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Rethinking Iran's brain drain: System dynamics modeling and causal layered analysis to investigate the future behaviors of complex societal issues

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ABSTRACT

Iran's ongoing brain drain crisis is among the most challenging issues of the country, attributed to the compounding effects of multiple factors. As communities and their challenges become more complex, new sets of mixed research tools that critically investigate these issues as whole systems rather than isolated parts are crucial for future decision makings. In light of this, mixed research approaches offer the chance to overcome most of the limitations of individual methods and provide potential solutions to complicated problems that are more in-depth than a single form of research method. In this paper, by drawing on the complementary characteristics of Causal Layered Analysis and Participatory System Dynamics, a mixed approach for investigating the future behaviors of complex socio-economic systems and exploring the effectiveness of various policy interventions over time is proposed. Moreover, Iran's brain drain case study is presented for further assessment of the proposed approach. The implication of the proposed approach to skills mobility or the so-called brain drain phenomenon is the undisputable role of human capital efficiency in the future developments of the nation. Through this approach, in the first step, an issue is critically analyzed and unpacked into four layers, namely as litany, structure, worldview, and metaphor. In the second step, a participatory approach is implemented to systematically model the issue based on the results of the previous step via five stages. The utility of this approach is its ability to critically examine the future behaviors of complex systems under the effect of different policy interventions and scenarios. Therefore, the proposed approach will generate theoretical value for researchers in the field of futures studies and harbor practical value for policymakers who seek a better mechanism to critically investigate complex socio-economic systems.

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1. Introduction

As communities and their challenges become more complex and multi-dimensional, new sets of tools that enable critical thinking and investigate these issues as a whole system rather than isolated parts are crucial to assist the managers in their future decision makings. In other words, real-world challenges are most complicated, and various research methods should be employed to explore different facets of a case (Morgan et al., 2017). On account of this, adopting mixed research methods provides the opportunity to resolve most of the limitations and drawbacks of individual inquiry methods (Morgan et al., 2017) and offer possible solutions to complex problems that are more in-depth than a single research method do (Zolfagharian et al., 2018). Therefore, this study responds to this research agenda by focusing on mixing two methods of inquiry, which differentiate in nature and each has its own contributions and limitations and have been significantly used to address different challenges individually, namely as System Dynamics (SD) and Causal Layered Analysis (CLA).

On the one hand, the System Dynamics method has been significantly used by many scholars and practitioners to model complex socio-economic systems over time and analyze the effectiveness of the intervening policies (Sterman, 2000). On the other hand, Causal Layered Analysis as a tool for critically unpacking an issue has been the focus of many researchers in the field of futures studies (Inayatullah, 2017). However, to the best knowledge of this paper's authors, no prior works have discussed the complementary features of SD and CLA in the literature.

Therefore, this study proposes a new mixed approach that draws on the complementary characteristics of System Dynamics and Causal Layered Analysis to enable a deep investigation of the future behaviors of complex socio-economic systems over time and analyzing the effectiveness of various policy interventions in the long run. Moreover, a case study of skills mobility, as a concerning multi-dimensional issue in most of the developing and under-developing countries, is conducted for further implementation and assessment of the proposed approach. The implication of the proposed approach to skills mobility or the so-called brain drain phenomenon is the undisputable role of human capital efficiency in the future developments of the nations (Ngoma & Ismail, 2013).

International organizations such as the Organization for Economic Cooperation and Development (OECD), the United Nations Development Program (UNDP), the International Labor Organization (ILO), and the World Bank recognize "global knowledge divide" or emigration of the educated people as a barrier to economic growth in developing countries, since they will unavoidably be replaced by the less educated, and lower-skilled people (Chaichian, 2010; Rizvi, 2005), if at all. While the word "brain" implies any skill, competency, or attribute that is considered as a potential asset, "drain" expresses that the level of exit rate is greater than "normal" or than what might be an acceptable level. Using these two words at the time describes the movement of the most talented individuals at an appreciable rate from their homeland (Davenport, 2004).

The remainder of the paper is as follows. Section 2 provides a background on the history of Iran's brain drain, whereas Section 3 reviews the literature on Iran's skilled migration issue. Section 4 is devoted to the proposed mixed approach: Section 4.1 describes causal layer analysis, while Section 4.2 explains the Participatory System Dynamics method. In Section 5.1, Iran's brain drain is studied through causal layered analysis in the first step and then modeled using system dynamics simulation in Section 5.2. The results are discussed in Section 6 while Section 7 concludes them.

2. Background on the case study's experience in skills migration

Stepping back in Iran's history reveals that, although Iranian people were themselves immigrants to Iran plateau, for centuries they never witnessed drastic emigrations until the contemporary period (Naghdi, 2010). Many Iranian scholars believe that Iran has experienced three waves of highly skilled migration in its contemporary history (Chaichian, 2010; Roudgar & Kanagasundram, 2018).

The first wave started in the 1960s and ended before the Islamic Revolution in 1979, in which many students were sent out to western countries especially the United States of America for further education with the governmental scholarships or their families due to the former regime's economic and development policies to come back and apply the acquired expertise in their own country. The second wave was initiated a couple of months before the Islamic Revolution of Iran by the emigration of many government experts who were opponents and deeply dependent on the former system. The second wave was then accelerated by the closure of universities in the era of cultural revolution from 1980 to 1983 and continued in the time of the Iran-Iraq war between 1980 and 1988. Finally, the third wave was formed in the post-Iran-Iraq war for different stimuli, as the Post-Fordism educated Iranian emigrants do not subscribe to nationalist ideology, which encourages them to respond to the demands of an international job market while still maintaining their Iranian cultural identity (Chaichian, 2010). Moreover, based on the availability of data on the outflow population of highly educated emigrants from Iran, it could be inferred that a new wave of migration among the community of experts and elites of Iran has been initiated in 2005 mainly due to the fundamental sanctions imposed against Iran which had significant effects on the political, economic and social atmosphere of the country. Fig. 1 depicts these four waves of skilled migration under major historical events of Iran and Fig. 2 demonstrates the new and fourth wave of Iranian highly-educated migration in the form of the total population of students studying abroad.

The significance of Iran's skilled migration can be indisputably captured by shedding light on international reports. A report in 2017 indicates that Iran is among the youngest countries in terms of the median age of its emigrants which is 30.2-year-old (United Nations Population Division, 2017). Likewise, a study declared that Iran has the highest number of highly educated emigrants in the world with 68.4 % of its emigrants (Arslan et al., 2014). Similarly, an international report in 2017 reveals that the population of Iranian emigrants with university degrees who are residents of other countries is 2.8 times greater than the population of Iranians with university degrees who reside within the borders (Fargues, 2017). Furthermore, the statistics show continuous growth in the total

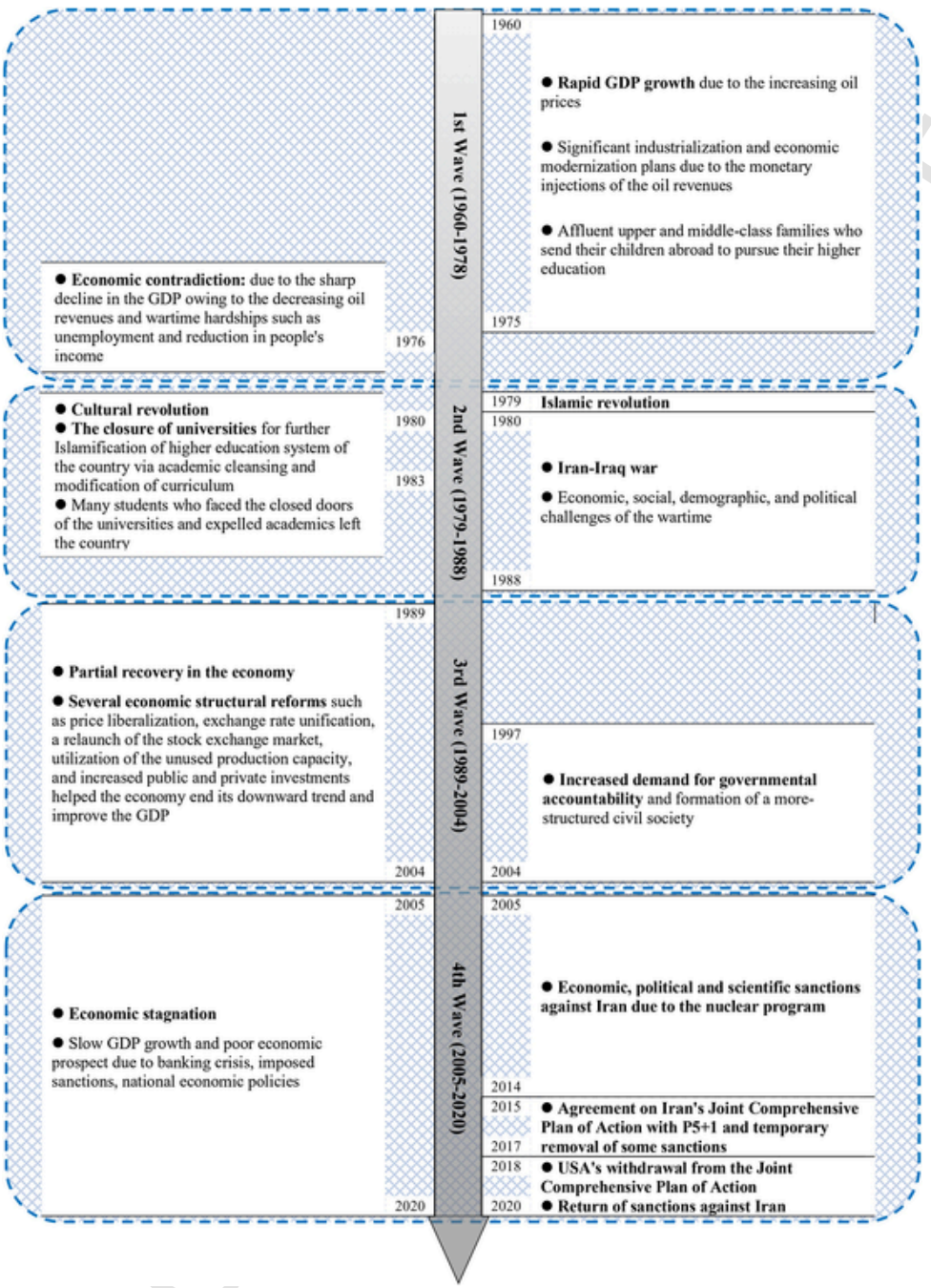

Fig. 1. Waves of Iran's skilled migration under major driving events (Based on the data derived from the Statistical centre of Iran, 2020).

number of Iranian tertiary students studying abroad (UNESCO Institute for Statistics, 2019).[1] Additionally, it is revealed that the United States of America, Germany, Canada, Australia, the United Arab Emirates, and England are their top six favorite destinations (UNESCO Institute for Statistics, 2019). Moreover, a recent research studied the intentions of international students to stay in the United States after completing their doctoral studies in 2014 reveals that only Iran has a common increasing tendency in the number of its doctorate recipients from 2008 to 2014 among the countries in West Asia (Karaca, 2018). Furthermore, this study reveals that Iranian doctorate recipients have the highest rate of intentions to stay after receiving their doctoral degrees in the US (85.4 %) (Karaca, 2018). The detailed information on the above facts is demonstrated in Figs. A1–A10 in Appendix A.

[1] Void cells implies for the unavailable data in the specific year and region.

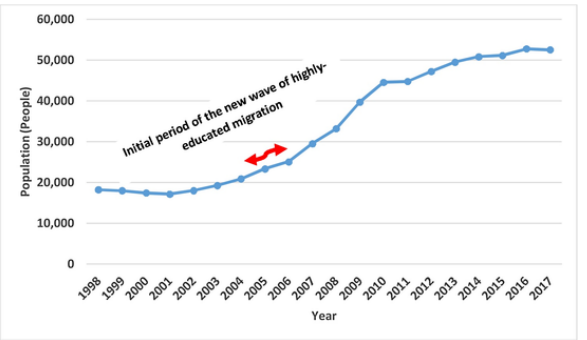

Fig. 2. The population of Iranian students studying abroad from 1998 to 2017 (Based on the data derived from UNESCO Institute for Statistics, 2019).

Another insightful measurement for addressing Iran's brain drain is to investigate whether the massive highly-educated migration happens during a demographic era called the window of opportunity, in which the population of the working cohort outnumbers the population of the non-working cohort significantly (Van der Ven & Smits, 2011), or not. In other words, this demographic opportunity provides the necessary skilled and educated young workforce for major economic developments. As it is demonstrated in Fig. 3, the ratio of the population working-age cohort to the population of non-working age cohort of Iran has been witnessing a growth since 2005 which will be continued till 2030 based on probabilistic estimations (United Nations Population Division, 2019a, 2019b). Consequently, a close look at Iran's demographic window of opportunity and the new wave of highly-educated migration reveals a period of synchronization of both events from 2005. Therefore, these findings highlight the fact that Iran has not been successful in seizing the opportunity so far.

3. Literature review on the case study

The continued brain drain in Iran is concerning for the government as it politically represents the country as an unpleasant place for elites and highly educated people (Mahmoodi, 2014). The brain drain phenomenon has always been a controversial topic in Iran but during the last two decades, it has turned into an ever-growing issue. The large-scale one-way movement of Iranian elite migration to more developed countries has been the subject matter of many studies, newspaper articles, and official statements. However, a recent study reveals that there is significant neglect in general policies about providing the proper conditions to encourage the educated and talented Iranian, which not only discourages educated and talented individuals to return to the country but also persuades others to emigrate as well (Roudgar, 2018). Different factors and stimuli had potentially affected the occurrence and the rate of the talent flow in Iran through the past four waves of skilled migration. Most of the literature regarding the history of Iran's brain drain recognizes that the decision of highly educated individuals to migrate is the result of the widely used theoretical framework called push-pull factors, first introduced by Lewin (Lewin, 1951). This model is constituted of push factors that drive migrants to leave their countries of origin and pull factors that attract skilled migrants into their preferred destinations.

On the one hand, amongst the studied push factors are the economic factors which involve I) high living cost and inflation, economic downturn, unfair access to resources, unemployment, and job insecurity (Kamyab, 2015; Nafari et al., 2017; Panahi, 2012; Rahmandoust et al., 2011), II) the political factors that include unsatisfactory political atmosphere and managerial structure (Kazemi et al., 2018; Nafari et al., 2017; Panahi, 2012; Rahmandoust et al., 2011; Roudgar & Kanagasundram, 2018), III) the social and cultural factors that consist of civil rights, religious limitation, discriminations and equalities (Asadi et al., 2017; Rahmandoust et al., 2011; Salmani et al., 2011), and IV) the scientific factors refer to insufficient research budgets and facilities, and the intellectual atmosphere at universities (Kamyab, 2015; Panahi, 2012; Roudgar, 2018). On the other hand, the pull factors mostly relate to I) higher

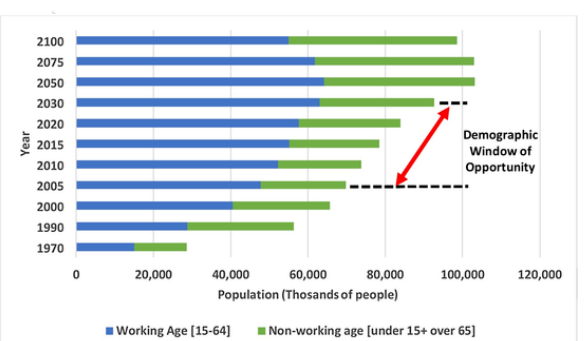

Fig. 3. Demographic comparison of the populations of working age cohort with non-working age cohort from 1970 to 2100 based on probabilistic estimation (Based on the data derived from United Nations Population Division, 2019a, 2019b).

welfare and economic opportunities (Kamyab, 2015; Panahi, 2012), II) better social rights (Kazemi et al., 2018; Panahi, 2012), III) greater research grants and facilities (Kamyab, 2015; Kazemi et al., 2018; Nafari et al., 2017).

Nonetheless, the previous works not only have failed to address all the underlying driving factors of Iran's skills mobility but also lack the systematic perspective to model this issue as a whole rather than isolated parts and overlook to explore the policy interventions to improve the status of Iran's skilled migration, the research gaps that this study intends to fill out. Table 1 demonstrates this research gap and depicts the distinction of the presented study with previous research works.

4. Proposed approach

Understanding the future behaviors of complex systems that are associated with the collective communities of people within natural and social environments underlines the development of mixed research methodologies, which investigate the system as a whole rather than individual parts (Floyd, 2008; Sterman, 2000). Real-world challenges are mostly complicated and various research methods should be employed to explore different facets of a case (Morgan et al., 2017).

On account of this, adopting mixed research methods provides the opportunity to resolve most of the limitations and drawbacks of individual inquiry methods (Howick & Ackermann, 2011; Morgan et al., 2017) and offer possible solutions to complex problems that are more in-depth than a single research method do (Zolfagharian et al., 2018).

With reference to this need, the presented study proposes a new mixed approach to the Participatory System Dynamics method as a response to understanding the behaviors of complex socio-economic systems over time and analyze the effectiveness of the intervening policies (Forrester, 1958) and Causal Layered Analysis as a tool for critical futures studies (Inayatullah, 1998). Although these two methods of inquiry, which differentiate in nature and each of them has its own contributions and limitations, have been significantly used to address different challenges individually, their complementary and comparable characteristics for investigating the future behaviors of complex socio-economic systems have not been explored yet. The first complementary characteristic of CLA and SD pertains to their abilities for deeply investigating societal issues. While almost all of the SD practices conceptualize and model the complex systems only at the most obvious and macro levels and lack critical power to delve much more than the existing structures and stereotypes (Ding et al., 2018; Morgan et al., 2017; Zolfagharian et al., 2018), CLA is capable of moving the exploration of an issue beyond the superficial and obvious to the deeper and marginal (Inayatullah, 2017). Therefore, linking up these two methods allows for systematic and deep analysis and modelling of an issue. In other words, combing CLA with SD enable policymakers and scholars to harness the full capacity of systems and critical thinking simultaneously. The second complementary characteristic concerns to their capacities for designing and exploring policy interventions. Whereas CLA is mostly spent on problematizing an issue and not enough on designing new policy actions solely (Inayatullah, 2004), SD is an effective method for developing and testing various policy interventions to understand how key variables of an issue change over time (Forrester, 1997; Sterman, 2000). Hence, SD as a method that allows for being combined with other research methods, considers the combination of both qualitative and quantitative aspects of a dynamic phenomenon, and is efficient in designing and analyzing various policy interventions in the long run (Forrester, 1997; Sterman, 2000; Zolfagharian et al., 2018), can complement CLA suitably in this sense. Moreover, other reasons for the mixed application of CLA and SD are the existence of several comparable characteristics which potentially contribute to an efficient approach when dealing with complex societal issues. Firstly, although both CLA and SD can be employed as stand-alone research methods, they are best used when paired with other methods to overcome their limitations (Inayatullah, 2017; Zolfagharian et al., 2018). Secondly, CLA is a futures research method that is applicable in all fields of studies (Inayatullah, 2017) and SD is similarly a powerful tool for investigating any dynamic systems such as social, political, economic, ecological, etc. issues (Forrester, 1997; Sterman, 2000).

Table 1
The research gap in Iran's Brain Drain.

Researcher (s)	Research approach	Investigation of underlying assumptions and factors							Future behavior study	Policy intervention analysis
		Litany	Systematic				World view	Myth	✗	✗
			Political	Economic	Social	Scientific				
(Rahmandoust et al., 2011)	Interview	✓	✓	✓	✗	✗	✗	✗	✗	✗
(Salmani et al., 2011)	Questionnaire	✓	✗	✗	✓	✗	✗	✗	✗	✗
(Panahi, 2012)	Questionnaire	✓	✓	✓	✓	✓	✗	✗	✗	✗
(Kamyab, 2015)	Descriptive	✓	✗	✓	✗	✓	✗	✗	✗	✗
(Asadi et al., 2017)	Questionnaire	✓	✗	✗	✓	✓	✗	✗	✗	✗
(Nafari et al., 2017)	A multi-criteria decision-making quantitative approach	✓	✓	✓	✓	✗	✗	✗	✗	✗
(Roudgar & Kanagasundram, 2018)	Interview	✓	✓	✗	✓	✓	✗	✗	✗	✗
(Kazemi et al., 2018)	Questionnaire	✓	✓	✓	✓	✓	✗	✗	✗	✗
This study	Causal Layered Analysis and System Dynamics Modelling	✓	✓	✓	✓	✓	✓	✓	✓	✓

Finally, both CLA and SD allow for capturing various stakeholder's perspectives and different viewpoints to widen the knowledge of the subject matter (Forrester, 1997; Inayatullah, 2017; Sterman, 2000).

The complementary and similar characteristics of Causal Layered Analysis and System Dynamics Modelling are demonstrated through the harmonious-color contributions and limitations of each method provided in Table 2.

Therefore, this study draws on these complementary and comparable characteristics to propose a new mixed approach to enable deep investigation of the future behaviors of complex socio-economic systems over time and analyze the effectiveness of various policy interventions to see how key variables behaviors fold out in the long run. Subsequently, a case study of skills mobility is presented for further assessment of the proposed approach. Fig. 4 demonstrates how SD and CLA are conducted within the presented approach.

Table 2
Complementary and comparable characteristics of Causal Layered Analysis and System Dynamics Modelling (Forrester & Forrester, 2007; Lyneis, 2000; Sumari et al., 2013).

Dynamics Modelling		
Method	**Contributions**	**Limitations**
Causal Layered Analysis (CLA)	Applicable in all domains (Sohail Inayatullah, 2017)	Unable to forecast the future per se and is better used to discuss challenges and situations when paired with other methods (Sohail Inayatullah, 2004)
	Can be employed as a stand-alone tool to better explain and collect multiple viewpoints on an issue (Sohail Inayatullah, 2017)	Mostly spent on problematizing an issue and not enough on designing new policy actions (Sohail Inayatullah, 2004)
	Move the discussion beyond the superficial and obvious to the deeper and marginal (Sohail Inayatullah, 2017)	Dependent on the availability of a skilled facilitator and requires time and patience (Sohail Inayatullah, 2004)
	Critically unpacks an issue that helps to build longer-lasting, robust, reliable, productive, and deeper solutions (Sohail Inayatullah, 2017)	
System Dynamics (SD)	A tool to address complex systems, e.g. social, political, economic, or ecological systems (Jay Wright Forrester, 1997; J D Sterman, 2000)	Possible to become very complex, when real situations with so many variables are modeled (Ding et al., 2018; Jay Wright Forrester, 1997; Sumari et al., 2013)
	Suitable for capturing various stakeholder's perspectives into dynamically modeling a problem (Zolfagharian et al., 2018)	
	Enables understanding of feedback-driven explanations of complex systems behaviours over time (Jay Wright Forrester, 1997; J D Sterman, 2000)	Not suitable for providing numerical precise forecasts and can be paired with discrete modelling methods (Jay Wright Forrester, 1997; Lyneis, 2000)
	Allows for the combination of both qualitative and quantitative aspects of a dynamic phenomenon (J D Sterman, 2000; Zolfagharian et al., 2018)	Mostly inclined to analyze dynamics systems only at the macro-level (Ding et al., 2018; Zolfagharian et al., 2018)
	Efficient in designing and testing various policies interventions to see how the key variables' behaviors of an issue fold out in the long run (Jay Wright Forrester, 1997; J D Sterman, 2000)	Not appropriate for complex systems with unknown structures due to the dependency of this method on the quantified relationships of variables (Ding et al., 2018)
	Conducive to investigate cases with poor numerical databases and rich expert knowledge of key participants (Jay W Forrester & Forrester, 2007; J D Sterman, 2000)	

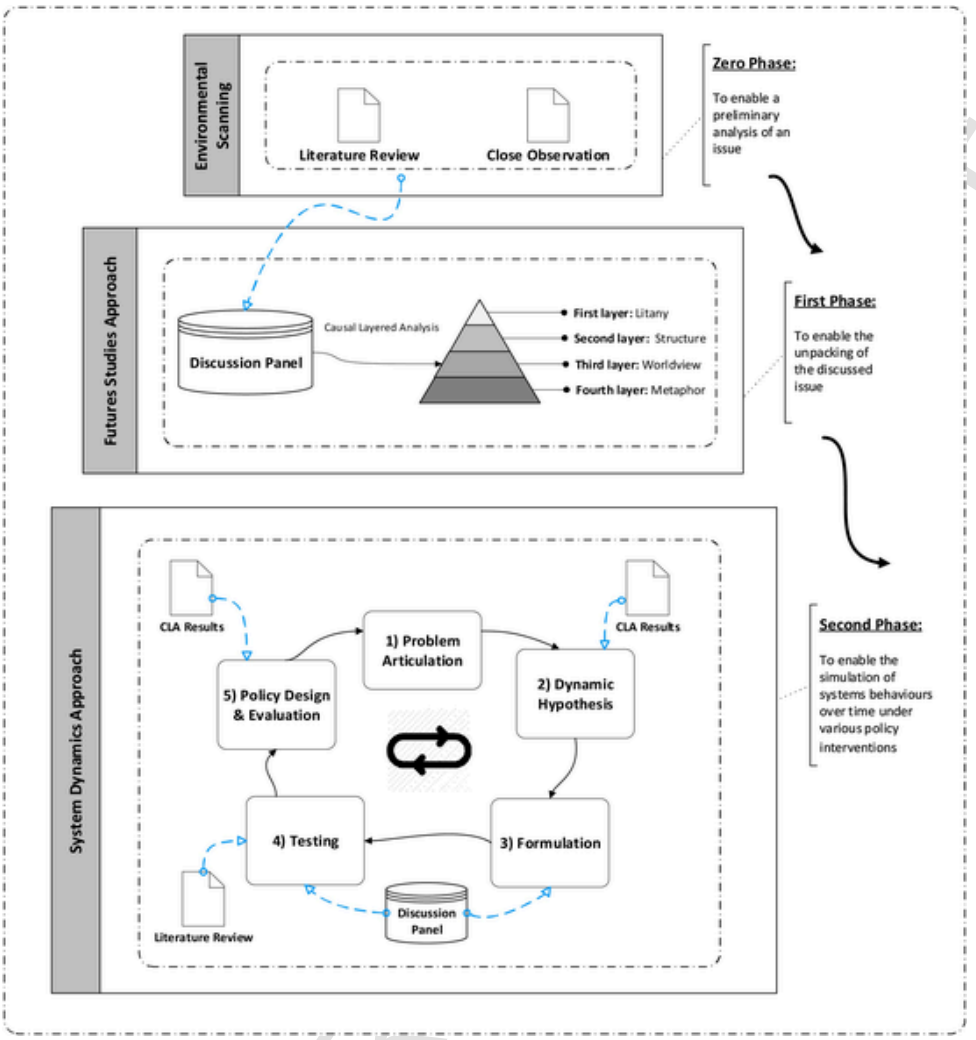

Fig. 4. The proposed framework to study the future behaviors of complex socio-economic systems under various policy interventions through a futuristic perspective.

4.1. Causal layered analysis

By diversity and transdisciplinary, strategic foresight and futures studies have defied attempts at straightforward definition. Unlike other disciplines, such as biology, sociology, or economics, futures studies do not have fixed theoretical boundaries, theories, paradigms, authorities, or well-established designated areas of research and thought. Rather, it borrows from the breadth and histories of all canons with a view to apply pragmatic interventions for imagining (or reimagining) alternative futures. In this regard, it is not a discipline, rather a systematic and open-ended mode of inquiry (Sardar, 2013). The present investigation is concerned with critical futures research, which seeks to ask problematic questions (Gidley, 2017) and to create transformation through the analysis of issues.

Developed by Inayatullah (Inayatullah, 2004), Causal Layered Analysis (CLA) concerns itself with exposing the underlying assumptions of futures thinking to emphasize the parochial nature of current social practices so they are not unconsciously projected in the future as truths and practices (Inayatullah, 2010; Sardar, 2013). CLA enables the 'unpacking' of the perspectives and assumptions of the key stakeholders. With reference to CLA, Inayatullah highlights that "its utility is not in predicting the future but in creating transformative spaces for the creation of alternative futures and is likely to be useful in developing more effective, deeper, inclusive longer-term policy (Inayatullah, 2004)." Inayatullah's use of CLA can be seen in academic research and through workshops in consultancy to areas such as the futures of health, energy, democracy, communities, and policing in Asia (Inayatullah, 2005).

CLA encompasses four vertical layers within which horizontal discourses may be entered (Inayatullah, 2004, 2017; Inayatullah & Milojevic, 2015). Firstly, the litany level. At this level, issues analysis is based upon quantitative trends, empirical data, and news media. The secondary level explores the social causes or systems view. At this level, issues are framed and analyzed from systemic causation perspectives and include analysis from social, technological, economic, environmental, and political perspectives (Inayatullah, 2004, 2017; Inayatullah & Milojevic, 2015). The next level, the third level, is the worldview. At this level, analysis is concerned with discerning the deeper assumptions behind the issue (Inayatullah, 2004, 2017; Inayatullah & Milojevic, 2015). Finally, the metaphor

level aims to find the more profound stories, the sub-conscious and emotive view/s of issues (Inayatullah, 2004, 2017; Inayatullah & Milojevic, 2015).

4.2. Participatory system dynamics

The System Dynamics (SD) method was first introduced by Prof. J.W. Forrester in the 1950s to study the behaviors of large-scale, complex socio-economic systems over time through computer simulations (Forrester, 1958). The core concept of the SD method implies that time delays, non-linearities, system feedbacks, amplifications, and structural relationships among a system's components play a significant role in determining the aggregate system behavior than the individual elements themselves (Forrester, 1958; Neuwirth, 2017; Sterman, 2000). This method improves the traditional management methods by taking into account the science of feedback control and has been employed by various field, including but not limited to environmental (Kotir et al., 2016; Neuwirth, 2017), demographics (Meadows et al., 1972), economic growth (Kovalevsky & Hasselmann, 2014; Milić Beran, 2015), business development (Gold, 2014; Weil, 2007), and natural resources studies (Ahmad et al., 2016; Robalino-lópez et al., 2020; Shen et al., 2009; Wei et al., 2016; Xi & Poh, 2013). In SD, a problem is demonstrated by a network of cause-effect relationships and feedback loops with three building variables: 1) stock variables which demonstrate the level of any system status at a specific time instant, 2) flow variables that are responsible for increasing or decreasing of the stock variables, and 3) auxiliary variables which can be calculated from other variables within the system (Sterman, 2000). Different approaches to the system dynamics modelling process were presented by several scholars (Martinez-Moyano & Richardson, 2013; Randers, 1980; Richardson & Pugh, 1981; Sterman, 2000). Participatory SD is a recent approach that involves multiple participants in the model building processes to obtain consensus on the problem articulation, to create a common understanding among the key players to model the system, and to enable testing various hands-on policy interventions suggested to management actors (Schmitt Olabisi et al., 2010). In the proposed approach, participatory SD modelling was implemented to enable the reflection of various stakeholders.

This study employs the 5-stage system dynamics modelling approach proposed by Sterman (Sterman, 2000) using VENSIM PLE simulation software. This process initiates with (I) problem articulation to select the boundary of the system, following (II) formation of dynamic hypothesis by drawing causal loop diagrams of the system variables and linking the major variables in feedback fashion by arrows (positive arrows for direct and negative for inverse influence). Then, (III) a simulation model is formulated through the mathematical stock and flow diagrams. The last two phases are to (IV) test the system dynamics model in terms of structure and behavior and (V) design policy and evaluate the model by sensitivity tests and what-if analyses (Ahmad et al., 2016).

5. Case study: Iran's brain drain

In this section, the case study of Iran's skilled migration or the so-called brain drain is explored using the proposed mixed approach.

5.1. Implementation of causal layered analysis

CLA method enables the 'unpacking' of the perspectives and assumptions of the key stakeholders. To enable this, an expert panel discussion was conducted at the Center for Science and Technology Studies, Iranian Academy of Sciences in Tehran, in September 2018. A panel of academic scholars (n = 11) with multidisciplinary backgrounds was formed. This panel consists of I) three experts with a long history of research and teaching in the field of science and technology policy and has hands-on experiences from his former positions at the ministry of science, II) one expert with a long history of research and teaching in the field of the triple bottom line sustainability and has been the advisor to the president of the Iranian Department of Environment and the ministry of energy in Iran, III) two experts with a long history of research and teaching in the field of innovation and technology management and has years of experiences in entrepreneurship and knowledge-based ecosystems, IV) three experts with a significant amount of research in the field of futures studies and higher education and V) two experts in the field of social science and community planning and development. Despite the various academic backgrounds of the participated experts, the synergy of their individual knowledge in the interdisciplinary concept of brain drain contributes extensively to a comprehensive investigation of Iran's elite migration. Consequently, a series of questions were developed for each of the four layers of the CLA analysis and a panel of discussion was coordinated. The results of the expert panel discussion are as follows.

The litany layer is the level that brings the general data sets and concerns of community members into light through rationalistic reductionist and sometimes quantitative data is interrogated. The litany level is usually the presentation of issues as would be seen in mainstream media, discussed amongst colleagues, and presented as part of superficial analysis. For the presented study, it was determined that terms responding to the question of how the international outflow of Iranian elites and professionals is described are the best fit at the litany level. In this sense; skills mobility, brain drain, human capital flight, highly-educated migration, elite migration, migration of brains, and migration of elite genes should be indicated to commence the analysis. Whilst the systemic layer is the second level, it brings the interpretation to the litany level and identifies the social causes shaping the issue as it appears to participants of the expert panel. For this study, the experts determined the assortment of factors to include the scientific, economic, socio-cultural, and managerial-political implications and their associated factors.

The third layer of analysis, the discourse or the world view layer, examines the perception, perspective, and aperture from a wider context such as the regional, state, national, or even global context, civilizational perspectives and epitomes, ontologies and tradi-

tions. In this regard, the experts determined that the worldview layer should respond to the question; what deeper assumptions have made changes in the systematic/structure layer of Iran's brain drain or elite migration phenomenon? The presented issue is shaped by the worldviews perceived by two specific groups including I) Iranian highly-educated elites and II) Iranian governors and policymakers whose ideologies have constituted Iran's brain drain phenomenon. The first discourse that has given rise to this issue is the fact that Iranian elites are not being recognized and acknowledged by the Iranian governors and authorities as one of the main valuable asset and the driving force for the further economic and scientific development of the country, while in many developed countries various measures have been taken by the policymakers to gain the best and brightest minds from other regions to meet the adequate human capitals for the future prosperity of their nations. As an extension to the previous discourse, another discourse has given rise to Iran's brain drain. The poor human capital formation and retention in Iran have engendered low social dignity of elites as these qualified labor forces are incorporated into occupations that do not correspond to the level of educations these graduates have received throughout the years, all of which leads to brain waste to some extent in the country. The third worldview is concerned with the globalization paradigm and how it has facilitated the information and monetary flow between poor and rich countries, induced massive mobilizations across geographical and cultural borders, and has encouraged many talented minds including Iranian elites to respond to the international market opportunities in other regions than their homeland. As an extension to the globalization worldview is the discourse of western lifestyle and how it has attracted many Iranian elites, who are more drawn to the western culture and its standards of lifestyle rather than conventional cultural structures and religious stereotypes in Iran, via the internet, media or short-time visits. The fifth worldview stands for the Islamic-Iranian ideology, its popularity among the community of Iranian elites, and how the inefficient advertisement of the Islamic-Iranian traditions has influenced the human capital flight in Iran. The final discourse pertains to the cultural, religious, and family ties and how these remaining strengths of what is perceived as the notions of homeland and national identity play the role of catalyzer to students' decisions on repatriation to home after completing their studies overseas to repay their duties to their country.

The fourth and deepest layer of analysis is the myth/metaphor layer, which responded to the question: What historical metaphor/myths can explain the worldviews in Iran's brain drain or elite migration phenomenon? The discussion panel on this level revealed that the myth driving the brain drain in Iran is the belief in the existence of a utopia outside the homeland, an ideal place where, without any obstacles, he/she may be what he/she is or what he/she thinks is, develop his/her personal and cultural identity without any forms of pressure. Young Iranian elites who desire to break the historical stereotypes and oppressive situations that constrain or condemn him/her in their home country, long for a far-off place where nothing is impossible and consequently, find migration as an escape from their predetermined destination. Table 3 demonstrates the detailed results of Iran's brain drain causal layered analysis.

5.2. Implementation of participatory system dynamics

The 5-stage system dynamics modelling approach proposed by Sterman (Sterman, 2000) is employed in a participatory way based on the final results of CLA in the previous step. The group of scholars who participated in the CLA stage was again involved in the group modelling sessions as well. These sessions were coordinated by an SD practitioner to lead the group through defining the sys-

Table 3
Final results on the Causal Layer Analysis of Iran's brain drain based on the expert panel.

Surface (Short term)	**Litany Layer: How is the international outflow of Iranian elites and professionals described?**						
	Skills Mobility	Brain Drain	Human Capital Flight	Highly-Educated Migration	Elite Migration	Migration of Brains	Migration of Elites Genes
	Structure/ Systematic cause layer: What systematic factors (procedures and driving forces) have caused the phenomenon of elite migration or brain drain in Iran?						
	Scientific						
	Weak industry-university relationship	Insufficient governmental support	Inadequate educational and budgetary facilities	Outdated educational system	Lack of scientific networks utilizing elites' expertise	Absence of practical & entrepreneurship-based educations	
	Economic						
	Unemployment	Low financial affordability	Expensive cost of living	Insufficient salary and income	Lack of job security	Low welfare level of the country	High exchange price fluctuations	Instability of prices
	Socio-Cultural						
	Insufficient personal and social freedom	Inadequate personal and social security	Lack of respect to law and regulations	Insufficient personal and social justice	Lack of personal and social privacy	Low level of social rights quality of the country	
	Managerial-Political						
	Internal conflicts among parties	Political, economic, scientific sanctions	Vain bureaucracy	Financial corruptions	Lack of meritocracy	Instability and inconsistency in macro policies	Low level of adequacy in the administrative structure of the country	Incompetent governors and managers
	Discourse/Worldview layer: What assumptions have made changes in the systematic/structure layer of Iran's brain drain or elite migration phenomenon?						
	Elites are not being acknowledged as valuable asset of Iran		Poor social dignity of elites as human capitals of Iran	Attraction of western lifestyle	Globalization	Inefficient advertisement of Islamic-Iranian Culture	Cultural, Religious, and family ties to Iran
Deep (Long term)	**Myth/Metaphor Layer: What historical metaphor/myths can explain the worldviews in Iran's brain drain or elite migration phenomenon?**						
	Belief in the existence of a utopia outside the homeland among Iranians including the elites						

tem's boundary and determining the time horizon, identification of the stock, flow and auxiliary variables and determination of their relations through feedback loops and stock and flow flowcharts, and finding the leverage points for further policy implications.

5.2.1. Problem articulation

To characterize the problem of Iran's elite migration dynamically, a reference mode which is a behavioral pattern of Iranian elite migration, unfolding over time, is needed. Additionally, a time horizon that extends far enough into the future to capture the delayed and indirect effects of potential policies should be set. In this regard, this paper investigates the migration of Iranian tertiary education graduates from 2011 to 2111 and other types of migrations are excluded. Due to the lack of consistent and reliable statistics from Iranian governmental resources, Fig. 2 in Section 2 shows the growing trend in the number of Iranian students studying outside the country according to the data released from the UNESCO Institute for Statistics.

5.2.2. Formation of dynamic hypothesis

The dynamic hypothesis of Iran's brain drain discusses the theories and causes of how this problem arose. Iran's Brain drain represents the unbalanced relationship between the outflow of Iranian highly educated individuals leaving the country for pursuing their higher education in developed countries and the inflow of the Iranian highly educated who completed their studies abroad to their home country. Assumingly, leaving the country for pursuing higher education in developed countries is not a concerning issue itself, but the decision to abandon any relationship with the home country could deprive developing countries from their elite's expertise, skills, and remittances (Bollard et al., 2011). More specifically, Iranian diasporas have both direct and indirect impacts on their home country. Direct influences are associated with their desire to maintain their individual ties to their homeland, in the form of remittances, financial investments, and knowledge transfer. Indirect impacts imply their contribution in improving their homeland reputation in international business networks; and playing an effective facilitator and broker between partners, customers, and suppliers (Miguélez, 2018).

In this regard, Iran's population is divided into three main groups namely; the young population (from age 0–18), the productive population (from age 19–50), and the aging population (from age 51- and higher). After graduating from each stage of the tertiary educations (B.Sc., M.Sc., Ph.D.), Iranian elites who are inside the country are facing three specific decisions; 1) to pursue their higher education in their country, 2) to pursue their higher education abroad, and 3) to enter the workplace in Iran. Those Iranian elites who are outside the country are facing two specific decisions after the completion of their studies; 1) to come back to Iran and join the group of Iranian elites inside the country or 2) to stay outside the country. Fig. B1 in Appendix B shows the dynamics hypothesis of Iran's brain drain.

5.2.2.1. Causal loop diagrams and feedback loops. Causal loop diagrams are simply representing the causal links among variables with arrows from a cause to an effect. Each causal link is either positive or negative to indicate how the dependent variable changes when the independent variable changes. Each causal loop is either positive (reinforcing) or negative (balancing). Overall, Iran's elite's decisions about returning to the country or staying abroad are affected by different stimuli. In this paper, the causal loops of Iran's brain drain are constructed based on the results obtained from causal layered analysis and are presented in Appendix B. In this regard, the variables in the black color belong to the litany layer, while red, green, and pink colors are representing the structure, worldview, and metaphor respectively. Fig. B2 demonstrates the first causal loop diagram addressing the managerial-political dissatisfaction of Iranian elites. In this sense, the tension in the political atmosphere of Iran which is affected by internal parties' conflicts and different political and economic sanctions, vain bureaucracy, financial corruptions, meritocracy, incompetent managers, instability and inconsistency in the macro policies of the country identify the adequacy of the administrative structure of Iran. The difference between the inside and outside levels of adequacy influences the managerial-political dissatisfaction among Iranian elites and eventually becomes one of the effective factors on staying abroad after graduation. Fig. B3 shows how scientific dissatisfaction makes Iranian highly educated individuals stay abroad after completing their studies. In this regard, the scientific level inside Iran is defined by how much entrepreneurship-based (which is affected by Industry-university relationship, research facilities, governmental supports and scientific, economic, and political sanctions) and updated (which is influenced by the strength of the scientific networks, and scientific, economic and political sanctions) is the education system in Iran. The bigger this gap between the scientific level inside Iran and outside the country is, the more the scientific dissatisfactions among Iranian elites become and the more their inclinations become towards staying abroad. Fig. B4 depicts how the difference in the level of welfare between Iran and developed countries results in the economic dissatisfaction of Iranian elites and their decisions to not return to their home country. Concerning the welfare level of Iranian highly educated people, employment, Job security, financial affordability (which is defined by the amount of salary and income and the cost of living) and stability of prices (which is influenced by exchange price fluctuations, political and economic sanctions, instability and inconsistency in macro policies and adequacy of the administrative structure of the country) play the key role. Fig. B5 addresses the effect of socio-cultural dissatisfaction on the decision to stay abroad. Socio-cultural dissatisfaction is defined by the quality of social rights in the country which is directly affected by the amount of personal and social freedom, personal and social privacy, respect to law and regulations, personal and social justice, and personal and social security. The wider the gap between the quality of social rights in Iran and other developed countries is, the bigger the socio-cultural dissatisfaction of Iranian elites becomes. Fig. B6 shows the effect of belief in utopia outside the homeland on the intention of Iranian elites to stay outside the country and how early education about making our homeland a utopia can influence this decision. Fig. B7 demonstrates how the social dignity of elites in Iran can potentially be one of the effective factors in the decisions of abroad graduates to return to the country. In this regard, the social dignity of Iranian

elites is defined by being recognized as valuable assets of the country and real job opportunities based on knowledge-based entrepreneurship (which is affected by the adequacy of the administrative structure of Iran, Industry-university relationship, governmental support, and scientific networks utilizing Iranian elite's expertise). Fig. B8 addresses the impact of cultural, religious, and family ties to Iran on the intention of Iranian elites to return to the country after completion of their studies. These ties are defined by the attraction of the western lifestyle (which is affected by globalization) and advertisement of the Islamic-Iranian culture (which is affected by the role of the educational system in Iran). The more strengthened the ties are, the more population of Iranian elites will come back to the country.

5.2.3. Formulation of a simulation model

In this stage, stock and flow diagrams are drawn, mathematical equations are written and parameters are estimated.

5.2.3.1. Stock-flow diagram. Stocks represent the state of the system and generate the information upon which decisions are based. These decisions then change the rates of flow, changing the stocks and closing the feedback loops in the system (Sterman, 2000). Figs. B9, B10 in Appendix B represent the stock and flow diagrams of Iran's brain drain at I) litany layer and II) structure, worldview, and metaphor layers.

Fig. 5 demonstrates the stock and flow diagram of Iran's brain drain at four layers of litany (variables in black color), structure (variables in red color), worldview (variables in the green color), and metaphor (variables in pink color). On the grounds of this stock-flow diagram, Iran's brain drain problem is mathematically formulated, tested, and then simulated under various policy interventions in the following sections.

5.2.3.2. Mathematical formulations. Stocks accumulate or integrate their flows. In other words, the net flow into the stock is the rate of change of the stock (Sterman, 2000). Hence the stock variables can be calculated via Eq. (1);

$$Stock\,(t) = \int_{t_0}^{t} \left[Inflow\,(s) - Outflow\,(s)\right] ds + Stock(t_0) \tag{1}$$

The mathematical equations of stock, flow, and auxiliary variables of the system dynamics model of Iran's brain drain are presented in Tables B1–B3 in Appendix B, respectively.

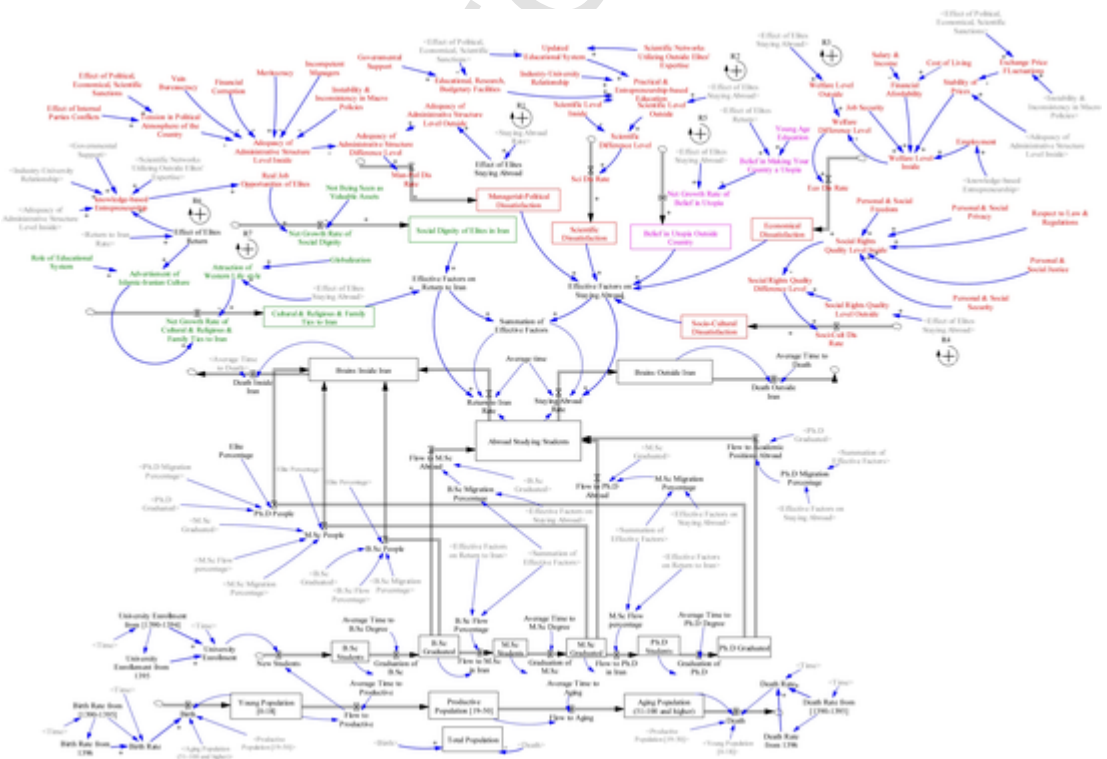

Fig. 5. Stock and flow diagram of Iran's brain drain at four layers.

5.2.4. Testing

Validation of system dynamics models differs from the traditional simulation models. Firstly, no single test can validate the SD models and the confidence in SD models increases as they pass more tests and the correspondence between empirical data and the model are strengthened (Senge & Forrester, 1980; Sterman, 2000). Secondly, the final goal of the SD model's testing is to build confidence in terms of the soundness and usefulness of the model as a policy tool rather than validity in terms of absolute correctness as it is prevalent in conventional statistical models (Senge & Forrester, 1980). In other words, an SD model's validity cannot be absolute, but it must be valid for the purpose for which it was created (Martis, 2006).

In order to build confidence in SD models, testing the appropriateness of the model's structure is required in the first step (McLucas et al., n.d.; Senge & Forrester, 1980). Once the structure of the model proves to be adequately valid, the model needs to be tested in terms of how well it regenerates the observed behavior of the real system (McLucas et al., n.d.; Qudrat-ullah & Seo, 2010; Senge & Forrester, 1980). As a result, having a model output that replicates some reference behavior is not a true or comprehensive test of model validity, because structural validity must come first (Barlas, 1996). Moreover, due to the non-predictive character of SD models (Zolfagharian et al., 2018), the behavioral reproduction of these models are not expected to have the same degree of predictive accuracy as statistical and econometric models (McLucas et al., n.d.) and can reproduce historical data when paired with proper statistical methods to estimate parameters (Sterman et al., 2002).

5.2.4.1. Structural test. In this paper, to assess the structure of the model, the dimensional consistency test, parameter assessment, and extreme condition test were applied. It was convenient for the VENSIM to carry out the dimensional consistency test and parameter assessment test using options called "units check" and "check model". The results show that the model maintains dimensional consistency and reasonable parameter estimation successfully.

As for testing the structure of the model under extreme conditions, several parameters were set to the limits of their meaningful ranges of variation. Fig. B11 in Appendix B shows that the increase in the political, economic, scientific sanctions against Iran will result in a higher staying abroad rate among Iranian elites, while a decrease in these sanctions will lead to lower staying abroad rates. Fig. B12 demonstrates that the more expensive the cost of living in Iran, the higher the staying abroad rate of Iranian elites will be. Fig. B13 represents the extreme condition test of meritocracy in Iran in which the more meritocracy is applied in Iran, the less staying abroad rate of Iranian highly educated people will be. Fig. B14 depicts that the return to the country rate of Iranian elites will decrease in case of the increase in the effect of globalization and its implications such as internet penetration and vice versa. Fig. B15 reveals that the more Iranian elites are not being recognized as valuable assets of the country, the less the return rate will be. Therefore, the presented model behaves rationally when individual variables are subjected to extreme conditions.

5.2.4.2. Behavioral test. To assess the model's ability to reproduce the behavior of Iran's Brain drain phenomenon, the population of Iranian students studying abroad according to available estimated data of the UNESCO Institute for Statistics from 2011 to 2017 is compared to the simulated results within the same time frame. Fig. B16 in Appendix B shows the simulated population of Iranian students studying abroad and Table B4 in Appendix B compares the reference mode's behavior and the results derived from the simulation. The results indicate a similar pattern of growing behavior between 2011 and 2017 as expected by the definition of behavioral validity in SD models. However, some differences exist due to the lack of provided data on the population of Iranian students abroad and the precise value of emigration rates among Iranian students at various levels of educations by Iran's national authorities and organizations. As a response to this absence of data, this study had to make use of the delayed estimations from the UNESCO Institute for statistics, which are not precise according to this database. All of which, accompanied by the non-predictive nature of SD simulation models have caused point-to-point differences between the available estimated historical data and the simulated results of the presented model.

5.2.5. Policy design and evaluation

After the validation of the model is verified, it is time to design and evaluate policies for the improvement of the system. Therefore, it is necessary to identify the parameters that strongly affect the behavior of Iran's brain drain model called leverage points for further scenario analysis and policy intervention.

5.2.5.1. Identification of leverage points. The parameters that have a significant influence on the staying abroad rate and return to the country rate of Iranian elites are identified in the causal layered analysis which are associated with the structure layer (including factors causing socio-cultural, managerial-political, scientific, and economic dissatisfaction in Iran), worldview layer (including factors affecting the social dignity of the elites in Iran and cultural, religious and family ties of Iranian elites to their country) and metaphor layer (including factors influencing the belief in the existence of utopia outside the country among Iranian).

5.2.5.2. Scenario generation. Based on the leverage points of Iran's brain drain model which are obtained during the panel discussion and causal layered analysis, 4 main scenarios and 9 detailed scenarios are generated as below:

- **Zero Scenario**: Continuing the status quo
- **First Scenario**: Focusing on the improvement of the structure layer
  - **1-A Scenario**: Improvement of the socio-cultural status
  - **1-B Scenario**: Improvement of economic status

- **1-C Scenario**: Improvement of the scientific status
- **1-D Scenario**: Improvement of the managerial- political status

- **Second Scenario**: Focusing on the improvement of worldview layer
  - **2-A Scenario**: Improvement of the social dignity of elites
  - **2-B Scenario**: Strengthening the family, religious and cultural ties
- **Third Scenario**: Focusing on the improvement of metaphor layer: modification of Iranian's thoughts about the existence of a utopia outside the country
- **Fourth Scenario**: Focusing on the simultaneous improvement of all layers

6. Discussion and policy evaluation

Once the scenarios are generated, to evaluate policies for the improvement of Iran's ability to retain its talents for the future, the model is simulated under each scenario. Figs. B17–B21 in Appendix B show how I) the return to Iran rate, II) the staying abroad rate, III) the population of students studying abroad, IV) the population of Iranian highly educated inside the country, V) and the population of Iranian highly educated outside the country change over 100 years under 9 different scenarios, respectively. This study renders three specific implications as follows;

Firstly, the results from the simulation of Iran's brain drain under the circumstances that the current status of quo (managerial-political, scientific, economic, socio-cultural) continues in Iran, implying that the population of highly educated Iranians inside the country will be increased from 2553170 in 2011 to approximately 4690850 in 2111 (1.83 times), while that of outside Iran will be amplified from 254800 in 2011 to about 895981 in 2111 (3.51 times). These results shed light on the future outlook of the Iranian pools of experts and highly skilled individuals inside the country and overseas, which indicates the possibility of Iran's suffer from talent deprivation in near future. Another ramification of Iran's brain drain issue is the fact that one-way migration of highly talented and educated Iranians to developed countries will not only results in the loss of Iran's human capitals (the prerequisite for breakthroughs for the scientific and economic development of the country) in the contemporary periods but also after some centuries will affect the average intelligence genes of the country which will evidently affect negatively the sustainable development in Iran.

Secondly, final results from the model's simulation under each scenario indicate that 1) simultaneous improvement of all layers 2) improvement of the managerial-political status of Iran, 3) improvement of the scientific status of Iran, 4) improvement of the social dignity of elites in Iran, 5) improvement of the economic status of Iran, 6) improvement of the socio-cultural status of Iran, 7) strengthening the family, religious and cultural ties, and 8) Modification of Iranian's thoughts about the existence of a utopia outside the country have the highest effect on increasing the return of elites to return the country and decreasing the staying abroad rate of elites, respectively. These results will be of great importance for the national authorities and governors, if there is a serious determination to address this issue, by showing how specific policy alleviations or solutions to the underlying layers of Iran's brain drain will affect the behaviors of highly-educated and elites' community in terms of migration.

Finally, the crucial implication of this study is an urgent call for a reconsideration of Iran's national strategies in dealing with brain drain efficiently. Consequently, due to the effectiveness of simultaneous improvement of all underlying factors in the identified layers in the reduction of staying abroad rate and increase of return to the country rate of Iranian elites, this study recommends that the governors and authorities of Iran regulate a policy package consisting of short, medium, and long-term strategies to promote the following priorities:

1) **managerial-political subcategory:** alleviating the internal conflicts among political parties seeking out the superior power at the national level (reformists and conservatives), possible reduction of political, economic, and scientific sanctions, surmounting vain bureaucracy in the governmental organizations of the country, strong regulations to control the financial corruptions, valuing the meritocracy in the government and its associated organizations, strong regulatory and auditing rules for stable and consistent macro policies in different sectors, assignment of more competent governors and managers in the government and its associated organizations.
2) **scientific subcategory:** strong industry-university relationship to solve real challenges of the industry in the universities and research laborites, sufficient governmental support of the research institutions and universities, adequate educational and laboratories facilities in the universities and research institutions, updated educational system in terms of the taught materials and evaluation processes of the university students, establishment of virtual scientific networks utilizing elites' expertise who are outside the country for further scholarly works and industrial collaborations in forms of short term invitations for international conferences, workshops, and seminars, providing practical & entrepreneurship-based majors and courses in the universities.
3) **social dignity subcategory:** full support of the elites to retain them as the country's assets by proving them with real financial and non-financial incentives, protecting elites' intellectual properties, valuing and employing elites' opinions and recommendations in real challenges (financial, social, cultural, political, managerial, etc.) and offering them more substantial roles to run the country.
4) **economic subcategory:** improving the employment situation in the country by making breakthrough changes in the industry and especially surmounting the obstacles of the elites employments in the universities, research laboratories, and industrial sectors, improving the job security situation in the country by stronger insurance and labor laws, lowering the cost of living by regulating strong market control rules for consumer goods and housing, increasing salary and income based upon the real inflammation rate annually, controlling the exchange price fluctuations by efficient financial and supervision rules.

5) **social-cultural subcategory:** increasing social and personal freedom, privacy, security, and justice via breakthrough changes in the judicial organizations, police, and security forces.
6) **cultural, religious, and family ties subcategory:** efficient reinforcement of the Iranian-Islamic identities among Iranians via long-term, educational and nonbelligerent measures of the institutions in charge.
7) **existence of utopia subcategory:** early-stage and long-term education about the importance of citizens and especially elites' contributions to the country's development via visual arts performances such as movies, books, theater plays, talk shows, and documentaries.

7. Conclusion

As the challenges of societies have become more complicated and multifaceted, managers and policymakers need to be equipped with new sets of tools for their future decision makings that empower them with critical thinking and allow for the exploration of these issues as whole systems rather than isolated parts. Bearing this in mind, the adoption of mixed research approaches offers the ability to overcome much of the shortcomings of individual methods of research and provide potential solutions to complicated issues that are more in-depth than a single research method. With regards to the complementary characteristics of the chosen research methods, the presented study proposes a new mixed approach to Participatory System Dynamics as a method for understanding the behaviors of complex socio-economic systems over time and analyzing the effectiveness of the intervening policies and Causal Layered Analysis as a tool for critically unpacking issues. Moreover, a case study of skills mobility is conducted for further assessment of the proposed approach. The implication of the proposed approach to skills mobility or the so-called brain drain phenomenon is the undisputable role of human capital efficiency in the future developments of the nations.

The implementation of the proposed approach to Iran's skills mobility outline three specific implications. Firstly, the results from the simulation of Iran's brain drain if the current status of quo (managerial-political, scientific, economic, socio-cultural) continues, indicates that while the population of highly educated Iranians inside the country will approximately be increased by 1.83 times after 100 years, the population of overseas highly-educated Iranians will be escalated by 3.51 times after the same time frame. The comparison of the growth rate of the Iranian elites' population living inside the country (about 0.84) and the growth rate of the Iranian elites' population living overseas (about 2051) emphasizes on the possibility of Iran's suffer from talent deprivation and intelligence genes flights in near future.

Secondly, 8 different scenarios were generated based on the leverage points of the model which are obtained during the panel discussion and causal layered analysis, and then Iran's brain drain model was simulated under each scenario to analyze and compare the effectiveness of each scenario on decreasing the rates of Iranian elites who decide to stay overseas and on increasing the rates of Iranian elites who decide to return to the country. As expected, the results reveal that the scenario in which all the underlying layers are improved simultaneously has the highest effect on controlling the inflow rate and outflow rate of Iranian highly-educated elites.

Finally, A glance at Iran's migration and demographic profile reveals three specific findings: I) Iran's brain drain is mostly in the form of young university graduates' migration with the motivation of pursuing their higher educations' outside the country, II) Iran is currently experiencing in the demographic window of opportunity, which represents a situation that the population of the working-age population to the children and elderly remains high for about half a century and is a facilitator to major economic flourishment, and III) the starting point of Iran's demographic window of opportunity and the new wave of highly-skilled migration are synchronized from 2005. Therefore, an urgent call for a reconsideration of Iran's national strategies in dealing with brain drain efficiently in order to retain its highly-educated human capital for the future development of the country is required. Hence, this study recommends a prioritized policy package to improve all the underlying layers and driving factors to the national authorities and governors based upon the obtained results from the simulation of Iran's brain drain model.

Despite the theoretical contributions and managerial implications of the proposed mixed approach to understanding the future outlooks of various socio-economic issues, it faces a possible drawback. Accordingly, in cases of complex societal issues with so many causal relationships and multiple perspectives among stakeholders, the effectiveness of the obtained model for capturing all the underlying layers and feedback loops is dependent on the availability of skilled facilitators, participants, modelers and requires knowledge of the subject matter, time, and patience in conducting both phases of CLA and SD modeling. Moreover, the presented case study is subject to a few limitations which could lead to further research. Firstly, the main limitation of this study was the lack of valid and creditable data on the population of Iranian elites overseas and the rate of emigration among the bachelors, masters, and doctorate graduates. Although there have been several estimations from the international organizations, national authorities and custodians have not been successful in providing annual and updated data regarding the discussed issue. Thus, further empirical study needs the contribution of the Iranian policymakers and authorities to prepare regular data in order to have a more in-depth analysis of the number of Iranian elites inside and outside the country. Secondly, SD simulation models are non-predictive and particularly useful to provide policy insights which make them different from other discrete event simulation models that provide more precise predictions. Although the participatory System Dynamics model of this paper is validated in terms of behavior and structure, the variables of the model are estimated based upon the experts 'group modelling. As a result, the presented case study deals with parametric uncertainties which make the simulated results less reliable in the sense of prediction and more appropriate for providing enlightenments for the managers. However, in future case studies that stakeholders prefer to anticipate objective policy solutions to their problems, they would benefit from combining the presented approach with statistical methods for more precise estimations of variables. Finally, in cases that systems include variables that rather than precise numerical values, it can carry on linguistic variables, incorporating fuzzy methods into the proposed approach can potentially help to gain more confidence in translating qualitative data into mathematical formulations of such variables.

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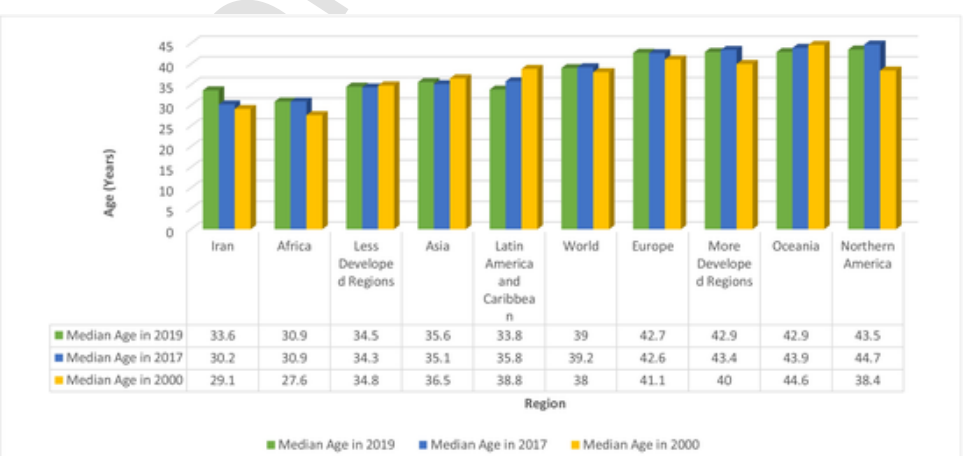
Appendix A.

Appendix B.

	World	More developed regions	Less developed regions	High-income regions	Middle-income regions
1990	629834	516925	112909	558435	71399
1995	747809	611925	135884	657241	90568
2000	832298	697783	134515	744179	88119
2005	889308	784227	105081	830296	59012
2010	1003210	898677	104533	945163	58047
2015	1111953	1003925	108028	1051706	60247
2017	1170491	1060652	109839	1106649	63842
2019	1301975	1130032	171890	1176388	124388

Fig. A1. The total population of Iranian migrants in different regions over time (Based on the data derived from United Nations Population Division, 2017, 2019a, 2019b).



	Iran	Africa	Less Developed Regions	Asia	Latin America and Caribbean	World	Europe	More Developed Regions	Oceania	Northern America
Median Age in 2019	33.6	30.9	34.5	35.6	33.8	39	42.7	42.9	42.9	43.5
Median Age in 2017	30.2	30.9	34.3	35.1	35.8	39.2	42.6	43.4	43.9	44.7
Median Age in 2000	29.1	27.6	34.8	36.5	38.8	38	41.1	40	44.6	38.4

Fig. A2. Comparison of the median age of Iranian migrants with other nationalities migrants in 2000 and 2017 (Based on the data derived from United Nations Population Division, 2017, 2019a, 2019b).

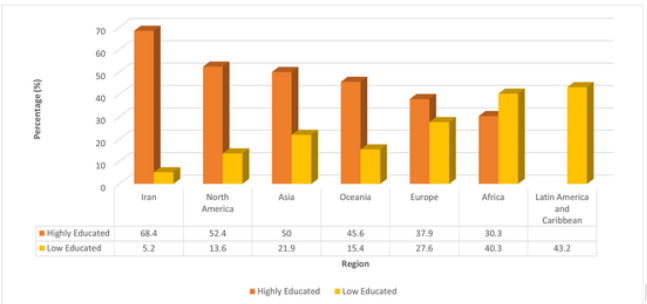


Fig. A3. Comparison of the education Level of recent Iranian migrants with other nationalities migrants aged over 15 years old living in the OECD countries in 2011 (Based on the data derived from Arslan et al., 2014).

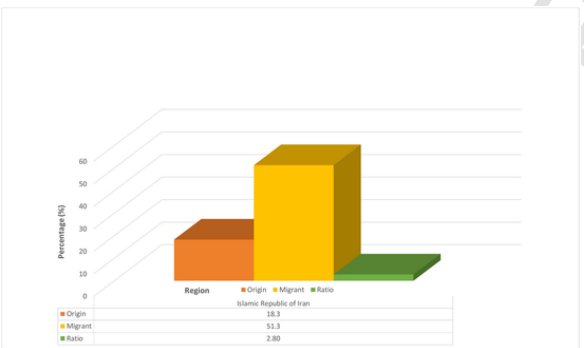
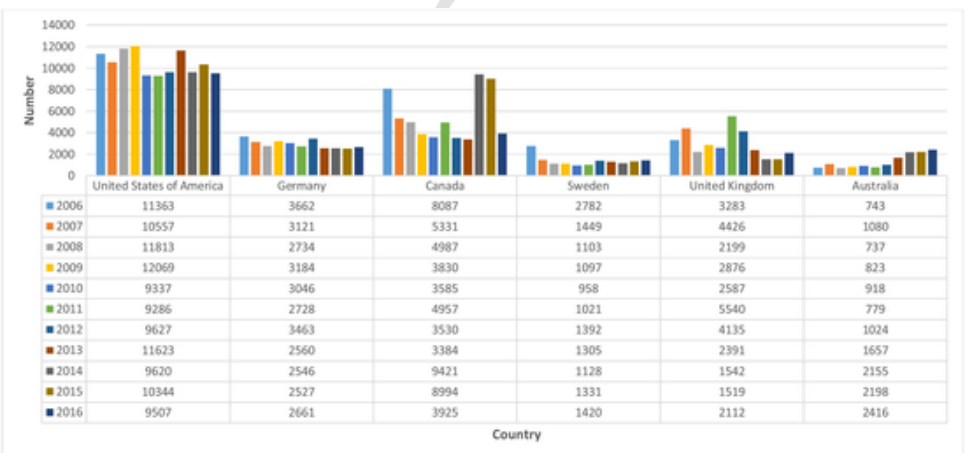


Fig. A4. Comparison of Iranian migrants with tertiary education aged over 25 years old living in OECD countries with Iranian residents in 2010 (Based on the data derived from Fargues, 2017).



	United States of America	Germany	Canada	Sweden	United Kingdom	Australia
2006	11363	3662	8087	2782	3283	743
2007	10557	3121	5331	1449	4426	1080
2008	11813	2734	4987	1103	2199	737
2009	12069	3184	3830	1097	2876	823
2010	9337	3046	3585	958	2587	918
2011	9286	2728	4957	1021	5540	779
2012	9627	3463	3530	1392	4135	1024
2013	11623	2560	3384	1305	2391	1657
2014	9620	2546	9421	1128	1542	2155
2015	10344	2527	8994	1331	1519	2198
2016	9507	2661	3925	1420	2112	2416

Fig. A5. Number of second nationalities acquired by Iranian migrants over time from top 6 OECD countries from 2000 to 2016 (Based on the data derived from OECD International Migration Database Statistics, 2019).

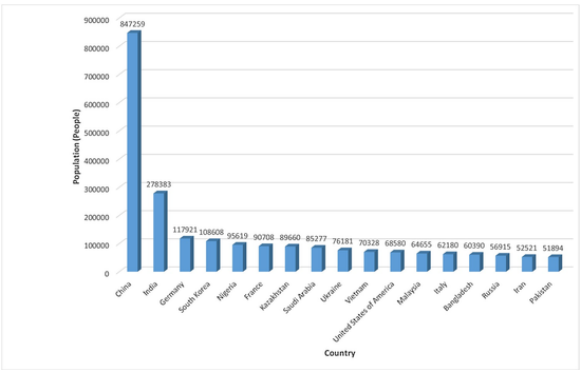


Fig. A6. Top 17 countries with the highest total population of outbound tertiary students in 2017 (Based on the data derived from UNESCO Institute for Statistics, 2019).

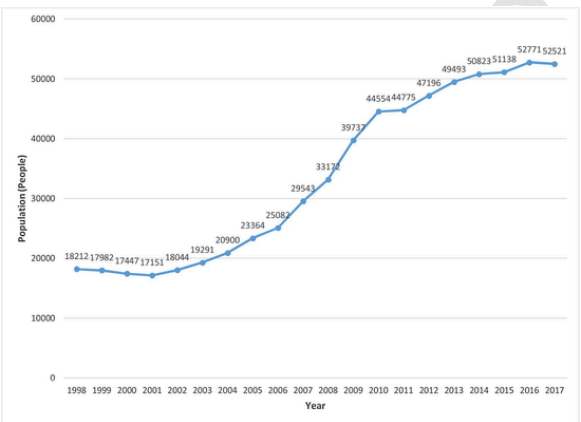


Fig. A7. Total Population of Iranian outbound tertiary students from 1998 to 2017 (Based on the data derived from UNESCO Institute for Statistics, 2019).

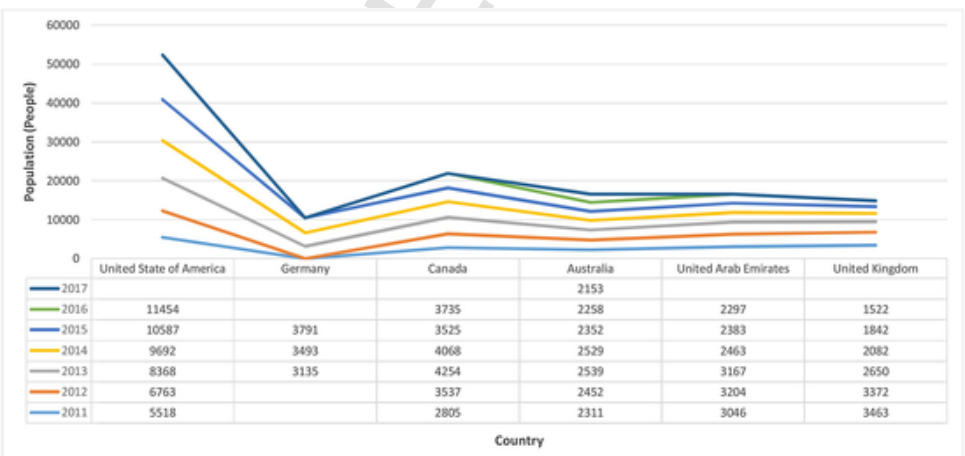
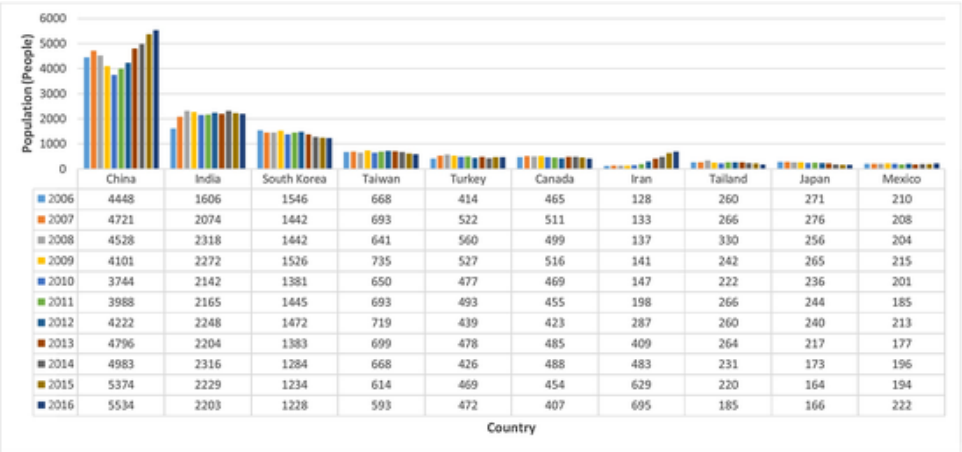
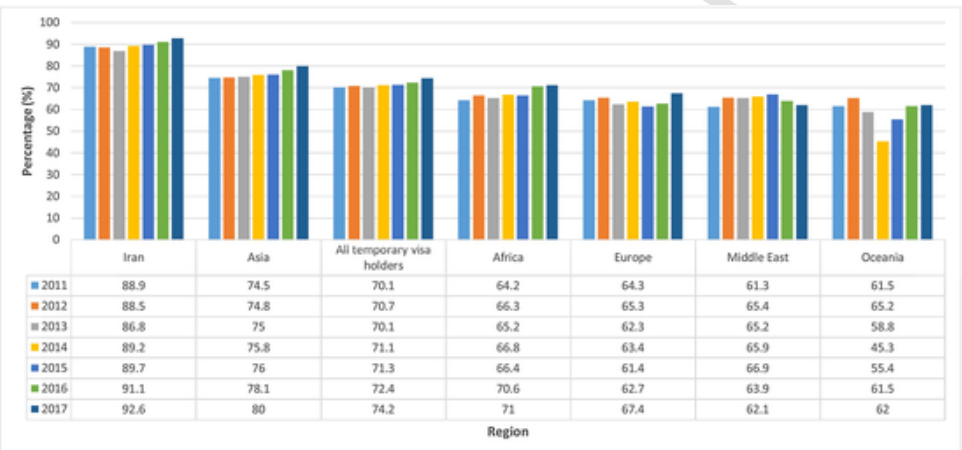


Fig. A8. The population of Iranian tertiary students in the top 6 destinations from 2011 to 2017 (Based on the data derived from UNESCO Institute for Statistics, 2019).



	China	India	South Korea	Taiwan	Turkey	Canada	Iran	Tailand	Japan	Mexico
2006	4448	1606	1546	668	414	465	128	260	271	210
2007	4721	2074	1442	693	522	511	133	266	276	208
2008	4528	2318	1442	641	560	499	137	330	256	204
2009	4101	2272	1526	735	527	516	141	242	265	215
2010	3744	2142	1381	650	477	469	147	222	236	201
2011	3988	2165	1445	693	493	455	198	266	244	185
2012	4222	2248	1472	719	439	423	287	260	240	213
2013	4796	2204	1383	699	478	485	409	264	217	177
2014	4983	2316	1284	668	426	488	483	231	173	196
2015	5374	2229	1234	614	469	454	629	220	164	194
2016	5534	2203	1228	593	472	407	695	185	166	222

Fig. A9. The population of top 10 international doctorate recipients intending to stay in the USA from 2006 to 2016 (Based on the data derived from Karaca, 2018).



	Iran	Asia	All temporary visa holders	Africa	Europe	Middle East	Oceania
2011	88.9	74.5	70.1	64.2	64.3	61.3	61.5
2012	88.5	74.8	70.7	66.3	65.3	65.4	65.2
2013	86.8	75	70.1	65.2	62.3	65.2	58.8
2014	89.2	75.8	71.1	66.8	63.4	65.9	45.3
2015	89.7	76	71.3	66.4	61.4	66.9	55.4
2016	91.1	78.1	72.4	70.6	62.7	63.9	61.5
2017	92.6	80	74.2	71	67.4	62.1	62

Fig. A10. Comparison of the staying rate of Iranian doctorate recipients intending to stay in the USA with other nationalities students from 2011 to 2017 (Based on the data derived from Karaca, 2018).

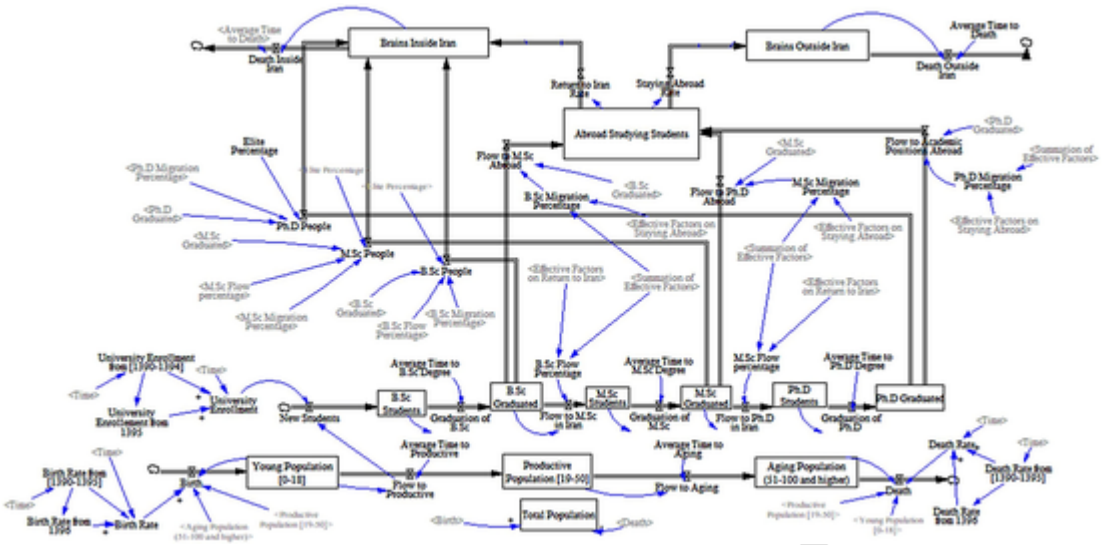


Fig. B1. The dynamics hypothesis of Iran's brain drain.

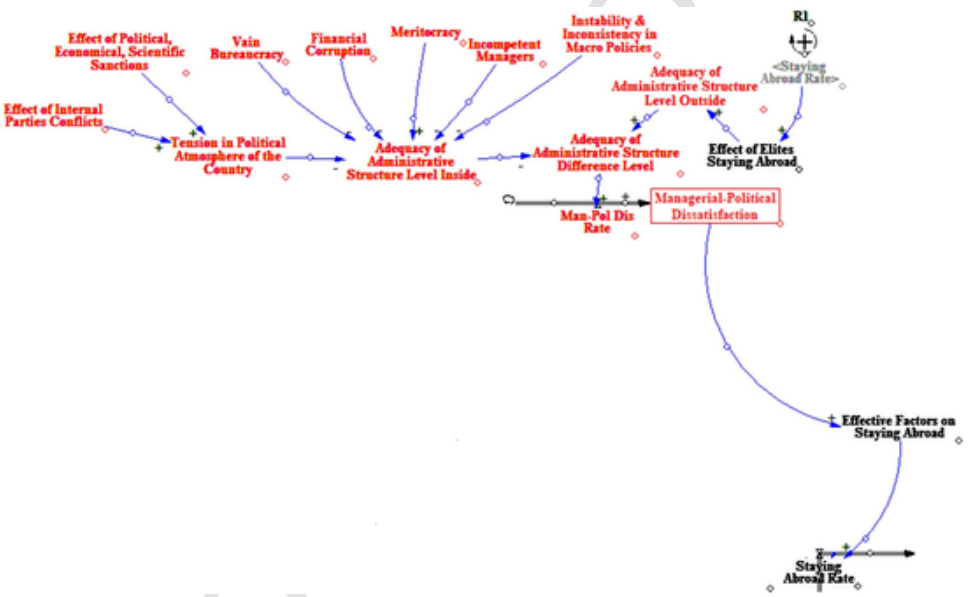


Fig. B2. The first positive causal loop diagram addressing the effect of Iran's managerial-political state on the staying abroad rate (R1).

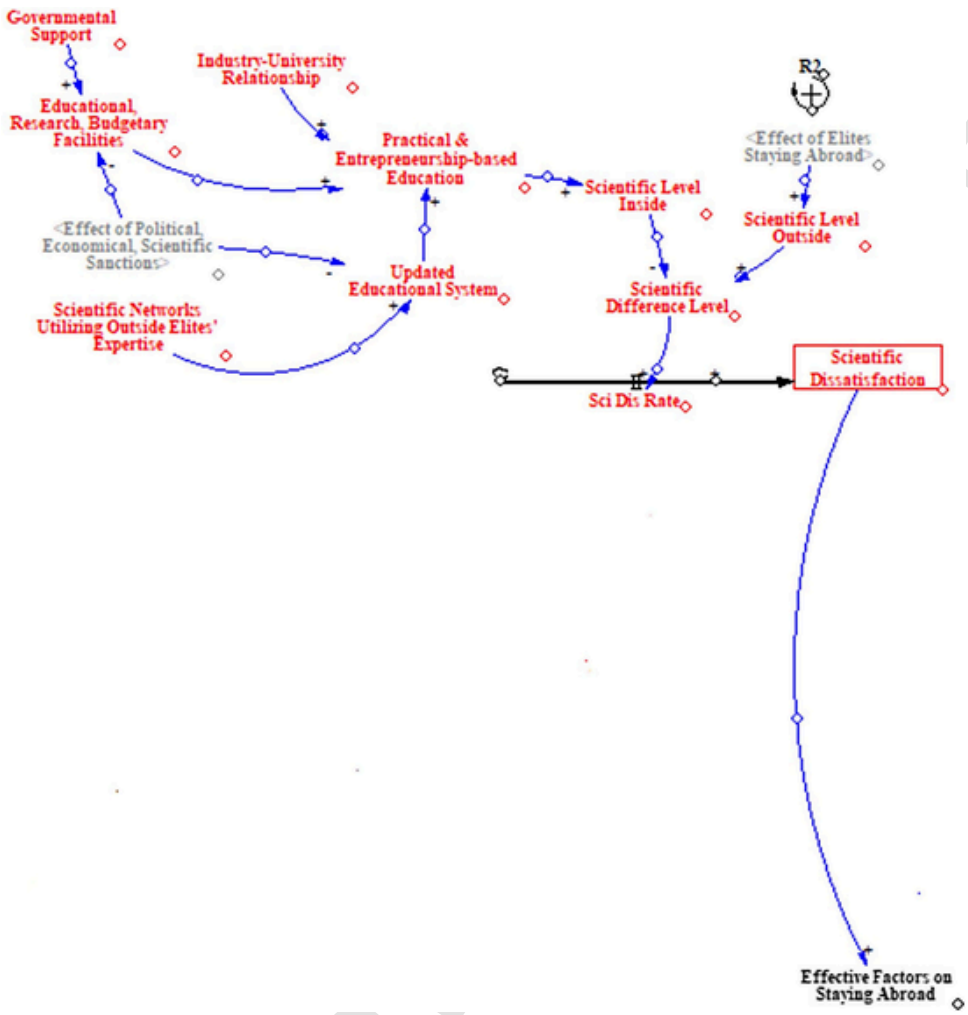


Fig. B3. The second positive causal loop diagram addressing the effect of Iran's scientific state on the staying abroad rate (R2).

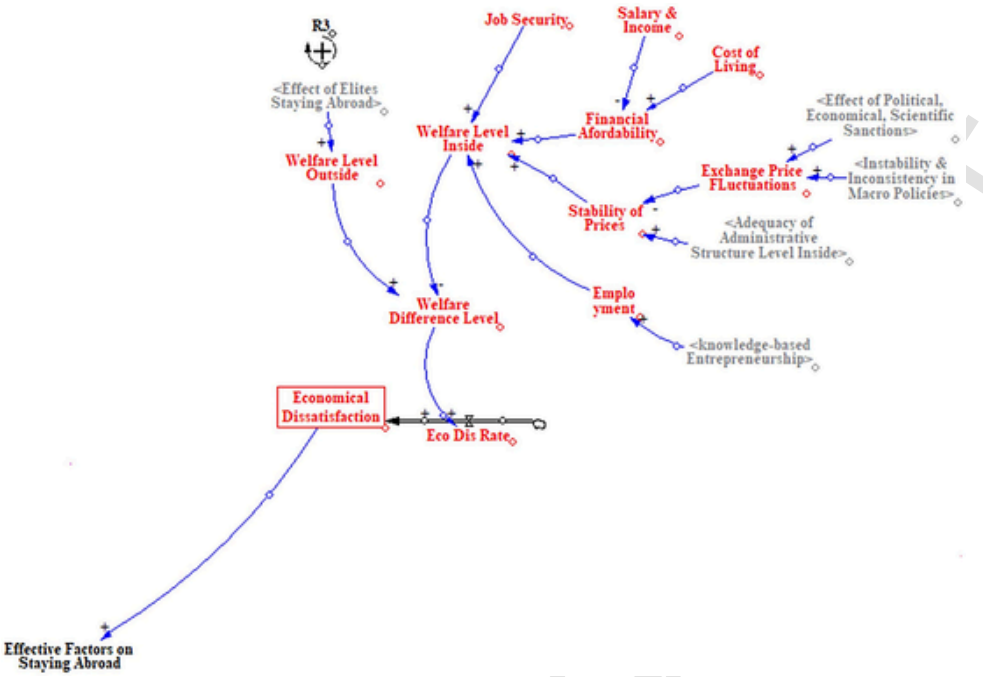


Fig. B4. The third positive causal loop diagram addressing the effect of Iran's economic state on the staying abroad rate (R3).

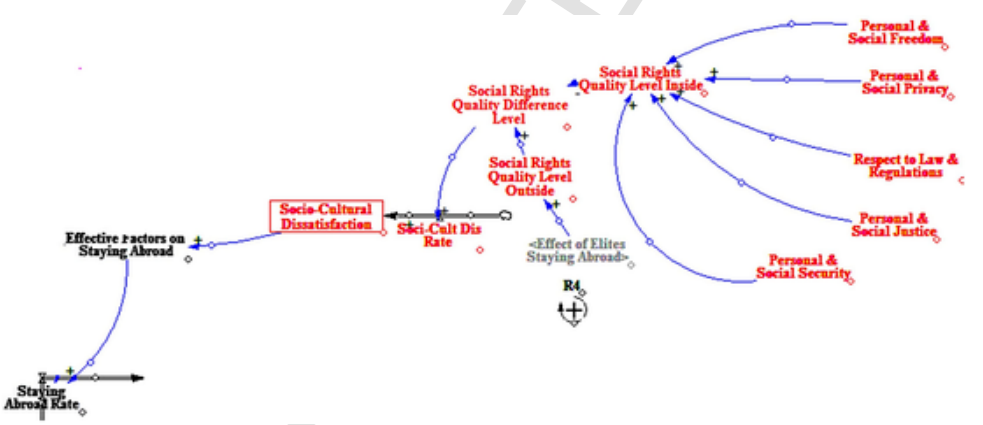


Fig. B5. The fourth positive causal loop diagram addressing the effect of Iran's socio-cultural state on the staying abroad rate (R4).

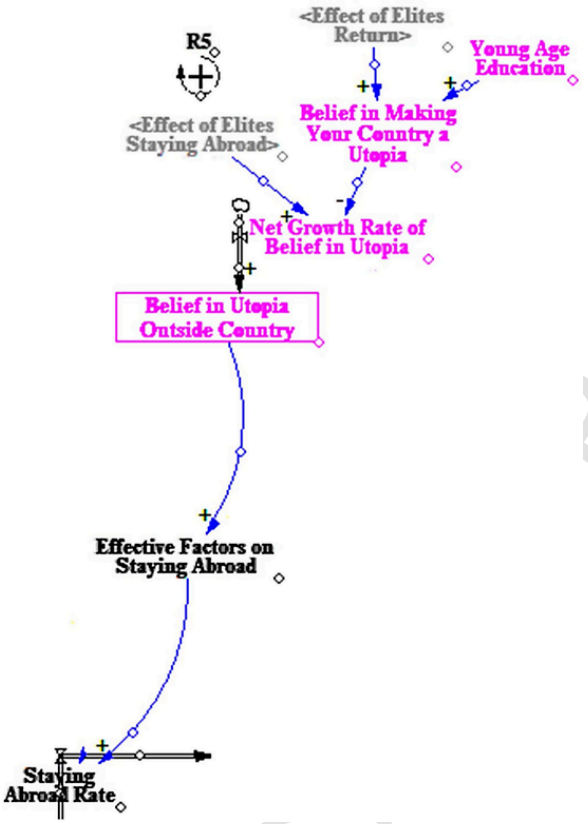


Fig. B6. The fifth positive causal loop diagram addressing the effect of Iranians belief in the existence of utopia outside their homeland on the staying abroad rate (R5).

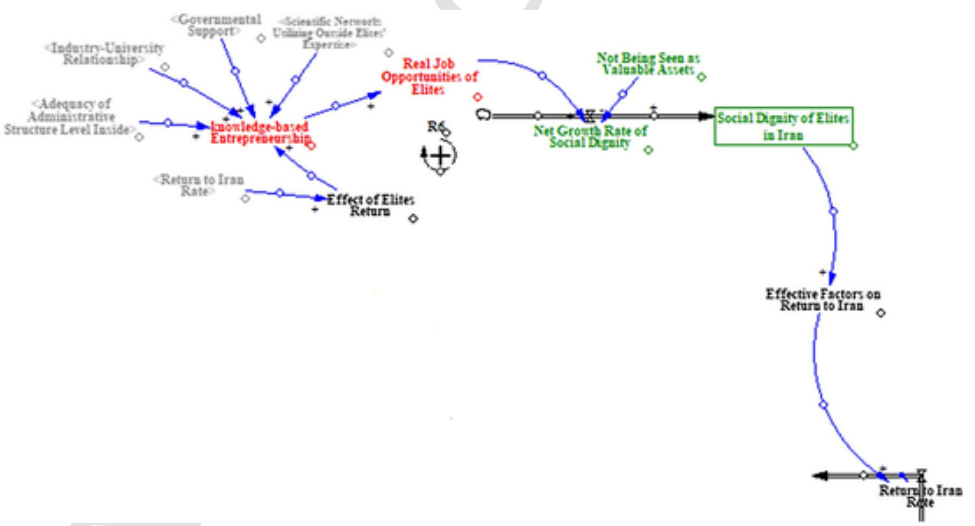


Fig. B7. The sixth positive causal loop diagram addressing the effect of Iranian elites' social dignities state on the return to Iran rate (R6).

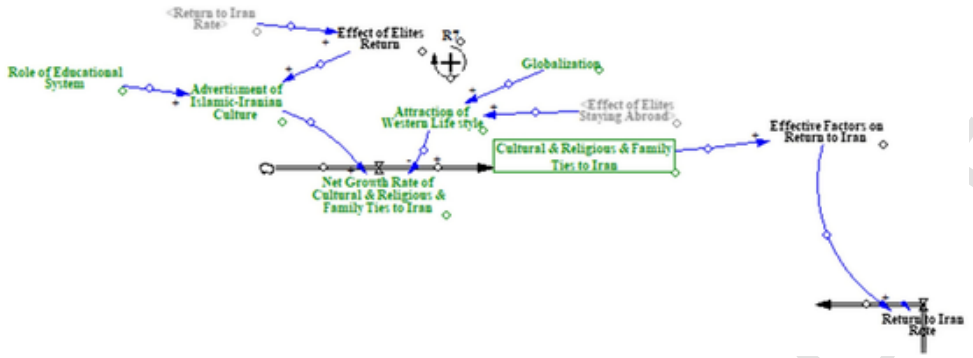


Fig. B8. The seventh positive causal loop diagram addressing the effect of cultural, religious, and family ties state of Iranian elites on the return to Iran rate (R7).

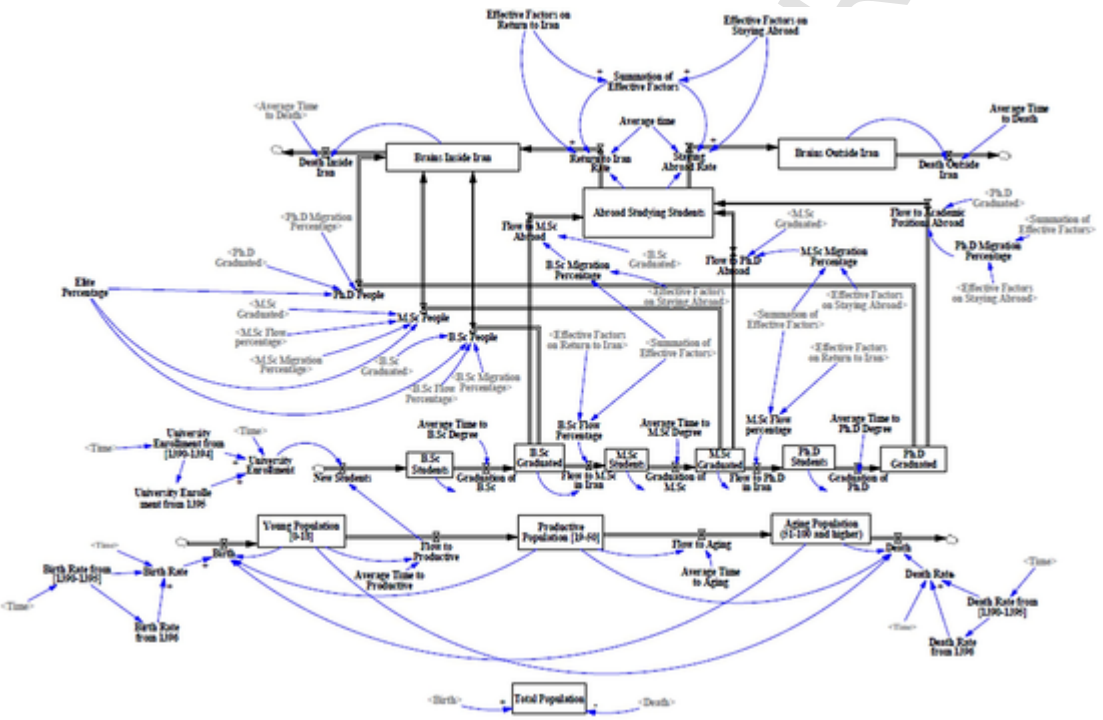


Fig. B9. Stock and flow diagram of Iran's brain drain at litany layer.

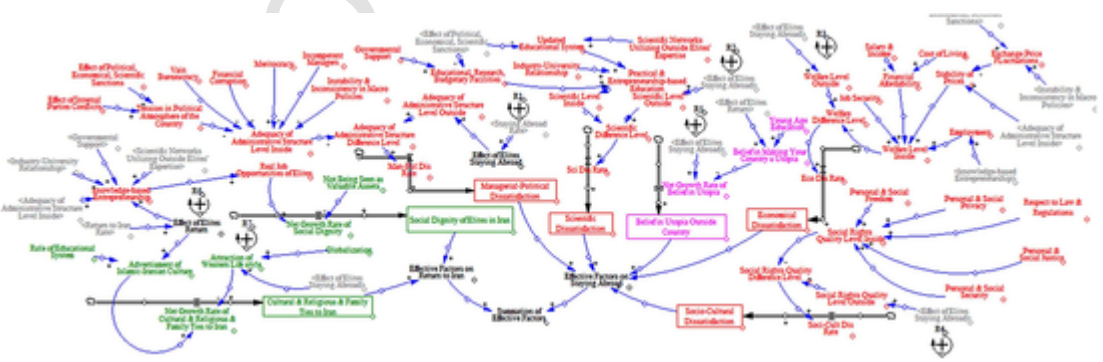


Fig. B10. Stock and flow diagram of Iran's brain drain at structure, worldview, and metaphor layers.

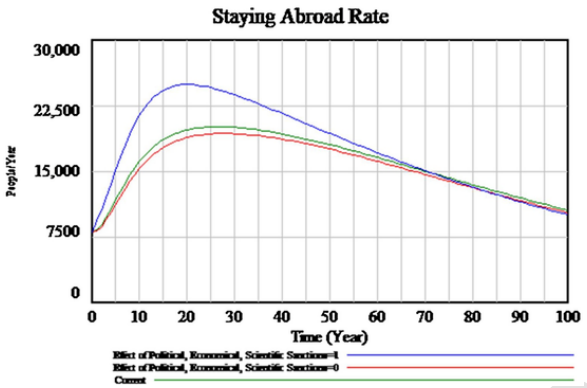


Fig. B11. Extreme conditions test of the effect of political, economic, and scientific sanctions against Iran.

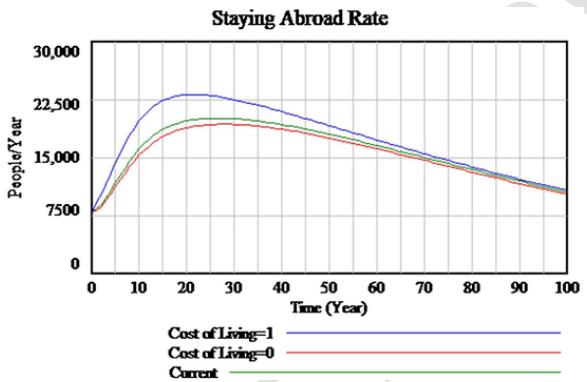


Fig. B12. Extreme conditions test of the cost of living in Iran.

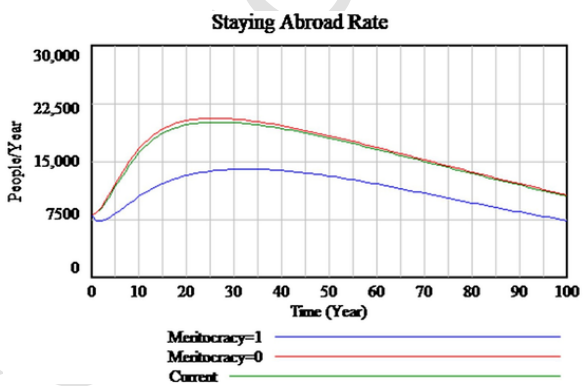


Fig. B13. Extreme conditions test of the meritocracy in Iran.

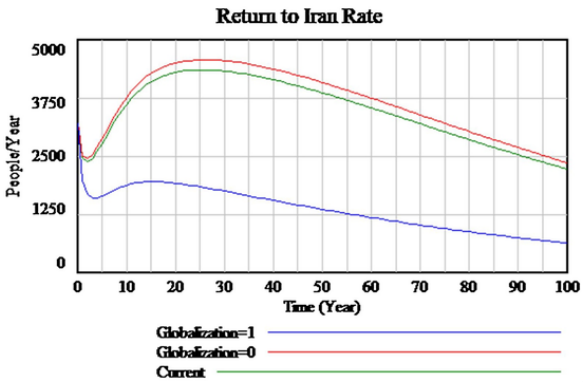


Fig. B14. Extreme conditions test of the effect of globalization in Iran.

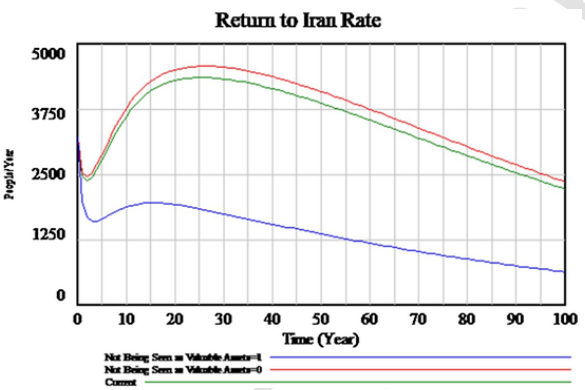


Fig. B15. Extreme conditions test of not being recognized as valuable assets of Iran.

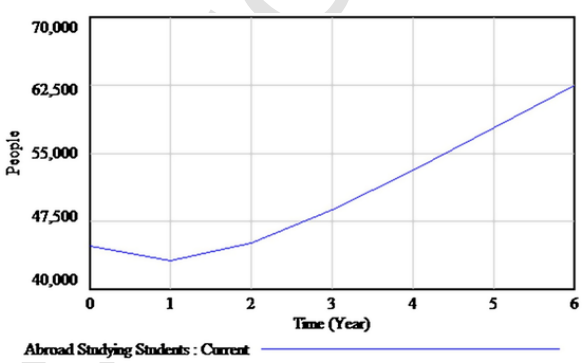


Fig. B16. The simulated population of Iranian students studying abroad from 2011 to 2017.

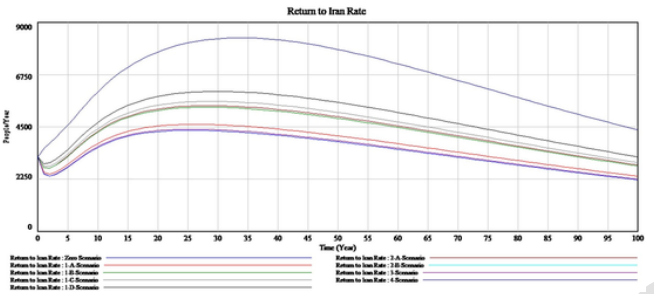


Fig. B17. Simulation of the return to Iran rate of elites under 9 different scenarios over a 100-year time frame [2011-2111].

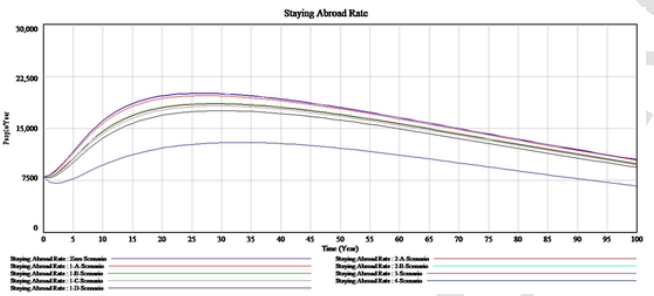


Fig. B18. Simulation of the staying abroad rate of Iranian elites under 9 different scenarios over a 100-year time frame [2011-2111].

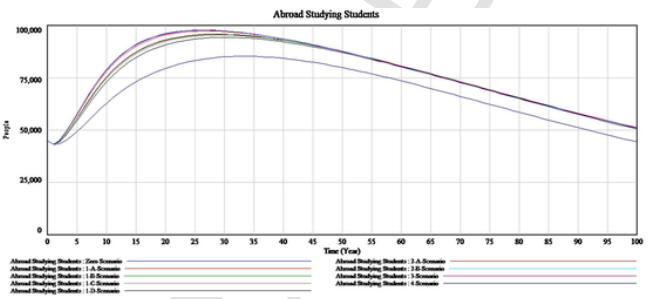


Fig. B19. Simulation of the population of Iranian elites studying abroad under 9 different scenarios over a 100-year time frame [2011-2111].

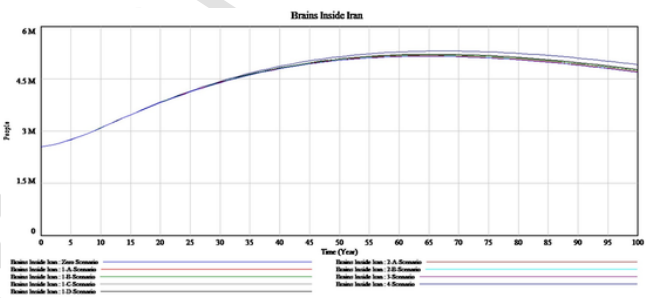


Fig. B20. Simulation of the population of Iranian elites inside the country under 9 different scenarios over a 100-year time frame [2011-2111].

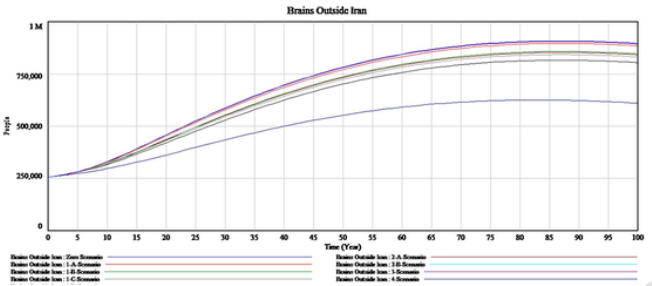


Fig. B21. Simulation of the population of Iranian elites outside the country under 9 different scenarios over a 100-year time frame [2011-2111].

Table B1
Mathematical equations of the stock variables.

Equation	Stock Variable	Category
INTEG (Man- Pol Dis Rate, 1)	Managerial-Political Dissatisfaction	**Variables affecting the staying abroad rate of elites**
INTEG (Sci Dis Rate, 1)	Scientific Dissatisfaction	
INTEG (Eco Dis Rate, 1)	Economical Dissatisfaction	
INTEG (Soci-Cult Dis Rate, 1)	Socio-Cultural Dissatisfaction	
INTEG (Net Growth Rate of Belief in Utopia, 1)	Belief in Utopia Outside the Country	
INTEG (Net Growth Rate of Social Dignity, 1)	Social Dignity of Elites in Iran	**Variables affecting the return to Iran rate of elites**
INTEG (Net Growth Rate of Cultural & Religious & Family Ties to Iran, 1)	Cultural & Religious & Family Ties to Iran	
INTEG (Birth- Flow to Productive, 22712821)	Young Population [18−0]	**Variables related to the population of Iran**
INTEG (Flow to Productive- Flow to Aging, 40823795)	Productive Population [50−19]	
INTEG (Flow to Aging- Death, 115566731)	Aging Population [51−100 and higher]	
INTEG (Birth- Death, 75149700)	Total Population	
INTEG (New Students- Graduation of B.Sc., 2899120)	B.Sc. Students	**Variables related to Iranian students**
INTEG (Graduation of B.Sc.- B.Sc. People- Flow to M.Sc. Abroad- Flow to M.Sc. in Iran, 3786153)	B.Sc. Graduated	
INTEG (Flow to M.Sc. in Iran- Graduation of M.Sc., 458015^2)	M.Sc. Students	
INTEG (Graduation of M.Sc.- Flow to Ph.D. Abroad- Flow to Ph.D. in Iran- M.Sc. People, 577260)	M.Sc. Graduated	
INTEG (Flow to Ph.D. in Iran- Graduation of Ph.D., 47315^2)	Ph.D. Students	
INTEG (Graduation of Ph.D.- Ph.D. People- Flow to Academic Positions Abroad, 93614)	Ph.D. Graduated	
INTEG (Flow to M.Sc. Abroad + Flow to Ph.D. Abroad + Flow to Academic Positions Abroad- Return to Iran Rate- Staying Abroad Rate, 44775)	Abroad Studying Students	
INTEG (Staying Abroad Rate- Death Outside Iran, 254800)	Brains Outside Iran	**Variables related to Iranian elites and experts**
INTEG (B.Sc. People + M.Sc. People + Ph.D. People + Return to Iran Rate- Death Inside Iran, 2553173)	Brains Inside Iran	

Table B2
Mathematical equations of the flow variables.

Equation	Flow Variable	Category
Adequacy of Administrative Structure Difference Level	Man-Pol Dis Rate	**Variables affecting the staying abroad rate of elites**
Scientific Difference Level	Sci Dis Rate	
Welfare Difference Level	Eco Dis Rate	
Social Rights Quality Difference Level	Soci-Cult Dis Rate	
Effect of Elites Staying Abroad- Belief in Making Your Country a Utopia	Net Growth Rate of Belief in Utopia	
Real Job Opportunities of Elites- Not Being Seen as Valuable Assets	Net Growth Rate of Social Dignity	**Variables affecting the return to Iran rate of elites**
Advertisement of Islamic- Iranian Culture- Attraction of Western Lifestyle	Net Growth Rate of Cultural & Religious & Family ties to Iran	
(Aging Population[51–100 and higher] + Productive Population [19–50] + Young Population[0–18])* Birth Rate	Birth	**Variables related to the population of Iran**
Young Population[0–18]/ Average Time to Productive	Flow to Productive	
Productive Population [19–50]/ Average Time to Aging	Flow to Aging	
"(Young Population [0–18]" + "Productive Population [19–50]" + "Aging Population (51–100 and higher))* Death Rate	Death	
Flow to Productive* University Enrollment	New Students	**Variables related to Iranian students**
B.Sc. Students/ Average Time to B.Sc. Degree	Graduation of B.Sc.	
B.Sc. Graduated* B.Sc. Flow Percentage	Flow to M.Sc. in Iran	
M.Sc. Students/ Average Time to M.Sc. Degree	Graduation of M.Sc.	
M.Sc. Graduated* M.Sc. Flow percentage	Flow to Ph.D. in Iran	
Ph.D. Students/ Average Time to Ph.D. Degree	Graduation of Ph.D.	
B.Sc. Graduated* (1- B.Sc. Flow Percentage- B.Sc. Migration Percentage)* Elite Percentage	B.Sc. People	**Variables related to Iranian elites and experts**
M.Sc. Graduated* (1- M.Sc. Flow percentage - M.Sc. Migration Percentage)* Elite Percentage	M.Sc. People	
Ph.D. Graduated* (1- Ph.D. Migration Percentage)* Elite Percentage	Ph.D. People	
B.Sc. Graduated* B.Sc. Migration Percentage	Flow to M.Sc. Abroad	
M.Sc. Graduated* M.Sc. Migration Percentage	Flow to Ph.D. Abroad	
Ph.D. Graduated* Ph.D. Migration Percentage	Flow to Academic Positions Abroad	
Abroad Studying Students* (Effective Factors on Return to Iran/ Summation of Effective Factors)/ Average time	Return to Iran Rate	
Abroad Studying Students* (Effective Factors on Staying Abroad/ Summation of Effective Factors)/ Average time	Staying Abroad Rate	
Brains Inside Iran/ Average Time to Death	Death Inside Iran	
Brains Outside Iran/ Average Time to Death	Death Outside Iran	

Table B3
Mathematical equations of the auxiliary variables.

Equation	Auxiliary Variable	Category
Adequacy of Administrative Structure Level Outside- Adequacy of Administrative Structure Level Inside	Adequacy of Administrative Structure Difference Level	**Variables affecting the staying abroad rate of elites**
Effect of Elites Staying Abroad	Adequacy of Administrative Structure Level Outside	
LN(LN(Staying Abroad Rate))	Effect of Elites Staying Abroad	
Meritocracy- Financial Corruption-Incompetent Managers- Instability & Inconsistency in Macro Policies- Tension in Political Atmosphere of the Country- Vain Bureaucracy	Adequacy of Administrative Structure Level Inside	
Effect of Internal Parties Conflicts + Effect of Political, Economical, Scientific Sanctions	Tension in the Political Atmosphere of the Country	
0.1	Effect of Internal Parties Conflicts	
0.1	Effect of Political, Economical, Scientific Sanctions	
0.1	Vain Bureaucracy	
0.1	Financial Corruption	
0.1	Meritocracy	
0.1	Incompetent Managers	
0.1	Instability & Inconsistency in Macro Policies	
Scientific Level Outside- Scientific Level Inside	Scientific Difference Level	
Effect of Elites Staying Abroad	Scientific Level Outside	
Practical & Entrepreneurship-based Education	Scientific Level Inside	
Educational, Research, Budgetary Facilities + Industry-University Relationship + Updated Educational System	Practical & Entrepreneurship-based Education	
0.1	Industry-University Relationship	
Scientific Networks Utilizing Outside Elites' Expertise- Effect of Political, Economical, Scientific Sanctions	Updated Educational System	
0.1	Scientific Networks Utilizing Outside Elites' Expertise	
Governmental Support- Effect of Political, Economical, Scientific Sanctions	Educational, Research, Budgetary Facilities	
0.1	Governmental Support	
Welfare Level Outside- Welfare Level Inside	Welfare Difference Level	
Effect of Elites Staying Abroad	Welfare Level Outside	
Employment + Financial Affordability + Job Security + Stability of Prices	Welfare Level Inside	
0.1	Job Security	
(Salary & Income- Cost of Living)/ Salary & Income	Financial Affordability	
0.1	Salary & Income	
0.2	Cost of Living	
Adequacy of Administrative Structure Level Inside- Exchange Price Fluctuations	Stability of Prices	
Effect of Political, Economical, Scientific Sanctions + Instability & Inconsistency in Macro Policies	Exchange Price Fluctuations	
knowledge-based Entrepreneurship	Employment	
Social Rights Quality Level Outside- Social Rights Quality Level Inside	Social Rights	

Table B3 (*continued*)

Equation	Auxiliary Variable	Category
knowledge-based Entrepreneurship	Real Job Opportunities of Elites	**Variables affecting the return to Iran rate of elites**
Adequacy of Administrative Structure Level Inside + Effect of Elites Return + Governmental Support + Industry-University Relationship	Knowledge-based Entrepreneurship	
LN(LN(Return to Iran Rate))	Effect of Elites Return	
0.1	Not being seen as Valuable Assets	
Effect of Elites Staying Abroad + Globalization	Attraction of Western Life Style	
0.1	Globalization	
Effect of Elites Return + Role of Educational System	Advertisement of Islamic-Iranian Culture	
0.1	Role of Educational System	
IF THEN ELSE(Time > = 0:AND:Time < = 5, Birth Rate from [1390–1395], Birth Rate from 1396)	Birth Rate	**Variables related to the population of Iran**
WITH LOOKUP (Time,([(0,0)-(100,0.03)],(0,0.018393),(1,0.018697),(2,0.0191291),(3,0.0197),(4,0.0199335), (5,0.01912), (6,0),(7,0),(8,0),(9,0),(10,0),(11,0),(12,0),(13,0),(14,0),(15,0),(16,0),(17,0),(18,0),(19,0),(20,0),(21,0),(22,0),(23,0),(24,0), (25,0),(26,0),(27,0),(28,0),(29,0),(30,0),(31,0),(32,0),(33,0),(34,0),(35,0),(36,0),(37,0),(38,0),(39,0),(40,0),(41,0),(42,0), (43,0),(44,0),(45,0),(46,0),(47,0),(48,0),(49,0),(50,0),(51,0),(52,0),(52,0),(53,0),(54,0),(55,0),(56,0),(57,0),(58,0),(59,0), (60,0),(61,0),(62,0),(63,0),(64,0),(65,0),(66,0),(67,0),(68,0),(69,0),(70,0),(71,0),(72,0),(73,0),(74,0),(75,0),(76,0),(77,0), (78,0),(79,0),(80,0),(81,0),(82,0),(83,0),(84,0),(85,0),(86,0),(87,0),(88,0),(89,0),(90,0),(91,0),(92,0),(93,0),(94,0),(95,0), (96,0),(97,0),(98,0),(99,0),(100,0)))	Birth Rate from [1390–1395]	
TREND(0.01912, 95, "Birth Rate from [1390–1395]")	Birth Rate from 1396	
18	Average Time to Productive	
50	Average Time to Aging	
IF THEN ELSE(Time > = 0:AND:Time < = 5, "Death Rate from [1390–1395]", Death Rate from 1396)	Death Rate	
WITH LOOKUP (Time, ([(0,0)-(100,0.006)], (0,0.00561723), (1,0.00483362), (2,0.00483844), (3,0.0057328), (4,0.00475832), (5,0.00462613), (6,0), (7,0), (8,0), (9,0), (10,0), (11,0), (12,0), (13,0), (14,0), (15,0), (16,0), (17,0), (18,0), (19,0), (20,0), (21,0), (22,0), (23,0), (24,0), (25,0), (26,0), (27,0), (28,0), (29,0), (30,0), (31,0), (32,0), (33,0), (34,0), (35,0), (36,0), (37,0), (38,0), (39,0), (40,0), (41,0), (42,0), (43,0), (44,0), (45,0), (46,0), (47,0), (48,0), (49,0), (50,0), (51,0), (52,0), (53,0), (54,0), (55,0), (56,0), (57,0), (58,0), (59,0), (60,0), (61,0), (62,0), (63,0), (64,0), (65,0), (66,0), (67,0), (68,0), (69,0), (70,0), (71,0), (72,0), (73,0), (74,0), (75,0), (76,0), (77,0), (78,0), (79,0), (80,0), (81,0), (82,0), (83,0), (84,0), (85,0), (86,0), (87,0), (88,0), (89,0), (90,0), (91,0), (92,0), (93,0), (94,0), (95,0), (96,0), (97,0), (98,0), (99,0), (100,0)))	Death Rate from [1390–1395]	
TREND(0.004626, 95, "Death Rate from [1390–1395]")	Death Rate from 1396	
IF THEN ELSE(Time > = 0:AND:Time < = 4, "University Enrollment from [1390–1394]", University Enrollment from 1395)	University Enrollment	**Variables related to Iranian students**
WITH LOOKUP (Time, ([(0,0)-(100,10)], (0,0.4991), (1,0.442909), (2,0.441624), (3,0.412192), (4,0.399453), (5,0), (6,0), (7,0), (8,0), (9,0), (10,0), (11,0), (12,0), (13,0), (14,0), (15,0), (16,0), (17,0), (18,0), (19,0), (20,0), (21,0), (22,0), (23,0), (24,0), (25,0), (26,0), (27,0), (28,0), (29,0), (30,0), (31,0), (32,0), (33,0), (34,0), (35,0), (36,0), (37,0), (38,0), (39,0), (40,0), (41,0), (42,0), (43,0), (44,0), (45,0), (46,0), (47,0), (48,0), (49,0), (50,0), (51,0), (52,0), (53,0), (54,0), (55,0), (56,0), (57,0), (58,0), (59,0), (60,0), (61,0), (62,0), (63,0), (64,0), (65,0), (66,0), (67,0), (68,0), (69,0), (70,0), (71,0), (72,0), (73,0), (74,0), (75,0), (76,0), (77,0), (78,0), (79,0), (80,0), (81,0), (82,0), (83,0), (84,0), (85,0), (86,0), (87,0), (88,0), (89,0), (90,0), (91,0), (92,0), (93,0), (94,0), (95,0), (96,0), (97,0), (98,0), (99,0), (100,0)))	University Enrollment from [1390–1394]	
TREND(0.3995, 96, "University Enrollment from [1390–1394]")	University Enrollment from 1395	
4	Average Time to B.Sc. Degree	
0.0453436* (Effective Factors on Return to Iran/ Summation of Effective Factors)	B.Sc. Flow Percentage	
2	Average Time to M.Sc. Degree	

(*continued on next page*)

Table B3 (*continued*)

Equation	Auxiliary Variable	Category
0.0190278* (Effective Factors on Return to Iran/ Summation of Effective Factors)	M.Sc. Flow Percentage	**Variables related to Iranian elites and experts**
4	Average Time to Ph.D. Degree	
0.22692*0.01 (Effective Factors on Staying Abroad/ Summation of Effective Factors(	B.Sc. Migration Percentage	
0.797848* 0.01 ⋆(Effective Factors on Staying Abroad/ Summation of Effective Factors)	M.Sc. Migration Percentage	
0.0227968 0.01* ⋆ (Effective Factors on Staying Abroad/ Summation of Effective Factors)	Ph.D. Migration Percentage	
72.75	Average Time to Death	
4	Average Time	
0.0124261	Elite Percentage	
Effective Factors on Return to Iran + Effective Factors on Staying Abroad	Summation of Effective Factors	

Table B4
Comparison of the population of Iranian students studying abroad from 2011 to 2017.

Year	Simulated results	Reference mode
2011	44775	44775
2012	43160.3	47196
2013	45146.6	49493
2014	48787.2	50823
2015	53160.7	51138
2016	57811.6	52771
2017	62501.7	52521

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