

Systems dynamics (DS) modeling can be applied in a variety of areas, including business and education, to improve understanding of complex systems and assist in decision-making processes. DS is an approach that allows you to analyze and solve complex problems with an emphasis on policy analysis and design. This is particularly useful in business and education, where decisions can have far-reaching implications and are often affected by complex interactions between multiple factors. By simulating different scenarios and policies, managers can predict the effects of their decisions and identify optimized strategies to achieve organizational objectives.

The main contributions of the research can be summarized as follows: Development of an analysis model for performance assessment in postgraduate studies, which meets the demands of regulatory bodies such as CAPES and seeks to direct academic production to be not only quantitative, but also qualitative, especially in more prestigious strata. Creation of an evaluation and regulatory instrument to strategically manage Postgraduate Programs (PPGs), journals and academic career development guidance, contributing to the construction of a new perspective on academic research and the researcher's professional development.

This article has some limitations, the system dynamics simulation was carried out based on data collected from Lattes curricula and technical documents, which may limit the generalization of results to other institutions or contexts that do not share the same characteristics or data sources. Research may have faced

methodological limitations due to the diversity of approaches and definitions of academic inbreeding in different studies, which may make it difficult to compare and transfer results to other contexts.

REFERENCES

Altbach, P. G., Yudkevich, M., & Rumbley, L. E. Academic inbreeding: Local challenge, global problem. **Asia Pacific Education Review**, 16(3), 317–330, 2015.

Appolinário, F. **Metodologia científica**. Cengage Learning, 2016.

Azadi, S., Khoshnevisan, B., Nabavi-Pelesaraei, A., & Mohammadi, M. Optimizing cropping pattern to improve the performance of irrigation network using system dynamics—Powell algorithm. **Environmental Science and Pollution Research**, 1–13, 2022.

Balbachevsky, E. An emerging academic market in transition. In **Professorial pathways: Academic careers in a global perspective** (p. 119), 2019.

Blignaut, J., Groenewald, Y., & van der Elst, L. An integrative bio-physical approach to determine the greenhouse gas emissions and carbon sinks of a cow and her offspring in a beef cattle operation: A system dynamics approach. **Agricultural Systems**, 195, 103286, 2022.

Borenstein, D., Perlin, M. S., & Imasato, T. The academic inbreeding controversy: Analysis and evidence from Brazil. **Journal of Informetrics**, 16, 101287, 2022.

CAPES – Coordenação de Aperfeiçoamento de Pessoal de Nível Superior, 2021. **Dados abertos**. <https://dadosabertos.capes.gov.br/>

Collazo-Reyes, F. Growth of the number of indexed journals of Latin America and the Caribbean: The effect on the impact of each country. **Scientometrics**, 98(1), 197–209, 2014.

Costa, H. A., & Hoffmann, V. E. Competitividade de destinações turísticas. **Turismo em Análise**, 17(2), 113–134, 2006.

Crouch, G. I., & Ritchie, J. R. B. Tourism, competitiveness, and societal prosperity. **Journal of Business Research**, 44(3), 137–152, 1999.

Dwyer, L., & Kim, C. Destination competitiveness: Determinants and indicators. **Current Issues in Tourism**, 6(5), 2003.

Forrester, J. W. Urban dynamics. **Industrial Management Review**, 11(3), 67, 1970.

Gooroochurn, N., & Sugiyarto, N. Measuring competitiveness in the travel and tourism industry. **Discussion Paper – TTRI**. Nottingham University Business School, 2004.

Gorbea-Portal, S., & Suárez-Balseiro, C. A. Análisis de la influencia y el impacto entre revistas periféricas no incluidas en el science citation index. **Revista Interamericana de Bibliotecología**, 30(2), 47–70, 2007.

Hafezi, M., Abedi, S., Stewart, E., & Salman Mahiny, A. Evaluating coral reef ecosystem services outcomes from climate change adaptation strategies using integrative system dynamics. **Journal of Environmental Management**, 285, 112082, 2021.

Hirsch, J. E. An index to quantify an individual's scientific research output. **Proceedings of the National Academy of Sciences**, 102(46),

16569–16572, 2025.

Horta, H., & Yudkevich, M. The role of academic inbreeding in developing higher education systems: Challenges and possible solutions. **Technological Forecasting and Social Change**, *113*, 363–372, 2016.

Horta, H., Sato, M., & Yonezawa, A. Academic inbreeding: Exploring its characteristics and rationale in Japanese universities using a qualitative perspective. **Asia Pacific Education Review**, *12*(1), 35–44, 2011. <https://doi.org/10.1007/s12564-010-9126-9>

Horta, H., Veloso, F. M., & Grediaga, R. Navel gazing: Academic inbreeding and scientific productivity. **Management Science**, *56*(3), 414–429, 2010. <http://pubsonline.informs.org/doi/abs/10.1287/mnsc.1090.1109>

Horta, H. Deepening our understanding of academic inbreeding effects on research information exchange and scientific output: New insights for academic based research. **Higher Education**, *65*(4), 487–510, 2013. <https://doi.org/10.1007/s10734-012-9559-7>

Horta, H. Academic inbreeding: Academic oligarchy, effects, and barriers to change. *Minerva*, 1–21, 2022. <https://doi.org/10.1007/s11024-022-09469-6>

Kunc, M., Morecroft, J. D. W., & Brailsford, S. Special issue on advances in system dynamics modelling from the perspective of other simulation methods. **Journal of Simulation**, *12*(2), 87–89, 2018.

McGee, R. The function of institutional inbreeding. **The American Journal of Sociology**, *65*(5), 483–488, 1960.

<http://www.jstor.org/stable/2774077>

Morescalchi, A., Pammolli, F., Penner, O., Petersen, A. M., & Riccaboni, M. The evolution of networks of innovators within and across borders: Evidence from patent data. **Research Policy**, 44(3), 651–668, 2015.

Pelz, D. C., & Andrews, F. M. **Scientists in organizations: Productive climates for research and development**, 1966.

Pluchinotta, I., Giordano, R., Pagano, A., & Tsoukiàs, A. A system dynamics model for supporting decision-makers in irrigation water management. **Journal of Environmental Management**, 223, 815–824, 2018.

Pluchinotta, I., Kazakçi, A., Giordano, R., & Tsoukiàs, A. A participatory system dynamics model to investigate sustainable urban water management in Ebbsfleet Garden City. **Sustainable Cities and Society**, 67, 102709, 2021.

Reddy, K. J. M., Rao, A. N., & Krishnanand, L. Manufacturer performance modelling using system dynamics approach. **Materials Today: Proceedings**, 33, 142–146, 2020.

Romero-Torres, M., Acosta-Moreno, L. A., & Tejada-Gómez, M. A. Ranking de revistas científicas en Latinoamérica mediante el índice h: Estudio de caso Colombia. **Revista Española de Documentación Científica**, 36(1), e003–e003, 2013.

Royal Societ. **Knowledge, networks and nations: Global scientific collaboration in the 21st century**. Royal Society, 2011.

Soda, G. The management of firms' alliance network positioning: Implications for innovation. **European Management Journal**, 29, 377–388, 2011.

Sterman, J. D. **Business dynamics: Systems thinking and modeling for a complex world**. McGraw-Hill, 2000.

Sterman, J. D. System dynamics at sixty: The path forward. **System Dynamics Review**, 34(1–2), 5–47, 2018.

Yudkevich, M., Altbach, P. G., & Rumbley, L. E. **Academic inbreeding and mobility in higher education: Global perspectives**. Springer, 2015.

Zare, F., & Alizadeh, M., & Fattahi, P., & Rakhshani, E. Improved integrated water resource modelling by combining DPSIR and system dynamics conceptual modelling techniques. **Journal of Environmental Management**, 246, 27–41, 2019.

¹ Ph.D. in Administration (Federal University of Santa Maria – UFSM).
Administrator at the Federal University of Santa Maria. E-mail:
roni.barros@ufsm.br

² Master's degree in Administration (University of Vale do Itajaí – UNIVALI). Professor in the field of Administration at the Federal Institute of Roraima (IFRR). E-mail: claudetesantosadm@gmail.com

³ Master's degree in Education (State University of Roraima – UERR).
Professor at the Federal Institute of Roraima (IFRR). E-mail:
marielianalima1977@gmail.com

⁴ Master's degree in Administration (University of Vale do Itajaí – UNIVALI). Independent researcher. E-mail: erick.williammkt@gmail.com

⁵ Ph.D. in Administration (University of Vale do Itajaí – UNIVALI). Professor in the Administration, Civil Engineering, and Psychology programs at Luciano Feijão College (FLF). E-mail: rogeanemoraes@yahoo.com.br

⁶ Ph.D. in Administration and Controllershship (Federal University of Ceará – UFC). Professor in the Undergraduate Administration Program at Luciano Feijão College (FLF). E-mail: socorromesquita@yahoo.com.br

⁷ Master's degree in Controllershship (Federal University of Ceará – UFC). Professor in the Undergraduate Accounting Program at State University Vale do Acaraú (UVA), Betânia Campus. E-mail: helena_mara@uvanet.br

⁸ Ph.D. in Administration and Controllershship (Federal University of Ceará – UFC). Professor in the Undergraduate Accounting Program at State University Vale do Acaraú (UVA), Betânia Campus. E-mail: rodrigues_antonio@uvanet.br