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A System Dynamics Model of Nursing and Midwifery Workforce Supply

Paul Caulfield, Terence Hynes, Peter O'Connor

Research Services & Policy Unit, Department of Health

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Contents

1. Introduction	10
2. Policy Context	12
2.1 International nursing and midwifery demand and supply	13
2.2 Demand for nursing and midwifery in Ireland	15
2.3 Supply of nurses and midwives in Ireland	16
2.4 HEI places for nurses and midwives	18
2.5 Trends affecting the nursing profession	19
2.5.1 Masculinisation	19
2.5.2 Attrition	19
2.5.3 Reduction in working week	20
2.6 Education of nurses and midwives in Ireland	20
3. Literature Review	22
3.1 Objective of the literature review	22
3.2 Scope	22
3.3 Search method and strategy	22
3.4 Results	22
3.5 Narrative description of results	23
4. Methods	24
4.1 Overview of system dynamics modelling	24
4.2 Using stocks and flows to model systems	25
4.2.1 Data sources	25
4.2.2 NMBI register data	26
4.2.3 Limitations of NMBI register data	26
4.2.4 Other data sources	27
4.3 Nursing and midwifery workforce supply model description	29
4.3.1 Higher Education Institution view	30
4.3.2 Age and sex cohorts view	30
4.3.3 Foreign educated workforce view	35
4.3.4 Description of model variables, data sources, and assumptions at baseline	36
4.3.5 Description of scenarios	43
5. Results	45
5.1 Scenario A: Baseline	45
5.1.1 Scenario A: Baseline results with a lower demand growth rate (1.00%)	47
5.1.2 Scenario A: Baseline results with a higher demand growth rate (2.50%)	48
5.2 Scenario B: Moderate increase in domestic supply	49

5.3 Scenario C: Significant increase in domestic supply	49
6. Discussion	52
6.1 Limitations	52
7. Conclusion	54
Bibliography	55
Appendix 1: The Standard Method for SD Modelling (Lyneis & Hines, 2007)	60
Appendix 2: Estimated cost per student of nursing and midwifery education in Ireland	61
Appendix 3: Note on countries which have significantly increased student nursing places in recent years	62
Appendix 4: Baseline scenario sensitivity analysis	63
Appendix 5: HSE Nursing & Midwifery WTE trends.....	66
Appendix 6: CCPS requests made by individual Irish educated nurses and midwives per year67	
Appendix 6: Search Strategy.....	68
A6.1 Details of search terms and sources	68
A6.2 Prisma flow chart.....	69
A6.3 Studies included in final set of literature review with abstracts.....	70

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An early version of the model utilised in this paper was developed as part of the IGEES internship programme.

Abbreviations, Acronyms and Glossary

Acute Care	Acute Care refers to care provided in relation to critical, high-dependency and high clinical need cases.
Acute Medical Assessment Unit	An Acute Medical Assessment Unit (AMAU) is a facility with beds separate from ED whose primary function is the immediate and early specialist management of acutely unwell adult patients who present to, or from within, a hospital requiring urgent medical care. AMAUs enable appropriate streaming of patients away from EDs to improve clinical care and patient experience.
AMNJ	Australian Nursing and Midwifery Journal
Birthrate Plus	An evidence-based approach to determine the clinical midwifery staffing levels across all appropriate maternity units required to provide care.
CCPS	Certificate of Current Professional Status. This is required if a nurse or midwife is moving to another country that they were not originally educated in. Additionally, for a foreign educated nurse or midwife registering in Ireland from abroad, the NMBI request a CCPS from all previous countries they were employed in.
Clinical Instruction	The clinical training of nursing students takes place through clinical placements in a variety of clinical settings. The duration of these placements varies in each year of a nursing programme.
CR	Health Service Capacity Review 2018: Review of Health Demand and Capacity Requirements in Ireland to 2031 – Main Report
CPC	Clinical Placement Coordinator. A CPC is a nurse or midwife who supports students, oversees the attainment of skills in the clinical area and provides a central role in liaising with nurse and midwifery ward managers, educators and Practice Development Coordinators.
CPC Ratio	The Clinical Placement Coordinator to student ratio used in the is paper 1:19.6. This estimate assumes that the typical CPC to student ratios in place are 1:20 for nursing students and 1:15 for midwifery students
DoH	The Department of Health
DoH-RSPU	The Department of Health's Research Services and Policy Unit
Dom.	Domestically
Domestically Educated	Domestically Educated reflects those educated in Ireland, rather than the nationality of nurses/midwives.
DPER	The Department of Public Expenditure and Reform
DFHERIS	The Department of Further and Higher Education, Research, Innovation and Science
DKIT	Dundalk Institute of Technology
ED	Emergency Department
Edu.	Educated
ERB	Expert Review Body
ESRI	The Economic and Social Research Institute
ESRI Hippocrates Model	The Hippocrates Model was developed at the ESRI in a programme of research funded by the Department of Health. The Model provides base year projections of healthcare demand, capacity and expenditure for selected Irish health and social care services.
Flow	A Flow is material or information that enters or leaves a stock over a period.
Foreign Educated Nurse	A nurse that was educated outside the Republic of Ireland. It does not relate to their nationality or country of birth.
Framework for Safe Nurse Staffing and Skill-Mix	An evidence-based approach for determining the nursing and healthcare assistant staffing requirements based on the measurement of patient acuity and dependency and the complexity of care required.
GEN	Graduate Entry Nursing
GEM	Graduate Entry Midwifery
GP	General Practitioner

Graduate Training Model	The Graduate Training Model refers to the undergraduate nursing and midwifery programmes in Ireland which typically last four years.
HEI	Higher Education Institution
HSE	Health Service Executive
Inpatient	A person who goes into hospital to receive medical care and stays there one or more nights while they are being treated.
Internship	A 36-week, paid internship period undertaken in the final year of a nursing programme.
Link Lecturer	A Link Lecturer encourages the utilisation of nursing theory in the clinical setting.
OECD	Organisation for Economic Co-operation and Development
OT	Occupational Therapist
NMBI	The Nursing and Midwifery Board of Ireland
PC	Primary Care
PDC	Practice Development Coordinator. A PDC oversees and coordinates the running of nurse education centre or practice development unit within a hospital or other health facility.
Practice Nurse	A Practice Nurse works in a general practice providing services such as long-term condition caseload management, immunisation, screening and health promotion.
Preceptor	A registered nurse who during a practice placement provides a student nurse with support and supervision and assists them with the development of knowledge, know how, skills and competence required to become a proficient nursing practitioner.
Primary Care	Primary Care relates to health or social care services provided in the community, outside of hospital.
Professionally Active Nurse	A Professionally Active Nurse is one who is practicing but not necessarily patient facing (i.e., may not be working in a clinical setting). Following discussions with the NMBI, it is estimated that 90% of nurses who did not report on their professionally active status in the annual renewal process are in fact active.
Proj.	Projected
PSPC	Public Service Pay Commission
Public Health Nurse	A Public Health Nurse is a registered nurse with a specialist nursing qualification, who provides core nursing or midwifery care in the community and offers guidance and information to patients about how best to meet their health needs.
Registered Midwife	A Registered Midwife is a person who has successfully completed a recognised and approved midwifery education programme, acquired the necessary requirements to be registered to practise midwifery and demonstrates and maintains competency in the practice of midwifery.
Registered Nurse	A registered nurse is a person who has successfully completed a recognised and approved nursing education programme in the country where the qualification was achieved, acquired the necessary requirements to be registered to practise nursing in this jurisdiction and use the title 'registered nurse' and demonstrates and maintains competency in the practice of nursing.
S&LT	Speech and Language Therapist
Safe Nursing and Midwifery Staffing	Safe nurse and midwife staffing means having enough nursing or midwifery staff with the right knowledge and skills, in the right place, at the right time to provide safe and quality care to patients and service users.
SALO	The role of Student Allocations Liaison Officer (SALO) is to establish, organise and co-ordinate multiple core and specialist clinical placements for undergraduate (including internship) nursing students in partnership with HEIs.
SD	System Dynamics
SDM	System Dynamics Model
Staff Midwife	A Staff Midwife is a registered midwife who is involved in direct patient care.
Staff Nurse	A Staff Nurse is a registered nurse who is involved in direct patient care.

Stock	A Stock is an accumulation of material or information that has built up in a system over time.
Stock-Flow Supply Model	A model which, starting from a stock measured at year 0, estimates the evolution of the stock, assuming inflows and outflows that modify the initial stock year after year.
Strategic Workforce Planning	Strategic Workforce Planning is a process of analysing the current workforce, determining future workforce needs, identifying the gap between the workforce you have available and your future needs, and implementing solutions so that an organisation can accomplish its mission, vision and strategic plan.
Supernumerary Basis	Supernumerary Basis means that student nurses should not be counted as part of the workforce (at least from a practical perspective) while on placement and should not be asked to work as such.
System	A System is a regularly interacting or interdependent group of items forming a unified whole.
WHO	World Health Organization
WHO-GCP	World Health Organization Global Code of Practice on International Recruitment of Health Personnel
WF	Workforce
WTE	Whole Time Equivalent

Executive Summary

Introduction

Over the period 2014 to 2021 first-year nursing and midwifery places in Irish Higher Education Institutions (HEIs) grew from 1,570 to 2,032 – an increase of almost 30%. Despite this increase in places, in 2021 almost 43% of nurses and midwives registered in Ireland were educated abroad. The international recruitment of staff from developing countries is a global issue across all categories of the health workforce. The World Health Organization have developed Code of Practice on International Recruitment of Health Personnel (WHO-GCP) which entails attaining self-sufficiency in health workforce requirements through the training of adequate numbers of local staff (WHO, 2010).

While international comparisons are subject to significant data limitations, Ireland has a relatively high number of nurses per capita (4th highest) compared to OECD countries. There remains an urgent need to increase the domestic supply of nurses and midwives to meet expected increases in demand, address workforce challenges and reduce Ireland's reliance on the recruitment of foreign educated nurses.

This Spending Review paper develops a nursing and midwifery workforce supply model using systems dynamics modelling to examine the potential increases in student nurse/midwife intake required to reduce Ireland's reliance on the foreign-educated workforce. This paper does not include an assessment of demand for nursing or midwifery, nor does it make any comment on the appropriateness of the current numbers of nurses and midwives, skill-mix or grade-mix within the health system.

Findings

Based on current trends, the proportion of domestically educated nurses and midwives in the WTE workforce will decrease from 54% to approximately 38% over a 20-year projection period which will exacerbate the challenge of reaching national self-sufficiency. Ireland produces 31 graduate nurses and midwives per 100,000 people each year. Gradually increasing this figure by 87% over 14 years to the level of the Netherlands (58 per 100,000) decreases Ireland's reliance on foreign educated nurses and midwives relative to the baseline.

In this scenario, approximately 50% of nurses and midwives in the WTE workforce would be domestically educated compared to 38% in the baseline. Significantly increasing the production of nursing and midwifery graduates by 250% to the per capita level of Australia (109 per 100,000), the highest in the world, reduces Ireland's reliance on foreign educated nurses and midwives to approximately 30% after 20 years. This compares with 62% in the baseline.

Conclusions

This paper uses system dynamics modelling as part of an evidence-based framework to model the supply of the nursing and midwifery workforce in Ireland. While there is uncertainty in the projections for the total number of domestically educated nurses in Ireland, this paper demonstrates a need to significantly increase Ireland's domestic production to ensure that the State meets the WHO-GCP commitment. Demand for nursing and midwifery is expected to grow into the future and this conclusion holds for a wide range of potential growth rates. Supply gaps are likely to continue to be met by the large-scale recruitment of foreign nurses and midwives into the foreseeable future. However, the expansion of nursing and midwifery student places in Ireland would reduce the need to recruit internationally.

1. Introduction

Demand for health services (including the services of nurses and midwives) is anticipated to grow for the foreseeable future. This growth in demand is being driven by demographic factors (e.g., population growth and aging) and non-demographic factors (e.g., income, technology and policy changes) (Keegan, Brick, García-Rodríguez, & Hill, 2022).

Over the period 2014 to 2021 first-year nursing and midwifery places in Irish Higher Education Institutes (HEIs) grew from 1,570 to 2,032 – an increase of almost 30%. Despite this increase in student places, in 2021 almost 43% of nurses and midwives registered in Ireland were educated abroad (in fact the proportion of newly registered nurses and midwives with the NMBI that were educated in Ireland fell from 74% of all new registrations in 2014 to 31% in 2021). It should be noted that this was in the context of the total number of new NMBI registrations growing from 1,913 in 2014 to 5,008 in 2021. While foreign educated nurses and midwives make essential and valued contributions to the Irish health system and their employment in Ireland is often beneficial to their countries of origin, the current situation presents risks to health system resilience in relation to future shocks (e.g., pandemics creating bans on international travel etc.) and raises ethical concerns as significant proportions of foreign educated nurses/midwives are recruited from developing nations with their own requirements for nurses/midwives.

The international recruitment of staff from developing countries is a global issue across all categories of the health workforce. The World Health Organization have developed a Code of Practice on International Recruitment of Health Personnel (WHO-GCP) which entails attaining self-sufficiency in health workforce requirements through the training of adequate numbers of local staff (WHO, 2010). The Code centres on the topic of ethical international recruitment. Participating countries, including Ireland, have committed to ending active recruitment of health personnel from developing countries, particularly those facing critical shortages (WHO, 2010). There is an urgent need to redress this imbalance to align with Ireland's commitments under the WHO-GCP.

The objectives of this Spending Review are to:

- Develop a nursing and midwifery workforce supply model using System Dynamics Modelling (SDM), and;
- Examine the potential increases in student nurse/midwife intake required to reduce Ireland's reliance on the foreign educated nursing and midwifery workforce in the long-term.

This paper does not include an assessment of demand for nursing and midwifery, nor does it make any comment on the appropriateness of the current numbers of nurses, midwives, skill-mix or grade-mix within the health system.

Midwifery is a separate and distinct profession from nursing, according to the Nurses and Midwives Act 2011.¹ Note: a previous version of this paper used “nurses” to refer to both nurses and midwives. This version has been revised to reference nurses and midwives or nurses/midwives. No changes to the descriptive analysis, supply modelling, findings or conclusions were required.

This paper will first give an overview of the current policy context in Ireland. Subsequently, to inform this spending review’s modelling approach, a review of the literature on system dynamics and related models used in health workforce forecasting was undertaken. A brief overview of this literature is provided to the reader. Next, the methods, followed by, results, discussion and conclusion sections are set out.

¹ Note the Nurses and Midwives Act 2011 (<https://www.irishstatutebook.ie/eli/2011/act/41/enacted/en/print>).

2. Policy Context

Nurses - particularly at Staff Nurse level - provide the majority of direct patient care. Factors including greater nurse staffing numbers, greater levels of nursing hours, higher quality nursing education and a lower number of patients per nurse, have been identified as having significant positive impacts on patient outcomes including reduced mortality rates, reduced hospital-acquired infections, reduced length of stay, reduced hospital readmission rates and increased patient satisfaction (Office of the Chief Nurse, 2018) (DoH, 2022). Midwifery is a separate and distinct profession from nursing, according to the Nurses and Midwives Act 2011.²

The key initiative driving strategic change in the Irish health system including health workforce planning is the Sláintecare reform programme, which has been set out in a series of reports.³ This 10-year strategy envisages a healthier Ireland, with improved health and wellbeing for all, and with the right care being delivered in the right place at the right time. The Sláintecare reforms acknowledge the central role that the nursing profession will play in improving health and wellbeing and expanding the primary, community and social care sectors. Recommendations for the future of the health workforce include enhancing access to Public Health Nurses and child health nursing services, and the expansion of nursing and midwifery roles in primary healthcare teams.

The implications of the expansion of these roles in primary healthcare teams (non-acute settings) for the nursing and midwifery professions were outlined in Sláintecare and the National Maternity Strategy. These implications were also addressed by the Expert Review Body (ERB) on Nursing and Midwifery, established by the Minister for Health in 2021 (DoH, 2022). A comprehensive report was published in 2022 detailing a number of recommendations pertinent to the strategic workforce planning of nurses and midwives. One recommendation outlined the need for the Department of Health (DoH) to develop an integrated workforce strategy for nursing and midwifery, including the planning and forecasting of staffing requirements. Another recommendation was for the stakeholders, including the Health Service Executive (HSE), the Nursing and Midwifery Board of Ireland (NMBI) and HEIs, to review the capacity of undergraduate education in Ireland and ensure sufficiency in meeting demand for nursing into the future. The report notes the requirement for an increase in undergraduate student numbers but also recommends consideration of the introduction of Graduate Entry Nursing (GEN) and Graduate Entry to Midwifery (GEM) programmes as additional pathways

² Note the Nurses and Midwives Act 2011 (<https://www.irishstatutebook.ie/eli/2011/act/41/enacted/en/print>).

³ Sláintecare Report (Houses of the Oireachtas, 2017), the Action Plan (DoH, 2019) and the Implementation Strategy (Government of Ireland, 2021).

for individuals to access nursing and midwifery careers. In the UK, a variety of routes to becoming a Registered Nurse are available including undergraduate degrees, GEN and apprenticeship programmes.⁴ Another recommendation of the report is that the HEIs monitor and report student attrition rates from undergraduate nursing and midwifery programmes.

2.1 International nursing and midwifery demand and supply

WHO projections point to increasing global demand for nurses. Current trends indicate there will be a global requirement for 36 million nurses by 2030, leaving a projected needs-based shortage of 5.7 million, primarily in the African, South-East Asia and Eastern Mediterranean regions. In parallel, it is anticipated that several countries in the American, European and Western Pacific regions will be challenged with nationally defined shortages (WHO, 2020).

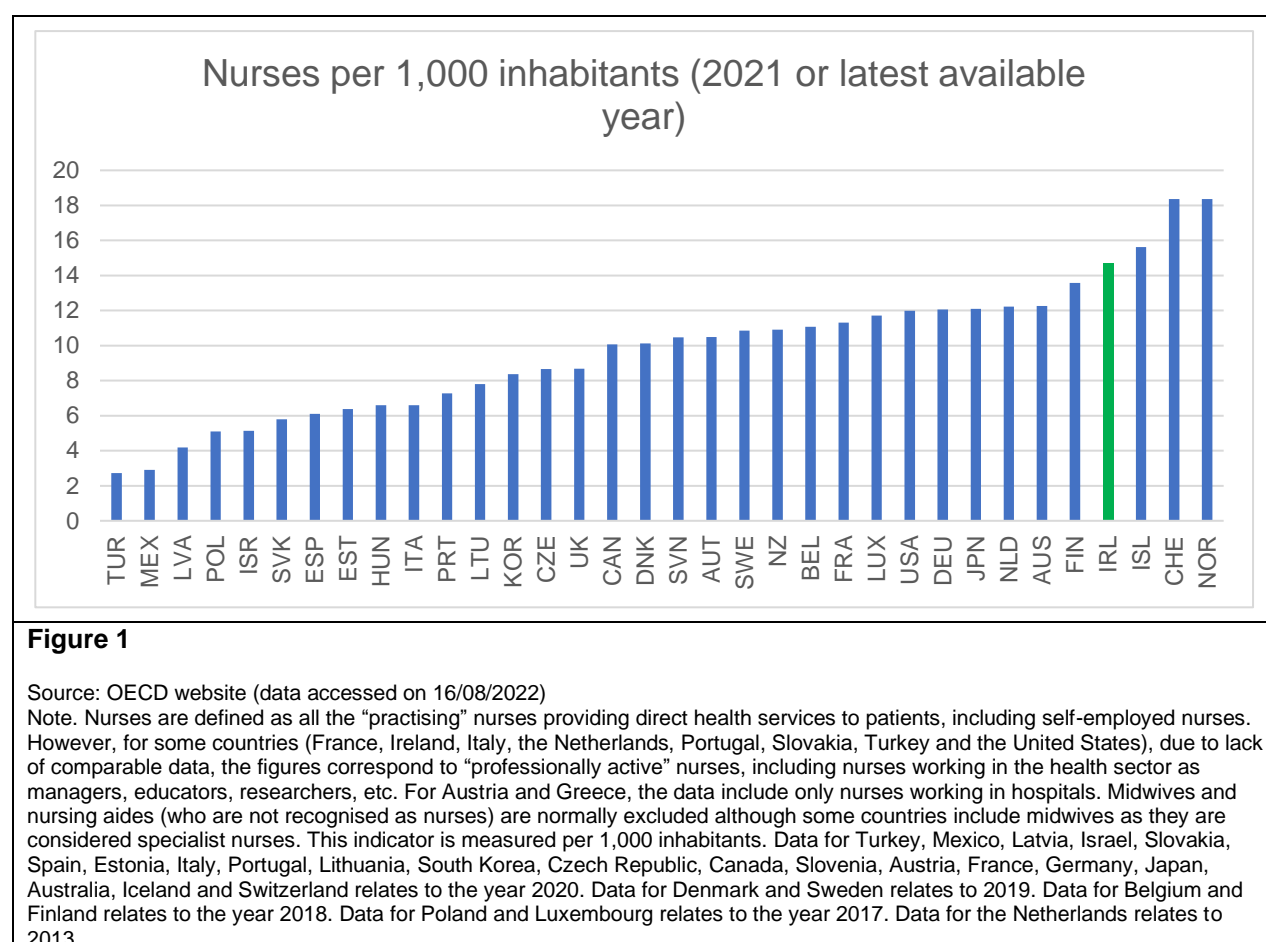
The WHO estimates there to be a global shortage of 900,000 in the number of midwives and the wider midwifery workforce (WHO, 2021).

The large-scale movement of health workers from lower-income to higher-income countries has long been recognized as a challenge. The worldwide shortage of nurses and midwives has led to the so-called 'poaching' or 'stealing' of these professionals from developing countries by employers in wealthier countries. It is argued that the migration of the health workforce to wealthier countries has exacerbated shortages in the developing world, raising access and equity issues (WHO, 2020). However, it should also be noted that in some developing countries the prospect of emigration following the completion of a nursing degree acts as a significant driver in attracting students to the nursing profession. Furthermore, in certain instances governments such as Philippines have actively encouraged the outmigration or 'export' of nurses to the developed world, with emigrant nurses providing significant levels of remittances to their home country (Arends-Kuenning, Calara, & Go, 2015).

OECD member states now employ more health workers than ever before (OECD, 2021). Between 2000 and 2019, the number of nurses per capita grew in almost all OECD countries, with the notable exceptions being the United Kingdom, Ireland and the Baltic states; in these countries the number of nurses per capita in 2019 was about the same as it was in 2000, as the changes in the number of nurses closely tracked changes in population. Norway and Switzerland have significantly increased the number of nurses employed over the past two decades (OECD, 2021).

⁴ See NHS website (Link: <https://www.healthcareers.nhs.uk/explore-roles/nursing/how-become-nurse/how-become-nurse>)

As can be seen in **Figure 1** below, Ireland has 14.69 nurses per 1,000 population. This is well above the OECD average of 8.8 per 1,000 population (OECD, 2021). Interpretation of these data are subject to some qualifications e.g., Irish authorities report the figure for all professional nurses working in clinical, educational, management and research roles whereas some OECD countries report figures only for practicing nurses providing direct patient care (DoH, 2022). For Austria and Greece, the data include only nurses working in hospitals. Midwives and nursing aides (who are not recognised as nurses) are normally excluded although some countries include midwives as they are considered specialist nurses. Midwives are included in the figures for Australia, Ireland and Spain (OECD, 2021).



To keep pace with the increase in demand for nursing services associated with ageing populations and increasing levels of people with long-term health conditions, since the year 2000 many OECD member states have taken policy decisions to expand the number of graduates. The latest figures report an average of 44.5 new nursing graduates per year per 100,000 population (OECD, 2021). As can be seen in **Figure 2** below, at 30.77 per 100,000, the number of new nursing graduates in Ireland is substantially below countries such as Australia (107.88), Switzerland (111.86), Finland (67.73), Norway (75.64) and the United

States (65.17).⁵ See a note on countries which have significantly expanded nursing places in **Appendix 3**.

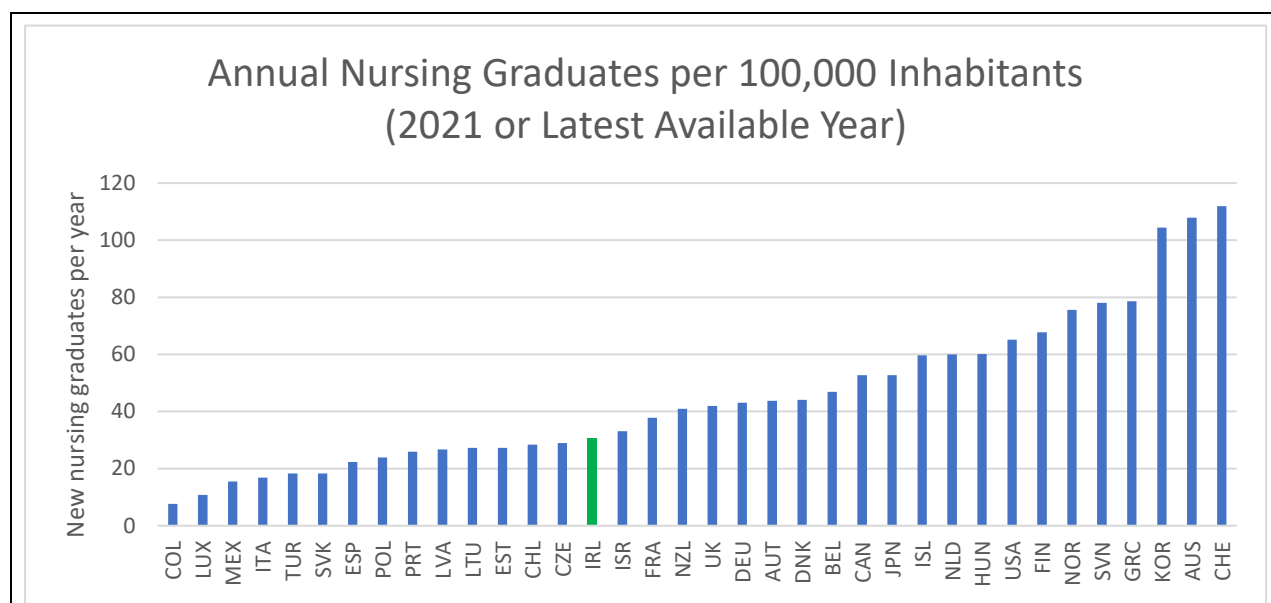


Figure 2

Source: OECD website (data accessed on 16/08/2022).

Note: This indicator presents the number of nursing graduates each year. In response to concerns about current or anticipated shortages of nurses, many OECD countries have taken steps in recent years to expand the number of students in nursing education programmes. Increasing investment in nursing education is particularly important as the nursing workforce is ageing in many countries and the baby-boom generation of nurses approaches retirement. Nursing graduates refer to the number of students who have obtained a recognised qualification required to become a licensed or registered nurse. They include graduates from both higher level and lower-level nursing programmes. They exclude graduates from master's or PhD degrees in nursing to avoid double-counting nurses acquiring further qualifications. This indicator is measured per 100,000 inhabitants. Data for Australia, Austria, Czech Republic, Finland, France, Germany, Hungary, Ireland, Italy, South Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, Slovakia, Spain, Switzerland, Turkey, USA, Chile and Lithuania relates to 2020. Data for Denmark, Iceland, Greece and Colombia relates to 2019. Data for Poland and Slovenia relates to 2018. The data for Canada relates to 2018.

2.2 Demand for nursing and midwifery in Ireland

In Ireland, demand for nursing and midwifery is expected to grow in tandem with demand for healthcare generally.

The 'Health Service Capacity Review 2018: Review of Health Demand and Capacity Requirements in Ireland to 2031' (CR) and its update reports are being used to inform health system reform, service planning and capital investment (DoH, 2018). The CR developed projections based on scenarios which reflected the expected major drivers and policies impacting health system capacity. Notably, the CR highlights the growing role that the nursing professions will play in the delivery of health care in Ireland in the years up to 2031. Specifically, there will be an estimated 40% increase in demand for Practice Nurse appointments and a 46% increase in demand for appointments with Public Health Nurses.

⁵ Data sourced from OECD website (Link: <https://data.oecd.org/healthres/nursing-graduates.htm>). This indicator presents the number of nursing graduates in a given year.

Also, it projects a 39% increase in the need for long-term residential care and a 70% increase in the provision of in-home care. Demand for hospital care is also projected to increase with a 16% increase in emergency department attendances, a 37% increase in acute medical assessment unit attendances and a 24% increase in inpatient non-elective admissions (DoH, 2018).

A recent report by the ESRI has utilised the Hippocrates Model to project health workforce demand in the publicly funded acute hospital sector. The ESRI's analysis considers the impact of healthy ageing and expansion of care into the community alongside adjustments to workforce activity ratios which capture the potential impact of changes to workforce grade-mix and skill-mix. It projects a 1.4% to 2.1% annual growth rate for nurses and midwives in the acute sector out to 2035.

2.3 Supply of nurses and midwives in Ireland

The Irish health system is heavily reliant on recruiting foreign educated nurses and midwives to meet workforce needs (see **Figures 3** and **4** below).⁶

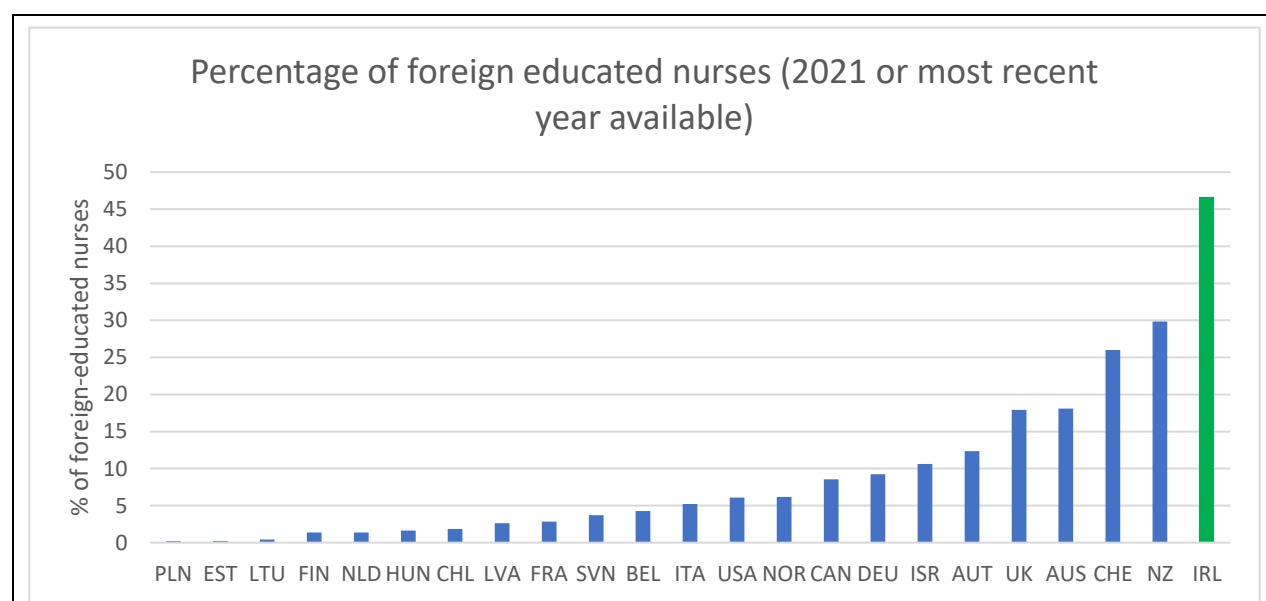


Figure 3

Source: OECD (data accessed on 16/08/2022)

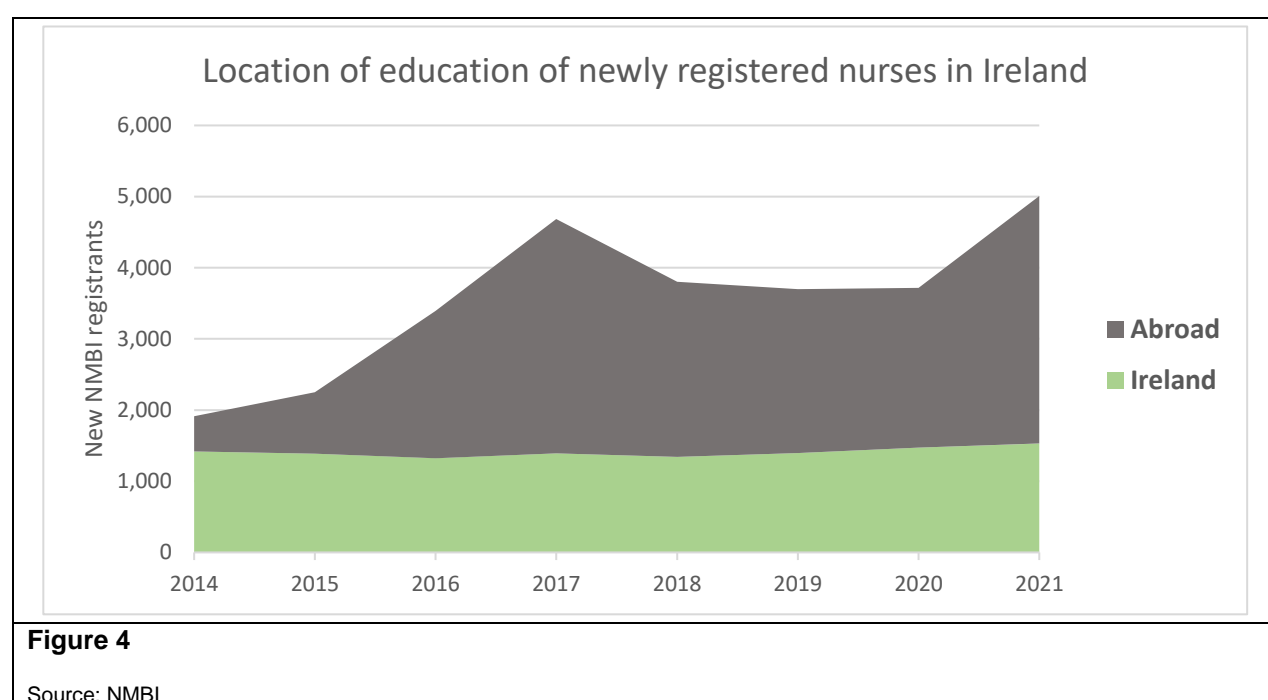
Note that this data relates to the number of nurses who have obtained a recognised qualification in nursing in another country and are working as a nurse in the receiving country. Also note that the data for Finland, Netherlands, Hungary, Latvia, France, Slovenia, USA, Canada, Germany, Austria, Australia and Switzerland relates to 2020. Data for Ireland relates to the percentage of practicing nurses and midwives who were educated abroad.

In 2021, nurses and midwives educated in India accounted for over 2,439 registrations alone (out of a total of 5,008 new registrations).⁷ As set out in **Figure 4** and **Table 1** below, as growth

⁶ The OECD report that 46.56% of nurses and midwives in Ireland in 2021 were foreign educated. Their figure may differ from the NMBI 43% figure reported elsewhere in this paper due to the date of data collection.

⁷ In 2021 Indian nurses and midwives accounted for 49% of all new NMBI registrations.

in demand for nurses and midwives has increased, the proportion of newly registered nurses and midwives with the NMBI that were educated in Ireland fell from 74% of all new registrations in 2014 to 31% in 2021.⁸ Note that this isn't due to a fall in numbers of newly registered Irish educated nurses and midwives (which grew from 1,418 in 2014 to 1,530 in 2021), rather it's driven by the increase in the recruitment of foreign educated nurses and midwives. The surge in newly registered nurses and midwives shown in **Figure 4**, particularly in the years 2015, reflects increasing availability of health system financial resources as the economy recovered after a period of austerity and the impact of the COVID-19 pandemic.



See a breakdown of the percentages of newly registered nurses and midwives with the NMBI by place of education in **Table 1** below:

Year	Ireland	Abroad
2014	74%	26%
2015	62%	38%
2016	39%	61%
2017	30%	70%
2018	35%	65%
2019	38%	62%
2020	40%	60%
2021	31%	69%

Table 1: New registrant breakdown
Source: NMBI

⁸ Figures sourced from NMBI.

2.4 HEI places for nurses and midwives

Over the period 2014 to 2021, first year nursing and midwifery intake places in Irish HEIs grew from 1,570 to 2,032 – an increase of almost 30% (see **Figure 5** below).⁹ The polynomial trendline shows the overall trend in minimum points requirements for nursing and midwifery study programmes; each blue dot represent the minimum points required for an individual undergraduate study programme.

As shown in **Table 2** below, demand for nursing/midwifery education has been largely robust with an oversubscription of student nursing/midwifery places. Nursing/midwifery points generally fell during the period 2012 to 2017. Grade inflation appears to be present in the CAO points data for 2020 and 2021.¹⁰ In 2021, there were 2,032 first year places on offer in bachelor's degree courses of which 5,951 were first-preference applications. In 2022 there were only 4,363 first preference applications for nursing/midwifery programmes, the lowest figure on record.¹¹ Similarly, 2022 saw a fall in the number applications for nursing programmes in the UK, with the decrease largely driven by a fall in the number of mature applicants.¹²

⁹ The increases in first year places from 1,830 to 1,985 in 2020 and 2,032 in 2021 were temporary measures.

¹⁰ This is likely due to the changed approach to examinations arising from the impact of Covid-19 and school closures. Overall, the proportion of leaving cert students receiving over 500 CAO points grew rapidly in both 2020 and 2021.

¹¹ See the CAO website (https://www.cao.ie/index.php?page=app_stats&bb=mediastats)

¹² See the UCAS website (<https://www.ucas.com/undergraduate-statistics-and-reports>)

Year	First Year Intake	First Preference Applications	Level 8 Applicants Total	Percentage of first choice applications
2005	1,640	4,869	53,784	9.1%
2006	1,880	5,279	53,488	9.9%
2007	1,880	5,018	55,172	9.1%
2008	1,880	4,668	56,315	8.3%
2009	1,570	5,227	58,799	8.9%
2010	1,570	5,541	62,082	8.9%
2011	1,570	5,598	61,490	9.1%
2012	1,570	5,775	61,845	9.3%
2013	1,570	5,807	60,747	9.6%
2014	1,570	5,490	62,345	8.8%
2015	1,570	5,368	63,130	8.5%
2016	1,630	5,955	65,030	9.2%
2017	1,832	5,376	65,294	8.2%
2018	1,832	5,494	62,751	8.8%
2019	1,949	5,324	64,375	8.3%
2020	1,990	4,909	63,378	7.7%
2021	2,032	5,951	70,307	8.5%
2022	-	4,363	68,480	6.4%
Table 2: Nursing & Midwifery education – places, applications, points ¹³ Sources: CAO				

2.5 Trends affecting the nursing profession

2.5.1 Masculinisation

While the representation of men in the nursing profession has been steadily increasing over time in countries such as Israel (Popper-Giveon, Keshet, & Liberman, 2015) and the United States, there is no detectable shift towards masculinisation in Ireland. The proportion of males in the profession affects Whole Time Equivalence (WTE) calculations as on average male nurses tend to work more hours compared with their female counterparts.¹⁴ In most developed countries (including Ireland), men account for approximately 10% of the nursing workforce. Since 2013, the proportion of males among newly registered domestically educated nurses has ranged between 7% and 10%.¹⁵

2.5.2 Attrition

A factor that needs to be considered in measuring trends in nursing and midwifery is attrition. Attrition, as defined in this paper, are nurses or midwives in Ireland that withdraw from practice

¹³ These figures exclude places in the Higher Diploma in Midwifery courses.

¹⁴ HSE personnel census March 2022

¹⁵ NMBI data 2022

and/or de-register with the NMBI for reasons other than emigration or retirement. An attrition rate for the overall health sector is not available. Within the HSE, the overall adjusted turnover rate for all grades of nurses and midwives, which excludes the turnover rate of pre/post-registration nursing and midwifery students, is 6.6% and is particularly high among those at staff nurse and midwife grade (DoH, 2022). However, these figures are inflated proxies for attrition as individuals are reported in the turnover even if they remain in roles for another employer or a different HSE region. A number of factors cause attrition, not all of them necessarily negative, but of greatest concern is burnout which is associated with higher workloads, poorer staffing levels, greater psychological demands, poor leadership, and challenging team relationships (DoH, 2022).

2.5.3 Reduction in working week

Recently, changes have been made in relation to the additional 1.5 hours per week worked by nurses and midwives in the HSE since the 2013. The Haddington Road Agreement hours will be phased out during 2022. The working week is being reduced from 39 hours to 37.5 hours per week. This may lead to a redefinition of WTE e.g., a potential effect of the reduction of 1.5 working hours per week, excluding overtime payments, would be the need to recruit 1 extra staff member per 25.

2.6 Education of nurses and midwives in Ireland

The Irish model of nursing/midwifery education takes place exclusively at bachelor's degree level. It is generally referred to as the 'graduate training model' to distinguish it from the now defunct apprenticeship model of education which previously operated in Ireland. Degree-level education for nurses has been shown to have a positive impact on patient care (Kutney-Lee, Sloane, & Aiken, 2013). Completion of the undergraduate honours bachelor's degree programmes leads to registration with the Nursing and Midwifery Board of Ireland (NMBI) in one or more of the following nursing specialities:

1. General Nursing
2. Children's Nursing
3. Intellectual Disability Nursing, or
4. Psychiatric Nursing

Or

5. Midwifery ¹⁶

¹⁶ Midwifery was introduced as a separate degree programme in 2006. Since 2010, graduates of this study programme, which is offered by six HEIs (DKIT, TCD, UCC, UCD, UG and UL), have been conferred with a BSc (Hons) in Midwifery and are eligible to be entered into the Division of Midwives held by the NMBI.

In total, 13 HEIs offer programmes in nursing and/or midwifery. Most undergraduate nursing and midwifery programmes are four years in duration, with the exception being the combined Children's and General Nursing programmes¹⁷ which are four and a half years in duration (DoH, 2022). As set out in **Table 3** below, the four-year Bachelor of Nursing degrees combine classroom-based theoretical instruction provided in formal higher education settings with practical experience gained in clinical placements in a wide variety of health and social service settings, including acute hospitals (NMBI, 2016). Learning during clinical placements is on a Supernumerary Basis for years one to three and the first part of year four, following which students undertake an internship placement for 36 weeks. The internship experience is important for the consolidation of knowledge, helping to develop clinical decision-making and judgement skills in the final stages of the undergraduate education programme (DoH, 2022). Student nurses and midwives receive an income during the internship placement.

Nursing study programme essential requirements	No. of weeks
Theoretical Instruction	63 weeks
Clinical Instruction	45 weeks
Internship	36 weeks
Total	144 weeks
Table 3	
Source: (Nursing and Midwifery Board of Ireland, 2015)	

While student nurses and midwives are on clinical placements, they are facilitated by funded clinical supports, including clinical staff, Clinical Placement Coordinators (CPCs), nurse and midwifery Practice Development Coordinators (PDCs) and Link Lecturers. CPCs are nurses or midwives who support students, overseeing the attainment of skills in the clinical area and providing a central role in liaising with nursing and midwifery ward managers, educators and practice development coordinators (DoH, 2022). PDCs oversee and coordinate the running of nurse and midwife education centres or practice development units within a hospital or other health facility.

¹⁷ Combined children's and general nursing programmes are offered by DCU, UCC, UCD and TCD only.

3. Literature Review

3.1 Objective of the literature review

To inform this spending review's modelling approach, an information search in relation to the existing literature on the use of system dynamics models (and related models) in health workforce and health human resourcing contexts was undertaken.

3.2 Scope

Within the scope of the literature review are the identification of existing system dynamics papers on the topic of nursing, midwifery and medical doctor workforce planning.

3.3 Search method and strategy

The literature review included searches for peer reviewed articles using the PubMed, MedLine and EconLit¹⁸ databases and a search of grey literature (i.e., non-peer reviewed literature) on Google Scholar. This was conducted during January and February 2022.

A snowball search of key literature was used to identify additional studies. This was conducted between August and December 2021. The details of the search strategy are reported in **Appendix 6**.

The search combined the concepts of system dynamics (and related terms), doctors, medicine, nursing, midwifery and workforce. The results were then reviewed by a single author for inclusion or exclusion. Studies were included if they contained the use of system dynamics or related techniques and focused on applying these methods to health workforce planning or health human resourcing topics. Studies were excluded if they did not use system dynamics modelling (or related methods) and/or were not specific to health workforce planning or health human resourcing. No formal appraisal of study quality or statistical pooling of results was performed, and evidence synthesis was carried out via a narrative overview of selected primary and secondary studies.

3.4 Results

The search identified a total of 77 unique citations. Following review, 31 relevant studies were identified that use system dynamics (and related methods) that were applied specifically to

¹⁸ The MedLine and EconLit searches were performed together on the EBSCOhost platform.

health human resources or health human resourcing topics. The details of the studies included in the final set are reported in **Appendix 6**.

3.5 Narrative description of results

All papers identified in the literature review deal with the supply of health professionals. The three main types of health workforce system dynamics (or related method) models are (i) supply-based models, (ii) demand-based models and (iii) needs-based models.

Supply-based models generally consider stock, inflow and outflow variables to determine the availability of health workers, e.g., the number of active health professionals, the number of newly registered health professionals and the level of annual attrition due to retirement, emigration or other factors (Gresenz, Auerbach, & Duarte, 2013), (Joyce, McNeil, & Stoelwinder, 2006), (Relic & Bozikov, 2020). Supply-based models are sometimes criticised because they may assume that the existing health workforce configuration is optimal.

Demand-based models generally consider both supply and demand drivers which influence requirements for health professionals. Many demand-based models consider changes in trends in the utilisation of primary, community and hospital care as well as trends in health service consumption, organisational changes and epidemiological factors. In a similar fashion to supply-based models, demand-based approaches may perpetuate existing inefficiencies and inequalities in access to healthcare (Alonso, 2003), (Dill & Hirsch, 2021), (Ishikawa, Ohba, Yokooka, Nakamura, & Ogasawara, 2013), (Morii, et al., 2019), (Ricketts, et al., 2017), (Senese, et al., 2015), (Streeter, Zangar, & Chattopahyay, 2017), (Wu, Yu, & Huang, 2013).

Need-based models are seen as an alternative to demand-based models as they aim to detect population healthcare needs and then link the number of health professionals required to those needs. The distinction between need and demand is important because demand for healthcare is not independent of supply. Important factors in needs-based models can include demography, epidemiology, level of service, and productivity. Improvements in productivity associated with new technology, staffing composition changes and service delivery methodology as well as healthy aging trends may mean that fewer health professionals are required to deliver the same level of service (Lopes, Almeida, & Almada-Lobo, 2016), (Murphy, et al., 2012), (Abas, et al., 2017), (Barber & López-Valcárcel, 2010), (Morgan & Graber-Naidich, 2019), (Rafiei, Daneshvaran, & Abdollahzade, 2018), (Vanderby, Carter, Latham, & Feindel, 2014).

4. Methods

4.1 Overview of system dynamics modelling

The SD approach was developed by the computer engineer and system scientist Jay Forrester in 1961. In the years since, the approach has been applied to a range of areas such as fisheries management, urban planning, and environmental resource management (Lyons & Duggan, 2015). It has also been successfully applied in the field of healthcare Strategic Workforce Planning in many countries (Joint Action Health Workforce Planning and Forecasting, 2015) (Vanderby, Carter, Latham, & Feindel, 2014).

SD models are widely applied as problem-solving tools as they can be used to represent complex systems visually and demonstrate how different qualitative factors relate and interact with each other, before numerical values are added. The ability to represent SD models visually is a key feature which contributes towards their applicability to public policy and the development of models which require input from a diverse range of stakeholders.

Decisions about undergraduate intake and overseas recruitment are time sensitive¹⁹ and the impact of retention and retirement on workforce supply in the future is uncertain. The time taken to educate health staff and the generally long lead-in times for capital investment in educational capacity are important factors in workforce planning. SD modelling has the capability to account for these sorts of factors, enabling more informed and effective policy decision-making (Barber & López-Valcárcel, 2010).

The SD modelling process is a problem-led approach; the development method of this model is based on the 'Standard Method' for SD Modelling (Lyneis & Hines, 2007).²⁰ One of the first steps in the Standard Method is the development of a succinct problem statement which represents the essential aspects of the problem or decision that needs to be made. The structure, flows, and stocks of the model outlined in section 4 are developed out of this problem statement. The problem statement for this model was identified through a workshop format with officials in the Office of the Chief Nurse:

- Ireland is not educating enough nurses/midwives to meet domestic demand, which is leading to high levels of recruitment from overseas.

¹⁹ Anecdotally the recruitment of nurses from abroad can take around six months (and can take place at any time of the year). The recruitment and intake of Irish graduate nurses and midwives generally takes place once a year around the time of graduation, and there is four-year lead time when educating a nurse or midwife. In addition, HEIs need time to make decisions about the capital infrastructure and staff recruitment required to increase student places.

²⁰ An overview of the sequence of steps involved in the Standard Method can be found in **Appendix 1**.

- There is a government commitment to move towards a domestic recruitment model, which entails educating the required number of nurses/midwives in Ireland and reducing the reliance on overseas recruitment.
- Demand for nurses/midwives is outstripping supply globally.
- Student nursing/places in Ireland are oversubscribed.

4.2 Using stocks and flows to model systems

Stock and flow diagrams are the building blocks of SD models. 'Stock' variables describe the states or amounts of the system (e.g., the number of nurses and midwives in 2021). Flow variables depict the rates of change - increases or decreases - of stocks (e.g., the retirement rate for nurses and midwives). A factor that distinguishes a Stock from a Flow in the context of workforce planning is that a Stock represents the number of individuals qualified to work, or who are working, in a profession at a given point in time, whereas a 'Flow' relates to movements into and out of the Stock (e.g., newly qualified nurses or midwives entering the profession, retiring nurses or midwives) over time. Stocks accumulate or deplete in a model.

For an illustration of the basic modelling concepts, see the diagram in **Figure 6** below which outlines factors that are relevant in the context of the healthcare workforces:

- Stock: Total Workforce.
- Inflows: Graduates, Immigrants, People returning to practice.
- Outflows: Attrition, Emigrants, Retirees.

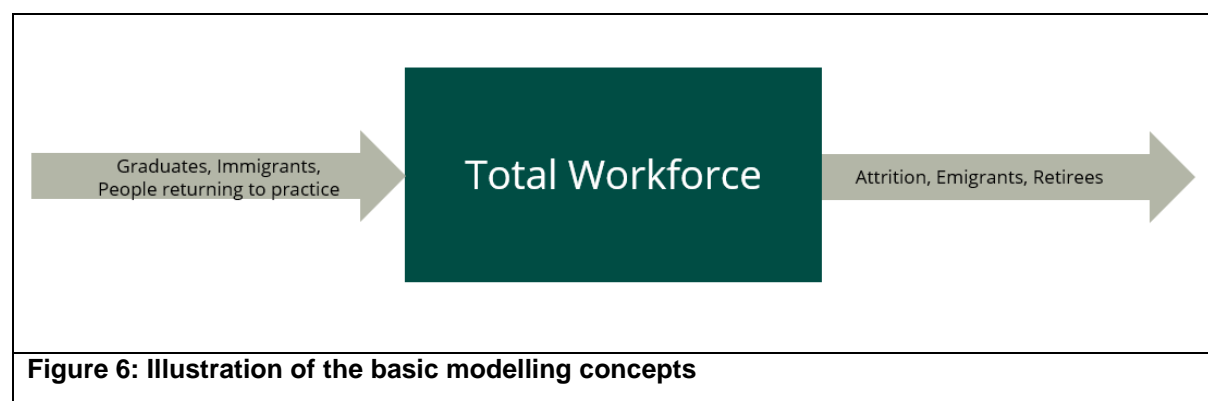


Figure 6: Illustration of the basic modelling concepts

4.2.1 Data sources

This section provides an overview of the main data sources used to develop this model. The full list of data used is shown in **Table 5** below.

Relevant data sources and variables were identified through desk-based research and in consultation with stakeholders. Data has been obtained from various sources including government agencies, government departments, independent commission reports and statutory organisations e.g., the Department of Further and Higher Education, Research, Innovation and Science (DFHERIS), the Health Service Executive (HSE), the DoH, the Higher Education Authority (HEA), the NMBI and the Public Service Pay Commission (PSPC).

4.2.2 NMBI register data

The Nursing and Midwifery Board of Ireland is the independent, statutory organisation which regulates the nursing and midwifery professions in Ireland.²¹ Its core functions are:

- Maintaining the Register of Nurses and Midwives.
- Evaluating applications from Irish and overseas applicants who want to practise as nurses and midwives in Ireland.
- Supporting nurses and midwives to provide care by developing standards and guidance that they can use in their day-to-day practice.
- Setting requirements for nursing and midwifery educational programmes in HEIs.
- Investigating complaints made from patients, their families, health care professionals, employers and holding Fitness to Practise inquiries.

The NMBI register data provides information about the number of registered nurses and midwives, the number of active nurses and midwives, flows of individuals coming onto the register, flows of individuals coming off the register and Certificate of Current Professional Status (CCPS) requests. A recent reform of the database has substantially increased the quality and availability of this dataset which was essential in enabling the development of this model.²² The system is coordinated and maintained by staff at the NMBI. The NMBI require that all nurses and midwives pay an annual retention fee to maintain their registration. Those who fail to pay their fees are removed from the register.

4.2.3 Limitations of NMBI register data

The NMBI's data is collected principally for the purposes of regulating the nursing and midwifery professions. In utilising the database for quantitative supply modelling several limitations were encountered, and which should be borne in mind when reading this paper:

²¹ See the NMBI website (Link: www.nmbi.ie/Home)

²² The NMBI's 'Project Nightingale' delivered a modernised integrated online registration system, which provides an accurate and secure register, accessible data at every step of the registration process, improved records, streamlined processes and enhanced self-service for applicants and registrants.

1. Firstly, nurses and midwives who have recently emigrated may continue to pay NMBI registration fees. Therefore, some active nurses and midwives on the register are likely to be working abroad rather than in Ireland or in other roles but are maintaining their registration. This means that the model's baseline estimate of the total active number of nurses in Ireland may be an overestimate as it is based on active members of the register (some of whom are active outside Ireland).
2. Secondly, the NMBI's data on CCPS requests per year is used as a proxy for emigration.²³ It should be noted that in some instances nurses or midwives may make a CCPS request but later decide against emigration. This means that the emigration figures used in this spending review are likely to be somewhat overstated.²⁴ Additionally, nurses or midwives may make CCPS requests, emigrate, and then return to Ireland after a short period abroad.²⁵
3. Thirdly, it was not possible within the lifetime of this project to track certain flows with NMBI registry data e.g., the number of nurses and midwives returning from emigration or flows between those moving between patient-facing and non-patient facing roles.
4. Fourth, it is difficult to get a detailed breakdown of those coming off the register. The register does not capture details on employment changes, it can only be broken down into those have been removed, lapsed or voluntarily withdrew.

4.2.4 Other data sources

In addition to the NMBI, data from several other sources was used:

DFHERIS data: The DFHERIS data details student nurse and student midwife intake figures for 2020-2021 and 2021-2022 as well as certain nursing education cost figures.

HEA data: The HEA information used in this paper relates to data on completion rates per 100 students (HEA, 2021). A limitation of the HEA's completion analysis is that it is limited to entrants into study programmes from the academic years 2008/09, 2009/10 and 2010/11.²⁶

PSPC data: The data reported by the PSPC in 2018 on HSE turnover and retirements is used as a basis for the domestically educated attrition rates and 'Foreign Educated Attrition Rate' flows in this paper (PSPC, 2018). A limitation is that the figures are likely to be overstating the level of attrition of nurses and midwives as, when calculating turnover, the HSE do not distinguish between those who resign to take up other employment outside the public health

²³ Nurses and midwives applying for registration outside Ireland provide a CCPS to the nursing or midwifery regulator in that jurisdiction. The regulator in the foreign jurisdiction uses the document to verify registration in Ireland. The number of CCPS issued can be used as a proxy for the number of nurses and midwives who intend to find employment abroad.

²⁴ Assertion based on anecdotal information.

²⁵ See a table showing CCPS requests made by individual Irish educated nurses and midwives from 2015 to 2021 in **Appendix 5**.

²⁶ See the HEA website (Link: hea.ie/statistics/interactive-reports-articles/completion-data-release-march2021/)

service, those who move to another area or move location within the public health service, or those who leave the nursing or midwifery professions entirely; all are counted as attrition. Another limitation of this data is the fact that these figures relate to HSE staff only, and not all nurses and midwives working throughout the entire health economy.

HSE data: HSE Census figures for nurses and midwives were as a basis for whole time equivalence (WTE) in the wider health economy. A limitation of this data is the lack of WTE information for those working outside the HSE/Section 38 hospital/ certain voluntary agencies, which may differ. This data was also not available by age.

4.3 Nursing and midwifery workforce supply model description

This section provides a narrative overview of the SD model. It describes important variables and their parameters underpinning them in the model. See **Table 5** for a detailed description of all variables, data sources, parameters, with explanatory notes.

The supply model (shown from **Figure 7** to **Figure 11**) has three interacting sections; (i) the Higher Education Institution view, (ii) the Age-Sex Cohorts view and (iii) the Foreign Educated Workforce view.

In general, variable names are written in italics and in single quotation marks as follows '*Variable Name*'.

A note on the interpretation of Vensim Model Diagrams. As noted in a previous section, system dynamics modelling decomposes the workforce into inflows, Stocks and outflows. The images included in this document below reflect that decomposition by arrows and rectangles. Rectangles represent Stocks. When a Stock has an arrow point towards it from the left – that is an inflow. When a Stock has an arrow exiting it from the right that is an outflow. The reader will also note that there are blue arrows which connect elements of the graphs together. These indicate that Stocks or Flows are connected in some way. Mathematically, they indicate that they are used in the formulas underlying the model.

4.3.1 Higher Education Institution view

The model is developed around the career of a nurse in Ireland. It begins with an inflow representing new students entering *Year 1* of the bachelor's degree programme in nursing/midwifery and ends with retirement, attrition, or emigration outflows. Student nurses/midwives enter HEIs in *Year 1* through the variable '*Enrol New Students*'. They either pass *Year 1* and carry on to *Year 2* or drop out of *Year 1*. This repeats for each of the stocks *Year 1-4*. Repeat year students are not catered for in the model. Furthermore, we do not adjust the '*Graduate Nurses_Midwives*' flow or include a delay to account for nursing students undertaking the 4.5-year combined children's and general nursing programme or take those who remain in education upon graduation to undertake a master's or other programme into account.²⁷ Key parameters are:

- 1 '*Enrol New Students*' is set at 2,000 per year in the baseline.
- 2 '*The Dropout Rate per Year of Study*' is 2.9% in each year.²⁸

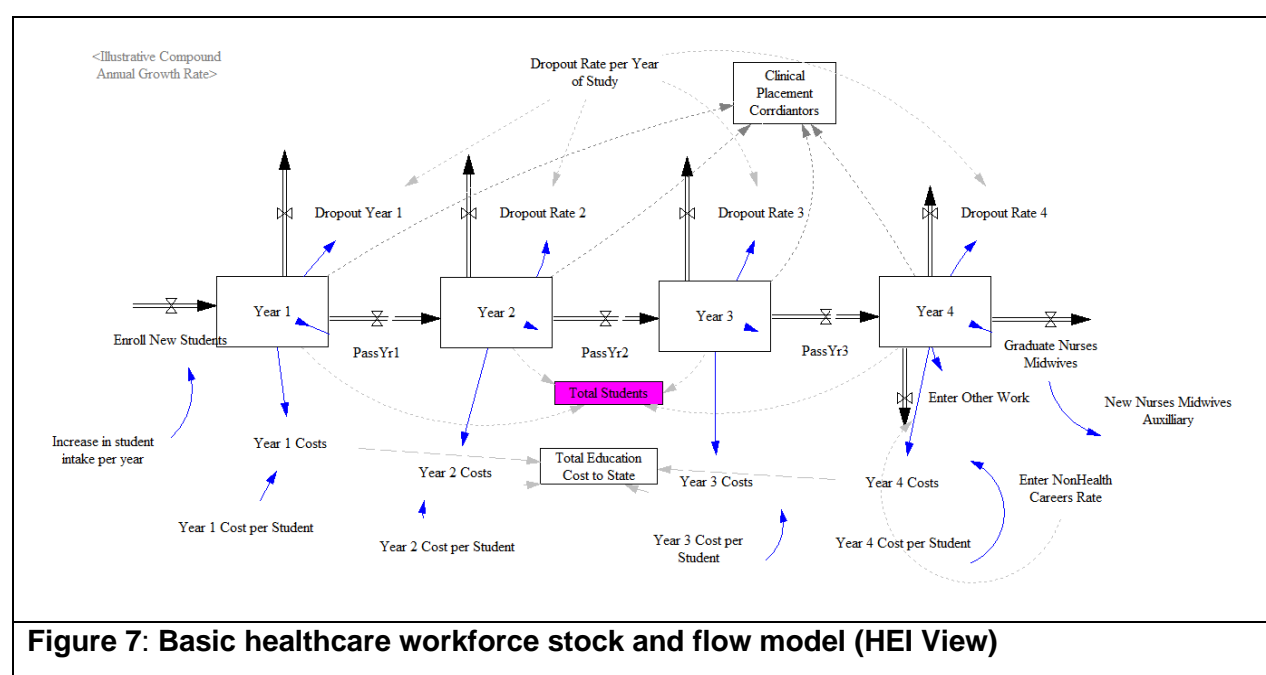


Figure 7: Basic healthcare workforce stock and flow model (HEI View)

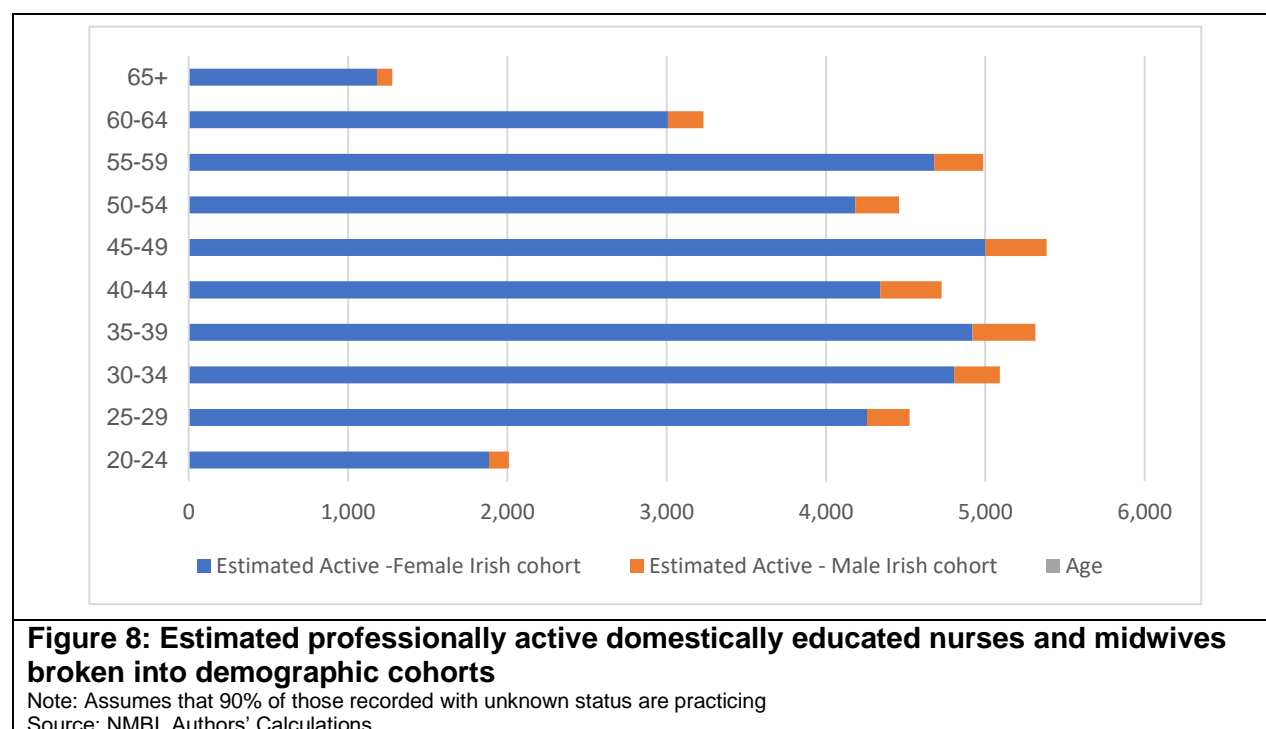
4.3.2 Age and sex cohorts view

As previously outlined, the representation of domestic nursing and midwifery supply is developed around the career of a professional nurse/midwife in Ireland. The domestically educated workforce is decomposed into age and sex cohorts. The virtue of disaggregating the workforce by sex is that males tend to work more hours compared with their female counterparts and therefore have a different WTE adjustment factor. The age cohorts for each

²⁷ According to HEA data, 1% of nursing and midwifery graduates pursue a masters the following year.

²⁸ Estimate based on HEA data on 2009, 2010 and 2011 entrants.

sex are in five-year intervals from age 20 up to 64 after which there is a '65 and over' cohort. **Figure 8** shows these age-sex cohorts for the entire domestically educated workforce. This allows one to quantify the aging of the workforce and specification of outflows based on specific rates of attrition, returns to practice, retirements, and emigration for different demographic cohorts.



Data from the NMBI allows for the domestically educated workforce to be disaggregated into those practicing and not practicing by age and gender.

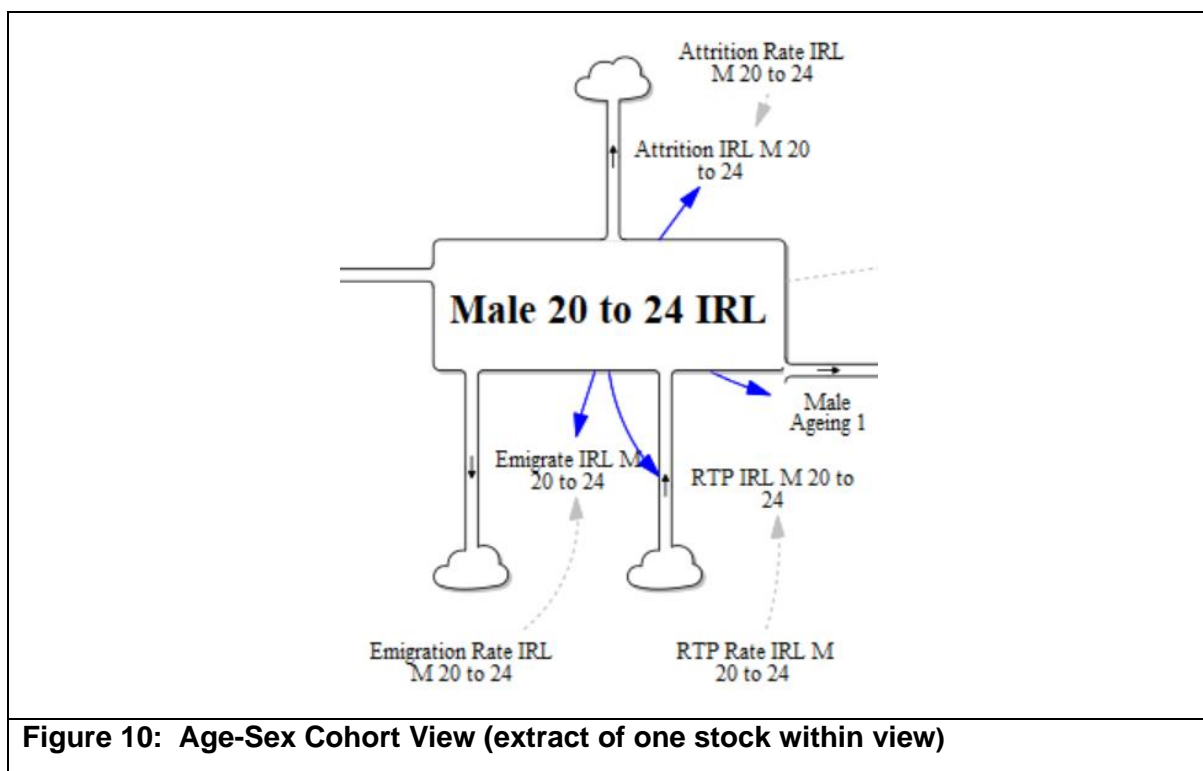
The majority of nurses and midwives graduating from HEIs are in their early 20s, however some nurses graduate at an older age. **Table 4** provides the age breakdown of newly registering domestically educated nurses and midwives in Ireland for the years 2013 to 2022. This data is used to allocate new graduates to the appropriate age and sex cohorts in the model. **Figure 9** below shows the diagram of the age-sex cohorts of the model. **Figure 10** shows a close-up of the stock for males aged 20-24.

Year First Registered	20 to 24	25 to 29	30 to 34	35 to 39	40 to 44	45 to 49	50 to 54
2013	829	143	103	54	29	17	**
2014	847	167	111	62	26	16	**
2015	861	148	93	53	37	17	**
2016	865	116	110	60	42	21	**
2017	869	144	112	65	41	17	10
2018	877	152	100	53	34	28	**
2019	956	137	103	63	43	29	12
2020	1,097	134	90	72	50	18	10
2021	1,100	138	118	64	48	33	14
2022	102	18	12	**	**	**	**
Grand Total	8,403	1,297	952	546	350	196	70
Percentage in each cohort	70.95%	10.95%	8.04%	4.65%	2.98%	1.67%	0.65%
Male new starter age cohort as a proportion of total new starters*	6.07%	0.94%	0.69%	0.40%	0.25%	0.14%	0.06%
Female new starter age cohort as a proportion of total new starters* ²⁹	64.89%	10.02%	7.35%	4.25%	2.73%	1.53%	0.59%
Table 4: Age and Sex breakdown of newly graduated nurses and midwives³⁰							
**Cell Number <10							
Source: NMBI							

²⁹ *Uses average male/female proportion of new NMBI registrants from the years 2013-2022 to apportion between sex.

³⁰ Source: NMBI data and author's calculations.

Figure 10 zooms in on one of these cohorts to explain it in further detail. The stock records the number of males aged between 20 and 24 in the model. In each period this stock is added to by newly graduated nurses and midwives (6% of new graduates are males aged between 20 and 24), and by those returning to practice (2% in each period). It is depleted by an attrition rate (2.8%) and emigration (see definitions and explanations of these variables in **Table 5**). It is also depleted by the Male Ageing outflow which reduces the stock by one fifth in each period. This proportion approximates the number of men transitioning between the age group 20-24 and 25-29 in each period.



4.3.3 Foreign educated workforce view

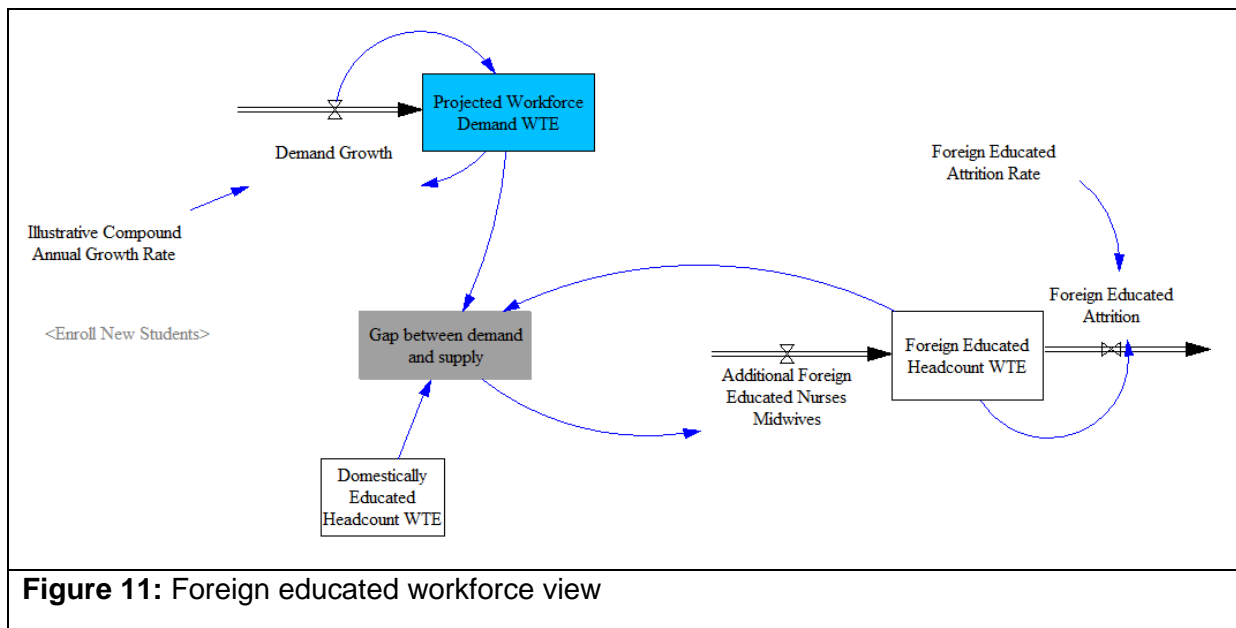


Figure 11: Foreign educated workforce view

Demand growth is included in the model as a means to examine how different growth paths impact on decisions to increase or decrease student nurse/midwife intake. The principal mechanism is the addition of foreign educated nurses and midwives to the stock based on the gap between demand and supply (see **Figure 11**). Firstly, the model quantifies the gap between demand and total supply (domestic and foreign) in each period. If this gap is positive, then it adds that many foreign educated nurses/midwives to the *Foreign Educated Headcount WTE* stock through the *Additional Foreign Educated Nurses Midwives* inflow. This figure is essentially a head count of qualified, practicing nurses/midwives and is defined in terms of WTE. The WTE adjustment factor implicitly accounts for reduced work intensity.

4.3.4 Description of model variables, data sources, and assumptions at baseline

Table 5 below provides a detailed description of the variables, data sources, and assumptions used in the model. Where possible, data is used for parameters on a one-to-one basis. However, data availability and quality requires some assumptions to bridge the gap between the data and parameters used. These deviations and their rationale are set out in the table below. Lastly, it should be noted that utilisation of historical data for parameters may not be a reliable estimate of how the future unfolds (see sensitivity analysis in **Appendix 4**).

Name of stock, flow or variable	Definition of variable/stock	Source of data	Model Parameter Value	Explanatory notes
Age and sex cohort stocks: • 'Female 20 to 24 IRL', 'Female 25 to 29 IRL', 'Female 30 to 34 IRL', 'Female 35 to 39 IRL', 'Female 40 to 44 IRL', 'Female 45 to 49 IRL', 'Female 50 to 54 IRL', 'Female 55 to 59 IRL', 'Female 60 to 64 IRL' and 'Female 65 and over IRL'. • 'Male 20 to 24 IRL', 'Male 25 to 29 IRL', 'Male 30 to 34 IRL', 'Male 35 to 39', 'Male 40 to 44 IRL', 'Male 45 to 49 IRL', 'Male 50 to 54 IRL', 'Male 55 to 59 IRL', 'Male 60 and 64 IRL' and 'Male 65 and over IRL'.	The various age and sex stocks refer to different cohorts of the practicing, Domestically Educated workforce.	Source: NMBI	(20-24) 1,885 Female; 124 Male; (25-29) 4,257 Female; 268 Male; (30-34) 4,805 Female; 287 Male; (35-39) 4,919 Female; 396 Male; (40-44) 4,341 Female; 385 Male; (45-49) 5,002 Female; 383 Male; (50-54) 4,183 Female; 275 Male. (55-59) 4,679 Female; 307 Male. (60-64) 3,007 Female; 223 Male. (65+) 1,182 Female; 97 Male.	The professionally active domestically educated workforce is broken down into different age, and sex cohorts. The information for each of the professionally active domestically educated cohorts was provided by the NMBI. According to the NMBI, approximately 90% of those who do not report their active/inactive status can assumed to be active. The bulk of non-respondents on active status are first time registrants who are not asked about their active/inactive status in their questionnaire.
Attrition , domestically educated rate, various outflows and variables • 'Attrition Rate IRL F 20 to 24', 'Attrition Rate IRL F 25 to 29', 'Attrition Rate IRL F 30 to 34', 'Attrition Rate IRL F 35 to 39', 'Attrition Rate IRL F 40 to 44', 'Attrition Rate IRL F 45 to 49', 'Attrition Rate IRL F 50 to 54', 'Attrition Rate IRL F 55 to 59' and 'Attrition Rate IRL F 60 and over'. • 'Attrition Rate IRL M 20 to 24', 'Attrition Rate IRL M 25 to 29', 'Attrition Rate IRL M 30 to 34', 'Attrition Rate IRL M 35 to 39', 'Attrition Rate IRL M 40 to 44', 'Attrition Rate IRL M 45 to 49', 'Attrition Rate IRL M 50 to 54', and 'Attrition Rate IRL M 55 to 59'. • 'Domestic Attrition Total', 'Attrition IRL Female' and 'Attrition IRL Male'.	These variables relate to the rate of domestically educated nurses/midwives (that are practicing in Ireland) de-registering or stopping practicing with the NMBI for reasons other than emigration or retirement.	Source: PSPC, NMBI and author's calculations/estimates	2.8%	<p>The Domestically Educated workforce in this model is defined as those registered with NMBI and practicing as a nurse/midwife. As such, attrition in this context is defined as domestically educated nurses/midwives de-registering with the NMBI <u>and/or</u> no longer professionally active as a nurse/midwife.</p> <p>The rate of turnover in the HSE in 2017 was 6.8%. The 2017 data from the PSPC review is historical data and the rate is assumed for the purposes of this paper to be constant into future. This includes retirements, people moving to a different payroll system in the HSE, moving into the non-HSE health system, leaving the country, stopping practice as a nurse/midwife, and leaving the profession.</p> <p>Attrition in this model is only defined as the latter two in this list. As such, the 6.8% is reduced by the retirement rate for the same year. The 2018 PSPC report used data showing that the HSE nurse/midwife retirement rate was 1.8% in 2017. It is reduced further by netting out the emigration rate of 2.2% (this data is referenced further down this table) leaving a remainder of 2.8% for attrition: $6.8\% - 1.8\% - 2.2\% = 2.8\%$</p> <p>2.8% is an overestimate given the original 6.8% included nurses/midwives staying in the HSE and nurses/midwives staying clinical practice but working in the private or voluntary sector. Additionally, the original 6.8% turnover figure may include those nurses/midwives moving within the HSE from a clinical role to a non-clinical role which would be considered attrition by the above definition. Another important limitation is</p>

				that the turnover data is from the HSE and applied to the health sector as a whole. The figure of 2.8% is used for both the male and female cohorts.
Clinical Placement Coordinators	The 'Clinical Placement Coordinators' relates to the required number of clinical placement coordinators needed to who support students, oversee the attainment of skills in the clinical area and liaise with ward managers, educators and PDCs.	Source: HSE and internal DoH information	1:19.6	The CPC to student ratio is 1:20 for nursing students and 1:15 for midwifery students. 19.6 is a blended figure to account for the breakdown of nursing (91.4%) and midwifery (8.6%) cohort sizes. This is lower than the maximum 1:30 ratio advised by the NMBI.
Demand Growth / Illustrative Compound Annual Growth Rate	These variables relate to illustrative rates of growth in demand for nurses and midwives in Ireland.	Source: N/A	1.0%-2.5%	Arbitrary Value. Multiple growth rates will be used in paper. It does not relate to future overall available supply of nurses/midwives.
Domestically Educated Workforce (DEW) Headcount WTE / DEW Headcount Male / DEW Headcount Female	"Domestically Educated Workforce Headcount" is defined as the number of active nurses and midwives registered to practice in Ireland in 2021 (in both the public and private sectors) that were educated in Ireland.	Source: NMBI	35,101 = Domestically educated workforce total in WTE (initial value)	Data for active nurse/midwife cohorts were provided by the NMBI. There are 41,005 Irish-educated active nurses/midwives on the register (note that this may count active members working outside Ireland). This is reduced to a figure of 35,101 WTE based on HSE WTE rates for nurses/midwives. • The figure for active female nurses/midwives was multiplied by at 85% to adjust for WTE. The 85% figure is calculated based on figures in the HSE census (and not for the entire health economy). • The figure for active male nurses/midwives was multiplied by at 94% to adjust for WTE. The 94% figure is calculated based on figures in the HSE census (and not for the entire health economy).
Dropout Rate variables: • 'Dropout per Year of Study', 'Dropout Year 1', 'Dropout Year 2', 'Dropout Year 3', 'Dropout Year 4', • 'PassYr1', 'PassYr2', 'PassYr3' and 'PassYr4'	These variables refer to the fraction of student nurses and midwives who drop out of their study programme per year.	Source: HEA	2.90%	According to HEA data, 88.9% of Level 8 Nursing and Caring programme students complete their degrees (HEA 2021). The completion rate has been used to estimate a uniform annual dropout rate in each of the four years of a nursing/midwifery study programme as follows: $1.00 \times 97.1\% \times 97.1\% \times 97.1\% \times 97.1\% = 88.9\%$. However, the actual dropout rate may be concentrated in first year. This means that we may be overestimating education costs if we assume that many unsuccessful students continue as far as 2 nd , 3 rd and 4 th year. In addition, dropout rates may across the various study programmes e.g., dropout rates may be higher in midwifery programmes. The dropout rate is included as it influences the total number of qualified graduates in the model.

				The 'Dropout Rate' outflow is set at 2.9% of the annual student stock
<p>Emigration, domestically educated rate, various outflows and variables:</p> <ul style="list-style-type: none"> • 'Emigrate IRL F 20 to 24', 'Emigrate IRL F 25 to 29', 'Emigrate IRL F 30 to 34', 'Emigrate IRL F 35 to 39', 'Emigrate IRL F 40 to 44', 'Emigrate IRL F 45 to 49', 'Emigrate IRL F 50 to 54' and 'Emigrate IRL F 55 to 59'. • 'Emigrate IRL M 20 to 24', 'Emigrate IRL M 25 to 29', 'Emigrate IRL M 30 to 34', 'Emigrate IRL M 35 to 39', 'Emigrate IRL M 40 to 44', 'Emigrate IRL M 45 to 49', 'Emigrate IRL M 50 to 54' and 'Emigrate IRL M 55 to 59'. 	Domestically Educated Emigration refers to domestically educated nurses or midwives who seek employment abroad.	Source: NMBI	<p>(Age) Emigration Rate:</p> <p>(20-24) 8.66%</p> <p>(25-29) 11.76%</p> <p>(30-34) 2.16%</p> <p>(35-39) 0.53%</p> <p>(40-44) 0.32%</p> <p>(45-49) 0.35%</p> <p>(50-54) 0.22%</p> <p>(55-59) 0.16%</p>	<p>This figure was calculated using 2021 figures for CCPS requests per domestically educated age cohort divided by active nurses/midwives per domestically educated age cohort. This assumes that no inactive nurses/midwives made CCPS requests. It also assumes that once a nurse/midwife makes a CCPS request, he/she emigrates. It also assumes that nurses/midwives who make CCPS requests emigrate permanently unless they are part of one of the 'Returners to Practice' inflows. Two individuals over the age of 60 made CCPS requests which are excluded from the model.</p> <p>Also note, the CCPS figures for 2021 were used as a baseline but may be unusually low due to the after-effects of Covid-19 and may be higher in future.</p> <p>Note that Irish educated nurses/midwives typically continue to pay NMBI fees while working overseas (therefore remaining on the register). CCPS data per age for Irish nurses/midwives was provided by the NMBI. Overall, in 2021, 898 of the domestically educated nurses/midwives made CCPS requests (this is 2.2% of active domestically educated nurses/midwives).</p> <p>Excluding 2020, the number of Irish educated nurses/midwives making CCPS requests ranged from 686 to 898 per year from 2015 to 2021.</p>
Enter Other Work / Enter Non-Health Careers Rate	These variables relate to the number of student nurses/midwives who successfully complete the four-year degree programme each year but enter non-nursing work upon graduation.	Source: NMBI, HEA and author's estimates/calculations.	1.00%	<p>A proportion of nursing/midwifery graduates enter non-nursing related work upon graduation. A figure of 1% was discussed by the HSE. This figure may be adjusted after further stakeholder engagement.</p> <p>See sensitivity analysis section for a variation in this model parameter based on Graduate Outcomes Survey Data. This data could not be incorporated to the model in sufficient time before publication.</p>

Exchequer cost variables • 'Total education cost to State', 'Year 1 Costs', 'Year 2 Costs', 'Year 3 Costs', 'Year 4 Costs', 'Year 1 Cost per Student', 'Year 2 Cost per Student', 'Year 3 Cost per Student' and 'Year 4 Cost per Student'.	The exchequer cost variables refer to calculations prepared which consider the clinical costs, formal education costs and student contributions in nursing and midwifery study programmes. It takes student nurse/midwife pay into account.	Source: Internal DoH / DHERIS data	Year 1 = €11,669. Year 2 = €11,519. Year 3 = €11,519. Year 4 = €21,669.	Estimated cost of education. See further details in Appendix 2
Additional Foreign Educated Nurses Midwives	This inflow adds foreign educated nurses and midwives to the stock based on the gap between demand and supply. Supply is the sum of foreign educated and domestically educated.	NA	Determined within the model	This inflow adds Foreign-Educated nurses/midwives to the stock of foreign educated nurses/midwives. The number of nurses/midwives added is determined by the gap between demand and supply (see below variable). If the gap is zero then no nurses/midwives are added. In period 0, the value of this inflow equals the outflow of attrition in period 0. This is done to avoid an artificial drop in the Foreign-Educated Nursing and Midwifery. Stock which would arise because the gap between demand and supply is zero at the start, but the attrition rate is 6.8%.
Gap between demand and supply	Calculates the difference between demand and domestically educated supply plus foreign educated supply	NA	Determined within model	Used in the model to add additional foreign educated nurses/midwives.
Foreign Educated Attrition / Foreign Educated Attrition Rate	"Foreign Educated Attrition Rate" refers to the attrition rate of foreign educated nurses or midwives who are registered and working in Ireland. This outflow includes emigration, retirement, leaving clinical practice.	Source: No available data source for this parameter. PSPC data on HSE turnover is used as a proxy.	6.80%	A certain number of 'Foreign Educated Nurses Midwives' will leave the Irish system every year. The attrition rate (which includes emigration, retirements and other attrition) used for the foreign educated workforce is the same as the combined rate attrition, emigration, and retirement for the domestically educated Workforce. Attrition for foreign nurses/midwives is likely to be different. The various forms of foreign nurse/midwife attrition are not split into separate outflows as they are for domestically educated attrition.
Foreign Educated Headcount WTE	"Foreign Educated Workforce WTE" is defined as the number of the active nurses and midwives registered to practice in Ireland in 2021 that were educated outside Ireland (e.g., in the UK, EU, rest of world etc.), adjusted for WTE.	Source: NMBl	29,535 (initial value)	Data for active foreign nurses/midwives (and estimates for active nurses/midwives and an estimate for active nurses/midwives who reported a 'blank' active status figure) were provided by the NMBl. There are an estimated 33,953 foreign active nurses/midwives on the register in 2021 (assuming that 90% of 'blank' respondents to the active/inactive status question are actually active). This is reduced to a figure of 29,535 WTE based on overall HSE WTE rates for nurses/midwives. According to the NMBl there were 32,587 practicing foreign education nurses/midwives in 2021. In addition, there were 1,518

				<p>nurses/midwives who did not indicate whether they were practicing or not (this figure is multiplied by 90%). The subtotal is multiplied by the HSE's combined gender WTE adjusted factor of 87% as follows:</p> $[32,587 + (1,518 \times 0.9)] \times 0.87$
Graduate Nurses_Midwives	The "Graduate Nurses_Midwives" inflow relates to the number of student nurses who successfully complete the four-year degree programme each year and then enter nursing-related work.	Source: HEA	Variable amount	The "Graduate Nurses" inflow is equal to those successfully completing Year 4 of the nursing/midwifery degree, excluding those entering other work.
Projected Workforce Demand WTE	"Projected Workforce Demand WTE" is defined as the projected total supply of active nurses and midwives that will be registered to practice in Ireland, adjusted for WTE.	Source: NMBI	64,636 (initial value)	<p>Total number of registered nurses/midwives that recorded themselves as practicing was 72,207 in 2021 according to the NMBI. Another 3,054 did not record their status. Assuming that 90% of those not recording their status are actually active the estimated total number of nurses/midwives practicing was 74,956 for the year 2021. This figure is adjusted downwards to 64,637 based on HSE WTE levels (i.e., 85% for females, 94% for males and under 87% overall). A number of nurses/midwives may remain on the active register but are not working in nursing/midwifery roles or reside abroad.</p> <p>Note that data collected from the NMBI's live register at a different time point – for OECD reporting purposes – in 2021 recorded 82,208 total nurses/midwives licenses to practice; 73,532 professionally active and 64,072 practicing.</p>
Proportion of new additions (i.e., new graduates) by age and sex:	New additions by age and sex refers to the demographic breakdown of new graduate nurses.	Source: NMBI	<p>(20-24) 6.07% Male; 64.89% Female; (25-29) 0.94% Male; 10.02% Female; (30-34) 0.69% Male; 7.35% Female; (35-39) 0.40% Male; 4.25% Female; (40-44) 0.25% Male; 2.73% Female; (45-49) 0.14% Male; 1.53% Female; (50-54) 0.06% Male; 0.59% Female.</p>	This data shows the age of domestically educated nurses/midwives registering with the NMBI for the first time (usually around the time of completion of their degree). There are significant levels of mature students in nursing/midwifery courses i.e., not all graduates enter the nursing/midwifery workforce at age in the 20-24 age cohort. Newly graduated nurses/midwives each year are allocated to age-sex cohorts based on these estimates. This breakdown does not vary over the projection period.

Retirement , domestically educated rate, various outflows and variables <ul style="list-style-type: none"> • 'Retirement Rate', • 'Retirement Female', and • 'Retirements Male' 	<p>The "Retirement rate" outflow relates to the fraction of nurses retiring from the 'Domestically Educated Workforce' stocks each year.</p>	<p>Source: Arbitrary/PSPC</p>	<p>For the 60-64 age cohort a retirement rate of 11.2% is used.</p> <p>For the 65+ age cohort a retirement rate of 33.1% is used.</p>	<p>This outflow relates to the fraction of nurses/midwives retiring from the 60-64 and 65+ age cohorts. The retirement rates used in the model relate to the exits from the register data by age (including both voluntary removals and non-payment removals) as a fraction of total registered nurses/midwives (not just those who are professionally active). The exit figures give retirement rates of 11.2% and 33.1% for the 60-64 and 65+ cohorts respectively.</p>
Return to Practice , domestically educated rate, various flows and variables <ul style="list-style-type: none"> • 'RTP IRL F 20 to 24', 'RTP IRL F 25 to 29', 'RTP IRL F 30 to 34', 'RTP IRL F 35 to 39', 'RTP IRL F 40 to 44', 'RTP IRL F 45 to 49', 'RTP IRL F 50 to 54', 'RTP IRL F 55 to 59' and 'RTP IRL F 60 and over' • 'RTP IRL M 20 to 24', 'RTP IRL M 25 to 29', 'RTP IRL M 30 to 34', 'RTP IRL M 35 to 39', 'RTP IRL M 40 to 44', 'RTP IRL M 45 to 49', 'RTP IRL M 50 to 54', and 'RTP IRL M 55 to 59'. 	<p>"Return to Practice" relates to nurses who are re-registering with the NMBI after a lapse in registration.</p>	<p>Source: NMBI, McHugh</p>	<p>2%</p>	<p>This inflow relates to former members of 'Domestically Educated Workforce Headcount' who are returning to practice each year from periods outside the profession or working abroad. The figure of 2% is an estimate based on the fact that there were 1,000 restorations to the register in 2021. There was a total of 82,000 nurses/midwives on the register. 57% are Irish educated. Therefore, we estimate there to be 46,470 domestically educated nurses/midwives on the register. We assume that restorations largely relate to domestically educated nurses/midwives.</p>
Student stocks <ul style="list-style-type: none"> • 'Increase in student intake per year', 'Enrol New Students', 'Year 1', 'Year 2', 'Year 3', 'Year 4' and 'Total Students'. 	<p>The student stocks relate to the number of students being educated in undergraduate nursing and midwifery programmes in Ireland in 2021, as well as the level of annual intake of new student nurses and midwives.</p>	<p>Source: DoH/DFHERIS internal data and author's estimates.</p>	<p>Initial Values: Year 1 = 2,000 Year 2 = 1,927 Year 3 = 1,725 Year 4 = 1,677)</p>	<p>The HEA collects data on the number of student nurses/midwives each year and provides it to DFHERIS. In 2021, the size of the third-level student intake was 2,032 for undergraduate nursing (general, psychiatric, intellectual disability and children's) and midwifery programmes (DFHERIS, 2021). Data may exclude students repeating academic years. Student figures for Year 2-4 are calculated based on an assumed dropout rate of 2.9% per year.</p>
Whole Time Equivalent (WTE) adjustment variables i.e. <ul style="list-style-type: none"> • 'WTE ADJ Male' • 'WTE ADJ Female' 	<p>The WTE ADJ variables refer to adjustments made to account for different levels of average hours worked / whole time equivalence by different genders.</p>	<p>Source: HSE and author's calculations.</p>	<p>85% Female. 94% Male. 87% Overall.</p>	<p>These figures are calculated based on information in the HSE census. HSE WTE figures may be different to those in the wider health economy.</p>
Table 5: Detailed description of model variables, data sources, parameters, and assumptions at baseline				

4.3.5 Description of scenarios

Data from all sources were collated and processed in Excel before being inputted into Vensim. The year 2021 was chosen as the starting year for the model, as it is the most recent year with available data for some of the more significant inputs. Estimates for some of the other variables come from previous years. The projection period is 20 years.

Scenario A: Baseline

The baseline scenario is used as a ‘status quo’ against which alternative policy scenarios are compared. The baseline scenario uses the inputs discussed in **Table 5**. The baseline scenario assumes model parameters remain stable. In this scenario the student nurse/midwife enrolment figures remain fixed at 2,000 per year for the duration of the period. Refer to **Table 5** for further details on the model parameters.

Scenario B: Moderate increase in domestic supply

Scenario B illustrates the potential effects of a change in policy where the intake of student nurses/midwives is moderately increased. The nursing/midwifery graduate rate per 100,000 is moderately increased to be in line with the Netherlands (a comparable country which has 58 graduates per 100,000 compared to 31 per 100,000 in Ireland). The policy change is set to increase Ireland’s nursing/midwifery student intake by the proportion to match the Netherlands per capita over a 10-year period and then maintain that proportion in line with population growth. In this scenario the student nurse/midwife enrolment places are increased by 185 places per year until 2031 and increased by a further 36 places per year from 2032 to 2041. A nursing/midwifery degree completion rate of 88.9% is assumed as well as the CSO’s M1F1 population growth scenario.³¹

Scenario C: Significant increase in domestic supply

Scenario C illustrates the potential effects of a change in policy where the intake of student nurses/midwives is significantly increased. The nursing/midwifery graduate rate per 100,000 is significantly increased to be in line with Australia (a comparable country which has 109 graduates per 100,000 compared to 31 per 100,000 in Ireland). The policy change increases Ireland’s nursing/midwifery student intake to match Australia’s per capita graduate production rate over a 10-year period and then maintain that proportion in line with population growth. In this scenario the student nurse/midwife enrolment places are increased by 515 places per year until 2031 and increased by a further 66 places per year from 2032 to 2041. A

³¹ For further information see the CSO website (<https://www.cso.ie/en/releasesandpublications/ep/p-plfp/populationandlabourforceprojections2017-2051/populationprojectionsresults/>)

nursing/midwifery degree completion rate of 88.9% is assumed as well as the CSO's M1F1 population growth scenario.³²

³² See the CSO website (<https://www.cso.ie/en/releasesandpublications/ep/p-plfp/populationandlabourforceprojections2017-2051/populationprojectionsresults/>). While the CSO's central scenario developed in 2016, M2F2, is often used for population projections, the estimated and actual population of Ireland in 2021 and 2022, 5.01m and 5.12m respectively, suggest that the population is growing faster than the central scenario. Therefore, the CSO's M1F1 population projection is used instead.

5. Results

5.1 Scenario A: Baseline

The baseline scenario (which uses the inputs discussed in **Table 5**) shows the results assuming that student intake and attrition rates stay at their current levels (i.e., the baseline scenario) and the Scenario B results. The baseline scenario illustrates the potential effects of a status quo policy, which results in the proportion of domestically educated nurses/midwives reducing over time as a share of the workforce. In this scenario the student nurse/midwife enrolment figures remain fixed at 2,000 per year. At the beginning of the model period in 2021, Domestically educated nurses/midwives account for 54% of WTE (and 57% of total Registered Nurses/Midwives). This baseline forecast estimates that the composition will shift to 38% domestically educated WTE and 62% foreign educated WTE in 2041, with a requirement for at least 51,215 foreign nurses/midwives by 2041 (compared with 29,535 today). See a sensitivity analysis of the baseline scenario in **Appendix 4**. See an overview of the different scenario projections in **Figure 12**.

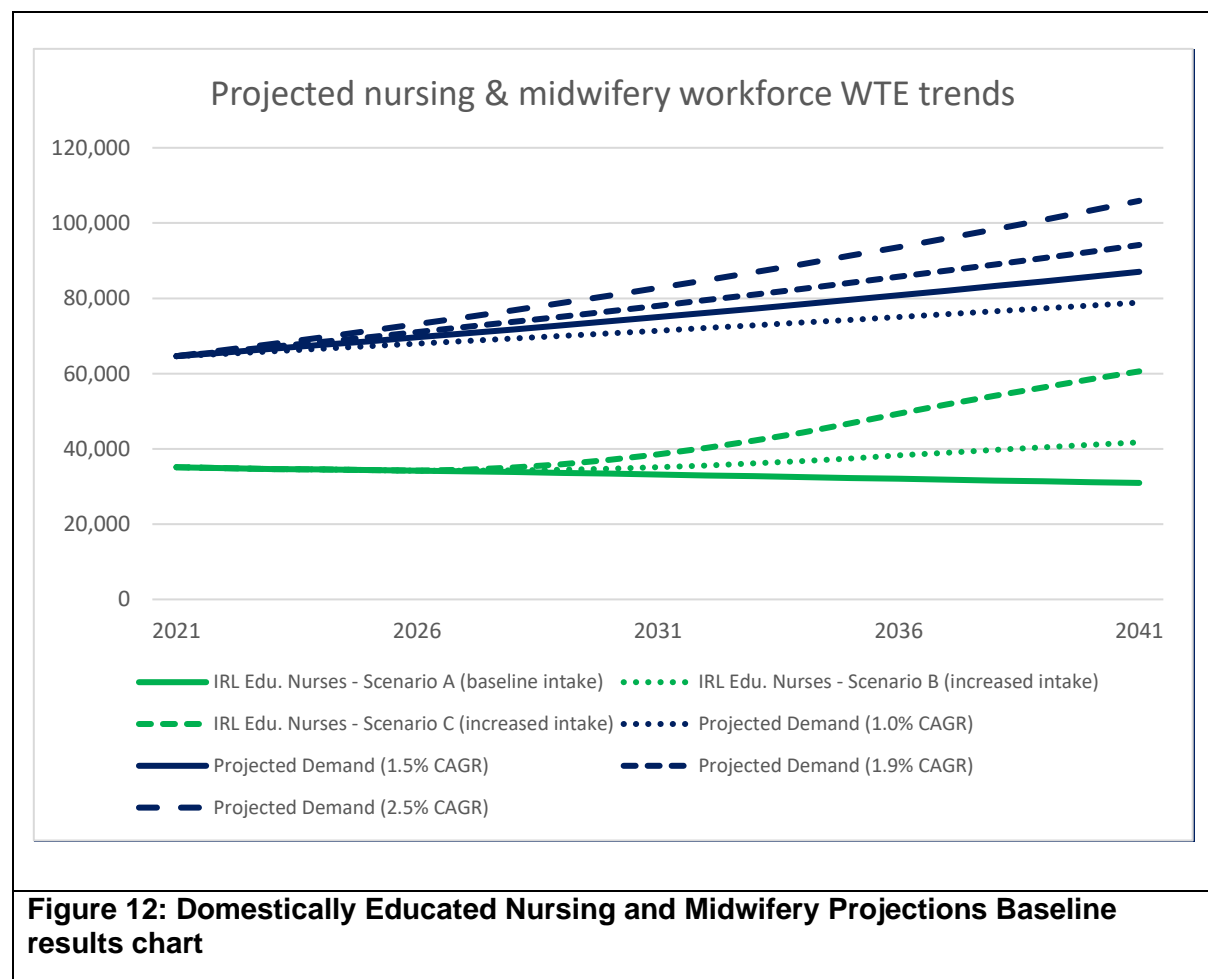


Table 6 below shows the results of the baseline scenario:

Year	Demand growth rate	Proj. WF Demand WTE	Dom. Edu. WTE	Foreign Educated WTE	Gap between demand and supply	First Year Intake	Grads (entering careers)
2021	1.50%	64,637	35,101	29,535	1	2,000	1,677
2022	1.50%	65,607	34,907	29,536	1,164	2,000	1,610
2023	1.50%	66,591	34,659	28,691	3,241	2,000	1,754
2024	1.50%	67,590	34,531	29,980	3,079	2,000	1,763
2025	1.50%	68,603	34,389	31,019	3,195	2,000	1,762
2026	1.50%	69,632	34,224	32,105	3,303	2,000	1,762
2027	1.50%	70,677	34,040	33,225	3,412	2,000	1,762
2028	1.50%	71,737	33,842	34,377	3,518	2,000	1,762
2029	1.50%	72,813	33,631	35,558	3,624	2,000	1,762
2030	1.50%	73,905	33,413	36,764	3,728	2,000	1,762
2031	1.50%	75,014	33,190	37,992	3,832	2,000	1,762
2032	1.50%	76,139	32,963	39,241	3,935	2,000	1,762
2033	1.50%	77,281	32,735	40,508	4,038	2,000	1,762
2034	1.50%	78,440	32,506	41,792	4,142	2,000	1,762
2035	1.50%	79,617	32,278	43,093	4,246	2,000	1,762
2036	1.50%	80,811	32,050	44,409	4,352	2,000	1,762
2037	1.50%	82,023	31,825	45,741	4,457	2,000	1,762
2038	1.50%	83,254	31,603	47,088	4,563	2,000	1,762
2039	1.50%	84,503	31,383	48,449	4,671	2,000	1,762
2040	1.50%	85,770	31,167	49,825	4,778	2,000	1,762
2041	1.50%	87,057	30,956	51,215	4,886	2,000	1,762
Table 6							

5.1.1 Scenario A: Baseline results with a lower demand growth rate (1.00%)

Year	Demand growth rate	Proj. WF Demand	Dom. Edu. WTE	Foreign Edu. WTE	Gap between demand and supply
2021	1.00%	64,637	35,101	29,535	1
2022	1.00%	65,283	34,907	29,536	840
2023	1.00%	65,936	34,659	28,368	2,909
2024	1.00%	66,596	34,531	29,348	2,717
2025	1.00%	67,262	34,389	30,069	2,804
2026	1.00%	67,934	34,224	30,828	2,882
2027	1.00%	68,614	34,040	31,614	2,960
2028	1.00%	69,300	33,842	32,423	3,035
2029	1.00%	69,993	33,631	33,253	3,109
2030	1.00%	70,693	33,413	34,100	3,180
2031	1.00%	71,400	33,190	34,961	3,249
2032	1.00%	72,114	32,963	35,833	3,318
2033	1.00%	72,835	32,735	36,714	3,386
2034	1.00%	73,563	32,506	37,603	3,454
2035	1.00%	74,299	32,278	38,500	3,521
2036	1.00%	75,042	32,050	39,403	3,589
2037	1.00%	75,792	31,825	40,312	3,655
2038	1.00%	76,550	31,603	41,226	3,721
2039	1.00%	77,315	31,383	42,144	3,788
2040	1.00%	78,089	31,167	43,067	3,855
2041	1.00%	78,869	30,956	43,993	3,920
Table 7					

5.1.2 Scenario A: Baseline results with a higher demand growth rate (2.50%)

Year	Demand growth rate	Proj. WF Demand	Dom. Edu. WTE	Foreign Edu. WTE	Gap between demand and supply
2021	2.50%	64,637	35,101	29,535	1
2022	2.50%	66,253	34,907	29,536	1,810
2023	2.50%	67,909	34,659	29,338	3,912
2024	2.50%	69,607	34,531	31,255	3,821
2025	2.50%	71,347	34,389	32,950	4,008
2026	2.50%	73,131	34,224	34,718	4,189
2027	2.50%	74,959	34,040	36,546	4,373
2028	2.50%	76,833	33,842	38,434	4,557
2029	2.50%	78,754	33,631	40,378	4,745
2030	2.50%	80,723	33,413	42,377	4,933
2031	2.50%	82,741	33,190	44,428	5,123
2032	2.50%	84,809	32,963	46,530	5,316
2033	2.50%	86,930	32,735	48,682	5,513
2034	2.50%	89,103	32,506	50,885	5,712
2035	2.50%	91,330	32,278	53,137	5,915
2036	2.50%	93,614	32,050	55,440	6,124
2037	2.50%	95,954	31,825	57,793	6,336
2038	2.50%	98,353	31,603	60,199	6,551
2039	2.50%	100,812	31,383	62,657	6,772
2040	2.50%	103,332	31,167	65,168	6,997
2041	2.50%	105,915	30,956	67,733	7,226
Table 8					

5.2 Scenario B: Moderate increase in domestic supply

At the beginning of the model period in 2021, 54% of nurses/midwives are domestically educated. Scenario B estimates that the composition will shift to 50% domestically educated WTE and 50% foreign educated WTE in 2041 (compared with 38% domestic WTE; 62% foreign WTE in the baseline scenario), with a requirement for at least 41,890 foreign nurses/midwives 2041 i.e., compared to the Scenario A baseline, this would lower need for foreign-educated nurses/midwives by nearly a fifth.

See a breakdown of Scenario B's outputs in **Table 9** below:

Year	Demand growth rate	Proj. WF Demand	Dom. Edu. WTE	Foreign Educated WTE	Gap between demand and supply	First Year Intake	Grads (entering careers)
2021	1.50%	64,637	35,101	29,535	1	2,000	1,677
2022	1.50%	65,607	34,907	29,536	1,164	2,185	1,610
2023	1.50%	66,591	34,659	28,691	3,241	2,370	1,754
2024	1.50%	67,590	34,531	29,980	3,079	2,555	1,763
2025	1.50%	68,603	34,389	31,019	3,195	2,740	1,762
2026	1.50%	69,632	34,224	32,105	3,303	2,925	1,932
2027	1.50%	70,677	34,188	33,225	3,264	3,110	2,094
2028	1.50%	71,737	34,266	34,230	3,241	3,295	2,257
2029	1.50%	72,813	34,450	35,144	3,219	3,480	2,420
2030	1.50%	73,905	34,735	35,973	3,197	3,665	2,583
2031	1.50%	75,014	35,113	36,724	3,177	3,850	2,746
2032	1.50%	76,139	35,580	37,404	3,155	3,886	2,909
2033	1.50%	77,281	36,132	38,015	3,134	3,922	3,072
2034	1.50%	78,440	36,765	38,564	3,111	3,958	3,235
2035	1.50%	79,617	37,477	39,053	3,087	3,994	3,398
2036	1.50%	80,811	38,264	39,485	3,062	4,030	3,425
2037	1.50%	82,023	39,007	39,862	3,154	4,066	3,457
2038	1.50%	83,254	39,718	40,306	3,230	4,102	3,489
2039	1.50%	84,503	40,404	40,795	3,304	4,138	3,520
2040	1.50%	85,770	41,074	41,324	3,372	4,174	3,552
2041	1.50%	87,057	41,733	41,886	3,438	4,210	3,584
Table 9							

5.3 Scenario C: Significant increase in domestic supply

At the beginning of the model period in 2021, 54% of nurses/midwives are domestically educated. Scenario C estimates that the composition will shift to 70% domestic educated WTE and 30% foreign educated WTE in 2041 (compared with 38% domestic WTE; 62% foreign WTE in the baseline scenario), with a requirement for at least 25,842 foreign nurses/midwives

2041. i.e., compared to the Scenario A baseline, this would more than halve the need for foreign-educated nurses/midwives.

See a breakdown of Scenario C's outputs in **Table 10** below:

Year	Demand growth rate	Proj. WF Demand	Dom. Edu. WTE	Foreign Educated WTE	Gap between demand and supply	First Year Intake	Grads (entering careers)
2021	1.50%	64,637	35,101	29,535	1	2,000	1,677
2022	1.50%	65,607	34,907	29,536	1,164	2,515	1,610
2023	1.50%	66,591	34,659	28,691	3,241	3,030	1,754
2024	1.50%	67,590	34,531	29,980	3,079	3,545	1,763
2025	1.50%	68,603	34,389	31,019	3,195	4,060	1,762
2026	1.50%	69,632	34,224	32,105	3,303	4,575	2,234
2027	1.50%	70,677	34,451	33,225	3,001	5,090	2,687
2028	1.50%	71,737	35,023	33,967	2,747	5,605	3,141
2029	1.50%	72,813	35,911	34,405	2,497	6,120	3,594
2030	1.50%	73,905	37,092	34,562	2,251	6,635	4,048
2031	1.50%	75,014	38,544	34,463	2,007	7,150	4,502
2032	1.50%	76,139	40,249	34,127	1,763	7,216	4,956
2033	1.50%	77,281	42,193	33,570	1,518	7,282	5,410
2034	1.50%	78,440	44,363	32,806	1,271	7,348	5,863
2035	1.50%	79,617	46,751	31,846	1,020	7,414	6,317
2036	1.50%	80,811	49,348	30,701	762	7,480	6,360
2037	1.50%	82,023	51,790	29,376	857	7,546	6,419
2038	1.50%	83,254	54,115	28,236	903	7,612	6,477
2039	1.50%	84,503	56,345	27,219	939	7,678	6,535
2040	1.50%	85,770	58,502	26,307	961	7,744	6,593
2041	1.50%	87,057	60,602	25,479	976	7,810	6,651
Table 10							

See a breakdown of the total nursing/midwifery education costs associated with the three scenarios outputs in **Table 11** below. This costing is based on the estimated costs discussed in **Appendix 2** and includes CPC salary costs, SALO salary costs, uniform costs, the intern year cost and HEA funding specific to student places (i.e., fee plus grant). Note that capital costs (in relation to HEI expansion)³³, employer's PRSI costs, pension-related costs, PDC salary costs, travel reimbursements, accommodation reimbursements, indirect overhead costs incurred by hospitals and SUSI grants are not included in the costing. If these were included they would substantially increase the costs. The student contribution, which would lower the cost, is also not included. Therefore, the costing is indicative only. Further work

³³ In particular, the costing does not include the capital expenditure that would be required to expand nursing and midwifery places to the levels included in the scenarios described in this paper.

would be required to accurately cost the proposed initiatives. Also note the sensitivity analysis in **Appendix 4**. The cost in each year is calculated by multiplying the number of students in each year of the nursing/midwifery degree by the cost per student in that year. The costs in 2021 therefore reflect the costs for all current student nurses/midwives in that year. The costs occurring in the future are not discounted.

Year	Scenario A (intake of 2,000 in 2041)	Scenario B (intake of 4,210 in 2041)	Scenario C (intake of 7,810 in 2041)
2021	101.744 M	101.744 M	101.744 M
2022	102.139 M	102.139 M	102.139 M
2023	105.438 M	107.597 M	111.448 M
2024	105.623 M	112.009 M	123.402 M
2025	105.615 M	118.239 M	140.758 M
2026	105.616 M	128.147 M	168.338 M
2027	105.616 M	137.911 M	195.519 M
2028	105.616 M	147.681 M	222.715 M
2029	105.616 M	157.450 M	249.911 M
2030	105.616 M	167.219 M	277.107 M
2031	105.616 M	176.989 M	304.303 M
2032	105.616 M	186.758 M	331.499 M
2033	105.616 M	194.789 M	353.456 M
2034	105.616 M	201.153 M	370.391 M
2035	105.616 M	205.899 M	382.449 M
2036	105.616 M	207.689 M	385.600 M
2037	105.616 M	209.595 M	389.098 M
2038	105.616 M	211.496 M	392.583 M
2039	105.616 M	213.397 M	396.068 M
2040	105.616 M	215.298 M	399.554 M
2041	105.616 M	217.199 M	403.039 M
Table 11			

6. Discussion

This paper develops a system dynamics-based model of nursing/midwifery workforce supply for the whole health system. Although it was challenging to identify data for a number of parameters, this is not uncommon internationally. An EU initiative on health workforce planning highlights that countries with more developed workforce planning functions utilise qualitative research to overcome data gaps and parameterise uncertainty over the future as part of workforce planning exercises (Joint Action Health Workforce Planning and Forecasting, 2016).

The baseline scenario shows the impact of a status quo student nurse/midwife intake size remaining in place over the next 20 years. Based on current trends, inflows and outflows, the proportion of domestically educated nurses/midwives will decrease over the period which will exacerbate the challenge of reaching national self-sufficiency. The baseline scenario indicates that a significant increase in the number of student nursing/midwifery places in Ireland is required to reduce reliance on foreign-educated nurses/midwives.

Scenario B increases the student nursing/midwifery intake over a 10-year period to match a comparator country, the Netherlands, in terms of graduate nurse/midwife production by 2035 and then grows intake thereafter in line with population growth. This brings Ireland's growth in domestic supply closer into line with the growth in demand for nurses/midwives and, relative to baseline, redresses some of Ireland's reliance on foreign educated nurses/midwives. However, it does not bring Ireland closer towards national self-sufficiency compared to the level in 2021. These results suggest that a more rapid expansion in nursing/midwifery places in HEIs is necessary to make up for undersupply from previous decades followed by a reduction in nursing/midwifery places once the proportion of domestically educated nurses/midwives begins to approach the total number of nurses/midwives in the country.

Scenario C increases the student nursing/midwifery intake over a 10-year period to match a comparator country, Australia, in terms of graduate nurse/midwife production by 2035 and then grows intake thereafter in line with population growth. This scenario reduces Ireland's reliance on foreign-educated nurses/midwives.

6.1 Limitations

There are a number of limitations of this paper. As noted, several model parameters (particularly in relation to outflows) could not be evidenced appropriately with historical data and it was beyond the scope of this paper to undertake qualitative research to identify reasonable parameter estimates. Furthermore, the paper does not include scenario analysis

of other factors which could impact on parameters in the model e.g., the impact of economic growth on emigration, retirements and attrition. Where data can be provided to underpin parameters it is often derived from the public health system. As the model scope is the whole nursing/midwifery workforce this includes the private health system as well. Parameter estimates derived from the public health system may deviate in important ways from the private health system.

While the paper evidences the need for a significant expansion in nursing/midwifery places in higher education, further research or analysis may be required in relation to the capacity of the higher education system to increase nursing/midwifery places to an optimum level, as well as the capacity of the Irish health system to absorb significant increases in domestically educated nurses/midwives each year. In this context a number of issues should be considered further.

Firstly, within the model all nurses/midwives are treated the same. This paper does not include an assessment of demand for nursing/midwifery, nor does it make any comment on the appropriateness of the current numbers of nurses/midwives, skill-mix or grade-mix within the health system. In reality, nurses are educated and work in different specialities i.e., general nursing, children's nursing, intellectual disability nursing, psychiatric nursing. Additionally, nurses and midwives can also be employed in clinical nurse/midwife specialist and advanced nurse/midwife practitioner roles. Expansions of nursing/midwifery places should be cognisant of the future demands for skillsets in these individual areas.

Secondly, increasing nursing/midwifery places in HEIs as suggested by this research is subject to practical constraints which would require significant and costly (see **Appendix 2**) increases in educational capacity within HEIs and in the health system as a whole. These costs would likely include significant capital investment. Further work should be undertaken to assess the capacity of HEIs and the health system to educate significantly more nurses/midwives in the future (this could include the creation of GEM and GEN pathways).

Thirdly, increases in nursing/midwifery places in HEIs would need to ensure the quality of learning is maintained, otherwise course dropout rates may increase.

7. Conclusion

This paper uses system dynamics modelling as part of an evidence-based framework to model the supply of the nursing and midwifery workforce in Ireland. While there is uncertainty in the projections for the total number of domestically educated nurses and midwives in Ireland, this paper demonstrates a need to significantly increase Ireland's domestic production of nurses and midwives to ensure that the State meets the WHO-GCP commitment. Demand for nursing/midwifery is expected to grow into the future and this conclusion holds for a wide range of potential growth rates. Supply gaps are likely to continue to be met by the large-scale recruitment of foreign nurses and midwives into the foreseeable future. However, the expansion of nursing/midwifery student places in Ireland would reduce this need to recruit internationally.

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Appendix 1: The Standard Method for SD Modelling (Lyneis & Hines, 2007)

The complete sequence of steps in the Standard Method are as follows:

No.	Sequence of steps
1.	Problem definition i.e., list of variables, reference modes (hopes and fears), momentum policies, and definition of “success”
2.	Dynamic hypothesis i.e., causal loops linked to reference modes
3.	Simulation model of first loop
4.	Analyse first loop and generate insights
5.	Simulation model of second loop
6.	Analyse second loop and generate insights
7.	Simulation model of third loop
8.	Analyse third loop and generate insights
9.	Continue until complete model developed (may take multiple iterations)
10.	Design policies to improve performance

Appendix 2: Estimated cost per student of nursing and midwifery education in Ireland

Nursing/Midwifery Undergraduate Costs ³⁴³⁵³⁶	per student	Unit Cost	Cost Year 1	Cost Year 2	Cost Year 3	Cost Year 4	Full four-year cost
<u>Clinical Placements</u>							
CPC ratio to students of 1:19.6 ³⁷		€55,469 ³⁸	€2,830	€2,830	€2,830	€2,830	€11,320
SALO ratio to students of 1:50		€55,469 ³⁹	€1,109	€1,109	€1,109	€1,109	€4,438
Uniform	1 st and 4 th year	€150	€150			€150	€300
Intern Salary ⁴⁰	4 th year	€10,000				€10,000	€10,000
Total Cost Clinical Placements⁴¹			€4,089	€3,939	€3,939	€14,089	€26,058
<u>Higher Education Institution⁴²</u>							
HEA funding specific to student places ⁴³ (i.e., fee plus grant) SUSI		€7,580	€7,580	€7,580	€7,580	€7,580	€30,320
Student contribution							
Total HEI Costs			€7,580	€7,580	€7,580	€7,580	€30,320
Estimate Total Nursing / Midwifery Degree Costs per Student			€11,669	€11,519	€11,519	€21,669	€56,378

³⁴ Note that increased student nurse/midwife intakes may require additional HEI infrastructure. Therefore, additional capital expenditure requirements may need to be considered. Capital costs are not included in this table.

³⁵ PDC costs are not included in this table

³⁶ Travel and accommodation reimbursement are addressed by Circular 01/2022 but could not be costed at an individual level for this table so are excluded. Note recommendation 1.1. of the McHugh Report 2021 recommended an enhanced scheme for reimbursement for travel and subsistence, including accommodation costs incurred resulting from the requirements in relation to mandatory, supernumerary placements within the nursing and midwifery degree programmes.

³⁷ CPC ratios for nursing and midwives differ. The 1:19.6 reflects a weighted average as set out in Table 3.

³⁸ Employers PRSI and Pensions are not included in this costing.

³⁹ Employers PRSI and Pensions are not included in this costing.

⁴⁰ PQ Ref: 41032/21 indicates a cost of €10,000 for a nurse intern.

⁴¹ Note that unlike previous costings (Carney, 1999), we have not included indirect overhead costs incurred by hospitals in relation to nursing education such as seminar rooms, labs, clinical rooms, computer space and nursing tutor office space.

⁴² SUSI Grants are not included in this calculation. The Student Grant Scheme is the main financial support scheme for students studying in Ireland. It is also known as the SUSI grant. Students' grants are divided into a maintenance grant and a fee grant. Maintenance grants help students with their living costs. Fee grants pay tuition fees for students who do not qualify for the Free Fees Scheme. Fee grants can also pay the Student Contribution and the cost of essential field trips. A proportion of nursing and midwifery students each year benefit from the grant.

⁴³ There are three grant values depending on the type of HEI. The cost included here is an arithmetic average of these three grant values.

Appendix 3: Note on countries which have significantly increased student nursing and midwifery places in recent years

Australia

The annual number of students completing Bachelor of Nursing study programmes tripled between 2002 and 2019 (Australian DoH, 2019). In 2019, there were 26,493 undergraduate nursing student commencements courses leading to registration.⁴⁴

Between 2009 and 2012, the Australian government eased restrictions on the number of undergraduate students that universities were permitted to enrol in all courses except medicine. Universities can enrol as many students as they wish. In response to forecasts that the country was facing a shortage of nurses, universities increased nursing enrolments and completions dramatically. The expansion of the higher education sector in general (and nursing places in particular), opened access to higher education to students whose performance at school would previously not have been good enough for them to gain admission. Australian HEIs are obligated to provide these students with adequate instructional and learning support. However, not all students receive adequate attention. Some nursing graduates fail to find employment upon completion of their studies. A survey conducted by the Queensland Labour Economics Office found that common reasons for employers judging applicants to be unsuitable for nursing positions were their poorly presented applications and inadequate communication skills. Some nurse managers complain that some nursing students are unable to do simple arithmetic such as calculating drug dosages based on body weight. There have been calls to improve literacy and numeracy by raising the entry requirements for admission to nursing courses (Australian DoH, 2019). Attrition from nursing study programmes is higher than Ireland, with the average rate being 34% (Australian DoH, 2014).

Norway

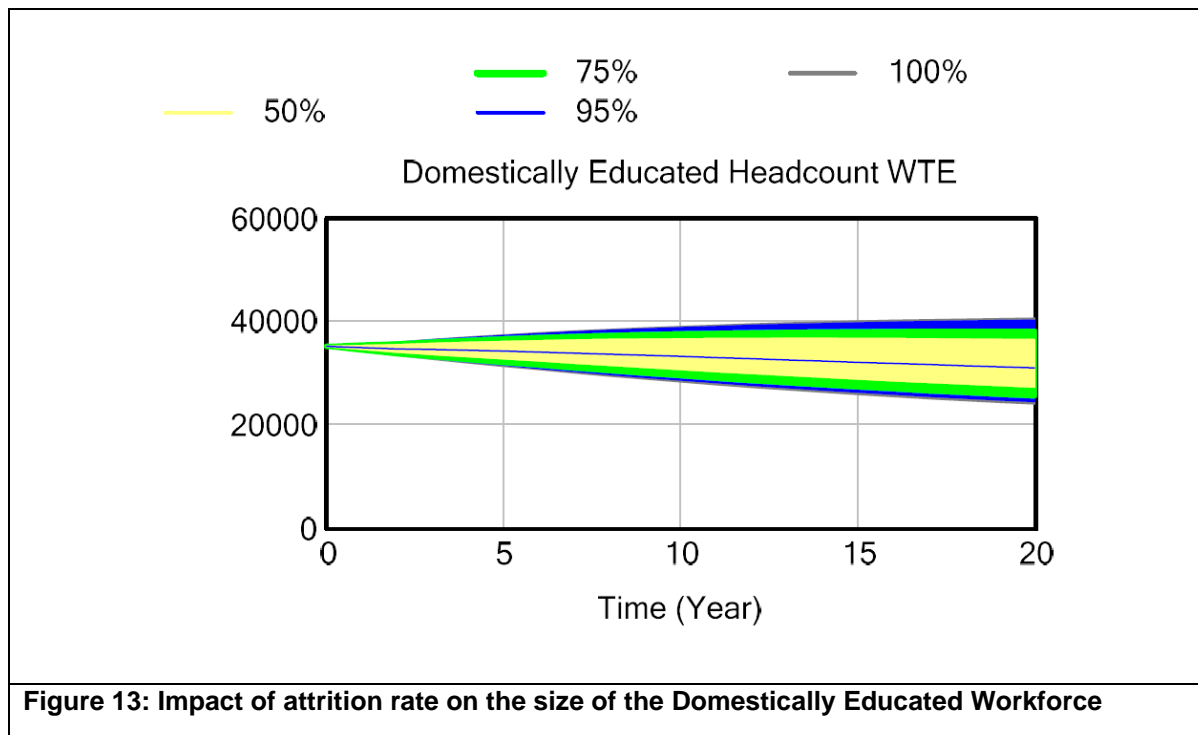
Norway, a country with a similar population to Ireland, has significantly increased its student nursing places in the years since 2010. The substantial increase has been driven by a series of measures to attract more students into nursing education and to retain more nurses in the profession by improving their working conditions. However, the dropout rate from the profession continues to be high, especially among nurses working in long-term care (OECD, 2021). In 2022, there were 5,100 first year places in nursing study programmes.⁴⁵

⁴⁴ See ANMJ website (Link: <https://anmj.org.au/securing-a-working-future-for-new-graduate-nurses-and-midwives/>)

⁴⁵ See Norwegian government website (Link: <https://www.regjeringen.no/no/aktuelt/okt-opptak-med-500-studieplasser-i-sykepleie/id2892839/>)

Appendix 4: Baseline scenario sensitivity analysis

Domestic Attrition: In **Figure 13** below see the impact of changes in the attrition rate on the domestically educated WTE figures with a minimum bound of 0.8% and a maximum bound of 4.8% annual attrition (this attrition is in addition to retirements and emigration).



Retirement: In **Figure 14** below, see the impact of changes in the retirement rate of domestically educated Irish nurses and midwives aged between 60 and 64 on the domestically educated WTE figures, with a minimum bound of 6% and a maximum bound of 20% annual retirements.

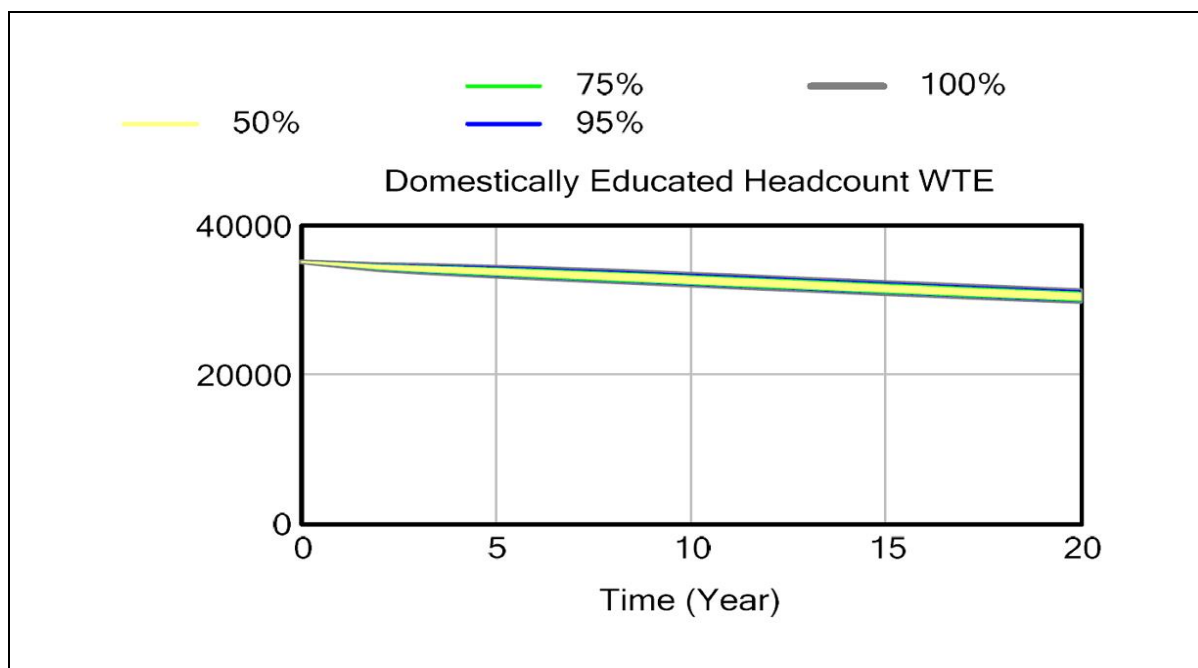


Figure 14: Impact of changes in retirement rate

Nursing/Midwifery Demand Growth: In **Figure 15** below, see the impact that changes in the annual growth rate in nursing/midwifery demand has on projected workforce demand WTE, with a minimum bound of 0.5% growth and a maximum bound of 2.5% annual growth.

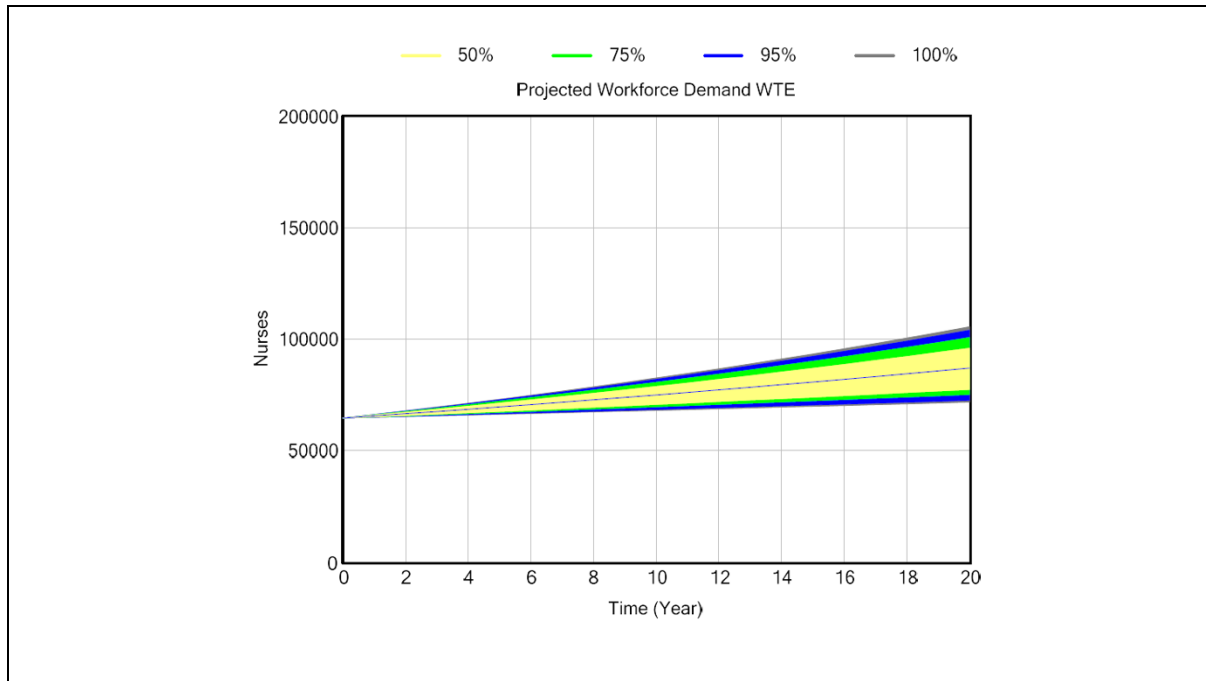


Figure 15: Impact of changes in nursing and midwifery demand growth

Foreign nurse/midwife attrition: In **Figure 16** below, see the impact that changes in the foreign education attrition rate (which includes emigration, retirements and other attrition) has on foreign educated WTE.

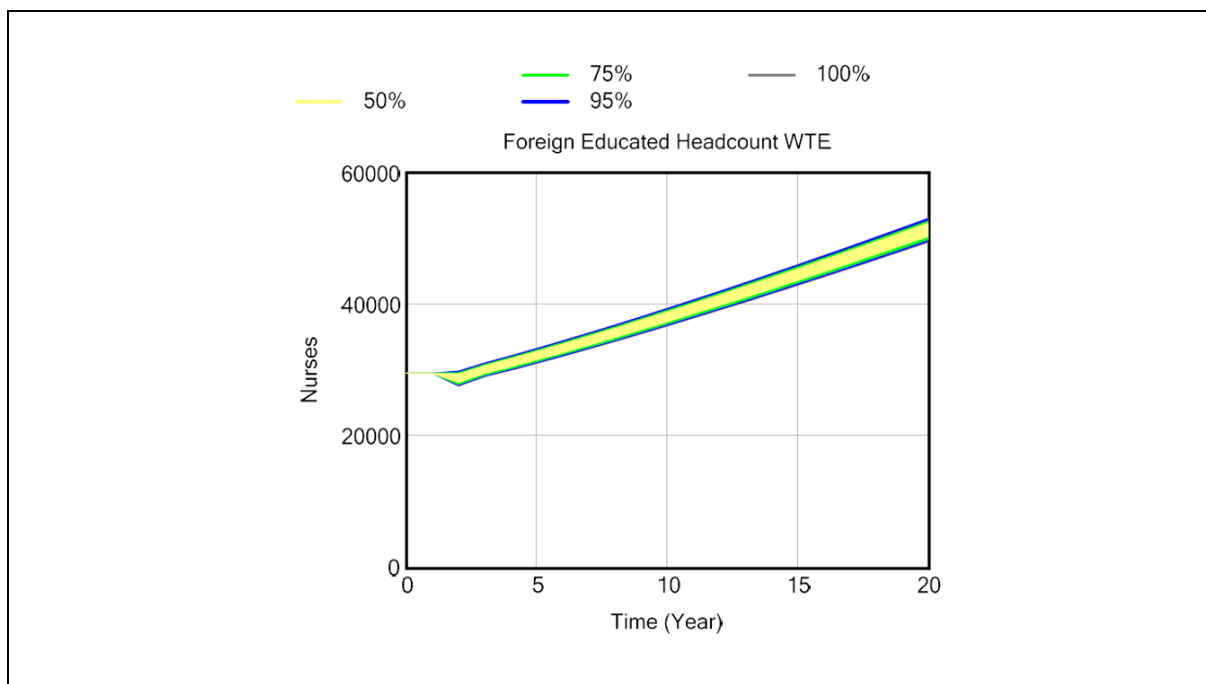
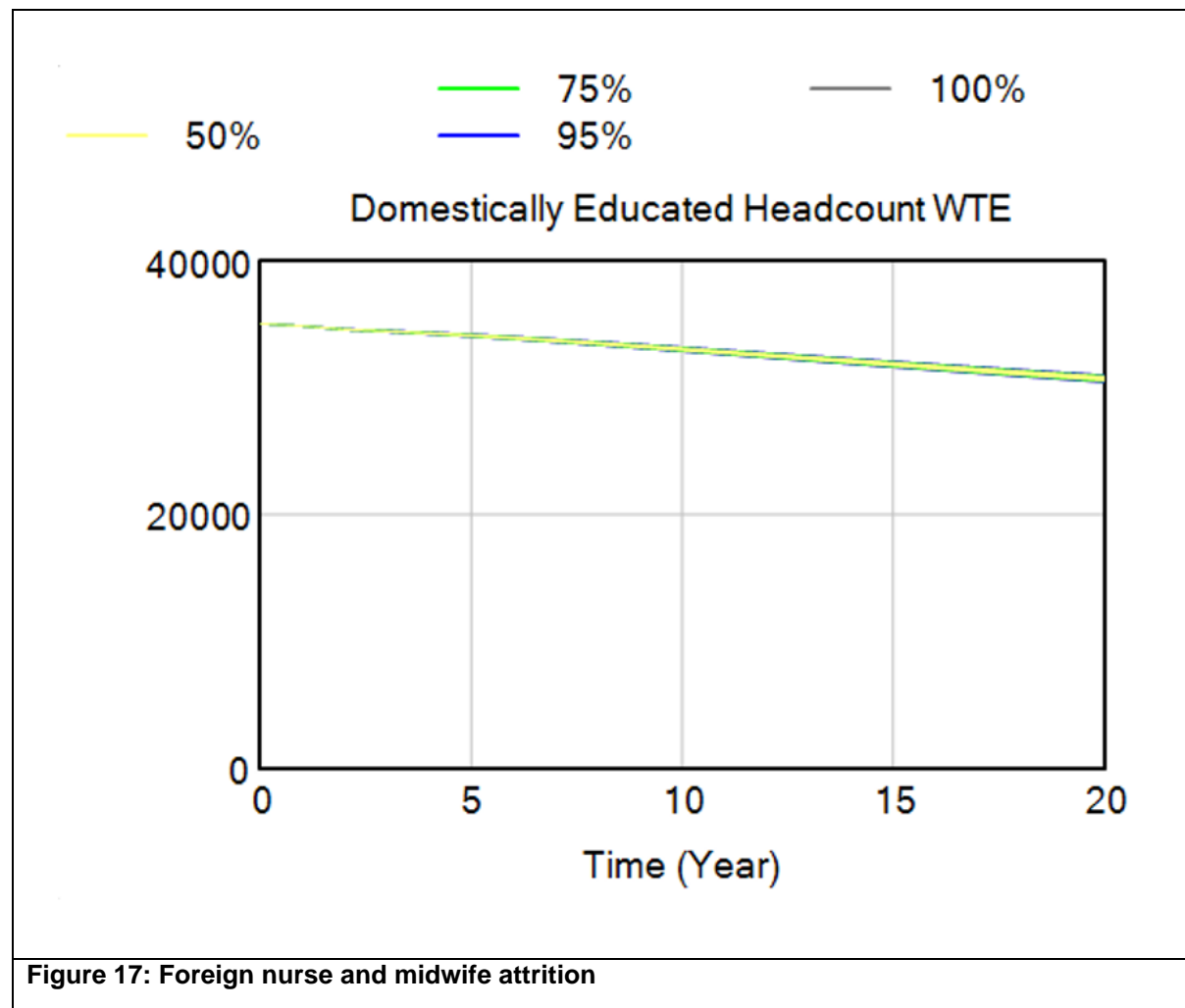


Figure 16: Foreign nurse and midwife attrition

Enter Other Careers Rate: In **Figure 17** below, see the impact that changes in the proportion of nursing/midwifery graduates entering other careers upon completion of their studies has on the domestically educated WTE figures, with a minimum bound of 0.5% and a maximum bound of 4%.



Appendix 5: HSE Nursing & Midwifery WTE trends

See a chart showing the growth of HSE nursing and midwifery WTE figures below:

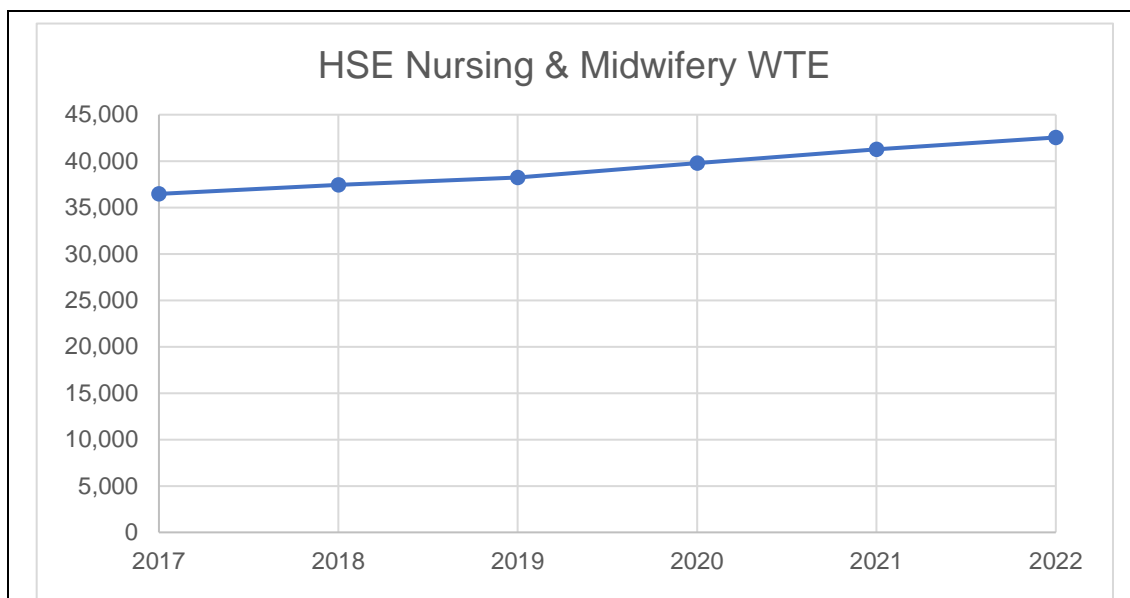


Figure 18

Source: HSE Census

Appendix 6: CCPS requests made by individual Irish educated nurses and midwives per year

See a breakdown of the number of domestically educated nurses and midwives making CCPS request from 2015 to 2021:

Year	CCPS requests made by individual Irish educated nurses and midwives
2015	686
2016	740
2017	753
2018	770
2019	857
2020	530
2021	898

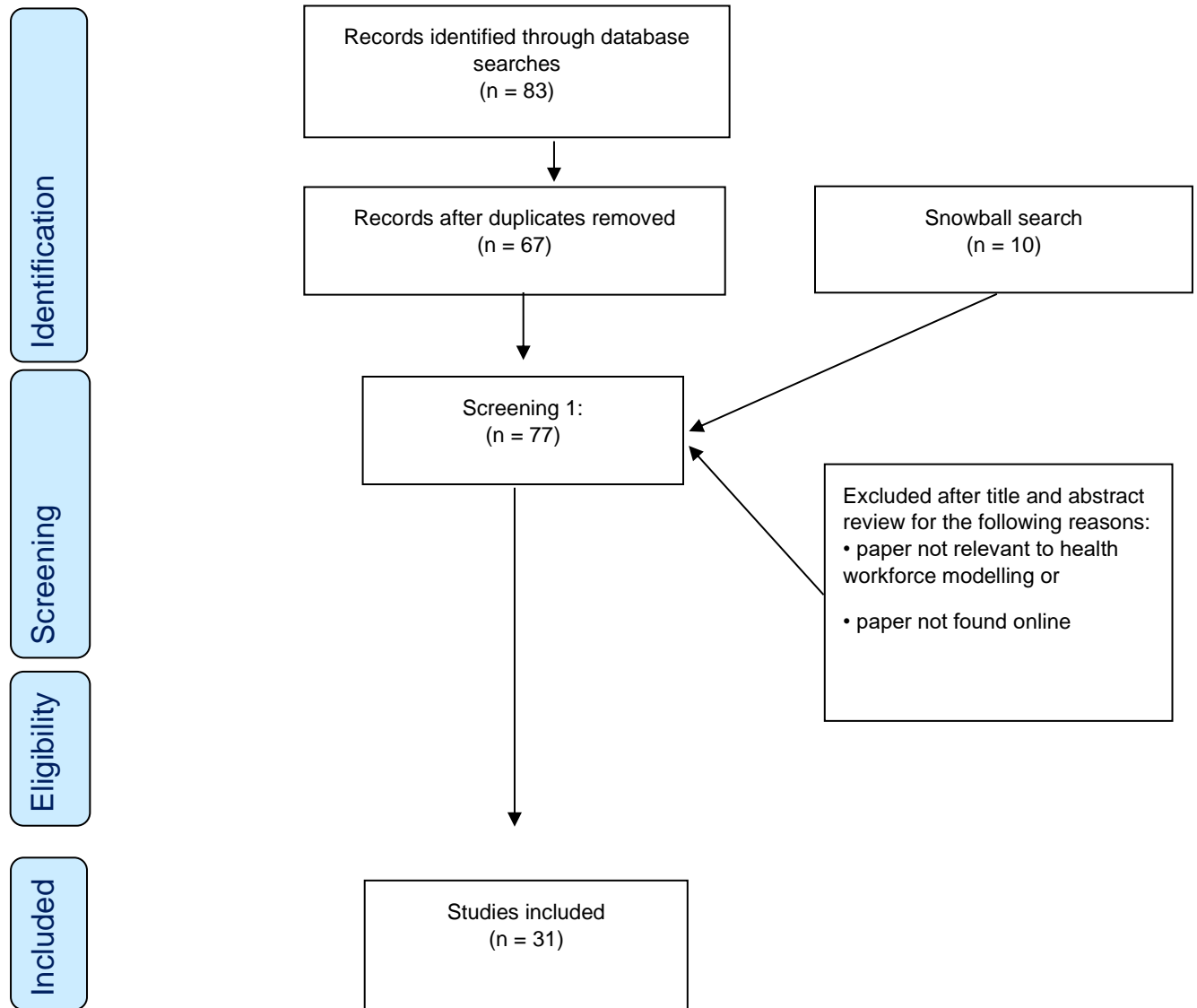
Appendix 6: Search Strategy

A6.1 Details of search terms and sources

Searches	Search String/Terms
PubMed search string 20 January 2022	("system dynamic*" [Title/Abstract] OR "microsimulation" [Title/Abstract] OR "microanalytic simulation" [Title/Abstract] OR "microscopic simulation" [Title/Abstract]) AND ("Workforce" [Title/Abstract] OR "Planning" [Title/Abstract] OR "supply" [Title/Abstract] OR "demand" [Title/Abstract] OR "work force" [Title/Abstract]) AND ("nurs*" [Title/Abstract] OR "physician*" [Title/Abstract] OR "medical special*" [Title/Abstract] OR "medical prac*" [Title/Abstract] OR "surgeon" [Title/Abstract] OR "doctor*" [Title/Abstract] OR "midwife" [Title/Abstract] OR "midwi*" [Title/Abstract] OR "general prac*" [Title/Abstract])
EBSCO (MedLine EconLit) host and search string 20 January 2022	Searched abstracts containing: system dynamic* OR microsimulation OR microanalytic simulation OR microscopic simulation AND Workforce OR Planning OR supply OR demand OR work force AND nurs* OR physician* OR "medical special*" OR medical prac* OR surgeon OR doctor* OR midwife OR midwi* OR "general prac*" OR GP*
Google Scholar search string 8 February 2022 (first two pages of results)	(intitle:"system dynamic*" OR intitle:"microsimulation") (intitle:Workforce OR intitle:Planning OR intitle:supply OR intitle:demand) (nurse* OR physician* OR "medical special*" OR "medical prac*" OR surgeon OR doctor* OR midw* OR GP*
Snowball search 4 August to 17 December 2021	

A6.2 Prisma flow chart

The searches gave 77 citations after duplications were removed. After the title and abstract screening 31 publications were included in the final set.



A6.3 Studies included in final set of literature review with abstracts

No.	Author (Year)	Title	Country	Abstract
[1]	Abas ZA, Ramli MR, Desa MI, Saleh N, Hanafiah AN, Aziz N, Abidin ZZ, Shibghatullah AS, Rahman AF & Musa H (2017)	A supply model for nurse workforce projection in Malaysia	MYS	The paper aims to provide an insight into the significance of having a simulation model to forecast the supply of registered nurses for health workforce planning policy using System Dynamics. A model is highly in demand to predict the workforce demand for nurses in the future, which it supports for complete development of a needs-based nurse workforce projection using Malaysia as a case study. The supply model consists of three sub-models to forecast the number of registered nurses for the next 15 years: training model, population model and Full Time Equivalent (FTE) model. In fact, the training model is for predicting the number of newly registered nurses after training is completed. Furthermore, the population model is for indicating the number of registered nurses in the nation and the FTE model is useful for counting the number of registered nurses with direct patient care. Each model is described in detail with the logical connection and mathematical governing equation for accurate forecasting. The supply model is validated using error analysis approach in terms of the root mean square percent error and the Theil inequality statistics, which is important for evaluating the simulation results. Moreover, the output of simulation results provides a useful insight for policy makers as a what-if analysis is conducted. Some recommendations are proposed in order to deal with the nursing deficit. It must be noted that the results from the simulation model will be used for the next stage of the Needs-Based Nurse Workforce projection project. The impact of this study is that it provides the ability for greater planning and policy making with better predictions.
[2]	Alonso MI (2003)	Management of allocation of positions for specialist medical training	ESP	<p>OBJECTIVE: Currently there is a large imbalance between supply and demand for medical specialists in the Spanish Health System. The aim of this study was to demonstrate the possible effects of current policies of allocating vacancies for interns and residents as well as to describe several measures and alternative policies.</p> <p>METHODS: Using the methodology of System Dynamics, we designed a simulation model of the allocation process. Based on the validated model, possible changes in the system through time in response to diverse allocation policies were simulated. Specifically, changes in the accumulated number of graduates who over the years have remained without specialty, the number of unemployed specialists, and the imbalance between supply and demand in the period under consideration were observed.</p> <p>RESULTS: The results obtained from the simulation indicate that allocation policies such as the current one tends to reduce the accumulated number of graduates without specialty, due to the philosophy characterizing this policy, but that it considerably increases the number of unemployed specialists and aggravates the supply-demand imbalance. In the simulation, this tendency remained over time even though more restrictive measures in numerus clausus and retirement age were adopted. Equally, a policy based on social needs and aware of delays in training would substantially contribute to eliminating unemployment among specialists and supply-demand imbalance over time. If such a policy were combined with the above-mentioned measures the results would be even better, more rapidly eliminating graduates without specialty, unemployed specialists, and supply-demand imbalances.</p> <p>CONCLUSIONS: If the Health Administration continues with the current system of allocation of places, the present imbalance in supply and demand will become even worse. Therefore, new and far-sighted measures and policies are required, as well as greater coordination between undergraduate and postgraduate training.</p>
[3]	Ansah JP, Kornre DD, Bayer S, Pan C, Jayabaskar T, Matchar DB, Lew N, Phua A, Koh V, Lamoureaux E & Quek D (2015)	Future requirements for and supply of ophthalmologists for an aging population in Singapore	SGP	<p>BACKGROUND: Singapore's population, as that of many other countries, is aging; this is likely to lead to an increase in eye diseases and the demand for eye care. Since ophthalmologist training is long and expensive, early planning is essential. This paper forecasts workforce and training requirements for Singapore up to the year 2040 under several plausible future scenarios.</p> <p>METHODS: The Singapore Eye Care Workforce Model was created as a continuous time compartment model with explicit workforce stocks using system dynamics. The model has three modules: prevalence of eye disease, demand, and workforce requirements. The model is used to simulate the prevalence of eye diseases, patient visits, and workforce requirements for the public sector under different scenarios in order to determine training requirements.</p> <p>RESULTS: Four scenarios were constructed. Under the baseline business-as-usual scenario, the required number of ophthalmologists is projected to increase by 117% from 2015 to 2040. Under the current policy scenario (assuming an increase of service uptake due to increased awareness, availability, and accessibility of eye care services), the increase will be 175%, while under the new model of care scenario (considering the additional effect of providing some services by non-ophthalmologists) the increase will only be 150%. The moderated workload scenario (assuming in addition a reduction of the clinical workload) projects an increase in the required number of ophthalmologists of 192% by 2040. Considering the uncertainties in the projected demand for eye care services, under the business-as-usual scenario, a residency intake of 8–22 residents per year is required, 17–21 under the current policy scenario, 14–18 under the new model of care scenario, and, under the moderated workload scenario, an intake of 18–23 residents per year is required.</p> <p>CONCLUSIONS: The results show that under all scenarios considered, Singapore's aging and growing population will result in an almost doubling of the number of Singaporeans with eye conditions, a significant increase in public sector eye care demand and, consequently, a greater requirement for ophthalmologists.</p>

[4]	Barber P & López-Valcárcel BG (2010)	Forecasting the need for medical specialists in Spain: application of a system dynamics model	ESP	<p>BACKGROUND: Spain has gone from a surplus to a shortage of medical doctors in very few years. Medium and long-term planning for health professionals has become a high priority for health authorities.</p> <p>METHODS: We created a supply and demand/need simulation model for 43 medical specialties using system dynamics. The model includes demographic, education and labour market variables. Several scenarios were defined. Variables controllable by health planners can be set as parameters to simulate different scenarios. The model calculates the supply and the deficit or surplus. Experts set the ratio of specialists needed per 1000 inhabitants with a Delphi method.</p> <p>RESULTS: In the scenario of the baseline model with moderate population growth, the deficit of medical specialists will grow from 2% at present (2800 specialists) to 14.3% in 2025 (almost 21 000). The specialties with the greatest medium-term shortages are Anaesthesiology, Orthopaedic and Traumatic Surgery, Paediatric Surgery, Plastic Aesthetic and Reparatory Surgery, Family and Community Medicine, Paediatrics, Radiology, and Urology.</p> <p>CONCLUSIONS: The model suggests the need to increase the number of students admitted to medical school. Training itineraries should be redesigned to facilitate mobility among specialties. In the meantime, the need to make more flexible the supply in the short term is being filled by the immigration of physicians from new members of the European Union and from Latin America.</p>
[5]	Barlet M & Cavillon M (2016)	Projection of the supply of nurses in France: a microsimulation model	FRA	<p>As of January 1, 2010, nearly 520,000 nurses working in France are listed in the Adeli directory. The number of nurses in this profession has multiplied by 1.7 in 20 years. They have grown at a much higher rate than the population. As a result, the density of nurses has increased significantly. In 2010, there were more than 800 active nurses per 100,000 inhabitants. This profession, which is predominantly female (88% of the workforce), works mainly in public hospitals (49% of the workforce) and, unlike doctors, has a stable average age. Nurses, especially private practice nurses, are not well distributed between regions and these strong spatial inequalities have not been reduced in the last 10 years. Regional migrations are infrequent but always to the benefit (or detriment) of certain regions. Classically, the southern regions benefit from these migratory flows. Men are more inclined to change their mode of practice and to choose to set up in private practice. Finally, salaried nurses in public hospitals stop working on average at the age of 56, salaried nurses in private hospitals at 59 and self-employed nurses at 61.</p>
[6]	Chalk D & Legg A (2017)	What factors are driving increasing demand for community nursing?	UK	<p>Demand for district nursing services is increasing significantly. With increasing economic pressures, services are struggling to meet increases in demand, and are looking to become more proactive in planning for future demand. Traditional quantitative forecasting methods have limited use, because of the complexity of inter-linking factors that potentially drive demand for community services. Qualitative system dynamics approaches can be useful to model the complex interplay of causal factors leading to an effect, such as increased demand for services, and identify particular areas of concern for future focus. We ran a facilitated qualitative system dynamics workshop with representatives working across community nursing services in Cornwall. The generated models identified 7 key areas of concern that could be significantly contributing to demand for district nursing services. We outline the identified problem areas in this paper, and discuss potential recommendations to reduce their effects based on causal links identified in the models.</p>
[7]	Chung MH, Hung KC, Chiou JF, Fang HF & Chiu CH (2021)	Nursing manpower forecast for cancer patients	TWN	<p>BACKGROUND AND OBJECTIVES: This paper presents a dynamic model aimed at predicting nursing manpower requirements for cancer care over the next ten years. The proposed model, based on the Taiwan Health Insurance Database (2000 to 2010), is meant to serve as a reference in establishing policy for government health units.</p> <p>METHODS: The proposed prediction model uses fuzzy sets to replace definite values with interval values in order to account for uncertainties in real-world data and enhance the flexibility of prediction results.</p> <p>RESULTS: Our results suggest that the demand for nursing manpower for cancer care will grow steadily in the foreseeable future. The gap between the demand for nursing staff and the supply is expected to peak in 2027. By then, the number of oncologists is expected to reach 7,083 (54.32% of the total number of in-hospital physicians), but the number of oncology nurses will be less than 26,297 (56.5% of the total healthcare manpower). It is also expected that there will be fewer than 1,613 outpatient physicians (71.81% of the total number of physicians) and fewer than 4,967 outpatient nurses (68.46% of the total nursing manpower).</p> <p>CONCLUSIONS: This paper provides a valuable reference for government agencies involved in the nursing manpower planning to improve the quality of nursing care.</p>
[8]	De Silva D (2017)	How many doctors should we train for Sri Lanka? System dynamics modelling for training needs	LKA	<p>INTRODUCTION: Over the years, Sri Lanka has achieved remarkable health gains for the money spent on health. Currently about 1450 doctors enter the health system annually. While some advocate opening up of new medical schools to address an apparent shortage of doctors in the country, others argue against it.</p> <p>OBJECTIVE: To identify the number of doctors Sri Lanka need.</p> <p>METHODOLOGY: System dynamics, an analytical modelling approach and a methodology for studying complex feedback systems was used. Two sub models of "need" and "supply" were developed and simulated for a period of 15 years from 2017 to 2032</p> <p>RESULTS: At present the doctor to population ratio is 1:671 and 91% of the need has been met. This study shows that currently there is a shortage of doctors in the country. However, the supply will match the need by 2025/26. Increasing the number of doctors, will result in oversupply of doctors towards the latter part of the next decade.</p> <p>CONCLUSIONS: There is no acute necessity to open up new Medical Schools. However comprehensive health workforce analysis needs to be done once in 5 years and the number of doctors to be trained, decided accordingly.</p>

[9]	De Silva MD (2017)	How many Medical specialists do Ministry of Health - Sri Lanka need by 2025: Use of system dynamics modelling for policy decisions	LKA	<p>INTRODUCTION: The Ministry of Health is the largest health care provider in Sri Lanka in terms of funding, coverage and human resources. Long duration and high training cost of a medical specialist highlights the importance of health human resource planning. Ministry of Health, Sri Lanka has no scientific cadre planning for medical specialists.</p> <p>METHODS: System dynamics, an analytical modelling approach and a methodology for studying complex feedback systems was used. Two sub models of "need" and "supply" were developed and simulated over a period of 10 years from 2016 to 2025.</p> <p>RESULTS: By December 2015 there were 1860 clinician medical specialists with an average age of 46.8 years, in the government hospitals in Sri Lanka. In the surgical group of specialties, the Proposed Training Rate is more than Current Training Rate while in Medical and Paediatric groups and in Radiology, Anaesthesiology, Psychiatry, Dermatology and Haematology Proposed Training Rate is less than the Current Training Rate.</p> <p>CONCLUSIONS: In Surgical specialties the number of trainees enrolled in the Pre-MD programme should be increased from 55 to 71 and while in medical specialties the number of trainees enrolled in Pre- MD programmes should be reduced from 107 to 68 and in the Paediatric specialties from 47 to 39. During the 2016-2025 period, 765 specialists will be lost to the Ministry of Health costing nearly Rs 7.6 billion and there will be 4050 consultants by 2025, which is a 120% increase.</p>
[10]	Dill MJ & Hirsch GB (2021)	The Association of American Medical Colleges' Local Area Physician Workforce Modeling Project	USA	<p>Physician workforce planning must address multiple concerns such as having sufficient numbers and adequate geographic distribution of physicians and pressures for physicians to adapt to new models of care and payment. Though there are national workforce planning tools, planning tools for local areas have been scarce. This article describes a dynamic simulation model developed as a pilot project to support physician workforce planning in 2 metropolitan areas, Cleveland and Albuquerque (February 2014-June 2016). This model serves as a prototype for planning tools that could be used by medical educators and local health systems to project the effect of different policies on physician supply and demand. System dynamics and group model building approaches were used to develop the model with the participation of local stakeholders to create the model's causal structure. The model included determinants of the demand for primary and specialty care for the local population and projected the effects of births and deaths, aging, level of chronic illness present, and migration on demand. Physician supply was disaggregated by primary versus specialty care, age, sex, and work setting and projected based on completions of local residency programs, physician migration in and out of the area, and retirements. Feedback relationships between supply and demand (e.g., adequacy of care affecting the distribution of chronic illnesses, demand for care influencing in- and out-migration of physicians) were also included and had important effects on the results produced by the model. Scenarios were simulated that projected increased demand for care (e.g., through expanded insurance coverage) and increased supply (e.g., through practice incentives to encourage in-migration) and a combination of these. An expanded advanced practice registered nurse and physician assistant capacity scenario was also simulated. In Albuquerque, the combination scenario yielded the greatest increases in local physician supply.</p>
[11]	Edwards JP, Datta I, Hunt JD, Stefan K, Ball CG, Dixon E & Grondin SC (2014)	A novel approach for the accurate prediction of thoracic surgery workforce requirements in Canada	CAN	<p>OBJECTIVE: To develop a microsimulation model of thoracic surgery workforce supply and demand to forecast future labour requirements.</p> <p>METHODS: The Canadian Community Health Survey and Canadian Census data were used to develop a microsimulation model. The demand component simulated the incidence of lung cancer; the supply component simulated the number of practicing thoracic surgeons. The full model predicted the rate of operable lung cancers per surgeon according to varying numbers of graduates per year.</p> <p>RESULTS: From 2011 to 2030, the Canadian national population will increase by 10 million. The lung cancer incidence rates will increase until 2030, then plateau and decline. The rate will vary by region (12.5% in Western Canada, 37.2% in Eastern Canada) and will be less pronounced in major cities (10.3%). Minor fluctuations in the yearly thoracic surgery graduation rates (range, 4-8) will dramatically affect the future number of practicing surgeons (range, 116-215). The rate of operable lung cancer varies from 35.0 to 64.9 cases per surgeon annually. Training 8 surgeons annually would maintain the current rate of operable lung cancer cases per surgeon per year (range, 32-36). However, this increased rate of training will outpace the lung cancer incidence after 2030.</p> <p>CONCLUSIONS: At the current rate of training, the incidence of operable lung cancer will increase until 2030 and then plateau and decline. The increase will outstrip the supply of thoracic surgeons, but the decline after 2030 will translate into an excess future supply. Minor increases in the rate of training in response to short-term needs could be problematic in the longer term. Unregulated workforce changes should, therefore, be approached with care.</p>

[12]	Edwards JP, Datta I, Hunt JD, Stefan K, Ball CG, Dixon E & Grondin SC (2016)	Forecasting the impact of stereotactic ablative radiotherapy for early-stage lung cancer on the thoracic surgery workforce	CAN	<p>OBJECTIVES: To predict variation in thoracic surgery workforce requirements with the introduction of stereotactic ablative radiotherapy (SABR) for the treatment of early-stage non-small-cell lung cancer (NSCLC).</p> <p>METHODS: Using Canadian census microdata and the Canadian Community Health Survey, a microsimulation model representing the national population was developed. The demand component simulates the incidence of lung cancer, incorporating the impact of computed tomography (CT) screening for high-risk individuals (>30 pack-year smoking history; age 55-74 years). The supply component simulates the number of thoracic surgeons. SABR was introduced into the model to predict changes in the number of operable NSCLC cases per thoracic surgeon, modelling 30, 60 and 90% compliance with SABR for Stage IA and then for both Stage IA and IB NSCLC.</p> <p>RESULTS: In the absence of SABR, the volume of operative NSCLC per surgeon increases by a peak of 49.4% (by 2027) and then gradually declines to the present-day volume by 2049. More dramatic decreases are seen with increasing compliance with SABR for Stage IA/IB NSCLCs. If the number of new surgeons entering the workforce per year were reduced by 33%, the operative volume per surgeon would increase by a peak of 57.1% (30% Stage IA SABR compliance) and would decrease by up to 49.1% (90% Stage IA SABR compliance).</p> <p>CONCLUSIONS: With the implementation of SABR for treatment of early NSCLC, there would be a decrease in operative volume. The impact would depend on the stage of NSCLC for which SABR is recommended and on compliance. A national strategy for thoracic surgery workforce planning is necessary, given the complex interaction of CT screening and the treatment of medically operable early NSCLC with SABR.</p>
[13]	Gresenz CR, Auerbach DI & Duarte F (2013)	Opportunities and challenges in supply-side simulation: physician-based models.	USA	<p>OBJECTIVE: To provide a conceptual framework and to assess the availability of empirical data for supply-side microsimulation modelling in the context of health care.</p> <p>DATA SOURCES: Multiple secondary data sources, including the American Community Survey, Health Tracking Physician Survey, and SK&A physician database.</p> <p>STUDY DESIGN: We apply our conceptual framework to one entity in the health care market-physicians-and identify, assess, and compare data available for physician-based simulation models.</p> <p>PRINCIPAL FINDINGS: Our conceptual framework describes three broad types of data required for supply-side microsimulation modelling. Our assessment of available data for modelling physician behaviour suggests broad comparability across various sources on several dimensions and highlights the need for significant integration of data across multiple sources to provide a platform adequate for modelling. A growing literature provides potential estimates for use as behavioural parameters that could serve as the models' engines. Sources of data for simulation modelling that account for the complex organizational and financial relationships among physicians and other supply-side entities are limited.</p> <p>CONCLUSIONS: A key challenge for supply-side microsimulation modelling is optimally combining available data to harness their collective power. Several possibilities also exist for novel data collection. These have the potential to serve as catalysts for the next generation of supply-side-focused simulation models to inform health policy.</p>
[14]	HENSE (2012)	Review of Medical and Dental School Intakes in England	UK	This review considers whether the current levels of medical and dental student intakes are in line with the predicted future workforce requirements and makes recommendations for the future.
[15]	Ishikawa T, Fujiwara K, Ohba H, Suzuki T & Ogasawara K (2017)	Forecasting the regional distribution and sufficiency of physicians in Japan with a coupled system dynamics-geographic information system model	JPN	<p>BACKGROUND: In Japan, the shortage of physicians has been recognized as a major medical issue. In our previous study, we reported that the absolute shortage will be resolved in the long term, but maldistribution among specialties will persist. To address regional shortage, several Japanese medical schools increased existing quota and established "regional quotas." This study aims to assist policy makers in designing effective policies; we built a model for forecasting physician numbers by region to evaluate future physician supply-demand balances.</p> <p>METHODS: For our case study, we selected Hokkaido Prefecture in Japan, a region displaying disparities in healthcare services availability between urban and rural areas. We combined a system dynamics (SD) model with geographic information system (GIS) technology to analyse the dynamic change in spatial distribution of indicators. For Hokkaido overall and for each secondary medical service area (SMSA) within the prefecture, we analysed the total number of practicing physicians. For evaluating absolute shortage and maldistribution, we calculated sufficiency levels and Gini coefficient. Our study covered the period 2010-2030 in 5-year increments.</p> <p>RESULTS: According to our forecast, physician shortage in Hokkaido Prefecture will largely be resolved by 2020. Based on current policies, we forecast that four SMSAs in Hokkaido will continue to experience physician shortages past that date, but only one SMSA would still be understaffed in 2030.</p> <p>CONCLUSION: The results show the possibility that diminishing imbalances between SMSAs would not necessarily mean that regional maldistribution would be eliminated, as seen from the sufficiency levels of the various SMSAs. Urgent steps should be taken to place doctors in areas where our forecasting model predicts that physician shortages could occur in the future</p>

[16]	Ishikawa T, Ohba H, Yokooka Y, Nakamura K & Ogasawara K (2013)	Forecasting the absolute and relative shortage of physicians in Japan using a system dynamics model approach	JPN	<p>BACKGROUND: In Japan, a shortage of physicians, who serve a key role in healthcare provision, has been pointed out as a major medical issue. The healthcare workforce policy planner should consider future dynamic changes in physician numbers. The purpose of this study was to propose a physician supply forecasting methodology by applying system dynamics modelling to estimate future absolute and relative numbers of physicians.</p> <p>METHOD: We constructed a forecasting model using a system dynamics approach. Forecasting the number of physician was performed for all clinical physician and OB/GYN specialists. Moreover, we conducted evaluation of sufficiency for the number of physicians and sensitivity analysis.</p> <p>RESULT & CONCLUSION: As a result, it was forecast that the number of physicians would increase during 2008-2030 and the shortage would resolve at 2026 for all clinical physicians. However, the shortage would not resolve for the period covered. This suggests a need for measures for reconsidering the allocation system of new entry physicians to resolve maldistribution between medical departments, in addition, for increasing the overall number of clinical physicians.</p>
[17]	Joyce CM, McNeil JJ & Stoelwinder JU (2006)	More doctors, but not enough: Australian medical workforce supply 2001–2012	AUS	<p>OBJECTIVE: To project the future size of the Australian medical workforce, from 2001 to 2012.</p> <p>DESIGN AND SETTING: Stochastic simulation modelling of the Australian medical workforce, taking into account recent increases in medical school capacity and trends in the intake of foreign graduates.</p> <p>MAIN OUTCOME MEASURES: Number of full-time equivalent (FTE) medical practitioners per 100 000 persons within various occupation groups from 2001 (baseline) to 2012.</p> <p>RESULTS: The total medical workforce was projected to rise from 53 384 in 2001 to 67,659 by 2012 (95% CI, 63 924–71 036). On a per capita basis, the number of FTE clinicians was projected to rise from 331 per 100 000 persons in 2001 to 382 (95% CI, 359–403) per 100,000 persons in 2012. The general practice workforce was projected to fall from 133 FTE general practitioners per 100 000 persons in 2001, to 129 per 100 000 persons in 2003, and then remain at around this level through to 2012. The specialist workforce was projected to show steady growth, rising from 162 FTE specialists per 100 000 persons in 2001 to 206 (95% CI, 194–218) per 100 000 persons in 2012.</p> <p>CONCLUSIONS: The general practice workforce is likely to face continued chronic shortages, necessitating innovative policy responses to ensure that the community's need for primary medical care is met. Retirement rates are a key determinant of workforce supply, suggesting a need to encourage general practitioners to remain active as long as they remain effective. Further refinement of stochastic models will help facilitate a more proactive approach to workforce planning.</p>
[18]	Kinsella S & Kiersey RA (2016)	Health Workforce Planning Models, Tools and Processes in Five Countries	AUS, NLD, NZ, UK	<p>This evidence review examines examples from the health workforce planning frameworks of other countries to highlight the systems, tools, and models used to implement health workforce planning policy and strategies. The aim is to understand the functional requirements of a successful workforce planning approach. Five countries were chosen for examination during an initial scoping exercise by the Health Research Board based on their similarity in size to Ireland or their scattered rural population. The countries chosen were Australia, the Netherlands, New Zealand, Scotland, and Wales.</p>
[19]	Koichubekov B, Kharin A, Sorokina M, Korshukov I & Omarkulov B (2020)	System dynamics modeling for general practitioner workforce forecasting in Kazakhstan	KAZ	<p>BACKGROUND: Primary health care has been proven to be a highly effective and efficient way to address the main causes and risks of poor health and well-being today, as well as handling the emerging challenges that will threaten health and well-being tomorrow. In our study we used the System Dynamics approach to develop a model for the population and General Practitioner workforce to include multiple inputs and their relationships in the equations for each stock and flow.</p> <p>METHODS: We built the model in the Any Logic software to cover the flow of medical workers, demographic data of the population and the prevalence of the disease over time. Three scenarios were examined for forecasting primary health care personnel resources. The base year for forecasting was 2018, and the modelling was carried out until 2030.</p> <p>RESULTS: All of three scenarios indicate that with the current number of graduated General Practitioners, the shortage of primary care physicians will be exacerbated. In general, the shortage can reach more than 2,000 on a population of 18.3 million (2018).</p> <p>CONCLUSION: The projected shortage of doctors in the primary health care system requires special attention to human resource planning. Only one third of medical graduates in Kazakhstan go to work in the primary health care system. The government needs to develop measures to stimulate and support young medical doctors to become general practitioners.</p>

[20]	Lopes MA, Almeida AS & Almada-Lobo B (2016)	Forecasting the medical workforce: a stochastic agent-based simulation approach	PRT	Starting in the 50s, healthcare workforce planning became a major concern for researchers and policy makers, since an imbalance of health professionals may create a serious insufficiency in the health system, and eventually lead to avoidable patient deaths. As such, methodologies and techniques have evolved significantly throughout the years, and simulation, in particular system dynamics, has been used broadly. However, tools such as stochastic agent-based simulation offer additional advantages for conducting forecasts, making it straightforward to incorporate microeconomic foundations and behaviour rules into the agents. Surprisingly, we found no application of agent-based simulation to healthcare workforce planning above the hospital level. In this paper we develop a stochastic agent-based simulation model to forecast the supply of physicians and apply it to the Portuguese physician workforce. Moreover, we study the effect of variability in key input parameters using Monte Carlo simulation, concluding that small deviations in emigration or dropout rates may originate disparate forecasts. We also present different scenarios reflecting opposing policy directions and quantify their effect using the model. Finally, we perform an analysis of the impact of existing demographic projections on the demand for healthcare services. Results suggest that despite a declining population there may not be enough physicians to deliver all the care an ageing population may require. Such conclusion challenges anecdotal evidence of a surplus of physicians, supported mainly by the observation that Portugal has more physicians than the EU average.
[21]	Morgan, JS & Graber-Naidich, A (2019)	Small System Dynamics Model for Alleviating the General Practitioners Rural Care Gap in Ontario, Canada	CAN	The disproportionate concentration of healthcare professionals in urban areas is a concern in many countries, including Canada. A need to address this rural care gap has driven a large number of government-led initiatives worldwide over the years. This paper presents a model that can be used as a tool to examine the efficacy of such policies on the workforce distribution in the long term. A small system dynamics model is employed to simulate the current and future distribution of general physicians at a jurisdictional level. The model represents the transition of general practitioners to provide insight into the dynamics of care provision over time. The movement, and competition, between rural and urban areas is modelled to enable detailed exploration of the ability for proposed measures to alleviate the care gap in the future. Among the tested policies are such commonly used initiatives as financial incentives to rural professionals, promotion of medical education in rural areas, expansion of rural education programs and the engagement of international medical graduates etc. We demonstrate how the model can be used as a tool to determine an efficient and well-chosen combination of policies which can help alleviate the rural care gap in the future, given that some policies are more effective than others alone but also combined with other initiatives. The presented small system dynamics model is tested on Canada's reality, but its simple nature lends itself to easy application to other countries that experience a similar problem.
[22]	Morii et al (2019)	Projecting future supply and demand for physical therapists in Japan using system dynamics	JPN	OBJECTIVES: Japan is the oldest country in the world, and its demand for medical care is expected to increase. Although a clear vision regarding the supply and demand for physical therapy services is necessary, there has been no research that forecasts the supply and demand for physical therapists in Japan. Consensus has not been reached on whether the supply of physical therapists is sufficient. This study projects this supply and demand to provide medical policymakers with basic data. METHODS: A system dynamics model was created to predict the number of physical therapists working in hospitals and clinics in Japan from 2014 to 2040. The future demand for physical therapy was estimated using the rehabilitation service utilization data from Open National Database, a publicly available nationwide health claims database. Sufficiency rates (supply/demand) were calculated, and sensitivity analysis was conducted on supply-related parameters. RESULTS: The number of physical therapists was projected to be 1.74 and 2.54 times greater in 2025 and 2040, respectively, than in 2014. The sufficiency rates were 1.72, 2.39, and 3.30 in 2015, 2025, and 2040, respectively. The sensitivity analysis revealed that attrition rates had the greatest effects on sufficiency. CONCLUSIONS: Although the current supply appears to be needed, considering the expected increase and uncertainty in medical needs. However, there is a possibility of a future oversupply, especially after 2025, when the rate of increase in demand will lessen. Further studies are required to evaluate the distribution of physical therapists among regions and specialties.
[23]	Murphy, GT, S Birch, A MacKenzie, R Alder, A Lethbridge & Little L (2012)	Eliminating the shortage of registered nurses in Canada: An exercise in needs-based planning	CAN	OBJECTIVE: To demonstrate the application of a needs-based framework for health human resources (HHR) planning to illustrate the potential effects of policies on the shortage of Registered Nurses (RNs) in Canada. METHODS: A simulation model was developed to simultaneously estimate the supply of and requirements for RNs based on data on the health needs of Canadians with current service delivery patterns and levels of productivity as a baseline scenario. The potential individual and cumulative effects of various policy scenarios on the 'gap' between these were simulated. RESULTS: A baseline scenario estimated a shortage of about 11,000 RN FTEs in 2007 for Canada, increasing to over 60,000 by 2022. However, multifaceted approaches have the potential to eliminate the estimated shortage. Conclusions: Estimating the requirements for health human resources must explicitly consider population health needs, levels of service delivery and HHR productivity while changing supply to meet requirements involves consideration of a broad range of comprehensive interventions. Investments in improved data collection and planning tools are needed to support more effective HHR planning. The estimated Canadian shortage of RNs based on current circumstances can be resolved in the short to medium term through modest improvements in RN retention, activity and productivity.

[24]	Rafiei S, Daneshvaran A & Abdollahzade S (2018)	Forecasting the shortage of neurosurgeons in Iran using a system dynamics model approach	IRN	<p>CONTEXT: Shortage of physicians particularly in specialty levels is considered as an important issue in Iran health system. Thus, in an uncertain environment, long-term planning is required for health professionals as a basic priority on a national scale.</p> <p>AIMS: This study aimed to estimate the number of required neurosurgeons using system dynamic modelling.</p> <p>SETTING AND DESIGN: System dynamic modelling was applied to predict the gap between stock and number of required neurosurgeons in Iran up to 2020.</p> <p>SUBJECTS AND METHODS: A supply and demand simulation model was constructed for neurosurgeons using system dynamic approach. The demand model included epidemiological, demographic, and utilization variables along with supply model-incorporated current stock of neurosurgeons and flow variables such as attrition, migration, and retirement rate. STATISTICAL ANALYSIS USED: Data were obtained from various governmental databases and were analysed by Vensim PLE Version 3.0 to address the flow of health professionals, clinical infrastructure, population demographics, and disease prevalence during the time.</p> <p>RESULTS: It was forecasted that shortage in number of neurosurgeons would disappear at 2020. The most dominant determinants on predicted number of neurosurgeons were the prevalence of neurosurgical diseases, the rate for service utilization, and medical capacity of the region. CONCLUSIONS: Shortage of neurosurgeons in some areas of the country relates to maldistribution of the specialists. Accordingly, there is a need to reconsider the allocation system for health professionals within the country instead of increasing the overall number of acceptance quota in training positions.</p>
[25]	Relić D & Božikov J (2020)	Application of a system dynamics model in forecasting the supply and age distribution of physicians	HRV	<p>AIM: To predict the future supply and age distribution of physicians with a simulation model, which can be used as an advising tool for policymakers who decide on enrolment and specialization training (ST) quotas at the national level.</p> <p>METHODS: A simulation model was created using the system dynamics (SD) method. Changes in the number of physicians and their age distribution were projected in the context of the expected future changes of the Croatian population under different scenarios covering the period from 2017 to 2041.</p> <p>RESULTS: The two scenarios showed that Croatia would not face physician shortage in the future. The scenario 1 projected that Croatia would certainly reach the current European Union (EU) average of 360 physicians per 100 000 inhabitants by 2021, and that this figure would increase to 430 per 100 000 inhabitants by 2041. The scenario 2 suggested a similar trend, with Croatia reaching the current EU average by 2021 and the number of physicians increasing to 451 per 100 000 inhabitants by 2041. Both scenarios indicated that the Croatian physicians' age distribution will recover in favour of younger age groups of specialists.</p> <p>CONCLUSION: There is no need to increase the enrolment into the medical schools to ensure sufficient number of physicians per capita in Croatia, but it is necessary to keep the recently reached level of 550 licenses for ST per year. The developed dynamic model is available online and can be adapted to the analysis of different scenarios in different health care systems.</p>
[26]	Ricketts TC, Adamson WT, Fraher EP, Knapton A, Geiger JD, Abdullah F & Klein MD (2017)	Future Supply of Pediatric Surgeons: Analytical Study of the Current and Projected Supply of Pediatric Surgeons in the Context of a Rapidly Changing Process for Specialty and Subspecialty Training	USA	<p>OBJECTIVE: To describe the future supply and demand for paediatric surgeons using a physician supply model to determine what the future supply of paediatric surgeons will be over the next decade and a half and to compare that projected supply with potential indicators of demand and the growth of other subspecialties.</p> <p>BACKGROUND: Anticipating the supply of physicians and surgeons in the future has met with varying levels of success. However, there remains a need to anticipate supply given the rapid growth of specialty and subspecialty fellowships. This analysis is intended to support decision making on the size of future fellowships in paediatric surgery.</p> <p>METHODS: The model used in the study is an adaptation of the FutureDocs physician supply and need tool developed to anticipate future supply and need for all physician specialties. Data from national inventories of physicians by specialty, age, sex, activity, and location are combined with data from residency and fellowship programs and accrediting bodies in an agent-based or microsimulation projection model that considers movement into and among specialties. Exits from practice and the geographic distribution of physician and the patient population are also included in the model. Three scenarios for the annual entry into paediatric surgery fellowships (28, 34, and 56) are modelled and their effects on supply through 2030 are presented.</p> <p>RESULTS: The FutureDocs model predicts a very rapid growth of the supply of surgeons who treat paediatric patients-including general paediatric surgeon and focused subspecialties. The supply of all paediatric surgeons will grow relatively rapidly through 2030 under current conditions. That growth is much faster than the rate of growth of the paediatric population. The volume of complex surgical cases will likely match this population growth rate meaning there will be many more surgeons trained for those procedures. The current entry rate into paediatric surgery fellowships (34 per year) will result in a slowing of growth after 2025, a rate of 56 will generate a continued growth through 2030 with a likely plateau after 2035.</p> <p>CONCLUSIONS: The rate of entry into paediatric surgery will continue to exceed population growth through 2030 under two likely scenarios. The very rapid anticipated growth in focused paediatric subspecialties will likely prove challenging to surgeons wishing to maintain their skills with complex cases as a larger and more diverse group of surgeons will also seek to care for many of the conditions and patients which the general paediatric surgeons and general surgeons now see. This means controlling the numbers of paediatric surgery fellowships in a way that recognizes problems with distribution, the volume of cases available to maintain proficiency, and the dynamics of retirement and shifts into other specialty practice.</p>

[27]	Senese F, Tubertini P, Mazzocchi A, Lodi A, Ruozzi C & Grilli R (2015)	Forecasting future needs and optimal allocation of medical residency positions: the Emilia-Romagna Region case study	ITA	<p>OBJECTIVES: Italian regional health authorities annually negotiate the number of residency grants to be financed by the National government and the number and mix of supplementary grants to be funded by the regional budget. This study provides regional decision-makers with a requirement model to forecast the future demand of specialists at the regional level.</p> <p>METHODS: We have developed a system dynamics (SD) model that projects the evolution of the supply of medical specialists and three demand scenarios across the planning horizon (2030). Demand scenarios account for different drivers: demography, service utilization rates (ambulatory care and hospital discharges) and hospital beds. Based on the SD outputs (occupational and training gaps), a mixed integer programming (MIP) model computes potentially effective assignments of medical specialization grants for each year of the projection.</p> <p>RESULTS: To simulate the allocation of grants, we have compared how regional and national grants can be managed in order to reduce future gaps with respect to current training patterns. The allocation of 25 supplementary grants per year does not appear as effective in reducing expected occupational gaps as the re-modulation of all regional training vacancies.</p>
[28]	Streeter RA, Zangaro GA & Chattopadhyay A (2017)	Perspectives: Using Results from HRSA's Health Workforce Simulation Model to Examine the Geography of Primary Care	USA	<p>OBJECTIVE: Inform health planning and policy discussions by describing Health Resources and Services Administration's (HRSA's) Health Workforce Simulation Model (HWSM) and examining the HWSM's 2025 supply and demand projections for primary care physicians, nurse practitioners (NPs), and physician assistants (PAs).</p> <p>DATA SOURCES: HRSA's recently published projections for primary care providers derive from an integrated microsimulation model that estimates health workforce supply and demand at national, regional, and state levels.</p> <p>PRINCIPAL FINDINGS: Thirty-seven states are projected to have shortages of primary care physicians in 2025, and nine states are projected to have shortages of both primary care physicians and PAs. While no state is projected to have a 2025 shortage of primary care NPs, many states are expected to have only a small surplus.</p> <p>CONCLUSIONS: Primary care physician shortages are projected for all parts of the United States, while primary care PA shortages are generally confined to Midwestern and Southern states. No state is projected to have shortages of all three provider types. Projected shortages must be considered in the context of baseline assumptions regarding current supply, demand, provider-service ratios, and other factors. Still, these findings suggest geographies with possible primary care workforce shortages in 2025 and offer opportunities for targeting efforts to enhance workforce flexibility.</p>
[29]	Vanderby SA, Carter MW, Latham T, Ouzounian M, Hassan A, Tang GH, Teng CJ, Kingsbury K, Feindel CM (2010)	Modeling the cardiac surgery workforce in Canada	CAN	<p>BACKGROUND: Limited employment opportunities for recently trained cardiac surgeons are deterring medical students from entering cardiac surgery residency programs. Given the lengthy training period and the aging of both the general population and currently practicing cardiac surgeons, this reduced enrolment raises concerns about the adequacy of the future cardiac surgery workforce. A workforce model was developed to explore the future need for cardiac surgeons in Canada.</p> <p>METHODS: A novel system dynamics model was developed to simulate the supply and demand for cardiac surgery in Canada between 2008 and 2030 to identify whether an excess or shortage of surgeons would exist. Several different scenarios were examined, including varying surgeon productivity, revascularization rates, and residency enrolment rates.</p> <p>RESULTS: The simulation results of various scenarios are presented. In the base case, a surgeon shortage is expected to develop by 2025, although this depends on surgeons' response to demand-supply gap changes. An alternative scenario in which residency enrolment directly relates to the presence of unemployed surgeons also projects substantial shortages after 2021. The model results indicate that if residency enrolment rates remain at the 2009 level an alarming shortage may develop soon, possibly reaching almost 50% of the Canadian cardiac surgical workforce.</p> <p>CONCLUSIONS: These workforce model results project an eventual cardiac surgeon shortage in Canada. This study highlights the possibility of a crisis in cardiac surgery and emphasizes the urgency with which enrolment into cardiac surgery training programs and the employability of recently trained cardiac surgery graduates need to be addressed.</p>
[30]	Willis, G, A Woodward, and S Cave (2013)	Robust workforce planning for the English medical workforce	UK	<p>This paper describes the use of system dynamics in a major project for the UK Department of Health to inform a review of the intake to medical and dental school. It takes many years to train these professionals (typically 15 years or more for a hospital consultant), so an under or over-supply cannot be corrected quickly or easily. The cost of training and employing an individual is significant so the decisions to be made are highly important. The system dynamics approach meant that robust, evidence-based supply and demand models could be created to test potential policies and their impact. It also meant that the model was "transparent" and enabled the expertise of several hundred stakeholders from the healthcare system to be captured and synthesised. Significant decisions were made as a result of this work, including:</p> <ul style="list-style-type: none"> • A 2% reduction in medical school intakes to be introduced with the 2013 intake, with a further review in 2014 • No immediate change to dental school intakes because of issues over data quality highlighted by the modelling, with another review in 2013 • A rolling cycle of reviews of medical and dental student intakes should be established; to be undertaken every three years.

[31]	Wu (2012)	Theoretical System Dynamics Modelling for Taiwan Paediatric Workforce in an Era of National Health Insurance and Low Birth Rates	TWN	<p>BACKGROUND: In an era of declining birth rates and a single-payer health care system, the paediatric workforce might overreact to its demands. System dynamics (SD) were therefore applied to establish models to predict the future need and demand for the paediatric workforce.</p> <p>MATERIALS AND METHODS: Data of population and workforce were extracted from national databases and models developed using Vensim software.</p> <p>RESULTS: In the past decade, the child-to-paediatrician ratio correlated with infant mortality in Taiwan ($p < 0.001$, $r^2 = 0.88$, child-to-paediatrician ratio $Z = 146$ $p = 354$ infant mortality/1000 live births). Currently, the child-to-paediatrician ratio is 1742:1. Using the Millennium Development Goals (2.437/1000 live births) for infant mortality, the child-to-paediatrician ratio was estimated as 1009:1. The paediatric population model incorporated the birth and mortality rates in each age category, accurately predicted population changes between 1974 and 2010, and projected a decreasing trend until 2017. The paediatric workforce model, which considered rates of enrolment, completion, certification, and retention, predicted a decrease in the supply of paediatricians in the mid-2010s that could be delayed by policy incentives. When targeting the base scenario, the model indicated that discrepancies between demands and supply of paediatricians would occur in the late 2010s toward 2020. When targeting the Millennium Development Goals scenario, however, the discrepancies would be consistent.</p>
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