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MIND THE GAP?

Projecting demand and supply for healthcare professionals

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1 Introduction

Manpower or workforce planning, which is defined as “ensuring that the right people are available to deliver the right services to the right people at the right time” (1), is believed to be the appropriate approach to tackling the allocative and technical efficiency issues associated with the ‘production’ function of healthcare. Human resources for health (HRH) planning and forecasting is an important strategic objective in many countries and often reflects an increasing mismatch between the need/demand for and supply of healthcare professionals at regional as well as national levels.

Historically, HRH forecasting has been weakly linked to national health policies and population health needs. It was based on the assumption that more healthcare input produced better health, and was done by modelling supply, demand and need for manpower independently (2-4).

HRH forecasting is extremely complex and often framed by healthcare financing models and resources allocated to healthcare, service delivery models, the level and mix of healthcare services, controls on the volume and appropriateness of clinical activity, productivity, elasticity of supply, work-force complementarity and substitution (3, 5). Comprehensive forecasting models combine economic concepts with determinants of health, the peculiarities of the medical environment, and training time lags (6).

Modelling is an essential tool for manpower projections. Depending on the underlying assumptions, the models adopted may be deterministic or stochastic. Deterministic models are used when the outcome is certain, whereas stochastic models allow for uncertainty and flexibility in the model and deliver different results over multiple runs. Over time stochastic models are believed to reveal the most likely outcome, but they are more computational involved, use complex programming, and present analytical challenges. There are, however, also methodological limitations in these stochastic models including the lack of easily accessible clinical, administrative and provider databases for modelling, as well as conceptual challenges. Many of these models are of variable quality, and/or project only for (a) specific diseases(s) or professional group only. The quantity and quality of the data will directly determine how accurately the model reflects the real situation and therefore the reliability of the projections (7).

Considering the many factors that shape projection models (e.g. availability and quality of data, assumptions regarding characteristics of population change and growth, developments in medical technology, and/or clinical practice) selecting the model structure and attributes most suitable for the setting is essential. A number of projection models are described in the formal academic and grey literature; however, a comprehensive “gold standard” that fits all situations equally well remains elusive. There is little consensus on the best methods for estimating healthcare manpower in the literature. The most common approaches include workforce-population ratios, need-based, demand/utilisation-based, and supply models (8). Each method has its strengths and limitations and requires many compromises, simplifications, and assumptions.

2 Setting the scene

2.1 Models for policy level planning

2.1.1 Need-based models

Need-based models allow for estimates of true population need by considering changes in health status and efficacy of healthcare services (3, 8, 9) while adjusting for population size and characteristics including age, sex, household income, risk behaviour, and self-perceived health. These models project healthcare deficits as well as healthcare service need (both professional staff or quality of service to an optimum standard). As need-based approaches have greater data demands than approaches based on supply or utilisation, epidemiological data is an important limiting factor. For these models, detailed information on the efficacy of individual medical services for specific medical conditions is required (8). Although need-based models usually cannot account for historically unmet need they can avoid perpetuating existing inequity and inefficiency within the healthcare delivery system, a common problem with other forecasting models, however, the assumption that healthcare resources will be used in accordance with relative levels of need is seldom verified.

2.1.2 Demand/utilisation-based models

Demand/utilisation models are built on service utilisation data (8), under the assumption that healthcare workload remains constant over time, and population growth directly leads to increased workload (4, 9). Demand models commonly include 1) estimates of healthcare demand or at least historical utilisation patterns (most frequently by diagnosis), 2) anticipated change in practice patterns, 3) the impact of current and emerging technologies, and 4) policy change. The projections are often limited to age and sex although other characteristics of the population, market conditions, institutional arrangements, and patterns of morbidity may be included. Previous demand models have often assumed that doctors were required for all demanded service, current demand was appropriate, age and sex specific resource requirements were constant; and demographic change was predictable over time (8).

2.1.3 Benchmarking

Benchmarks refer to a current best estimate of a reasonable workforce. These estimates are valid for comparison only if communities and healthcare planning are comparable, i.e. adjusted for key demographic, health and health system parameters. Estimates of manpower requirements are based on healthcare worker-to-population ratios and current healthcare services. For such models to be relevant adjustments for differences in population demography, population health, health insurance, productivity and health system organization are important (8).

2.1.4 Trend analysis

Based on aggregate level, and time series historical data, trend analysis uses observed historical population growth and ageing trends for predicting future trends. It is a macro simulation based on the extrapolation of past trends. Trend analysis is often useful for projecting likely growth particularly in the private sector (7, 10). These models assume 1) a causal relationship between economic growth and the number of doctors per capita, 2) that future requirements will reflect current requirements (e.g. the current level, mix, and distribution of providers are sufficient), 3) productivity remains constant, and 4) demographic profiles (such as population growth) are consistent with observed trends (8, 11). Some argue these models have 'labour myopia' and should be revised to include determinants of doctor productivity and elasticity of labour supply for different provider groups (5). These models do not consider the evolution of the demand for care.

2.2 Learning from international organisations

2.2.1 World Health Organisation

The mission of the Department of Human Resources for Health, World Health Organisation (WHO), is to "provide equitable access for all people to an adequately trained, skilled, and supported health workforce to contribute towards the attainment of the highest possible level of health" (12). The strategic direction of the department is to provide technical and administrative coordination through several priority programmes one of which is the Health Workforce Information and Governance team. This team provides countries and other healthcare partners policy and planning advice, and technical support in the form of tools, guidelines, norms and standards on health workforce assessment, planning, monitoring and evaluation (7, 13-21). The WHO has identified three fundamental principles associated with the integration of healthcare service and the development of health personnel (13). First, the planning, production, and management functions for HRH must go together. Second, human resources are to serve the needs of the health system. Third, the health system must serve the people's needs. The WHO has developed a conceptual framework for HRH projection which pulls all these activities together. It consists of 4 different phases including: 1) situation analysis, 2) planning, 3) implementation, and 4) monitoring and evaluation (22). While the

HRH framework is applicable in all countries, its application will be influenced by elements specific to the country context. Figure 2.1 provides the outline adopted by the WHO to identify the mechanism by which balance in the requirements (demand for healthcare provision) and the supply can be achieved.

The WHO uses simulation as the tool to assess the potential impact of various strategies on change in the model outcomes. Both deterministic and stochastic processes can be applied to this model. Typically the variables included in these models are demographic growth and change; health policy and related legislation; technological change; burden of disease; service and provider utilisation; relevant service quality standards; organisational efficiency; skills mix; individual provider performance; public demand and expectations; and availability and means of financing. The most commonly used approaches to project workforce requirements are workforce-to-population; health-needs; service-demand; and service targets methods. Each has its advantages and disadvantages. Although supply side projections are relatively less complex and simpler, careful accounting is needed to ensure all relevant and available workers are included in the estimates. Aspects to consider are the capacity to produce healthcare workers, the different types of healthcare workers needed for future work, loss rates due to retirement, and emigration, death or pre-retirement leaving.

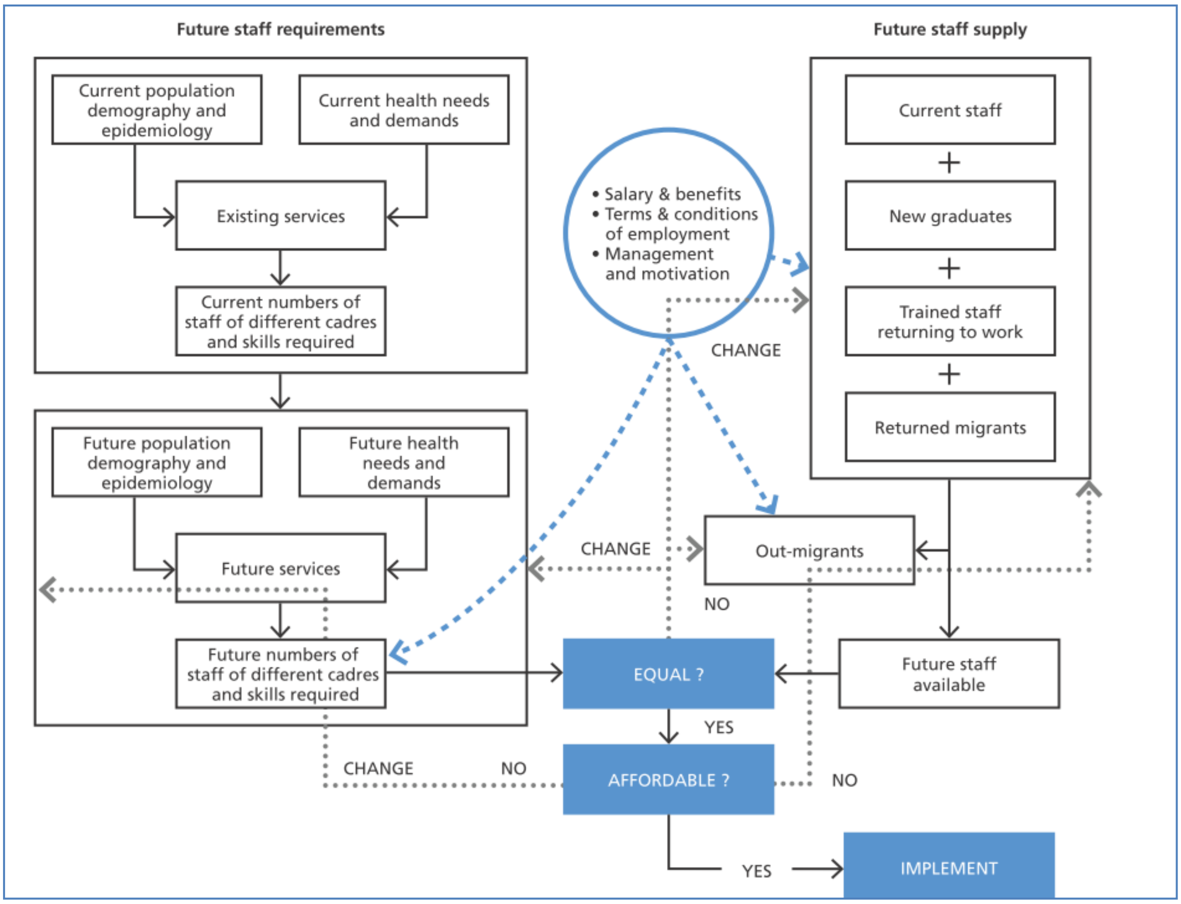

Figure 2.1 (reproduced from WHO original) WHO concepts for linking healthcare workforce requirements and supply projections (7)

2.2.2 Organisation for Economic Cooperation and Development (OECD)

The Health Division of the Directorate for Employment, Labor and Social Affairs of the OECD advises countries on how to meet future demand for health professionals and help countries improve health workforce planning (23). With a focus on doctors and nurses, the OECD has identified trends shaping the current and future health workforce in member states over the past decades in cross-country reports (24) and country-specific health system reviews (25). Both a prolonged increase in the supply of doctors and nurses across member states was identified. Factors identified as influencing the change in demand for doctors and nurses were increasing incomes, changing medical technology, and population ageing. Supply factors influencing the growth rate for doctors were controls on entry into medical school, for nurses capping the number of hospital beds, and for both professions: immigration, emigration, and changes in productivity (26). Factors likely to impact the shape and potential shortage of the future health workforce were: workforce ageing, feminisation, expectations of younger generations in terms of work-life balance, increasing specialisation, and changes in delivery of service such as an increase in day case treatment, and overall declining length of stay (26).

The OECD has also explored specific issues such as the impact of skill-mix and policy change on the health workforce (27), staff shortages (28), and strategies on how to adapt supply to a growing demand within particular workforce specialties (29).

The extensive work undertaken by the WHO and the OECD, and the development of manpower planning and forecasting tools by these organisations, are useful guides for manpower projections in Hong Kong. They provide an excellent source of benchmarking tools in the area of health manpower planning for both developing and developed countries.

2.3 Learning from overseas jurisdictions

To learn from international approaches to workforce planning, nine jurisdictions were selected for review – Australia (30), Canada (31), Japan (32), The Netherlands (33), New Zealand (34), Scotland (35), Singapore (36), United Kingdom (37), and the United States (38, 39) to determine: 1) strategies for national level manpower planning and forecasting; 2) methods used to project population level healthcare professional demand and supply, and 3) methods to improve workforce productivity and capability. **Appendix A (i), (ii) and (iii)** illustrates the context, framework, methods, and assumptions guiding these manpower planning and forecasting models. These jurisdictions were selected for the maturity of their manpower planning models, and comparability of workforce issues to Hong Kong.

2.3.1 Australia

Set up by the Council of Australian Governments and reporting to the Australian Health Ministers' Advisory Council, Health Workforce Australia (HWA) is responsible for projecting the healthcare manpower requirements in Australia, and advising and informing governing bodies on the dynamic changes in the healthcare workforce (30). HWA has adopted a 'models of care' approach based on competencies required for the delivery of the best healthcare. The HWA projects manpower requirements based on the expected change in model parameters (such as changes in immigration, innovation/technology, healthcare and health system reform, as well as skills or roles or healthcare professionals) through scenarios analyses.

The HWA 2025 healthcare workforce projection for midwives, registered and enrolled nurses used a stock and flow supply model and applied a constant linear growth rate model to calculate demand (40). Supply model parameters included graduates, immigration of nurses, no longer available for nursing practice, training time, and hours worked. The demand model parameters included total hospital bed-days by population growth, service related groups (similar to Diagnostic Related Groups), total number of aged care packages by population growth aged 70 years and over, service utilisation, total number of projected births, and total number of projected Registered Nurse (RN)/ Enrolled Nurse (EN) full time equivalent (FTE)[1] by population ratio (40).

The HWA adopted a similar model for the November 2012 projection of medical specialties. The stock and flow supply model parameters included workforce headcount, demographic characteristics, number of graduates and medical fellows, immigration of overseas specialists, lost to medical practice, FTE benchmarks, training time, and number of hours worked (40). The demand model parameters were service utilisation by sex and five-year age cohort, public/private hours worked, services related groups and enhanced service related groups. Diagnosis groups were used to assign medical services to medical specialties and sub-specialties (41) and to adjust for complexity of care (proxy for severity of illness). The assumption being that higher complexity inherently drives manpower requirements. These models derive estimates from a baseline year and assume a consistent linear future trend in healthcare need and technological change.

2.3.2 Canada

Prior to 2003, healthcare workforce planning in Canada was undertaken by each jurisdiction or province independently and did not address pan-Canadian supply and demand. In seven of the ten provinces, historical patterns of health service utilisation and health human resource supply, as proxies for public sector demand and supply, were used to project healthcare manpower requirements. The remaining three provinces adopted a need-based approach. Since 2003, Health Canada (a department of the federal government) has worked with the provinces and territories to improve coordination in and develop a conceptual model for human health resource planning (42). The proposal includes a stock and flow model for supply and a need-based model using utilisation of curative and preventive services (43).

[1] **Full-time equivalent** (**FTE**) is a standardized measure of time at work for an employed person. An FTE of 1.0 indicates a full-time worker, whereas FTE of 0.5 signals half-time.

More specifically, most jurisdictions calculated health workforce supply using parameters such as new local and non-local registrants, attrition, and employment status (44). Although many parameters were available to project manpower demand and supply, most of the provinces used historical trends (age and sex stratified) to project future healthcare workforce requirements (44). The newer projection models adopt additional supply-side parameters such as education, immigration, and career patterns (44). Overall, Canadian healthcare manpower demand models project FTE requirements on current utilisation patterns including parameters such as changes in the total population size and age-sex structure. Only two jurisdictions report including parameters such as socio-economic characteristics in the models or addressing the impact of externalities such as change in healthcare policy.

Although Health Canada is coordinating healthcare manpower planning and forecasting, as with most other heath care issues, healthcare manpower regulation and registration, planning and forecasting remains the jurisdiction of the provinces. While there are similarities and commonalities between provinces, the models as developed and applied are broadly applicable only to the province of origin.

2.3.3 Japan

The Ministry of Health, Labour and Welfare (Japan) projects the supply and demand for healthcare personnel (45). The 7th Projection of Estimated Supply and Demand for Nursing Personnel was prepared in 2010, estimated a shortfall of 15,000 nurses in 2016 (46). The supply parameters included current employment status by year, local and international graduates, re-employment and retirement. The demand parameters included service utilisation by hospitals, clinics, maternity clinics, long-term care facilities, social welfare facilities, health centres and municipal facilities; educational institutions, workplaces, and schools (46). Currently, the full report of the 7th Projection of Estimated Supply and Demand for Nursing Personnel is not released, thus more specific methods are not publicly available. Historical trends were used to quantify but not project the demand for other healthcare professionals, such as doctors, dentists and pharmacists (46).

2.3.4 The Netherlands

The Netherlands Institute for Health Services Research (NIVEL) is an independent organisation with manpower planning as a particular area of research (47). NIVEL deployed stock and flow methods to project supply and demand for healthcare professionals (48).

Parameters used in their supply model included working capacity, primary activity, graduates, drop-out rates, expected age of retirement, working hours and task delegation (48). The supply model also incorporated the flow of medical professionals by sex in and out of the healthcare market and projected total FTE. The demand model (a three-part model) used simulation methods to project service utilisation on demographic and epidemiological developments (48). Part 1 established the baseline supply and demand of healthcare professionals by FTE adjusted by gender (49). The manpower gap between the supply and demand was then estimated. Part 2 projected supply and demand FTE requirements for the target year by projecting parameters such as demographic change, and the inflow and outflow of health professionals (49). Part 3 compared the expected manpower supply by FTE from labour market returns with projected FTE supply in three scenarios (49). The base scenario used trend analysis to forecast the impact of demographic change on the demand for healthcare. The first scenario included parameters such as epidemiological, socio-cultural and technical developments as well as, efficiency change, horizontal substitution and working hours per FTE in the demand model. The second scenario considered the impact of vertical substitution on demand (49).

Although a comprehensive methodology has been used for healthcare manpower planning in the Netherlands, the models generally draw on a subjective interpretation of the demand (expert opinion determines unmet demand).

2.3.5 New Zealand

In New Zealand, Health Workforce New Zealand (HWNZ) has the overall responsibility for planning and development of the health workforce, ensuring that staffing issues are aligned with planning on the delivery of services, and that New Zealand's healthcare workforce is fit for purpose (50). Currently, HWNZ is undergoing workforce service review with the objective of determining future health workforce requirements in 13 areas: aged care, anaesthesia, eye health, palliative care, musculoskeletal diseases, gastroenterology, youth health, diabetes, mental health, rehabilitation, mother and baby, healthcare for the Maori, and healthcare for Pacific Islanders (50). The HWNZ has used trend analysis and predicted service utilisation to determine future requirements.

The HWNZ has projected healthcare manpower (51) from the Health Workforce Information Programme. The supply model projection used a dynamic supply model to calculate headcount and FTE from historical trends of new graduates, return rates, and retirements rates. Model parameters included current workforce inflow and outflow, age, sex, ethnicity, and occupation (51). The demand model included the following parameters population growth, age, sex, ethnicity, change in service, change in the care model, and the impact of current and emerging technologies (51). HWNZ contends that due to the shift toward population based healthcare delivery, the total population health needs and achievements are of particular importance in the forecast for demand.

The projection models rely heavily on trend analysis and linear regression to estimate manpower requirements. While simple models can provide a quick snapshot of current needs of population they lack the dynamic variation in scenarios and may misrepresent the demand for healthcare.

2.3.6 Scotland

NHS Scotland Workforce section of Information Services Division has used trend analysis to assess the supply and demand of medical, dental, nursing and midwifery, allied health professions, health science, ambulance staff, psychology, and pharmacy workforce (52). Parameters such as changing demography, and service utilisation, were used for the demand models and, workforce dynamics, workforce inflows and outflows for the supply models (53).

Three methods, dynamic models (stock and flow), healthcare professional-to-population ratio, demand/utilisation-based models were used to project healthcare professional supply and demand. The model parameters included service utilisation, service delivery, changing models of care, workforce skill mix (roles and competencies), integration and engagement of the workforce across the professions, health and social care, and care by sector (primary, secondary and tertiary) attendance rate, treatment rates, and for dentists average quantity of treatment per dentist per year (54, 55).

The supply model adopts stock and flow methods, that are commonly used by many other countries. The demand/utilisation-based models, while more sophisticated, require extensive and complex data, are susceptible to larger measurement error than projections based on population ratios (53).

2.3.7 Singapore

The National Manpower Council of the Singapore Ministry of Manpower is the decision-making body for the National Manpower Planning Framework (56). The Council has adopted an approach, where the future demand for healthcare manpower is based on trend analysis of population demographics and current healthcare workforce supply (57). In 2009-2011, the overall supply of doctors, registered nurses, enrolled nurses, dentists, pharmacists and optometrists increased across the board (58). As at 2012, Singapore had 10,225 doctors, (doctor-to-population ratio of 1:520), 60% of whom work in the public sector (58); 34,507 nurses and midwives (nurse-to-population ratio of 1:150). Strategies to manage the in- and out-flows of healthcare professionals (i.e. doctor, specialist, nurse) and to recruit more internationally qualified healthcare professionals from developed countries have been put in place to reduce workload demand. Included in this approach is the talent outreach programme (36). The Healthcare 2020 Masterplan healthcare demand and workforce planning projection parameters (57) included population growth and ageing, education, healthcare sector productivity and change in healthcare worker role (i.e. role extension), immigration of foreign healthcare workers and changes in the service delivery model. The supply model includes education and training of local professionals, and the recruitment of non-local graduates.

The available data from the Ministry of Health are total number of healthcare professionals by sectors (i.e. private and public sectors), and the professional-to-population ratio or vice versa (58). No full-time equivalent information was considered are given. For some healthcare professionals, professional-to-doctors ratio was used in the trend analysis.

2.3.8 United Kingdom

The Centre for Workforce Intelligence (CWI) provides advice and information to health and social care systems on workforce planning and development in the United Kingdom (37). CWI works closely with various organisations such as the NHS Information Centre, the medical Royal Colleges, and other regulatory bodies to access the highest quality, accurate and timely data for healthcare manpower planning (37). The CWI has focused on the supply of various health professions, (medical, dental, nursing, midwifery, and other allied health professionals). CWI released several reports in 2012 on technological, economic, environmental, political, social, and ethical factors that they consider/use in their supply and demand projection models (59, 60). Parameters used in the stock and flow model for medical and dental supply include current workforce, workforce participation, working time spent delivering service, active workforce, number of entering and returning to workforce, immigration, attrition, emigration, those not available for work at present, and retirement or other attrition. Parameters for the demand models include population size and characteristics, disease prevalence, level of need, and amount of service delivered by doctors and dentists (61). Baseline need was measured by types of care (acute, long-term or primary), and age sex subgroups. Population need was projected for each type of care using indicators such as number of general practitioner (GP) visits per type of care, or bed-days per type of care (61).

The CWI has adopted a need-based model where need was proxied by type of care. This approach assumes that 'type of care' appropriately reflects manpower requirements and that all care is in the 'formal' care sector. However, such a model cannot account for the multidisciplinary nature of patient care or for the complex determinants of the location of or patient placement for care (e.g., patients not discharged due to insufficient home care places or social services)

2.3.9 United States

The Health Resources and Services Administration (HRSA) and the National Center for Health Workforce Analysis of the US Department of Health and Human Services are the primary federal agencies for developing the tools to project the supply and demand for healthcare professionals in the US (62, 63). HRSA has released reports for doctors (by sub-specialty), registered nurses (RN), licensed practical nurses (LPN), pharmacy, dentistry, public health and clinical laboratory workforce (64). The stock and flow supply model parameters included licence renewal, retirement, death, disability, local and international graduates, productivity, career change and projected FTE. Specific to RNs, the model captures the progression from one educational level to another, and their interstate migration (65).

The demand model used a utilisation-based approach and included parameters such as service utilisation, demographics, insurance coverage/healthcare payment system, patterns of care delivery, technology, healthcare regulation, and workload measures such as inpatient days, visits, and nursing facility residents. Care delivery patterns were expressed as healthcare professional-to-population ratios by specialty and population segment defined by age, sex, geographical location, and insurance type. The demand model projected FTE's by service sector (65). The manpower gap between the supply and demand was expressed as an FTE ratio (65). The supply models used trend analysis and stock and flow methods. Supply model parameters included graduates, male-female ratio, death, retirement and projected FTE or FTE-to-population ratio.

HRSA has developed numerous models by healthcare professional groups and identified the core model parameters. The HRSA models could be improved by incorporating explicit measures of externalities in the model parameters.

2.4 Learning from commonly adopted technical approaches

Although a demand/utilisation-based approach was the most frequently used manpower projection method, need-based methods, trend analysis, and benchmarking (healthcare professional to population ratio) were also used. Demand/utilisation-based models for doctors, dentists, nurses and pharmacists project FTE based on service utilisation and have usually included the following parameters, hospital admissions and patient visits, utilisation weighted patient diagnosis, outpatient visits, treatment, population growth and age distribution, economic indicators, geographic factors, insurance status, and staffing intensity. For pharmacists the parameters have included the number of prescriptions filled, growth in prescription volume for pharmacists, direct-to-consumer marketing and Aggregate Demand Index (a measure of unmet demand at the population level). Many of the projection models were stratified by service sector. Data was derived from aggregate data from annual reports, historical utilisation data and doctor – population ratios. Model validity and reliability was compromised by data availability and quantity. A positive linear relationship between population and economic growth, healthcare utilisation and demand was assumed by most.

Model assumptions were often tested by scenario analysis including change in 1) supply (e.g. number of graduates, registered practitioners, or entrants to higher education, number of training places, migration, retirement rates, changes in funding, reimbursement and recruitment), 2) productivity and efficiency (activity rates), 3) population demographics, 4) burden of disease health and healthcare utilisation, 5) economic development, and 6) patient/staff satisfaction. The lack of normative standards defining work and productivity was a major impediment to workload analysis. Manpower requirements were most often expressed in FTE.

While methods for modelling manpower demand for other healthcare professionals (i.e., not doctors) are not as well developed, utilisation, service delivery, expected service growth and number of vacant positions were used to project FTE requirements. Some models based demand projections on subjective assessment of demand, workload and productivity. Scenarios, testing change in population demographics, service utilisation, service provision or practice structure, disease incidence and prevalence, and norms of care were used to assess the projection performance.

Existing supply models have used stock and flow methods to project headcount or FTE. These models have included parameters also used by supranational agencies (WHO and OECD) and national models. These included age, sex, number of graduates, number of registered doctors, attrition (retirement, immigration, or emigration), and practice location. Adjusted trend analysis and straight-line projections have been used for physiotherapist manpower supply projections. The models projected manpower requirements by headcount, FTE or by healthcare professional-to-population ratio.

Table 2.1 summarises projection methods, demand and supply parameters for manpower projection models by healthcare professionals (doctors, dentists, nurses, Chinese Medicine Practitioners (CMP), pharmacists (Pharm), chiropractors (Chiro), medical laboratory technologists (MLT), occupational therapists (OT), optometrists (Opt), physiotherapists (PT), radiographers (Radio), and dental hygienists (DentH). See **Appendix B** for the full list of healthcare manpower planning and forecasting publications.

Table 2.1 Projection methods, demand and supply parameters for manpower projection models by healthcare professionals

	Model methods	**Demand parameters**	**Supply parameters**
Doctors (11, 66-77)	Supply: stock and flow, trend analysis Demand: regression-based physician density model, demand/utilisation-based model, need-based model, benchmarking	Age, Gender, Population density, Consultation length, Number of consultations or procedures, Morbidity, Mortality, Life expectancy, Fertility rate, Literacy, GDP; GNI, Health expenditure, Insurance status, Epidemiology, Inputs of other types of professionals,	Age, Sex, Population growth, Retirement, Death, Migration, Re-entrants, Movement between occupations, Graduates, Work location, Working hours, Level of service, Intensity of work,
Dentists (78-91)	Supply: stock and flow Demand: demand/utilisation-based model, need-based model	Population projection, Income of population, Socio-demographic characteristics, Projected utilisation increase, Decayed, missing and filled teeth rates, Prostheses rates, Rates of edentulousness, Rates for other dental procedures, Dental attendance pattern, Patterns of disease, Dentist-to-population ratio	Retirement, Death, Graduates, Migration, Number of new dental schools, Number of other dental professionals, Population estimates, Gender ratio, Working hour, Productivity
Nurses (65, 92-111)	Supply: stock and flow, trend analysis, benchmarking Demand: benchmarking, demand/utilisation-based model, trend analysis, need-based model	Bed capacity/ occupancy rate, Working hours, Staffing intensity, Utilisation of services, Insurance status, Population growth and aging, Per capita income, Burden of disease and injury, Surgical intervention, Race/ethnicity classification, Area of practice, Nurse-to-physician ratio, Staff norms, Turnover rates, Vacancy rates	Graduates, Re-entrant, Retirement; Illness, disability and death, Working hour, Migration, Population, Education, Age, Sex, Career change, Maternity, Renewal rate
Chinese Medicine Practitioners	No specific published manpower planning and projection models		
Pharmacists (112-126)	Supply: stock and flow Demand: trend analysis, benchmarking, demand/utilisation-based model	Graduation rates, Population growth and aging, Expiring drug patents, Prescription volume, Role extension, Pharmacist-to-technician ratio, Pharmacist-to-population ratio, Direct-to-consumer marketing, Insurance coverage, Therapy improvement	Age, Male: Female ratio, Working hours, Graduates, Migration, Retirement, Death, Workload, Productivity.
Chiropractors (127-130)	Supply: stock and flow; supply description Demand: need-based model	Patient visits per week, Number of services per chiropractic user, Chiropractic use per capita, Change in technology, Change in patterns of the diseases, Prevalence of back and neck symptoms	Age, Sex , Education, Number of graduates, Geographic variation
Medical Laboratory Technologists (131,132)	Supply: trend analysis; stock and flow Demand: demand/utilisation model	Time units per activity, Number of laboratory tests per FTE, Population characteristics, Technology improvements	Number of graduates, Working hours, Examination pass rates, Field of practice, MLT post vacancy rate
Occupational Therapists (133-136)	Supply: stock and flow Demand: demand/utilisation model	Current OT employment data, Number of vacancies (in FTE), Hospital and home care average growth rate,	New graduates, Attrition and retention rate
Optometrists (137-141)	Supply: stock and flow	Diagnosis and service hours Population growth	Age, Sex, Number of registered optometrists, Local and non-local graduates, Mortality,

	Demand: trend analysis; demand/utilisation model		retirement, or emigration
Physiotherapists (142-145)	Supply: stock and flow Demand: trend analysis; need-based model	Population growth, Increase in personal healthcare expenditure, Personal health insurance, Number of in-patient, outpatient and home-bound Patient visits	Number of current vacant posts, Retirement and attrition, New graduates, New registrants, Registration renewals.
Radiographers (146,147)	Supply: stock and flow Demand: trend analysis; demand/utilisation	Service utilisation By procedures By modality, (e.g. CT, MRI, ultrasound and therapeutic procedures) Population demographics and growth	Age, Number of graduates, Retirement and other attrition, Training attrition, Working hours (full-time or part-time), Field of practice
Dental Hygienists	No specific published manpower planning and projection models		

2.5 Learning from local experience in workforce planning

2.5.1 Department of Health

The Department of Health (DH) has conducted Health Manpower Surveys (HMS) for healthcare professional groups with registration in Hong Kong since 1980. The surveys aim to provide up-to-date information on the characteristics and employment status of healthcare personnel working in Hong Kong. The data, compiled into aggregate health manpower statistics, aids the understanding the dynamics of healthcare professional manpower supply. However these are essentially repeated cross sectional surveys with no prospective predictive function or objective, thus cannot inform future needs without further analytical processing.

2.5.2 Hospital Authority

In Hong Kong, much of the current manpower planning and forecasting for public sector has been planned within the HA, which adopted an integrated approach in projecting its future healthcare workforce requirement. The process starts with an overall assessment on the future service demand which covers a comprehensive spectrum of HA services, ranging from in-patient, day-patient to outpatient, ambulatory and community services as well as clinical supporting specialty services. The service demand projection uses age- and specialty-specific service utilisation rates in a given year as the base year and took into account anticipated changes resulting from various factors. The HA model included population growth and ageing, changes in the service delivery model and utilisation pattern, medical technology advancement, and the development of new services.

To estimate the required doctor manpower, the projected service demand by specialty is translated into work-related time units (man-hours) for doctors. Together with respective specialty-specific clinical coordinating committees, the average time required for doctors to carry out other work-related tasks is estimated. Future doctor manpower requirement is then determined by assuming some specialty-specific parameters such as on- and off-site call, coaching, training and documentation, and community service. A similar work profile analysis is conducted for nurses in close collaboration with nurse representatives, and identified key nursing components of general and psychiatric work within different clinical settings.

Besides the additional demand generated by projected service growth, the future manpower requirement also considers replacement demand generated by staff turnover including retirement. Additional demand also takes into account manpower shortfall at the baseline. The HA manpower planning and projection model has provided a service level model, based on historical data. The model incorporates the impact of realised change in service delivery on future manpower requirements. While the HA provides a substantial proportion of in-patient and outpatient care to the population the model cannot represent all healthcare need (as proxied by utilisation) within the population. A comparison of the HA model and the territory wide model as presented in the report is not possible at this juncture.

2.5.3 Hong Kong Academy of Medicine

During the past decade, the Hong Kong Academy of Medicine, through the respective specialist Colleges, has reviewed medical manpower planning to determine the demand for different medical specialities and the requirements for training posts. Throughout the review a number of important externalities pertinent to manpower planning including the dynamics of the private and public interface, patient culture and expectations, and healthcare policy were identified. Individual colleges submitted estimates for manpower demand based on caseload or overseas benchmarks and provided input on the specific factors expected to influence future manpower need in their subspecialty (148). Individual colleges have found it difficult to project specialist manpower demand primarily due to difficulties in estimating the impact of the shift in practice location between the public and private sectors, medical tourism, changing technology, and areas of practice. The Academy acknowledges the limitation of assessing need from the medical perspective only and the difficulties in accurately determining demand, however, the recommendations put forward provide valuable input to manpower planning and forecasting in Hong Kong.

2.5.4 Independent manpower planning and policy reviews

The Business Professionals Federation of Hong Kong (BPF) healthcare manpower planning report of September 2010 recommends a more scientifically based and inclusive approach to manpower planning than what had been done previously (149). The report lists three essential planning ingredients for effective planning: 1) administrative data of past and present manpower resources, 2) research personnel equipped with skills and modelling tools to undertake dynamic projections, and 3) collaboration of all stakeholders.

In June 2012, HKGolden50 an independent not-for-profit research organisation, published their fourth report "How to Create A World-Class Medical System" with the aim to "alert our community that despite our World Class standard in Western and Chinese medicine our healthcare system is on the brink of breaking down due to insufficient hardware and personnel coupled with surging local and foreign demand for our quality medical services" (150). Based on HA data (i.e. public in-patient data only) the authors predicted a rapidly increasing (2% a year) shortage in doctors (150). Factors influencing this shortage are suggested to include 1) surging healthcare service demand deriving from population ageing, population growth, and medical tourism (demand for private healthcare from mainland China), and 2) stagnation supply due to retirement, declining competency due to the loss of senior staff, generation gap, feminisation of the work force, high entry barriers for overseas-qualified doctors, and insufficient support staff (nurses and administrative staff).

2.6 Implications for the Hong Kong manpower project

Many manpower-planning challenges have been previously identified in our review of work already completed. These include: 1) persistent manpower shortages and mal-distribution of the healthcare workforce, 2) population ageing, 3) rising incidence of chronic diseases, 4) lack of resources for medical training, 5) lack of cooperation within and between institutions, and 6) poor reliability and credibility of current manpower forecasting models.

The country level models identified lack consensus on the methodological approach for healthcare manpower planning and forecasting, and illustrated data-related problems including a lack of standardisation in variable parameterising; limited access to the quantity and quality of the data required; limited information on productivity, workload, and utilisation; and limited information on treatment efficacy and effectiveness. These models used routine administrative data (utilisation or financial data), or data from specialised surveys, and/or applied a predetermined set of assumptions in the demand/utilisation models.

Many country level models were deterministic and lacked the flexibility to examine the dynamic relationships between manpower supply and patient outcomes. In addition, the linear analysis adopted by many was problematic due to the underlying non-linearity of the data. More current manpower planning models used system dynamic methods, considered need, supply and demand simultaneously, projected manpower requirements from multiple perspectives and provided a more complete estimate of future manpower requirements. There was little evidence (in both qualitative and quantitative terms) of the impact (or evaluation) of these human resource-planning strategies on healthcare practice.

Models that did not specify benchmark standards or methods to determine the relationship between the volume of service/ number of patients and the number of staff were unable to robustly estimate the number of staff required for specific activities. Induced demand (as measured by utilisation data and doctor defined diagnosis in demand models) was a characteristic problem of manpower planning and forecasting and was a major limitation of the current country level manpower planning and forecasting models world-wide and locally.

In Hong Kong, population ageing, rising incidence of non-communicable disease, and historical healthcare utilisation patterns is related to rapidly increasing demand for healthcare service. Elsewhere, changing patterns of referral, location of service delivery (public and private), technology, scope of practice (including complementarity and substitution between healthcare professionals), feminisation of the workforce and healthcare policy (such as extended personal insurance coverage, increased in public healthcare benefits) and service delivery regulation (such as the recommendations of the Review Committee on Regulation of Pharmaceutical Products) have been implicated with increased demand for healthcare service (151). The increased demand arising from the mainland visa-free tourist policy are expected to increase future manpower demand. Economic and healthcare policy (i.e. Closer Economic Partnership Arrangement II (CEPA)), changing population demography, inter-regional and inter-sectoral (public/private) movement of healthcare professionals and patients, and medical tourism are expected to increase future healthcare demand and further complicate manpower projection.

Manpower projection is a highly data intense activity. Although public sector in-patient and outpatient data suitable for manpower projections is readily available, a substantial proportion of patient care occurs in the private sector, where data is less complete, more complex or simply unavailable. Such an environment necessitates manpower projection models that are adaptable to changing parameters and model structures.

3 Projecting demand

The overall model for Hong Kong manpower projection comprises two sub models, the utilisation model and the supply model. Building on an endogenous, historically-informed base case scenario (where current utilisation (proxying demand) and supply are assumed to be in equilibrium), this model is adopted to adjust for the impact of externalities and policy options. The difference between the demand and supply projections (in terms of total FTE numbers, accumulative and annual incremental FTE from 2012 -2041) is the manpower 'gap' or 'surplus/shortfall'.

3.1 Modelling demand

After a thorough literature review, assessing the suitability to the local context and exploratory analyses with the various possible projection modes, three approaches for projecting healthcare utilisation are shortlisted for further consideration, the 'empirically observed historical' (EOH), the 'macroeconomic scenario driven' (MSD) and the 'Andersen-type' (Andersen) approach within a 'top down' and 'bottom up' framework (Figure 3.1). Given the lack of required data elements for the Andersen approach, namely detailed individual-level data on predisposing and enabling factors as well as panel studies locally, the two 'top down' approaches are eventually executed.

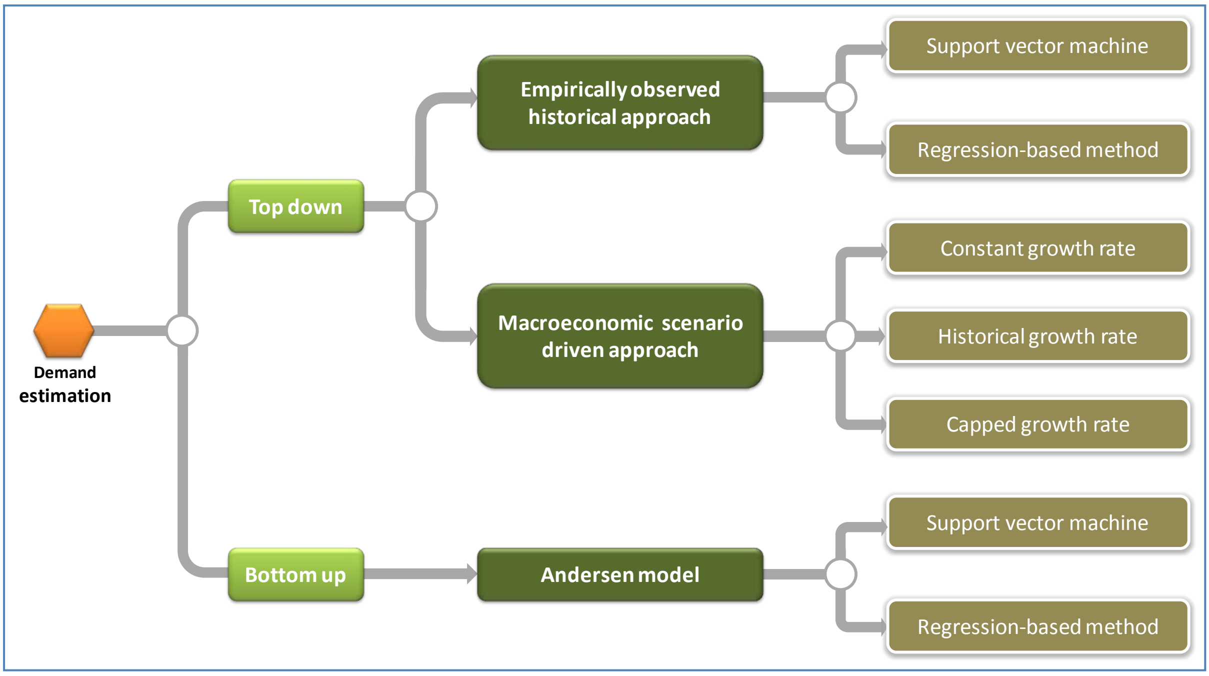

Figure 3.1 Approaches to estimating doctor demand

Support vector machine (neural network analysis), regression-based method, and stock and flow method, are variously deployed to project the required number of doctors as a function of healthcare demand/utilisation and doctor supply to 2041. The projections are stratified by service type (in-patient and outpatient) and by service location (public or private sector).

3.1.1 Empirically observed historical (EOH) approach

The EOH projection model expresses utilisation as the product of population *P* and utilisation rate *R*:

$$\text{Utilisation } z(y) \text{ at year } y = \sum_a \sum_s P(a,s,y) \times R(a,s,y)$$

where $P(a,s,y)$ is the population age-, sex-specific groups (a,s) at year y, and $R(a,s,y)$ is the utilisation rate by age-, sex-specific groups (a,s) at year y. Census and Statistics Department population projections are used for the projected $P(a,s,y)$, historical data inform the computation of $R(a,s,y)$.

3.1.1.1 Support vector machine (SVM)

SVM[2] is used to estimate the utilisation rate of each age-, sex-specific group at a given year. SVM is a kernel-based neural network that maps an input x to an output y where w_i is the weight and B is the bias term by the following expression:

$$y = \sum_i w_i \kappa(\mathbf{x}_i, \mathbf{x}) + B$$

As compared with linear and exponential regression models, SVM has the flexibility to 'evolve' an optimal structure according to historical data. A Gaussian radial basis kernel i.e. $\kappa(\mathbf{x},\mathbf{y}) = \exp(C\|\mathbf{x}-\mathbf{y}\|)$ is used as it is the 'universal approximator'. The structure is well regularised, and the generalisation ability of the network is maximized.

SVM *learn* the utilisation rate pattern from historical data expressed as:

[2] Artificial neural networks (ANN) and specifically the Support Vector Machine (SVM) used for these projections are able to predict the complex relationships driving utilisation. Support vector machine (SVM) is a supervised learning method that analyses data and recognizes data patterns in the historical data. As such this artificial intelligence predicts for each given variable the corresponding outcome. SVM was chosen for the projection as it will 'evolve' an optimal structure and estimate the service utilisation of a given individual based on characteristics such as age, and sex.

$$\begin{bmatrix} a_1, s_1, y_1 | r_1 \\ a_2, s_2, y_2 | r_2 \\ a_3, s_3, y_3 | r_3 \\ \vdots \end{bmatrix}$$

where r_i is the utilisation rate of age-, sex-specific group (a_i, s_i) at year y_i. A specific network construction algorithm is designed to evolve the structural parameters {w_i} and *B*. The trained SVM projects the utilisation rate *R*(*a*,*s*,*y*) of an age-, sex-specific group (*a*, *s*) at projection year *y* = 2012, 2013, …. using the following equation:

$$R(\text{a,s,y}) = \sum_i w_i exp\left(-\frac{(a-a_i)^2 + (s-s_i)^2 + (y-y_i)^2}{2\sigma^2}\right) + B$$

The utilisation volume at year y is computed as:

$$\sum_{a,s} R(\text{a,s,y}) \times P(\text{a,s,y})$$

where *P*(*a*,*s*,*y*) is the population size of the age-sex group (*a*,*s*) at year *y*.

3.1.1.2 Regression-based method (RBM)

In the RBM approach, $R(a,s,y)$ is estimated by Poisson regression, which assumes:

$$N(a,s,y) \sim Poisson(O(a,s,y)R(a,s,y))$$
$$\log R(a,s,y) = \alpha(a,s) + \beta(a,s)y$$

where $N(a,s,y)$ denotes the utilisation volume and $O(a,s,y)$ is an offset term in age group a, sex s, and year y. For the projection of all utilisation measures except average length of stay, the population of age group a, sex s, and year y are used for the offset term $O(a,s,y)$. For the projection of average length of stay, the offset term is the number of discharges. Since $\log R(a,s,y)$ is a linear function of y, $R(a,s,y)$ is an exponential function of y all age- and sex-specific demand variables are included in the Poisson regression. For utilisation measures where there are clear differences in slopes across age-, sex-specific groups (including public and private day case, acute care in-patient discharge and average length of stay (ALOS), as well as HA general outpatient (GOP), specialist outpatient (SOP), accident and emergency (A&E), and private outpatient visits), the projections have age-, sex-specific intercepts and slopes. For all other utilisation measures (public long stay discharge and average length of stay, as well as all DH service visits), the age-, sex-specific intercepts and slopes are constrained to be the same across age and sex groups.

In sensitivity analyses, the Poisson regression projections are compared with projections based on a linear trend. As utilisation rates in linear trend projections may drop below 0, linear projections are used only for utilisation rates that show an increasing trend. The utilisation rate increase is assumed to be the same across all age-, sex-specific groups for SOP, A&E, private outpatient, and all DH visit rates projections lest projections for individual age and sex groups reach zero.

A weighted linear regression is deployed, where the population in age group a, sex s, and year y are used as weights (i.e., $P(a, s, y)$). The following function is minimised with respect to $\alpha(a, s)$ and $\beta(a, s)$.

$$\sum_{a,s,y} P(a, s, y)(R(a, s, y) - \alpha(a, s) - \beta(a, s)y)^2$$

Projections of rates are given as:

$$\hat{R}(a, s, y) = \alpha(a, s) + \beta(a, s)y$$

The weights are needed to ensure the estimated age, sex, and year-specific rates $\hat{R}(a, s, y)$ are consistent with the observed rates $R(a, s, y)$.

3.1.1.3 Time series approach

As the utilisation at the sectors: pharmaceutical manufacturing and pharmaceutical company are not clearly defined, a time-series analysis is used to project the pharmacist demands at these sectors. The patterns of the demand trends $u(y)$ as follow:-

Linear trend

Where the number of pharmacists in pharmaceutical manufacturing is a linear function of projection year y:-

$$u(y) = ay + b$$

SVM-based trend

Where the number of pharmacists in a pharmaceutical company is a function of the projection year *y* and the structure of the function L is obtained through SVM-

$$u(y) = L(y)$$

Time series analysis is also applied to project the rate of change in the number of C3 aseptic dispensing item per case. An exponential decay function is assumed for the rate of change $\partial\beta_3^{HA}(y)$:

$$\partial\beta_3^{HA}(y) = we^{-\alpha y} + c$$

3.1.2 Macroeconomic scenario driven (MSD) approach

As in the EOH-RBM approach, the MSD approach expresses utilisation as the product of population *P* and utilisation rate *R*:

$$\text{Utilisation } z(y) \text{ at year } y = \sum_a \sum_s P(a,s,y) \times R(a,s,y)$$

where $P(a,s,y)$ is the age-, sex-specific population (a,s) at year y, and $R(a,s,y)$ is the age-, sex-specific utilisation rate (a,s) at year y. Population projections of the Census and Statistics Department are used for $P(a,s,y)$. $R(a,s,y)$ is estimated as follows:-

$$R(a,s,y) = R(a,s,2011) \times (1+x)^{y-2011}$$

Three methods (constant growth, historical growth, and capped growth) are used to calibrate healthcare utilisation trends against observed data.

3.1.2.1 Constant growth rate

The constant growth rate method sets ‘excess healthcare price/cost inflation’[3] growth at 0.2% public sector and 1% for the private sector, consistent with the international literature and to a

[3] The ‘excess healthcare price/cost inflation’ method is based on the United Kingdom Treasury’s Wanless projection method which requires health expenditure to be broken down by age, sex, unit cost and activity level (i.e. volume in terms of healthcare utilisation). The projections take into account aspects of medical inflation (that is medical inflation over and above per capita Gross Domestic Product growth), changes in the utilisation of healthcare services as a result of demographic change, and total health care expenditure (activity levels multiplied by projected unit costs). This comprises

previous local exercise (152). The public sector growth rate for each variable is benchmarked to the OECD (1999)(153). As the OECD reports utilisation growth rates of 0.4% per year, the model assumes a growth rate of 0.2% (154) because half of the growth is due to the net growth in the utilisation rate while the other half is assumed to be due to demographic changes.

Private sector growth rates are benchmarked to OECD (1999)(153) data for the United States and Switzerland, as these two countries predominantly provide healthcare in the private, albeit regulated, sector. The OECD reports an annual growth of 2.7% and 2.4% for the United States and Switzerland respectively. As the healthcare in Hong Kong is equally shared between the public and private sector, the utilisation growth rate in the private sector is assumed to be 1% (154).

3.1.2.2 Historical growth rate

For the historical growth rate method, 'excess healthcare price/cost inflation' x is estimated from the public and private hospital in-patient discharges and outpatient visits in Hong Kong. To estimate x, the following function is minimised:

$$\sum_{y} |N(y) - z(y)|$$

where $N(y)$ is the utilisation volume (number of public and private sector in-patient discharge and outpatient visits) and $z(y)$ is the estimated utilisation volume for that year:

$$z(y) = \sum_{a} \sum_{s} P(a, s, y) \times R(a, s, y)$$

$$R(a, s, y) = R(a, s, 2011) \times (1 + x)^{y-2011}$$

3.1.2.3 Capped growth rate

As it may be inappropriate to assume ever exponentially increasing utilisation rates, the capped growth rate method is applied to the projection of discharge rates and outpatient (SOP and GOP) visit rates, such that rates would not indefinitely grow exponentially as follows:

two components medical price increase and per capita volume growth according to Huber's review of health expenditure among OECD countries in 1999.

$$R(a,s,y) = R(a,s,2011) \times \underbrace{\left(\frac{w}{1+e^{-\alpha(y-y_0-\mu)}} + B\right)}_{sigmoid\ function}$$

where $R(a,s,2011)$ is the age-, sex-specific utilisation rate for the baseline year 2011. For average length of stay projections, a biased exponential function is used rather than the sigmoid function to prevent the projection falling below zero.

.

$$ALOS(a,s,y) = ALOS(a,s,2011) \times \underbrace{e^{-\alpha(y-\mu)}}_{biased\ exponential\ function} + B$$

The parameters w, α, μ and B are estimated by optimising the objective function:

$$\sum_{y} |N(y) - z(y)|$$

as in the historical growth rate model.

3.1.3 Adjusting for under-reporting

THS under-reporting rates for outpatient visits for the public and private sector are estimated for the THS 2002, 2005, 2008, and using routine HA and private hospital outpatient visits data (Figure 3.2). Due to data unavailability, estimates of under-reporting rates for private sector outpatient visits is not possible. Private sector under-reporting rates are assumed to be the same as for HA outpatient visits.

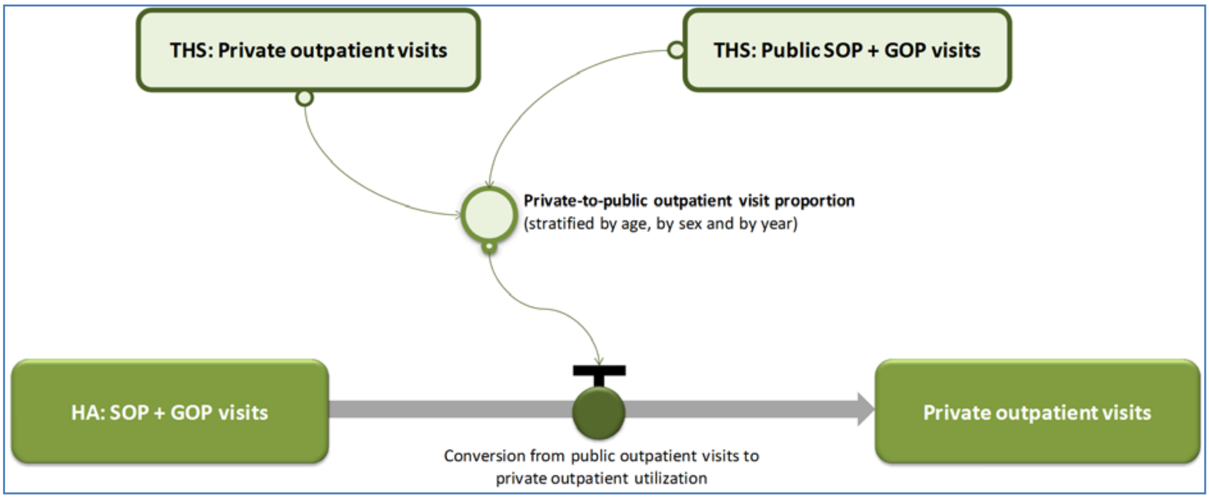

Figure 3.2 Under-reporting adjustment of THS outpatient visit data

3.1.4 Capping rates

The RBM gives exponential rate increases across all utilisation variables. This leads to projections that are too extreme to be realistic beyond the first few years. To address this problem, age-, sex-specific utilisation rates are allowed to continue until 2016 after which they are held constant (i.e. capped) for the rest of the projection period. The discharge and outpatient visit rate caps are benchmarked to the historical OECD utilisation trend data (OECD 2012) (154).

To set the discharge rate cap, the current OECD acute care in-patient discharge rate for Hong Kong (178 discharges/1000 person-year (152)) is compared to OECD individual country trends (Figure 3.3). Hong Kong discharge rate increase is benchmarked to the 90th percentile of the 2011 OECD countries discharge rate (237 discharges/1000 person-year) (representing an average discharge rate increase of 33%). Based on historical data Hong Kong will reach this estimated discharge rate by 2016, after which the discharge rate increase is capped.

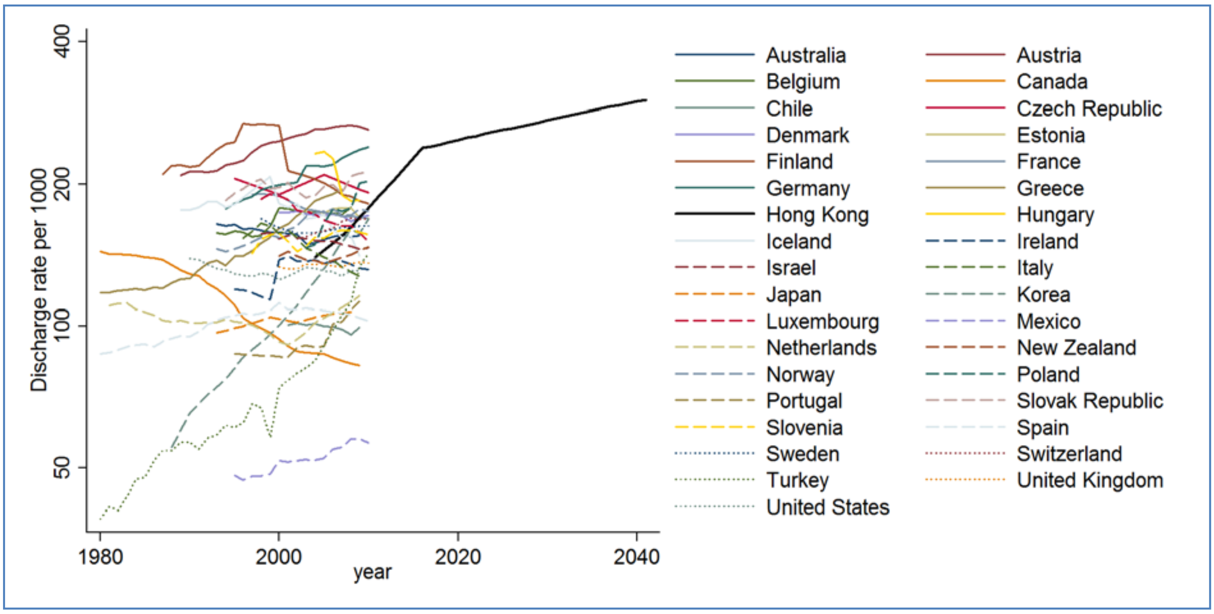

Figure 3.3 Comparison of Hong Kong and OECD acute care in-patient hospital discharge rates (152,153)

Similarly for outpatient visit rates, the doctor visit rate as published by the OECD for HK (2011) (11.2 visits per person-year (152)) is benchmarked against OECD individual country trends (highest rate 13.1 visits per person per year in Japan) (Figure 3.4). Based on this comparison, Hong Kong outpatient visit rates are expected to increase by 17% and will reach this target by 2016. The outpatient visit rate is capped after 2016.

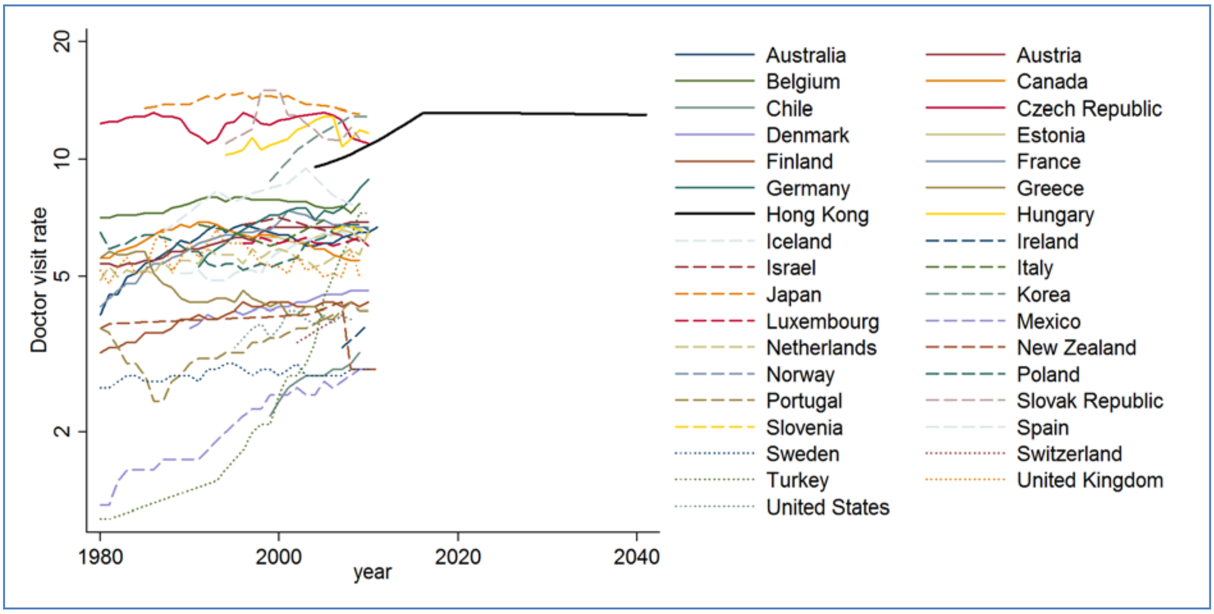

Figure 3.4 Comparison of Hong Kong and OECD doctor outpatient visit rates (152,153)

3.2 Model comparison

The top down methods (EOH and MSD), with relatively fewer data requirements, are based on the expectation that simple, aggregate models provide more reliable and reproducible healthcare utilisation projections. Further consistent, comprehensive data (number of observations and data-points) are available for the public sector. Much less reliable data are available for the private sector. The performance of a model is represented by the sum of absolute rate error $E(\theta, u)$:

$$E(\theta, u) = \sum_{a,s,y} \left| \widetilde{M_u}(a, s, y|\theta) - R_u(a, s, y) \right|$$

where $E(\theta, u)$ is the sum of absolute rate error of model θ ∈ {EOH-SVM, MSD-constant growth rate, MSD-historical growth rate} on utilisation rate *u*

$\widetilde{M_u}(a, s, y|\theta)$ is the estimated utilisation rate on *u* of age-sex group (*a*,*s*) at year *y* by model θ

$R_u(a,s,y)$ is the actual utilisation rate on *u* of age-sex group (*a*,*s*) at year *y*.

Note that the index *y* in the formulate of $E(\theta, u)$ has different range for different utilisation measures: $y \in \{2005, 2006, \ldots, 2011\}$ for public sector and private outpatient utilisation; and $y \in \{2007, 2008, \ldots, 2011\}$ for private sector inpatient utilisation. Table 3.1 lists the estimation error of EOH-SVM, MSD-constant growth rate and MSD-historical growth rate. The EOH-SVM models give a better model fit than the MSD models (Table 3.1). The EOH-SVM estimation errors are smaller than those for the MSD-constant growth or MSD-historical growth rate models.

Table 3.1 Comparison of EOH-SVM, MSD-constant growth, MSD-historical growth rate estimation errors

	EOH-SVM	MSD – constant growth rate	MSD – historical growth rate
Day case discharge rate (public)	0.93	7.56	1.53
Acute care in-patient discharge rate (public)	0.82	3.83	2.05
Acute care in-patient bed day rate (public)	7.29	44.65	17.19
Long stay discharge rate (public)	0.03	0.08	0.05
Long stay bed day rate (public)	11.09	28.42	20.21
SOP visit rate	3.67	8.09	8.08
GOP visit rate	4.04	16.95	10.06
A&E attendance rate	2.26	5.30	4.69
Day case discharge rate (private)	0.18	0.57	0.48
Acute care in-patient discharge rate (private)	0.11	0.42	0.33
Acute care in-patient bed day rate (private)	1.06	2.45	2.28
Private outpatient rate	99.03	252.69	251.94

In a sensitivity analysis, as would be expected, the EOH-RBM linear based model gives projections that are less steep than the Poisson model (which assumes an exponential trend) however, the data do not support a linear trend more than an exponential trend. The mean squared error is smaller for most utilisation measures projected by the RBM-Poisson model (Table 3.2). To avoid negative values, age-, sex-specific utilisation measures in the RBM linear model, share the same intercepts and slopes.

Table 3.2 Comparison of the linear and exponential RBM utilisation projections mean squared error (MSE) for selected demand/utilisation variables.

Demand/utilisation variables	**Natural scale**		**Log scale**	
	Linear	Exponential	Linear	Exponential
Public day cases	25.8	**18.0**	0.0038	**0.0026**
Public specialist outpatient visits	700	**522**	0.0014	**0.0007**
Public general outpatient visits	1189	**830**	0.0038	**0.0017**
Accident and Emergency visits	165.4	**125.8**	0.0021	**0.0016**
Private day cases	**1.63**	1.76	**0.0029**	0.003
Private acute care in-patient discharges	**6.13**	6.69	0.0028	**0.0013**
Private outpatient visits	771405	**561993**	0.032	**0.026**
DH Student and child services	1022	**982**	1.21	**0.09**
DH Port Health Office	0.20	**0.18**	0.18	**0.05**

SVM models have the ability to generalize, learn from examples, adapt to situations based on historical data and generalize patterns from historical data in response to unknown situations. SVM implicitly detects complex nonlinear relationships between independent and dependent variables. When responding to nonlinearity between the predictor variables and the corresponding outcomes, the model automatically adjusts its structure to reflect these nonlinearities. The predictor variables in SVM undergo multiple nonlinear transformations and can thereby potentially model much more complex nonlinear relationships than RBM.

Regression models can also be used to model complex nonlinear relationships. However, these models require an explicit search for these relationships by the model developer and these may not be known or well understood. Appropriate transformations may not always be available for improving model fit, and significant nonlinear relationships may go unrecognized by model developers.

When complex data and relationships are involved, as compared to RBM, SVM would in theory at least, and empirically shown by the model fit statistics above, provide a more robust projection outcome, more flexibly integrates complex data into the model, and is not dependent on a pre-determined hypotheses about the relationships between model variables. For these reasons, the EOH-SVM approach has been used for all model projections in the report.

4 Projecting pharmacist demand

The overall model for Hong Kong pharmacist manpower projection comprises two sub models, the utilisation model and the supply model. Building on an endogenous, historically-informed base case scenario (where current utilisation (proxying demand) and supply are assumed to be in equilibrium), this model is adopted to adjust for the impact of externalities such as: 1) de novo (i.e. exogenous) additional HA clinical pharmacy service and 2) the proposed role expansion of pharmacists in pharmaceutical companies and 3) HA Clinical Pharmacy service enhancement and policy options such as: Extend length of stay of pharmacists in Authorised Sellers of Poisons. The difference between the demand and supply projections (in terms of total FTE numbers, accumulative and annual incremental FTE from 2012 -2041) is the manpower 'gap' or 'surplus/shortfall'.

4.1 Parameters for pharmacist demand model projections

For the public sector, all HA age-, sex-specific in-patient discharge records (2004 to 2011; including day case, A&E, acute care in-patient and long stay) and all age-, sex-specific outpatient visits (for general and specialist outpatients, 2005-2011) are available for the healthcare utilisation projections. For the public sector model only data from 2005 are used as the data prior to these years would have been unduly influenced by organisational change within the HA and by the SARS epidemic. Data was also derived from the Pharmacy and Poisons Board of Hong Kong (PPBHK) annual report, the Thematic Household Survey, the Health Manpower Survey on Pharmacists (HMS), Assessment Report on Hong Kong's Capacity to Receive Tourists and the Hong Kong Census and Statistics Department demographic projection. Table 4.1 specifies the variables, parameterisation and data sources.

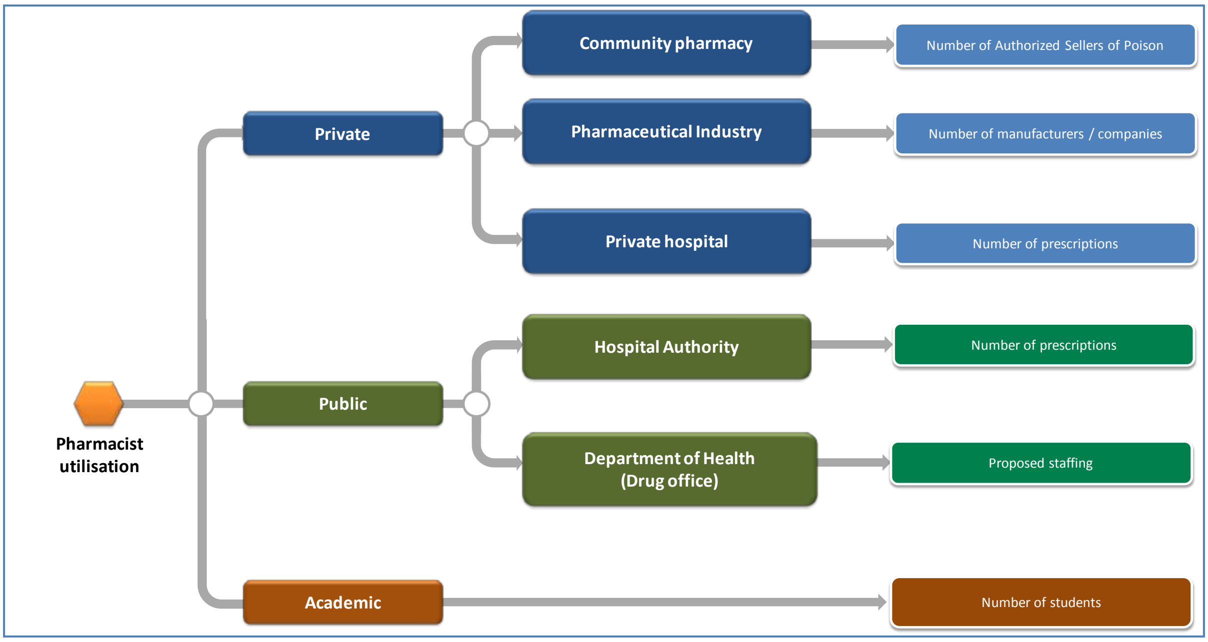

Figure 4.1 Flow diagram for estimating pharmacist demand in Hong Kong

Table 4.1 Demand model variables, parameterisation and data sources

Variables	Parameterisation[2]	Data source
Population to be served		
Resident population	Age- sex-stratified	C&SD 1999 through 2011
Population forecast	Age- sex-stratified	C&SD population projections 2012 - 2041
Mainland visitors	Aggregated	Assessment Report on Hong Kong's Capacity to Receive Tourists
In-patient		
Number of day cases		
Public sector	Age- sex-stratified	HA records 2005-2011
Private sector[1]	Age- sex-stratified	Hong Kong private hospitals 2007-2011[1]
Number of acute discharges		
Public sector	Age- sex-stratified	HA records 2005-2011
Private sector[1]	Age- sex-stratified	Hong Kong private hospitals 2007-2011[1]
Number of long stay discharges		
Public sector	Age- sex-stratified	HA records 2005-2011
Number of acute care bed-days		
Public sector	Age- sex-stratified	HA records 2005-2011
Private sector[1]	Age- sex-stratified	Hong Kong private hospitals 2007-2011[1]
Number of long stay bed-days		
Public sector	Age- sex-stratified	HA records 2005-2011
Number of drug items dispensed	Aggregated	HA records 2005-2011
Outpatient		
Number of visits (HA GOP/ SOP and A&E)	Age- sex-stratified	HA records 2005-2011
Number of visits (Private)	Age- sex-stratified	THS 2005-2009, 2011 adjusted for under reporting using HA outpatients records 2005-2011
Number of drug items dispensed	Aggregated	HA records 2005-2011
Pharmaceutical industry		
Number of pharmacists	Aggregated	PPBHK annual report
Number of pharmaceutical manufacturers	Aggregated	
Number of wholesale dealers licences to supply dangerous drugs	Aggregated	
Pharmaceutical retailers		
Number of pharmacists	Aggregated	PPBHK annual report
Number of community pharmacies	Aggregated	

[1]Private hospitals: Evangel Hospital, Hong Kong Adventist Hospital, Hong Kong Baptist Hospital, Hong Kong Central Hospital, Hong Kong Sanatorium and Hospital, Matilda International Hospital, Precious Blood Hospital, St Paul's Hospital, St Teresa's Hospital, Tsuen Wan Adventist Hospital, Union Hospital, The Canossa Hospital
[2]All data were stratified by age and sex groups in 5-year age categories.

For the private sector, private hospital age-, sex-specific in-patient discharge records (2007-2011: including day case and acute care in-patient) are used as utilisation trends and data available prior to 2007 were of inconsistent quality. Age-, sex-specific outpatients visits from the THS 2005, 2008, 2009 and 2011are used for the private sector outpatient utilisation projections with adjustment for underreporting.

4.2 Demand indicators

4.2.1 Average length of stay (acute care and long stay patients)

Average length of stay (ALOS) (total bed-days by age-, sex-specific discharges) is separately calculated for public acute care in-patients and long stay patients, and private acute care in-patients. Age-, sex-specific ALOS for acute care in-patients (length of stay (LOS) > 1 day, excluding long stay[4] episodes) is determined from HA in-patient discharge records (2004-2011) and private hospital in-patient discharge records (2007-2011). Age-, sex-specific ALOS for long stay in-patients (those designated officially as long stay episodes) is determined from HA in-patient discharge records (2004-2011).

4.2.2 Discharge rates (day case, acute care, long stay)

The discharge rates are based on HA (2004-2011) and private hospital in-patient (2007-2011) discharge records. All age-, sex-specific in-patient (day case (LOS ≤1 day), acute care (LOS > 1 day excluding long stay episodes) and long stay (those designated officially as such) discharges are included.

The number of public hospital day cases (Figure 4.2(a)), acute care in-patient (Figure 4.4(a)) and long stay discharges (Figure 4.6(a)) although projected to increase throughout the period the increase is most notable in day case discharges. After adjusting for population demographics discharge rates for day cases increase but acute care in-patient and long stay discharge rates decrease (Figure 4.3(a), 4.5(a) and 4.7(a)). Increased utilisation rates in public sector day cases are observed for both sexes in the 55+ year age groups (Figure 4.2(b-c)); however, women have more variable discharge rate changes throughout the adult years (Figure 4.2(c), 4.4(c) and 4.6(c)). In contrast to older women, the projected number of acute care in-patient and long stay discharges for older men have increased (Figure 4.4(c), Figure 4.6(c)).

[4] *Long stay episodes fulfil one of the following criteria: discharge specialty denoted by HA as either "infirmary", "mentally handicapped", or "psychiatry AND total length of stay >90 days*

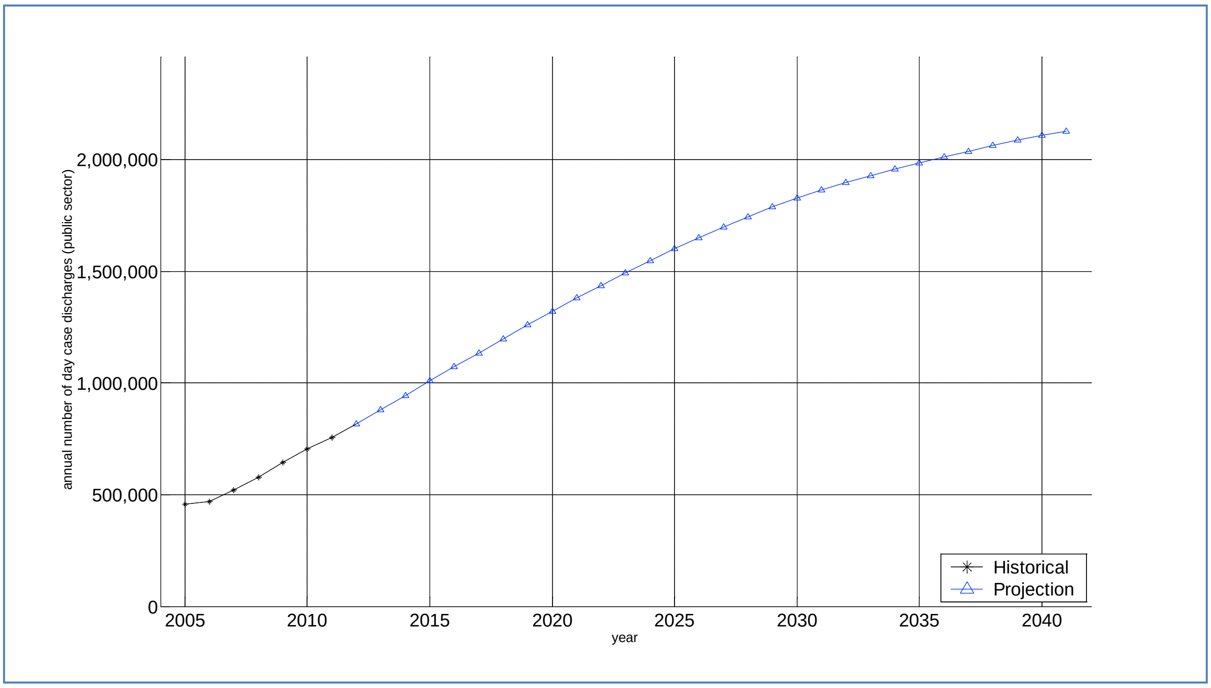

Figure 4.2(a) Projected number of public sector day case discharges (by SVM) (2005-2041)

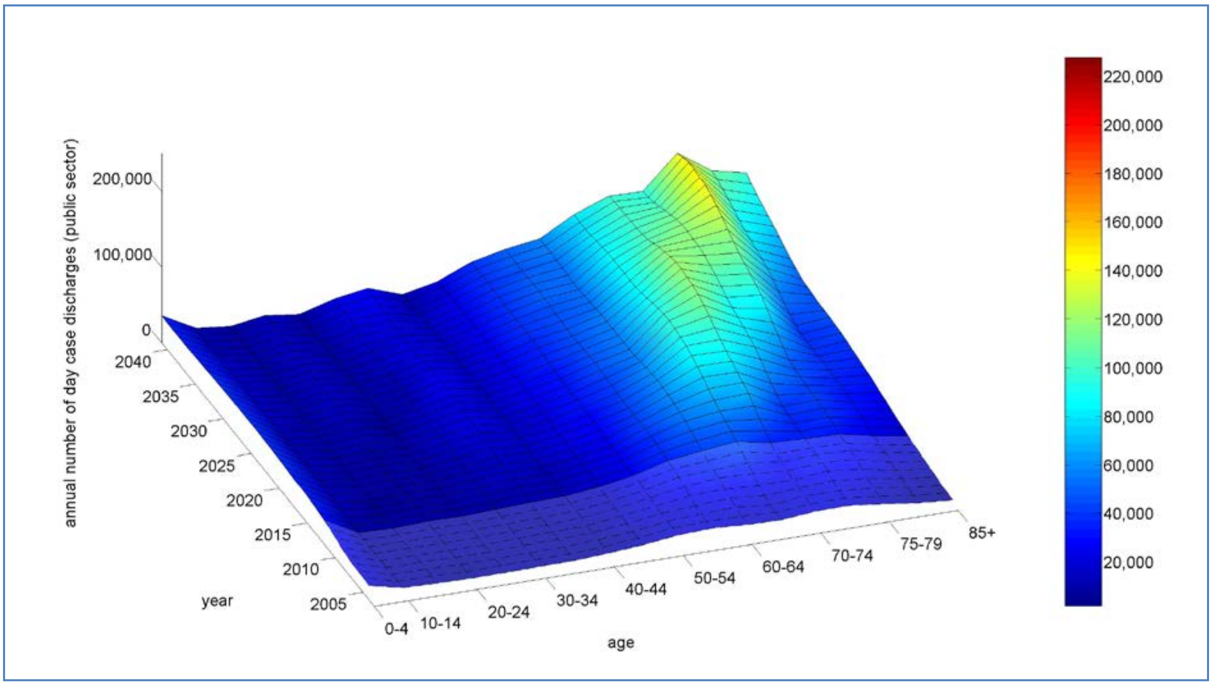

Figure 4.2(b) Projected number of public sector age-specific day case discharges (by SVM) – male (2005-2041)

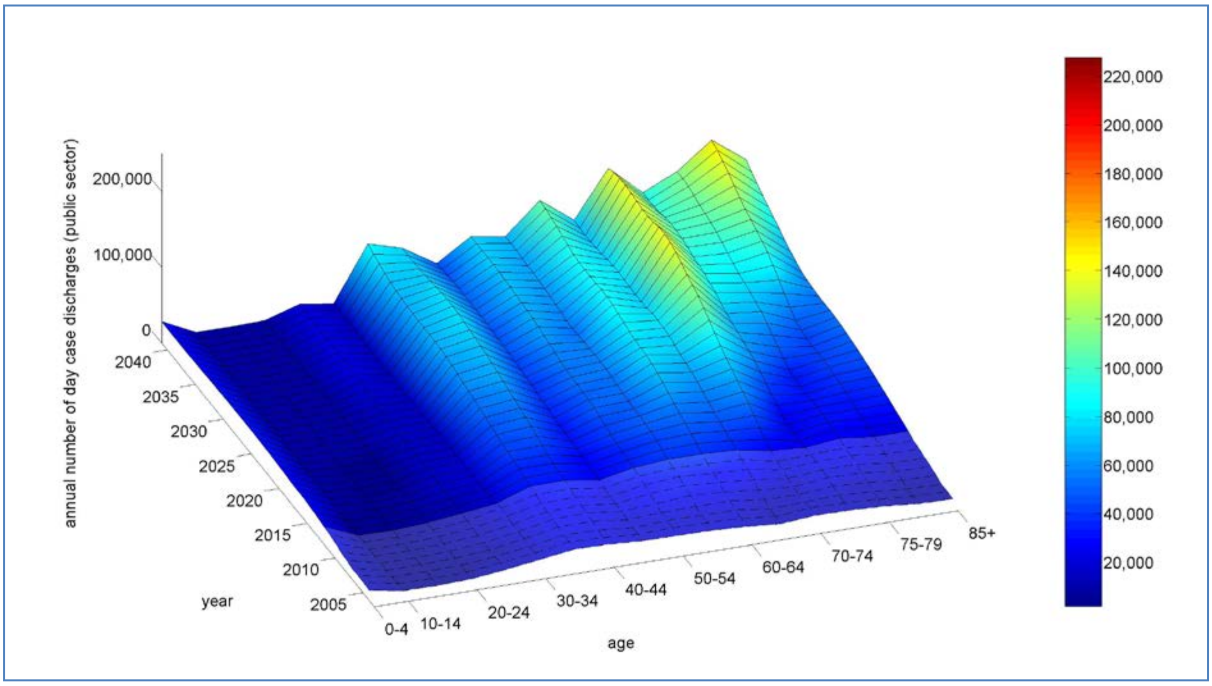

Figure 4.2(c) Projected number of public sector age-specific day case discharges (by SVM) – female (2005-2041)

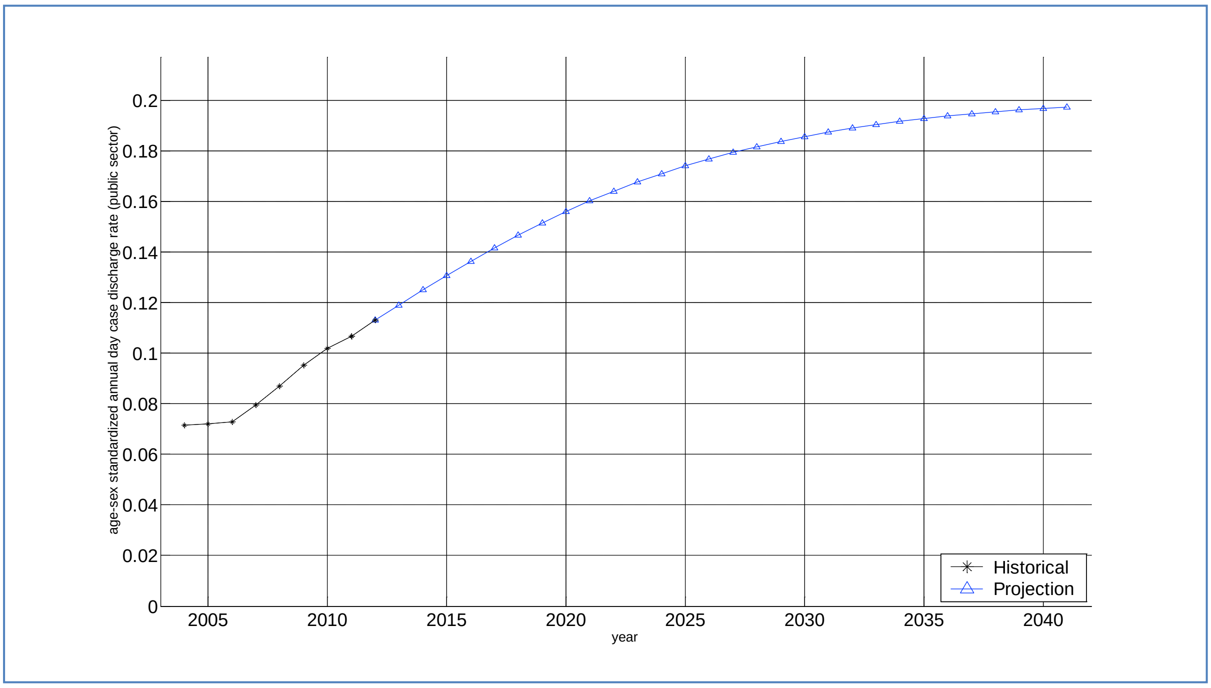

Figure 4.3(a) Projected annual public sector day case discharge rates (by SVM) (2005-2041)

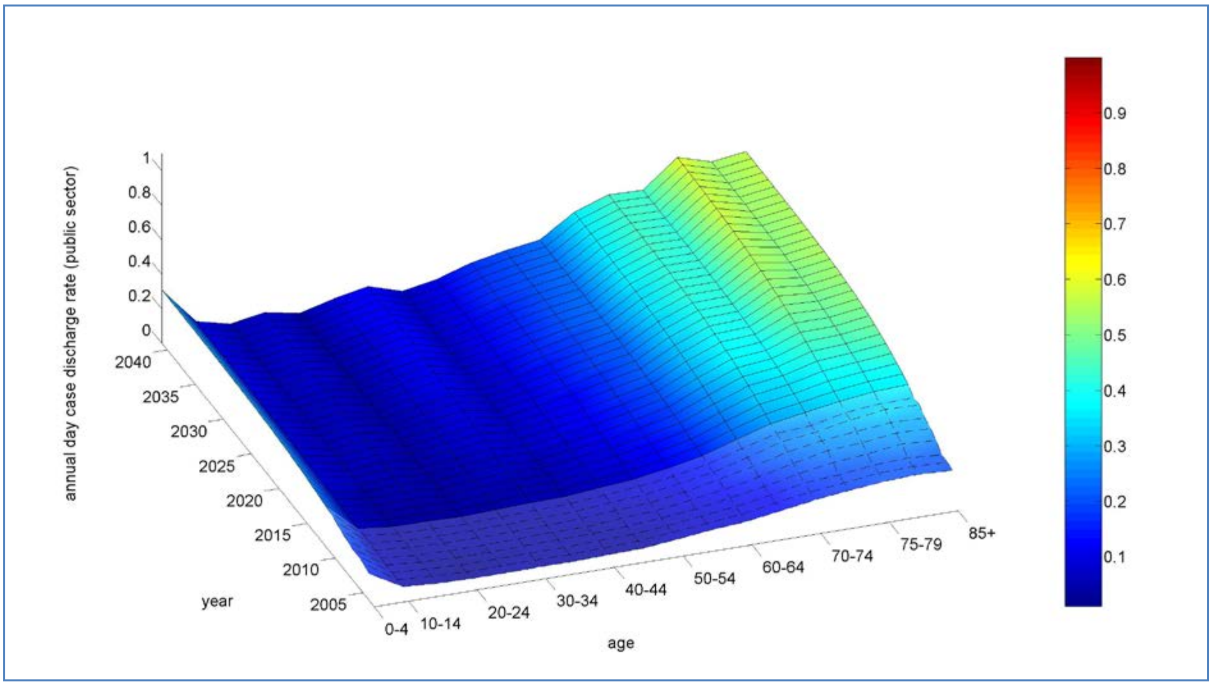

Figure 4.3(b) Projected annual public sector day case average discharge rates (by SVM) - male (2005-2041)

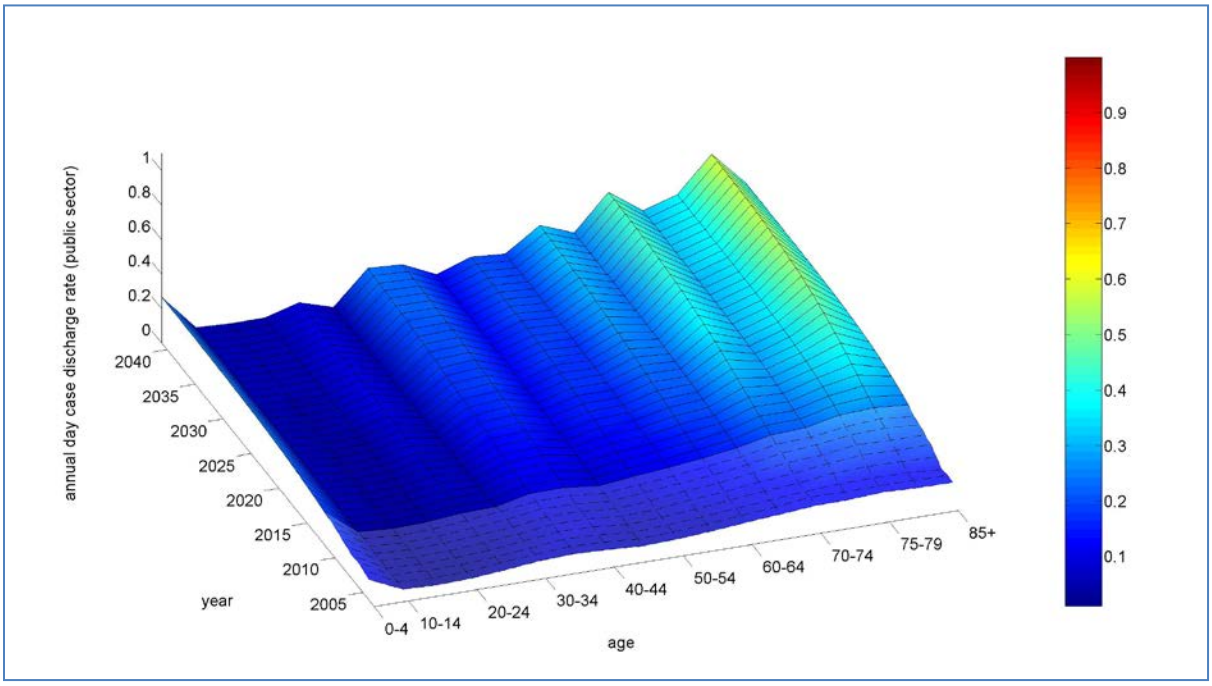

Figure 4.3(c) Projected annual public sector day case average discharge rates (by SVM) – female (2005-2041)

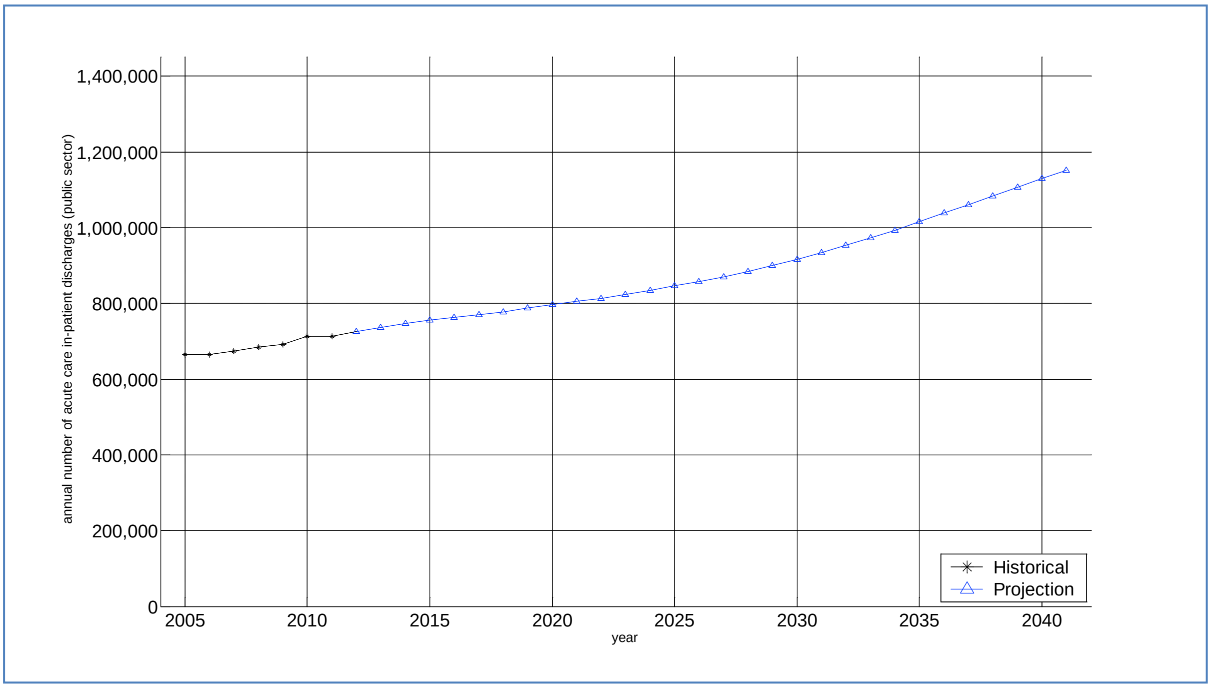

Figure 4.4(a) Projected number of public sector acute care in-patient discharges (by SVM) (2005-2041)

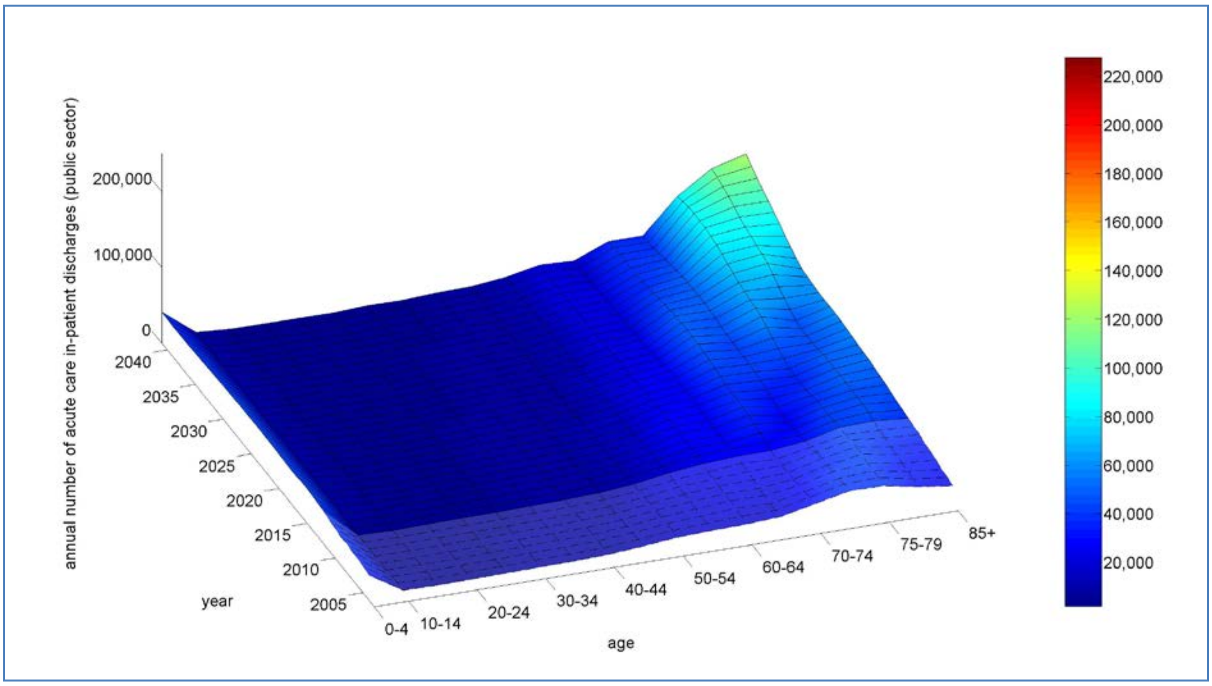

Figure 4.4(b) Projected number of public sector age-specific acute care in-patient discharges (by SVM) – male (2005-2041)

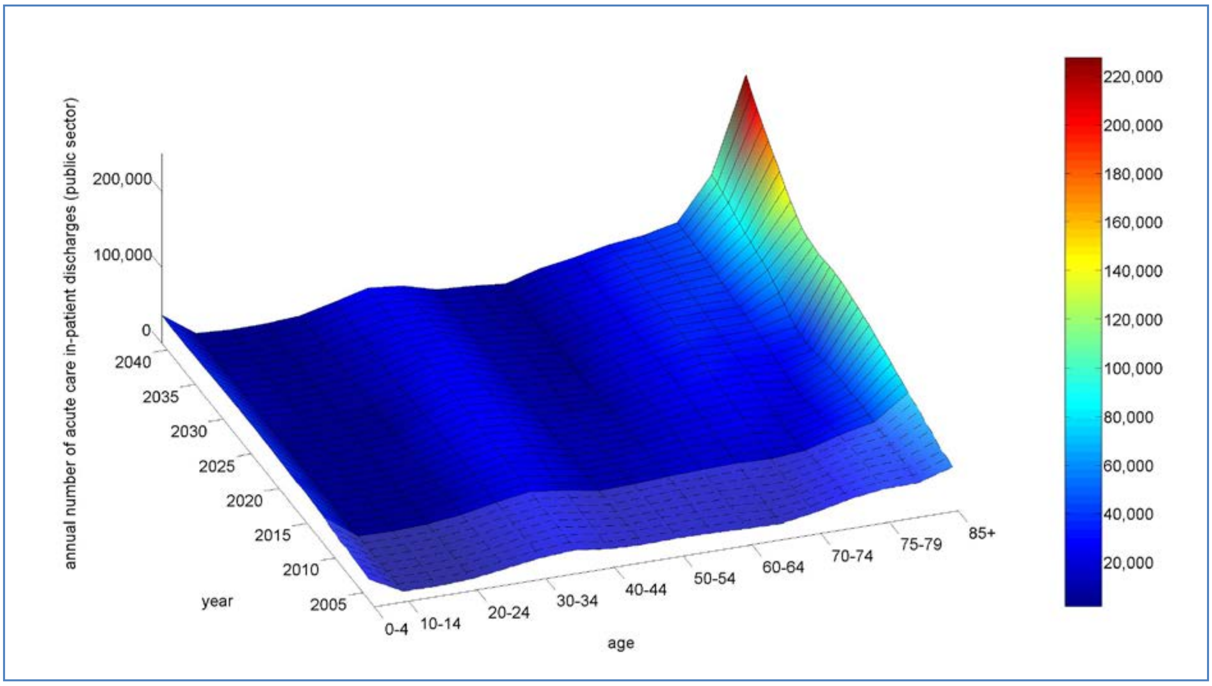

Figure 4.4(c) Projected number of public sector age-specific acute care in-patient discharges (by SVM) – female (2005-2041)

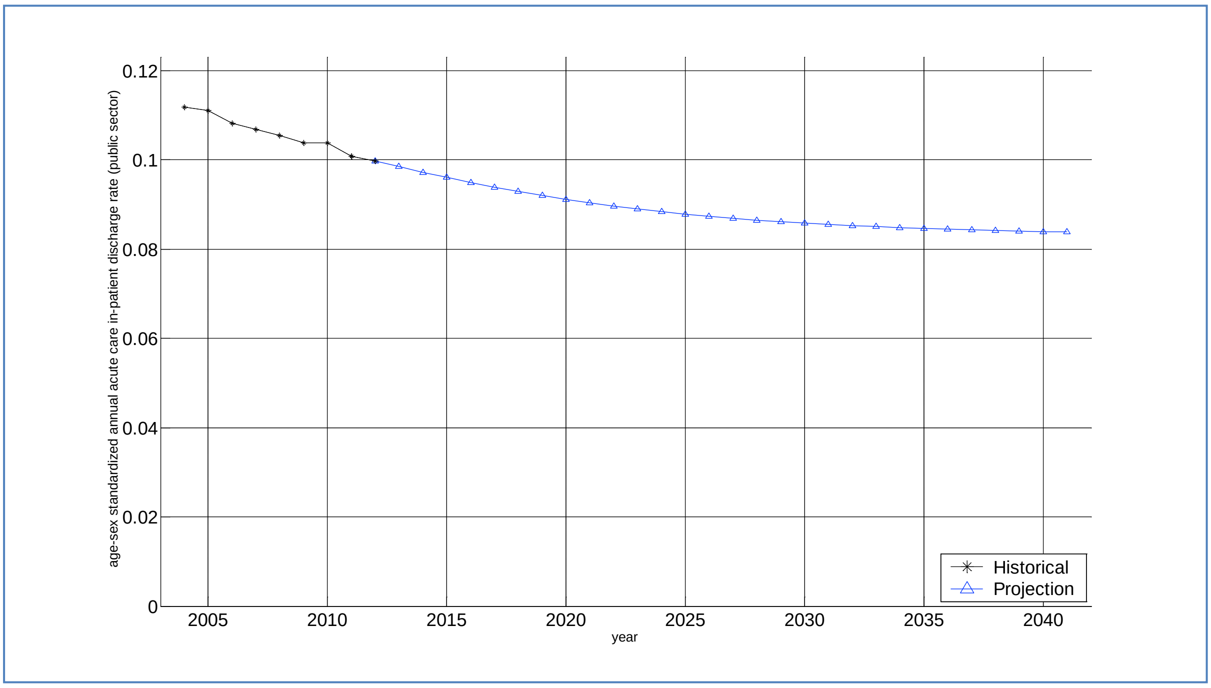

Figure 4.5(a) Projected annual public sector acute care in-patient discharge rates (by SVM) (2005-2041)

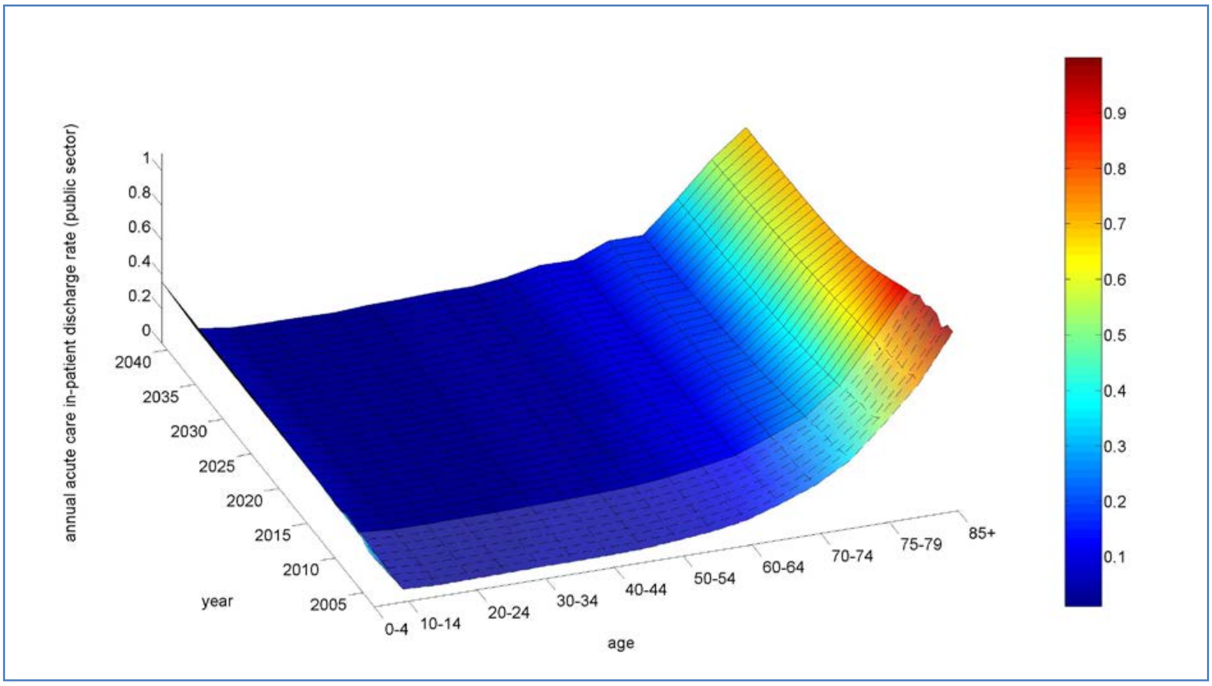

Figure 4.5(b) Projected annual public sector acute care in-patient average discharge rates (by SVM) - male (2005-2041)

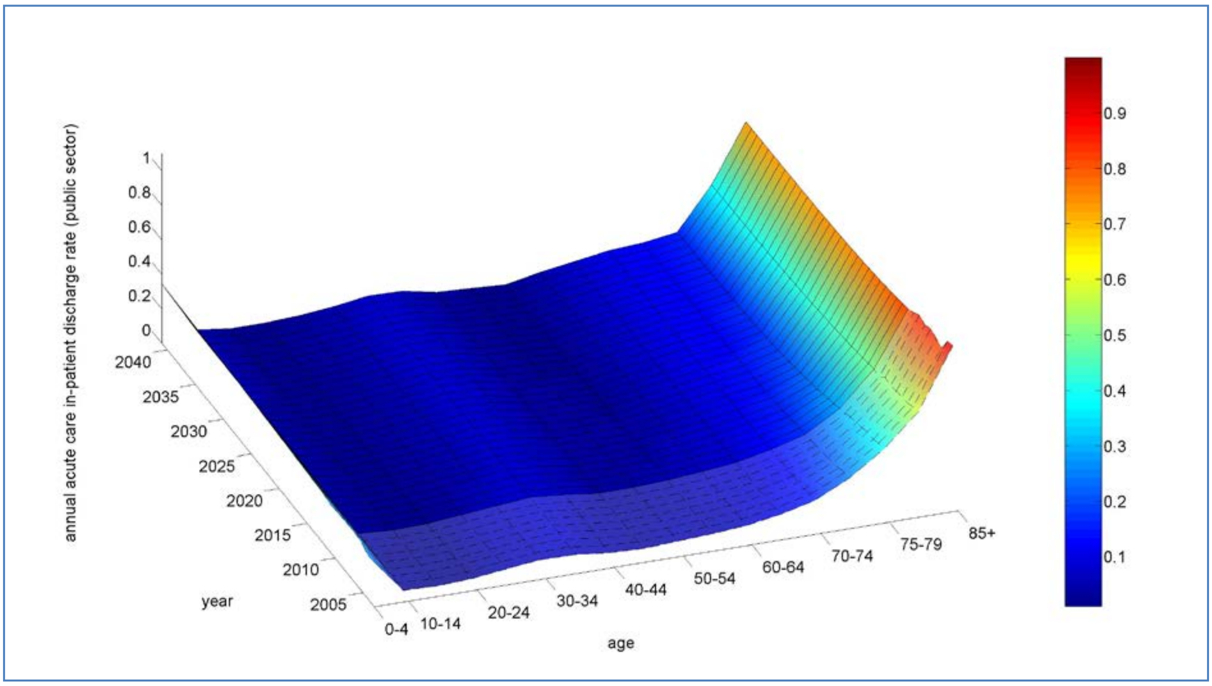

Figure 4.5(c) Projected annual public sector acute care in-patient average discharge rates (by SVM) – female (2005-2041)

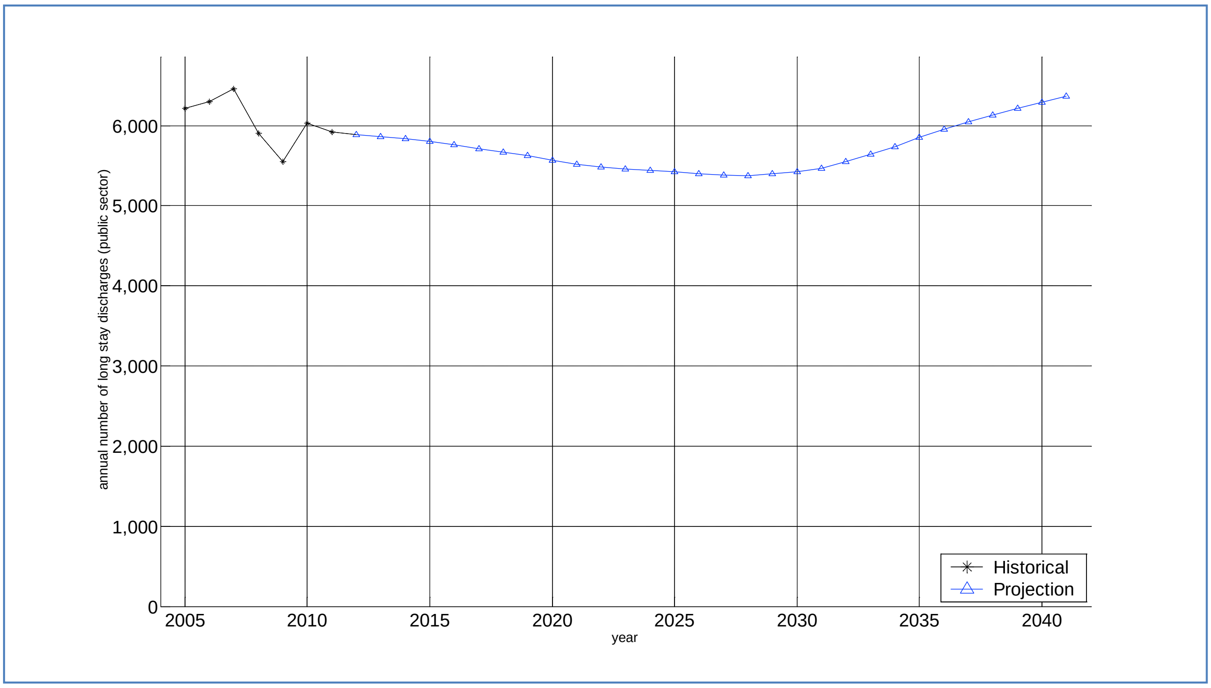

Figure 4.6(a) Projected number of public sector long stay discharges (by SVM) (2005-2041)

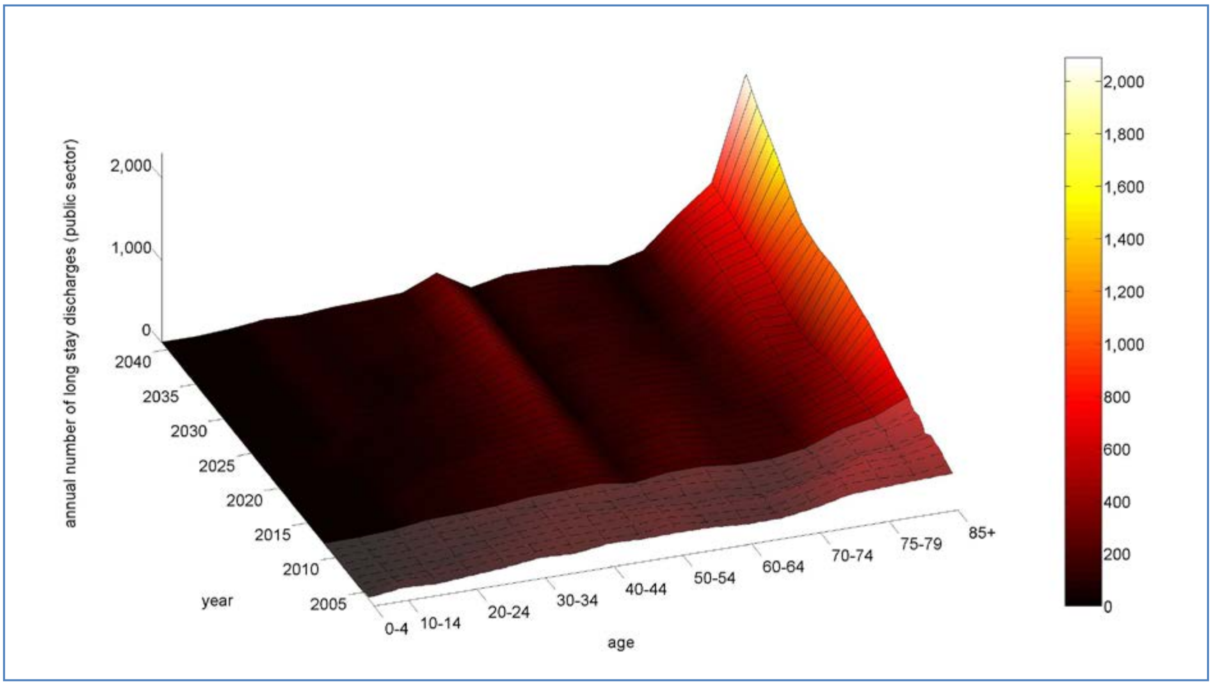

Figure 4.6(b) Projected number of public sector age-specific long stay discharges – male (2005-2041)

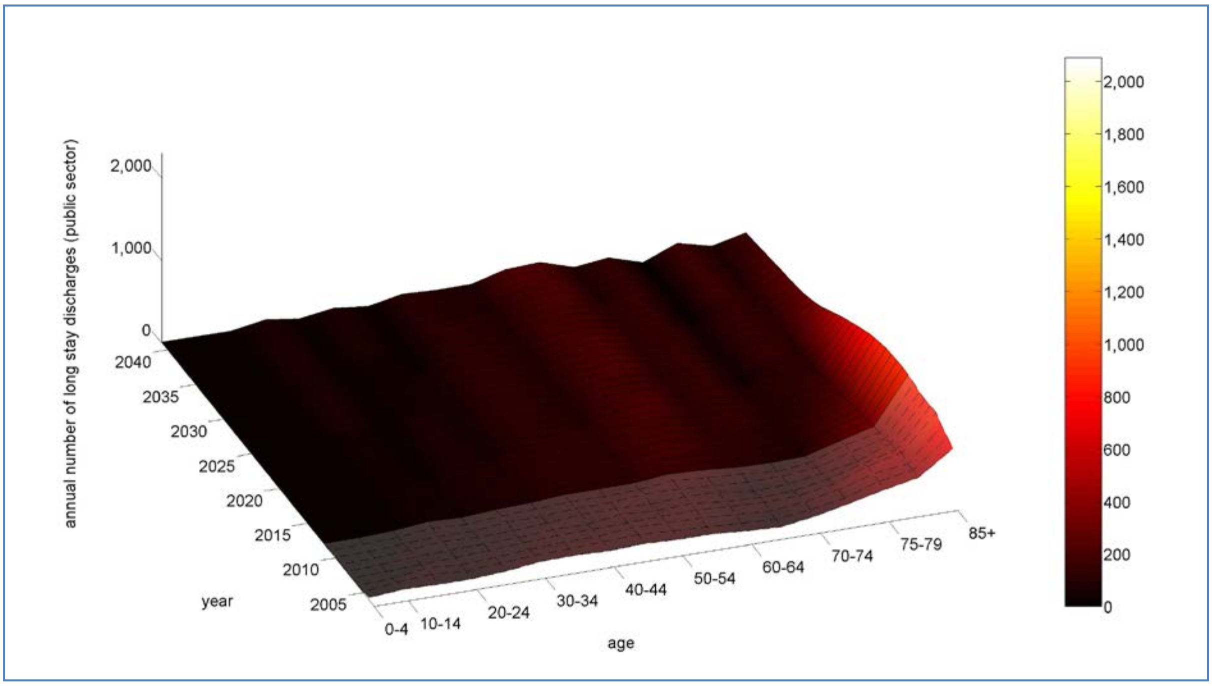

Figure 4.6(c) Projected number of public sector age-specific long stay discharges – female (2005-2041)

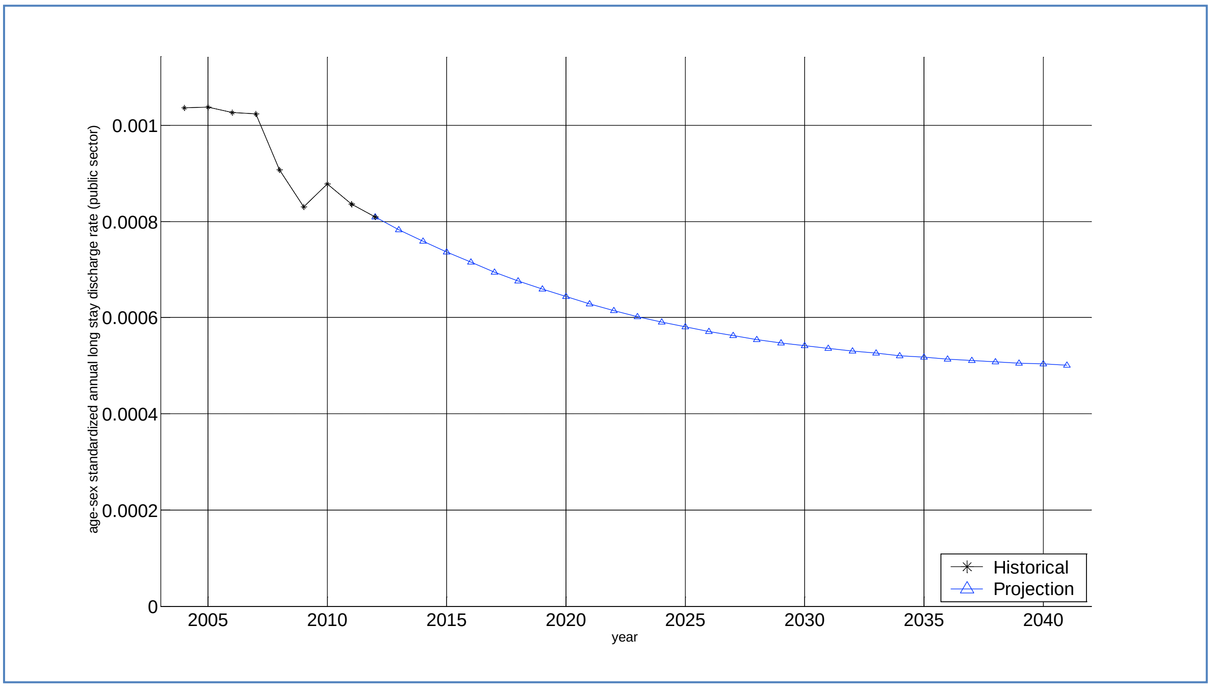

Figure 4.7(a) Projected annual public sector long stay discharge rates (by SVM) (2005-2041)

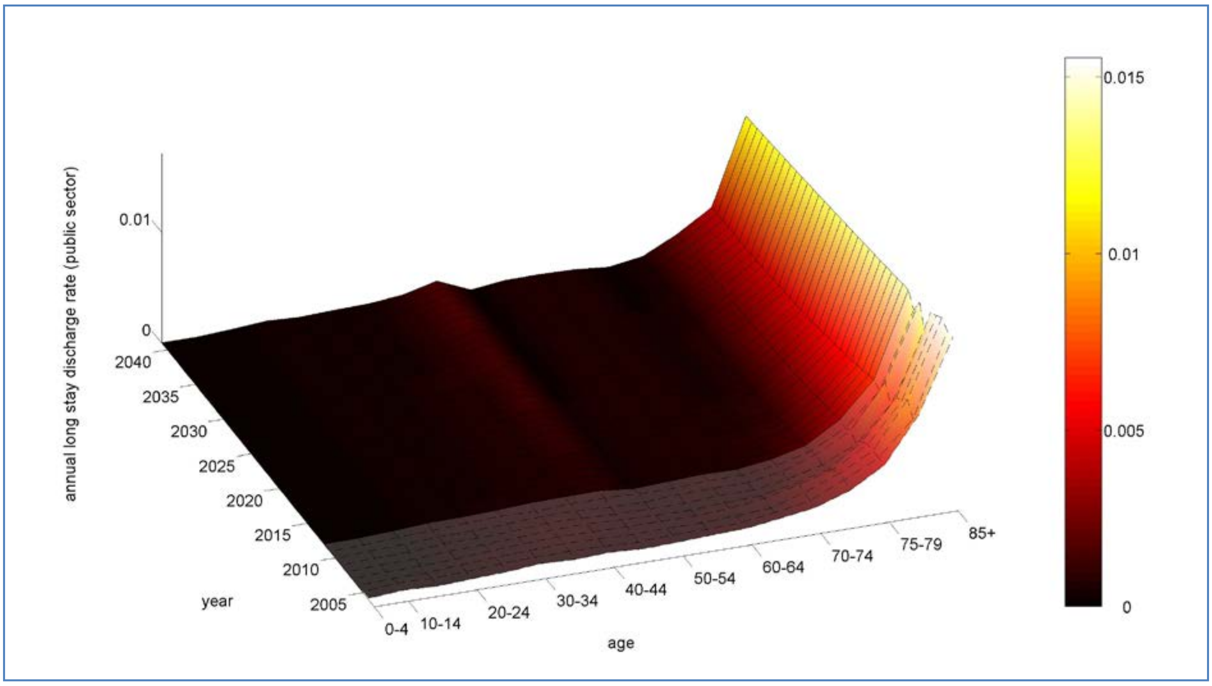

Figure 4.7(b) Projected annual public sector long stay average discharge rates (by SVM) – male (2005-2041)

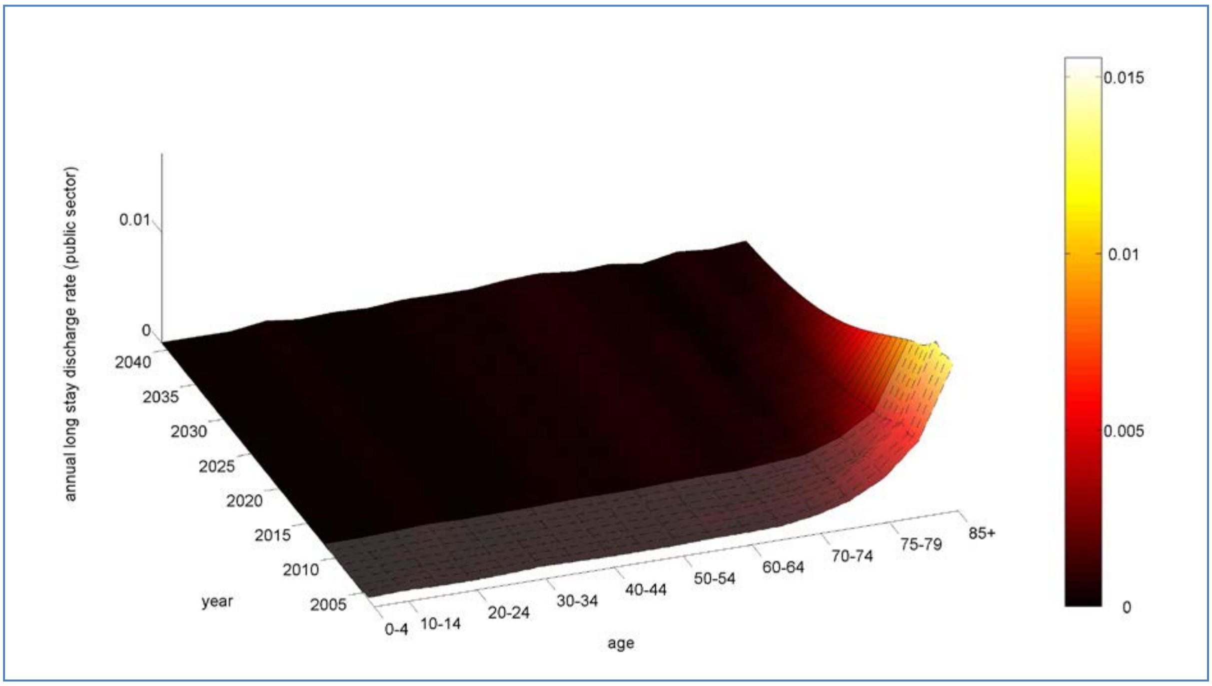

Figure 4.7(c) Projected annual public sector long stay average discharge rates (by SVM) - female (2005-2041)

In contrast to the public sector, the number of private sector day cases (Figure 4.8(a)) and acute care in-patient discharges (Figure 4.10(a)) increase and then plateau from 2020. Similarly private sector day case and acute care inpatient population-adjusted discharge rates increase to 2020 and then plateau (Figure 4.9(a) and 4.11(a)). Higher male vs. female private sector day case discharge rates at both ends of the age spectrum are observed (Figure 4.11(b-c). The increased day case discharges in the 35-65 year age groups for both sexes may suggest increased ability to pay for private acute care hospitalisation in these age groups (Figure 4.8(b-c)). In the private sector, increases in acute care in-patient discharges and discharge rates adjusted for population demographics are observed for the 0-5 year age groups and women of childbearing age (suggests an increase in the use of private hospitals for births) (Figure 4.10(b-c) and 4.11(b-c)).

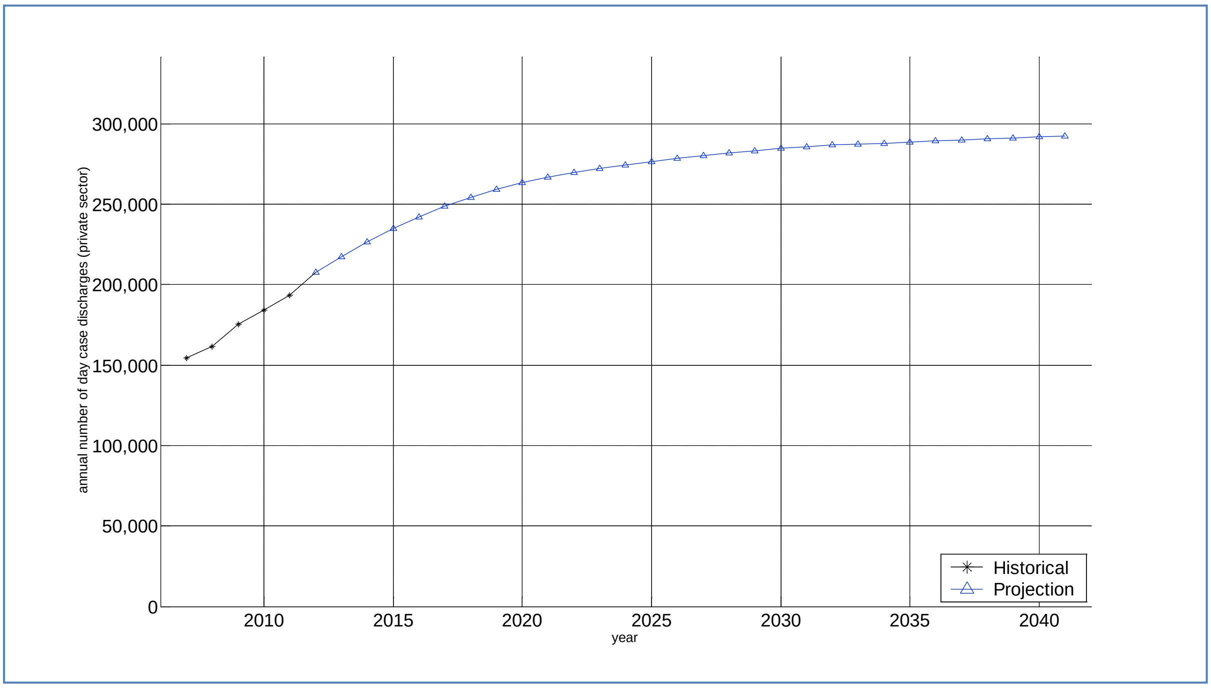

Figure 4.8(a) Projected number of private sector day case discharges (by SVM) (2005-2041)

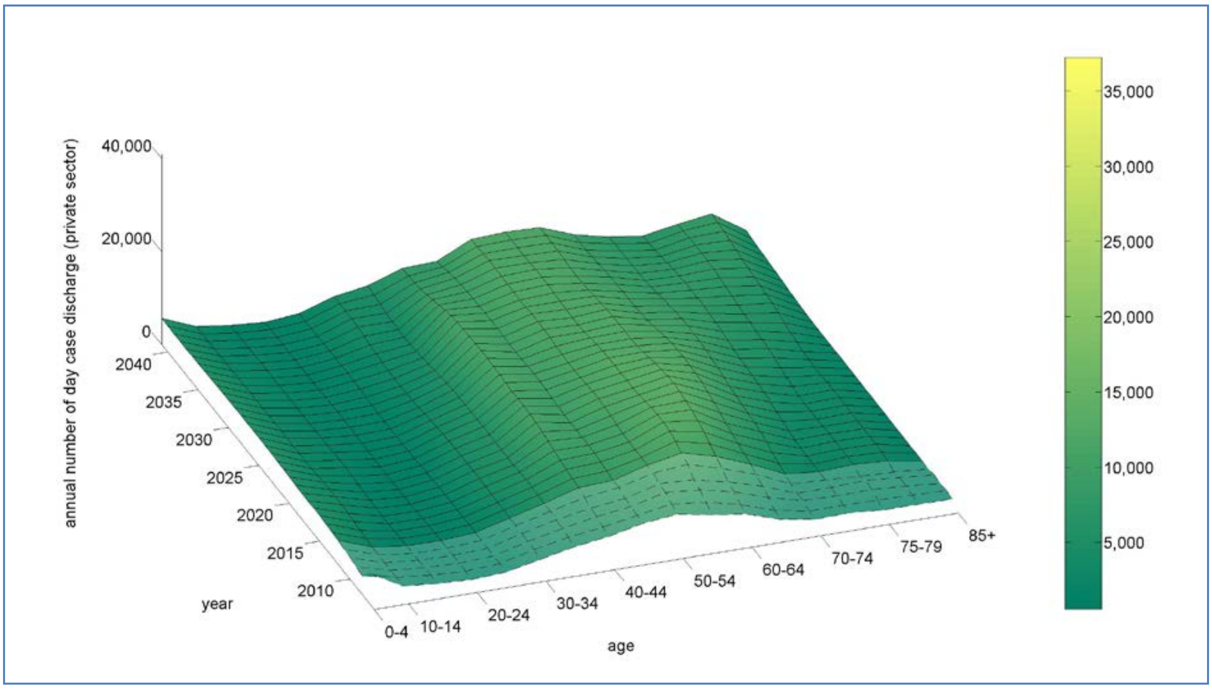

Figure 4.8(b) Projected number of private sector age-specific day case discharges (by SVM) – male (2005-2041)

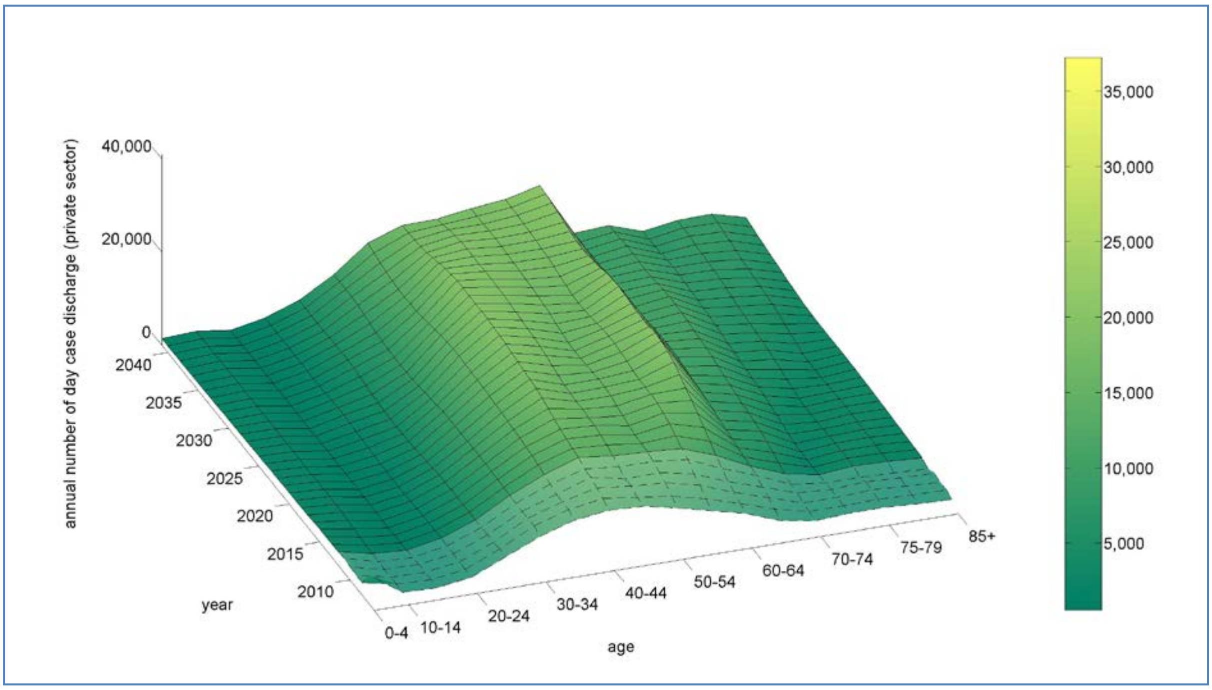

Figure 4.8(c) Projected number of private sector age-specific day case discharges (by SVM) – female (2005-2041)

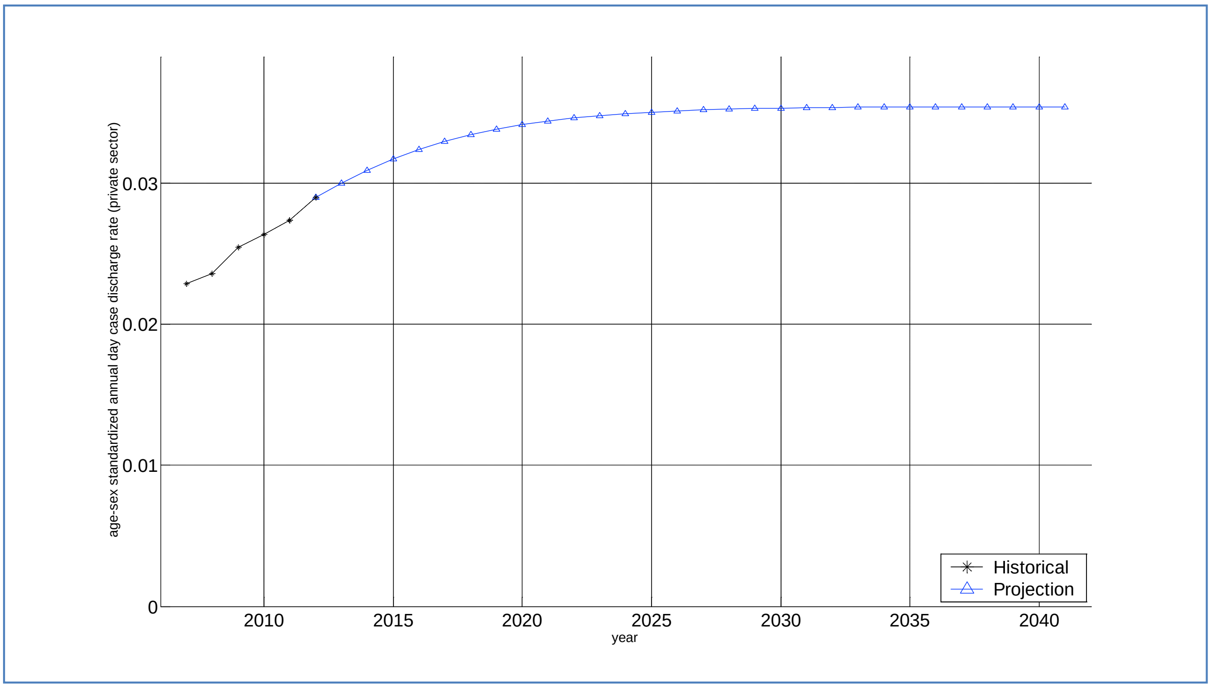

Figure 4.9(a) Projected annual private sector day case discharge rates (by SVM) (2007-2041)

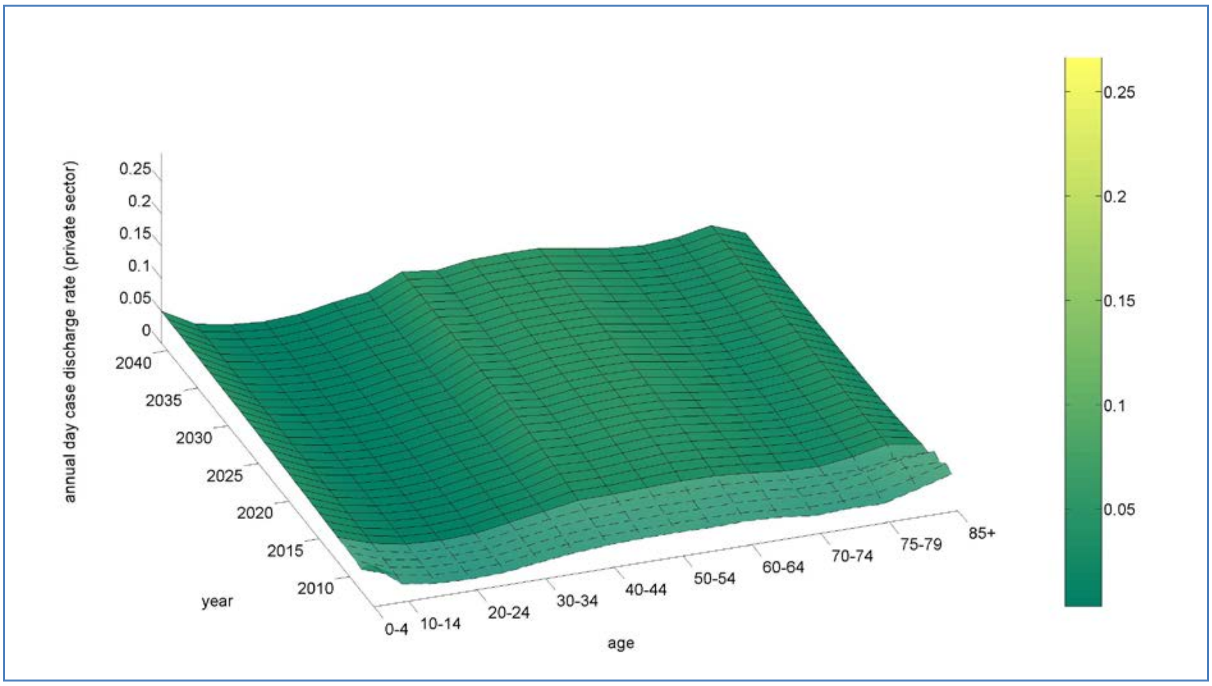

Figure 4.9(b) Projected private sector average day case discharge rates (by SVM) - male (2007-2041)

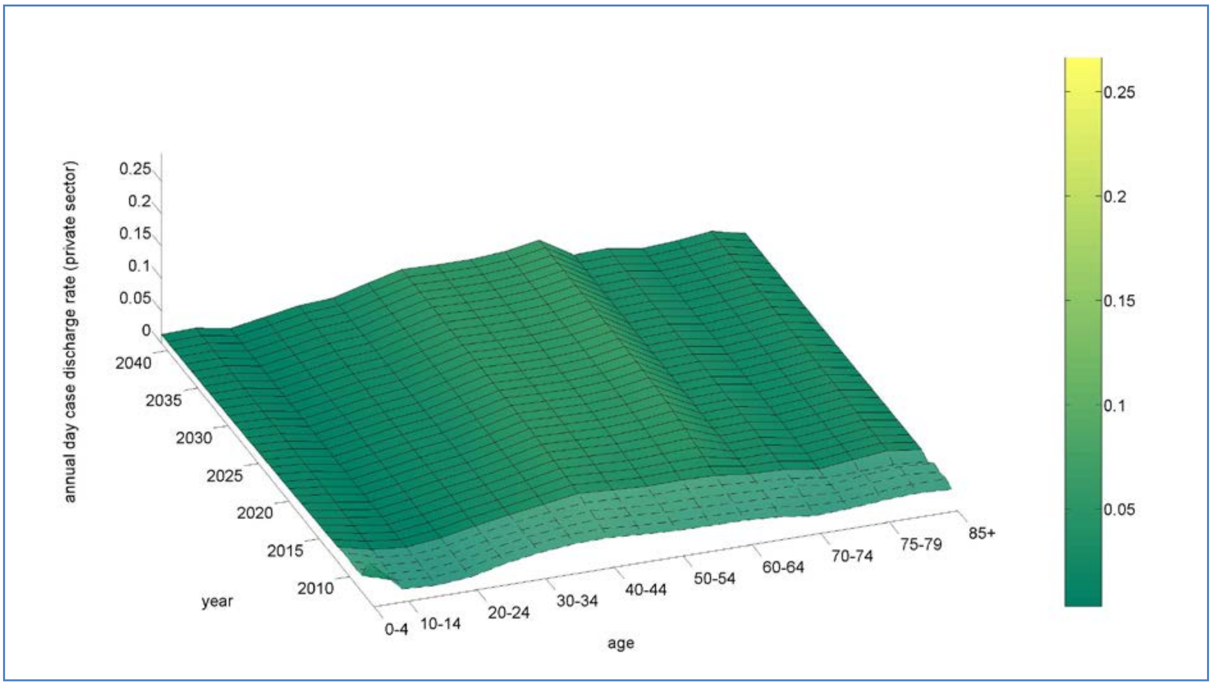

Figure 4.9(c) Projected private sector average day case discharge rates (by SVM) - female (2007-2041)

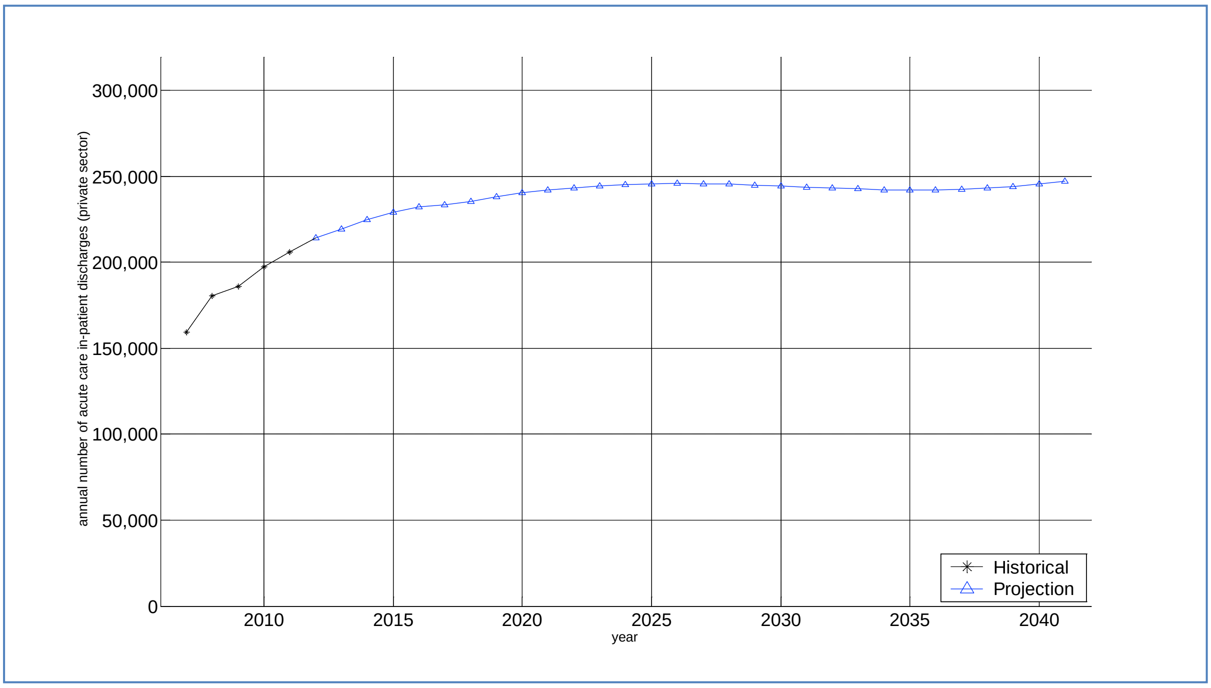

Figure 4.10(a) Projected number of private sector acute care in-patient discharges (by SVM) (2007-2041)

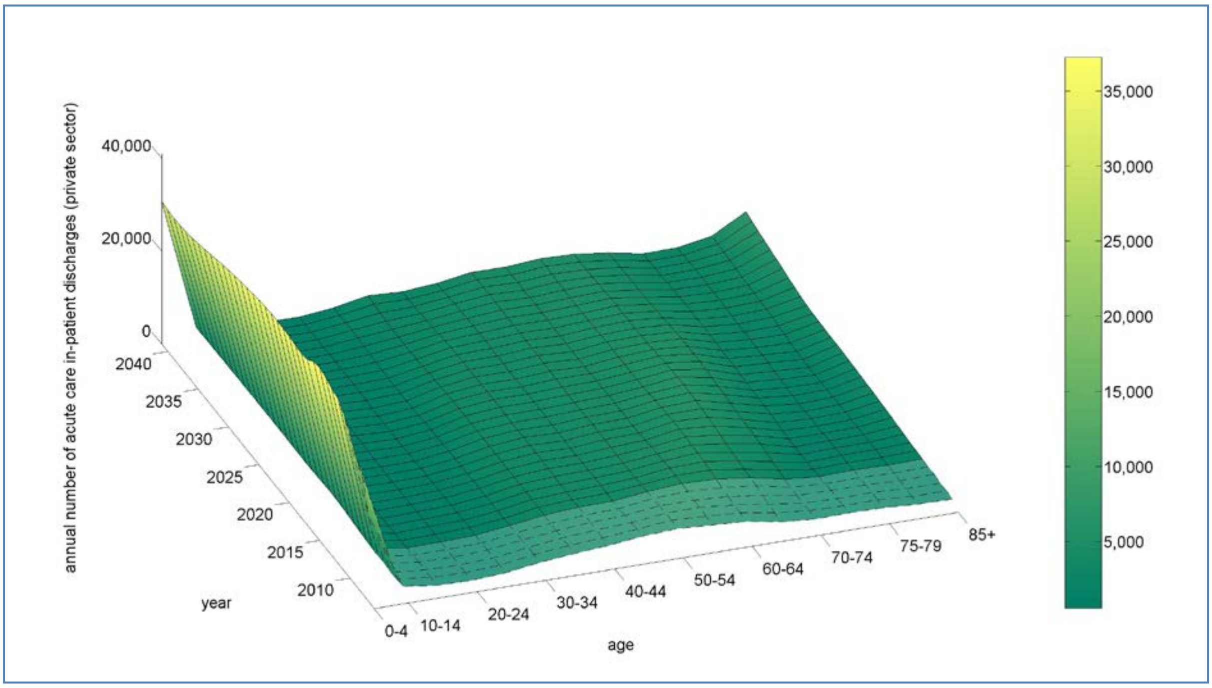

Figure 4.10(b) Projected number of private sector age-specific acute care in-patient discharges (by SVM) – male (2007-2041)

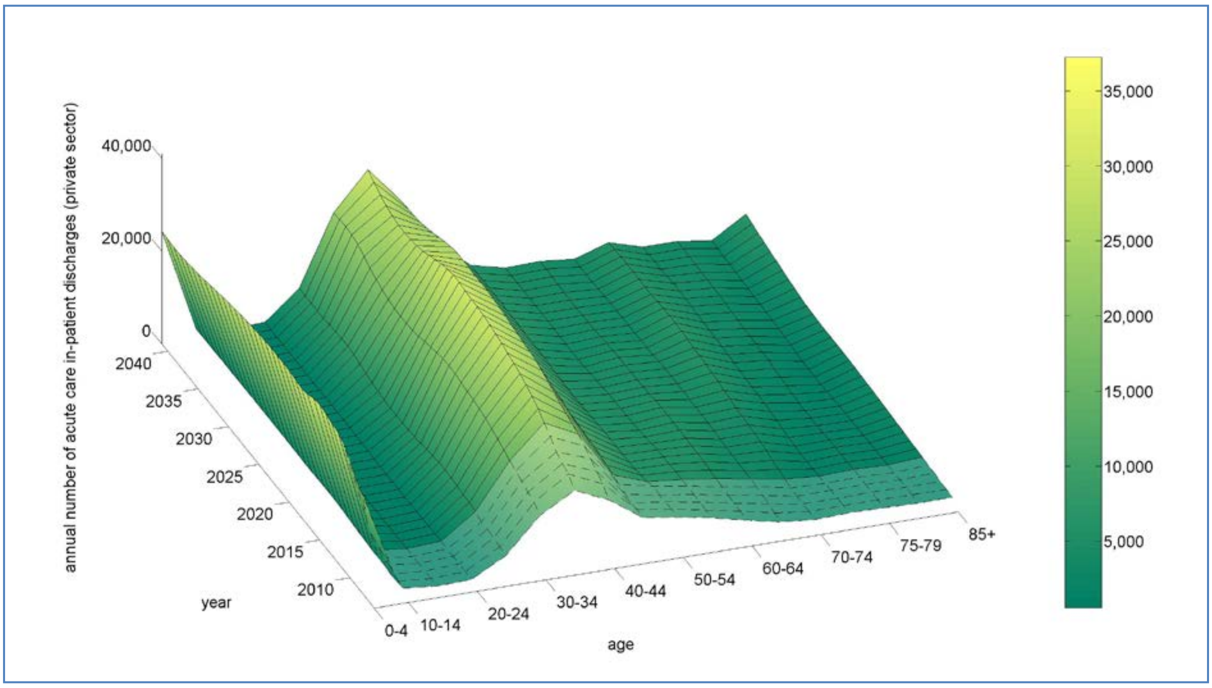

Figure 4.10(c) Projected number of private sector age-specific acute care in-patient discharges (by SVM) – female (2007-2041)

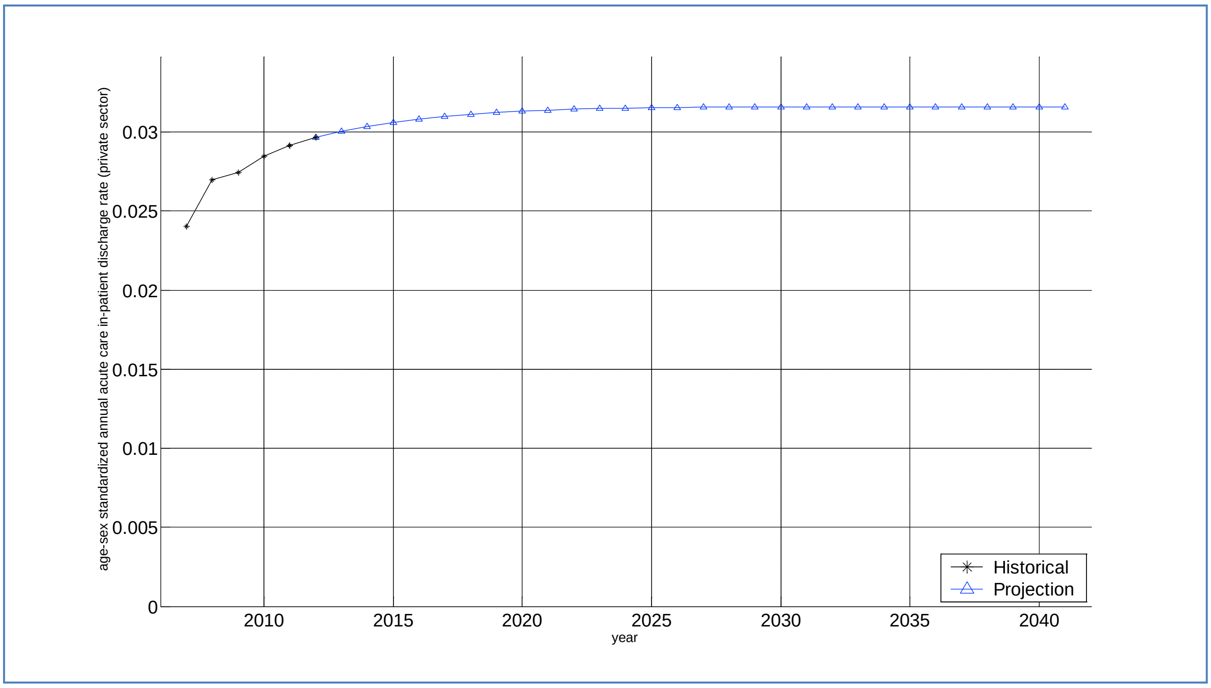

Figure 4.11(a) Projected annual private sector acute care in-patient discharge rates (by SVM) (2007-2041)

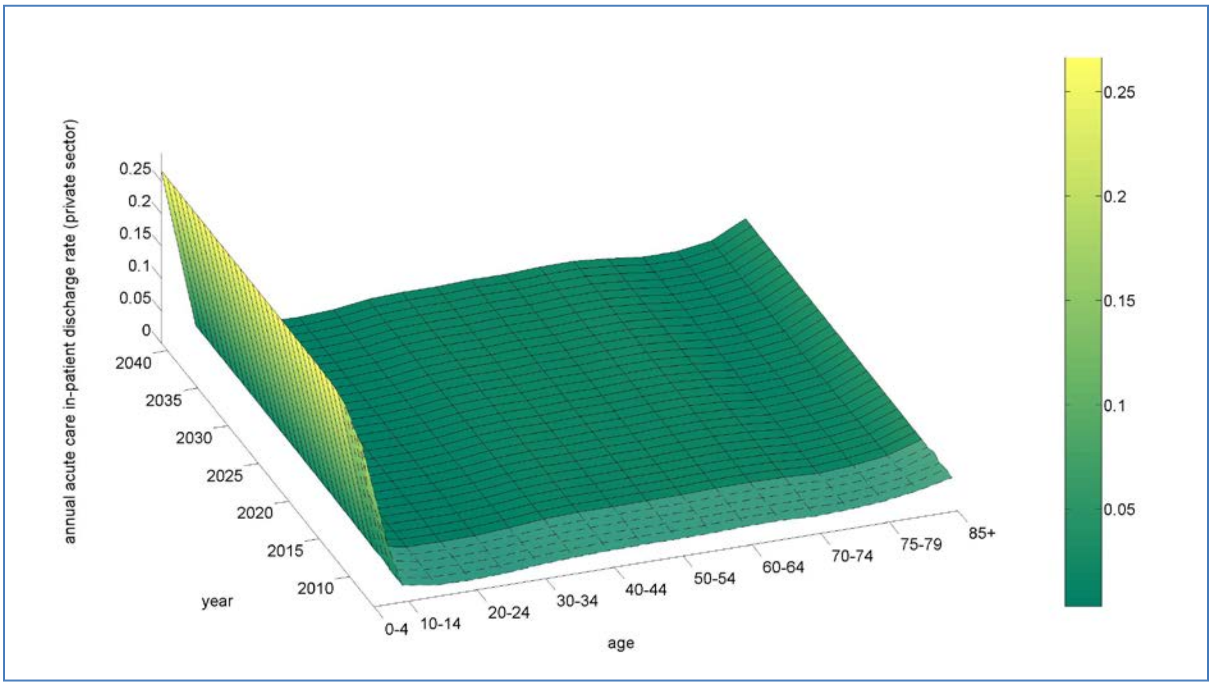

Figure 4.11(b) Projected private sector average acute care in-patient discharge rates (by SVM) - male (2007-2041)

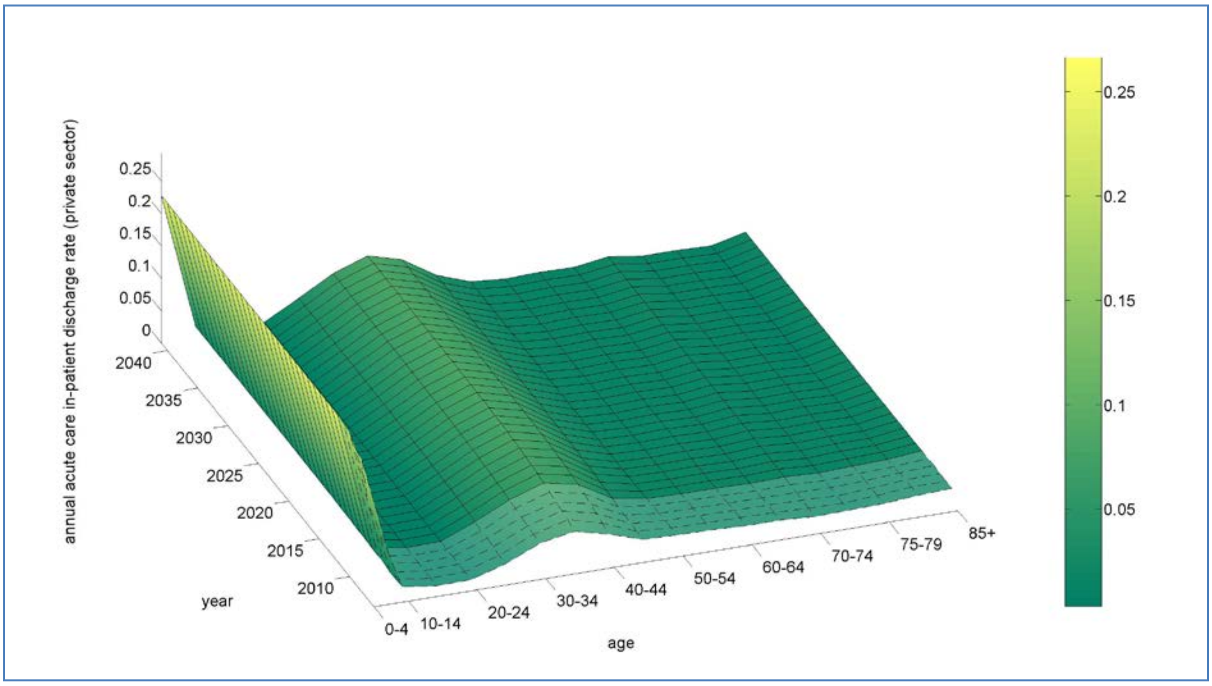

Figure 4.11(c) Projected private sector average acute care in-patient discharge rates (by SVM) – female (2007-2041)

4.2.3 Outpatient visit rates

HA A&E, general and specialist outpatient visit records per year (2004-2011) are used to project age-, sex-specific public sector outpatient visit rates. Due to the limited number of data points for private sector outpatient visits (THS data for 2005, 2008, 2009 and 2011) outpatient visit rates for 2006, 2007, and 2010 are estimated using the observed public (HA, excluding A&E) : private outpatient visit proportion as follows:-

$$\text{Number of private outpatient visits } (a, s, y)$$
$$= \text{Number of HA outpatient visits } (a, s, y)$$
$$\times \text{ Ratio of private to public outpatient visit } (\text{THS}(y), a, s)$$

The ratio of private to public outpatient visits for years 2006, 2007, and 2010 (for which no THS was available) were estimated by interpolating from the ratios estimated from THS 2005, 2008, 2009, and 2011. Only HA outpatient visits are included. Private sector outpatient visits include solo practice clinics (single practitioner), group practice clinics (multiple practitioners of single or multiple specialties), private hospital outpatient clinics, institutional clinics (charitable organization and ‘exempted’ clinics), university/tertiary institution clinics and Family Planning Association of Hong Kong clinics.

General and Specialist Outpatient Clinics

The number of GOP visits increase slowly (Figure 4.12(a)), however after adjustment for population demographics the GOP visit rates decrease reflecting the supply ceiling (lack of capacity to provide more service) in the public sector (Figure 4.13(a)). The public sector SOP number of visits and visit rates (after adjustment for population demographics) increase slowly (Figure 4.14(a) and 4.15(a)). There are more GOP and SOP visits for older women vs. men (Figure 4.12(b-c), 4.14(b-c)). The visits rates for older women vs. men are also higher (Figure 4.13(b-c) and 4.15(b-c)). In contrast, the number of private sector outpatient visits (Figure 4.16(a)) and visit rates increase and plateau from 2025 (Figure 4.17(a)). Women of child-bearing age have many more private sector visits than men (Figure 4.16(b-c). However, the private sector outpatient analysis should be interpreted with caution as the data for the private sector projections is less reliable than that for the public sector as these are based on interpolated estimates of the THS data.

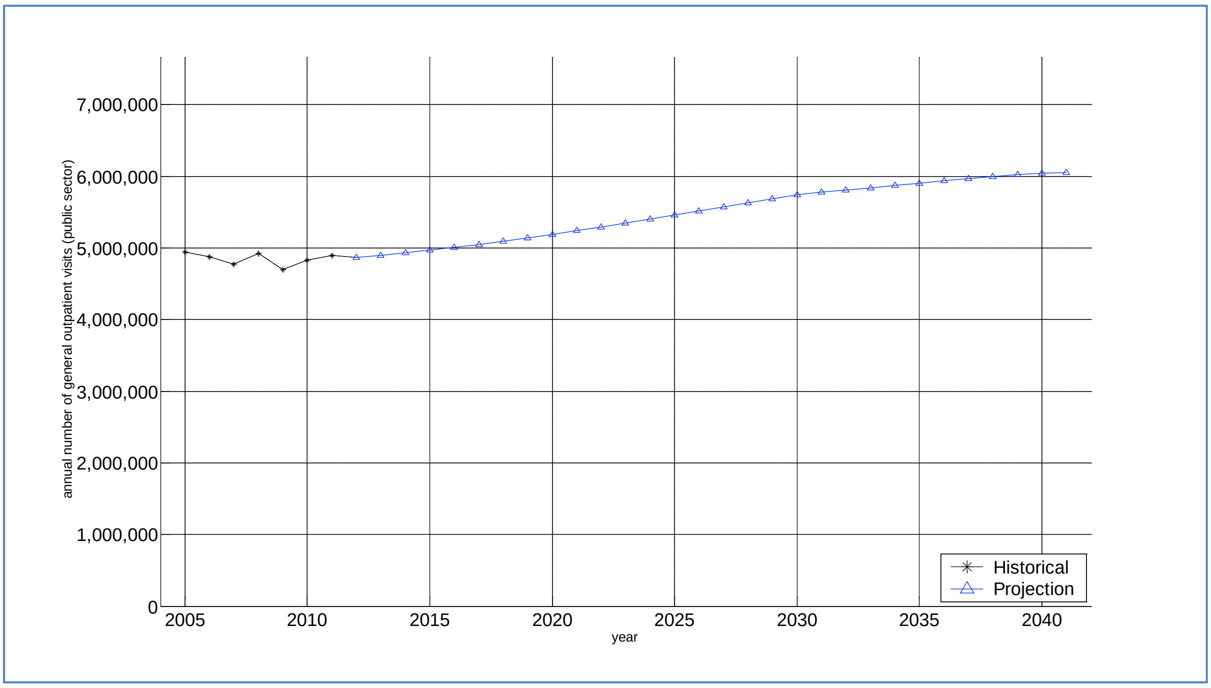

Figure 4.12(a) Projected number of public sector general outpatient visits (by SVM) (2005-2041)

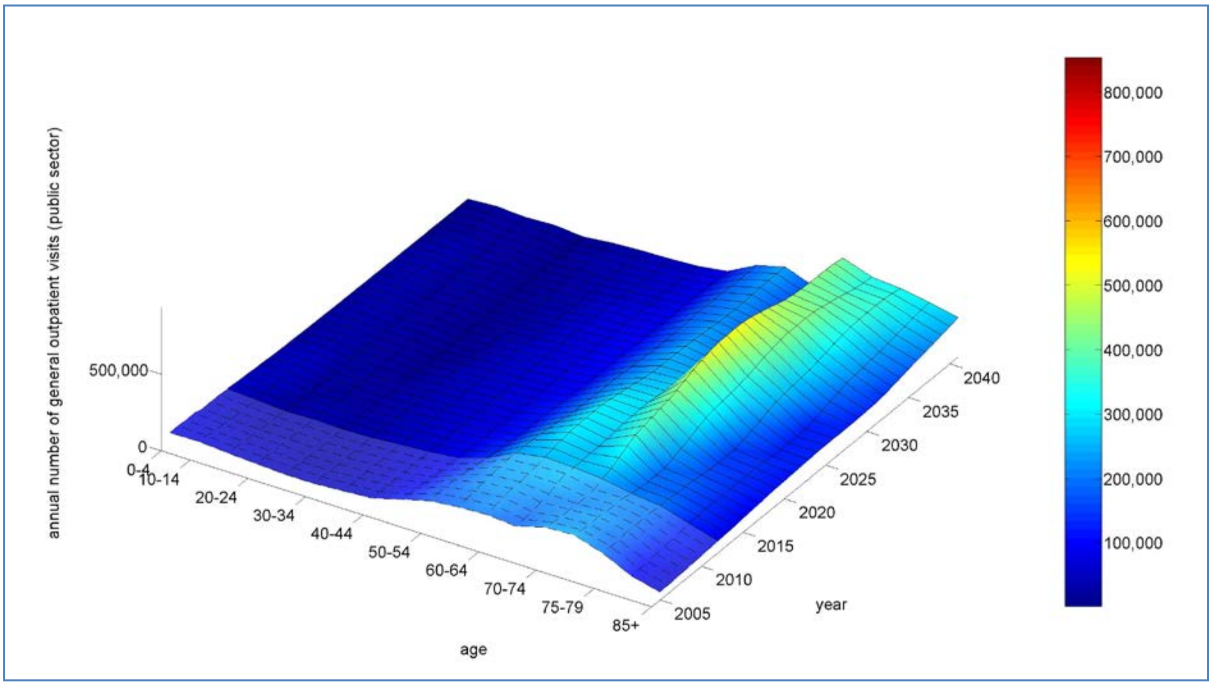

Figure 4.12(b) Projected number of public sector age-specific general outpatient visits (by SVM) – male (2005-2041)

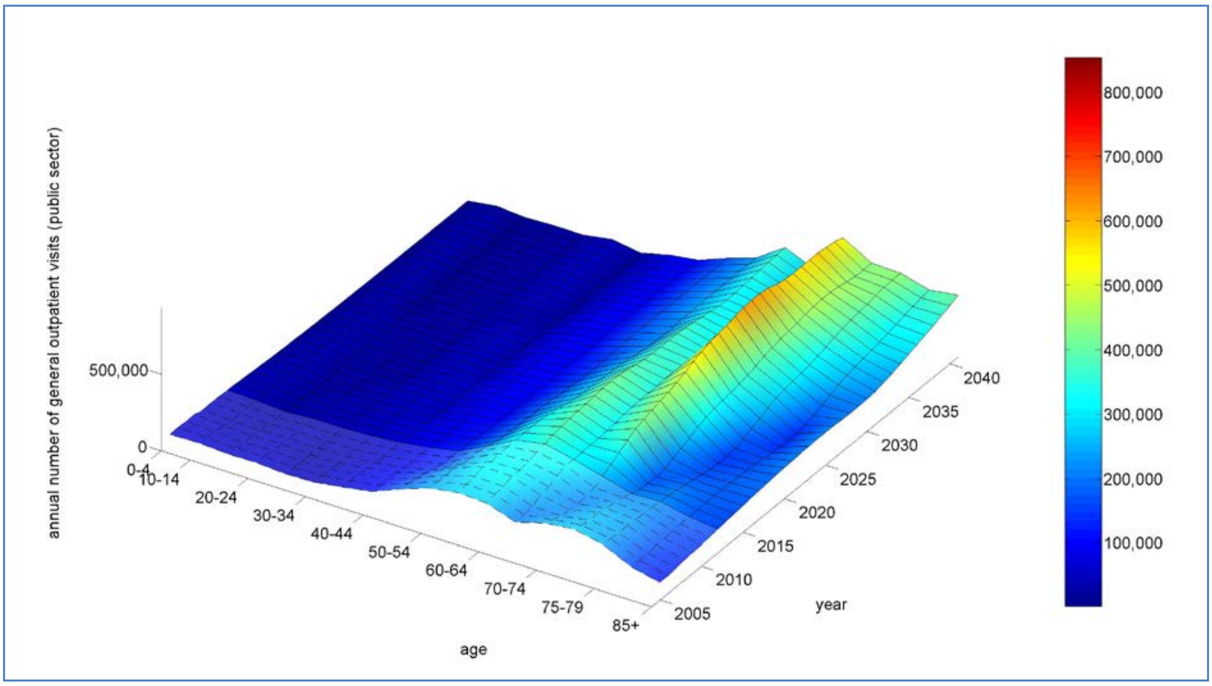

Figure 4.12(c) Projected number of public sector age-specific general outpatient visits (by SVM) – female (2005-2041)

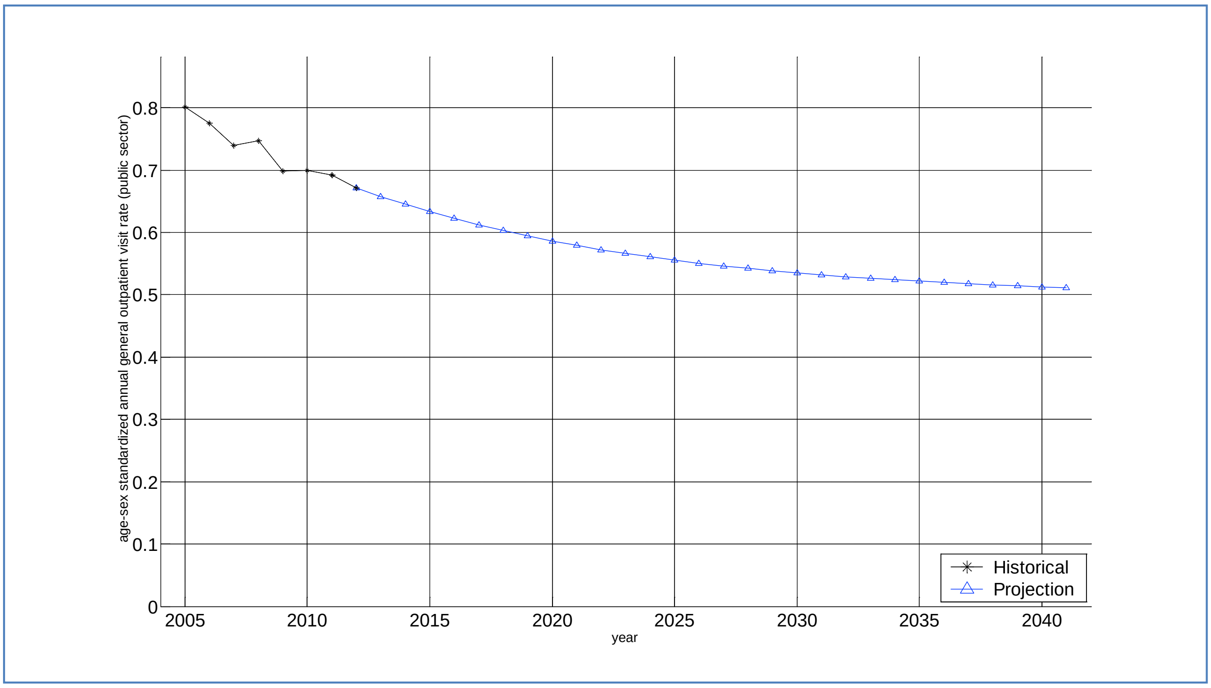

Figure 4.13(a) Projected annual public sector general outpatient visit rates (by SVM) (2005-2041)

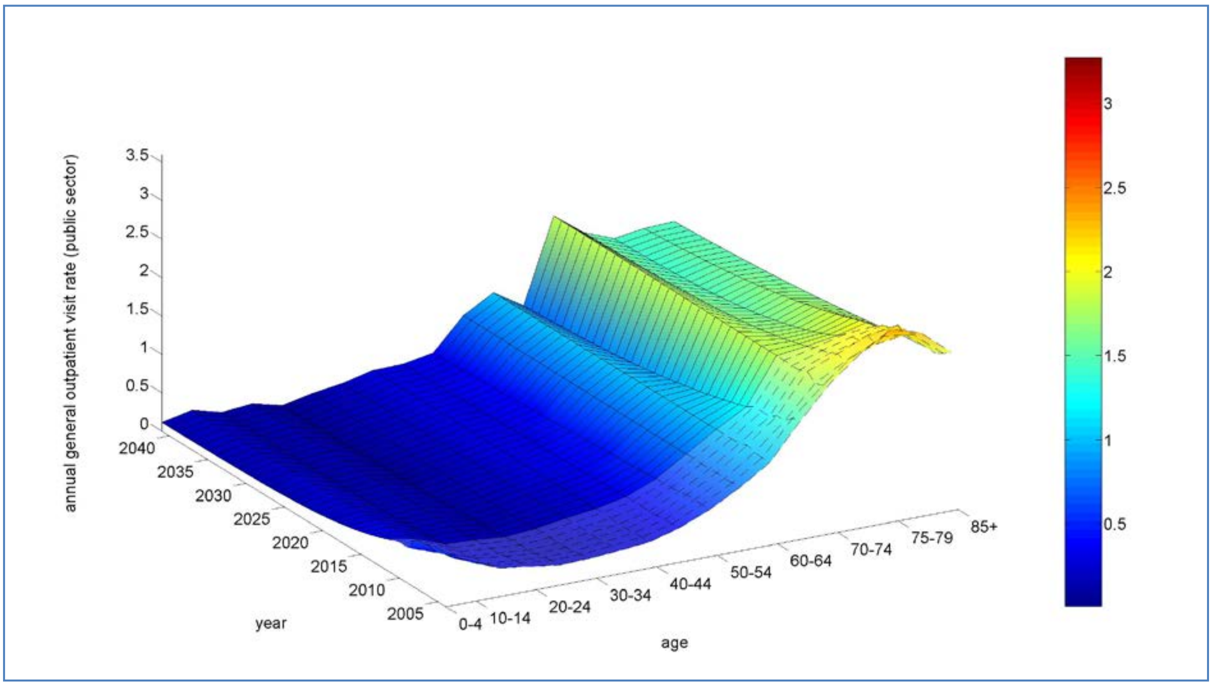

Figure 4.13(b) Projected public sector general outpatient average visit rates (by SVM) - male (2005-2041)

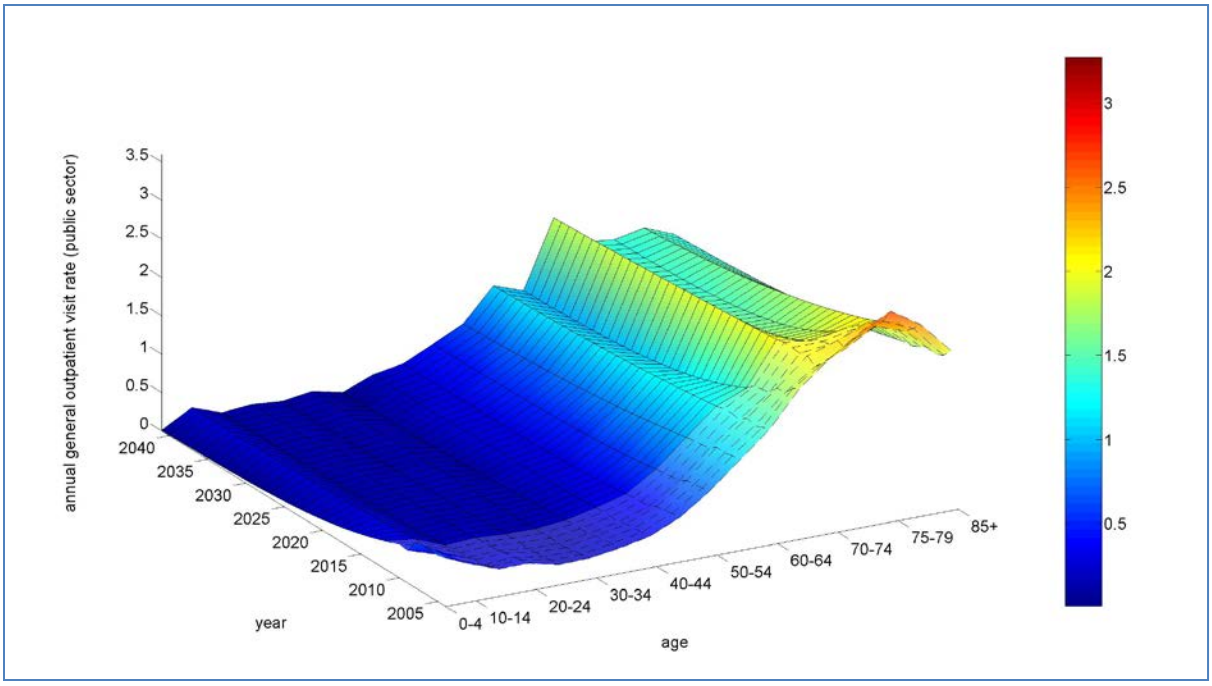

Figure 4.13(c) Projected public sector general outpatient average visit rates (by SVM) - female (2005-2041)

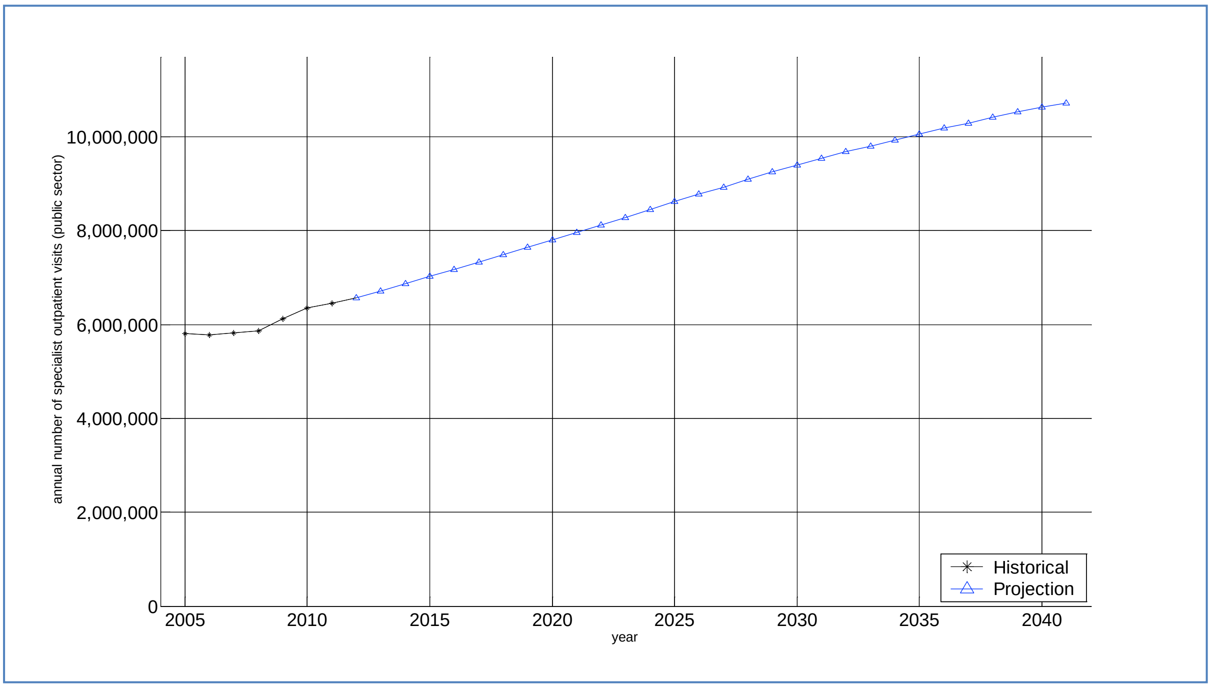

Figure 4.14(a) Projected number of public sector specialist outpatient visits (by SVM) (2005-2041)

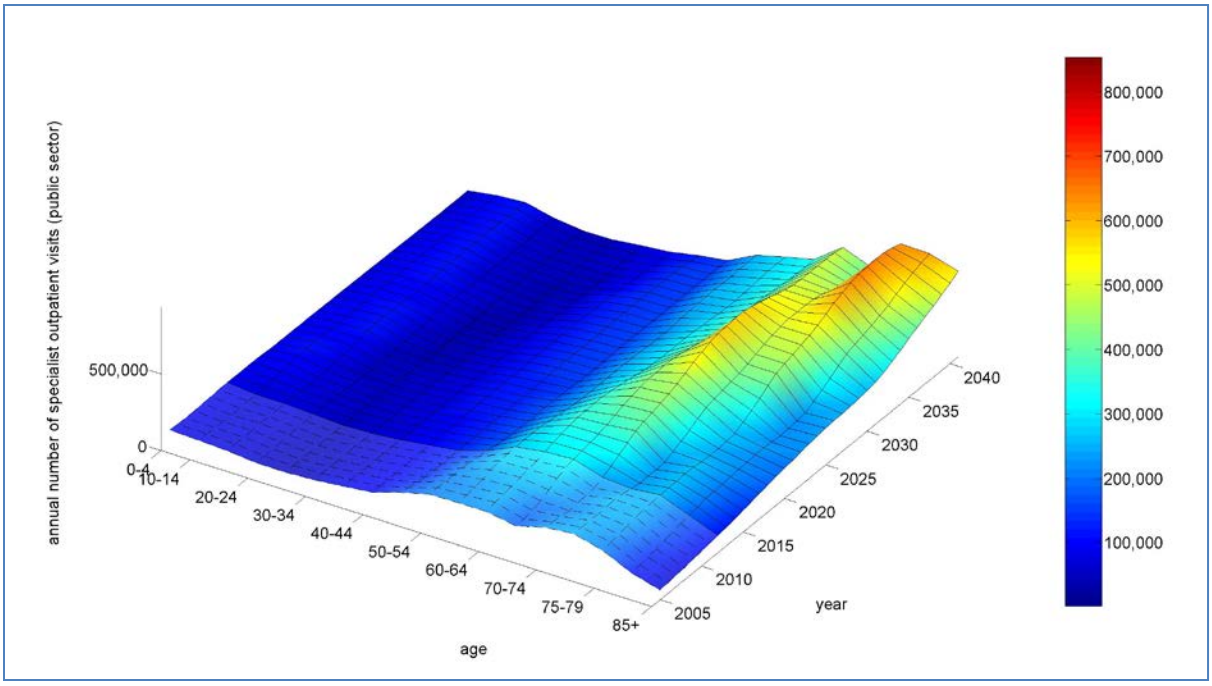

Figure 4.14(b) Projected number of public sector age-specific specialist outpatient visits (by SVM) - male (2005-2041)

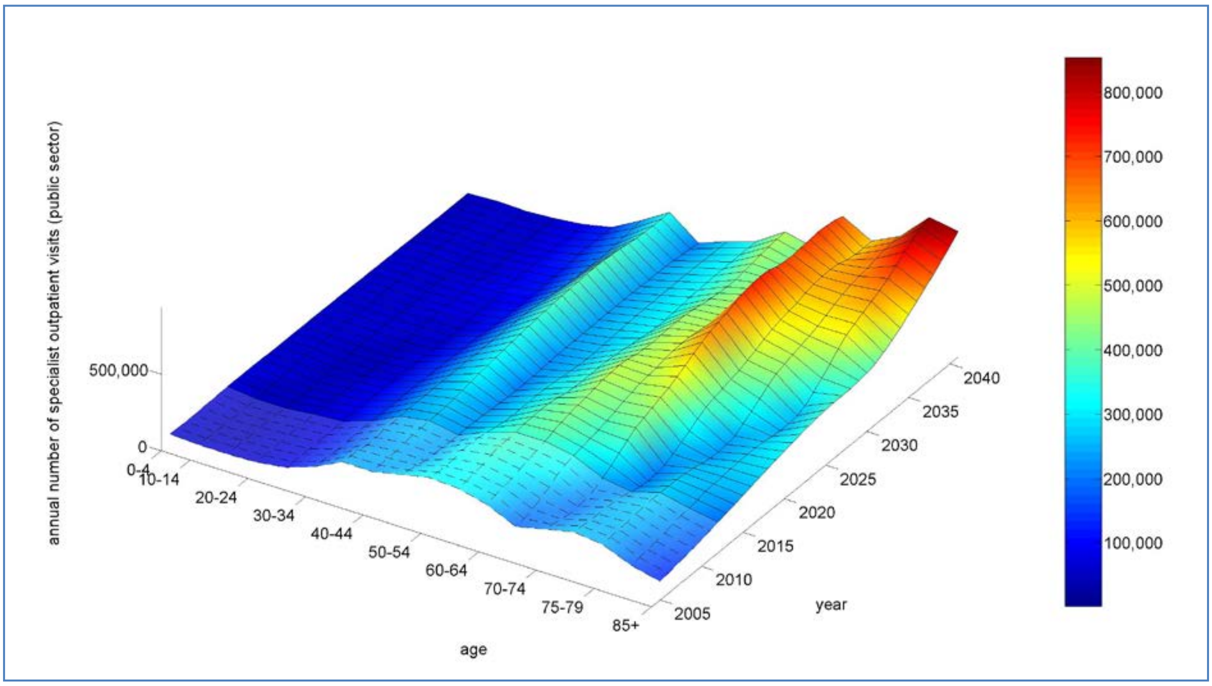

Figure 4.14(c) Projected number of public sector age-specific specialist outpatient visits (by SVM) - female (2005-2041)

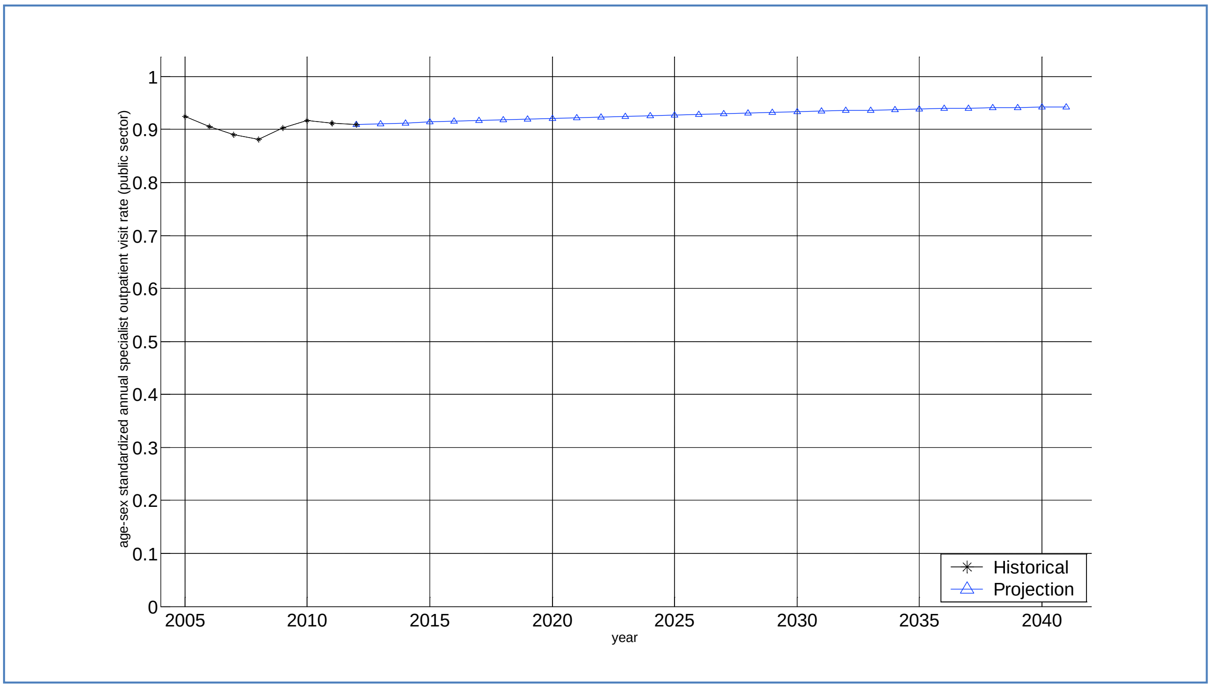

Figure 4.15(a) Projected annual public sector specialist outpatient visit rates (by SVM) (2005-2041)

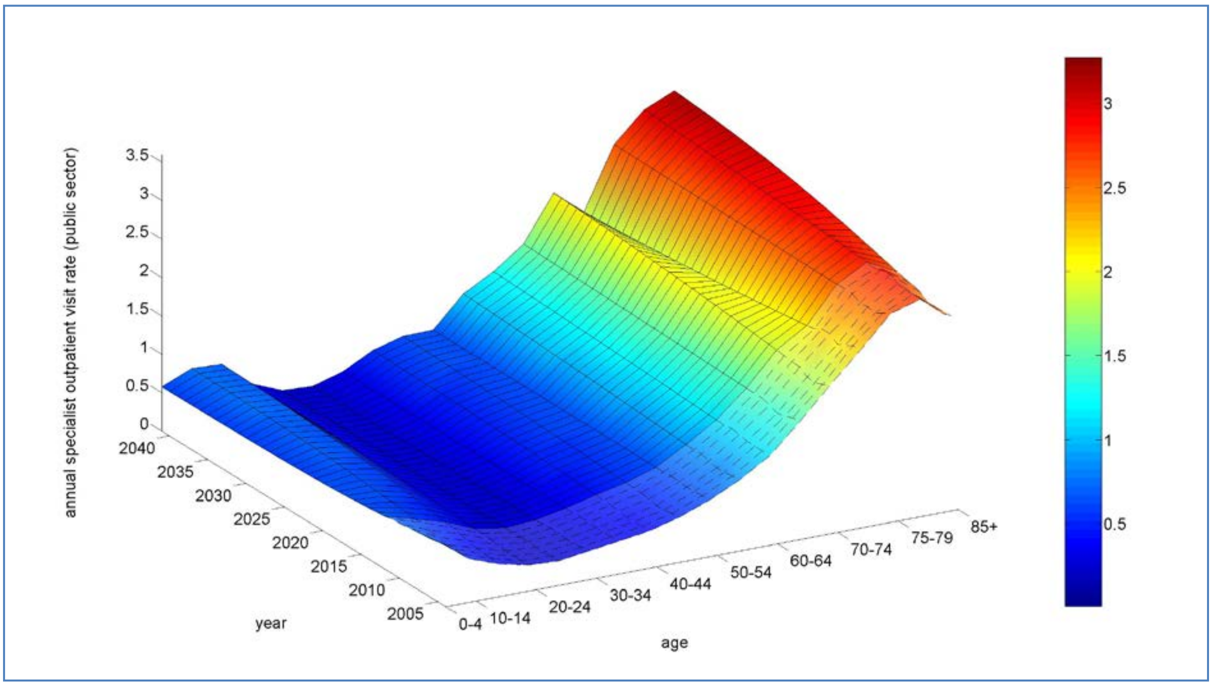

Figure 4.15(b) Projected annual public sector specialist outpatient average visit rates (by SVM) - male (2005-2041)

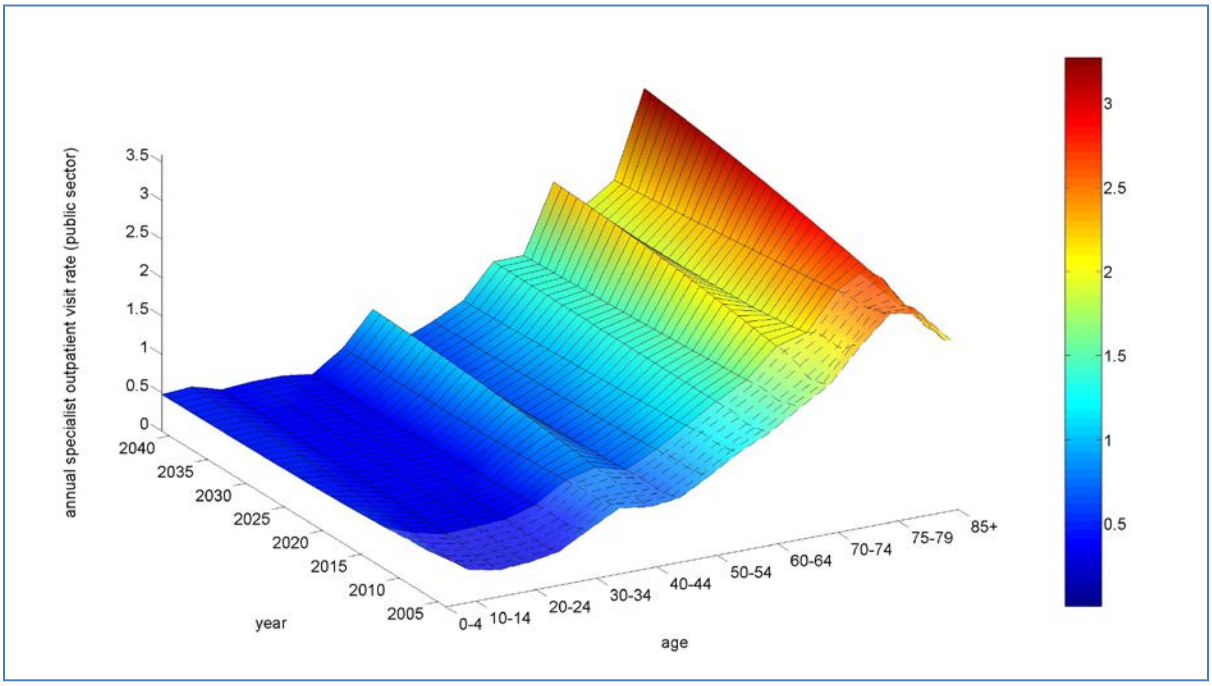

Figure 4.15(c) Projected annual public sector specialist outpatient average visit rates (by SVM) - female (2005-2041)

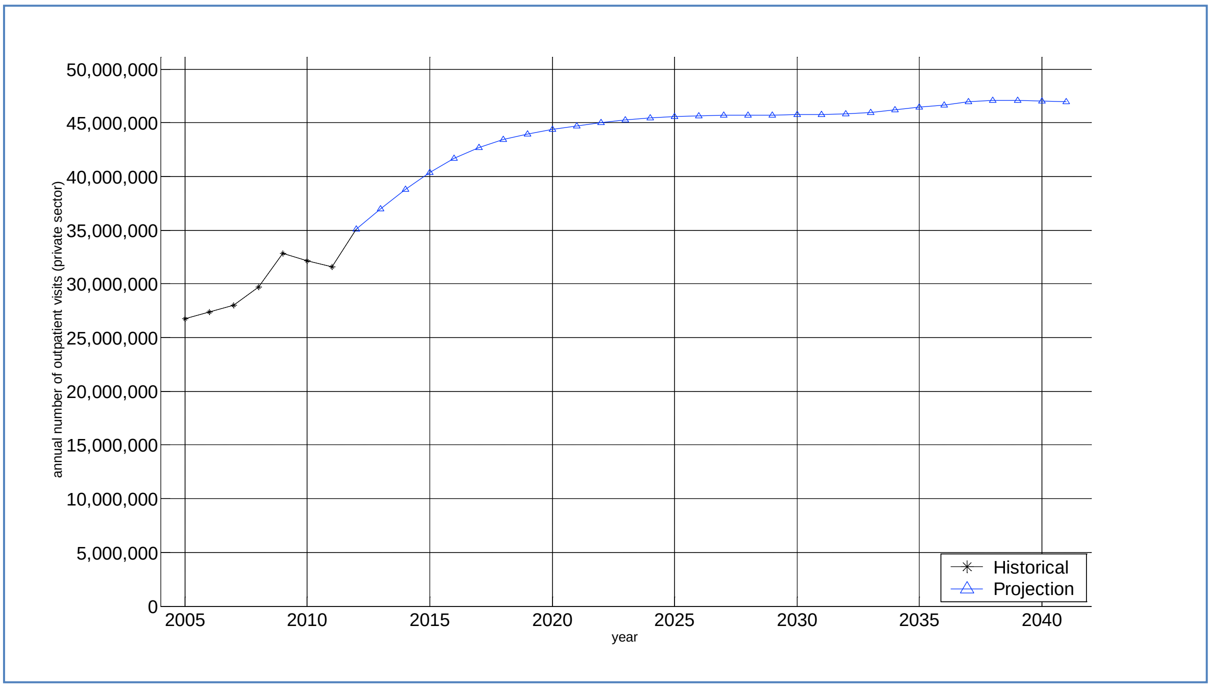

Figure 4.16(a) Projected number of private sector outpatient visits (by SVM) (2005-2041)

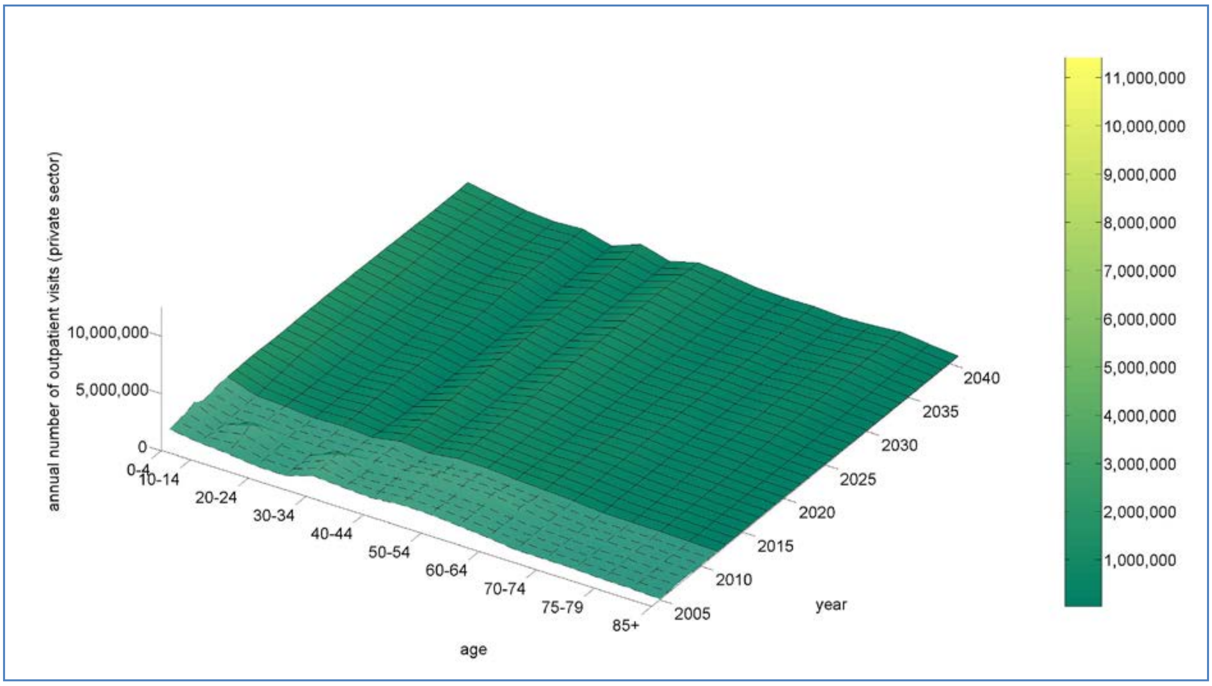

Figure 4.16(b) Projected number of private sector age-specific outpatient visits (by SVM) - male (2005-2041)

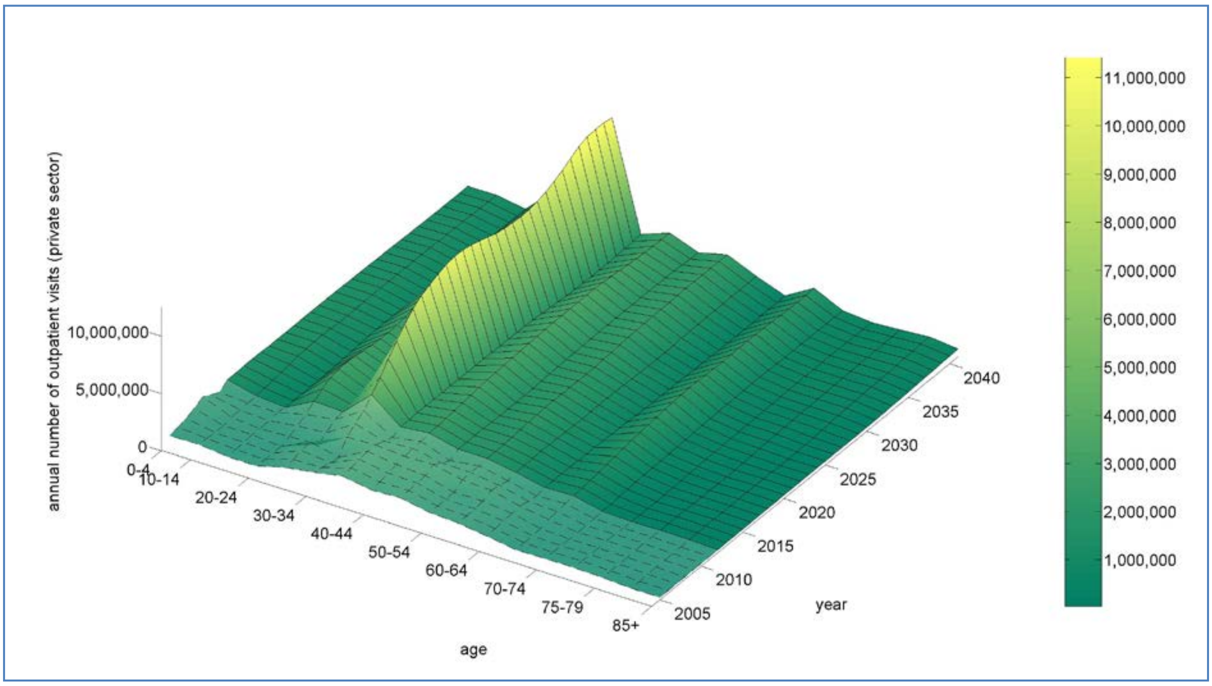

Figure 4.16(c) Projected number of private sector age-specific outpatient visits (by SVM) - female (2005-2041)

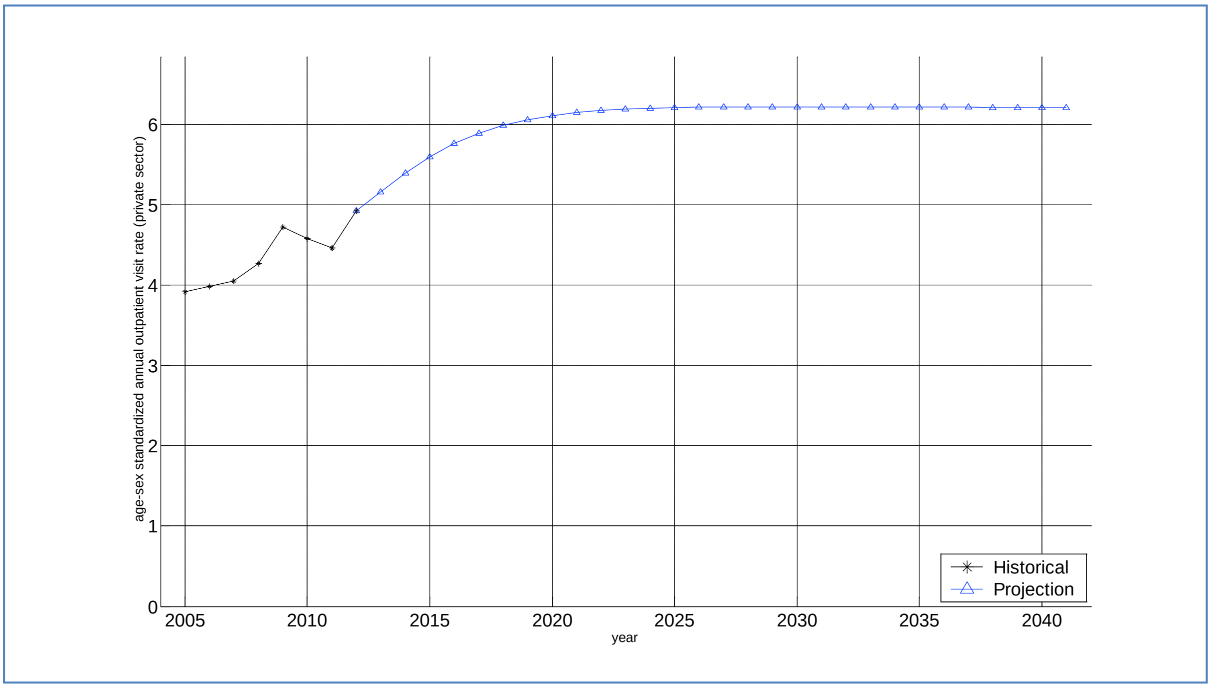

Figure 4.17(a) Projected annual private sector outpatient visit rates (by SVM) (2005-2041)

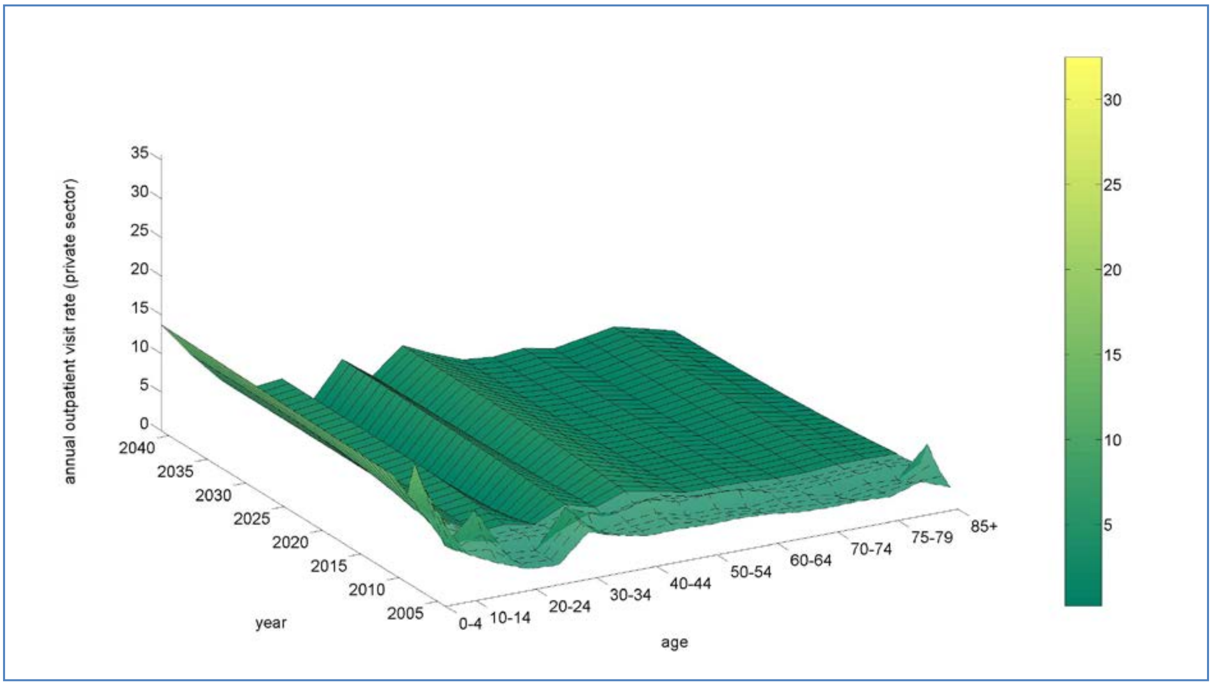

Figure 4.17(b) Projected annual private sector outpatient average visit rates (by SVM) - male (2005-2041)

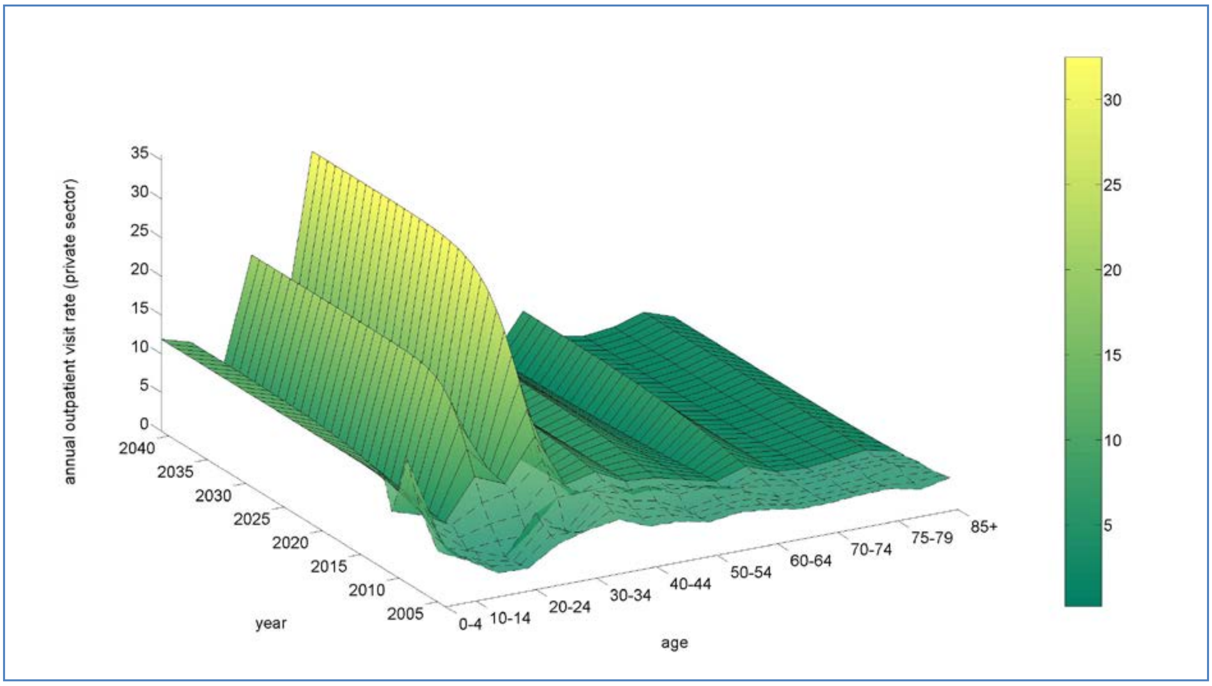

Figure 4.17(c) Projected annual private sector outpatient average visit rates (by SVM) - female (2005-2041)

<u>Accident and Emergency Department</u>

Although the total number of Accident and Emergency Department (A&E) attendances increase rapidly (Figure 4.18(a)), after adjustment for population demographics the attendance rate increase is less steep (Figure 4.19(a)). There are few male vs. female differences in the number of age-specific attendances (Figure 4.18(b-c)). However the attendance rate adjusted for population demographics is higher among younger and older males than females (Figure 4.19(b-c)).

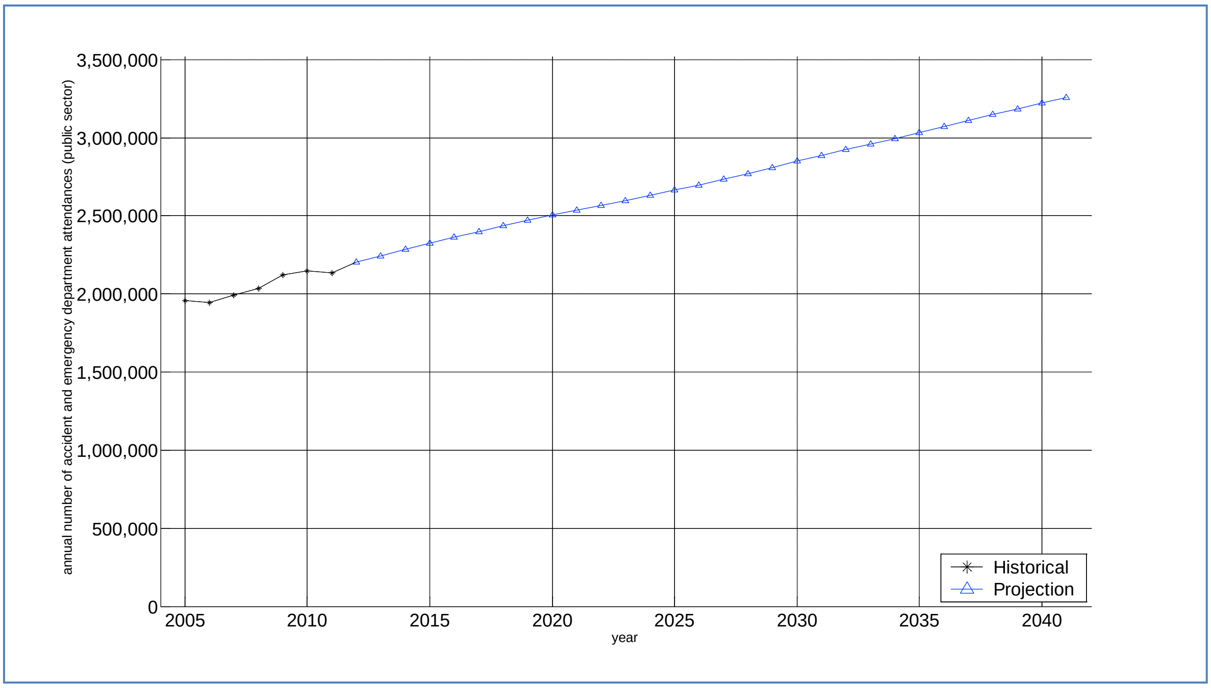

Figure 4.18(a) Projected number of public sector accident and emergency department attendances (by SVM) (2005-2041)

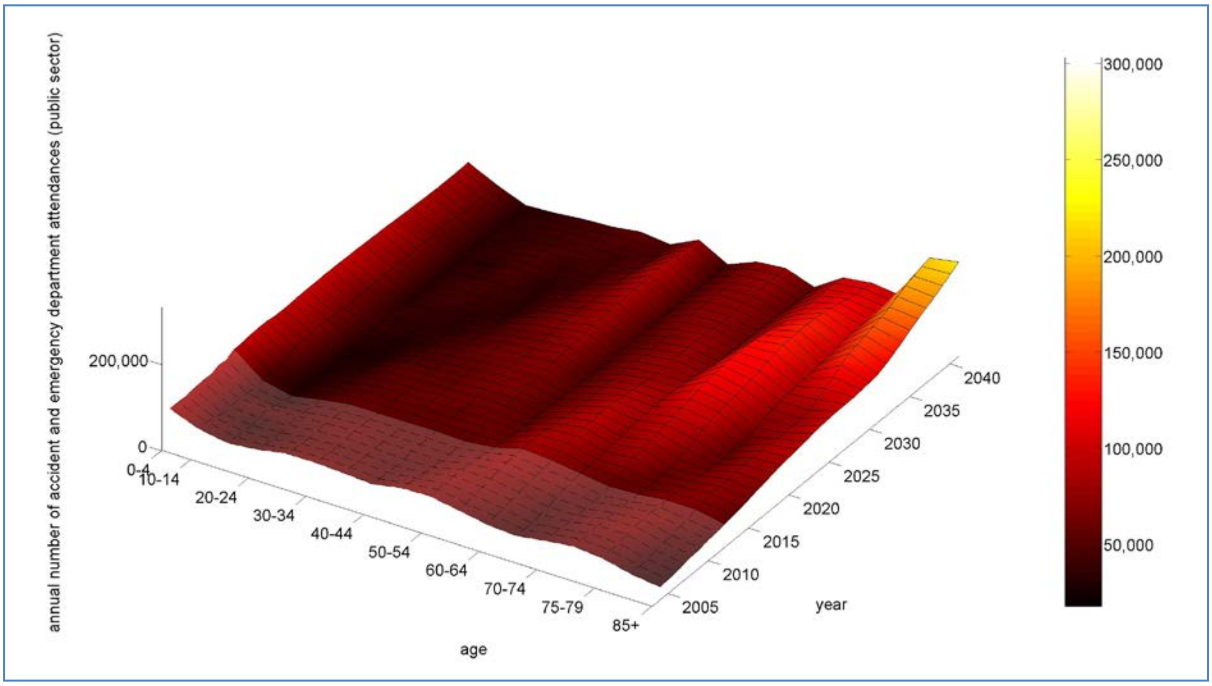

Figure 4.18(b) Projected number of public sector age- specific accident and emergency department attendances (by SVM) – male (2005-2041)

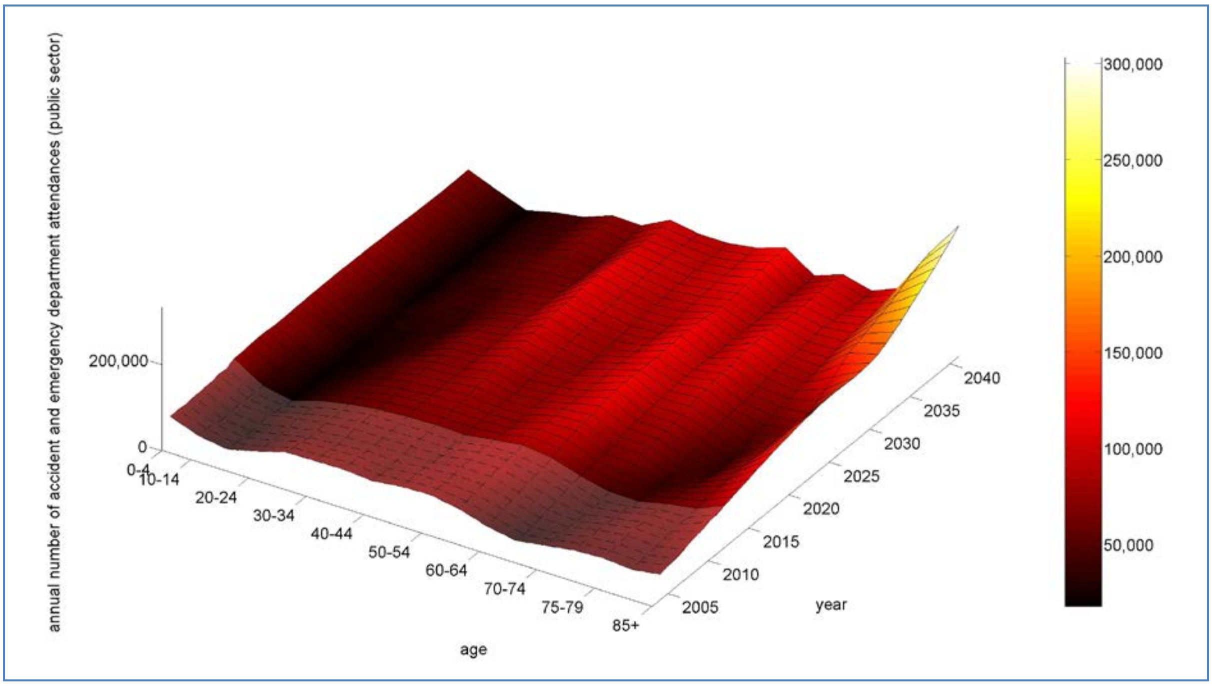

Figure 4.18(c) Projected number of public sector age- specific accident and emergency department attendances (by SVM) – female (2005-2041)

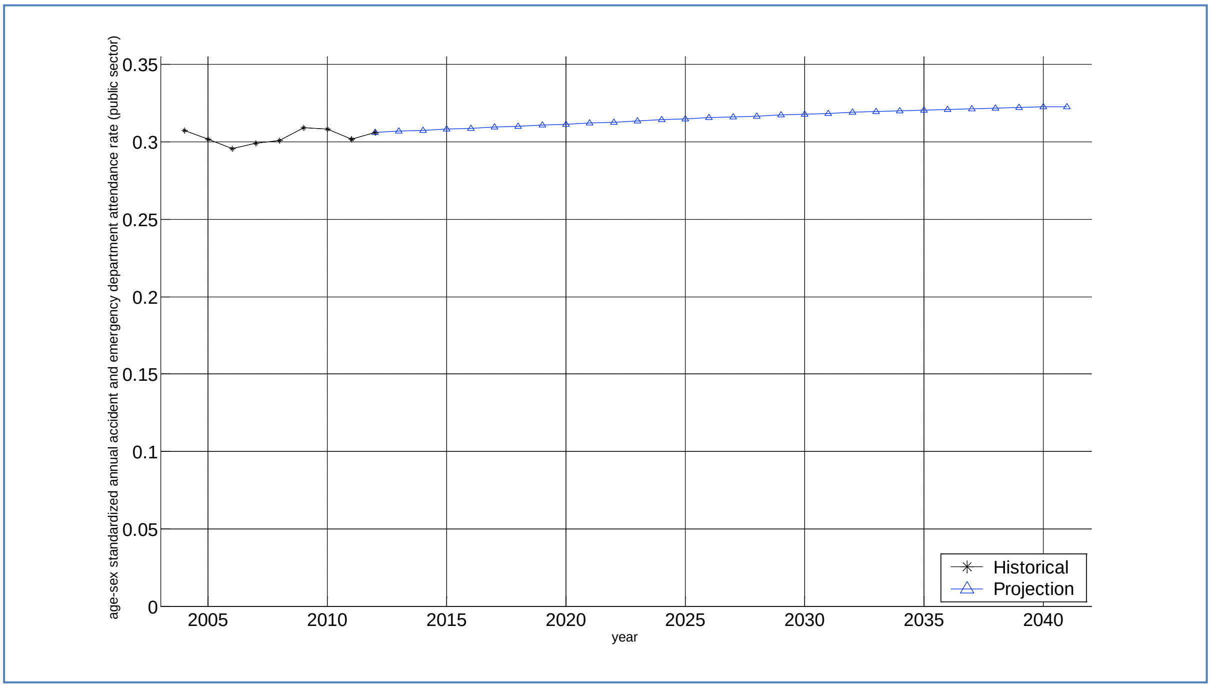

Figure 4.19(a) Projected annual public sector accident and emergency department attendance rates (by SVM) (2005-2041)

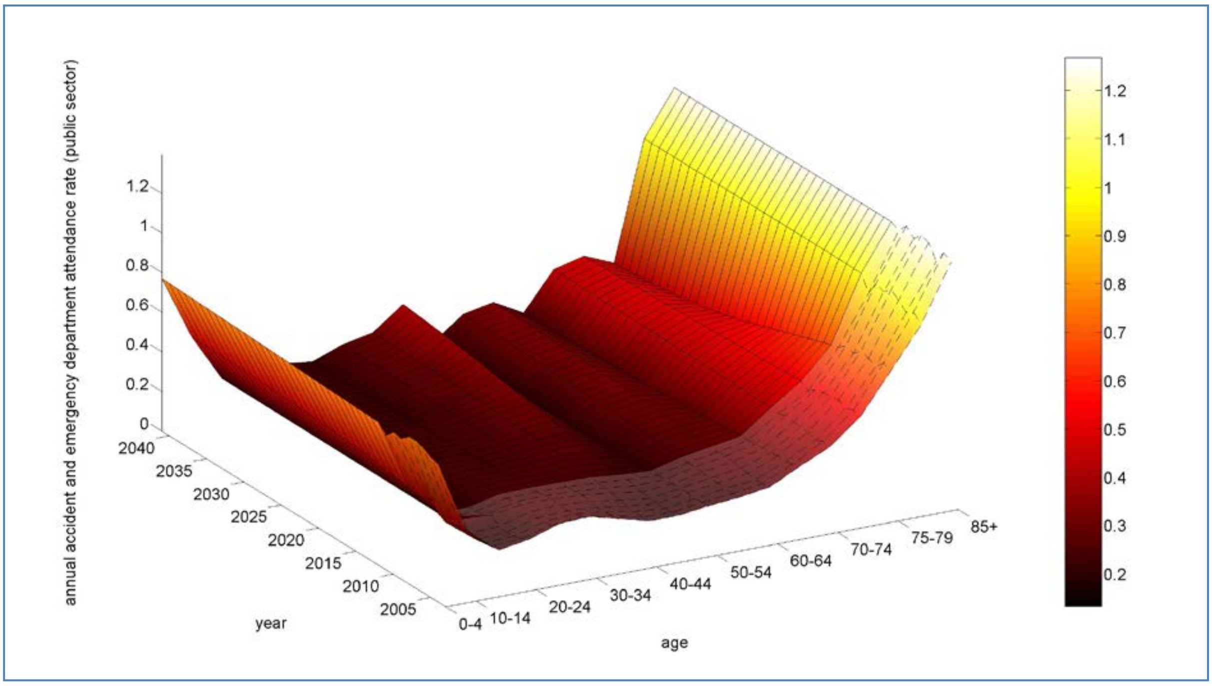

Figure 4.19(b) Projected annual public sector accident and emergency department average attendance rates (by SVM) - male (2005-2041)

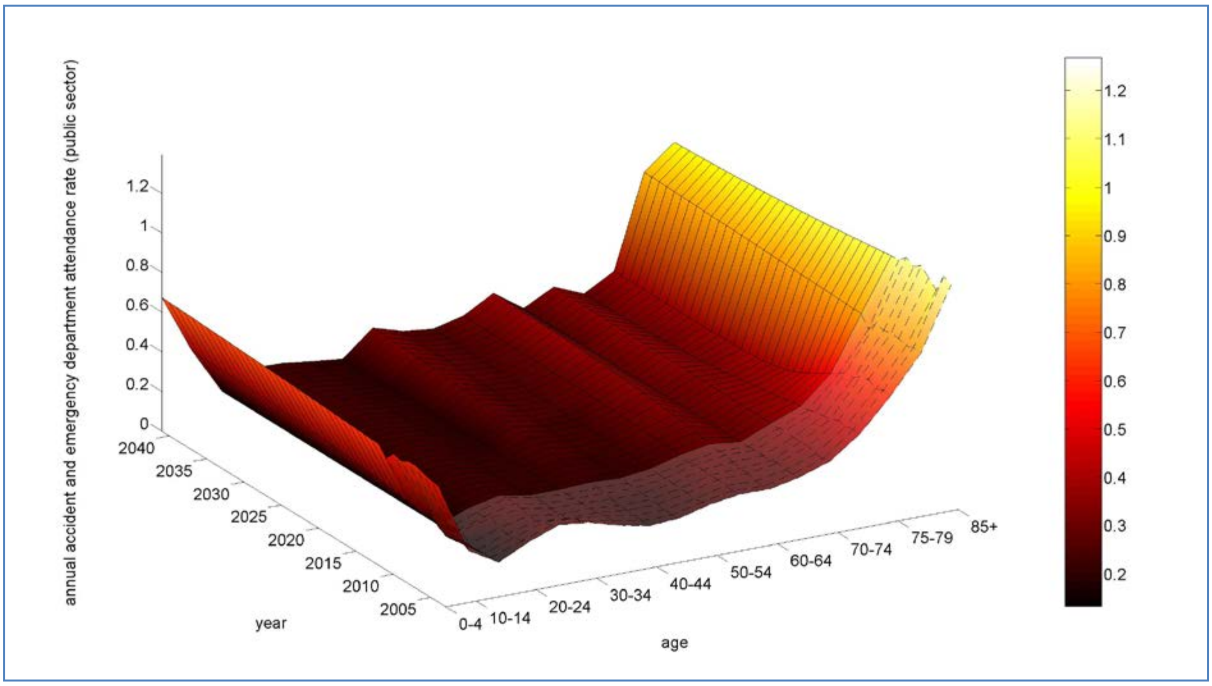

Figure 4.19(c) Projected annual public sector accident and emergency department average attendance rates (by SVM) - female (2005-2041)

4.2.4 Total bed-days

While the number of public hospital acute care in-patient bed-days and the age-specific bed-days increase (Figure 4.20(a-c)), the number of long stay bed-days decrease (Figure 4.22(a-c)). However after adjusting for population demographics the acute care in-patient bed day rates and the long stay bed day rates decline (Figure 4.21(a) and 4.23(a)). The acute care and long stay bed-day population adjusted rate decrease is similar across all age-, sex-specific groups (Figure 4.21(b-c) and Figure 4.23(b-c)). In contrast, both private sector number of acute care bed-days increase (Figure 4.24(a)) and population adjusted bed-days rate increases (Figure 4.25(a)). As expected the number of bed-days increase for young children, females in their child-bearing years and elderly men and women (Figure 4.24(b-c)). A bed-day rate increase (adjusted for population demographics) is observed for the youngest children (Figure 4.25(b-c)).

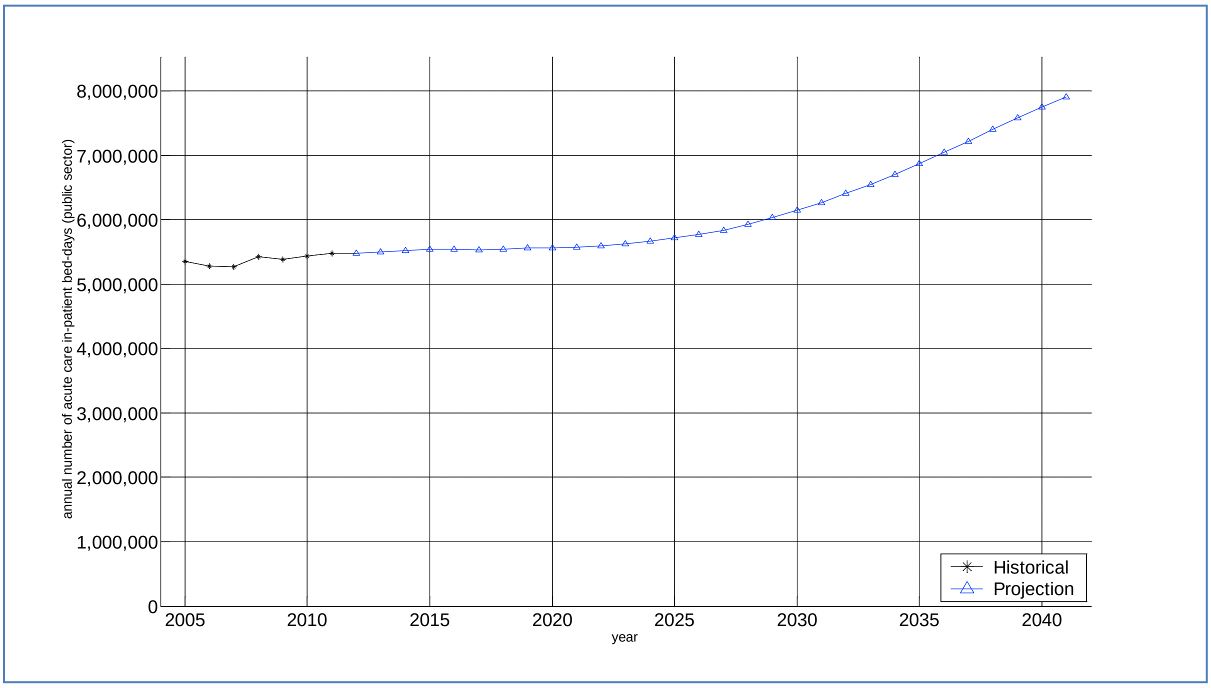

Figure 4.20(a) Projected number of public sector acute care in-patient bed-days (by SVM) (2005-2041)

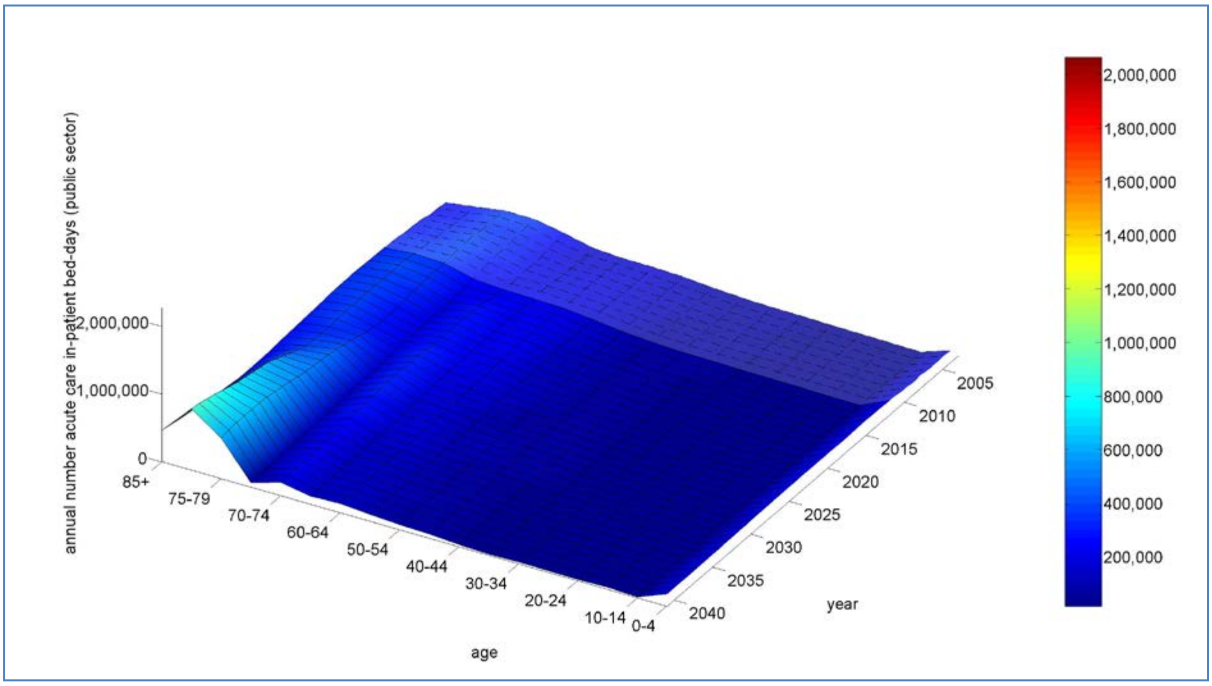

Figure 4.20(b) Projected number of public sector age-specific in-patient bed-days (by SVM) – male (2005-2041)

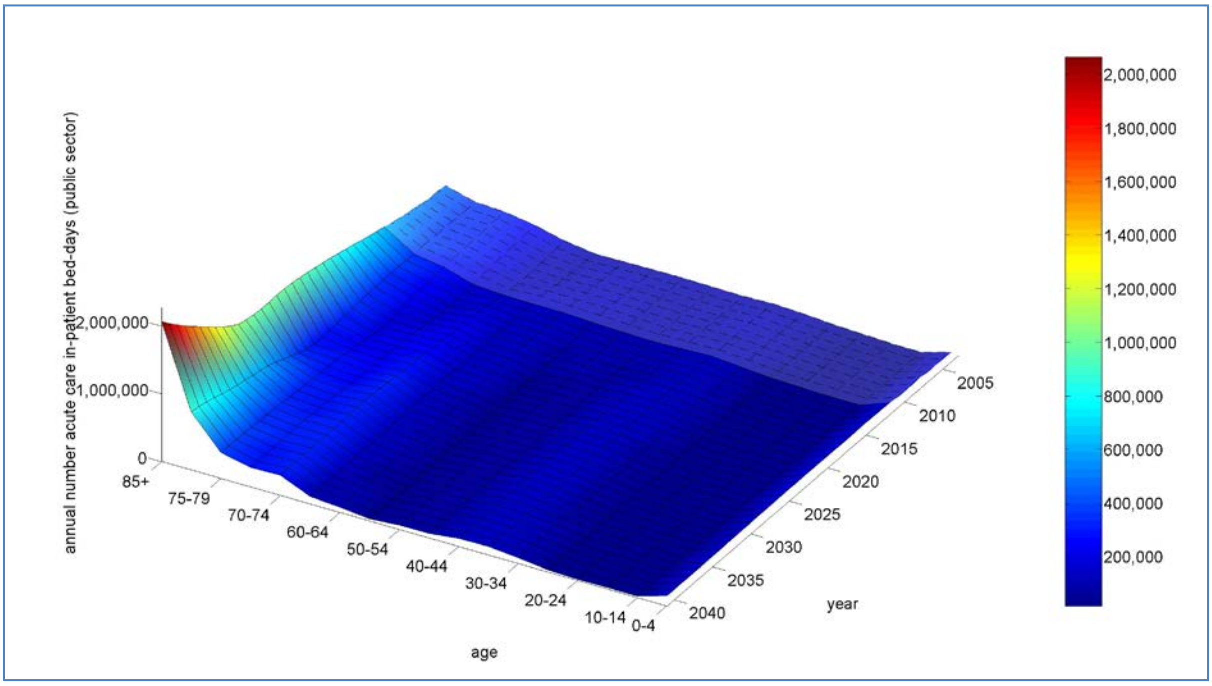

Figure 4.20(c) Projected number of public sector age-specific in-patient bed-days (by SVM) – female (2005-2041)

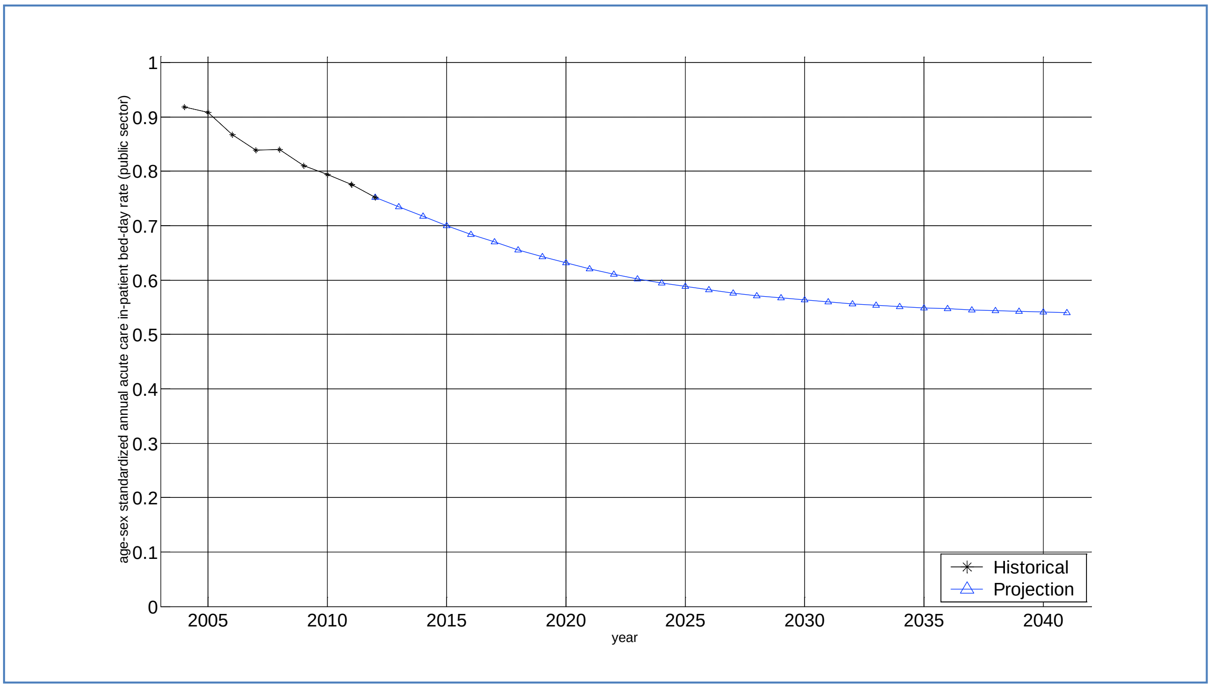

Figure 4.21(a) Projected annual public sector acute care in-patient bed-days rates (by SVM) (2005-2041)

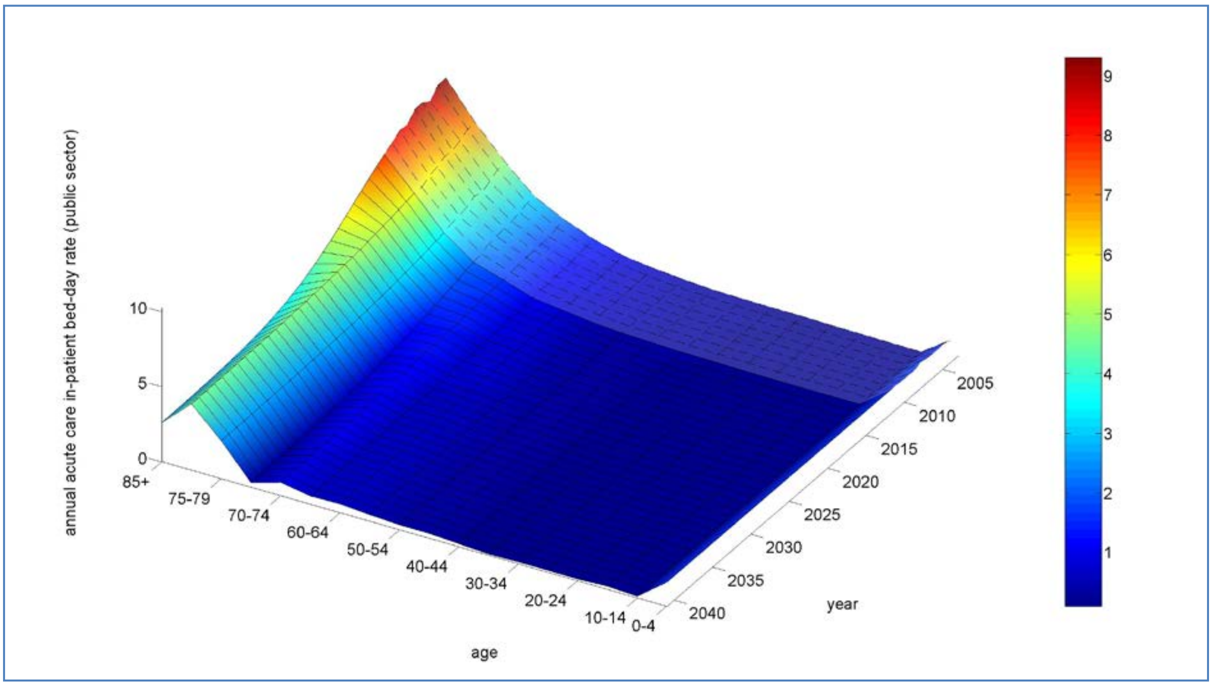

Figure 4.21(b) Projected annual public sector average number of acute care in-patient bed-day rates (by SVM) - male (2005-2041)

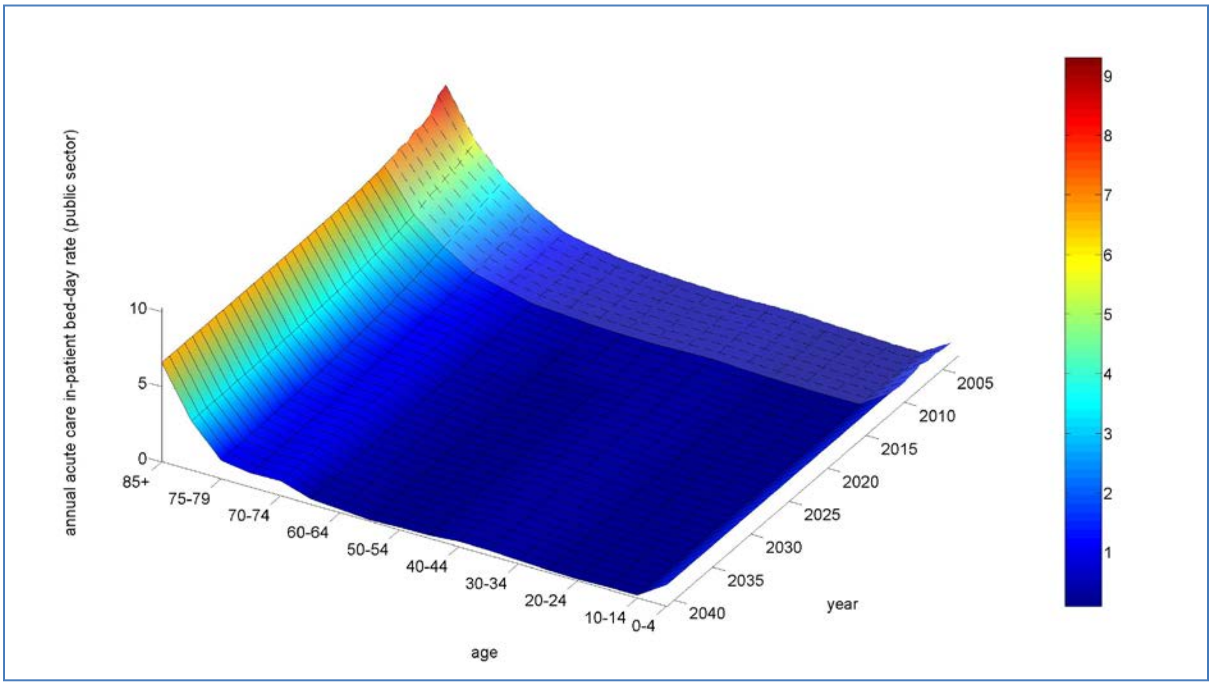

Figure 4.21(c) Projected annual public sector average acute care in-patient bed-day rates (by SVM) – female (2005-2041)

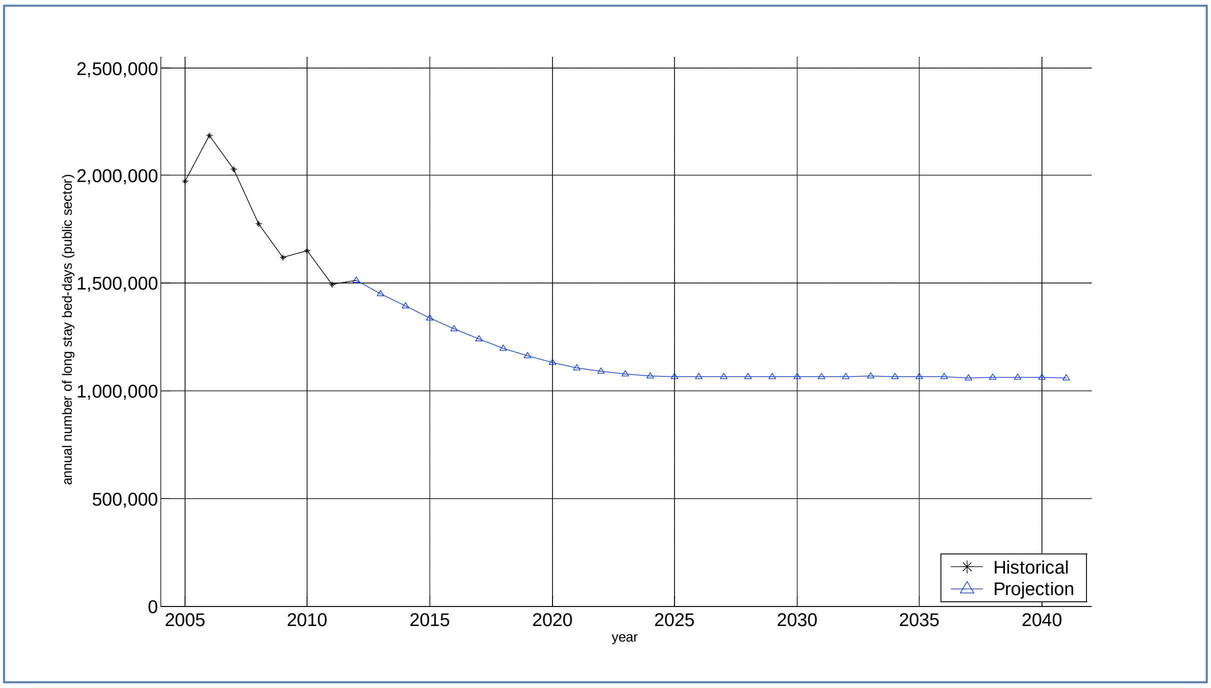

Figure 4.22(a) Projected number of public sector long stay bed-days (by SVM) (2005-2041)

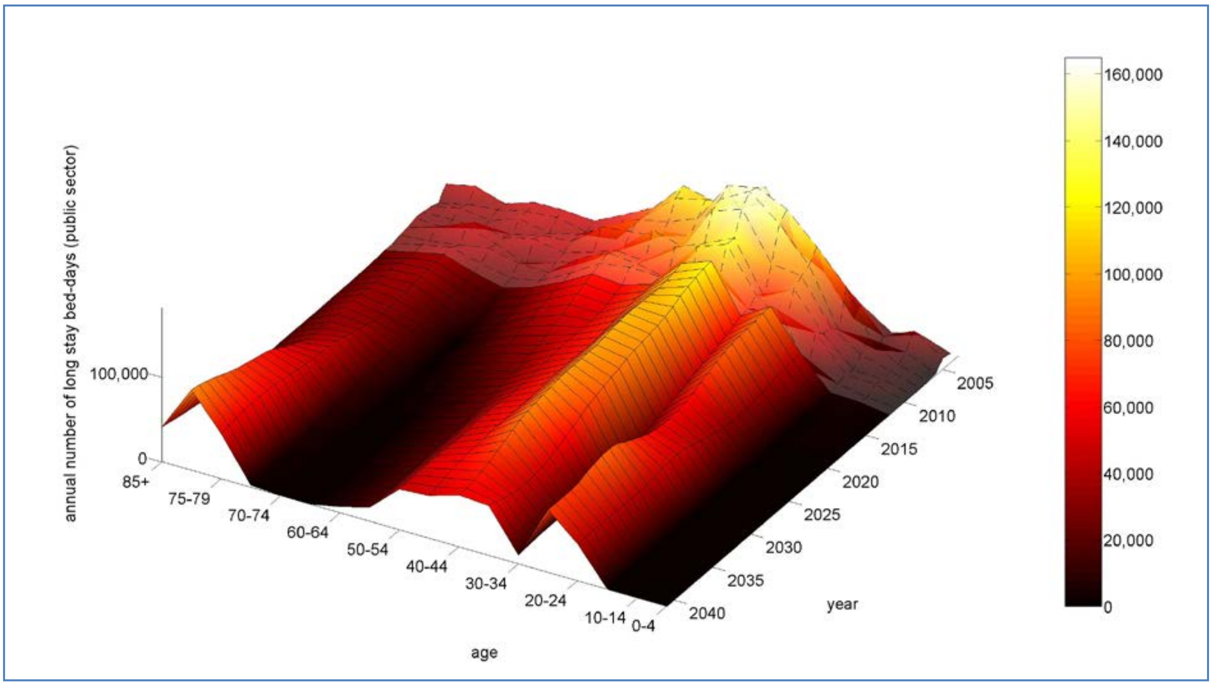

Figure 4.22(b) Projected number of public sector age-specific long stay bed-days (by SVM) – male (2005-2041)

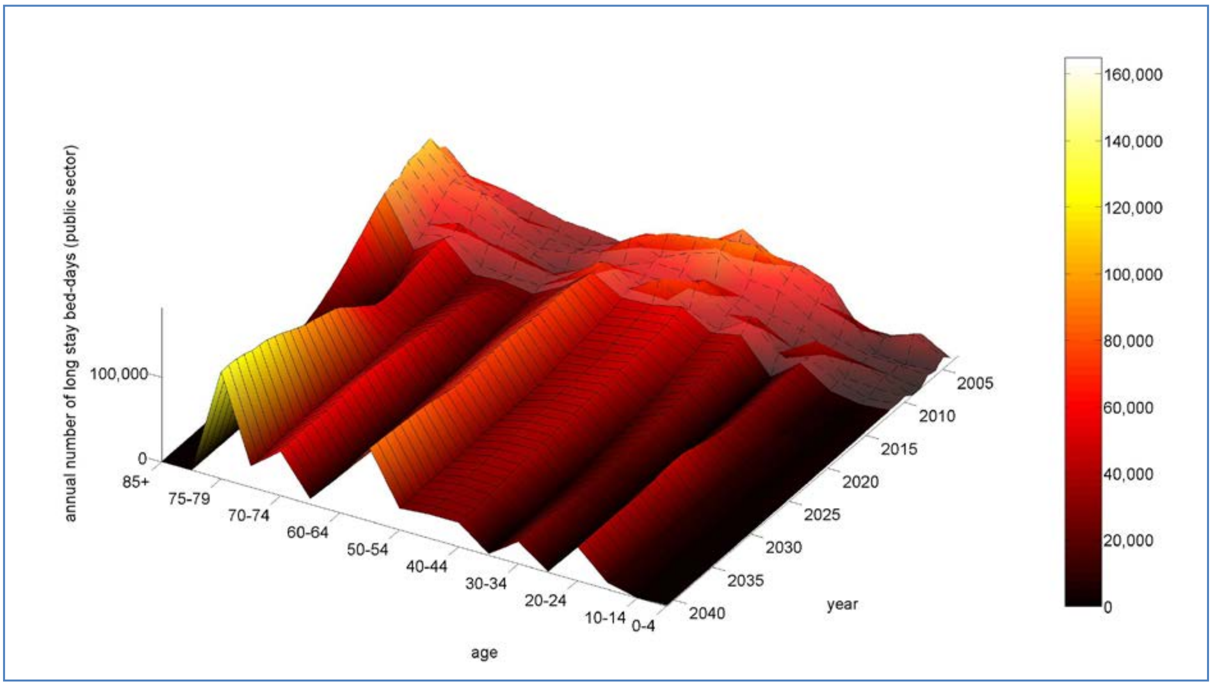

Figure 4.22(c) Projected number of public sector age-specific long stay bed-days (by SVM) – female (2005-2041)

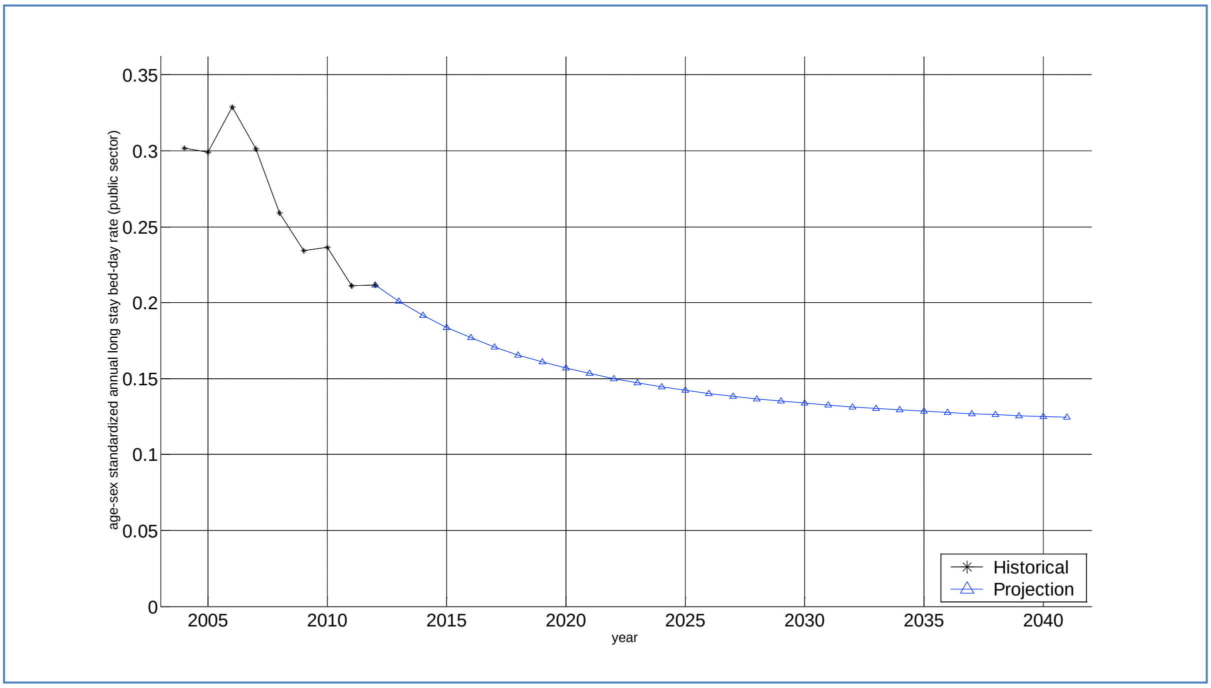

Figure 4.23 (a) Projected annual public sector long stay bed-day rates (by SVM) (2005-2041)

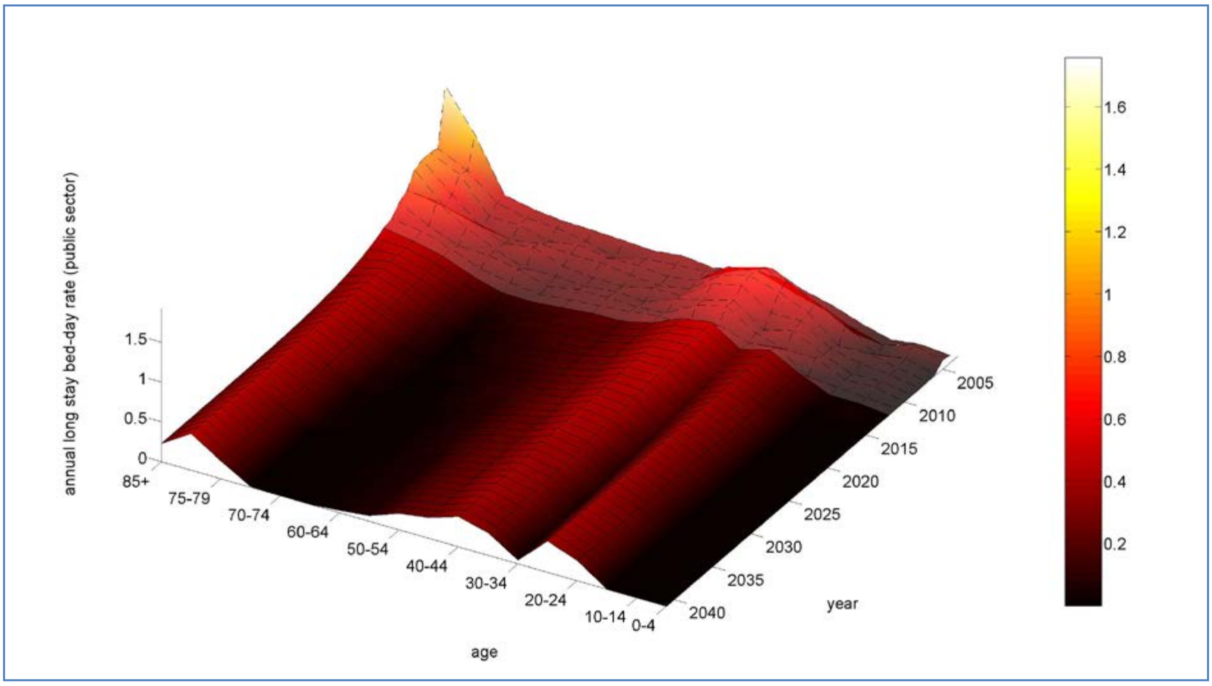

Figure 4.23(b) Projected annual public sector average long stay bed-day rates (by SVM) - male (2005-2041)

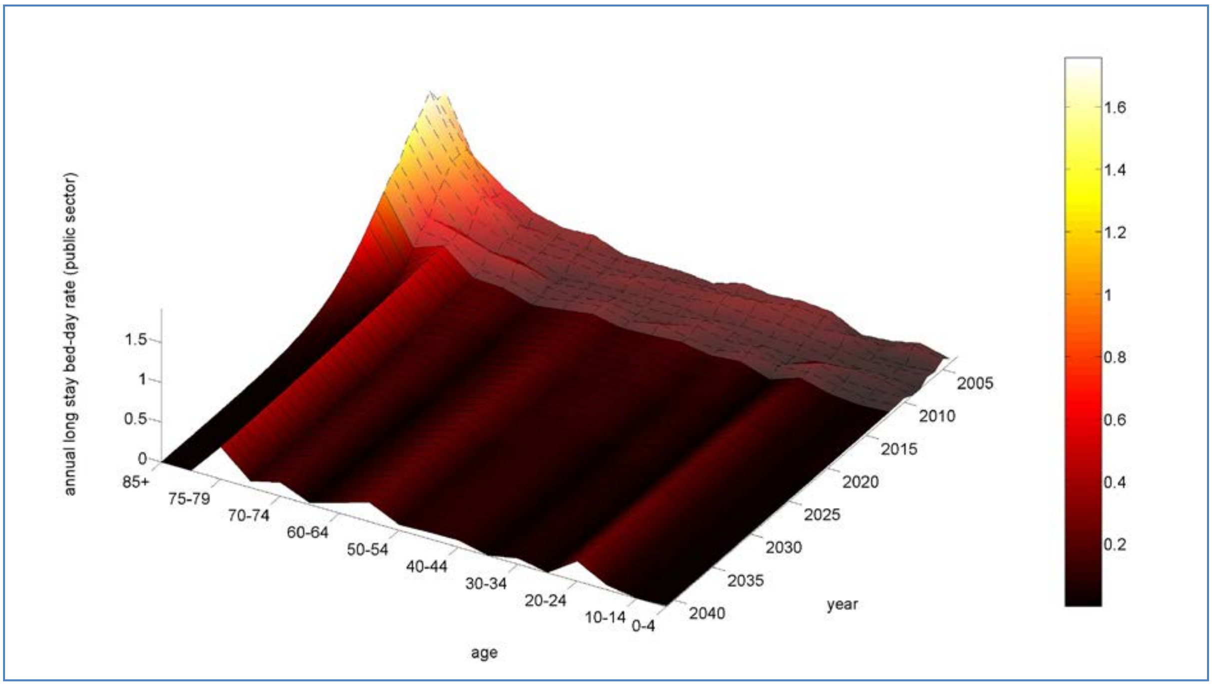

Figure 4.23(c) Projected annual public sector average long stay bed-day rates (by SVM) - female (2005-2041)

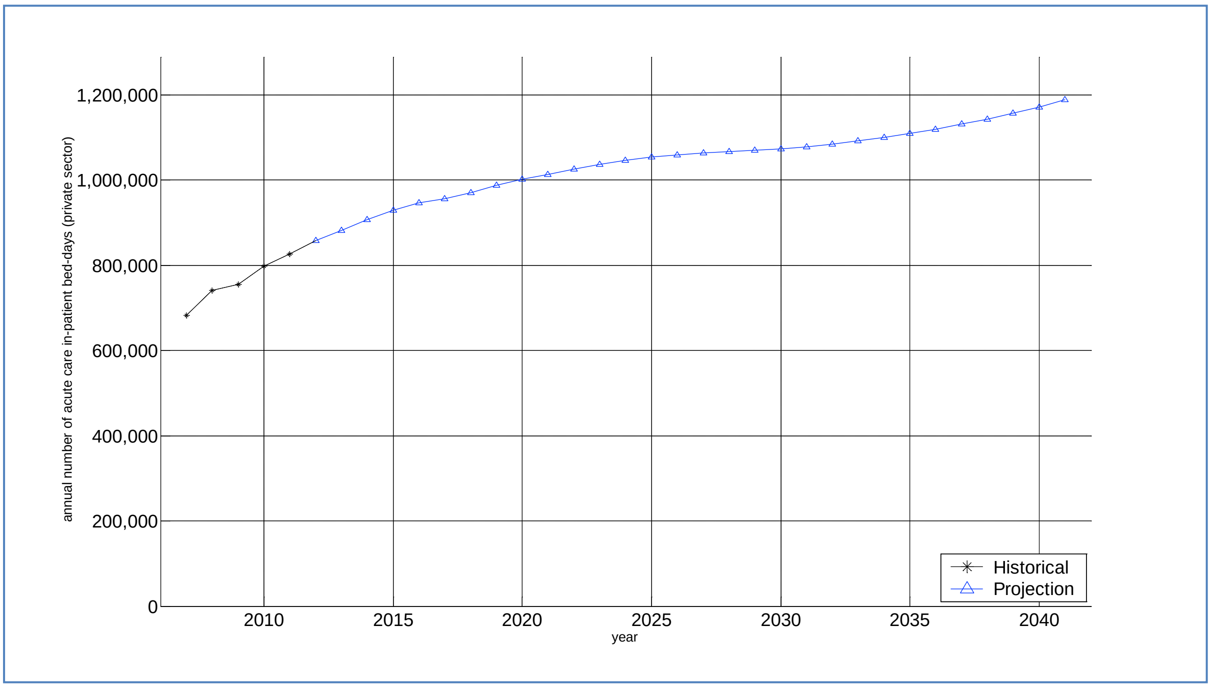

Figure 4.24(a) Projected number of private sector acute bed-days (by SVM) (2005-2041)

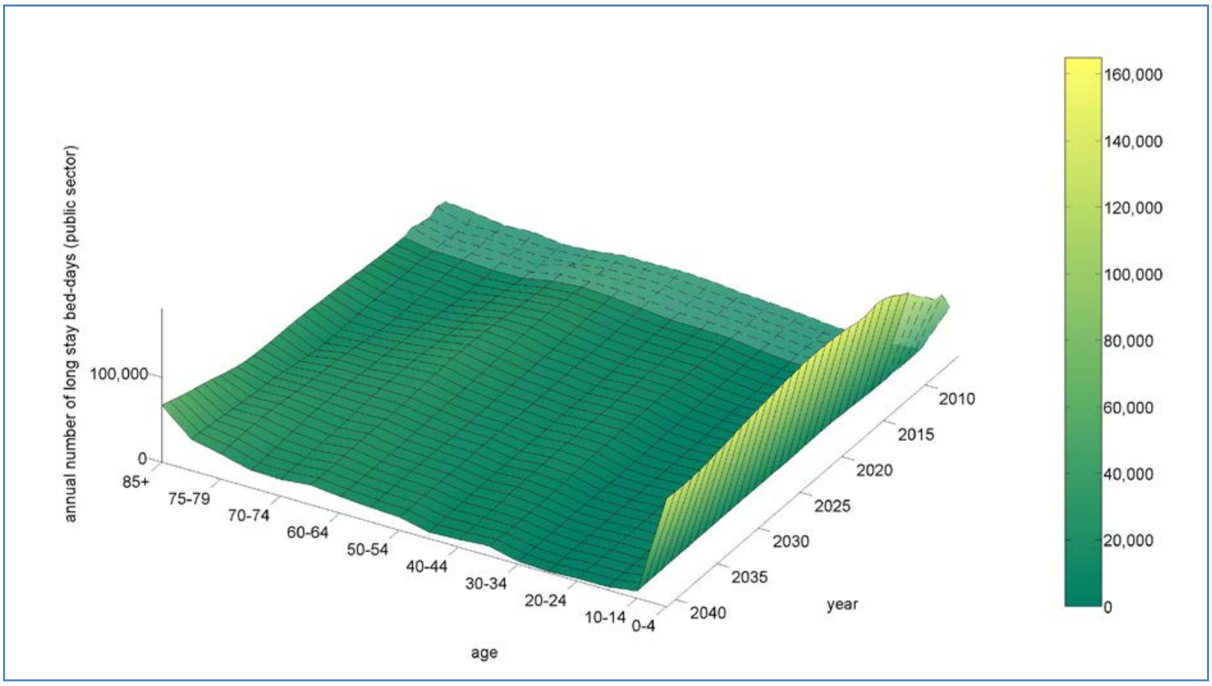

Figure 4.24(b) Projected number of age-specific private sector acute care bed-days (by SVM) – male (2007-2041)

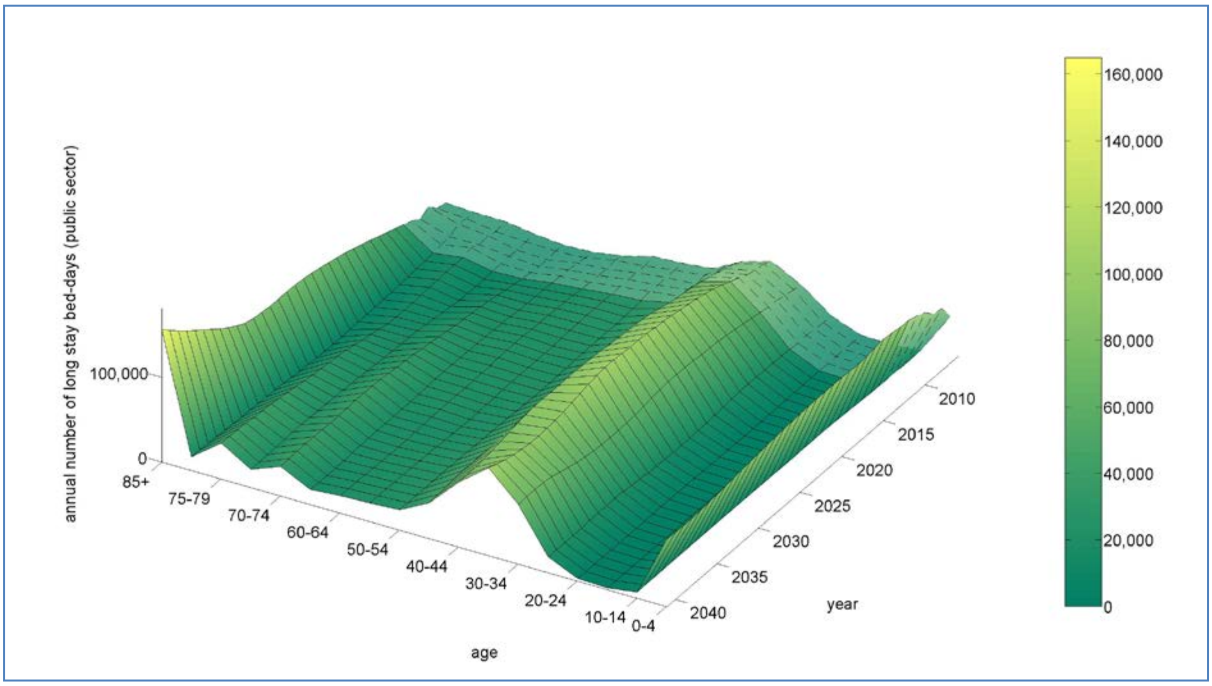

Figure 4.24(c) Projected number of age-specific private sector acute care bed-days (by SVM) – female (2007-2041)

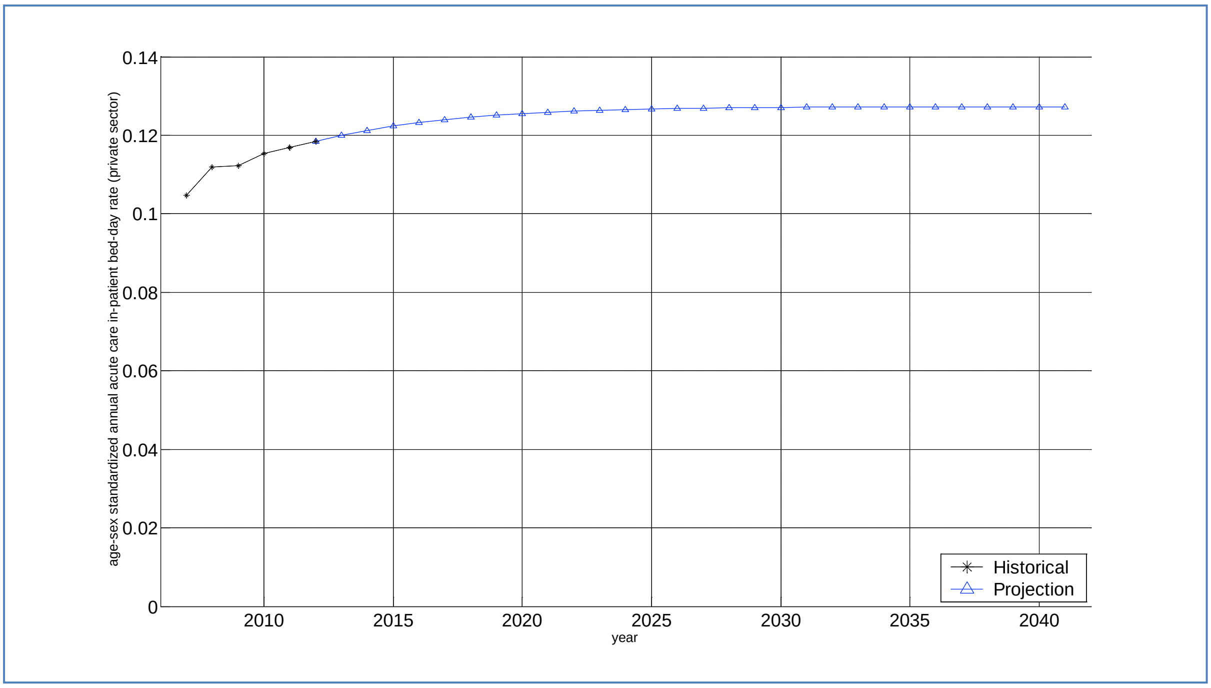

Figure 4.25(a) Projected annual private sector acute care bed-day rates (by SVM) (2007-2041)

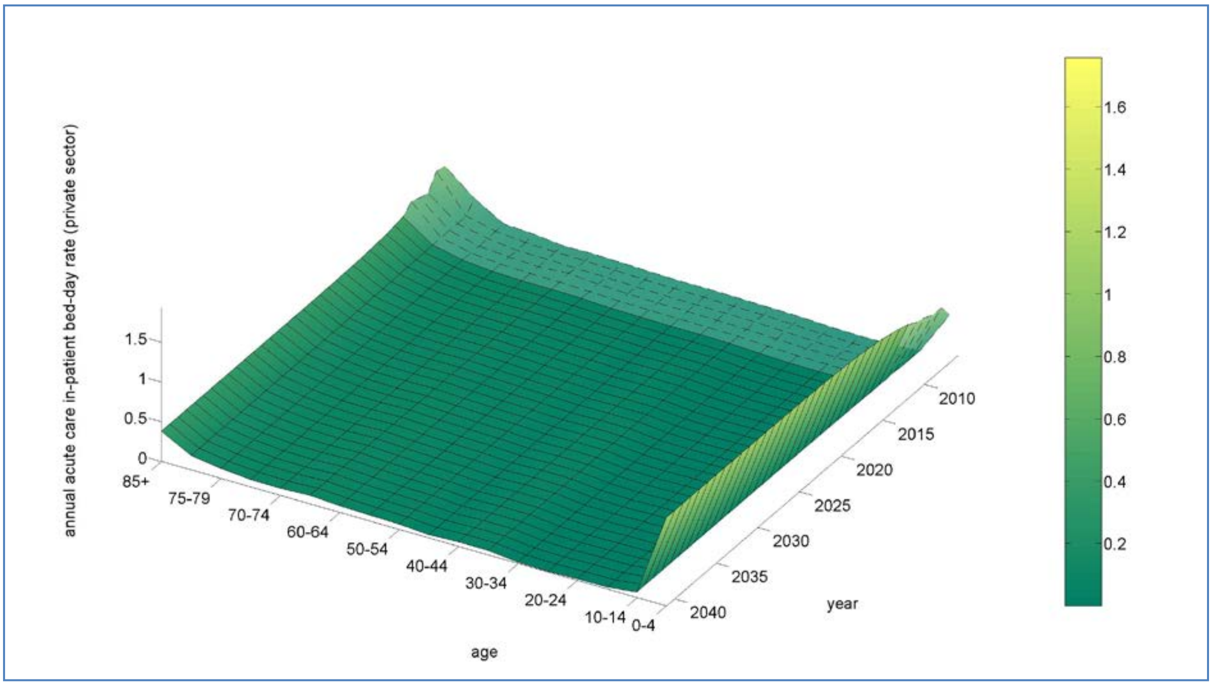

Figure 4.25(b) Projected annual private sector acute care bed-day rates (by SVM) - male (2007-2041)

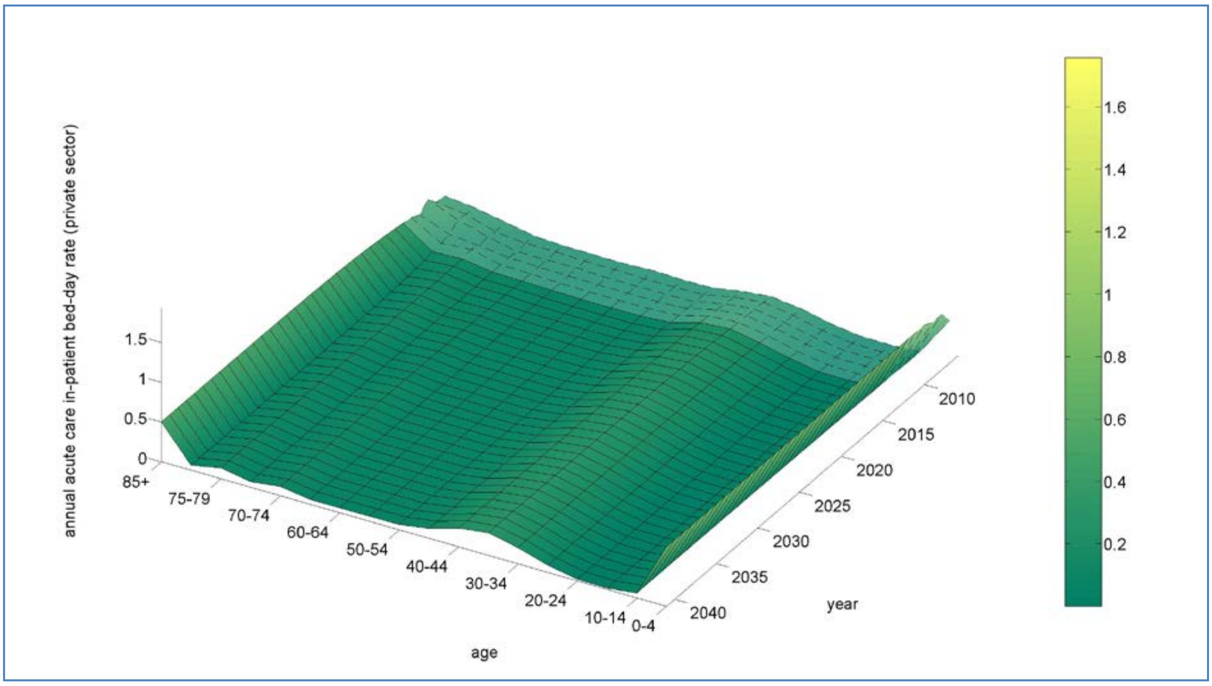

Figure 4.25(c) Projected annual private sector acute care bed-day rates (by SVM) - female (2007-2041)

4.2.5 Academic sector

The academic sector pharmacist demand projection is based on the number of students in pharmacy training programmes (2001 – 2011). The historical and projected number of students is estimated from the historical and projected number of pharmacy graduates provided by the two academic institutions: the School of Pharmacy, CUHK and the Department of Pharmacology and Pharmacy, HKU (Figure 4.26). As the program duration changed from 3 to 4 years in 2012, there is a sharp increase in the number of students from 2011 to 2012. The projected number of graduates is assumed to remain constant from 2020 to 2041.

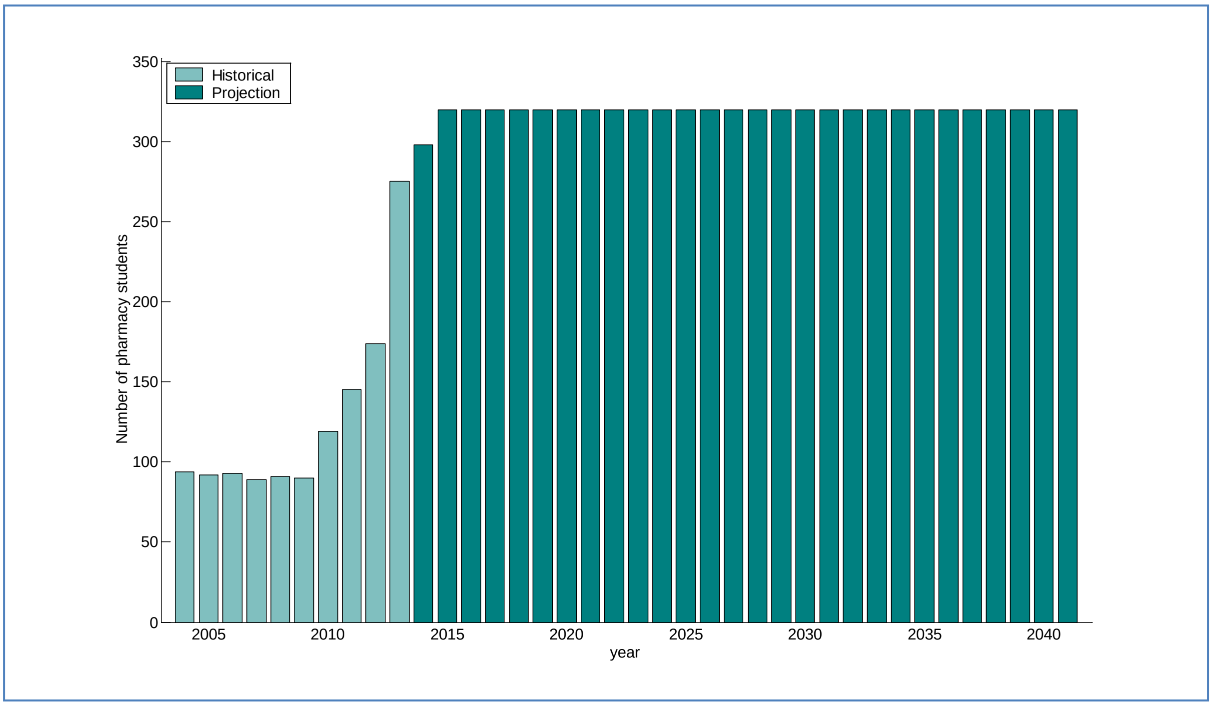

Figure 4.26 Historical and projected number of pharmacy students in Hong Kong 2004-2041

4.3 Converting healthcare utilisation to full time equivalents (FTEs)

A regression-based approach is used to convert healthcare demand/utilisation to pharmacist FTEs by service sector (public, private and academic) and by service type (outpatient and community pharmacy, pharmaceutical industry, hospital and education).

4.3.1 Community pharmacy: Authorised Sellers of Poisons (ASP)

As community pharmacy (ASP) licensing requirements include the supervision of the sale of poisons by registered pharmacists, the number of pharmacists in community pharmacies are expressed as a linear proportion to the number of ASPs:-

$$Number\ of\ pharmacists\ in\ community\ pharmacy\ (F_{ASP}) = \\ Number\ of\ community\ pharmacies \times \alpha_{ASP}$$

where α_{ASP} is the number of pharmacists per community pharmacy.

A steep increase in the number of ASPs from 1997 to 2011 is observed (Figure 4.27) however, the number of ASPs (and hence the pharmacists in community pharmacy) does not depend only on the number of prescriptions.

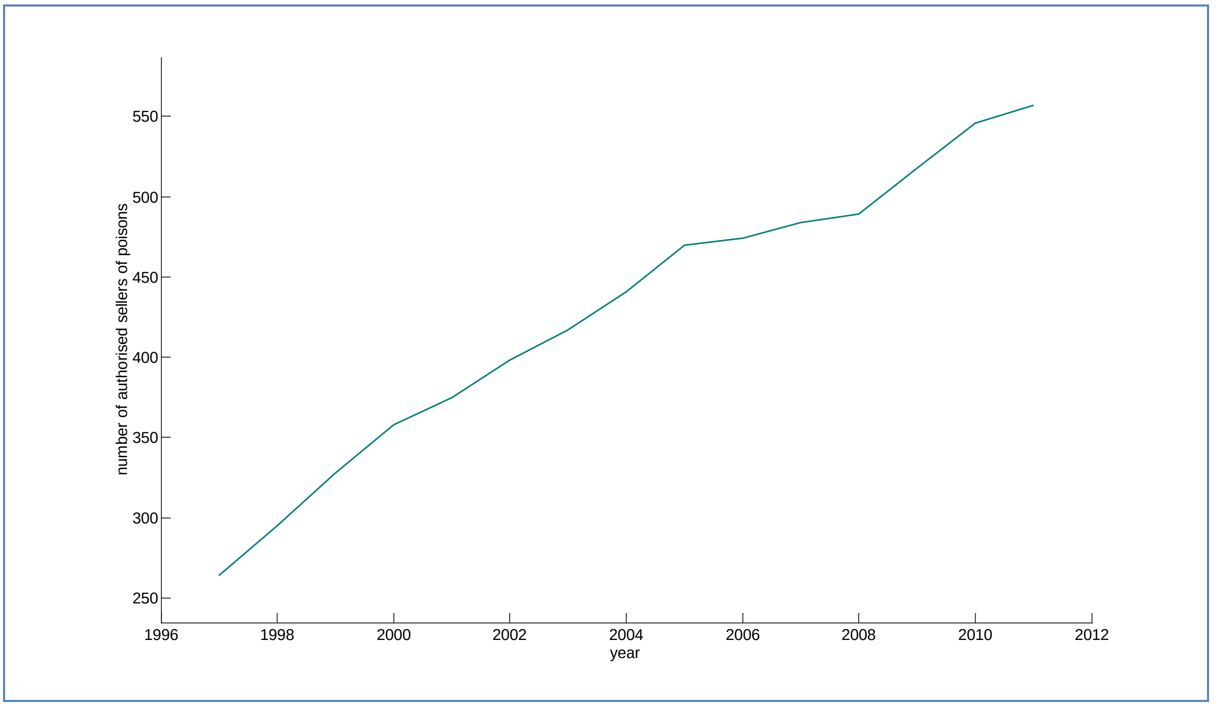

Figure 4.27 Number of Authorized Sellers of Poisons from 1997 to 2011

As commercial decisions play an important role in the number of ASPs, the number of ASPs can be modelled as:-

$$\begin{aligned} &Number\ of\ community\ pharmacies\ (n_{CP}) \\ &\quad = Hong\ Kong\ population\ size\ (P) \\ &\quad \times\ Number\ of\ prescriptions\ per\ Hong\ Kong\ residents\ (\alpha) \\ &\quad \div\ Number\ of\ prescriptions\ handled\ per\ community\ pharmacy\ (\beta) \end{aligned}$$

where β is a quantified market share of the community pharmacy. The variables α and β are combined as Hong Kong population per ASP (Υ) and the above equation is rewritten as:-

$$\begin{aligned} &Number\ of\ community\ pharmacies\ (n_{CP}) \\ &\quad = Hong\ Kong\ population\ size\ (P) \\ &\quad \div\ Number\ of\ Hong\ Kong\ residents\ \ per\ community\ pharmacy\ (\gamma) \end{aligned}$$

As there is a declining relationship between the number of ASPs and the population size (Figure 4.28) the number of prescriptions handled per ASP or a changing economic environment may be driving the increase in the number of ASPs.

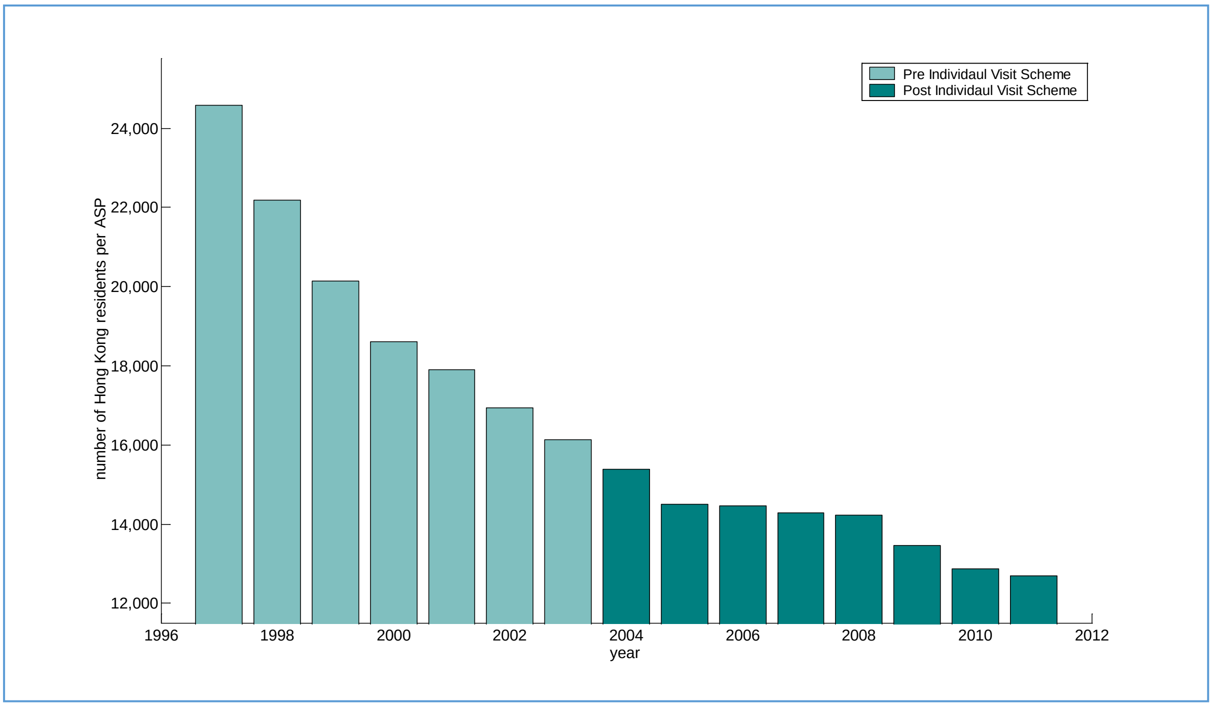

Figure 4.28 Number of Hong Kong residents per ASP (1997 and 2011)

The number of ASP's by district are not proportionate to the district population size (Figure 4.29).

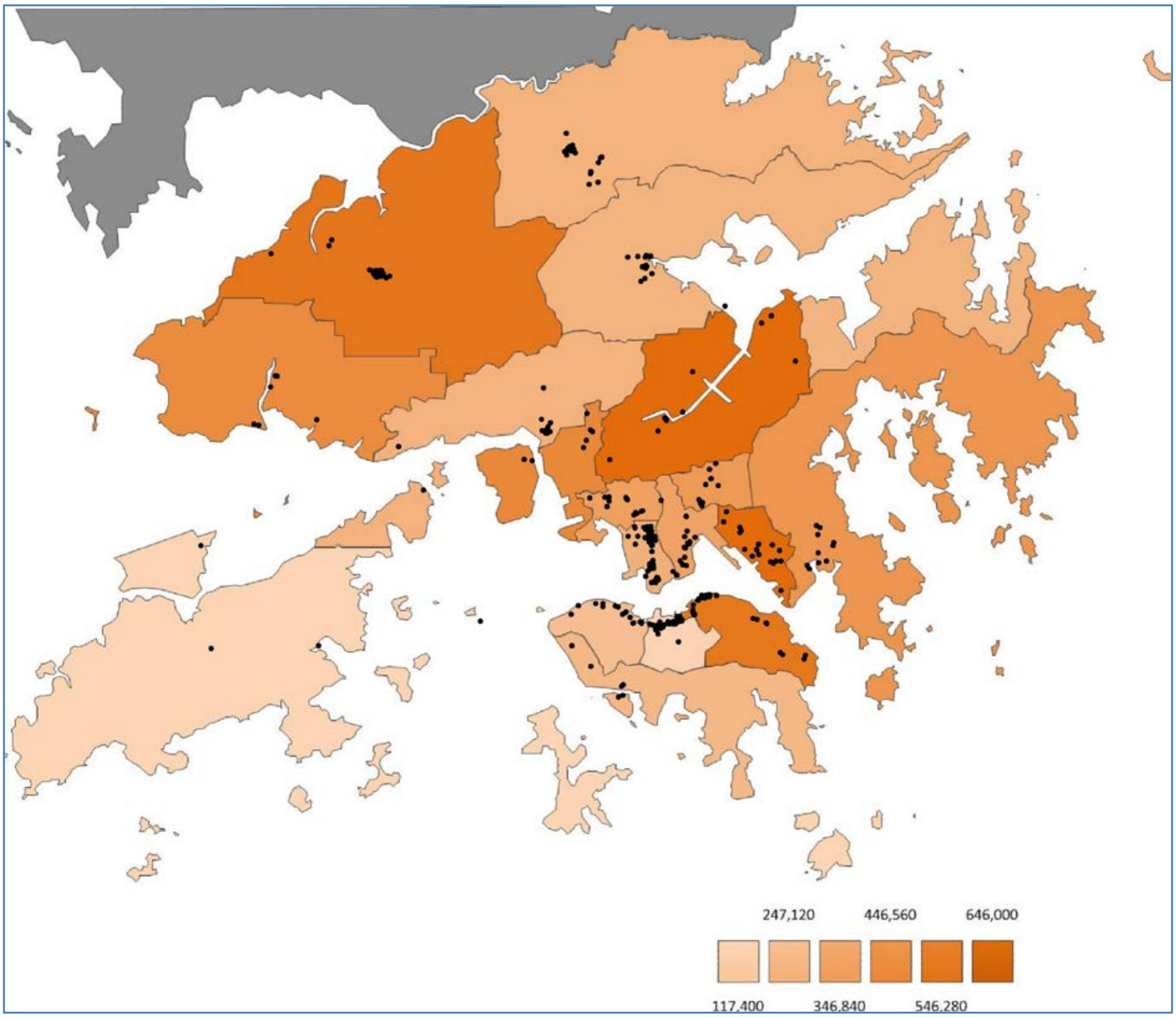

Figure 4.29 Hong Kong demographics and spatial distribution of ASP’s by district at 2013

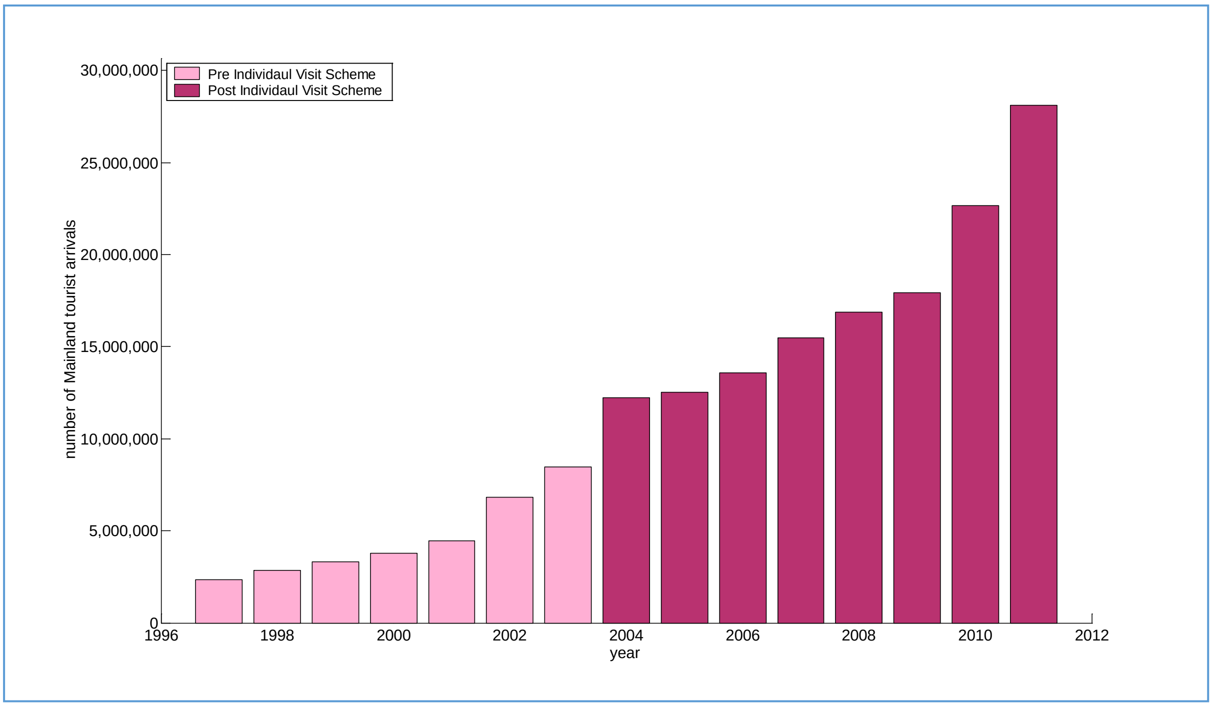

Figure 4.30 Number of Mainland tourists (2004 and 2011)

The increase in the number of ASPs and their spatial distribution (primarily located in Mong Kok, Causeway Bay, Yuen Long and Sheung Shui) is associated with the increasing number of Mainland tourists between 2004 and 2011. As the projected number of Mainland visitor arrivals [5] at 2017 and 2023 is available, a time series analysis is used to project the number of Mainland visitors arrivals for the remaining projection periods (i.e. 2014-2016, 2018-2022 and 2024-2041) (Figure 4.30). In April 2015, the Central Government announced a new measure to adjust the "multiple-entry" Individual Visit Endorsements for permanent residents of Shenzhen by replacing it with the "one trip per week" Individual Visit Endorsements. It is expected that the new measure will reduce the number of visitor arrivals under the "multiple-entry" Individual Visit Endorsements. As it will take time for the new measure to show full effect, a conservative approach adopting a discount factor of 0.75 is applied in estimating the number of mainland visitor arrivals (Figure 4.31).

[5] *Assessment Report on Hong Kong's Capacity to Receive Tourists* by Commerce and Economic Development Bureau, December 2013

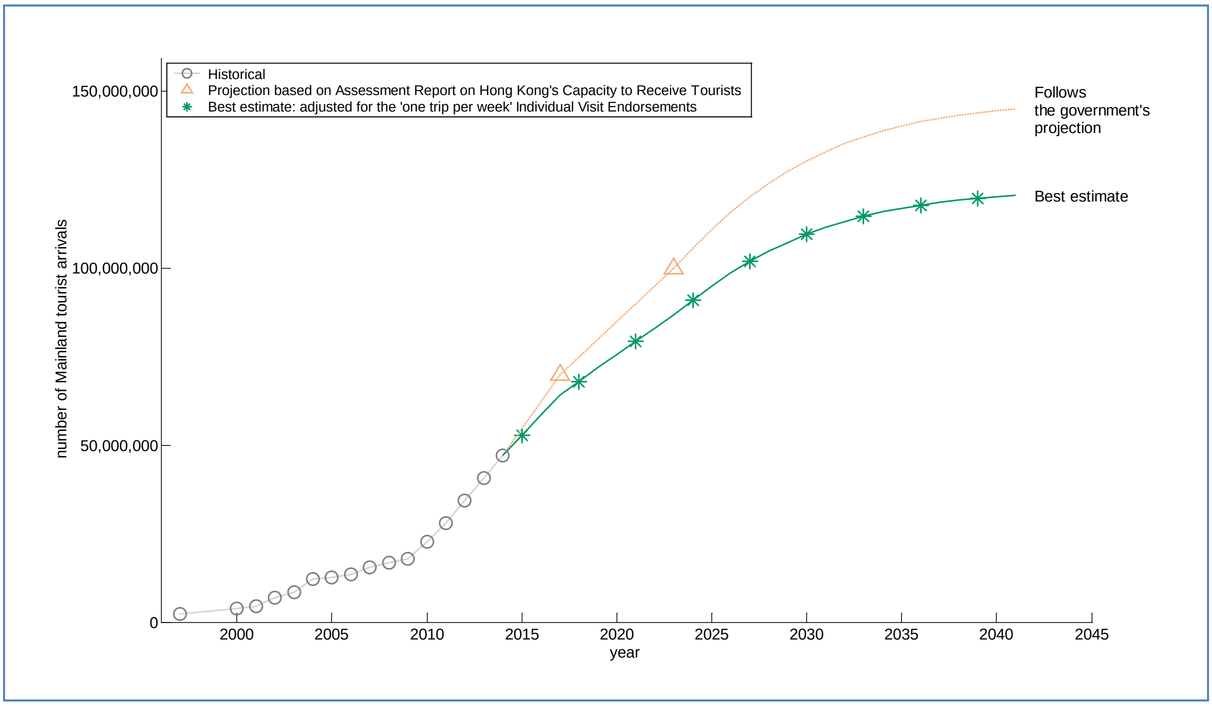

Figure 4.31 Projected number of Mainland tourists

The number of community pharmacies is stratified into those induced by the Hong Kong population and those by the number of Mainland tourists:-

$$\begin{aligned} &\mathit{Number\ of\ community\ pharmacies}\ (n_{CP}) \\ &\quad = \mathit{Hong\ Kong\ population\ size}\ (P_{HK}) \\ &\quad \times\ \mathit{Number\ of\ community\ pharmacies\ per\ Hong\ Kong\ resident}\ (\gamma_{HK}) \\ &\quad + \mathit{Number\ of\ Mainland\ tourists}\ (P_{IVS}) \\ &\quad \times\ \mathit{Number\ of\ community\ pharmacies\ per\ Mainland\ tourists}\ \ (\gamma_{IVS}) \end{aligned}$$

The number of prescriptions per Hong Kong resident is assumed to be independent of number of prescriptions per Mainland tourist; and number of prescriptions (per Hong Kong resident) and number of prescriptions (per mainland tourist) handled per community pharmacies are independent.

As the number of Mainland tourists prior to 2004 was relatively small a decomposition approach, illustrated in Figure 4.32, adopting a time series analysis is used to project n_{HK} and n_{IVS} where the:-

- Hong Kong population size and number of ASPs between 1997 and 2003 is used to compute the number of Hong Kong residents per community pharmacy Υ_{HK}.
- number of Hong Kong residents per community pharmacy $\tilde{\gamma}_{HK}$ from 2004 to 2041 is projected
- number of ASPs induced by the Hong Kong population $\tilde{n}_{HK}$ from 2004 to 2041 is estimated as $\tilde{n}_{HK} = \tilde{\gamma}_{HK} \times P_{HK}$
- number of ASPs induced by Mainland tourists is estimated as $\tilde{n}_{IVS} = n_{CP} - \tilde{\gamma}_{HK} \times P_{HK}$
- number of Mainland tourists per community pharmacy[6] $\tilde{\gamma}_{IVS}$ from 2004 to 2041 is projected
- number of ASPs $\tilde{n}_{CP} = \tilde{n}_{HK} + \tilde{n}_{IVS}$ is projected.

The projected number of ASP's are shown in Figure 4.33.

[6] *Assessment Report on Hong Kong's Capacity to Receive Tourists* by Commerce and Economic Development Bureau, December 2013

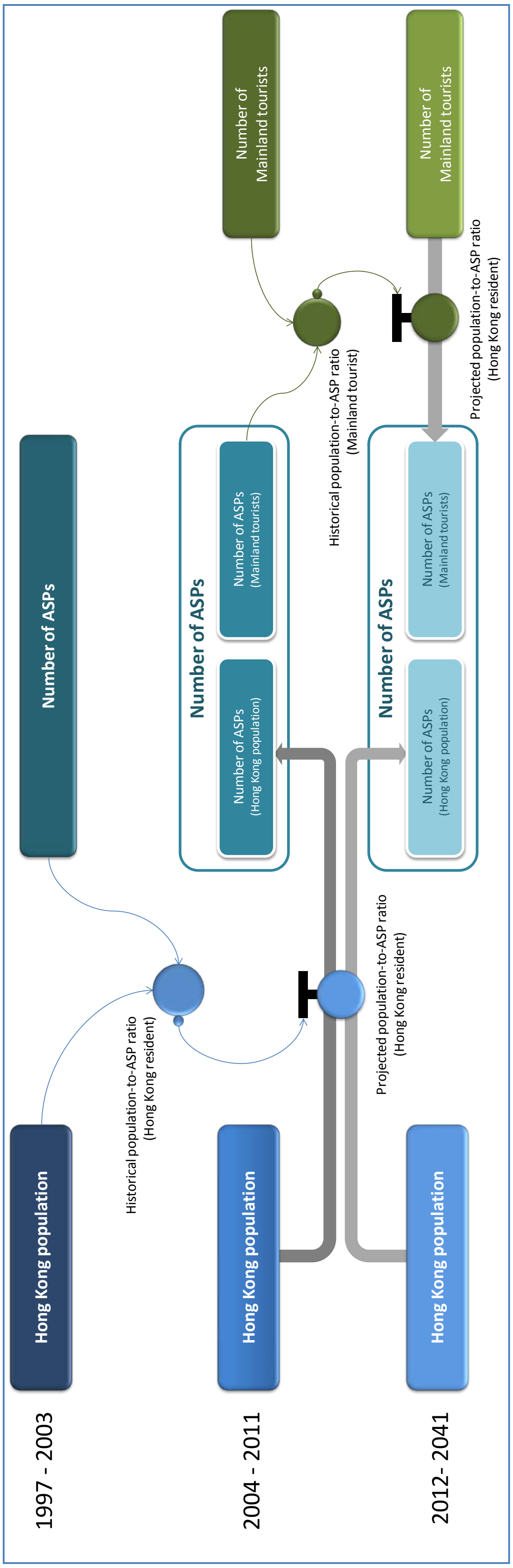

Figure 4.32 The Authorized Sellers of Poisons projection model

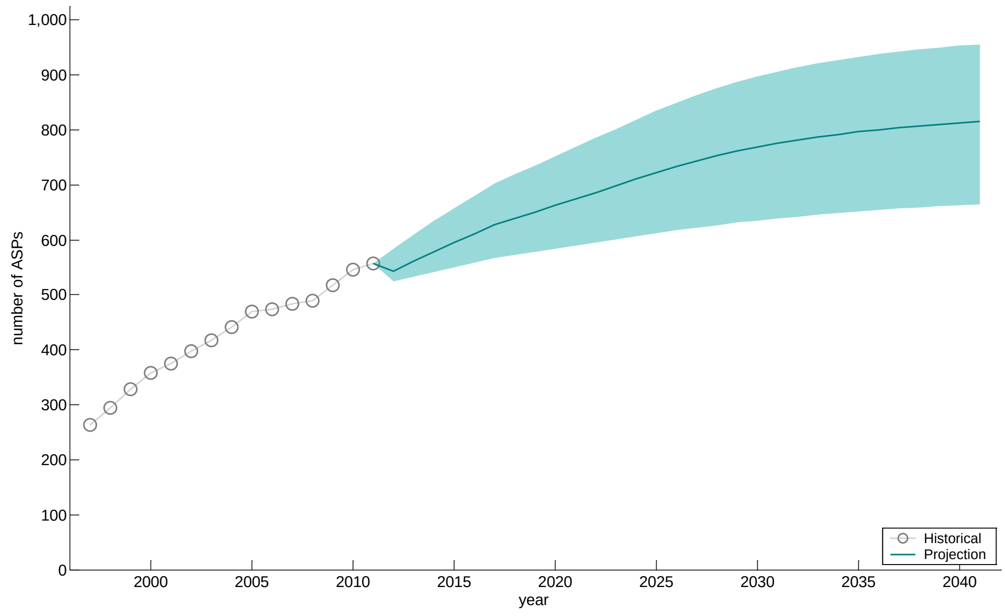

Figure 4.33 Historical and projected number of ASPs from 2012 to 2041

According to the pharmacy and poisons ordinance (Cap 138 Section 2(2)):-

> "it shall be a sufficient compliance with any requirement in this Ordinance that premises be under the personal control of a registered pharmacist if for not less than two-thirds of the hours of each day the premises are open for business a registered pharmacist is present at the premises and exercises control and supervision over the persons employed therein."

The empirical α_{ASP} at year 2004, 2005, 2006, 2007 and 2009 is estimated from the PPBHK annual report and the Health Manpower Survey on Pharmacists is used for the pharmacist per community pharmacy FTE projection and shown in Figure 4.34.

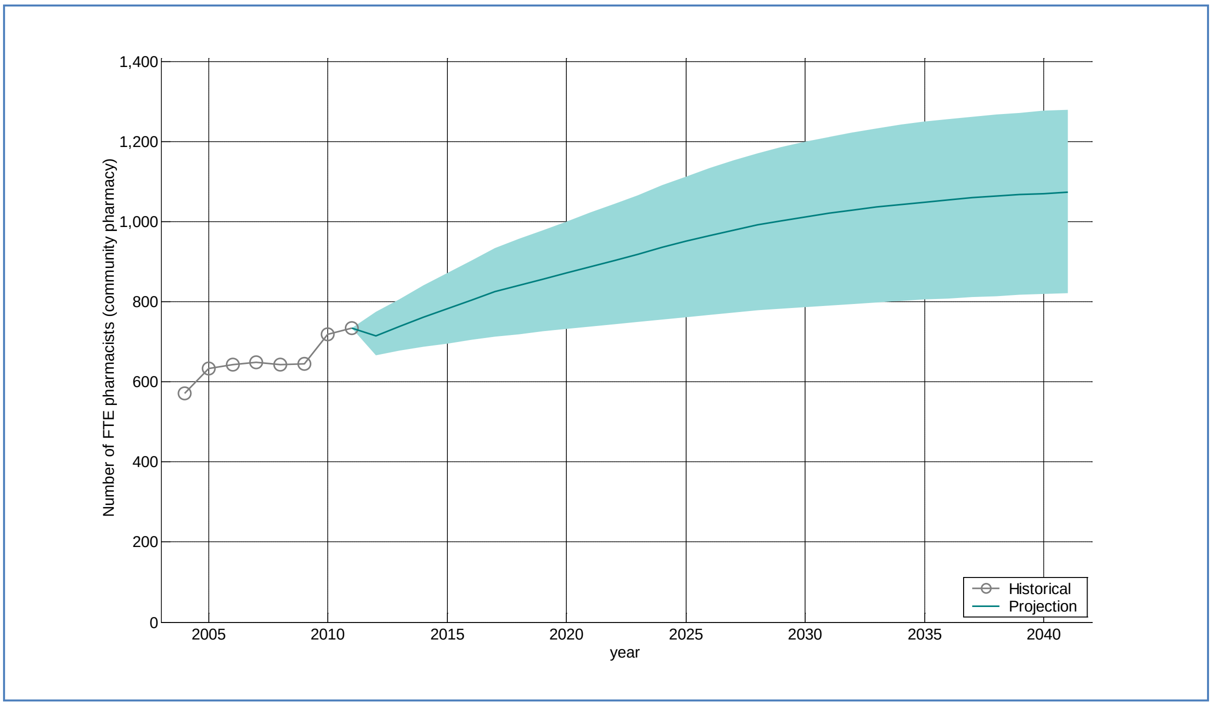

Figure 4.34 Historical and projected number of FTE pharmacists

4.3.2 Public Sector – Hospital Authority

HA pharmacists are engaged in five settings/services: general outpatient clinic dispensing services, hospital-based outpatient dispensing services, inpatient dispensing services, aseptic dispensing services, other professional services (Figure 4.35).

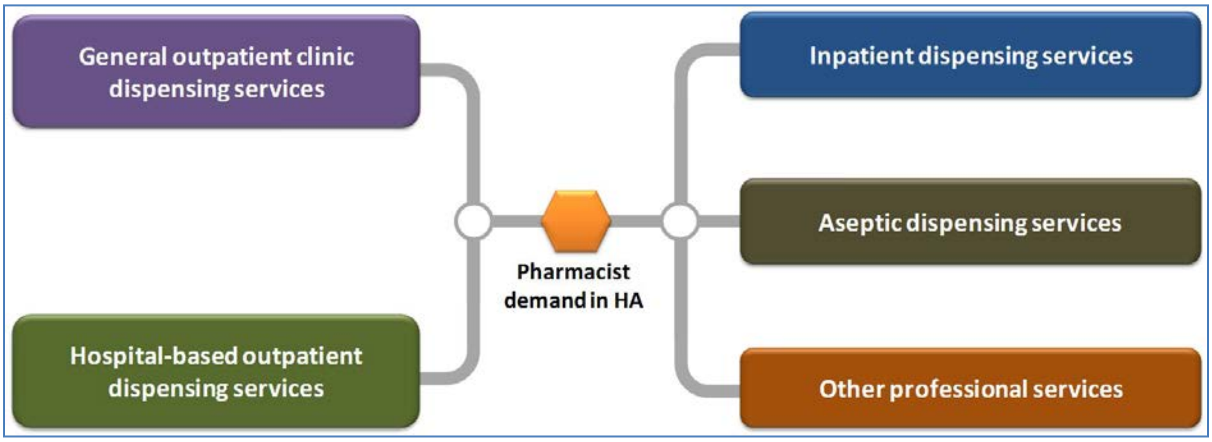

Figure 4.35 The five settings/services engaging HA pharmacist services

Similar to the demand projection models for doctors and nurses, HA service utilisation[7] is the 'back-bone' of the HA pharmacist demand projection model:

$$F = V \times \alpha$$

where F is number of FTE healthcare professions, V is service utilisation volume, and α is number of FTE healthcare professions per utilisation unit.

The number of drug items and drug volume are the fundamental workload units for pharmacists and are expressed in the above equation as 1) average number of drug items per utilisation unit, and 2) number of FTE healthcare professionals per drug item

$$F = V \times p \times \beta$$

where p links service volume to drug volume and V is an age-, sex- specific time-dependent utilisation variable. Variables p and β are time-dependent variables and reflect not only the age-, and sex-specific effect, but also changing technology and drug delivery service model.

The utilisation volume V is generally expressed as:

$$V(y) = \sum_{a,s} r(a,s,y) \times H(a,s,y)$$

where $r(a,s,y)$ is the age-, sex- group (a,s) at year y, and $H(a,s,y)$ is Hong Kong population age-, sex- group (a,s) at year y. The utilisation rate r is projected SVM. SVM is an artificial neural network that projects, based on the historical trend, values of a quantity in future time (i.e. year y between 2012 and 2041).

4.3.2.1 General outpatient clinic dispensing service (GODS)

The HA GODS pharmacist demand (F_{GODS}^{HA}) is expressed as:

---

[7] HA service utilisation includes number of day-case discharges, number of acute inpatient discharges, number of long-stay discharges, number of acute inpatient bed-days, number of long-stay bed-days, number of general outpatient visits, number of specialist outpatient visits and number of A&E attendances.

$$F_{GODS}^{HA} = Number\ of\ drug\ items\ dispensed\ in\ HA\ GODS\ pharmacy\ (D_{GODS}^{HA}) \times\ Number\ of\ FTE\ pharmacists\ per\ drug\ item\ dispensed\ in\ HA\ GODS\ pharmacy\ (\alpha_{GODS}^{HA})$$

D_{GODS}^{HA} is decomposed as:

$$D_{GOP}^{HA} = Number\ of\ GOPC\ visits\ (v_{GOP}^{HA}) \times\ Number\ of\ drug\ items\ per\ prescription\ per\ GOPC\ visit\ (p_{GOP}^{HA})$$

The following equation is derived:-

$$F_{GODS}^{HA} = v_{GOP}^{HA} \times p_{GOP}^{HA} \times\ \alpha_{GODS}^{HA}$$

The empirical number of HA GODS FTE pharmacists per 1,000 drug items dispensed in 2013 is held constant throughout the projection period. The projected number of drug items per prescription per HA general outpatient visit, number of drug items dispensed and FTE pharmacists in HA GODS pharmacy from 2012 to 2041 are shown in Figures 4.36, 4.37 and 4.38.

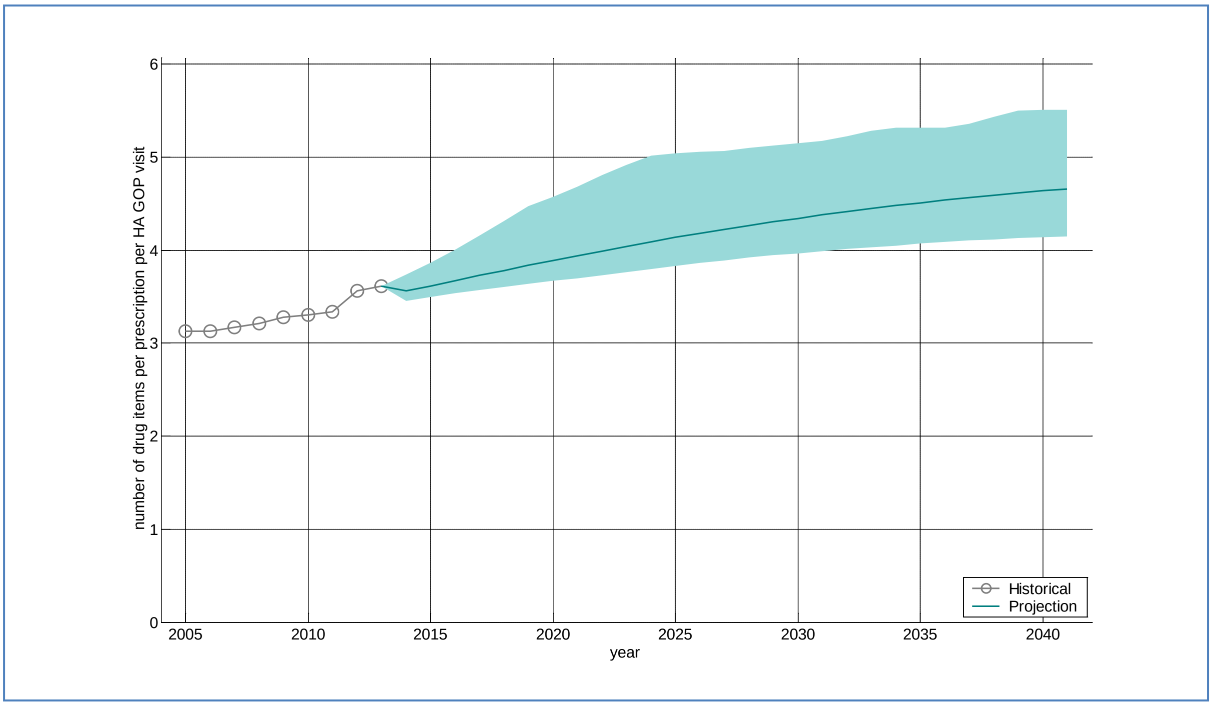

Figure 4.36 Historical and projected number of drug items per prescription per HA GOPC visit

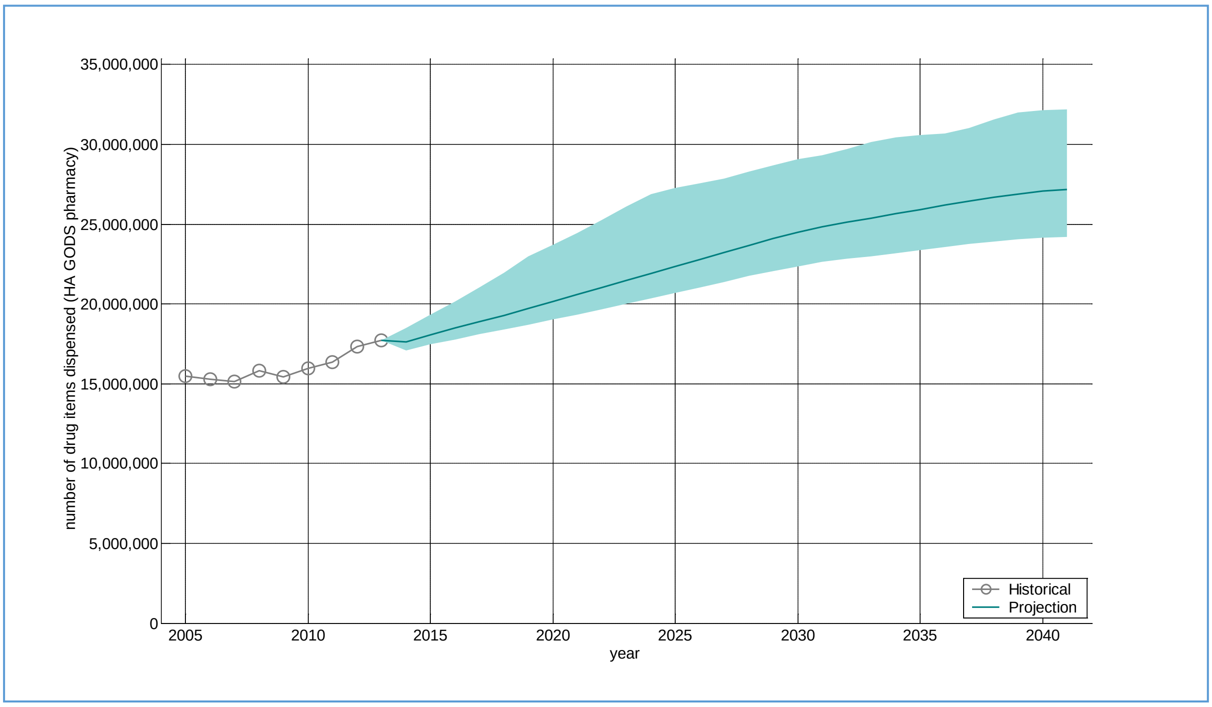

Figure 4.37 Historical and projected number of drug items dispensed (HA GODS pharmacy)

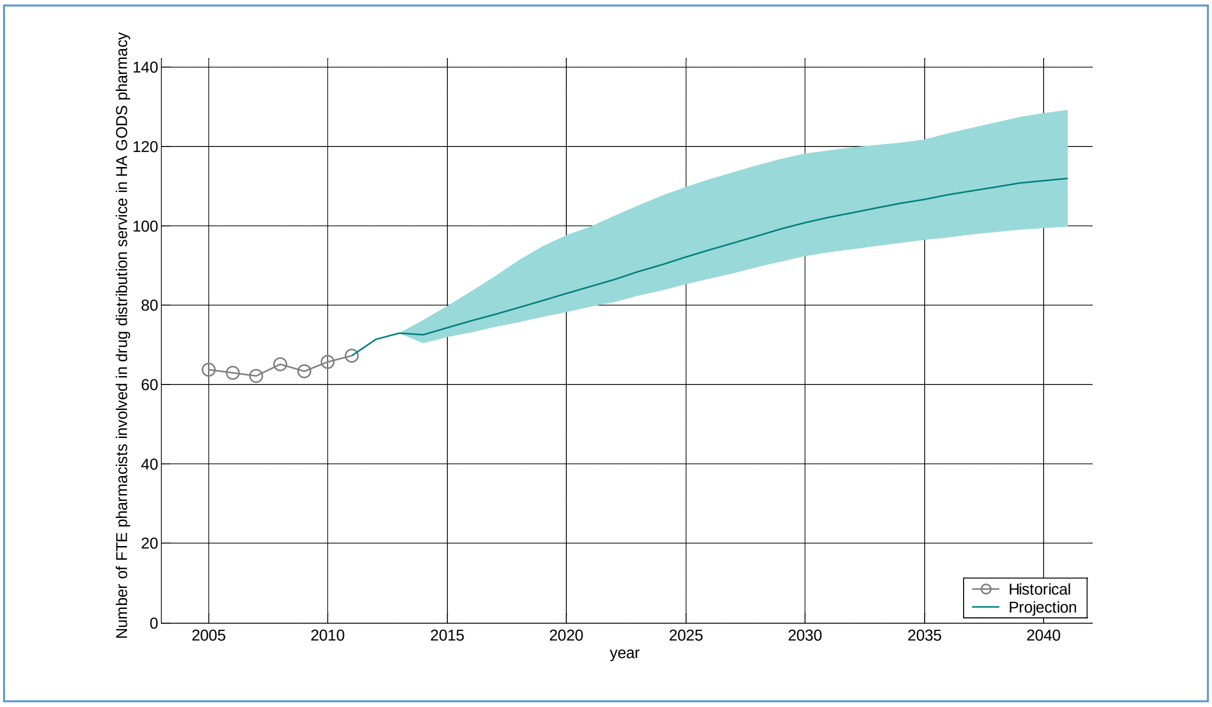

Figure 4.38 Historical and projected number of FTE pharmacists in HA GODS pharmacy

4.3.2.2 Hospital-based outpatient dispensing service

The HA hospital-based outpatient dispensing service (HODS) demand projection (F_{HODS}^{HA}) is expressed as:

$$F_{HODS}^{HA} = Number\ of\ drug\ items\ dispensed\ in\ HA\ HODS\ pharmacy\ (D_{SOPC}^{HA}) \times\ Number\ of\ FTE\ pharmacists\ per\ drug\ items\ dispensed\ in\ HA\ HODS\ (\alpha_{HODS}^{HA})$$

D_{SOPC}^{HA} is decomposed as follows:-

$$D_{SOPC}^{HA} = Number\ of\ HA\ HODS\ pharmacy\ prescriptions\ (p_{HODS}^{HA}) \times\ Number\ of\ drug\ items\ per\ HA\ HODS\ pharmacy\ prescription\ (r_{HODS}^{HA})$$

The HODS pharmacist workload includes prescriptions dispensed for SOPC, A&E, hospital discharge, ward follow-up, staff clinics, CGAT, VMO and private consultation clinics and the non-SOPD dispensing workload such as GOPD dispensing in the main pharmacy.

As the historical number of HODS drug items dispensed by each sub-set (i.e. SOPC, A&E, hospital discharge, ward follow-up, staff clinics, CGAT, VMO, and private consultation clinics) is not available, the number of prescriptions per case in each sub-set are assumed to be equal. The FTE demand projection is expressed as:-

$$D_{HODS}^{HA} = Number\ of\ cases\ (n_{case})\ \times\ Number\ of\ prescriptions\ per\ case(p_{case}) \times\ Number\ of\ drug\ items\ per\ HA\ HODS\ pharmacy\ prescription\ (r_{HODS}^{HA})$$

$$= Number\ of\ cases\ (n_{case}) \times\ Number\ of\ drug\ items\ per\ HA\ HODS\ pharmacy\ prescriptions\ per\ case\ \ (q_{HODS}^{public})$$

where n_{case} is approximated as

$$n_{case} \approx Number\ of\ \ HA\ SOPC\ visits + Number\ of\ A\&E\ attendances + Number\ of\ HA\ hospital\ discharges$$

The projected number of drug items per HA HODS pharmacy prescription per case and the projected number of drug items dispensed in HA HODS pharmacy are shown in Figure 4.39 and 4.40.

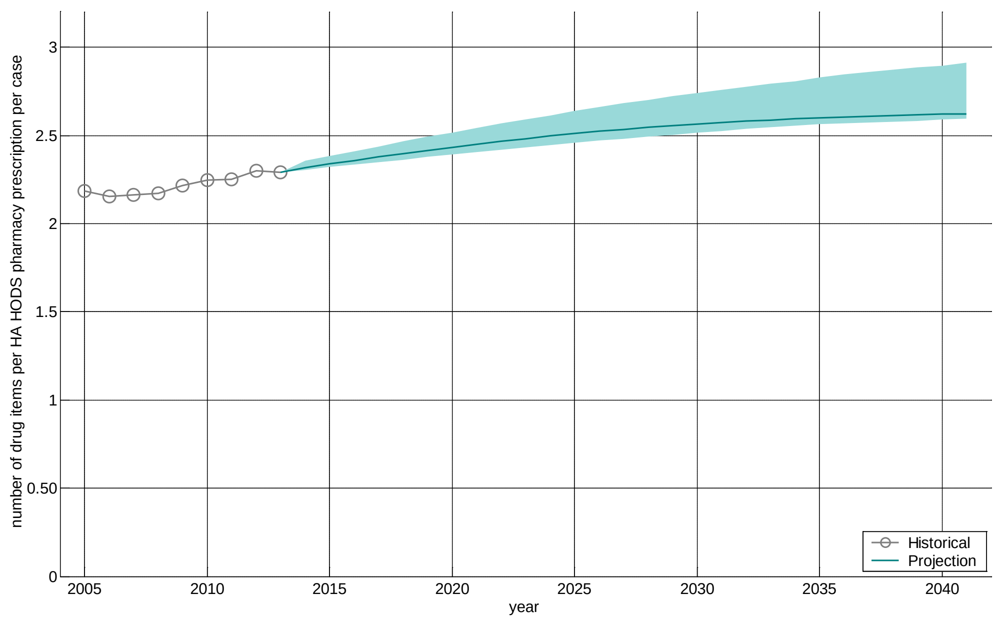

Figure 4.39 Historical and projected number of drug items per HA HODS pharmacy prescription per case

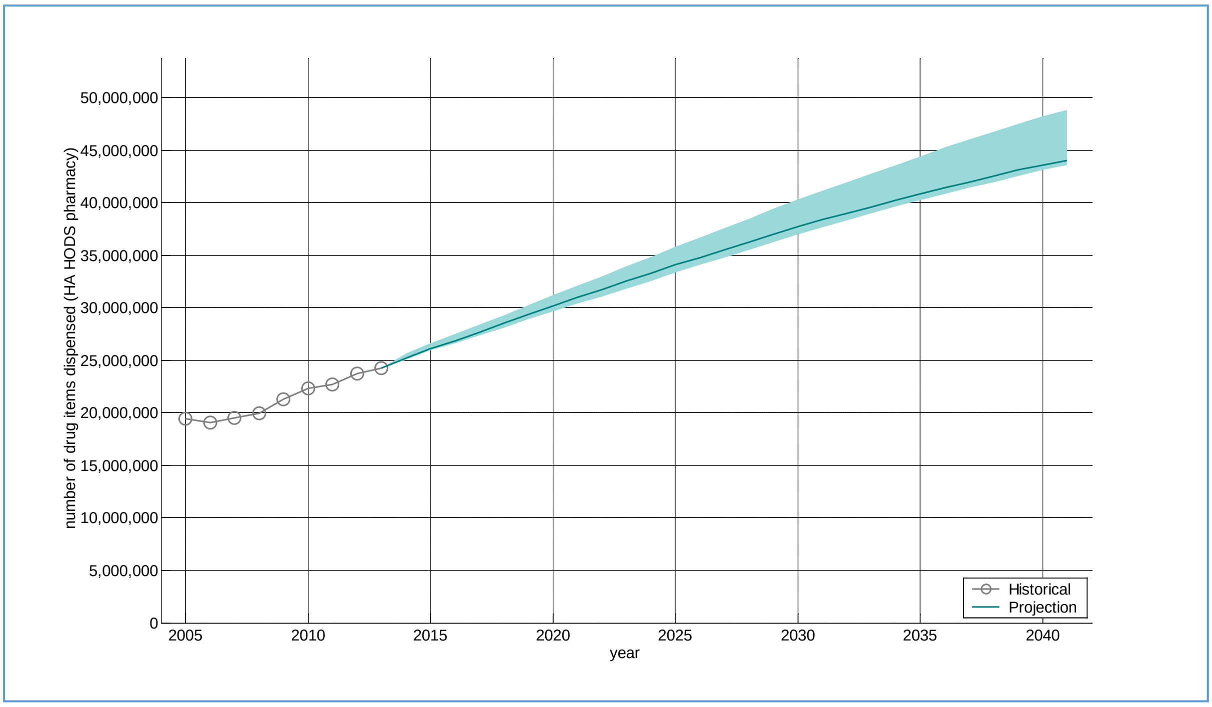

Figure 4.40 Historical and projected number of drug items dispensed (HA HODS pharmacy)

The number of items dispensed per pharmacist is held constant throughout the projection period. The projected number of FTE pharmacists in the drug distribution service in HA HODS pharmacy from 2012 to 2041 is shown in Figure 4.41.

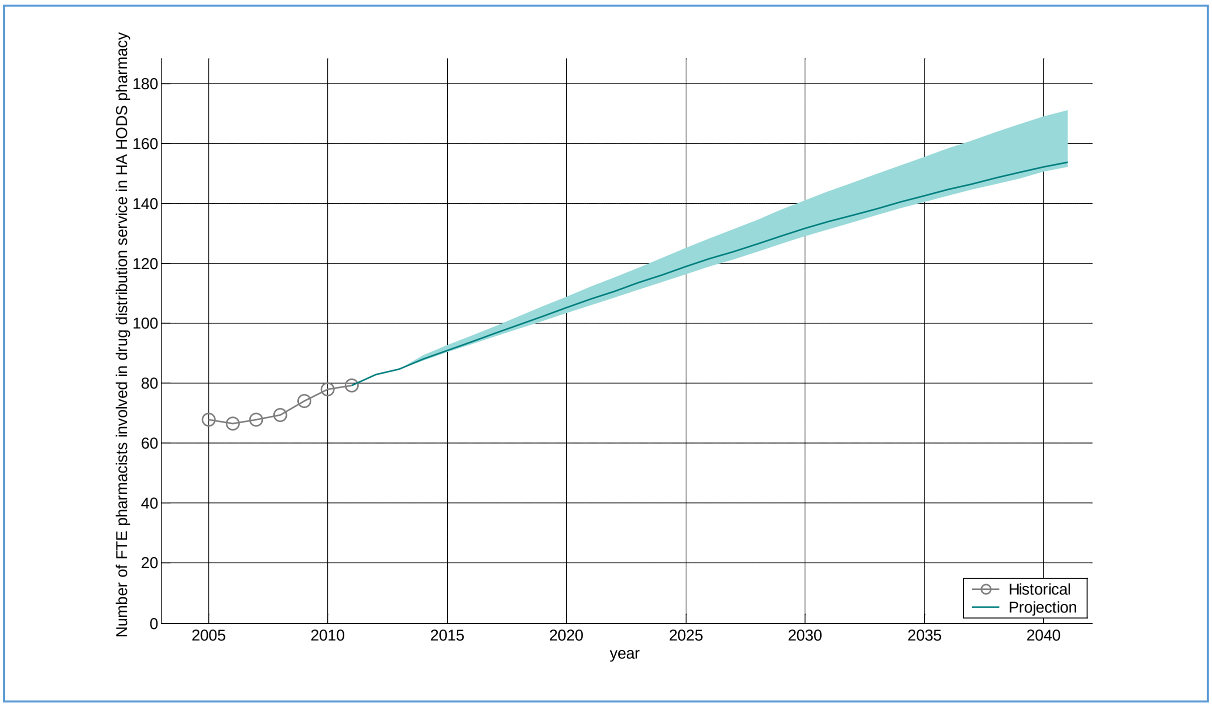

Figure 4.41 Historical and projected number of HODS FTE pharmacists

4.3.2.3 Inpatient dispensing services – Public sector

The inpatient dispensing services pharmacist demand projection (F_{IP}^{HA}) is expressed as:

$$F_{IP}^{HA}$$
$$= Number\ of\ drug\ items\ dispensed\ in\ HA\ acute\ inpatient\ dispensing\ service\ (D_{acute}^{HA})$$
$$\times\ Number\ of\ FTE\ pharmacists\ per\ drug\ item\ dispensed\ in\ HA\ acute\ inpatient\ dispensing\ servic$$
$$+$$
$$Number\ of\ drug\ items\ dispensed\ in\ HA\ non\text{-}acute\ inpatient\ dispensing\ service\ (D_{non-acute}^{HA})$$
$$\times$$
$$Number\ of\ FTE\ pharmacists\ per\ drug\ item\ dispensed\ in\ HA\ non\text{-}acute\ inpatient\ dispensing\ serv$$

D_{acute}^{HA} *is decomposed as:*

$$D_{acute}^{HA} = Number\ of\ HA\ acute\ inpatient\ bed\text{-}days\ (B_{acute})$$
$$\times\ Number\ of\ drug\ items\ per\ HA\ acute\ inpatient\ bed\text{-}day\ (r_{acute}^{HA})$$

where B_{acute} *= Number of day-case discharges + Number of acute inpatient bed-days for HA acute hospitals*

$D_{non-acute}^{HA}$ *is decomposed as:*

$$D_{non-acute}^{HA}$$
$$= Number\ of\ HA\ non\text{-}acute\ inpatient\ bed\text{-}days\ (B_{non-acute})$$
$$\times\ Number\ of\ drug\ items\ per\ HA\ non\text{-}acute\ inpatient\ bed\text{-}day\ (r_{non-acute}^{HA})$$

The projected number of drug items per HA inpatient bed-day (acute and non-acute) and the projected number of drug items dispensed by the inpatient pharmacy are shown in Figure 4.42 – 4.45. The number of drug items per prescription per acute inpatient bed-day increase sharply throughout the projection period, whereas the increase for non-acute inpatients is more gradual and plateaus by 2025. The projected number of HA inpatient dispensing services FTE pharmacists from 2012 to 2041 are shown in Figure 4.46.

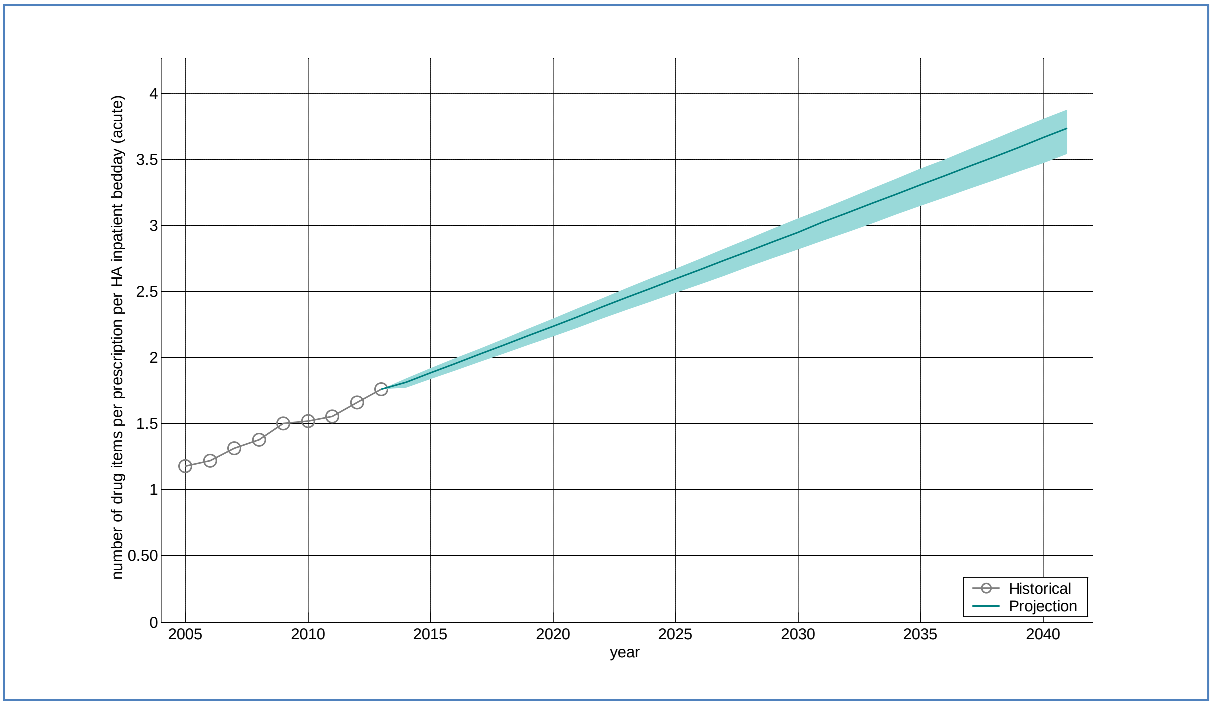

Figure 4.42 Historical and projected number of drug items per prescription per inpatient bed-day (acute)

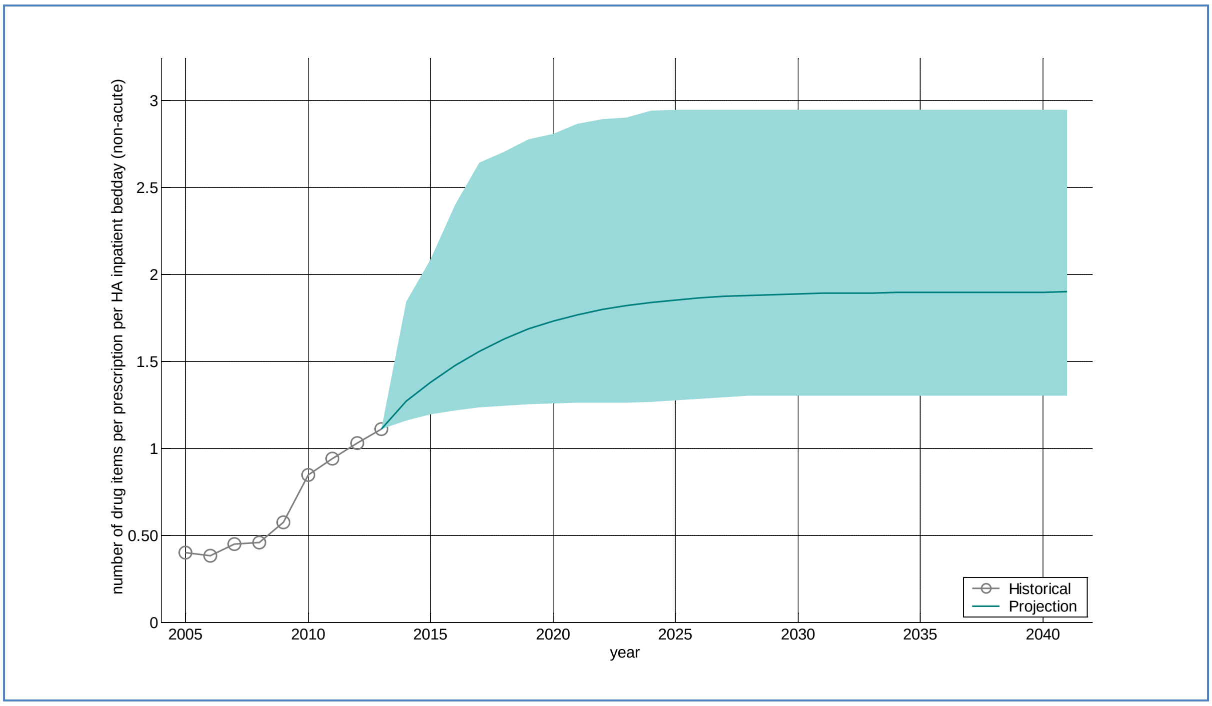

Figure 4.43 Historical and projected number of drug items per prescription per inpatient bed-day (non-acute)

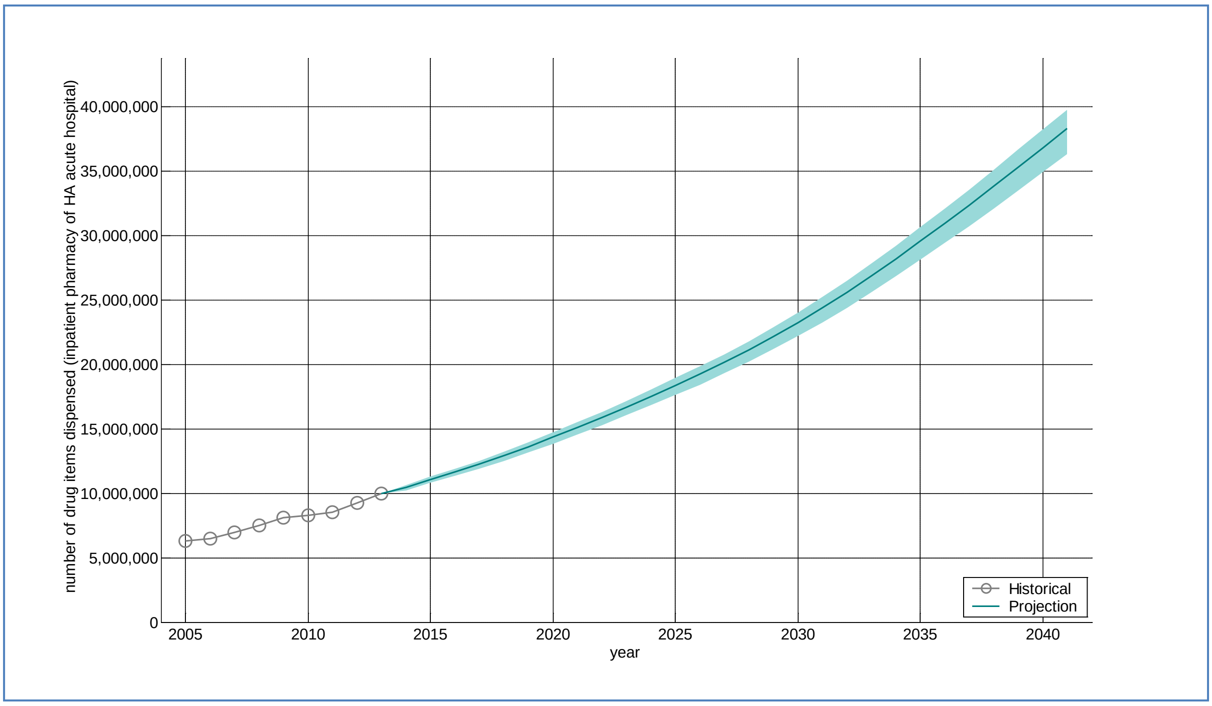

Figure 4.44 Historical and projected number of drug items dispensed (acute)

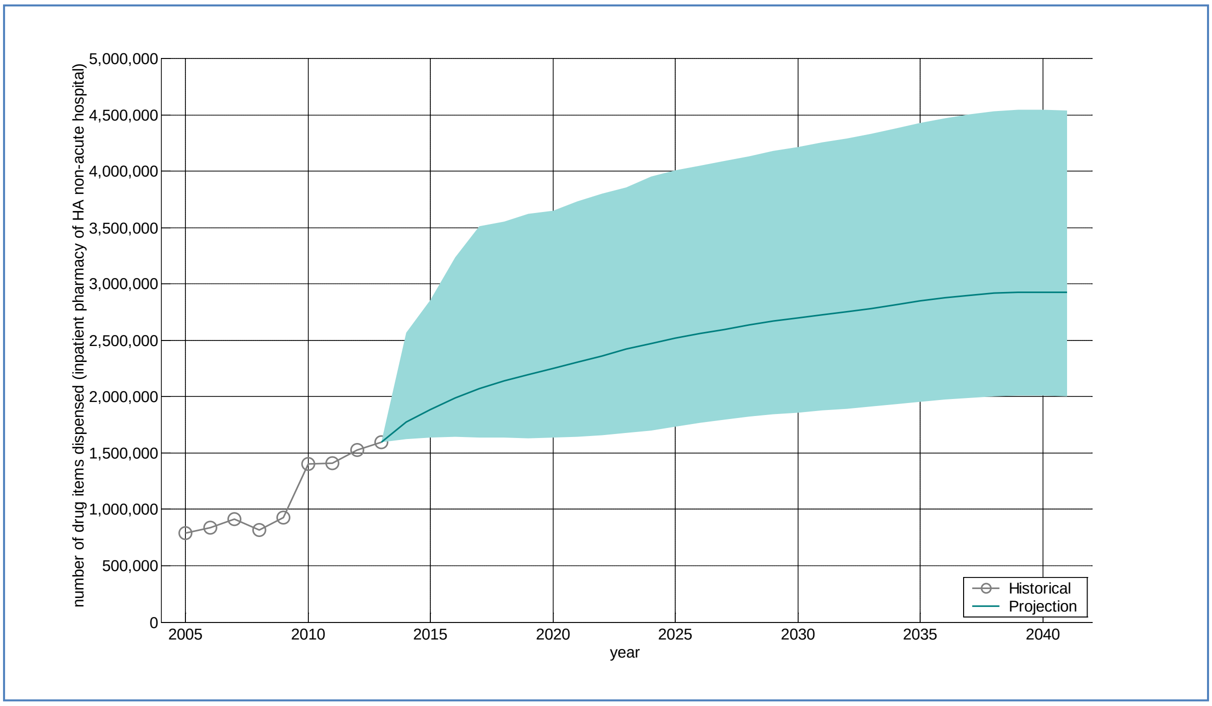

Figure 4.45 Historical and projected number of drug items dispensed (non-acute)

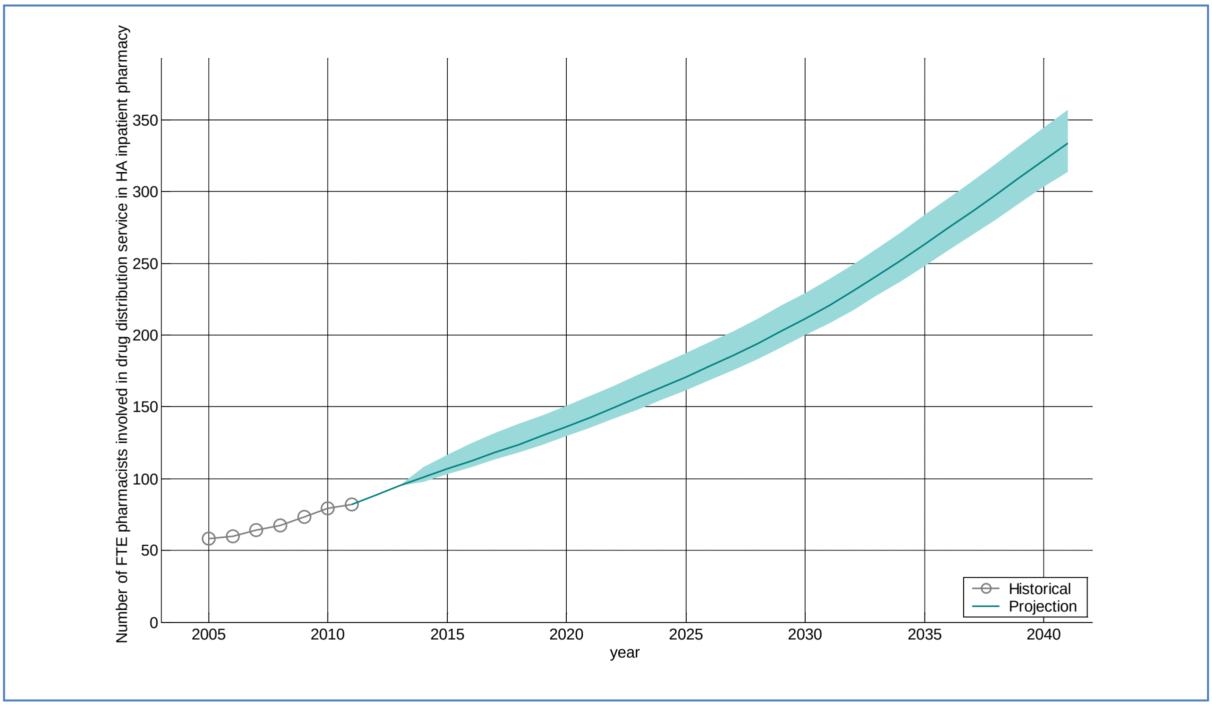

Figure 4.46 Historical and projected number of FTE pharmacists in HA inpatient pharmacy.

4.3.2.4 Aseptic dispensing services – Public sector

The number of FTE pharmacists assigned to the aseptic dispensing services is a linear function of the total number of aseptic dispensing items:-

$$Number\ of\ FTE\ aseptic\ dispensing\ services\ pharmacists\ in\ HA\ \left(F_{Aseptic}^{HA}\right)$$
$$= Number\ of\ aseptic\ dispensing\ items\ in\ HA\ \left(A_{Aseptic}^{HA}\right)$$
$$\times\ Number\ of\ FTE\ pharmacists\ per\ item\ (\alpha_{AS})$$

The aseptic dispensing item are classified as follows:-

C1: Total Parenteral Nutrition (TPN)

C2: Cytotoxic drugs (CDS)

C3: Intravenous drug admixture and others (including eye drops, PCA, clinical trial drugs, etc.)

The number of aseptic dispensing items (for C1, C2 and C3) in the HA is estimated from service utilisation volumes (number of discharges, bed-days and outpatient visits) for Paediatrics, Oncology, Surgery, and Intensive Care (Table 4.2). As each aseptic dispensing category involves different specialties and different types of utilisation, the corresponding number of dispensed aseptic items is projected independently using different utilisation volume models.

Table 4.2 Aseptic dispensing service utilisation by speciality

Specialty	**Service utilisation**	**Category 1**	**Category 2**	**Category 3**
Paediatrics	*Hospital day-case discharge*			✓
	Hospital bed-day	✓		✓
Oncology	*Hospital day-case discharge*		✓	✓
	SOP visit		✓	✓
Surgery	*Hospital bed-day*	✓		
ICU	*Hospital bed-day*	✓		

Aseptic dispensing item: Total Parental Nutrition (C1)

The number of C1 items dispensed $A_1^{HA}(y)$ in HA at year *y* is expressed as:

$$A_1^{HA}(y) = \sum_{j=\{P,S,I\}} \sum_{a,s} B_j(a,s,y) \times \beta_j^1(a,s,y)$$

where

$B_j(a,s,y)$ number of bed-days in specialty $j \in \{P, S, I\}$ (P = Paediatrics, S = Surgery, I = ICU) by age-, sex-group (a,s) at year y

$\beta_j^1(a,s,y)$ age-, sex-specific number of C_1 aseptic items per bed-day by specialty j at year y

The historical number of C1 items dispensed in HA are only available in aggregated format, β_j^1 and are assumed to be invariant of age, sex and specialty and is expressed as and shown in Figures 4.37 and 4.38 :-

$$A_1^{HA}(y) = \tilde{\beta}_1^{HA}(y) \sum_{a,s} B_j(a,s,y)$$

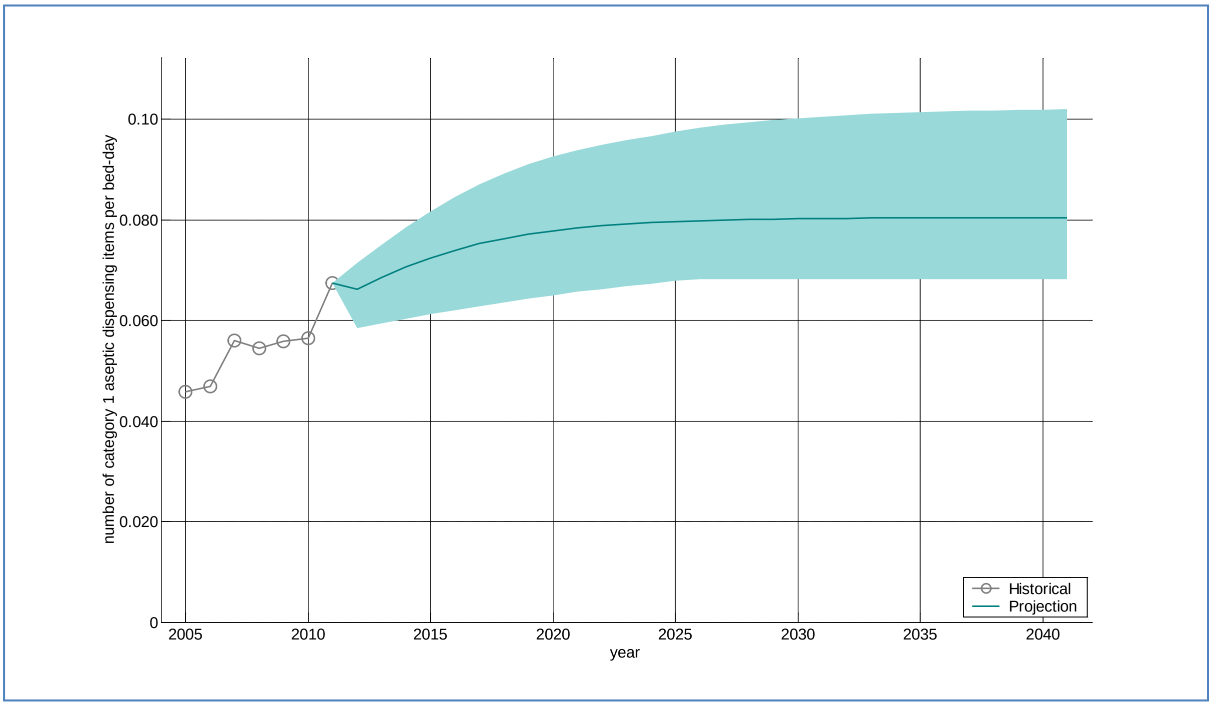

Figure 4.47 Historical and projected number of C1 aseptic items per bed-day

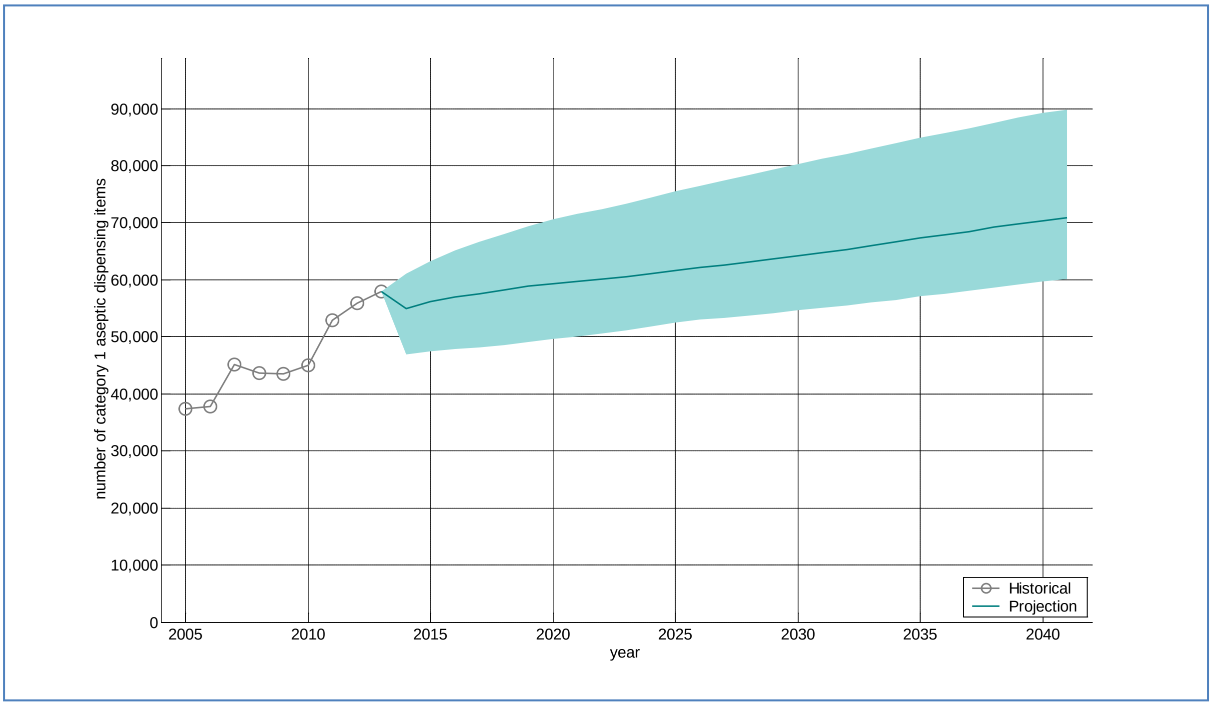

Figure 4.48 Historical and projected number of C1 aseptic items dispensed in HA

Aseptic dispensing item: Cytotoxic drugs (C2)

The number of C2 aseptic items dispensed in the HA depends on two quantities: *number of specialty discharges* D and *number of specialist outpatient visits* V for oncology. A_2^{HA} is expressed as a weighted sum of D and V:

$$A_2^{HA}(y) = \sum_{a,s}\left(\beta_j^2(a,s,y)\left(\sum_{j=\{D,I\}} d_j(a,s,y)\right) + \gamma_{SOP}^2(a,s,y)v(a,s,y)\right)$$

where

j discharge type index (i.e. D = day case discharge and I = acute inpatient discharge),

$d_j(a,s,y)$ number of age-, sex (a,s) discharges for oncology at year y,

$\beta_j^2(a,s,y)$ age-, sex-specific number of C2 aseptic item per discharge at year y

$v(a,s,y)$ age-, sex-specific number of outpatient visits for oncology at year y

$\gamma_{SOP}^2(a,s,y)$ age-, sex-specific number of category 2 aseptic item per SOP visit for oncology at year y

The variables $d_j(a,s,y)$ and $v(a,s,y)$ are further decomposed as

$$d_j(a,s,y) = r_j(a,s,y) \times H(a,s,y)$$
$$v(a,s,y) = r_V(a,s,y) \times H(a,s,y)$$

where

$H(a,s,y)$ Hong Kong population size of age-, sex- group (a,s) at year y,

$r_j(a,s,y)$ oncology age-, sex-specific discharge rate at year y, and

$r_V(a,s,y)$ oncology age-, sex-specific SOP visit rate at year y

The historical number of C2 aseptic items dispensed in HA are assumed to be:-

$$\beta_j^2(a,s,y) = \tilde{\beta}_2^{HA}(y) \text{ and } \gamma_j^2(a,s,y) = \tilde{\gamma}_2^{HA}(y)$$

The projection is re-expressed as:-

$$A_2^{HA}(y) = \tilde{\beta}_2^{HA}(y)\sum_{j=\{D,I\}}\sum_{a,s} r_j(a,s,y)H(a,s,y) + \tilde{\gamma}_2^{HA}(y)\sum_{a,s} r_V(a,s,y)H(a,s,y)$$

The relationship between the historical number of C2 aseptic items and the number of discharges D and number of SOPC visits V for oncology is linear. The optimal $\tilde{\beta}_2^{HA}$ and $\tilde{\gamma}_2^{HA}$ are computed as 0.25 and 0.99 respectively. The projected number of C2 aseptic items is shown in Figure 4.49.

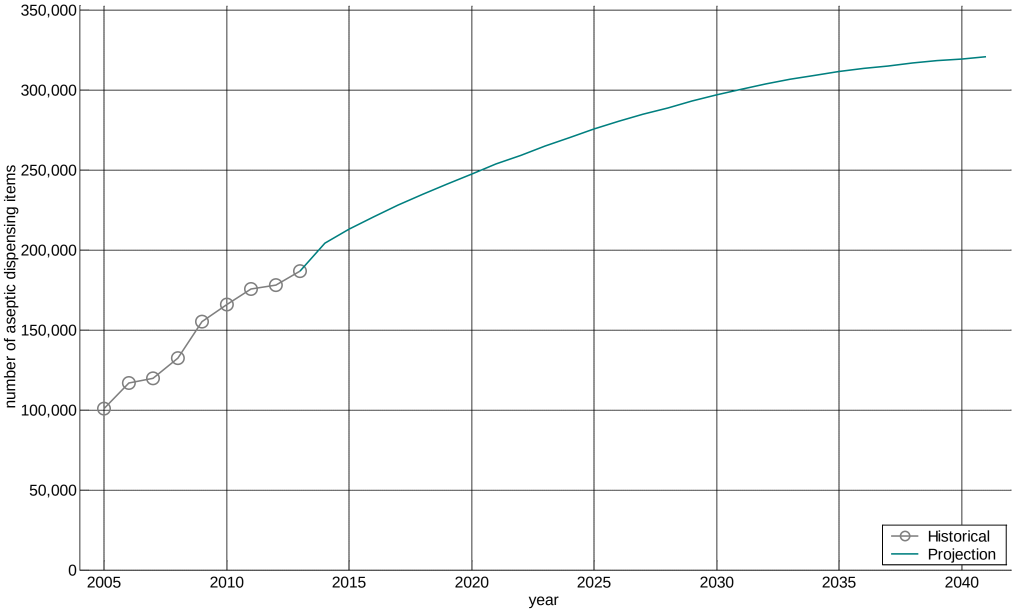

Figure 4.49 Historical and projected number of C2 aseptic items dispensed in HA

<u>Aseptic dispensing item: Drug admixture and others (C3)</u>

The utilisation demand for **<u>C3</u>** aseptic items $A_3^{HA}(y)$ in HA at year y is expressed as:-

$$A_3^{HA}(y) = \sum_{j=\{P,O\}} \sum_{a,s} \left(D_j(a,s,y) + B_j(a,s,y)\right) \times \beta_j^3(a,s,y)$$

where $j \in \{P, O\}$ is the specialty index (i.e. P = Paediatrics and O = Oncology)

$D_j(a,s,y)$ is the number of age-sex (a,s) day-case discharges of specialty j at year y,

$B_j(a,s,y)$ is the number of age-sex (a,s) acute inpatient bed-days of specialty j at year y,

$\beta_j^3(a,s,y)$ is the age-, sex-, specialty-specific number of category 3 aseptic items per case at year y

Figures 4.50 – 4.58 show the total and age-, sex- specific historical and projected number of C3 aseptic items dispensed for HA day case discharges and acute inpatient bed-days for Paediatrics and Oncology.

Day case discharge (Paediatrics)

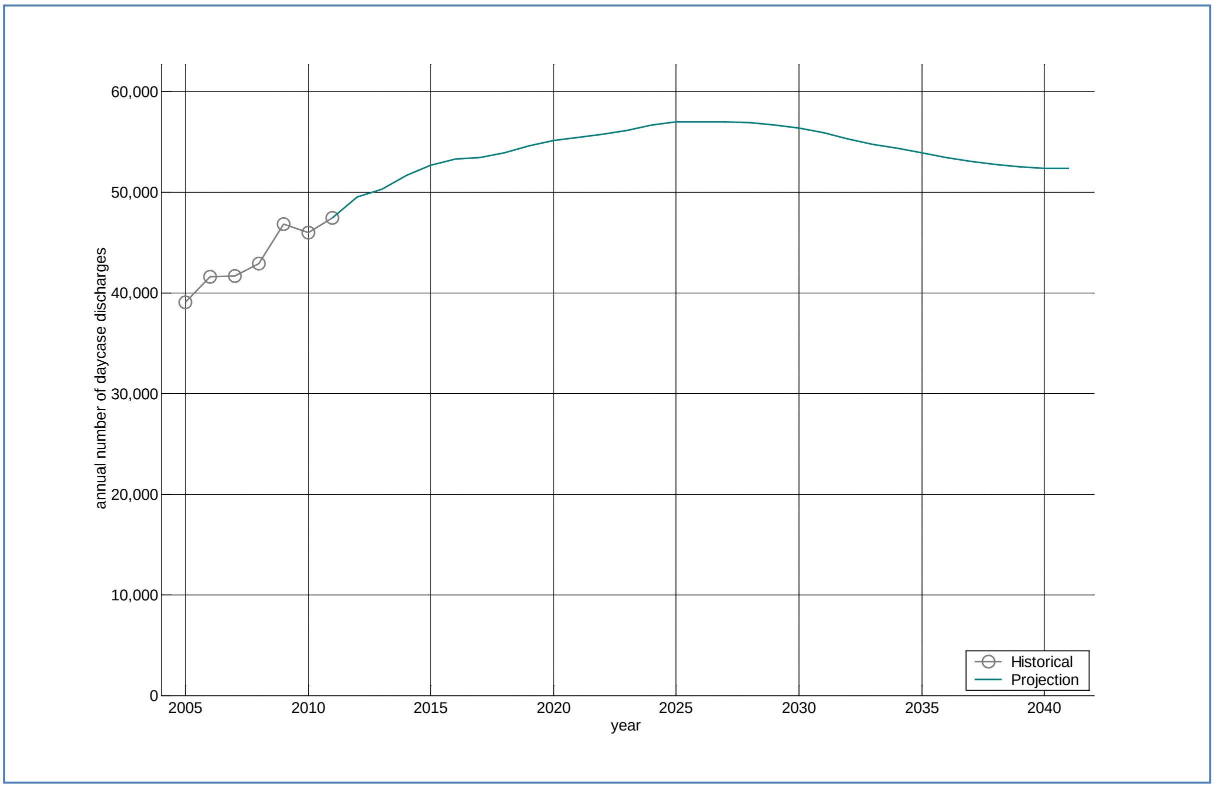

Figure 4.50 Historical and projected number of HA day case discharges for Paediatrics (2005-2041)

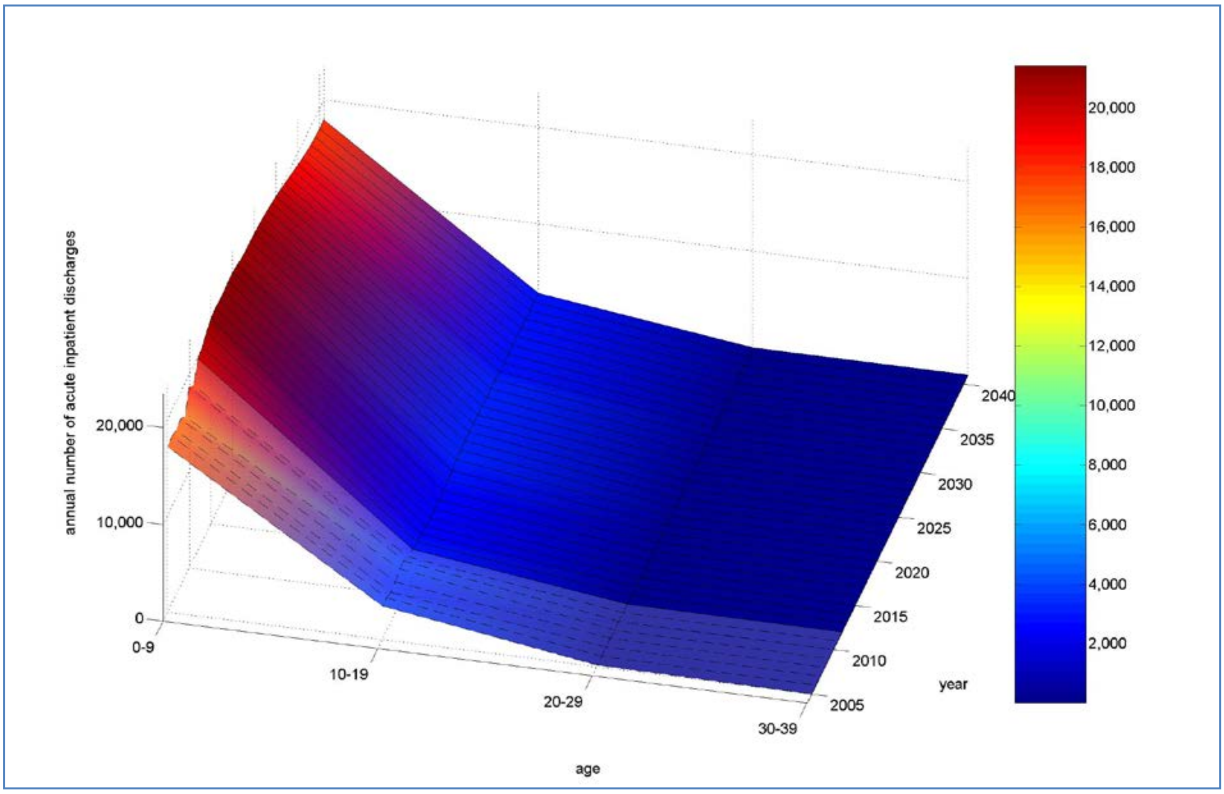

Figure 4.51 Projected age-sex specific number of HA day case discharges for Paediatrics – male (2005-2041)

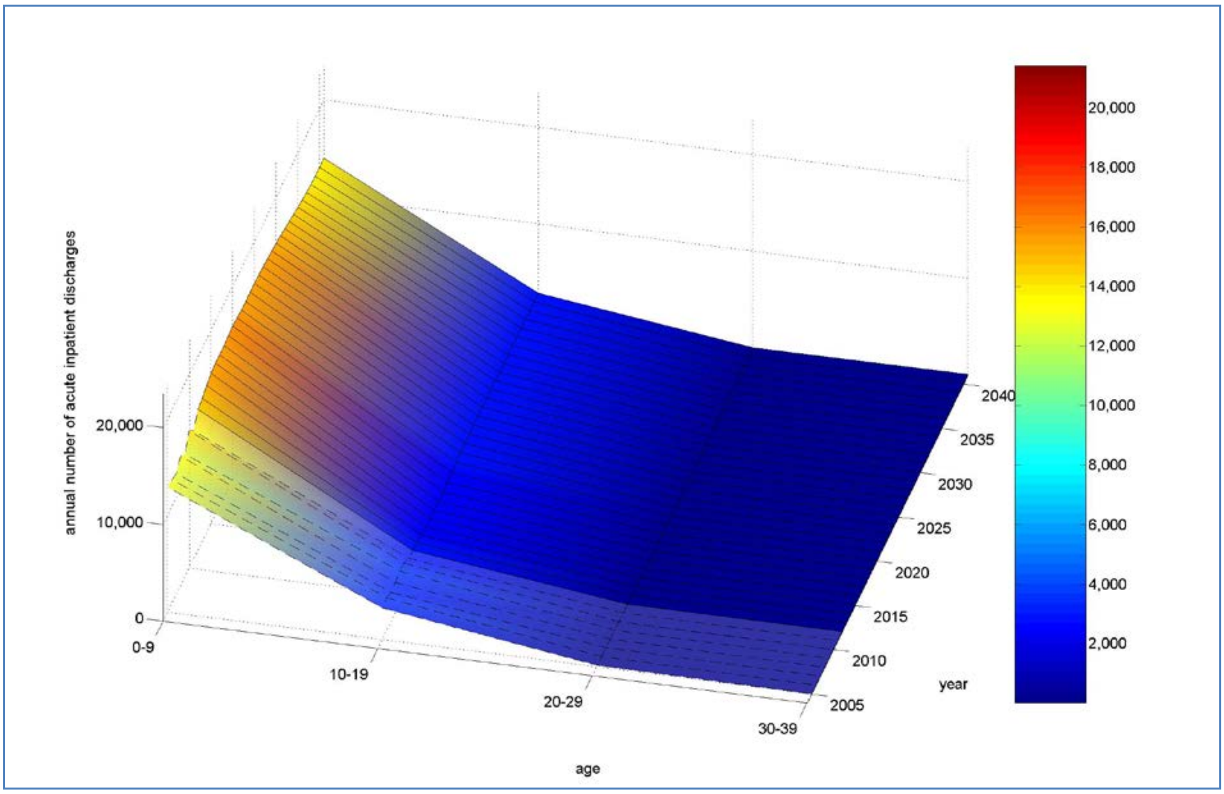

Figure 4.52 Historical and projected age-sex specific number of HA day case discharges for Paediatrics - female (2005-2041)

Acute inpatient bed-day (Paediatrics)

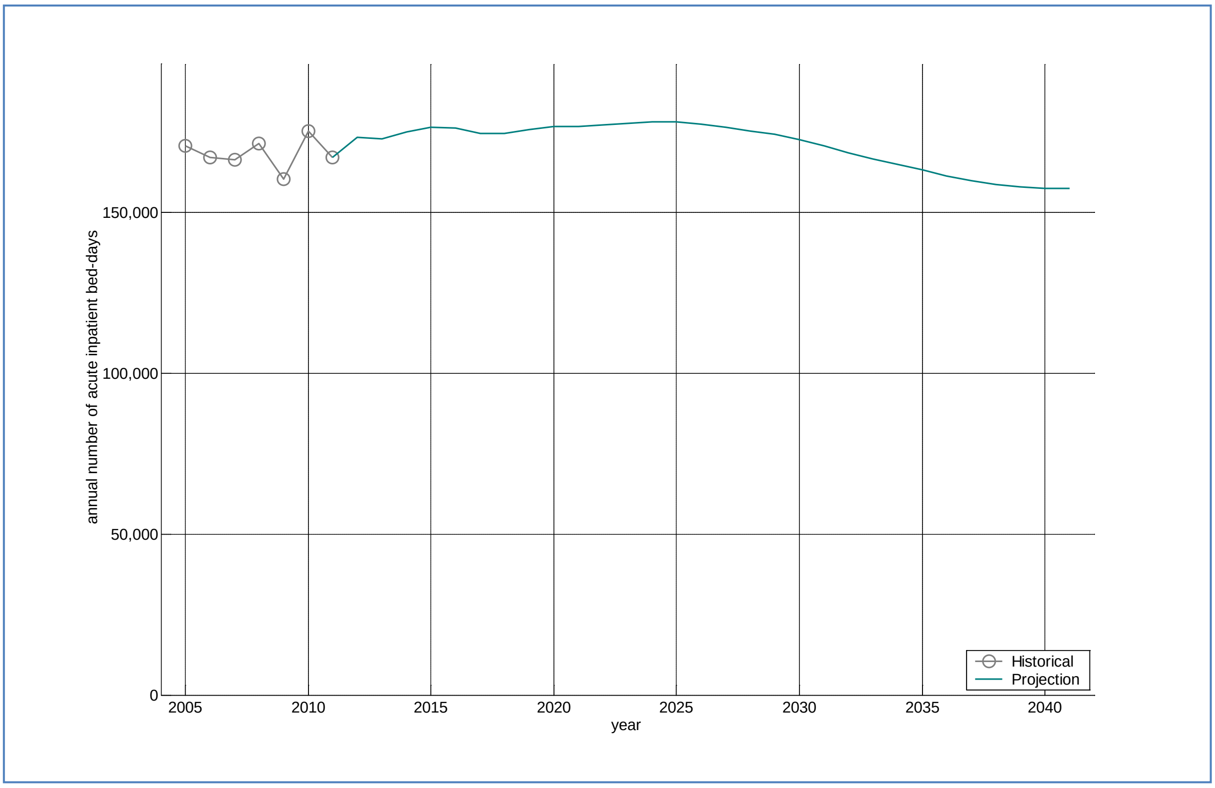

Figure 4.53 Historical and projected number of HA acute inpatient bed-days for Paediatrics (2005-2041)

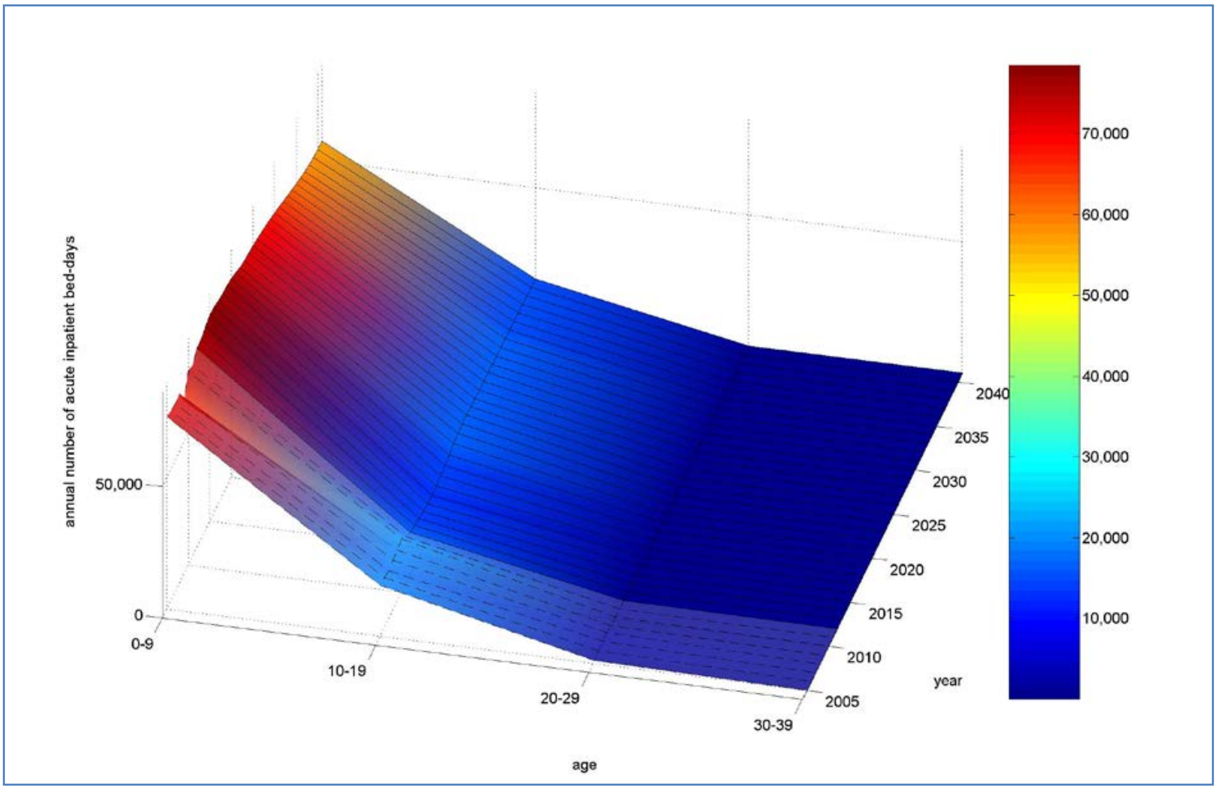

Figure 4.54 Projected age-sex specific number of acute inpatient bed-days for Paediatrics: Male

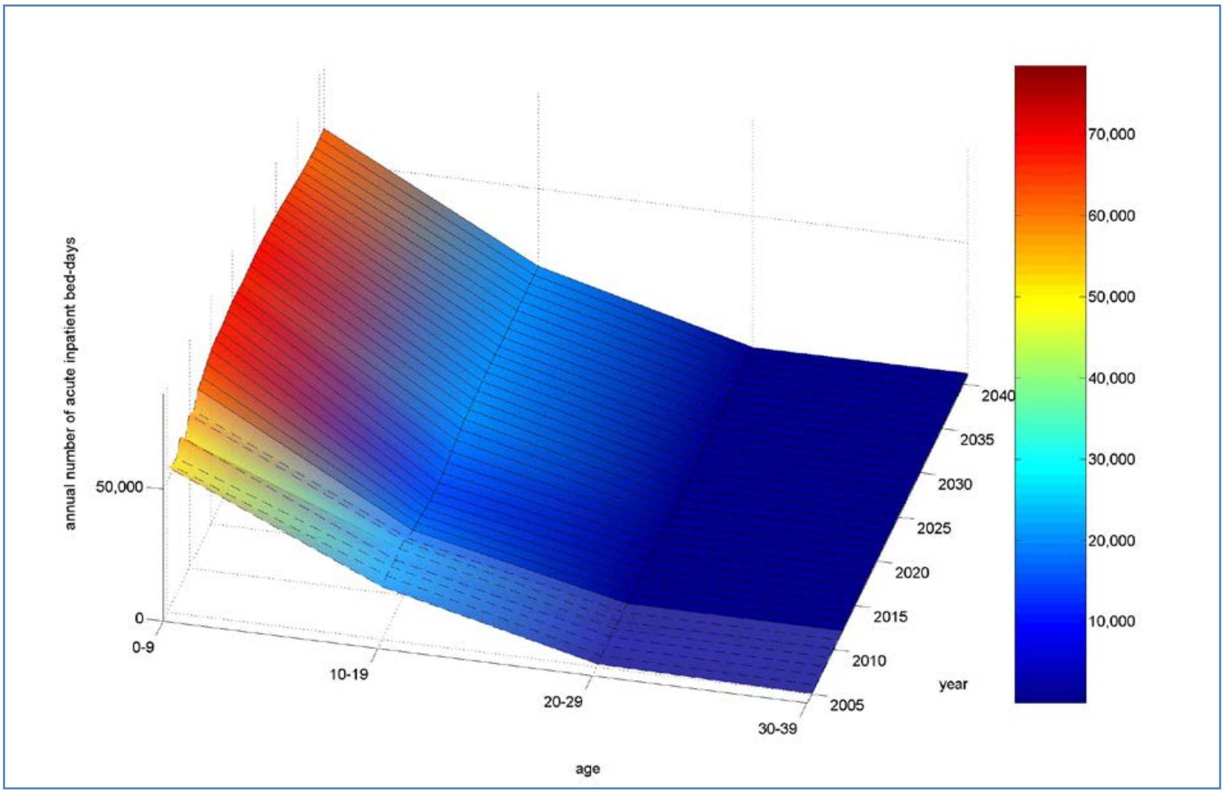

Figure 4.55 Historical and projected age-sex specific number of HA acute inpatient bed-days for Paediatrics – female (2005-2041)

Acute inpatient bed-day projection (Oncology)

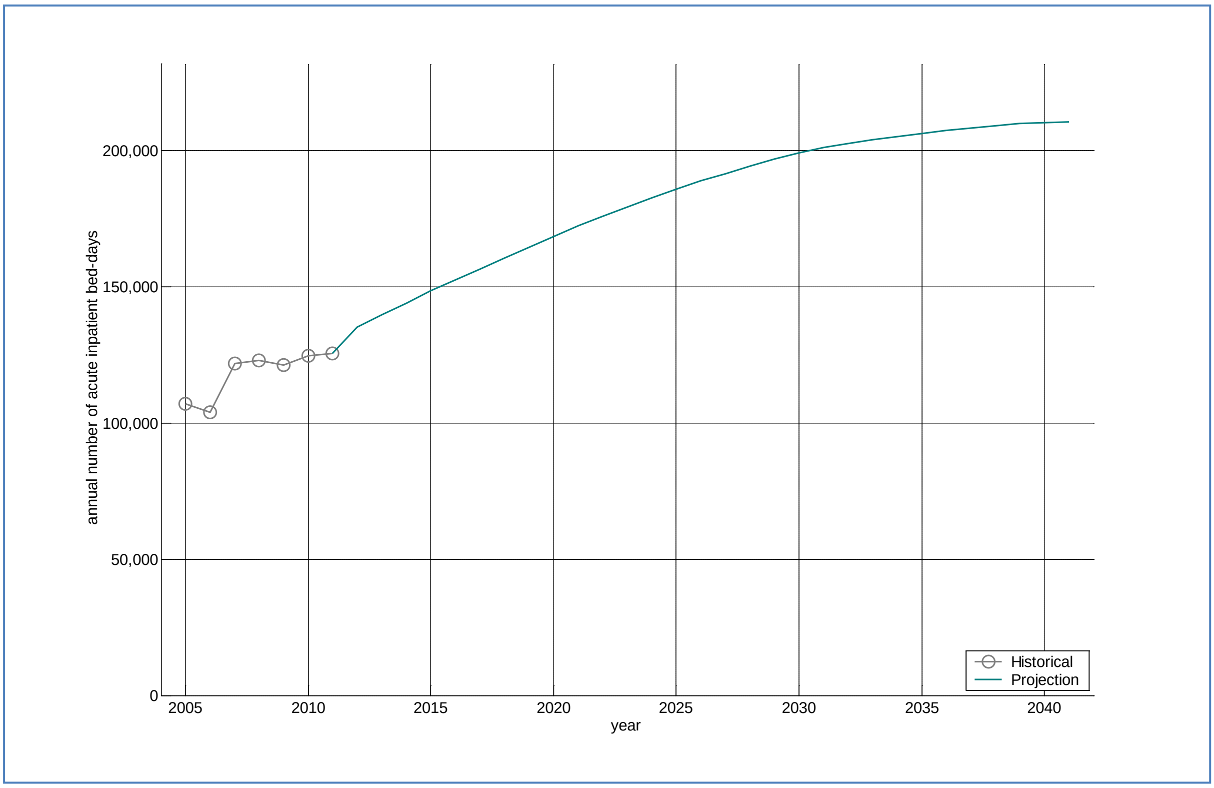

Figure 4.56 Historical and projected number of acute inpatient bed-days for Oncology (2005-2041)

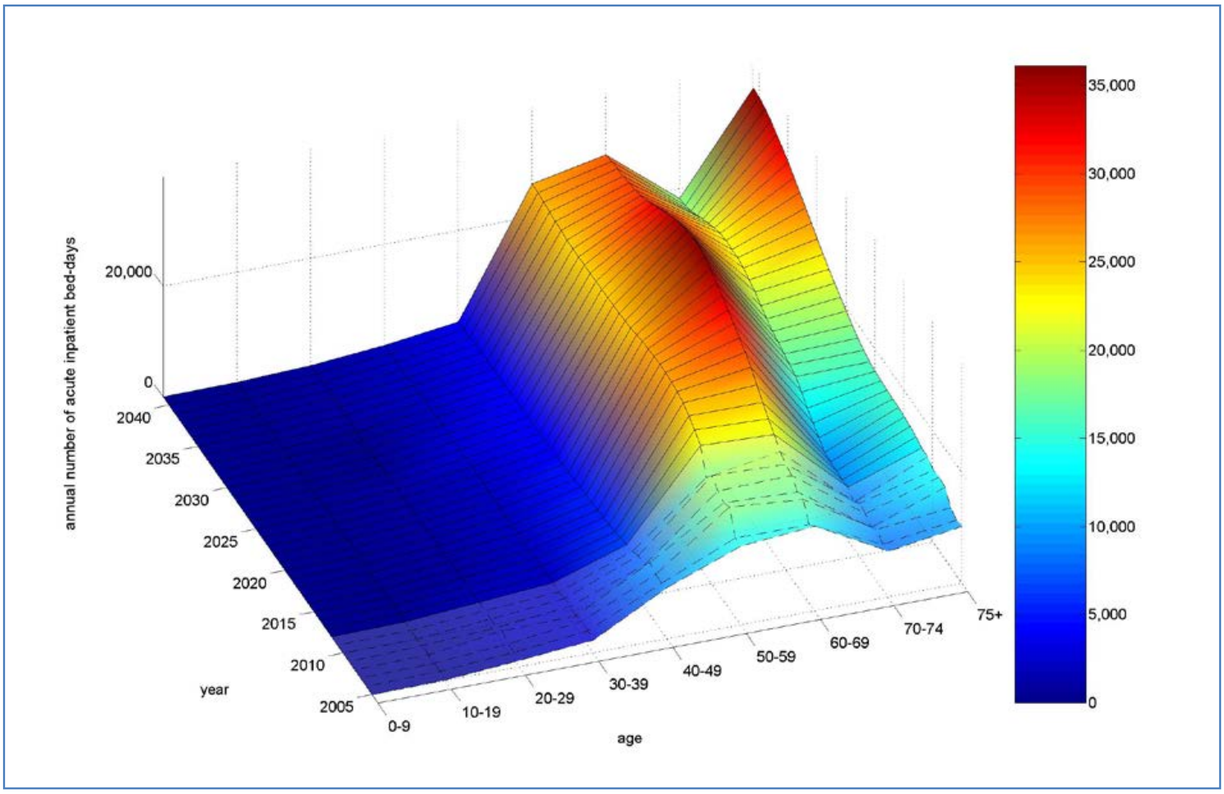

Figure 4.57 Historical and projected age-sex specific number of acute inpatient bed-days for Oncology - male (2005-2041)

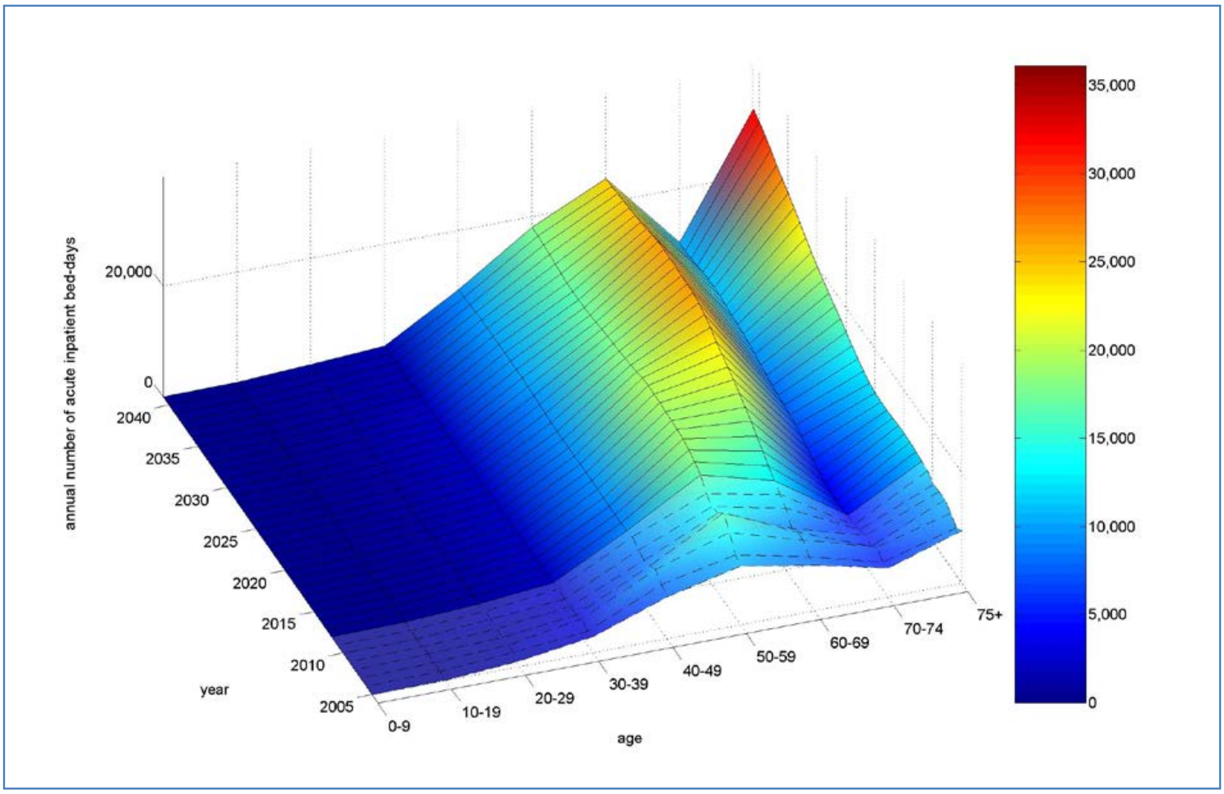

Figure 4.58 Historical and projected age-sex specific number of acute inpatient bed-days for Oncology: -female (2005-2041)

The total number of aseptic items dispensed and the number of category 3 aseptic items dispensed per case are projected to increase rapidly due to a change in the subvention for this service in 2012-2013 (Figure 4.59 and 4.60).

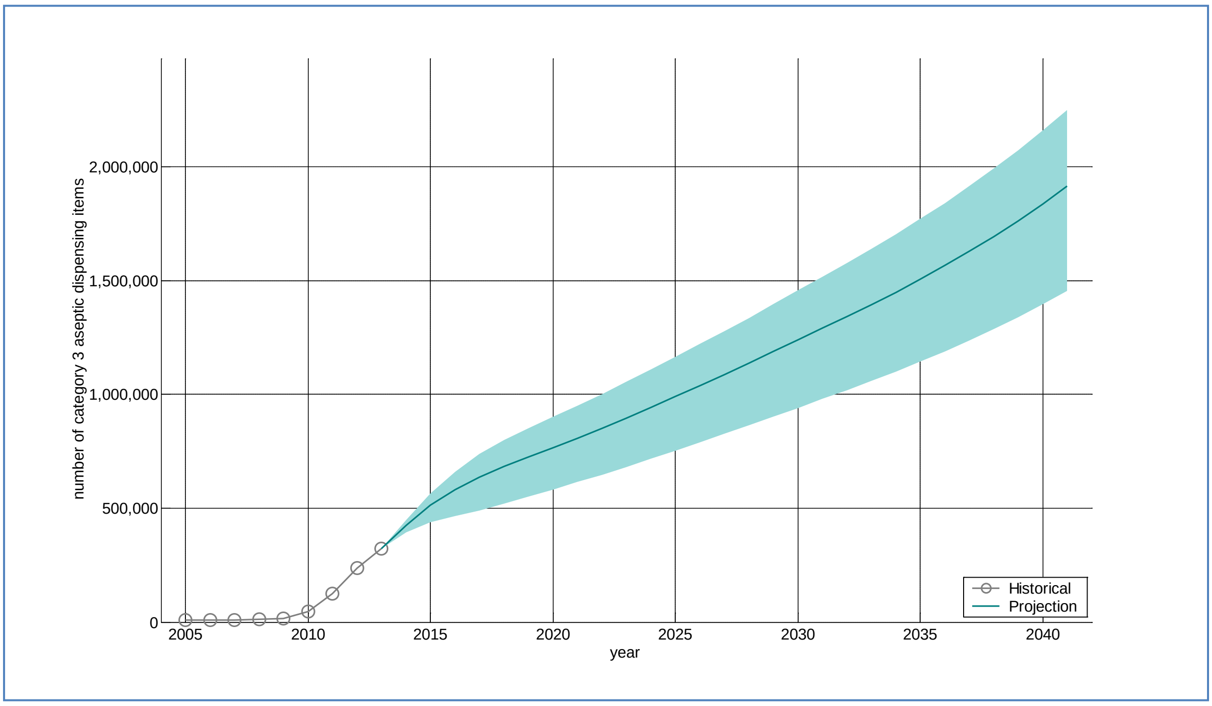

Figure 4.59 Historical and projected number of Category 3 aseptic items dispensed

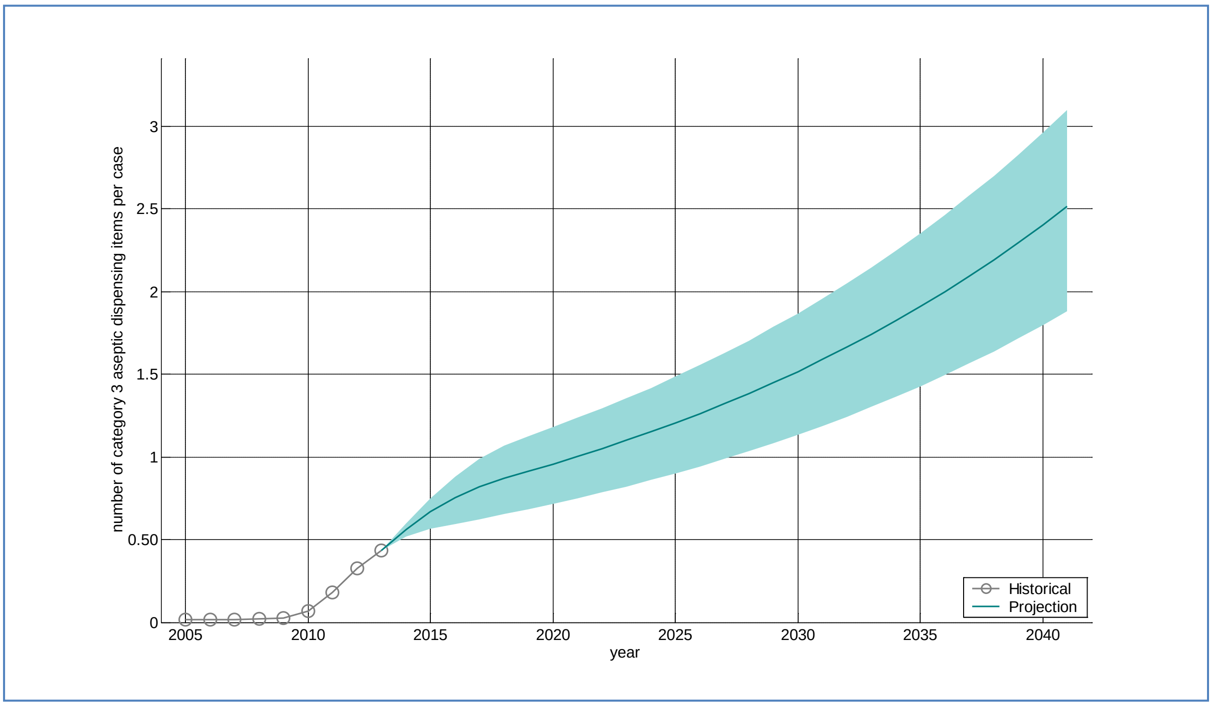

Figure 4.60 Historical and projected number of Category 3 aseptic items dispensed per case

The number of C1, C2, and C3 aseptic items dispensed in HA are projected to increase rapidly throughout the projection period (Figure 4.61). The projected number of FTE pharmacists for the aseptic dispensing service increases accordingly (Figure 4.62)

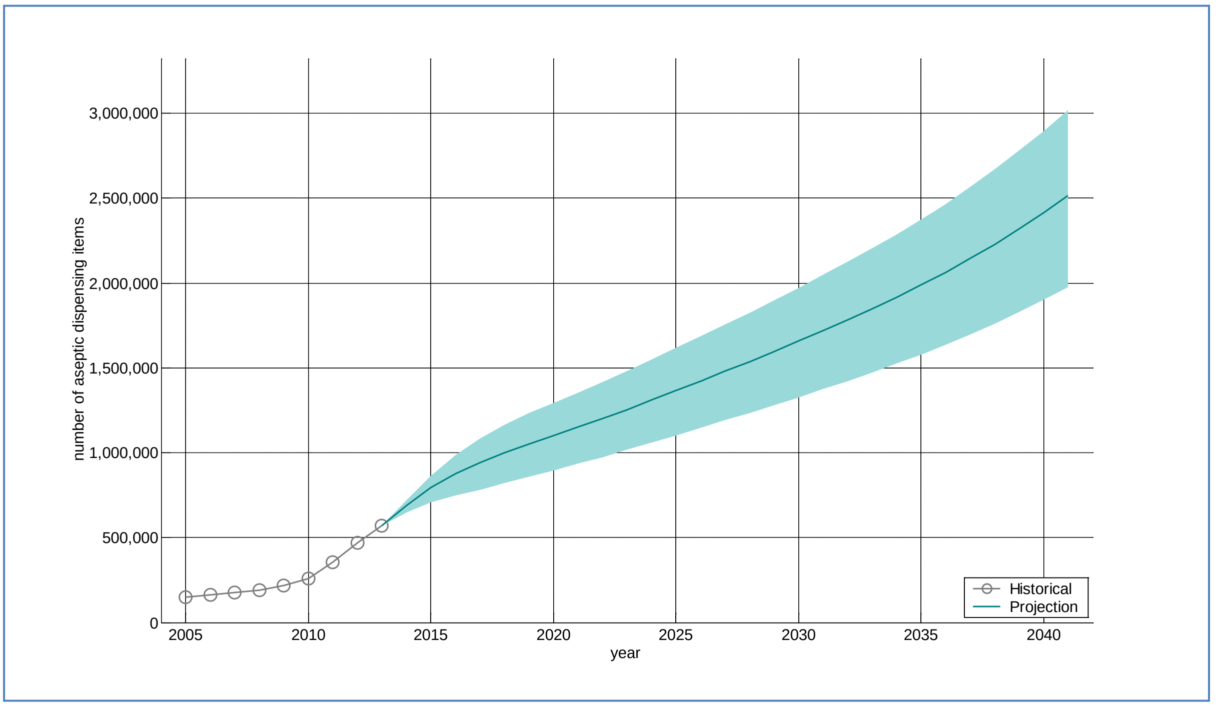

Figure 4.61 Historical and projected number of C1, C2 and C2 aseptic items dispensed

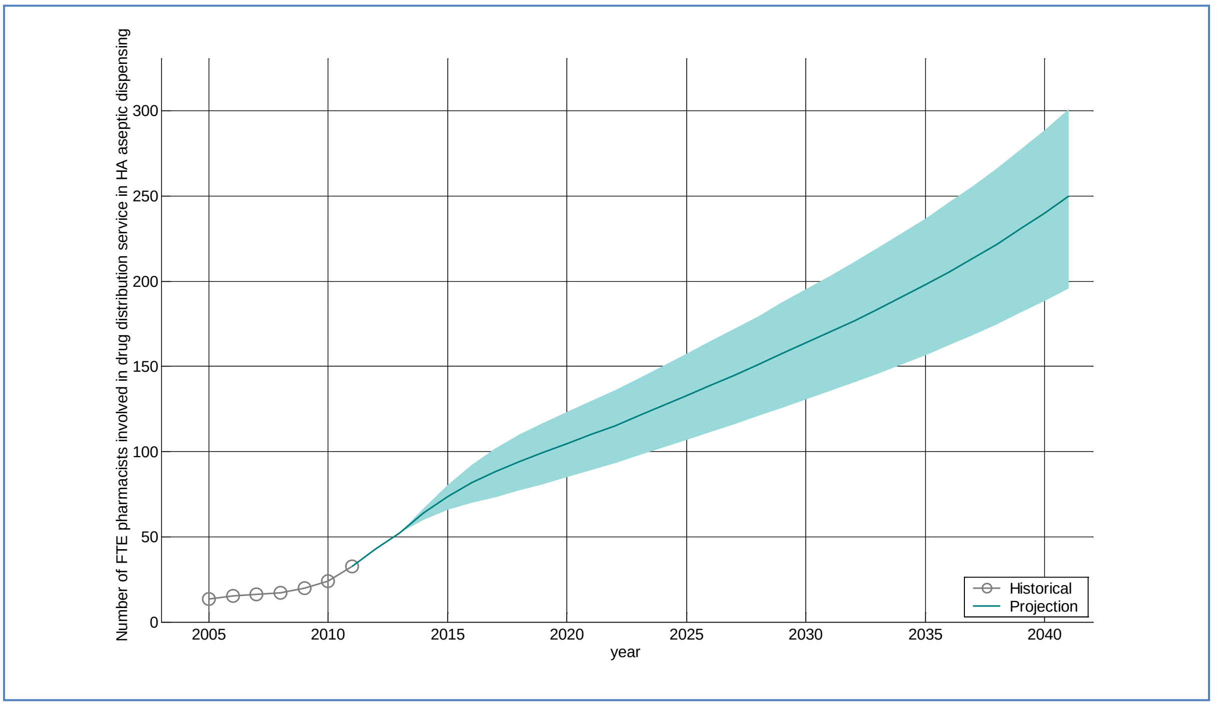

Figure 4.62 Historical and projected number of HA aseptic dispensing service FTE pharmacists

4.3.2.5 *Other professional services – public sector*

Pharmacists provide other services such as direct patient care clinical and other professional services. The proportion of pharmacists (approximately 64%) involved in the drug distribution service in 2013 is assumed to remain steady throughout the projection period. The pharmacist demand in the public sector pharmacy service is expressed as:-

$$\begin{aligned} &Number\ of\ FTE\ pharmacists\ in\ HA\ (F_{HA}) \\ &\quad = \left(F_{GODS}^{HA} + F_{HODS}^{HA} + F_{IP}^{HA} + F_{Aseptic}^{HA}\right) \\ &\quad \times\ scaling\ factor\ \ for\ other\ pharmacist\ service\ p\ (\beta) \end{aligned}$$

where β is assigned as 1/0.64 = 1.5625. The historical and projected number of FTE pharmacists in the HA is shown in Figure 4.63.

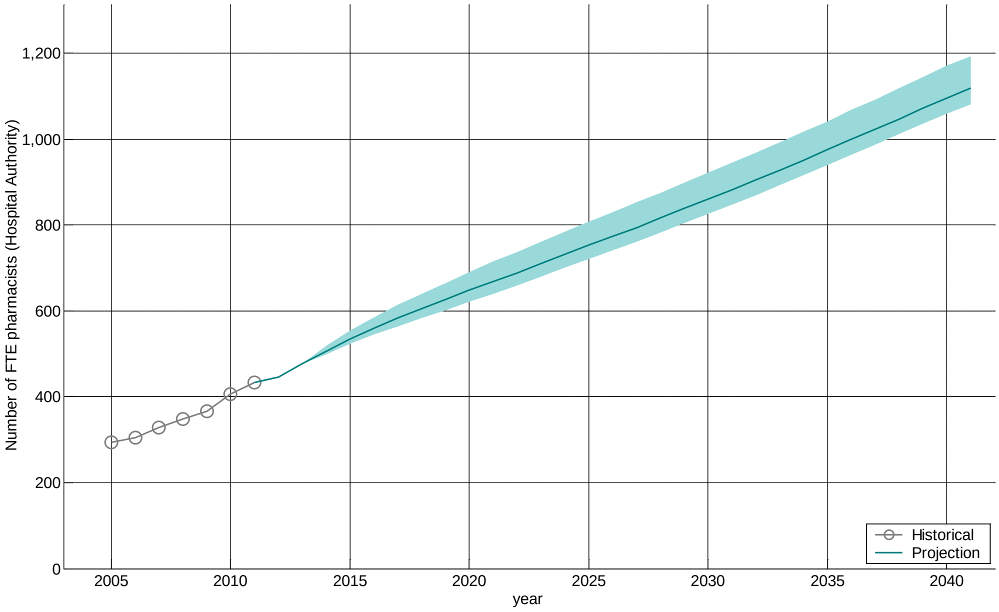

Figure 4.63 Historical and projected number of HA FTE pharmacists

4.3.3 Public sector – Department of Health

DH pharmacists mainly work in the Drug Office and the Chinese Medicine Division. The Drug Office (DO) pharmaceutical service utilisation volume trends are not significantly associated with the DO pharmacist manpower and are not used for the DO pharmacist demand projection. As the DO opines that the existing number of pharmacists is sufficient to handle service growth in the its areas of responsibility the pharmacist demand projection for the Drug Office holds the existing FTE level constant throughout the projection period (Figure 4.64).

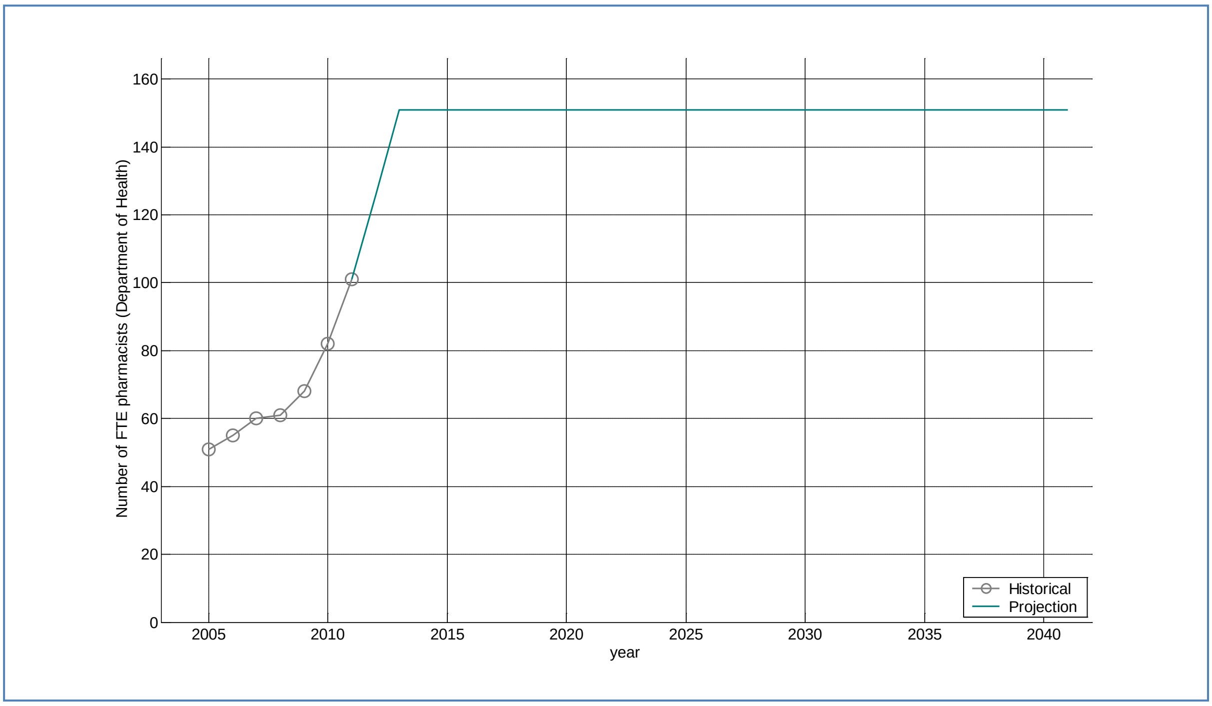

Figure 4.64 Historical and projected number of pharmacists in Department of Health

4.3.4 Private sector

Similar methods are used for the private sector inpatient pharmacist FTE conversion as follows:-

$$Number\ of\ FTE\ pharmacists\ in\ private\ inpatient\ pharmacy\ \left(F_{IP}^{private}\right) =$$
$$= Number\ of\ bed\text{-}days$$
$$\times\ Number\ of\ FTE\ pharmacists\ per\ private\ hospital\ bed\text{-}day\ \ (\beta_{bedday})$$

As only two years of private hospital discharge records are available (2007 and 2009) a constant trend in prescriptions per pharmacist is assumed.

The private hospital-based outpatient pharmacist FTE demand is expressed as a linear proportion of the number of prescriptions handled in the outpatient pharmacy assuming one prescription per outpatient visit and that the workload of a private hospital-based outpatient visit equals that of a public sector GOPC visit as follows and shown in Figure 4.65:-

$$Number\ of\ FTE\ pharmacists\ in\ private\ hospital\ outpatient\ setting\ (F_{OP})$$
$$= Number\ of\ private\ hospital\text{-}based\ outpatient\ visits\ (v_{OP})$$
$$\times\ Number\ of\ FTE\ pharmacists\ per\ private\ hospital\text{-}based\ outpatient\ visit\ (\alpha_{OP})$$

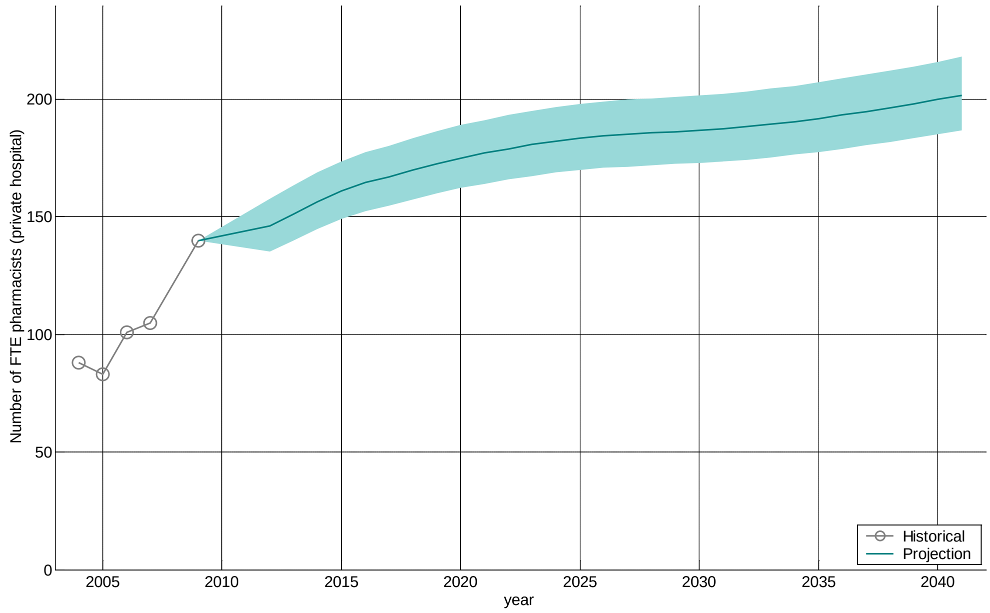

Figure 4.65 Historical and projected number of FTE pharmacists in private hospital

4.3.5 Pharmaceutical industry

The *pharmaceutical industry* refers to pharmaceutical manufacturers and pharmaceutical companies comprising importers and exporters, and wholesalers. The projection of pharmacist demand in the pharmaceutical industry is utilisation-based:-

$$Number\ of\ FTE\ pharmacists\ in\ pharmaceutical\ industry\ (F_{industry}) =$$
$$= Utilisation\ volume\ of\ pharmaceutical\ industry\ (V_{industry})$$
$$\times\ Number\ of\ FTE\ pharmacists\ per\ volume\ \ (\alpha_{industry})$$

4.3.5.1 Pharmaceutical manufacturing

The number of pharmacists in the pharmaceutical manufacturing sector changes coherently with the number of pharmaceutical manufacturers but is insensitive to the manufacturers gross output, domestic export or re-export of pharmaceutical products[8] (Figure 4.66)

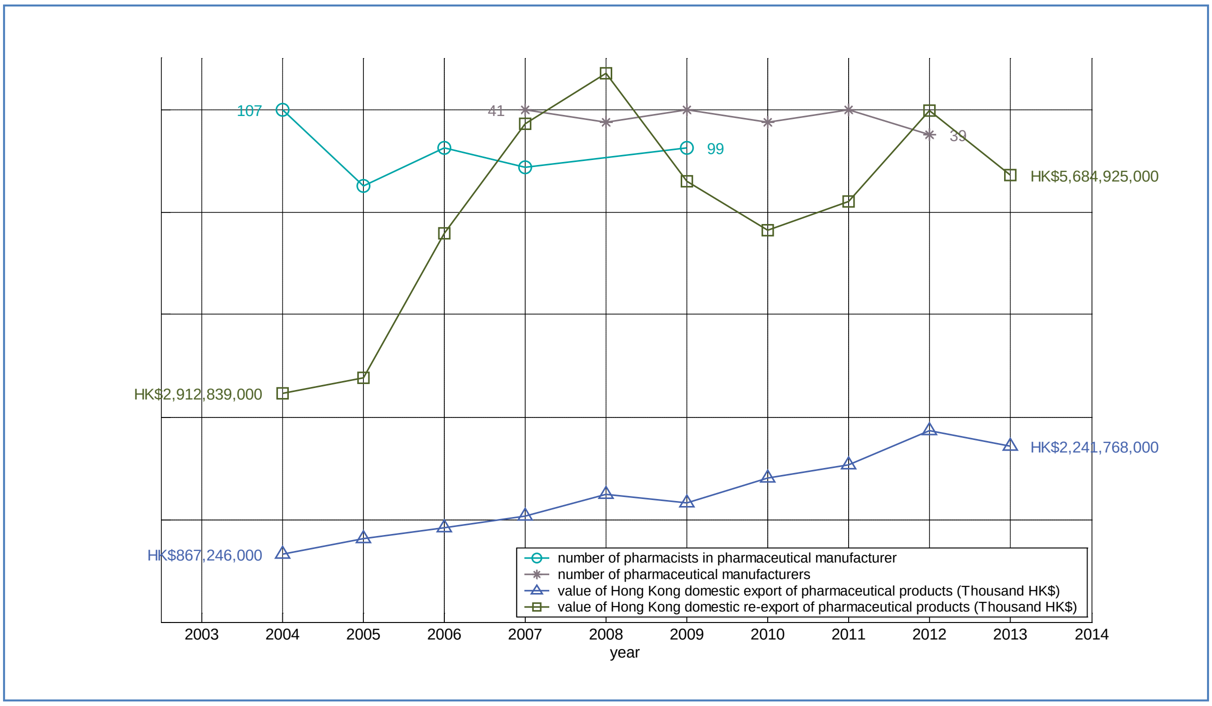

Figure 4.66 Comparison of the number of pharmacists in the pharmaceutical manufacturing sector, the number of pharmaceutical manufacturers, and the value of the Hong Kong domestic export and re-export of pharmaceutical products in thousand HK dollars.

Though quality control is a critical component for every manufacturing process, the number of pharmacists needed to maintain a product line is weakly proportional to the productivity of the pharmaceutical manufacturer unless the size of the product line physically expands. Therefore, pharmacist workload (i.e. pharmacist utilisation) is manufacturer-based rather than productivity-based.

The pharmacist demand by pharmaceutical manufacturer is proxied by the number of pharmaceutical manufacturers as:-

[8] The gross output of pharmaceutical products is proxied as the value of Hong Kong domestic export of pharmaceutical products reported in *Hong Kong Merchandise Trade Statistics – Domestic Exports and Re-exports*. The pharmaceutical product includes the Standard International Trade Classification, Revision 4 (SITC, Revision4) item number 541.12 – 541.62, 541.91, 542.23 – 542.29, and 542.32 – 542.93.

$$Number\ of\ FTE\ pharmacists\ in\ pharmaceutical\ manufacturer\ (F_{manufacturer})$$
$$= Number\ of\ pharmecutical\ manufacturers\ (U_{manufacturer})$$
$$\times\ Number\ of\ FTE\ pharmacists\ per\ pharmecutical\ manufacturer\ (\alpha_{manufacturer})$$

A time series analysis is used to project the number of pharmaceutical manufacturers (Figure 4.67)

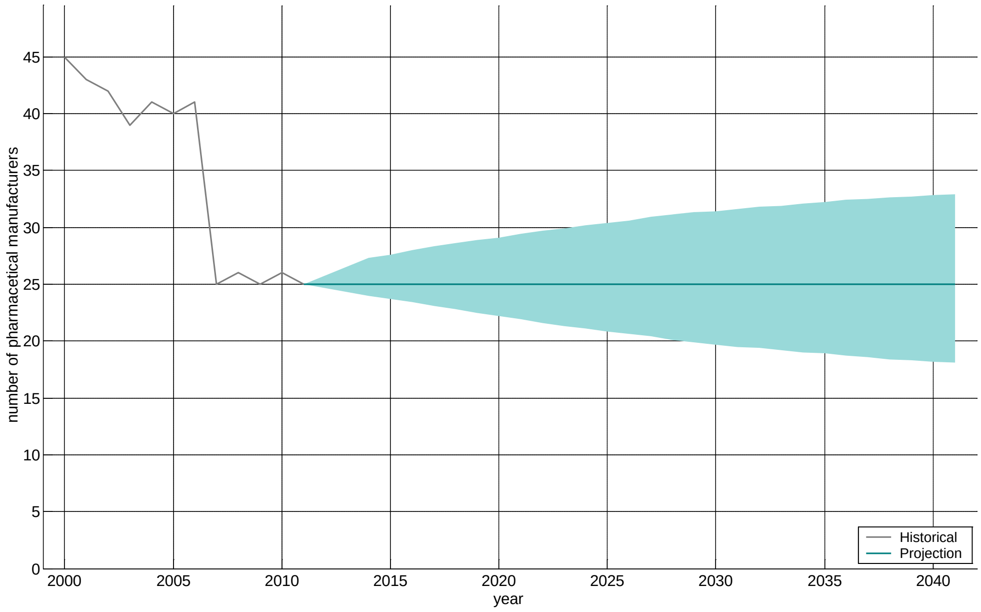

Figure 4.67 Historical and projected number of pharmaceutical manufacturers

The number of FTE pharmacists per pharmaceutical manufacturer $\alpha_{manufacturer}$ is estimated from historical data. The number of pharmacists employed per company as estimated from the Hong Kong Association of Pharmaceutical Industry (HKAPI) survey are adopted as the upper boundary of the projected $\alpha_{manufacturer}$. The historical and projected number of FTE pharmacists in the pharmaceutical manufacturing is shown in Figure 4.68.

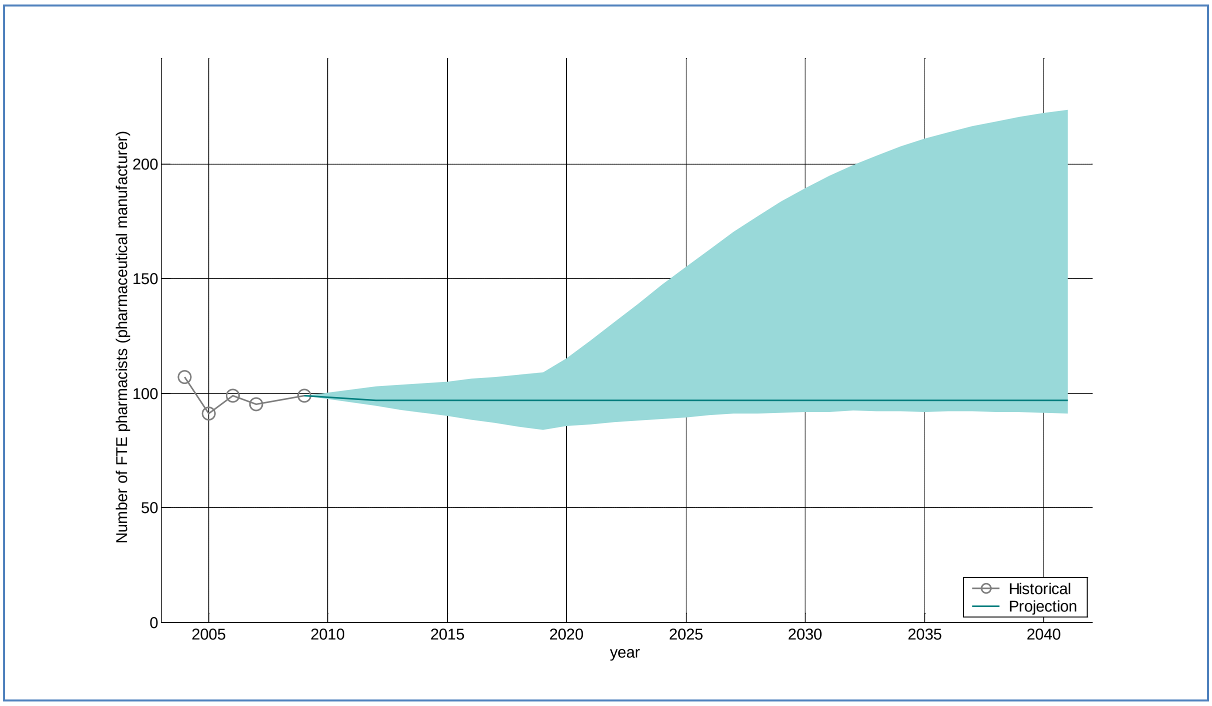

Figure 4.68 Projected number of FTE pharmacists in pharmaceutical manufacturing

4.3.5.2 Pharmaceutical company

The demand for pharmacists in pharmaceutical companies is proxied by the number of wholesale dealers licences to supply dangerous drugs. The number of pharmacists in pharmaceutical companies is expressed as:-

$$Number\ of\ FTE\ pharmacists\ in\ pharmaceutical\ companies\ \left(F_{company}\right) =$$
$$= Number\ of\ wholesale\ dealers\ licences\ to\ supply\ dangerous\ drug\ (n_{DD})$$
$$\times\ Number\ of\ FTE\ pharmacists\ per\ wholesale\ dealers\ licences\ to\ supply\ dangerous\ drug\ (\alpha_D)$$

The number of pharmacists per wholesale dealers licences to supply dangerous drugs is projected by time series analysis (Figure 4.69). Figure 4.70 shows the projected number of pharmacists per wholesale dealer’s licence supply dangerous drugs and Figure 4.71 the projected number of pharmacists for pharmaceutical companies.

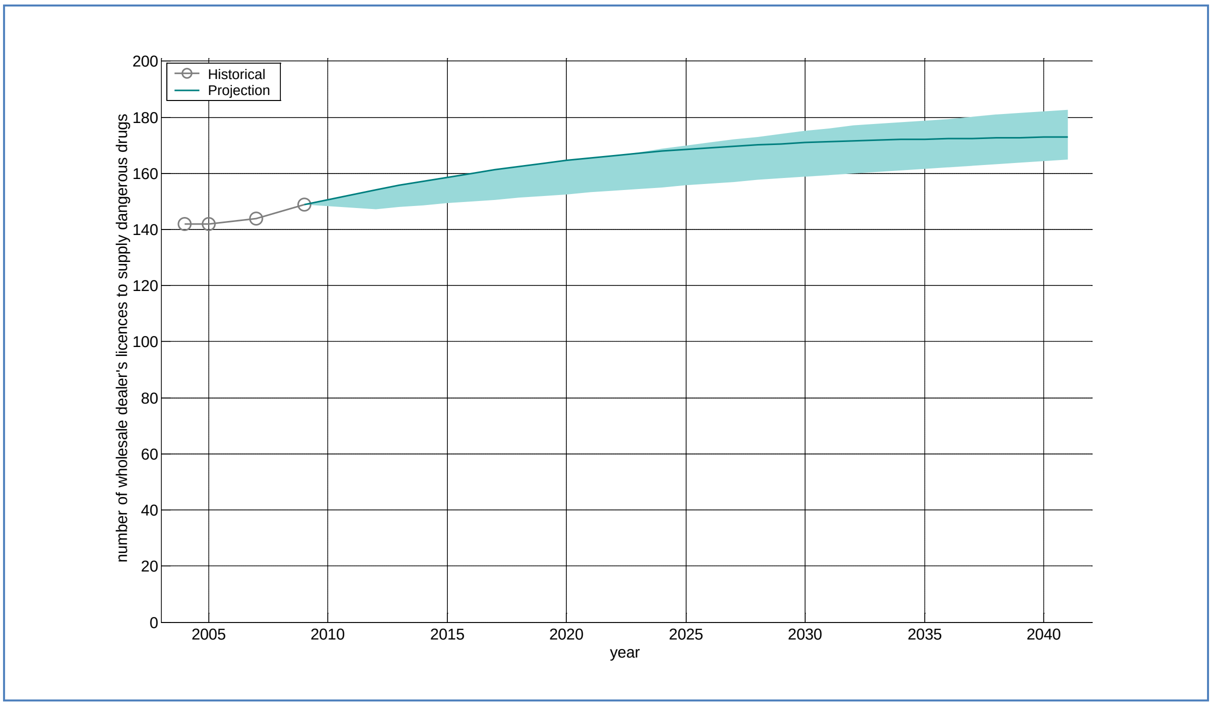

Figure 4.69 Historical and projected number of wholesale dealer's licence to supply dangerous drugs

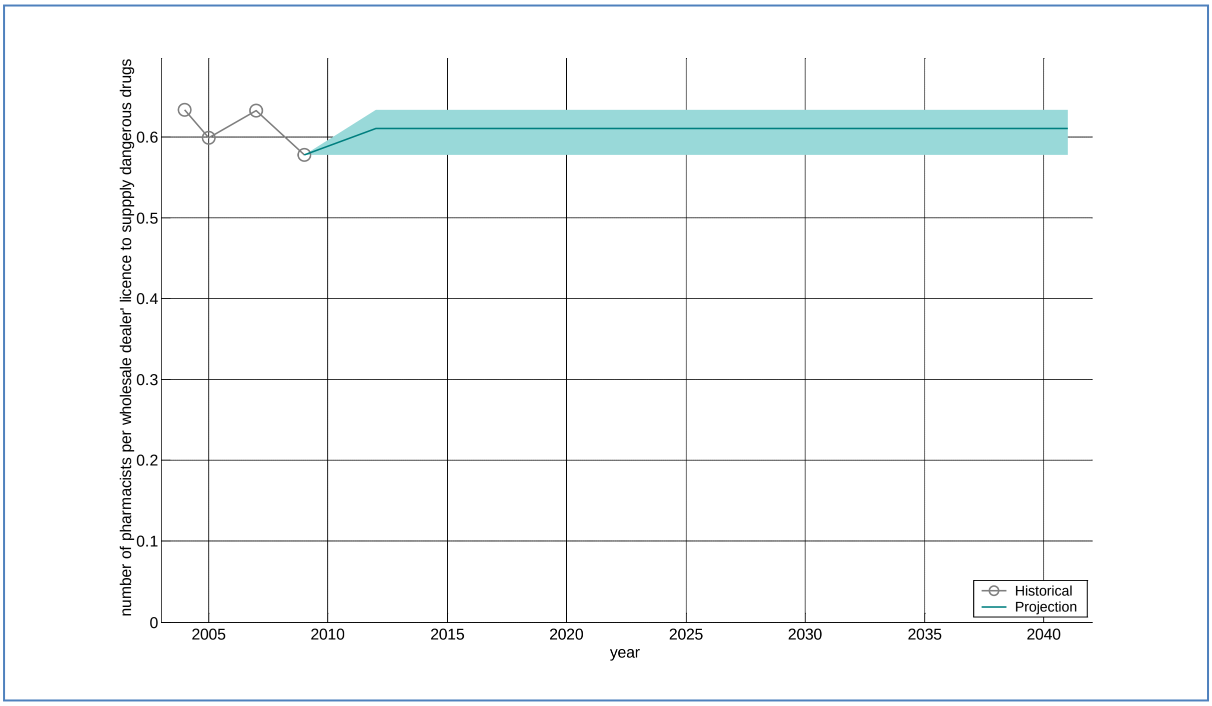

Figure 4.70 Historical and projected number of pharmacists per wholesale dealer's licence to supply dangerous drugs

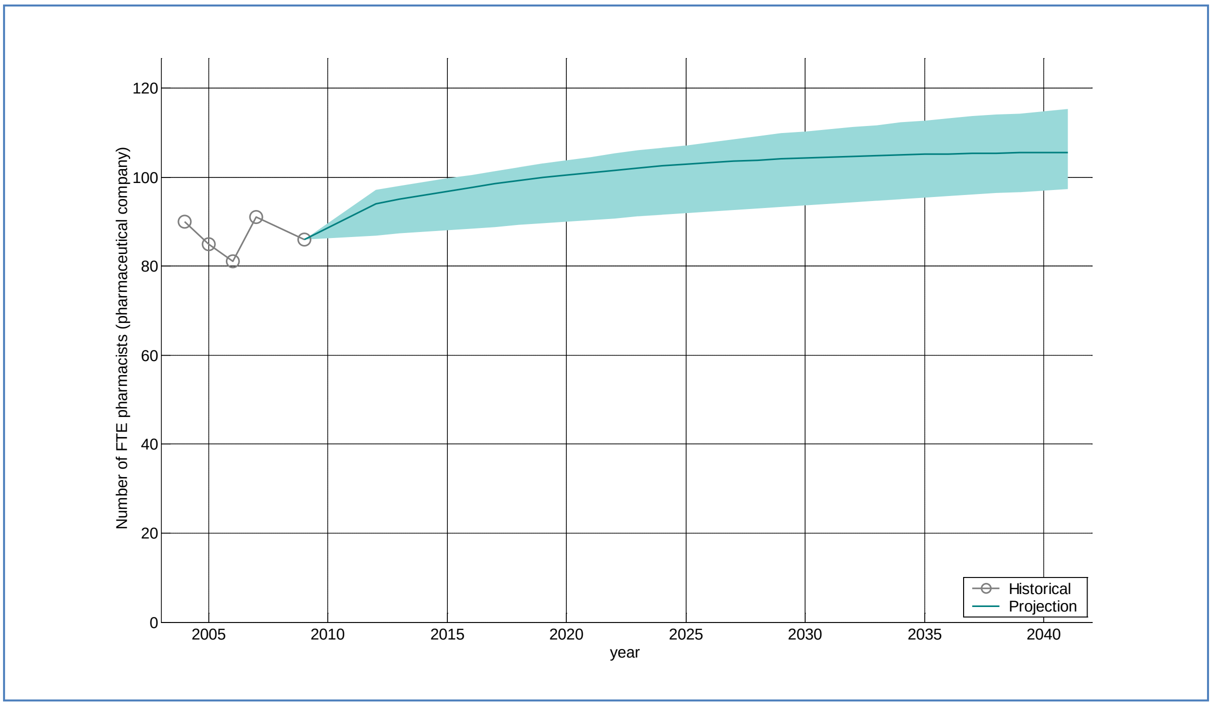

Figure 4.71 Historical and projected number of FTE pharmacists in pharmaceutical company

4.3.6 Academic sector

For the academic sector, the demand for pharmacists is linearly proportional to the number of pharmacy students:

$$Numberof\ FTE\ pharmacists\ in\ academic\ sector\ (F_{academic}) = Numberof\ pharmacy\ students\ \times\ \alpha_{academic}$$

where $\alpha_{academic}$ (0.2145) is the FTE pharmacists per pharmacy student.

The projected number of pharmacists is shown in Figure 4.72. The historical data is backward projected from historical number of pharmacy students and the $\alpha_{academic}$ calibrated for 2013 data.

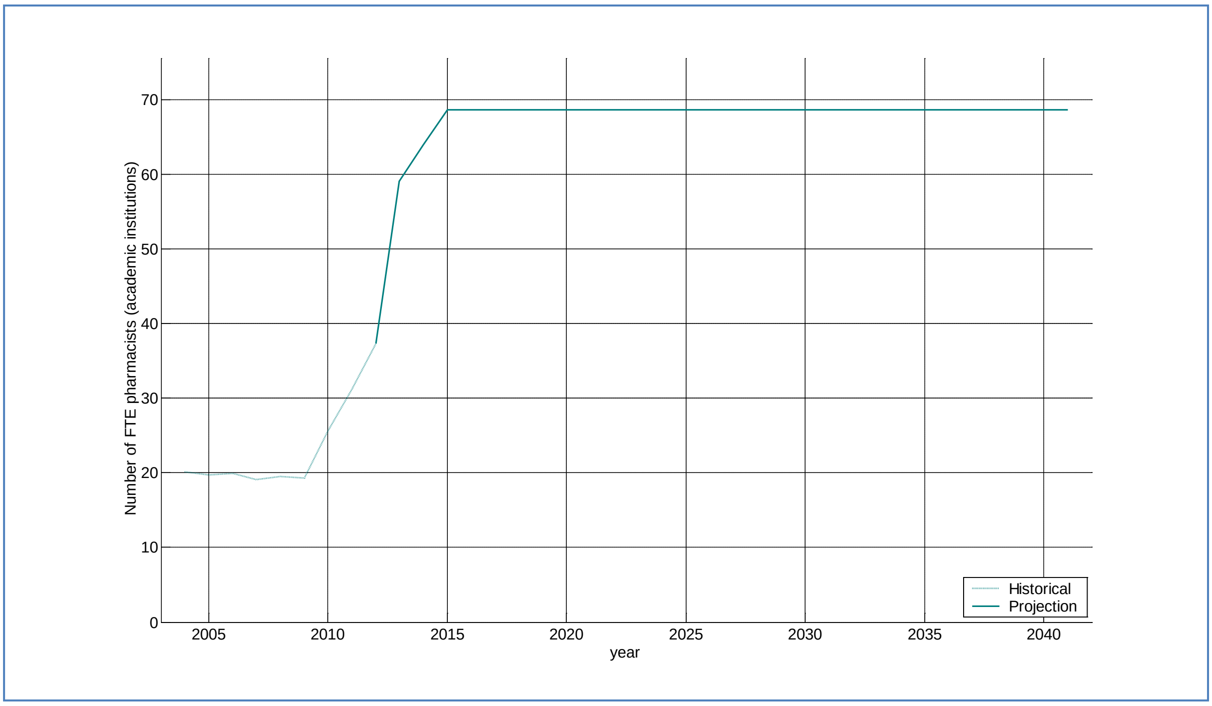

Figure 4.72 Historical and projected number of FTE pharmacists in academic sector.

5 Projecting pharmacist supply

The Pharmacy & Poisons Board Of Hong Kong (PPBHK) (155) pharmacist data (age-, sex-specific) for 2012 is used for the pharmacist supply base case. Data (for past and projected number of pharmacist graduates) from the Chinese University of Hong Kong (CUHK) and the University of Hong Kong (HKU), the PPBHK and from the DH Healthcare Manpower Survey (HMS) on Pharmacist 2004-2007 & 2009 (156-160) are used for the supply projections.

5.1 Models for pharmacist supply

The overall pharmacist supply model is a non-homogenous Markov Chain Model, where workforce systems are represented as "stocks and flow's" (Figure 5.1). Flow refers to manpower supply over a period of time. Stock denotes manpower supply at a particular point in time.

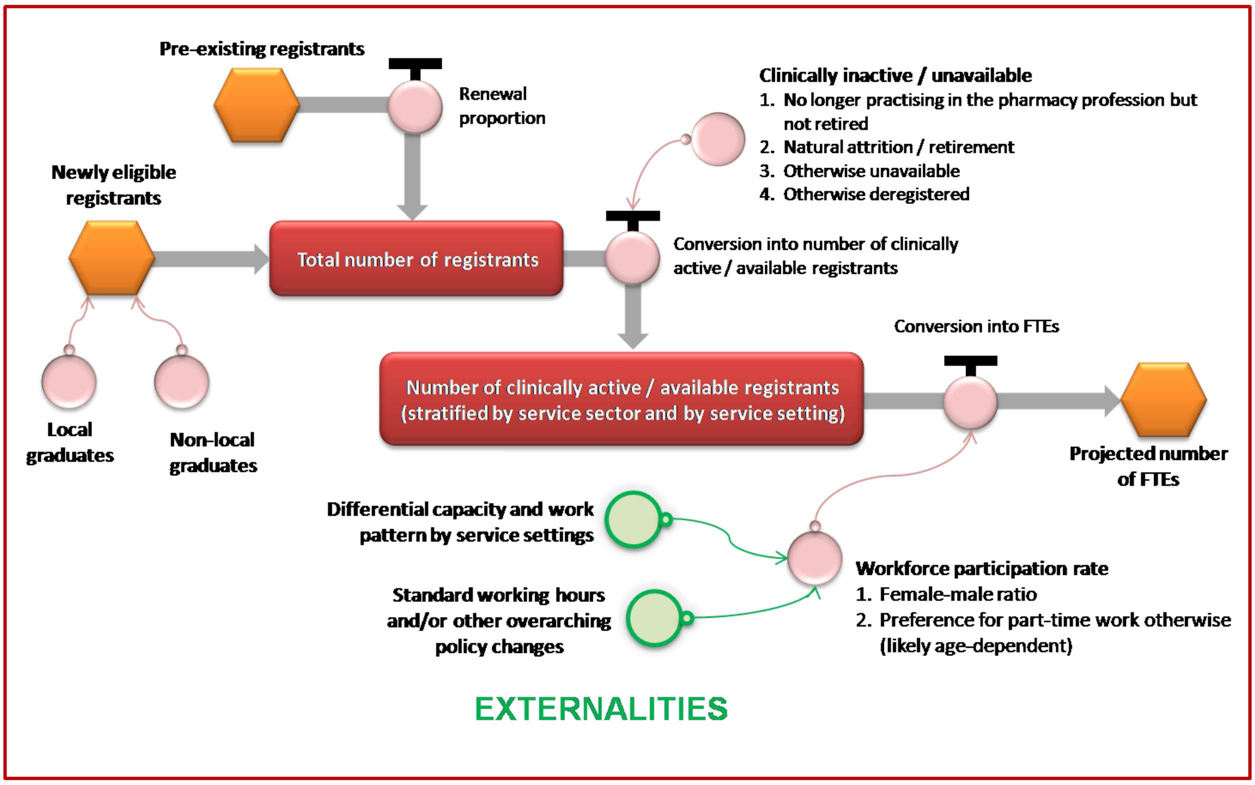

Figure 5.1Pharmacist supply model for Hong Kong.

There are five age-, sex-specific stocks by year (a,s,y) in the model:

n_{pre} number of pre-existing registrants

n_{local} number of local graduates

$n_{non\text{-}local}$ number of non-local graduates

$n_{current}$ number of current registrants

n_{active} number of active and available registrants

Flow in the supply model represents change in the stocks and is projected by determining the number of

a) current registrants (total number of local graduates, non-local graduates and pre-existing registrants):

$$n_{current}(a,s,y) = p_{renewal}(y) \times n_{pre}(a,s,y) + n_{local}(a,s,y) + n_{non\text{-}local}(a,s,y)$$

where $p_{renewal}(y)$ is the licence renewal proportion at year *y*.

b) active and available registrants:

$$n_{active}(a,s,y) = n_{current}(a,s,y) \times p_{active}(a,s,y)$$

where $p_{active}(a,s,y)$ is the active proportion.

FTEs by service sector *c* at year *y* are calculated as:

$$\text{FTE}(y,c) = \frac{\sum_a \sum_s n_{active}(a,s,y) \times p_{sector}(a,s,y,c) \times h(a,s,y,c)}{\text{Median working hours per week per FTE}}$$

where $p_{sector}(a,s,y,c)$ is the proportion of pharmacists working in the service sector *c* at year *y*, and $h(a,s,y,c)$ is the average number of working hours per pharmacist.

The supply projection is based on the stocks and also the parameters $p_{renewal}(y)$, $p_{active}(a,s,y)$, $p_{sector}(a,s,y,c)$ and $h(a,s,y,c)$. The average is used to project the parameters.

5.2 Determinants of supply: projecting stock and flow

5.2.1 Total number of registrants

The total number of registrants is defined as the number of pre-existing registrants (pool of pharmacists multiplied by the registration renewal proportion [99.4%; as provided by the PPBHK]) and the newly eligible registrants entering the pool by year (local graduates from the CUHK and HKU; non-local graduates from PPBHK) (Table 5.1).

The number of non-local graduates are projected using a sigmoid function based on the number of new non-local graduate registrations provided by the PPBHK. The number of new registrants (local and non-local) entering the system are held constant at 142 from 2019 – 2041.

Table 5.1 Projected number of graduates for 2013-2019 (Source: CUHK, HKU & PPBHK)

Institution	Projected Graduates						
	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
CUHK	30	31	68	56	52	52	52
HKU	24	19	33	25	32	30	30
PPBHK (non-local)	60	60	60	60	60	60	60

5.2.2 Number clinically active

The number of clinically active/available registrants is more relevant for workforce projection than the total number of registrants in the pharmacist pool. The supply model stratifies clinically inactive/unavailable pharmacists by age into four categories: no longer practicing in the pharmacy profession but not retired, natural attrition/retirement, otherwise unavailable, and otherwise deregistered. The five-year average proportion of clinically inactive/unavailable (based on the HMS on Pharmacist 2004-2007 & 2009) is applied to the projection and is adjusted to account for the variable response by age and sex in the HMS on Pharmacist.

5.2.2.1 No longer practising in the pharmacy profession but not retired

Based the HMS on Pharmacists data, the proportion of pharmacists (sex-stratified) ‘no longer practicing in the pharmacy profession but not retired’ (clinically trained, qualified and registered pharmacists who are no longer practising clinically) is projected to 2025 (Figure 5.2). The five-year average proportion is applied to the projection.

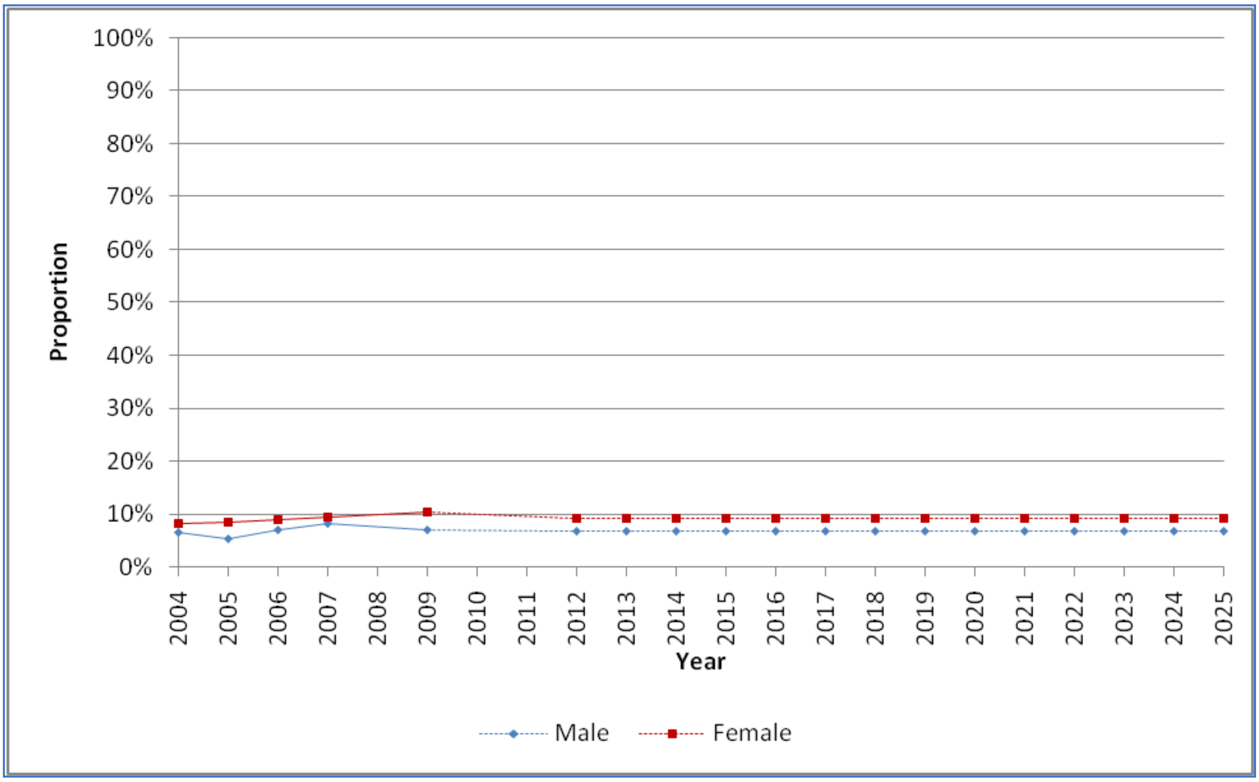

Figure 5.2 Proportion of pharmacists ‘no longer practising in the pharmacy profession but not retired’ by sex (2012-2025)

5.2.2.2 Natural attrition/retirement

The natural attrition/retirement projections for pharmacists are age- and sex-specific (Figure 5.3& 5.4). As expected, the projected retirement proportion increases by age, however, as the current population of pharmacists are young, the projection is based on small numbers.

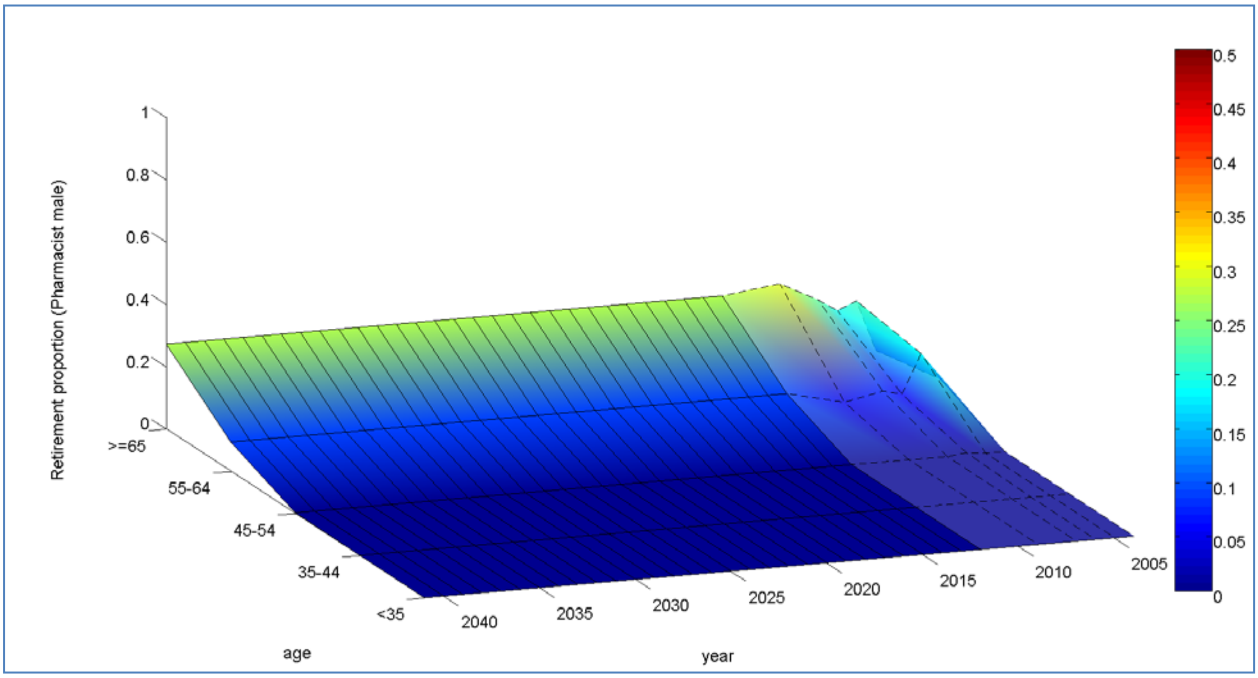

Figure 5.3 Proportion of pharmacists 'Natural attrition/retired' by age, male (2012-2025)

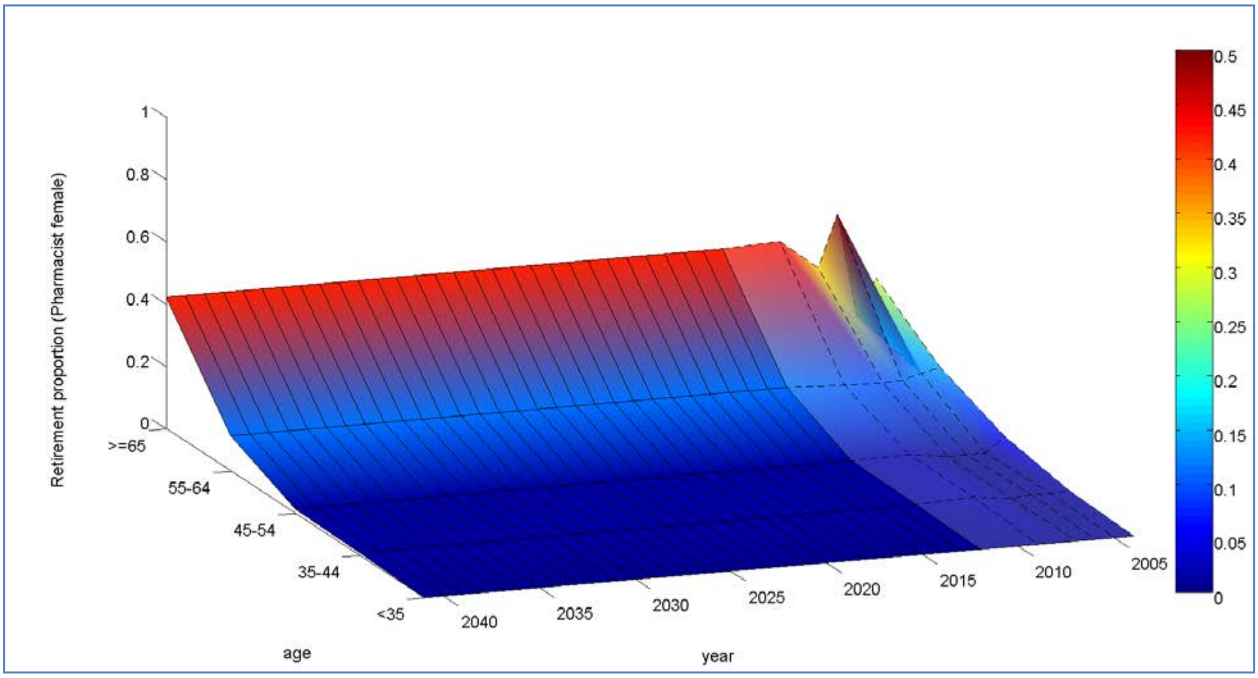

Figure 5.4 Proportion of pharmacists 'Natural attrition/retired' by age, female (2012-2025)

5.2.2.3 Otherwise unavailable

"Otherwise unavailable" (those who have moved away from Hong Kong) pharmacists are projected from the HMS on Pharmacists by sex and year (Figure 5.5). The five-year average proportion is applied to the projection.

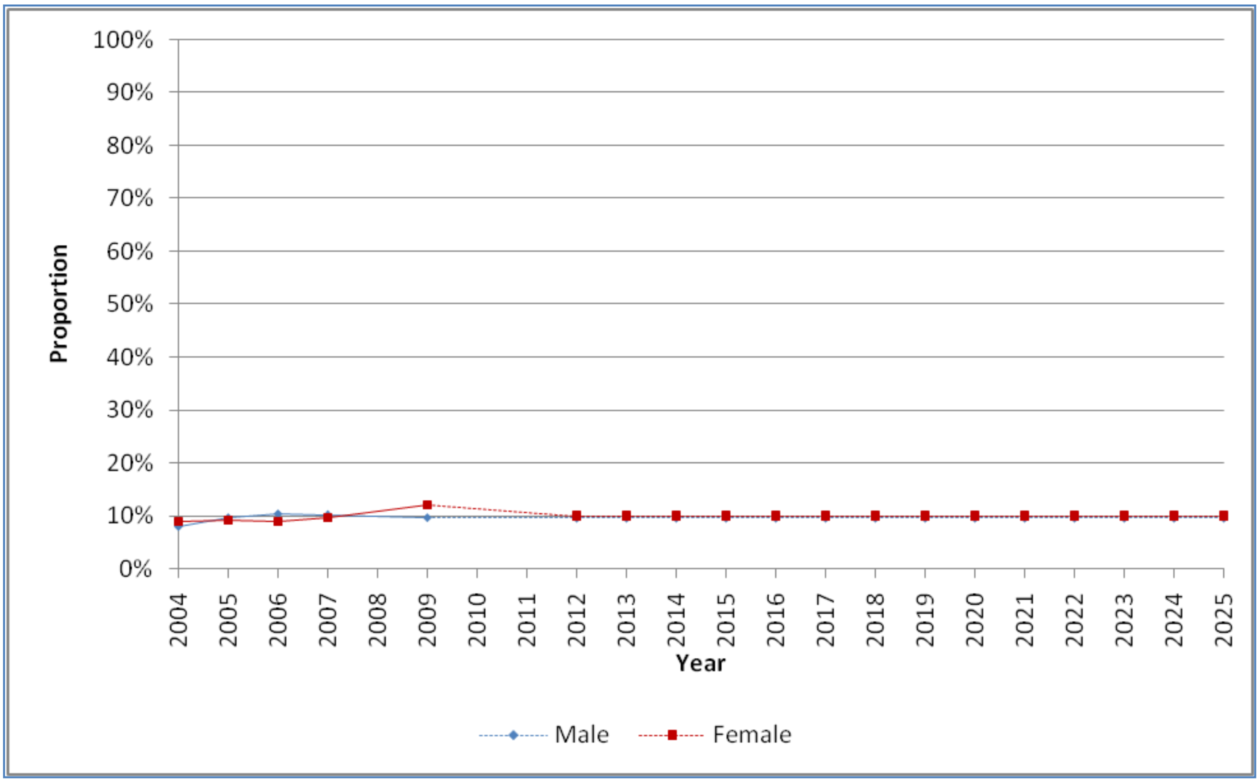

Figure 5.5 Proportion of pharmacists 'otherwise unavailable' by sex(2012-2025)

5.3 Supply externalities

5.3.1 Workforce participation and differential work capacity

The supply model use the HMS on Pharmacists to calculate the proportion of clinically active pharmacists by service sectors (Hospital Authority, Other public [Government, Academic & Subvented], Private [Community pharmacy], Private [Hospital and Other private health care institution] and Private institution [Pharmaceutical company and pharmaceutical manufacturer]) as each has different work patterns and female-male ratios (Figure 5.6). The supply model estimates the age-, sex-specific proportion of clinically active pharmacists by location and sector, differential work capacity, work pattern, and standard working hours.

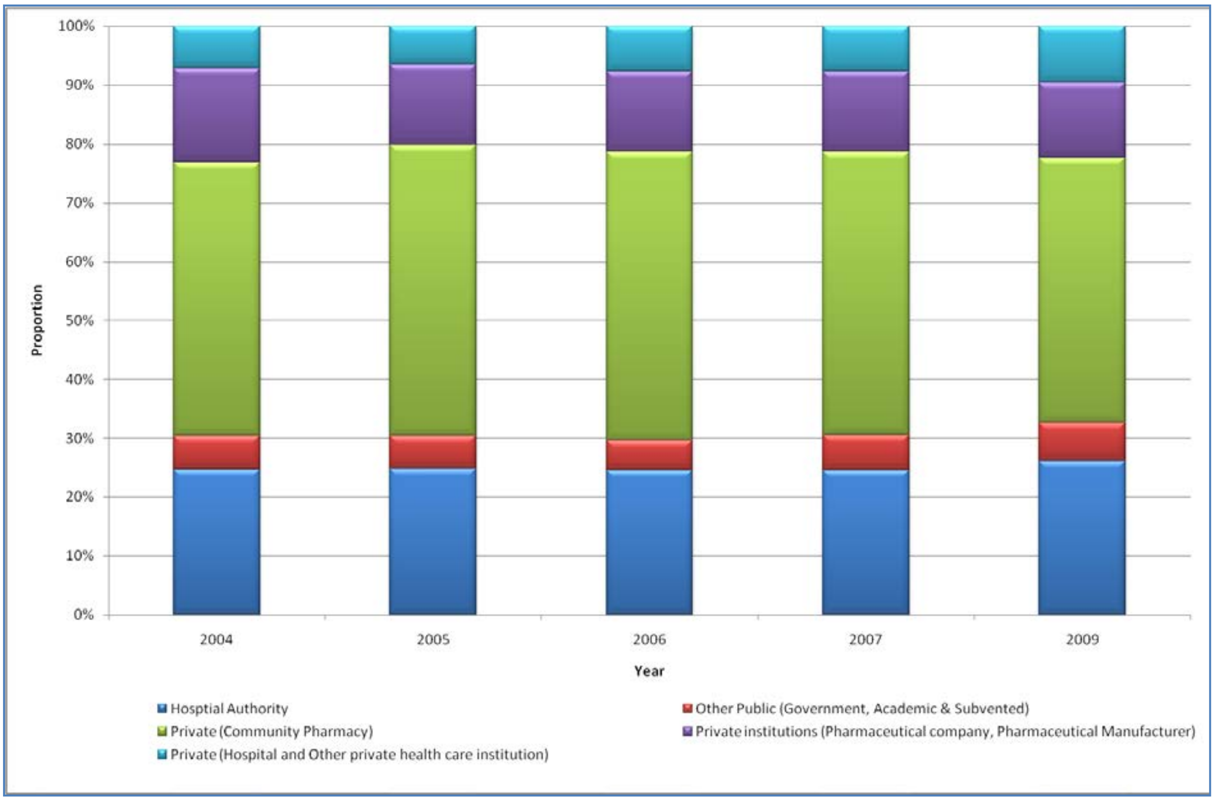

Figure 5.6 Proportion of pharmacists by sector (HMS 2004-2007 & 2009)

5.4 Converting workforce supply to full time equivalents (FTEs)

The model uses the age-, sex-specific stratified average working hours to determine the total hours worked by sector. The median working hours (44 hours per week) is calculated based on the HMS for Pharmacists 2004-2007 & 2009, and used as the standard working hours. The average working hours in any sector is then capped at 44 hours per week (equivalent to 1 FTE).

5.5 Pharmacist supply projection from 2012-2041

5.5.1 Retirement scenarios

As compared with HRSA and the Pharmacy Workforce Planning Study, Australia, the HK retirement proportion is much lower (Table 5.2). 97% of HK pharmacists are employees. Three retirement scenarios for the ">=65" age group are used to observe variation in the supply projection (Table 5.3)

Table 5.2 Comparison of retirement/inactive proportion

Source	Mean retirement proportion, age>=65	Mean inactive proportion, age>=65
Health Manpower Survey on Pharmacists 2004-2007&2009. Department of Health, Hong Kong	23.1%	33.5%
The Adequacy of Pharmacist Supply: 2004 to 2030. 2008, HRSA	NA	>50%
Pharmacy Workforce Planning Study. 2009, Department of Health and Ageing, Australia	NA	72.9%

Note: The HRSA study assumed all pharmacists have retired by age 75.

Table 5.3 Three scenarios of retirement assumptions for the ">=65" age group

Scenario	Retirement assumptions for the ">=65" age group
1	"Natural attrition/retirement" for ">=65" age group is assumed to be 100%
2	The average proportion of "Natural attrition/retirement" based on the HMS 2004-2007&2009 assumes all pharmacists retire by 70 years of age
3	The average proportion of "Natural attrition/retirement" based on the HMS 2004-2007&2009 assumes all pharmacists retire by 75 years of age

5.5.2 Pharmacist supply projection

Table 5.4 presents the detailed projection outcomes for each of the variables in the supply model and the total FTE supply projection from 2015-2040 of Scenario 1.

Table 5.4 Pharmacist supply projection for 2012-2040 (Scenario 1[1])

Year	**2012**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**
Pre-existing registrants	2075	2346	2965	3574	4165	4727	5276
Number of registrants after renewal[2]	2063	2332	2948	3552	4140	4699	5245
Number of graduates							
Local[3]	59	101	82	82	82	82	82
Non-local[4]	52	60	60	60	60	60	60
Newly eligible registrants[5]	78	110	142	142	142	142	142
Total number of registrants	**2141**	**2442**	**3090**	**3695**	**4282**	**4841**	**5387**
Clinically inactive/unavailable							
No longer practising in the pharmacy profession but not retired[6]	167	189	234	273	309	340	366
Natural attrition/retirement[6]	108	157	283	452	629	849	1091
Otherwise unavailable[6]	199	224	276	319	360	394	424
Otherwise deregistered[7]	1	1	1	1	1	1	1
Number of inactive registrants[8]	475	571	794	1044	1299	1583	1882
Number of clinically active/available registrants[9]	1666	1871	2296	2650	2983	3258	3505
Total FTE[10]	1656	1858	2280	2631	2960	3232	3476

1. In scenario 1, the proportion of "Natural attrition/retirement" for the ">=65" age group is projected by sigmoid function based on HMS on Pharmacists 2004-2007&2009, and assumes all pharmacists retire by 65 years of age.
2. The renewal rate is based on the data provided by PPBHK
3. The number of local graduates from CUHK and HKU; number of expected graduates are held constant from 2018.
4. The number of non-local graduate is projected by sigmoid function based on the data from 2003-2011 provided by the PPBHK
5. Local pharmacist graduates undergo a one-year internship before registration, therefore the number of newly eligible registrants is the sum of the local graduates in the previous year and the non-local graduate in current year.
6. Proportion of pharmacists clinically inactive/unavailable DH HMS for Pharmacists (2004-2007 and 2009); Average proportions are applied to the projection. Specially for "Natural attrition/retirement", sigmoid function is applied to the ">=65" age group, and assumes all pharmacists retire by 65 years of age.
7. Assume 1 permanent pharmacist deregistration per year
8. The total number of clinically inactive/unavailable pharmacists is calculated by summing the number of pharmacists in the categories of "No longer practising in the pharmacy profession but not retired", "Natural attrition/retirement", "Otherwise unavailable" and "Otherwise deregistered"
9. Total number of clinically active/available pharmacists
10. Total projected FTE

6 Gap analysis

The gap analysis quantifies the difference between the projected demand for and supply of pharmacists for the base case (assumed demand and supply is at equilibrium from 2005 – 2011, i.e. realised demand equals realised supply where the gap is defined to be zero). The base case was further adjusted for the externalities:- HA intravenous admixing service enhancement, role expansion of pharmacists in pharmaceutical companies and the HA clinical pharmacy service jointly in a best guestimate scenario and an additional scenario extending the length of stay of pharmacists in Authorised Sellers of Poison independently and jointly in an Omnibus scenario.

For the supply base case, the projected FTE supply includes only those working in the HA, the private sector, the DH and the pharmaceutical industry.

6.1 Method

Three methods (annual number of FTEs, year-on-year FTE, and annual incremental FTE) are used to quantify FTE pharmacist demand and compared to the base case supply projections.

6.1.1 Annual number of FTE

The number of FTE pharmacists required in year y is as a function of the various utilisation measures in year y as described in the previous sections where:-

$$\text{Number of FTE } (y) = \sum_i n_{(i)}(y)c_{(i)}$$

$n_{(i)}(y)$ is the projected utilisation measure i in year y, and the $c_{(i)}$ the estimated FTE: $n_{(i)}$ ratio.

6.1.2 Year-on-year FTE

The year-on-year FTE method quantifies the accumulated difference between demand and supply as follows:-

$$a(y) = \ Demand(y) - \ Supply(y)$$

where $a(y)$ is the year-on-year FTE at year y, $Demand(y)$ the FTE demand at year y, and $Supply(y)$ the FTE supply at year y.

6.1.3 Annual incremental FTE

The annual incremental FTE method quantifies the change in the demand supply gap from the previous year as follows:-

$$I(y) = a(y) - \ a(y-1)$$

where $I(y)$is the annual incremental FTE at year y, $a(y)$ the year-on-year FTE at year y, and $a(y-1)$ the year-on-year FTE from the previous year.

6.2 Base case

For the base case scenario, the model projects an FTE shortfall until 2016 and thereafter an FTE surplus (Figure 6.1 – 6.3, Table 6.1 and 6.2). The increasing surplus FTE gap reflects the additional graduates entering the workforce after 2016.

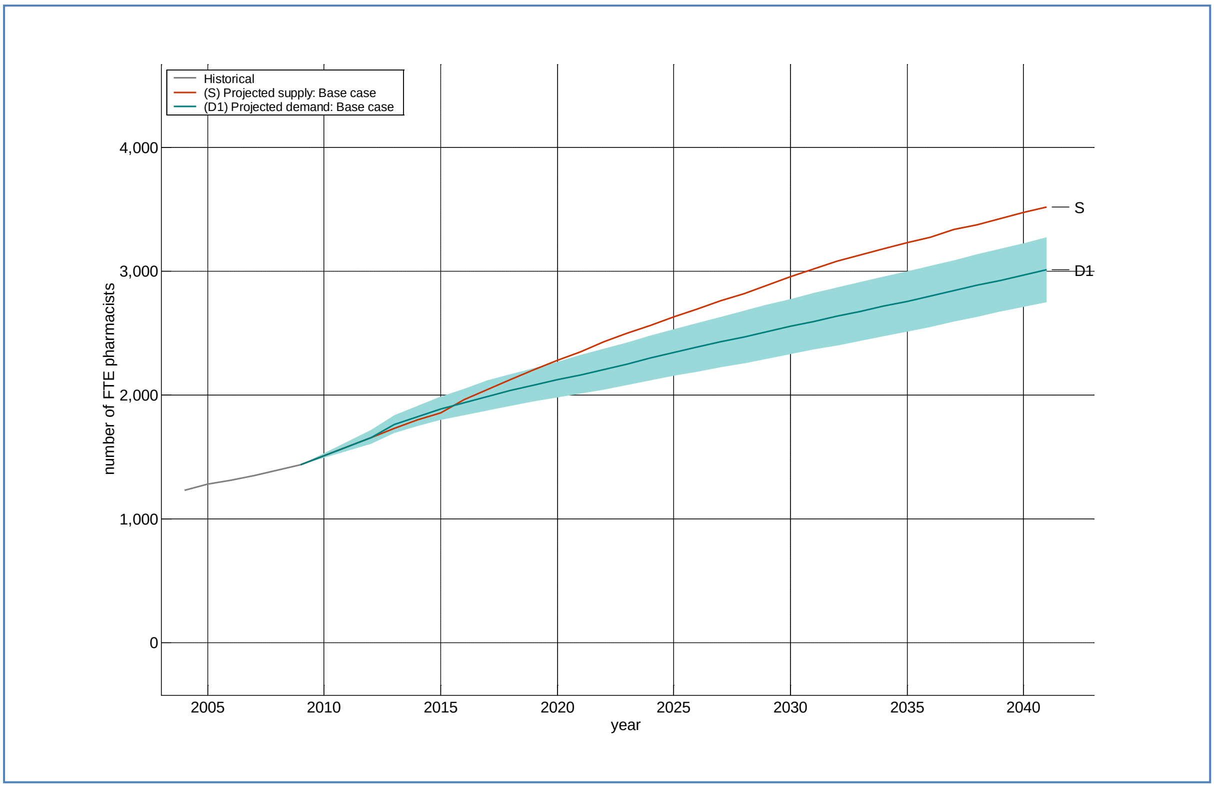

Figure 6.1 Projected number of FTE pharmacists: Base case supply and demand (Shaded area: 5th-95th percentile).

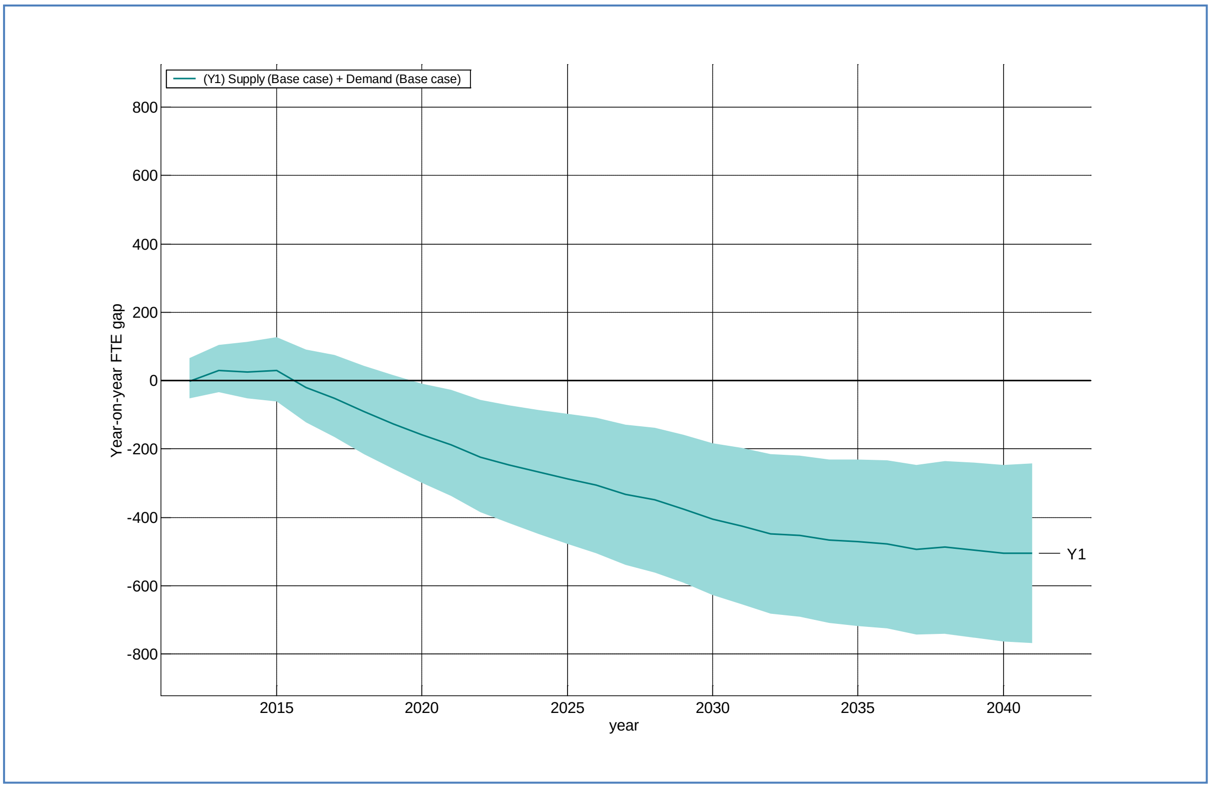

Figure 6.2 Year-on-year FTE gap: Base case demand model (Shaded area: 5th-95th percentile)

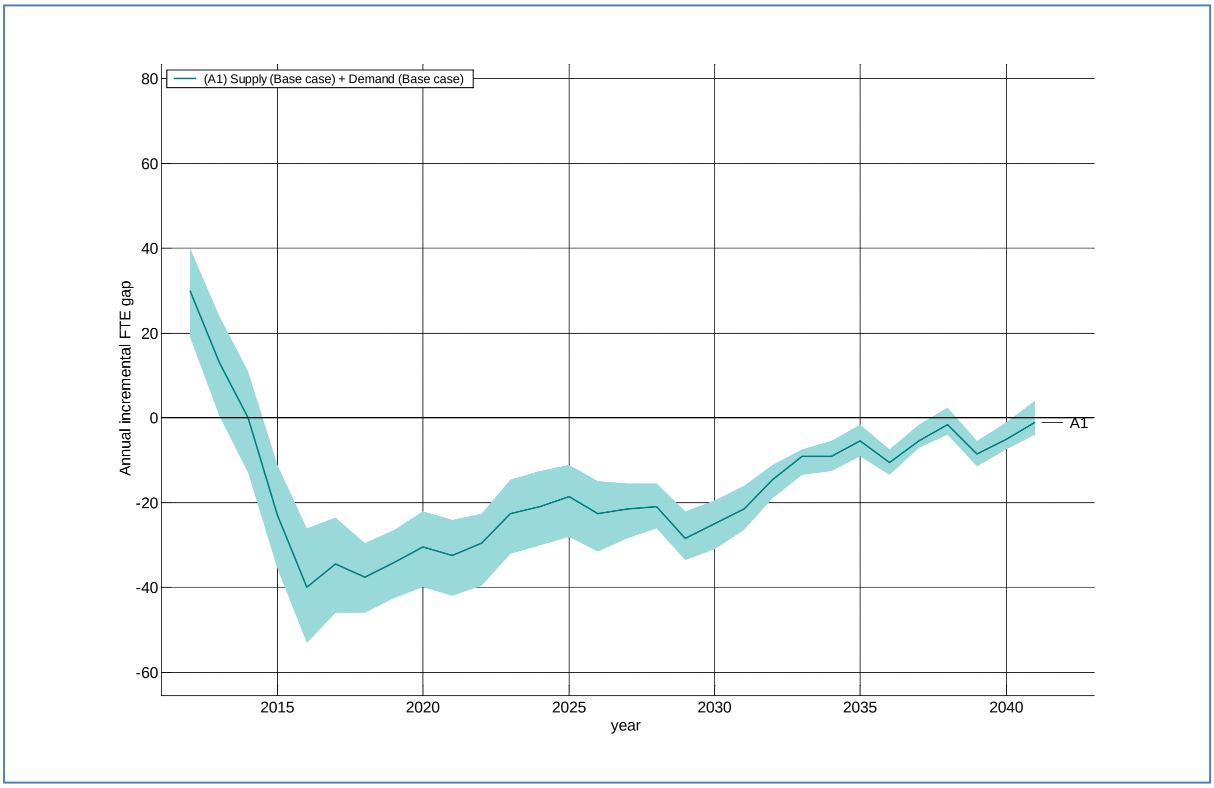

Figure 6.3 Annual incremental FTE gap: Base case demand model (Shaded area: 5th-95th percentile)

Table 6.1 Base case: projected year-on-year supply-demand gap (a negative number indicates surplus)

	Best guestimate	5th percentile	95th percentile
2015	29	-60	127
2020	-158	-300	-9
2025	-288	-477	-98
2030	-405	-628	-183
2035	-472	-717	-231
2040	-505	-763	-247

Table 6.2 Base case: projected annual incremental supply-demand gap (*a negative number indicates surplus)

	Best guestimate	5th percentile	95th percentile
2015	-23	-23	1
2020	-31	-31	1
2025	-19	-19	1
2030	-25	-25	1
2035	-6	-6	1
2040	-5	-5	1

6.3 Best guesstimate

The base case projection models took an empirical approach rather than asserting any normative level of demand or supply assuming that supply and demand were in balance (no shortfall or surplus of human resources), historically. Because of this conservative assumption, different sensitivity scenarios are simulated to test alternative normative preferences or policy actions. Specifically, a best guestimate scenario is derived to account for new policy developments which will have implications for pharmacist manpower, and yet are not captured in the base case scenario.

The best guestimate model considers the net effect of three major initiatives being introduced to enhance pharmacist service. In brief these service enhancements include:-

a. Enhanced HA clinical pharmacy service: - The clinical pharmacy service is expected to expand from its current focus on oncology and paediatric patients to include other ambulatory service. The number of clinical pharmacists needed for this service expansion is linearly proportion to the number of bed days in these services.
b. HA intravenous admixing service enhancement:- Simple intravenous (IV) admixing is currently undertaken by hospital ward based nursing staff whereas complex IV admixing services which involve dilution/calculation and high risk medications are provided by the pharmacy department. The number of FTE pharmacists induced by

the HA intravenous admixing service enhancement by pharmacy is expressed as a linear proportion of the number of aseptic items in IV admixing services.

c. Role expansion of pharmacists in pharmaceutical companies:- The number of pharmacists employed / to be employed per *company* as reported by a Hong Kong Association of Pharmaceutical Industry[9] survey is 2.2. The number of FTE pharmacists induced by the expansion of the role of pharmacists in pharmaceutical companies is expressed as a linear proportion of the number of pharmacists in pharmaceutical companies.

The best guesstimate model presents a comparison between the demand base case and the best guesstimate for the number of FTEs, the year-on-year and annual incremental FTE gap for pharmacists and the supply base case are illustrated in Figure 6.4 - 6.6, Tables 6.3 - 6.4. The net impact is a projected year-on-year demand supply shortfall at 2015 of 223 and a surplus at 2025 and 2040 of 6 and 186 FTEs respectively.

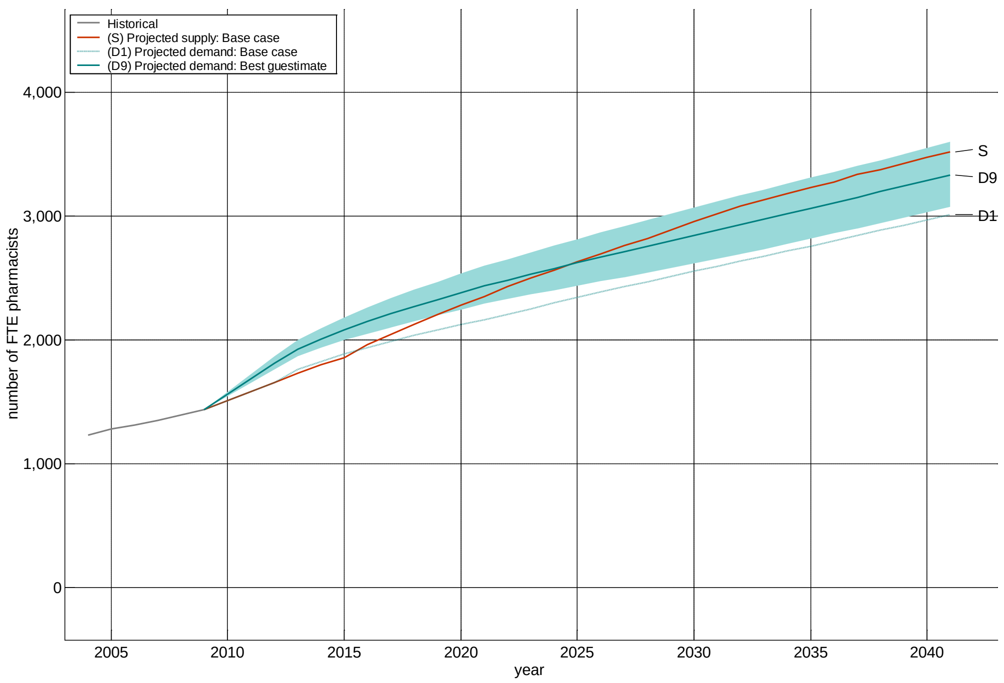

Figure 6.4 Projected number of FTE pharmacists: Base case supply and best guestimate (Shaded area: 5th-95th percentile).

[9] As at 2015, Hong Kong Association of Pharmaceutical Industry has 41 full members which provide over 70% of the prescription medicines in Hong Kong. The survey was sent to the members and 20 of them are responded.

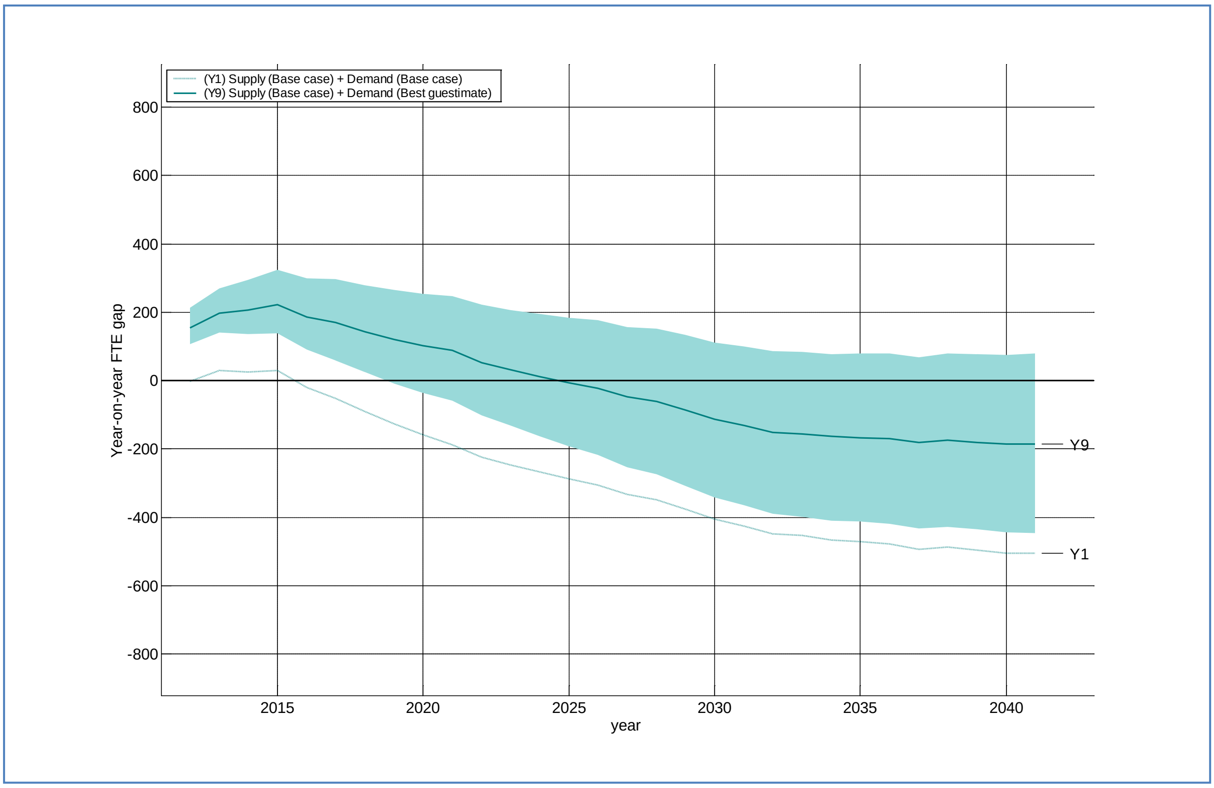

Figure 6.5 Year-on-year FTE gap: Base case supply and best guestimate (Shaded area: 5th-95th percentile)

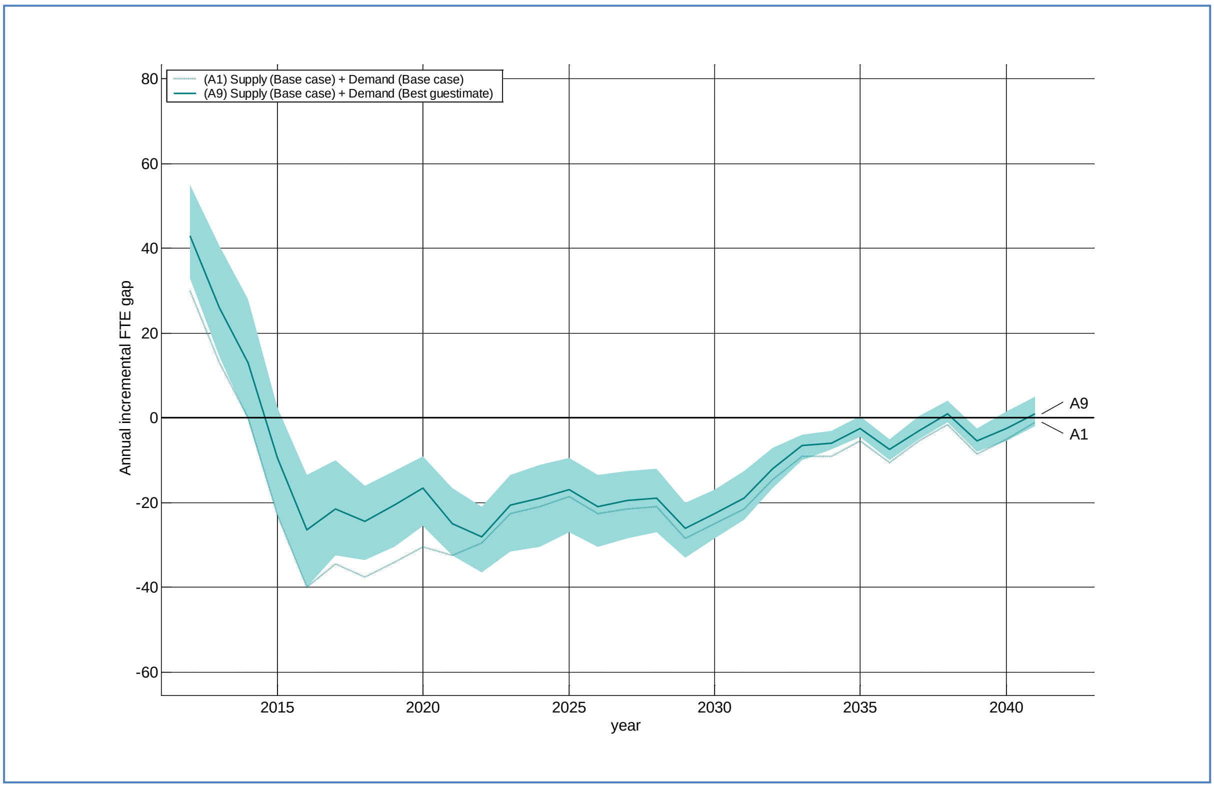

Figure 6.6 Annual incremental FTE gap: Base case supply and best guestimate (Shaded area: 5th-95th percentile)

Table 6.3 Best guestimate: projected year-on-year supply-demand gap (a negative number indicates surplus)

	Best guestimate	5th percentile	95th percentile
2015	223	139	325
2020	103	-36	255
2025	-6	-193	184
2030	-113	-341	111
2035	-167	-413	79
2040	-186	-444	75

Table 6.4 Best guestimate: projected annual incremental supply-demand gap (*a negative number indicates surplus)

	Best guestimate	5th percentile	95th percentile
2015	-10	-10	1
2020	-17	-17	1
2025	-17	-17	1
2030	-23	-23	1
2035	-3	-3	1
2040	-3	-3	1

6.4 Policy options

In light of public concern over unsafe and unregistered pharmaceutical products, the Government set up the Review Committee on the Regulation of Pharmaceutical Products in Hong Kong (the Review Committee) in March 2009 to conduct a comprehensive review on the existing regime for the regulation of pharmaceutical products. The Review Committee put forward 75 recommendations which covered improvements in areas from manufacturing to retailing including a recommendations to amend the Pharmacy and Poison Ordinance (Cap. 138) such that a registered pharmacist should be present whenever that authorized sellers of poisons was open for business. Therefore, in addition to the best guestimate scenario, a projection which takes into account the impact of such a recommendation on the manpower gap is provided.

The solid lines in Figures 6.8 – 6.9 for the projected number of FTEs, the accumulative and annual incremental FTE gap represent the additive impact of the '*Extend the number of hours of pharmacist coverage in Authorized Sellers of Poisons'* to the base case scenario (dashed lines) of the on FTEs (see also Tables 6.5 – 6.6). The net FTE induced demand of the proposed policy '*Extend the number of hours of pharmacist coverage in Authorized Sellers of Poisons'* is a substantial increase in the shortfall at 2015 and a reduction from the base case in the projected year-on-year FTE surplus. The on average year-on-year projected FTE shortfall for pharmacists at 2015, 2025 and 2040 is 420, 188, 30 respectively.

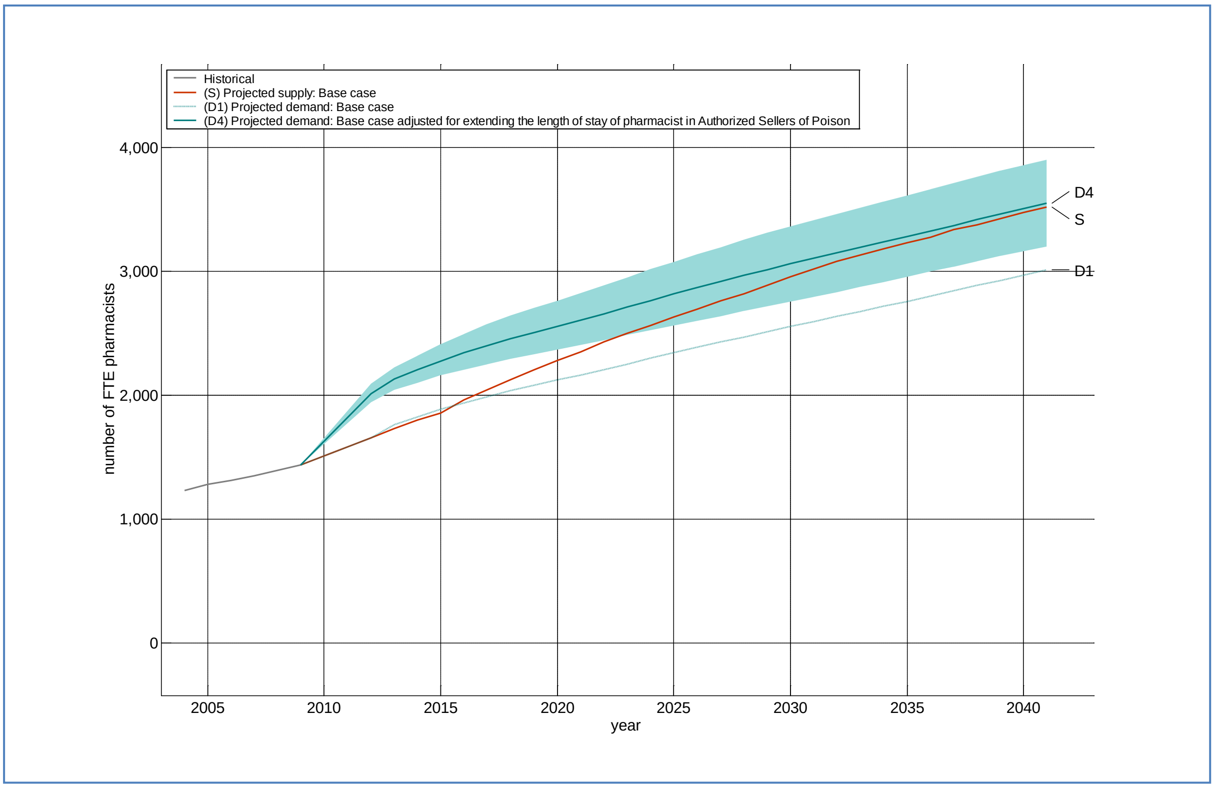

Figure 6.7 Projected supply and demand of FTE pharmacists in Hong Kong: *Extend the number of hours of pharmacist coverage in Authorized Sellers of Poisons*.

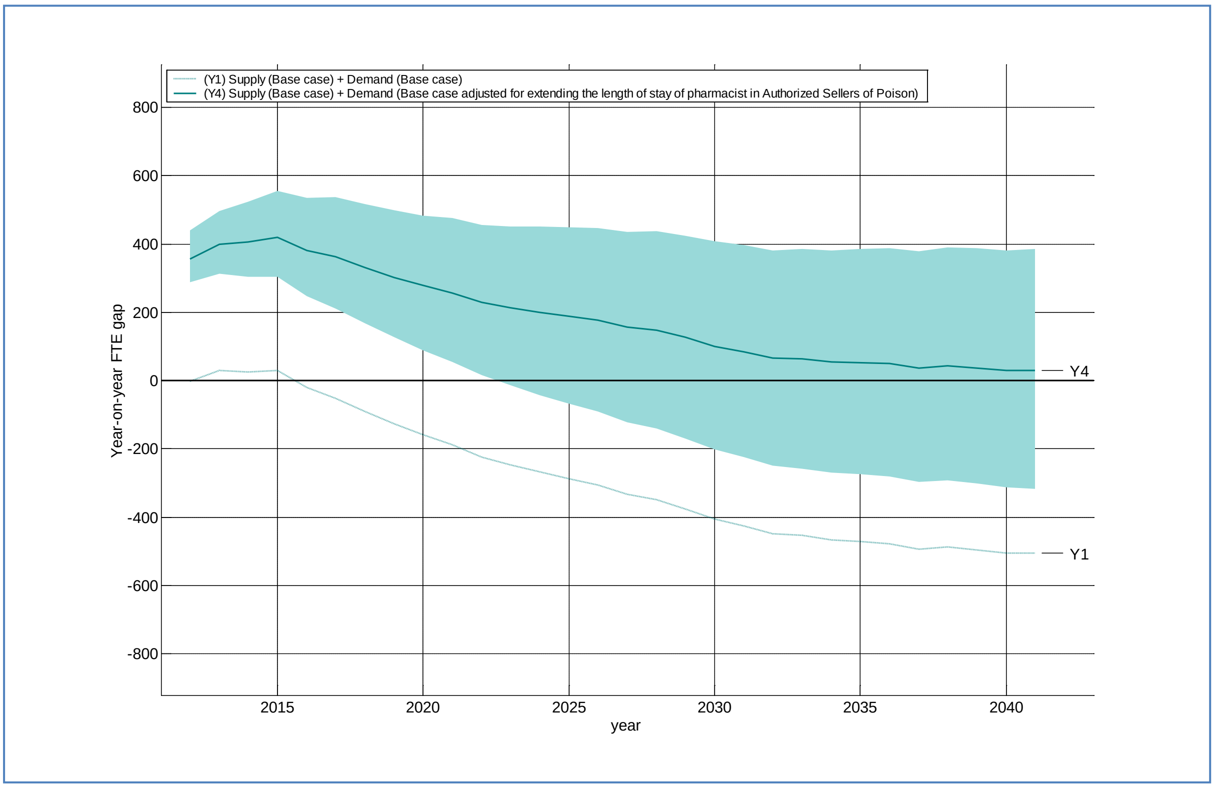

Figure 6.8 Year-on-year pharmacist FTE gap: *Extend the number of hours of pharmacist coverage in Authorized Sellers of Poisons*

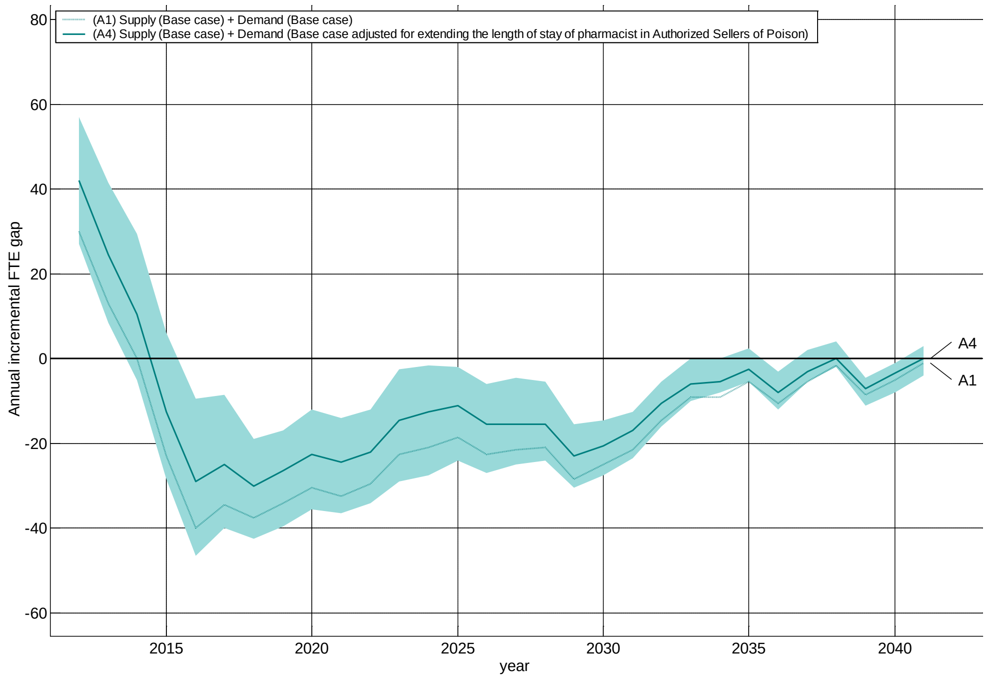

Figure 6.9Annual incremental FTE gap: *Extend the number of hours of pharmacist coverage in Authorized Sellers of Poisons*

Table 6.5 *Extend the number of hours of pharmacist coverage in Authorized Sellers of Poisons*: projected year-on-year supply-demand gap [*a negative number indicates surplus]

	Best estimate	5th percentile	95th percentile
2015	420	304	556
2020	278	88	484
2025	188	-68	448
2030	101	-202	407
2035	53	-273	385
2040	30	-313	382

Table 6.6 *Extend the number of hours of pharmacist coverage in Authorized Sellers of Poisons*: projected annual incremental supply-demand gap [*a negative number indicates surplus]

	Best estimate	5th percentile	95th percentile
2015	-13	-13	1
2020	-23	-23	1
2025	-11	-11	1
2030	-21	-21	1
2035	-3	-3	1
2040	-4	-4	1

7 Omnibus scenario

The overall FTE, accumulated FTE gap, and annual incremental FTE gap for the demand model Omnibus scenario[10] and the supply model base case are presented in Figures 7.1 – 7.3 and Tables 7.1 and 7.2. The on average year-on-year projected FTE shortfall for pharmacists in 2015, 2025 and 2040 is 615, 470 and 349 respectively.

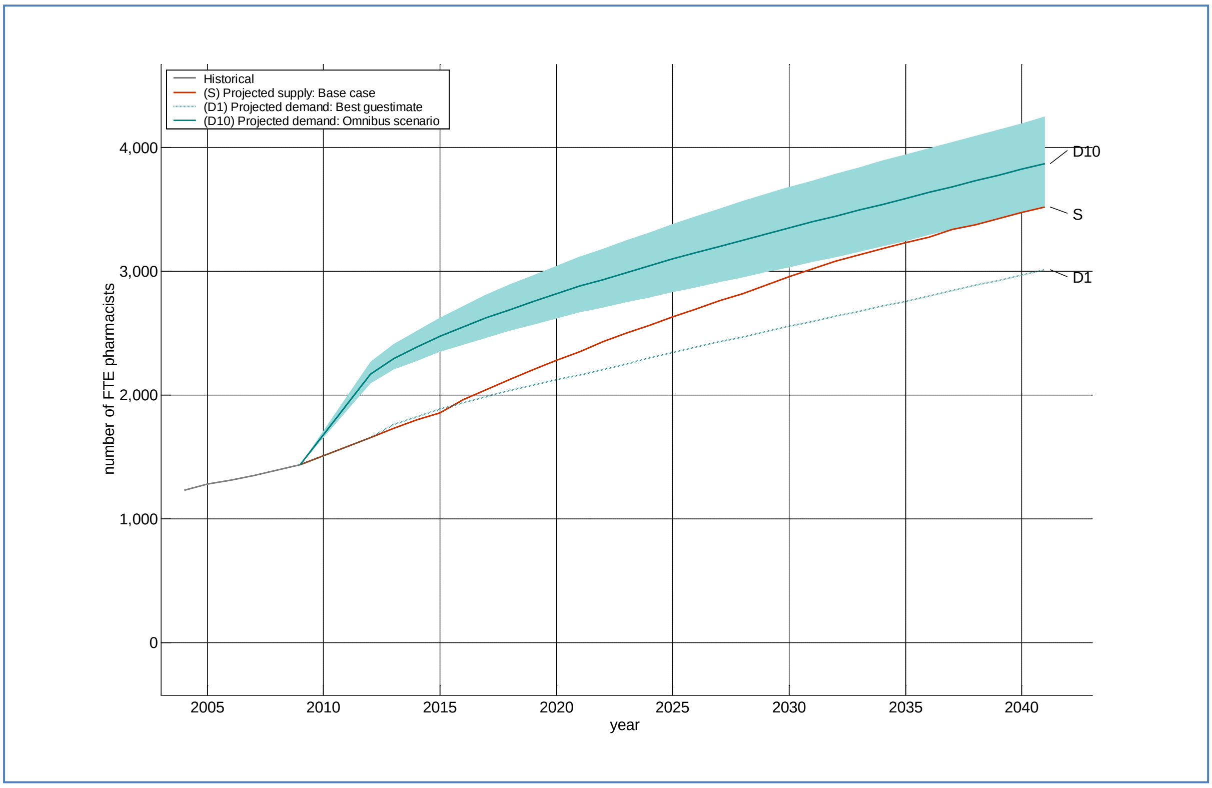

Figure 7.1 Projected supply and demand of FTE pharmacists in Hong Kong: Omnibus scenario

[10] The demand of *Omnibus scenario* = *Base case* + *HA clinical pharmacy service* +*Role expansion of pharmacists in pharmaceutical companies* +*HA intravenous admixing service enhancement* + *Extended length of stay of pharmacists in Authorised Sellers of Poison*

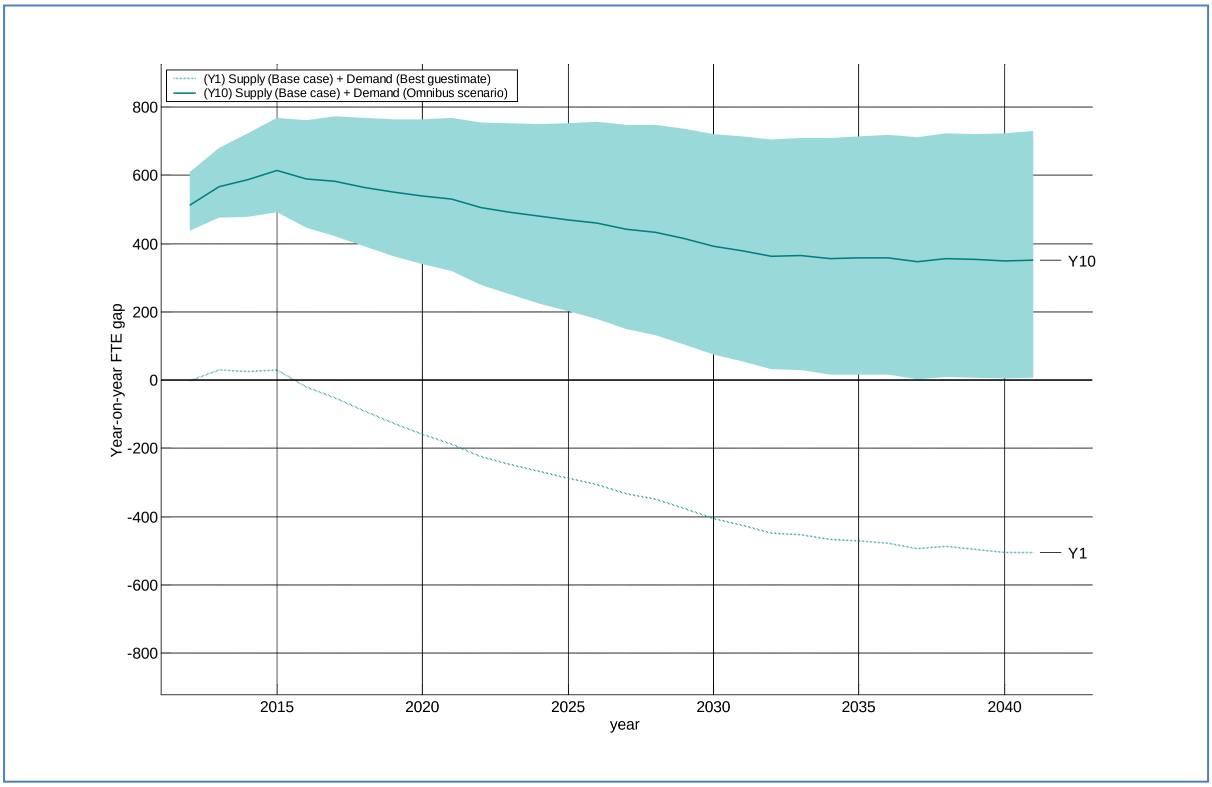

Figure 7.2 Year-on-year pharmacist FTE gap: *Omnibus scenario* (Shaded area: 5th-95th percentile)

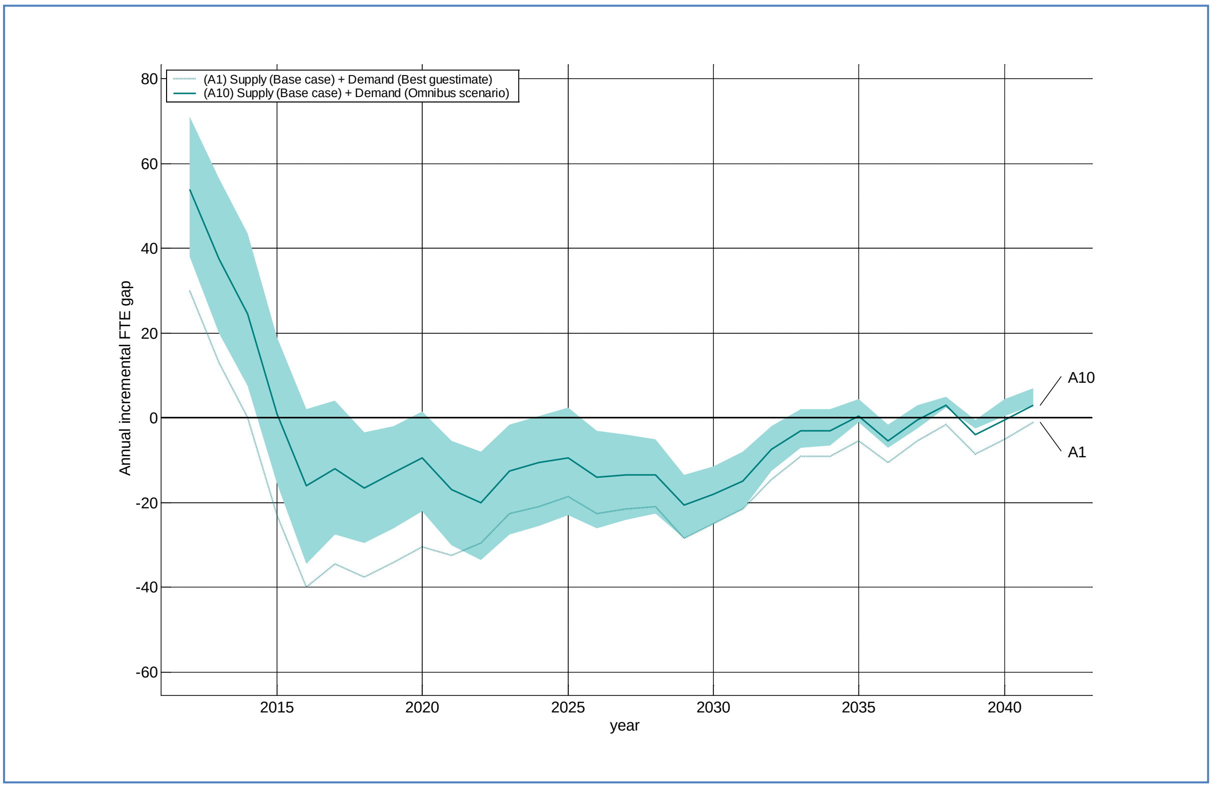

Figure 7.3 Annual incremental FTE gap: *Omnibus scenario* (Shaded area: 5th-95th percentile)

Table 7.1 Omnibus: projected year-on-year supply-demand gap [*a negative number indicates surplus]

	Best estimate	5th percentile	95th percentile
2015	615	487	763
2020	539	334	761
2025	470	195	755
2030	393	65	728
2035	358	4	722
2040	349	-18	731

Table 7.2 Omnibus: projected annual incremental supply-demand gap [*a negative number indicates surplus]

	Best estimate	5th percentile	95th percentile
2015	1	-18	19
2020	-9	-22	1
2025	-9	-24	4
2030	-18	-25	-11
2035	0	-4	5
2040	-1	0	3

8 Comparison of 2012-2041 and 2015-2064 projections

The final model presents four demand omnibus scenario (2012-2041 versus 2015-2064 CS&D demographic projections, and best guestimate versus omnibus scenario) FTE projections and the supply base case FTE projections as well as the year-on-year and annual incremental FTE gap (Figure 8.1 – 8.3, Tables 8.1 – 8.4). Based on the best guestimate scenario's the 2015-2064 vs. 2012-2041 on average year-on-year FTE projections shows a surplus in the number of FTE pharmacists. The opposite effect is observed with the omnibus scenario where the 2015-2064 vs. 2012-2041 FTE projections show a shortfall in the number of FTE pharmacists.

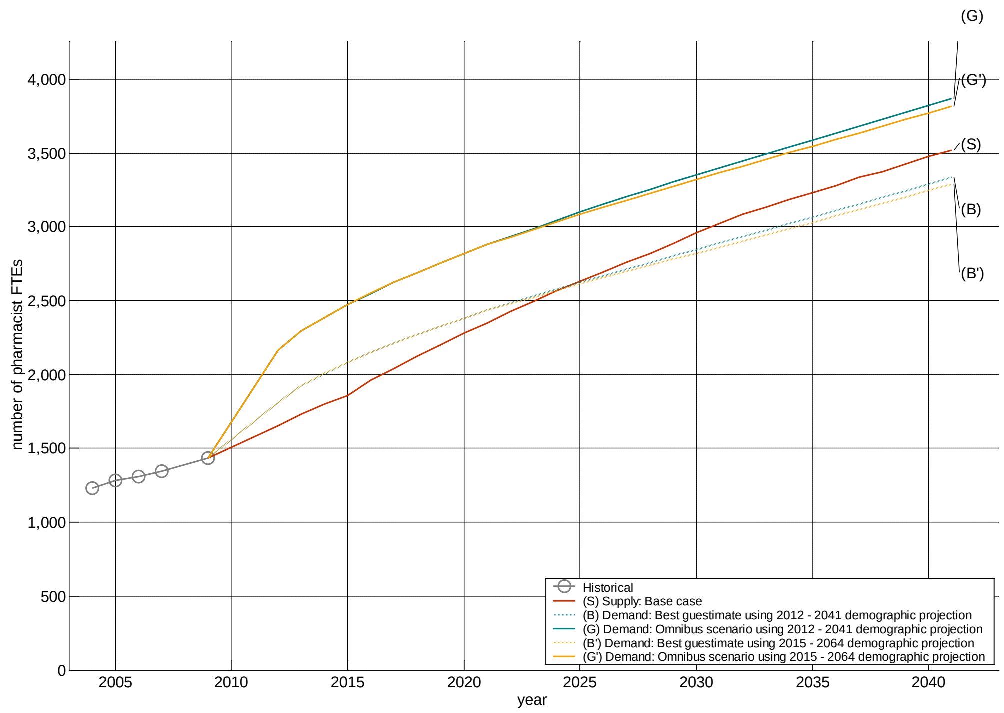

Figure 8.1 Historical and projected number of pharmacist FTEs: Base case supply and omnibus scenario demand (Shaded area: 5th-95th percentile).

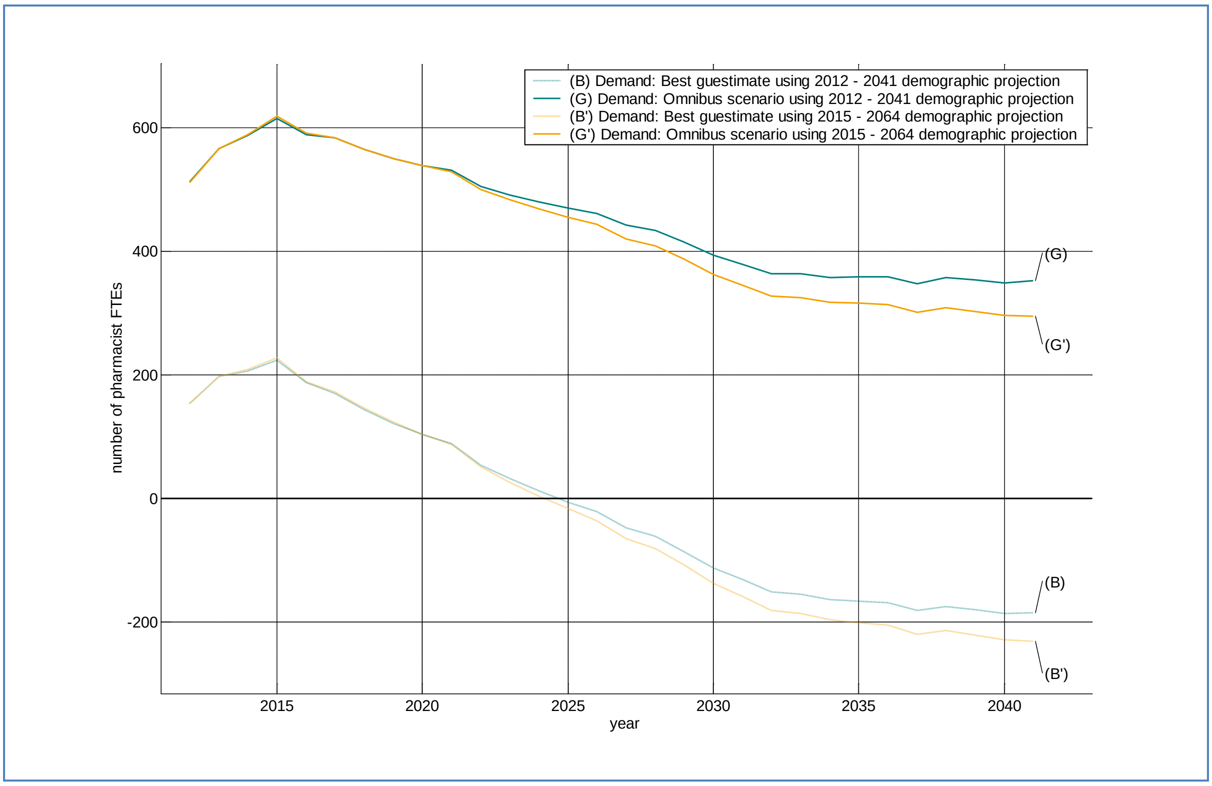

Figure 8.2 Year-on-year FTE gap: Omnibus scenario demand model (Shaded area: 5th-95th percentile)

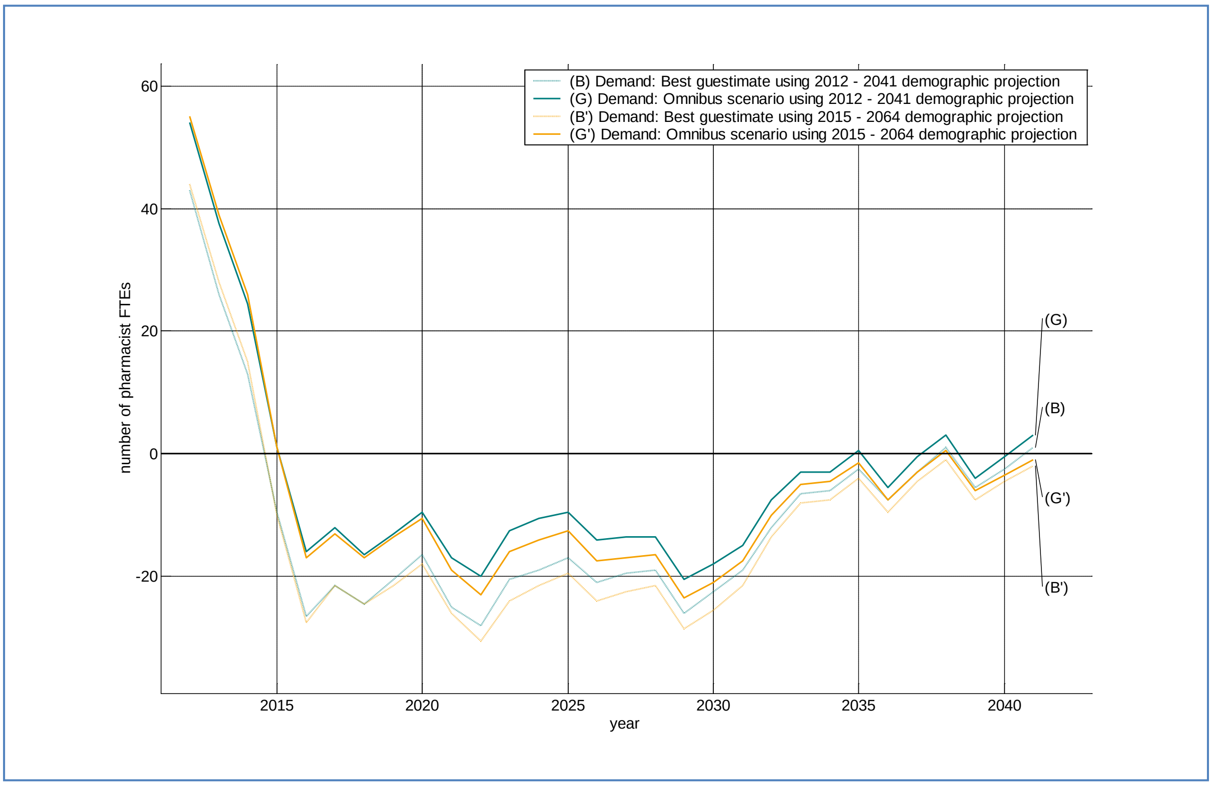

Figure 8.3 Annual incremental FTE gap: Omnibus scenario demand model (Shaded area: 5th-95th percentile)

Table 8.1 Best guestimate: projected year-on-year supply-demand gap (assuming retirement =>65 years of age) [*a negative number indicates surplus]

	Best estimate (2012-2041 demographic projection)	5th percentile	95th percentile	Best estimate (2015-2064 demographic projection)	5th percentile	95th percentile
2015	223	139	325	227	141	327
2020	103	-36	255	103	-34	261
2025	-6	-193	184	-17	-199	184
2030	-113	-341	111	-138	-354	99
2035	-167	-413	79	-201	-435	59
2040	-186	-444	75	-229	-478	49

Table 8.2 Best guestimate: projected annual incremental supply-demand gap (assuming retirement =>65 years of age) [*a negative number indicates surplus]

	Best estimate (2012-2041 demographic projection)	5th percentile	95th percentile	Best estimate (2015-2064 demographic projection)	5th percentile	95th percentile
2015	-10	-10	1	-10	-20	4
2020	-17	-17	1	-18	-27	-9
2025	-17	-17	1	-20	-29	-12
2030	-23	-23	1	-26	-30	-20
2035	-3	-3	1	-4	-7	0
2040	-3	-3	1	-5	-8	-1

Table 8.3 Omnibus scenario: projected year-on-year supply-demand gap (assuming retirement =>65 years of age) [*a negative number indicates surplus]

	Best estimate (2012-2041 demographic projection)	5th percentile	95th percentile	Best estimate (2015-2064 demographic projection)	5th percentile	95th percentile
2015	615	487	763	618	491	743
2020	539	334	761	538	334	727
2025	470	195	755	455	182	697
2030	393	65	728	362	42	651
2035	358	4	722	316	-37	629
2040	349	-18	731	296	-77	626

Table 8.4 Omnibus scenario: projected annual incremental supply-demand gap (assuming retirement =>65 years of age) [*a negative number indicates surplus]

	Best estimate (2012-2041 demographic projection)	5th percentile	95th percentile	Best estimate (2015-2064 demographic projection)	5th percentile	95th percentile
2015	1	-18	19	1	-22	15
2020	-9	-22	1	-11	-23	-1
2025	-9	-24	4	-13	-26	-2
2030	-18	-25	-11	-21	-28	3
2035	0	-4	5	-2	-7	4
2040	-1	0	3	-4	-9	4

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Appendix A(i): Summary of manpower planning and forecasting models (Australia, Canada, Netherlands)

	Australia	Canada	Netherland
Context	- shorter working hours for all healthcare professionals - ageing population - increasing demand for services - workforce distribution -	- utilisation-based planning failed to inform long-term workforce planning - planning has been done in isolation which resulted in unintended impacts, mismatch between need, supply and demand; - costly duplication, and inability to respond effectively to international issues/pressure	- shortage of medical specialist and nursing personal - steady growth in the healthcare workforce - increased feminization of the workforce and contracted GPs - impact of migration on health manpower planning
Objectives/ Strategic Directions	- ensure and sustain supply - optimise workforce and healthcare access - improve the healthcare work environment - enhance and coordinate health, education, vocational training and regulatory sectors - optimise use of workforce skills and ensure the best health outcomes - improve policy and planning to support the provision of staff - improve collaborative effort between all stakeholders	- increase the number of qualified healthcare trainees - focus on productivity and effective use of skills - improve access to healthcare services, address inappropriate variation of health human resources - create healthy, safe, supportive and learning workplace - maintain an skilled, experienced and dedicated workforce - more effective manpower planning and forecasting	- increase professional training - increase recruitment both to encourage staff to return to healthcare workforce and to recruit from overseas - retain staff by increasing support for staff and flexible working arrangements - change skill-mix
Framework	- align education and training supply with workforce requirements - improve workforce re-entry and ethical overseas recruitment - support work culture and develop flexible working environments - promote skills and competence initiatives - establish shared health workforce planning, research, information sharing, improve data collection - establish monitoring, evaluation and reporting processes - promote discussion and awareness amongst the stakeholders and community	- assess population health needs, demand for services including Aboriginal health needs - develop, implement and evaluate population need-based innovative service delivery and health human resource models - enhance collaboration and provide evidence for HHR planning information - align education curricula with health system needs and health policy - provide opportunities for to life-long learning - develop a locally, culturally and linguistically diverse workforce; - accelerate and expand the assessment and integration of internationally educated health professionals; - enhance healthcare career attractiveness - address health and safety issues, reduce work-related illnesses, injuries, and absenteeism	- increase collaboration between local and international institution in medical training programmes - increase training capacity, staff retention and recruitment - recruit healthcare professionals from within and outside EU - develop flexible and family-friendly working patterns - adjust the workloads for the older staff, and retirement age - provide learning and development opportunities - improve skill mix use and transfer of function between different professional groups - develop new roles and extend the range of work
Duration	since 2004 (reviewed in 2011)	since 2005	Since 2000s

	Australia	Canada	Netherland
Method for supply/ demand	**Supply and need-based model** **Demand** - utilisation of health services **Supply** - number of hours worked per year by the number of male and female health professionals in each age group - proportion of leavers and entries (graduates and migrants) into the health professional field	Collaborative system design and population health **need-based approach** to planning **Supply:** - actual number, type and geographical distribution of regulated and unregulated providers; productivity and scope of practice/service provided - labour market indicators: participation rate, provider-to-population ratios, demographic and educational characteristics of providers, employment status and sectors - death, retirement, emigration, replacement, general economic trends, work incentives, life-style choices. **Demand:** - population health needs for both curative and preventive health services	**The Dutch Simulation and Forecasting Model (supply-based)** confronted with 4 scenarios: - Scenario 0: unfulfilled demand for care + demographical developments - Scenario 1: Scenario 0 + non-demographical developments - Scenario 2: Scenario 1 + developments in working hour - Scenario 3: Scenario 2 + vertical substitution **The Dutch Policy and Planning Model** - a multi-stakeholder and multi-process consensus model - based on simulation model that generates GP training inflow advice yearly, allocation of funding and resources, and unplanned external factors to project GP workforce in coming years
Assumptions	**Demand** - time required for treating different conditions is binary - linear growth in demand. - demand model ignores labour substitution **Supply** - no change in technology - workforce entrance and exits, hours worked are disaggregated by age and sex groups. **General** - no interactions between the supply and demand models - no supplier-induced demand	- current supply of providers meet the current demand - observed trends are used to project future population size and demographic profile - future age and sex-specific resources remain constant	- historical trend continues - other projection of population growth, political and technical changes is on the right direction

	Australia	Canada	Netherland
Formulae	**Demand** $D_t = \beta_{st} \textit{activitysimple}_t + \beta_{ct} \textit{activitycomplex}_t$ D_t: Demand at a specific time *activitysimple*: simple utilisation *activitycomplex*: complex utilisation Each activity has a coefficient β_{st} and β_{ct} with $\beta_{st} < \beta_{ct}$ relating activity into demand for full-time equivalent health professional hours at time *t*, D_t. **Supply** $S_t = \Sigma_g[\beta_{g,male} male_{tg} + \beta_{g,female} female_{tg}] male_{tg} = (1-\beta^{loss}_{g,male}) male_{t-1g} + malegrads_{tg} + malemigrants_{tg} female_{tg} = (1-\beta^{loss}_{g,female}) female_{t-1g} + femalegrads_{tg} + femalemigrants_{tg}$ S_t: supply of labour hours in year *tg*: age groups $\beta_{g,male}$ and $\beta_{g,female}$: coefficients that represent the number of hours worked $\beta^{loss}_{g,male}$ and $\beta^{loss}_{g,female}$: proportion of the workforce loss every year $malegrads_{tg}$ and $femalegrads_{tg}$: number of graduates $malemigrants_{tg}$ and $femalemigrants_{tg}$: number of migrants	Modelling utilisation and predicted used based on needs $y_i = \sum_{j=1}^{J} \beta_j A_{ij} + \sum_{k=1}^{K} \lambda_k X_{ik} + \sum_{j=1}^{J} \sum_{k=1}^{K} \delta_{jk} A_{ij} X_{ik} + \sum_{l=1}^{L} \gamma_l Z_{il} + \sum_{m=1}^{M} \varphi_m R_{im} + \varepsilon_i$ Allocation of resources: $N_r = \sum_{I} {}_r w_i \hat{y}_i^{+} \Big/ \sum_{I} {}_r w_i$ y_i: utilisation for individual i; A_{ij}: vector of age-sex dummies X_{ik}: vector of additional needs indicators Z_{il}: vector of non-need determinants of utilisation R_{im}: dummy variables for regions *β, λ, γ, δ, ø* estimated coefficient vectors N_r: per capita resource need for residents of each allocation regionw: the survey sample weight for each individual i $w_{i:}$ survey sample weight for individual	- Required supply in year T vs. Required supply in year X => development required supply until T+X - Available supply in year T + Development available supply until T+X => Available supply in year T+X

	Australia	Canada	Netherland
Key factors used	- numbers in the workforce in a given year (by age and sex) - proportion of individuals leaving workforce by sex - number of graduates and migrants - utilisation of healthcare services	- actual and perceived population health status, socio-economic status - demographics - health behaviours - social, cultural, political, contextual, geographical, environmental - financial factors - categories/roles/characteristics of health workers and services, source of supply - production (education + training): target vs. actual needs projected - management, organization and delivery of health services (indirectly contribute to outcomes), formalization/centralization, environmental complexity, amount and quality of care provided, costs associated with delivery of services and outcomes - resource deployment and utilisation - health outcomes: e.g. mortality data, hospital discharge, life expectancy, and disease incidence. (depends on community's situation)	- available supply of GPs (total full-time equivalent) - unfulfilled demand for care - number of GP in training - inflow from abroad - outflow (male/female & projection year) - return on training - labour market return - epidemiological developments - socio-cultural developments - technical developments - substitution
Limitations/ Challenges	**Demand** - binary case-mix - linear demand growth - constant returns - no labour substitution **Supply** - no changes in technology - disaggregated by age and sex **General** - independent supply and demand - no supplier-induced demand	- require extensive data => difficulties in management and maintenance of data collection, delivery system - lack of consistent information on health human resource productivity, workload, utilisation demand and efficacy; and information about educational facilities - capacity to assess health needs, and forecast demand for health human resources- funding for ongoing data and modelling initiatives - compliance vs. flexibility and autonomy of local/regional planner with national strategies - updating model is difficult - the model is more likely to project unattainable service and staff targets	- technically complex: many parameters, heuristics, sub-models and data source - politically complex: multiple policy discussions and stakeholder involvement - intentionally complex: long-term planning, short-term acting, frequent updating
Organisation	National Health Workforce Taskforce Australian Health Ministries' Advisory Council (http://www.ahwo.gov.au/index.asp)	www.hc-sc.gc.ca (Health Canada)	NIVEL (the Netherlands Institute for Health Services Research) http://www.nivel.nl/ Dutch Ministry of Health, Welfare and Sport Dutch Health professional organizations and labour unions

Appendix A(ii): Summary of manpower planning and forecasting models (New Zealand, Scotland, United Kingdom)

	New Zealand	Scotland	United Kingdom
Context	- increasing burden of chronic diseases - lack of collaboration in planning and implementation of health workforce - mental health, rehabilitation and aged care are an emerging a problem	- increase the size of healthcare workforce - aging healthcare workforce - workforce is predominately female and predominately working fulltime	A number of changes in the UK population, service delivery model, and healthcare workforce - demographic - a growing, aging population - NHS funding and budgets - service plans and reconfiguration - policy (locus of care from hospital to community, from NHS to non-NHS) - legislative and regulatory framework - professional education - role definition for each of the professions
Objectives/ Strategic directions	- innovative approaches to workforce development - enhance communication - sector relationships - build a responsible and rational workforce development investment plan (set workforce development priority for mental health, rehabilitation and aged care) - support the healthcare workforce boards and policy makers	- develop and implement multi-disciplinary and multi-agency models of care which are more responsive, accessible and joined up to meet the needs of local communities and ensure efficient utilisation of skills and resources - motivate employees to improve their performance, provide opportunities for them to develop and contribute more - promote the benefits of preventative action and measures of self-care for patients and public across a range of health issues - maximise and wider access to education and training, especially for those at underserved areas	- engage with health sector employers to ensure the authoritative sector voice on skills and workforce development for the whole sector - inform the development and application of workforce policy through research and the provision of robust labour market intelligence - implement solutions which deliver a skilled, flexible and modernised workforce capable of improving productivity, performance and reducing health inequalities - champion an approach to workforce planning and development that is based on the common currency of national workforce competences.
Framework	- increase number of healthcare professionals - train and recruit more health professionals with generic skills, to increase flexibility and respond to the increasing shift towards primary and community-based models of care and integration between institutional and community settings - improve workforce activity linkages in health system, collaboration and economies of scales - develop regionally aligned approaches to professional training and career planning - enable health professionals to take on new tasks, responsibilities, opportunities for further development, and career satisfaction.	- partnership with professional groups to support delivery and development of services - support professional groups to achieve their full personal and professional potential - funding arrangement for professional development and continuing education - encourage sharing between professional groups, and learning from each others across national, regional sectors - provide guideline for better care delivery models, encourage innovative approaches - fund professional development courses - develop better evidence base to inform policies and strategies to help promote retention of staff	- develop workforce plans and strategies for investment - commission undergraduate training and clinical placements - manage post registration and post graduate training - invest in continuing professional development - train and develop wider healthcare workforce esp. nurse and other ancillary team - allocate and monitor investment of education and training funds - collaborate at all levels of the system to plan and develop the workforce for quality
Duration	HWAC: since 2000 HWNZ: since 2009	since 2000s	since 2000s

	New Zealand	Scotland	United Kingdom
Method for supply/ demand	Primary Healthcare Nursing projection modelling **(demand-based)** **Supply:** - projected proportion and distribution of healthcare professionals by age, sex, geographic - entrants to and graduates from education and training programme - retirement, mortality, career change, disability of healthcare workforce **Demand:** - population growth projections by age, gender and ethnicity - population health needs - historical, current, and future changes of services provided - anticipated development of and changes in-patient care practice - impact of current and emerging technologies	**Demand and supply-based plan** **Demand:** - rate of general practitioners - patients contact by sex and age (estimated by changes of characteristics of population) - working time targets and standards and real practice - working time regulations - service utilisation - service levels **Supply:** - destination of GP registrants (age profile; gender profile) - growth of GPs training	No single model/method used, but various in term of regional and local level Example: **England:** - NHS Workforce Review Team: conduct a pilot study to develop demand-side modelling (initially for mental health service) (England) - London Strategic Health Authority: used scenario-based workforce modelling (demand-based) - 6-step Workforce Planning Model (NHS South West) (supply and demand) **Northern Ireland:** - review of each professional group every three years, plan/strategies were made based on supply and demand **Scotland:** - based on Student Nurse Intake Planning project aligned with NHS and non-NHS employers projection (supply) - utilisation of service from Management Information and Dental Accounting System database (demand) **Wales:** - annual approach will be based on national unit linked to local planning process (supply)
Assumptions	- past trends define future trends - demand will increase at twice the rate of population growth	- estimated numbers based on average calculation of past trend and prediction of change of care delivery models, technology - significant work has been undertaken to ensure that workforce targets are consistent with the available resources	- each model applied holds different assumptions
Formulae	**Supply** = Headcounts + net inflow (inflow less outflow) (calculated for each workforce areas) **Demand** = [population growth] * [type of service] * [care delivery models] * [impact of current and future technologies]	Projected demand (Whole time equivalent) = current demand * yearly growth rate Required supply = estimated adequate ratio of supply to demand * projected demand	Supply=current headcounts + net inflow; Demand = population * dentist-to-population ratio,

	New Zealand	Scotland	United Kingdom
Key factors used	- projection of population growth by age, sex - population health needs: based on all types of healthcare services - burden of disease - technology development - models of care - projection of healthcare workforce growth according to population growth - entries to and exits from healthcare workforce - analysis of occupations, specialty - education and training sources	- workforce dynamics (characteristics of workforce development) - demographic changes - technology development - payment scheme - utilisation (service-based) - shrinkage (leave, mortality, retirement)	Depends on model used Example: - number of student intake for a professional training retirement, change of professions, expansion - financial planning for education and training - international recruitment - health indicators, demographic and socio-economic status
Limitations/ Challenges	- difficult to collect and monitor data - lack of financial support in services at rural areas, and which make coordination between care centres difficult. - difficult to evaluate impact of policy changes and health outcomes	- relies on pre and current data - quality of data is an issue - lack of collaborative approaches to workforce planning	- lack of supply-side modelling - lack of linkage between supply and demand projections - potential deficit in current workforce-planning capacity at regional level - most Strategic Health Authorities focused on improving the process, rather than planning capacity **Problems in the system:** - too "top-down" management- service, financial and workforce planning are poorly integrated - poor data to project funding arrangement - medical workforce planning and development is done largely in isolation - lack of long-term strategic commission - quality of education, training, recruitment
Organizations	Health Workforce Advisory Committee (HWAC) http://www.healthworkforce.govt.nz/about-health-workforce-nz/publications-and-reports Workforce Services Reviews	NHS Scotland National Workforce Planning	Department of Health Centre for Workforce Intelligence (http://www.cfwi.org.uk/) Skills for Health

Appendix A(iii): Summary of manpower planning and forecasting models (Japan, Singapore, USA)

	Japan	**Singapore**	**USA**
Context	- shortage of physicians - mal-distribution of medical practitioners in some areas - ageing population - ageing workforce - mismatch of supply-demand in some areas	- high density of doctors, but reported shortages in the public sector due to the low pay and long working hours compared with the private sector - promote medical tourism - import medical workforce, esp. nurses and doctors from Philippine and Indonesia - most of doctors in Singapore are foreign-trained	- shortage in primary care service and staff - nursing shortage - geographical variation in service - inappropriate funding plan - increased demand professional training program
Objectives/ Strategic directions	- to project the demand and supply of healthcare professionals	- increase medical and other healthcare professional training - improve working environment and benefits to attract more overseas healthcare workers - develop programmes to recruit and retain healthcare workforce (esp. professional Development)	- strengthen the Nation's Health and Human Services Infrastructure and workforce - invest in the HHS workforce to meet American's health and human service needs today and tomorrow - ensure that the Nation's healthcare workforce can meet increased demands - enhance the ability of the public health workforce to improve public health at home and abroad - strengthen the Nation's human service workforce
Framework	- train and recruit more health professionals to respond to the increasing shift towards elderly care and integration between institutional and community settings - enable health professionals to take on new tasks, responsibilities, opportunities	- Healthcare Manpower Development Programme for Intermediate and Long-term Care (since 1980) - funding for advanced training skill of local staff (local or overseas institution) - funding for visiting experts' lecture, fellowship programme - set up websites to attract more foreign healthcare workers	- fund medical training scholarships and loan repayment programmes - focus on human capital development - innovative approaches to recruiting, training, develop, retain and support a competent workforce - monitor and assess the adequacy of the Nation's health professions workforce - work with states to develop systems for the training and ongoing professional development, and opportunities for developing professional skills. - improve the cultural competence of the healthcare workforce - foster the use of evidence-based practices in human services to professionalize the field - establish regular evaluation, supervision of supply and demand of healthcare workforce to inform professional development and future action.
Duration	since 2000	since 2006	since 2006

	Japan	Singapore	USA
Method for Supply/ Demand	**Utilisation and supply-based approach** - current and past trend of utilisation (esp. for aging care) - expenses related to healthcare - education and training sources - population development - advancing medical technology - changing treatment patterns - labour market trends	- healthcare professionals to population ratio * Doctors to population ratio: 1:620 (2008); 1:600 (2009); 1:580 (2010); 1:550 (2011) * Nurse to population ratio: 1:200 (2008); 1:190 (2009); 1:170 (2010); 1:160 (2011) - **supply-based model** was used to project healthcare workforce	**Utilisation and supply-based model** **Supply:** - size and characteristics of current workforce (age, gender, work-hours, retirement, distribution, active in-patient care or other activities such as teaching, research) - new entrants and choice of medical specialty - separation from the physician workforce (retirement, mortality, disability, career change) - physicians productivity: hours spent providing patient care, number of patients seen, resource-based relative value scale **Demand:** - population growth - medical insurance trends - economic factors - physician to population ratio - technology, policy changes
Assumptions	- population projections, current patterns of employment and supply - models used are susceptible to measurement error	- assumption: current patterns of new local and non-local graduates, - rates of demand will remain	- baseline assumption: current patterns of new graduates, specialty choice, and practice behaviour continue - distribution of physicians in-patient-care and other activities remains constant
Formulae	stock and flow methods	- The healthcare workforce (doctors, nurses, pharmacists, dentists and allied health professionals) will need to be increased by more than 50%, by 2020.. - Factors being considered include ageing and growing population, and increasing number of healthcare infrastructure. On the supply side, local and overseas graduates and role extension of healthcare professionals were considered.	**Physician Supply Model** $P_{(y+1)} = P_{(y)} + P_a - P_i + P_n$ P(y+1): physicians supply in the year y+1 P(y): physicians supply in the year yPa: physicians remain active Pi: physicians inactive, retired, dead or disable Pn: new physicians graduated from US medical school or international institutions The model also generates Full-time equivalent (FTE) physicians, which is defined as the average hour annual hours worked in-patient care per physician in baseline year. **Physician Requirement Model** - Physicians Requirements = [*Population projections by age, sex, and metro/non-metro*] x [*Insurance distribution by age, sex, and metro/non-metro*] x [*physicians per population ratio by age, sex, and metro/non-metro, insurance and specialty*]

	Japan	Singapore	USA
Key factors used	- population growth rate - healthcare workers to population ratio - utilisation indicators	- number of physicians/nurses - inflow and outflow of healthcare workforce - population growth rate - medical education and training registrants	**Physician Supply Model** - number of physicians in the preceding years (starting with the base year 2000) - number of new US medical students, International medical students - attrition due to retirement, death and disability **Physician Requirement Model** - population projections by age, sex and metropolitan/non-metropolitan location - projected insurance distribution by insurance type, age, sex, metropolitan/non-metropolitan location - detailed physician-to-population ratio
Limitations/ Challenges	- slow adoption of new approaches across healthcare systems - loose control over supply and demand factors due to no central authority - difficulty in funding allocation	- past history may not adequately reflect future requirements - limited variables include in the analysis - overly reliant on ability to recruit non-local professionals	- numerous variables included in the analysis => difficult to control => uncertainty about adequacy of the analysis - no single entity in US in charge of workforce planning- - lack a cohesive approach to workforce shortage
Organisation	Ministry of Health, Labour and Welfare Human Resource Development Bureau	Ministry of Health Human Resource Advisory Board	US Department of Health and Human Services (http://www.hrsa.gov/index.html) American Society for Healthcare Human Resources Administration (ASHHRA http://www.ashhra.org)

Appendix B: Manpower planning literature by healthcare professional group

Doctors

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply models				
Bane et al., 1959 (161)	Stock and flow approach.	Graduates; Number of physicians; Retirees; Work locations;	•Number of physicians per 100000 people •Total output	• Estimates of future needs were projected through analysing the utilisation of services, growth of new types of services.
Craig et al., 2002 (74)	Trend analysis.	Number of specialist anaesthesiologists by age, as of January 1, 2000; Annual certificate numbers, 1971-2000; Estimated needs for anesthesia provider, 1999 & 2006.	•Number of required FTEs •Number of FTE deficits	• Assumption that each anaesthesiologist provides 1 FTE to anaesthesiology workforce underestimates requirement.; • Does not account for anaesthetic service provided by non-specialist practitioners.
Fraher et al., 2013 (162)	Stock and flow approach.	Graduate medical education pipeline; Length of training by specialty; Re-entry; Attrition (Death, retirement and career breaks); Age; Sex; Hours worked in-patient care by age and sex.	•Headcount of surgeons by age, sex and specialty in the United States from 2009 to 2028 FTE of surgeons by age, sex and specialty in the United States from 2009 to 2028	• Does not cover the complementary of physician assistant and nurses; • FTE contributions to patient care were adjusted downward significantly after the age of 65 years; • FTE by age and sex, retirement rates, workforce re-entry patterns and attrition from training stay the same in different specialties; • Only focus on overall supply.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Fehring et al., 2010 (71)	Stock and flow approach.	Age; Retirement; Graduates; Number of total knee and total hip arthroplasties performed per month; Historical incidence of arthroplasty.	•Procedural shortfall	• Selection and information bias through the use of estimates that are based on survey data; • Assumption of baseline scenario and conservative scenario for retirement; • Assumption of baseline scenario and conservative scenario for incidence; • The number of residents entering the workforce will be stable; • All the surgeons will perform joint arthroplasty at the same rate, no matter their experience.
Hilton et al., 1998 (75)	Stock and flow approach.	Number of current supply of physicians; Number of new trainees; Number of licensees expected; Retirement; Population; Number of office-based physicians; Hospital-based physicians; Specialties vs. primary care physicians; Other activities.	•Total number of office-based physicians per 100,000 population in 2001 & 2006 •The number of primary care physicians per 100,000 population in 2001 & 2006 •The number of specialist per 100,000 population in 2001 & 2006	• Limited effect of growth in demand on current number of physicians to 1%/year. • Limited retirement and other losses to 3%/year; Assume 70% retention rate of trainees; • 1.2% of population increase annually.
Joyce et al., 2006 (67)	Stock and flow approach.	Current supply in baseline; New graduates; Immigrants; Re-entrants; Death; Retirements; Attrition exits; Movement between occupations; Number of hours worked per week by age (5-year bands) and sex.	•FTE clinicians (per 100,000) •FTE GP (per 100,000) •FTE Specialist workforce (per 100,000)	• Estimate of parameters used in the model might not be accurate – question of data quality.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Koike et al., 2009 (72)	Trend analysis using multistate life table.	Specialty; Impact of further increase of female physicians Age groups; Place of work.	•Headcount of estimated numbers of physicians by specialty	• The characteristics and status of physicians will continue in the future; • Does not project the FTE number.
Miller, 1993 (76)	Stock and flow approach.	Age distribution; Number of otolaryngologists; Number of otolaryngologists entering practice; Death rates; Retirements; Current production of residents.	•Headcount of otolaryngologists	• Older-than-65 group was excluded from further analysis.
Satiani et al., 2009 (73)	Stock and flow approach, using population and workload analysis.	Current number of certified Vascular surgeons; Number of newly certified per year; Retired numbers per year; Operations needed per 100000 people; Average number of procedures performed per VSN	•Population analysis: Shortage of surgeons in percentage •Workload analysis: Shortage of surgeons in percentage	• Surgeon to population ratio maintained for the 40-year period, number of operations performed annually remain the same, number of years in training remain unchanged.
Demand models				
Craig et al., 2002 (74)	Needs-based model.	Per capita utilisation by age and sex; Population projection by age and sex; Time spent on providing clinical anaesthesia services;	•FTE of physicians	• Lack of direct data on non-clinical anaesthesiologists; • Assume that one full-time, full-year anaesthesiologist equals to 175,000 units of demand; • Assume that the supply meets the demand in the base year.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Etzioni et al., 2003 (11)	Demand/utilisation based model.	Population by age; Age-specific rates of surgical procedures; Relative value units (RVUs).	•Forecasted percept increases in Work RVUs by specialty	• Estimate workload/productivity; • Assume that the surgical demand by age and sex will be stable.
Greenberg et al, 1997 (163)	Demand/utilisation-based model.	Current utilisation rates for ambulatory and in-patient medical; Specialty services, by gender, race, age group, insurance status; Population by gender, race and age.	•Physician headcount required in 2020	• Recent trends will continue into the future.
Harrison et al., 2011 (164)	Demand/Utilisation-based model.	Number of general practice consultations by age and gender; Length consultations; Population projection.	•Increase in GP utilisation •Additional GPs required	• Assume that GPs would work similar average hours per week; • Assume that current primary care model and structure of general practice will remain the same.
Tsai et al., 2012 (165)	Regression-based physician density model.	Mortality rate (under age 5); Adult mortality rate; Life expectancy; Fertility rate; Literacy; Population density; Age structure; Economic growth; Expenditure on health.	•Under the model, countries were labelled as Negative discrepancy or Positive discrepancy	• Cannot use the absolute number to suggest for correction in the healthcare workforce; • Only be used for warning signs of workforce discrepancy
Mixed models				
Al-Jarallah et al., 2009 (166)	Supply: trend analysis; Demand: benchmark.	Population projections; Physician-to-population ratios; The average rate per annum for Kuwaiti physicians and non-Kuwaiti physicians.	•Number of indigenous physician and non-native expatriate physician •Projected requirement for physician •Disparity between need and actual number of physicians	• Projecting demand and supply over a long period leads to uncertainty, did not study age and structure of the physician workforce due the lack of data.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Barber et al., 2010 (69)	Supply: stock and flow approach; Demand: demand/utilization-based model.	Number of students admitted to medical school; Number of residencies available for each specialty; The mandatory retirement age; Immigration rate by specialty; Growth rate for specialists demand; Growth in population;	•Total FTE of medical specialists needed •Ratio specialists/100 000 inhabitants •Deficit/surplus specialists in percent	• Supply model: realistic entry parameters; • Demand model: lack normative standards, assume appropriate staff number.
Birch et al., 2007 (167)	Supply: stock and flow approach; Demand: needs-based framework using Vensim 2002 simulation model.	Number of provider by age and sex; Time spent in the production of services; Size of population by age and sex; Provider-to-population ratio by age and sex of population group; Number of services required by age and sex; Demography; Level of service; Epidemiology; Intensity of work; Technological inputs; Inputs of other types of professionals.	•Headcount of the providers •FTE of the providers •Need follows observed trends by different policy changes	• Assumption of different needs scenarios to look at how it will affect the physician workforce.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Blinman et al., 2012 (168)	Supply: stock and flow approach; Demand: demand-based model.	Headcount by nature of practice; Current supply; Population; National chemotherapy utilisation rate; Optimal workload of new patients seen per FTE MO per year; Number of retirement; Overseas and local training MOs.	•Supply, demand and shortfall of FTE medical oncologists (MOs) •Chemotherapy utilisation rate	• Only the clinical workload of MOs related to chemotherapy was included, some responses were estimated than counted, lead clinicians were surveyed rather than individual MOs.
Chang et al., 2008 (68)	Supply: stock and flow approach; Demand: needs-based model.	Number of new entrants; Current manpower and demographics; Withdrawals by nephrologists (e.g. retirement, death and turnover to other subspecialties); Population; Incidence and prevalence of ESRD and treatment modalities.	•FTE supply, demand	• Assume the probability of wastage for general doctors and internists are small and therefore ignored.
Cooper 1995 (169)	Supply: dynamic model; Demand: demand/utilisation-based model.	Medical students; Retirement; Size of workforce; Utilisation from HMOs; Aging; Technology; Productivity; Demographic factors; Population.	•FTE physician/100000 population (supply and demand)	• Supply: limited by predictions concerning the future number of USMGs and IMGs; • Demand: uncertainty of technology, data reliability from HMOs, HMOs' data not representative of the nation as a whole.
Deal et al., 2007 (170)	Supply: stock and flow approach; Demand: demand/utilisation-based model.	Healthcare utilisation - age & sex; Population projections; Retirement; Mortality rates; Hours of work; Number and fill rates of fellowship slots.	•Number of rheumatologists supplied and needed, by sex, age and specialty	• Supply and demand for rheumatology services are in equilibrium, the number of fellow position will remain static, gender differences will remain static.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Douglass et al., 1995 (171)	Supply: dynamic model; Demand: needs-based model.	Past and current Connecticut non-federal internist supply Present and future Connecticut internists supply and need Contribution of non-physician providers.	•FTE supply •FTE need	• Currently available data for specific specialties; • Uncertain flow of physicians in and out of the province; • Classifying specialty based on service provision; • Calculate the supply and need in Connecticut base on the share of US supply and need.
Greuningen et al., 2012 (172)	Supply: stock and flow approach; Demand: estimation.	Graduates; Attrition; Demographic developments; Epidemiological developments; Socio-cultural developments; Change of working hours; Technical developments; Developments regarding efficiency; Developments regarding substitution.	•Number of health professionals •Total FTE of health professionals	• The basic scenario assumed that the demand will increase by 6.0% due to the demographic developments from 2009-2019; • The parameters on the demand side were estimated by experts, however it was not clearly explained how they were being estimated.
Health Workforce 2025 Volume 1, 2012 (173)	Supply: stock and flow approach; Demand: demand/utilisation-based model.	Graduates; Re-entry; Working hours; Migration; Attrition (Death, retirement & career change); Age; Gender; Utilisation rates.	•Headcount of supply, demand and gap •FTE of supply, demand and gap	• Different assumption based on demand scenario.
HRSA, 2008 (63)	Supply: stock and flow model; Demand: Demand/utilisation-based approach.	Number of physicians age & sex; Graduates; Retirement and mortality by age and sex; Disability and career change; Direct patient care hours; Population projections; Insurance distribution.	•FTE active physician •Increase in demand due to aging and growth	• Limitations include using historical data to estimate future trends; • Assume insurance coverage and type, economic growth, and the increased use of NPCs.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Lee et al., 1998 (174)	Supply: dynamic model; Demand: needs-based model.	Surgeon population; Time spent in direct care; Entry rates of residents; Retirement and mortality rate; Number of office visits; Duration of office visit; Number of procedures; Duration of procedures.	•FTE supply •FTE demand	• Need for large amounts of data; • Accuracy of estimation; • Time and FTEs used as common measure for both supply and demand might be vulnerable to changes in real-life practice and structure of work; • Not able to address distributional issues.
McNutt, 1981 (175)	Supply: dynamic model; Demand: demand/utilisation-based model.	Medical graduates; Practitioner supply; Attrition rates; Morbidity; Prevention; Delphi panel rates.	•Head count of physicians supplied and required by each specialty (Only talked about the concept and analytic framework of the GMENAC model)	• Relied heavily on the Delphi panel to project future demand/utilisation.
Scarbrough et al., 2008 (176)	Supply: stock and flow approach; Demand: needs-based model.	Attrition (Death and retirement); Annual volume of Hepatic-Pancreatic-Biliary (HPB) procedures; Annual number of new HPB subspecialist; Level of fellowship training; Practice patterns of graduating fellows.	•Annual volume of HPB procedures per subspecialist in 2020 •Annual HPB procedure volume per subspecialist in 2020 at current level of fellowship training •Number of fellows needed to train each year to meet demand for HPB surgery	• Reliance on a series of assumptions to determine the current number of practicing HPB subspecialists and the current level of fellowship training; • Assume that none of the fellowship-trained HPB subspecialists first entering the workforce in 2007 would retire, die, or change fields before 2020; • Different scenarios for the projected number of fellows needed to train per year to meet the demand for HPB procedures.
Scheffler et al., 2009 (177)	Supply: trend analysis; Demand: needs-based model.	Number of physicians by country; Projected population.	•Headcount supply, demand, shortage	• Poor data quality in Africa which could undercount healthcare professionals, especially in the private sector; • Supply of physicians is provided from previous estimates and data (Scheffler et al., 2008).
Scheffler et al., 2008 (178)	Supply: trend analysis; Demand: needs-based model and demand-based model.	Historical data on physician numbers 1980-2001; Updated physicians numbers; Economic growth; Historical and projected population; Need-based benchmark: live births	•Supply - per capita physicians •The required headcount of physicians to reach the world health report 2006 goal •Demand for physicians in each country by headcount •Deficit or surplus by headcount	• Need estimated only reflects one aspect of healthcare delivery; • Projection of demand and supply rely on trends of either economic growth or physician per capita.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Shipman et al., 2004 (179)	Supply: stock and flow approach; Demand: benchmark.	Number of paediatricians by age and sex; Annual number of graduating trainees by age and sex; International medical graduates (IMGs); Death and retirements; Population; Current proportion of outpatient office visit by children to paediatricians; Productivity; Change in work effort.	•FTE General paediatricians •Child population	• Uses different key assumptions for projection, mainly have a set rate for different variables; • Assume that 25% of noncitizen IMGs will not stay in the US workforce after completing training.
Smith et al., 2010 (180)	Supply: stock and flow approach; Demand: demand/utilisation-based approach.	Age-, sex-, race-, population projections; Age-, sex-, race-, radiotherapy utilisation rates; Age-stratified and sex-stratified life-tables; Number of current board-certified radiation oncologists, 2009 residency graduates and 2010 to 2013 expected to graduates; Age- and sex-stratified proportion of radiation oncologists practicing full time, part time, and not practicing.	•Total number of patients receiving radiation therapy in 2020 •FTE radiation oncologists in 2020 •Size of residency training classes to have supply equal demand	• Extent the current supply of oncologists can accommodate increased patient volume; • Estimate of modest changes in radiation therapy practice patterns may impact patient throughout without compromising quality, future technologies.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Starkiene et al., 2005 (181)	Supply: stock and flow approach; Demand: needs-based model and demand/utilisation-based model.	Population projections; Mortality; Retirement; Migration; Drop out from training; Enrolment numbers of trainee.	•FTE-to-population ratio by different scenarios in supply and demand	• Used different assumptions to manipulate supply and demand scenarios; • Retirement Scenario 1: The retirement age was set to be 66 years and it was assumed that one fifteenth of the group of FPs aged more than 50 years would retire annually; • Retirement Scenario 2: The retirement age was set to be 71 years and it was assumed that one fifteenth of the group of FPs aged more than 55 years would retire annually.
Teljeur et al., 2010 (182)	Supply: stock and flow approach; Demand: demand/utilisation-based approach.	GP visit rates; Age-sex rates of GP attendance; Population projection 2009-2021; Mortality rate for higher professionals; Work practice; Services provided; Practice structure; Overseas graduates; Education/training; Retirement; Nurse substitution.	•GPs needed to meet population demand •GP numbers by different supply scenarios	• Nurse substitution Scenario 1: Nurses were equivalent to 0.25 FTE GPs; • Nurse substitution Scenario 2: Nurses were equivalent to 0.5 FTE GPs; • Assume that the number of GP vocational training places would increase by 20% in 2011; • Later retirement has been considered; • Lack of regional data resulted in failing to test potential impact of each intervention on geographical differences.

Author, year	Design, model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Weissman et al., 2006 (183)	Supply: stock and flow approach; Demand: needs-based model and demand-based model.	Age and sex distribution of anaesthesiologist population; Employment status (full-time/part-time); Country of medical school education; Last anaesthesiologist residency; Professional status (resident, certified specialist anaesthesiologist); Medical school academic appointment; Historical and projected age distribution and birth rate of the Israeli population; Immigration data on physicians; Physicians required per capita; Number of surgeries per anaesthesiologist.	•Anaesthesiologists per 100000 population •New anaesthesiologists needed	• Based on status quo of 10.8 anaesthesiologists per 100000 population.
Yang et al., 2013 (184)	Supply: stock and flow approach; Demand: population-based analysis.	Population growth; Number of plastic surgeons certified in 2010; Retirement; Graduate; Growth of the number of invasive and non-invasive cosmetic procedures.	•Headcount of practicing plastic surgeons •Headcount of plastic surgeons needed	• Only focus on plastic surgeons in US; • The number of new graduates would be constant; • The number of trainee positions would be static; • All practicing plastic surgeons would retire after 35 years' post residency work.

Nurses

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply model				
Buerhaus et al, 2000 (93)	Using retrospective analysis of employment trends to project long-term age and employment of RNs (Trend analysis)	Forecast of US population through 2020 by age; The propensity of individuals from a given cohort to work as RNs; The relative propensity of RNs t work at a given age.	•Supply projection, 2001-2020. •Annual FTE employment of RNs in total and by single year of age	• Future cohorts will enter nursing at a rate similar to current cohorts; • Changes of the workforce over time only depend on the age of the cohort.
National Health System, 2008 (92)	Dynamic model	Annual growth in 3 year pre reg commissions; FTE/Head count; Attrition; New registrants; International recruitment; Return to practice change; Other joiners; Other leavers;	•Number of registered nurses in 2008-2016	• Annual growth in 3 year pre registration commissions based on WRT assumptions; • FTE/Head count based on historic trend; • International recruitment based on 3-year average;

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Demand models				
Ghosh et al, 2005 (101)	Computer-based model, given certain prescribed patient-nurse ratios (Benchmarking)	**In-patient units:** bad capacity, bed occupancy rate, and the percentage share of patients in each unit according to an accepted patient classification system. **Outpatient Department**: Required physical allocation, Total OPD working days in a year, Total working days/nurse/year; **Operating theatres:** planned OT shifts per week, number of weeks per year, nurses per OT per shift, Total working days/nurse/year; **A&E:** Nurses/shift, Number of shifts in a day, Number of days in a year, Total working days/nurse/year; **Renal dialysis:** Number of sessions/station/week, Number of stations, Number of weeks in a year, Nurse/station, Total working days/nurse/year. Sickness, maternity & deputation leave.	•Overall nurses required adjusted for sickness, maternity & deputation leave.	• No variation included, all parameters are constant over years.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Mixed models				
Al-Jarallah, et al. 2009 (100)	Supply: Dynamic model. Demand: Projected by using the average nurse-to-population ratio for 1994-2006. (Benchmarking)	Supply: Graduates. Demand: Population growth; Nurse-to-physician ratio.	Workforce projection, 2007-2020. Supply: •Number of nurses. Demand: •Number of nurses needed.	• Changes in healthcare policies or nursing education can greatly affect the workforce.
Auerbach, et.al. 2012 (94)	Supply Demand: Utilisation-based model	Hours worked; Utilisation of services; Sector; Education; Marital status; Age group; Poverty; Insurance status; Race/ethnicity classification; Number of RN and NP;	Supply •Number of Nurse Practitioners (NP) and RN specializing in SRH. Demand •Utilisation of SRH services	• Different assumption used for various scenarios to predict the workforce for NPs in SRH. • Only focus on SRH service.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Canadian Nurse Association. 2002 (110)	Supply: Dynamic model. Demand: Need-based model and utilisation-based model.	Supply: Age; Sex; Population; Working hours; Graduates; Retirement; Migration Demand: Population;	Workforce projection, 2011 and 2016. Supply: •Number of RNs by age; •Percentage of RNs employed in Nursing by age. Demand: •Number of employed RNs required.	• Assume the average utilisation of services at any given age remains constant.
Health Resources and Services Administration, 2007 (107)	Supply: Measuring RN supply at the county level taken from the 2000 U.S. Census data. Demand: Utilisation-based model and benchmarking. Simplified Nurse Demand Model from HRSA's models	Population; Number of registered nurse; Short-term in-patients days; Long-term in-patient days; Psychiatric hospital in-patient days; Nursing home unit in-patient days; Outpatients visits; Emergency department visits; Population demographic; RNs per 100 hospital beds; Local nursing wages; Numbers of nursing schools and graduates; Number of new RNs passing exam; Turnover rates; Vacancy rates; Hard-to-fill positions; Staffing ratios; Poor facility outcomes; Case mix and acuity; Worker satisfaction; Turnover leadership;	Demand: •Utilisation: in-patient day. •Staffing ratio: Projected RNs per 100000 age-adjusted population, RNs per in-patient days, and RNs per visits, etc. •RN demand by county: staffing ratio*utilisation.	• Assumes that current staffing patterns at the national level reflect a balance of supply and demand, differences within types of care in factors such as patient acuity do not vary substantially across counties, and RN commuting patterns are similar to the commuting patterns of other workers in terms of county flow and outflow.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Health Resources and Services Administration 2002 (65)	Supply: Dynamic model Demand: Project the required nursing services by forecasting the future staffing intensity. (Benchmarking)	Supply: Graduates; Attrition; Aging of RN workforce; Decline in relative earnings; Alternative job opportunities. Demand: Population growth and aging; Per capita demand for healthcare; Trend in healthcare financing (health insurance); Workload by settings; Staffing intensity	Workforce projection, 2000-2020. Supply: •Number of FTE RNs by states •Employment distribution by settings Demand: •Number of FTE RNs by states	• Applying national estimate to the State level
Health Workforce Australia 2012 (95)	Supply: Dynamic model. Demand: Utilisation-based model and benchmarking.	Supply: Graduates; Migration Retirement; Illness and death; Career change; Working hours; Demand: Area of practice; Productivity; Working hours;	Workforce projection, 2009-2025. Supply: •Projected Number of nurse headcount. Demand: •Acute care nursing: number of bed-days; •Emergency care nursing: number of attendances at emergency departments; •Midwives: calculated from the total number of projected births based on the actual number of births from 2006 to 2008 by population projection ratio from 2009 to 2021.	• Only headcount numbers were presented in the report.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Health Workforce Information Programme, 2009 (185)	Supply: Dynamic model. Demand: Need-based model.	Population growth; Age; Surgical intervention; Career changes; Job patterns; Education; Outflows; Sectors (public and private);	Workforce projection of perioperative nurse (PN), 2009-2031. Supply: •Number of PN by sectors Demand: •Number of PN by sectors	• Only focus on perioperative nursing. • Assumes there will be an increase in the scope of practice for nurses. Also assumes that more non-nursing occupation groups will perform support roles for both medicine and nursing.
Juraschek et.al, 2011 (186)	Supply: Trend analysis. Demand: Linear Regression Model and Trend Analysis.	Population; Age; Personal health expenditure; FTE; RN job shortage ratios; RNs per 100,000 population;	Workforce projection, 2008-2020. Supply: •Number of RN jobs Demand: •Number of RN jobs needed	• Supply: the current RN utilisation, the education of new RNs and the national propensity of an individual to choose nursing as a career is the same across states in coming decades. • Demand: Used 2009 national mean as a baseline of demand model means there is no shortage in 2009 but in fact most studies consider the nation to already experience a large shortage. • Using RN jobs as measurement cannot take working hours into account.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
LeVasseur. 2007 (106)	Supply: Dynamic model Demand: Estimating the demand for FTE RNs by calculating the RN staffing intensity by healthcare setting, e.g. RNs/1,000 in-patient days in in-patient setting and RNs/10,000 population in the physicians' office (Benchmarking)	Supply: Based RN population (2000); Migration; Highest level of education; Attrition; State population and potential pool of applicants to nursing programs. Demand: Population uninsured; Medicaid eligible; Per capita income; Demographics; Geographic location; RN staffing intensity by healthcare setting.	Workforce projection, 2005-2020. Supply: •Estimated number of licensed RNs; •Active RN supply; •FTE RN supply. Demand: •Number of FTE RNs	• The supply and demand sides are independent of each other. • The demand model cannot model the substitution between different types of nurses and between nurses and other healthcare professions. • The demand model cannot capture the interaction between settings.
Author, year	**Design (Model type /analysis)**	**Parameters included (population level or individual level)**	**Outcomes**	**Assumptions & Limitations**
Malyon, et al. 2010 (98)	Supply: Dynamic model. Demand: Need-based model and trend analysis.	Supply: Age; Working hours; Graduates; Migration; Retirements; Maternity; Productivity. Demand: Population Burden of disease and injury; Technology impacts.	Workforce projection, 2006-2022. Supply: •Number of Nurse Headcount; •Number of Nurse FTE; Demand: •Number of Nurse Headcount	• Assumption of no productivity changes; • Assumption of no technology impacts.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Moulton et.al, 2008 (105)	Supply: Trend analysis, Nursing Supply Model (HRSA) Demand: Trend analysis, Nursing Demand Model (HRSA)	Age; Sex; Education; Graduates; Retirements; Population;	Workforce projection, 2008-2020. Supply: •Number of FTE RNs Demand: •Number of FTE RNs	• Assumed that the number of new RN graduates will remain constant over time; Trend and rates remain constant throughout.
Moulton, 2003 (109)	Supply and Demand Trend Analysis	Licensed nurses; Graduates; New license by exam, endorsement; Age; Aging population; Variation in strength of the economy; Part-time/full-time nurses;	Workforce projection for direct care nursing, 2003-2013. Supply: •Number of RNs and Licensed practical nurses (LPNs) Demand: •Number of RNs and (LPNs)	• Trend analysis that means the report assumes the trend will be the same rate though 2013.
Murray, 2009 (99)	The HRSA Nurse Supply and Demand Models, revised and updated in 2004, were used to create the Tennessee's projection. Supply: Dynamic model Demand: Project the required nursing services by forecasting the future staffing intensity. (Benchmarking)	Supply: Graduates; Retirement; Migration; Working hours; Renew rate; Demand: Population; Healthcare market conditions; Economic conditions; Patient acuity in different settings; Working hours;	Workforce projection, 2008-2020. Supply: •Number of RN FTE; •Number of Licensed Practical Nurse (LPN) FTE; Demand: •Number of RN FTE; •Number of Licensed Practical Nurse (LPN) FTE;	• The supply and demand sides are independent of each other. e.g. the projection of demand didn't consider the potential supply of nurses.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Rosenbaum, and Ramirez. 2006 (108)	Supply: Dynamic model. Demand: Convert the population projection into numbers of people needing care (Need-based model); Calculate the required FTE RNs per capita (Benchmarking).	Supply: Working hours; Migration; Nurse education; Attrition; Graduates; Demand: Aging population; Working hours;	Workforce projection, 2006-2020. Supply: •FTE Nursing supply Demand: •Estimated FTE RN demand = the units of healthcare usage in each setting * FTE RNs per unit of healthcare usage.	
Spetz. 2009 (102)	Supply: Dynamic model Demand: RN-to-population ratio (Benchmarking) and future hospital utilisation (utilisation-based model)	Supply: Graduates; Retirement; Migration; Working hours; Population. Demand: Population growth and aging; Working hours; Proportion of RNs who worked in hospital setting.	Workforce projection of RNs, 2009-2030. Supply: •Forecasted FTE supply of RNs; •Forecasted employed RNs per 100,000 population; Demand: •Forecasted FTE demand for RNs; •RNs per capita; •RNs per patient day;	• Do not account for short-term changes, e.g. economic conditions. • The utilisation-based model was only for hospital setting. The total demand was calculated by dividing the Hospital FTE by the proportion of RNs who worked in hospital setting.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Srisuphan et al. 1997 (111)	Supply: Dynamic model Requirement: Health demand analysis: Demand-based model determined by econometric projections. Health service development analysis: Demand-based model for public sector and trend analysis for private sector. Nurse population ratio: Demand-based model projected by estimating future economic and population growth.	Supply: Graduates; Attrition. Demand: Future economic; Population; Staff norms; Death rate; Urbanization; Health insurance coverage; Demand components (e.g. nursing services, teaching, and management).	Workforce projection, 1995-2015. Requirements: •Nurse-Population ratio; •Projected demand for nurses by units; •Projected demand for nurses by fields of practice. Supply: •Expected graduates; •Expected number of RNs.	

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Tomblin Murphy, et al. 2009 (103)	Simulation model for supply and requirement. Supply: Stock and flow approach. Requirement: Need-based model	Supply: Graduates; Migration; Attrition (Death and Retirement) Relocation; Change of profession. Requirement: Population size and profile Level and distribution of health and illness in the population; Risk factors of illness in the population; Level of service; Productivity; Sectors	Workforce projection, 2005-2020. Supply: •Number of new RNs entrants; •Number of exits from the stock over time. Requirements: •Estimates of RN productivity (e.g. number of acuity-adjusted episodes of care per RN FTE per year); •Estimates of the number of RN required.	• The efforts to support the projection would be significantly hindered by the data reliability and availability relevant to the work of RNs. • Sectors included acute care, long-term care, home care, community and public health.
Wisconsin Department of Workforce Development. 2011 (96)	Supply: constant RN-to-population ratios (Benchmark) Demand: constant nurse staffing intensity and healthcare usage by employment setting and by age. (Benchmark)	Supply: Graduates; Change in labour force participation; Retirement; Death and disability; Migration; Demand: Staffing intensity; Healthcare use by setting and by age;	•Workforce projection, 2010, 2015, 2020, 2025, 2030, 2035. •Headcount and FTE of RNs for direct patient care, broad nursing workforce.	• Assumed that the 2010 RN-to-population ratios would remain constant. • Better data required to determine quality of RN FTE. • Severity of illness or demand by diagnosis.

Dentist

Author, year	Model type/analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply models				
Chrisopoulos and Teusner, 2008 (81)	Stock and flow	Baseline number of dentists; Australian university Graduates; Overseas entrants; Return to practice (RTP): return from overseas, return after cessation of practice; Migration; Retirements Death; Alternative career; Study and parental leave.	•Number of dentists; •Dentists-to-population ratio.	• Hard to predict the trends in the future, practice activity of new graduates trained by new schools may be different from previously observed patterns.
Grytten and Lund, 1999 (82)	Dynamic model	Retirement; New entrants;	•Net change in man-labour years 1999-2015	• Assuming the number of new entrant remains constant.
Guthrie, et.al., 2009 (80)	Dynamic Model Plateau, linear, and exponential increases for new graduates; population growth was projected to be linear.	Productivity; Gender mix; Retirement rate; Projection of the number of graduates; Number of new dental schools ; Population growth.	•No. of dentists per 100,000; •Dentist-to-population ratio.	• Assumes that the dental services are delivered largely through private markets subject to the effects of supply and demand and that enrolment in dental schools reflects the rate of return of a career in dentistry in comparison to other options for college graduates

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Saman, et.al., 2010 (78)	Poisson regression modelling and geospatial analyses, System Dynamic Model (iThink, iSee Systems, Version 9.1)	Number of dentists retiring per year; Number of dentists entering profession; Population estimates.	•Number of dentists entering profession; •Dentist-to-population ratios	• The dentist-to-population ratio is not a sufficient measure by itself. • Fixed retirement rate at 82 per year, and fixed incoming rate at 55 per year.
Solomon, 2009 (79)	Dynamic Model	Number of graduates; Gender ratio; Retirements; Population; Specialists; Full time and part time.	•Number of dentists working full-time and part-time; •Number of dentists by specialty status; •Number of dentists per 100,000 populations.	• The paper isolates the different parameters and looks at it differently, does not tie in the parameters together
Spencer, et al. 1993 (83)	Dynamic model	Number of new surgeons per year recruited; Wastage rates.	•Number of surgeons; •Population-to-surgeon ratio.	• Wastage rates are not explicitly given, so assumptions not easy to ascertain
Demand models				
Morgan et al. 1994 (85)	Need-based and demand-weighted method.	Age-specific Decayed, missing and filled teeth (DMFT) rates; Prostheses rates; Rates for other dental procedures (not listed); Population projection;	•Required operator-to-population ratio	• Assume DMFT would decline, but at different rates for different age groups, and also rate of decline will decrease. • Assume prosthetic needs would increase. • Other assumptions for changes in demand.
Nash et al. 2002 (84)	Utilisation-based model	Population projection; Assumed yearly % increase in utilisation	•Number of endodontists required	• Assuming different scenario for utilisation increase.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Mixed models				
Australian Research Centre for Population Oral Health, the University of Adelaide, South Australia. 2010 (86)	Supply: stock and flow; Demand: Utilisation-based model.	Supply Recruitment; Retirement; Death; Outflow overseas; Cessation of practice; Practice sectors Demand: People with OMF diseases or conditions; Population.	Supply: •Number of OMF surgeons; •Practicing OMF surgeons per 100,000 populations Demand •Number of services.	• Only focus on Oral and maxillofacial surgeons (OMF). • In/out-flow probabilities stay constant over time. • Changes in demand not directly linked to external factors, e.g. technological advance or increased Medicare funding
Beazoglou, et.al., 2002 (89)	Supply: Dynamic model. Demand: Utilisation-based model.	Specialty distribution; Retirement; New entrant; Types of auxiliaries employed; Population; Income of population; Socio-demographic characteristics Productivity;	Supply •Number of dentists Demand: •Per capita utilisation; •Population-to-dentist ratio; •Number of dentists; •Number of dentists needed to maintain current levels of access to care.	• Assumes that the past rate of productivity improvement will continue for the next 10 years, low sampling due to national surveys. • Population not stratified. • Demand proxied by national expenditure on dentistry
Brown, et al. 2007 (88)	Trend analysis and need-based model	Supply: Female dentists; Productivity; Practice patterns; Demand: Population; Economic buying power; Knowledge and appreciation of dental services; Amount of disease;	Supply: •No of dentists. Demand: •No. of dentists needed.	• Supply: Considered both adjusting and not adjusting for productivity increase.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Gallagher, et al. 2010 (87)	Supply: Trend analysis and dynamic model. Demand: Utilisation-based model.	Supply: percept yearly increase over the previous 9 years; Short-term recruitment drive of over 1,000 dentists; Increased dental student intake; percept of time devoted to older people; percept devoted to NHS patients; percept women dentists; Number of dental hygienists and therapists and clinical dental technicians (CDTs). Demand: Rate of edentulousness; Dental attendance pattern; Treatment rates; General dental services (GDS). Treatment times Treatment type	Supply: •Number of WTE dentists; •Shortfall or surplus of WTE dental staff (not just dentists) Demand: •Total number of treatments; •Total demand for treatment hours; •Per capital demand.	• Supply of government dentists only. • Made various assumptions on which treatment can be performed by hygienists, therapists, and CDT. • Demand, only focus on the population aged over 65.
Try, 2000 (90)	Supply: Dynamic model. Demand: Utilisation-based model.	Supply: Graduates (net inflow); Working hours; Female dentists; Productivity; Demand: Population; Patterns of disease; Dental diagnosis; Age-sex-specific no. of courses of dental treatment;	Supply: •Whole Time Equivalent (WTE) of dentists. Demand: •Number of courses of treatment; •Courses of treatment per WTE dentist.	•Assumed that the proportion of female stays the same. •Assumed that Part-time working becomes more common.

Author, year	Design (Model type /analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Waldman, 1995 (91)	Simple calculations	Demand: Population projection (state-wise) Population : dentist ratio Assumptions on retirement	Supply: •Number of new periodontists available to practice Demand: •Number of active periodontists needed; •Number of new periodontists needed (to replace retirement);	•Only focus on periodontal patients; •Assumed that 18.6% of graduates are not from the US and will go back. •Assumed that in 2020, all dentists ≥ 40 in 1991 will have retired/died. All dentists < 40 still practicing

Pharmacist

Author, year	Design Model type/ analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply models				
Bond, et al. 2004 (114)	Dynamic model	Graduation; retirement	•Net increase in pharmacists from 2000-2020 •Increase in pharmacists who complete residencies from 2000-2020	•Data from a survey in 1998 may not be representative of the healthcare in 2020.
Cooksey, et al. 2002 (116)	Dynamic model	Graduation; Workload (average number of Prescriptions dispensed annually); Working hour; Productivity increase; Percentage of female pharmacist	•Projected pharmacists per 100,000 population ratio in 2005. •Projected female pharmacists (%) in 2005.	•No analysis of urban or rural practice
Johnson, et al.2009 (112)	Dynamic model Pharmacist to population ratio.	New graduate and training capacity; Increasing number of female pharmacist; working hour; Reference period: 2000-2008	•To project target workforce in 2008-2020 by using FTE measures.	•FTE definition: •One who works average 1890 hours per year (40 hours per week times 47.2 weeks per year)
Knapp and. Cultice, 2007 (113)	Stock-flow model	Age; Retirement and death; Graduates; Working hour; Number of female pharmacist Parameters included (population level or individual level)	•Age and gender based pharmacist supply projection 2004-2020.	Assumption: •All the pharmacists would retire by age 75. •The increase of female pharmacist percentage would continue.

Demand models				
Bond, et al. 2004 (115)	Trend analysis (clinical pharmacist)	Pharmacist time (hrs./wk.); Pharmacist time (min/patient); Number of patients who received each decentralized clinical pharmacy service; Working hour;	•Total No. of Clinical Pharmacists FTEs per Hospital needed in 2020 •Total No. of Clinical Pharmacists FTEs needed in 2020	•Data from a survey in 1998 may not be representative of the healthcare in 2020.
Johnson, 2008 (117)	Trend analysis	Graduation rates; Residency training	•Projected the no. pharmacists needed in 2020	•No detail of pharmacist-to-population ratio; no data of gender difference
Meissner, et al. 2006 (118)	Demand/utilisation base	Medicare Part D (Drug coverage); ADI (Aggregate Demand Index); Percentage of costs paid by third-party payer; prescription volume; pharmacist-to-technician ratio; Direct-to-Consumer (DTC); mail order; graduates; retirement; pharmacist wages;	•Projected Aggregate Demand Index (ADI) for 2009. •Prediction of no. of pharmacists needed in 2010. •Prediction of pharmacist shortage in 2020.	•Mainly focusing on drug coverage, not considering other services provided by pharmacists and the expanding roles.

Author, year	Design Model type/ analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Mixed models				
Department of Health and Ageing, Australian Government. 2007 (107)	Dynamic model Demand utilisation model	Supply: Working hour; Graduates; Immigration and emigration; Retirement, death and disability; Inactive workforce Demand: Population growth and ageing; Working hour; Sex- and age-specific ratios of scripts to persons per annum; Productivity of dispensing workforce; Technician-to-pharmacist ratio; Technician equivalence to pharmacist; Community pharmacy share of total service; Further expansion of the role of both hospital and community pharmacist; Number of people attending hospitals; The ratio of pharmacists to hospital separations(discharge or death);	Forecast on annual supply of pharmacist through 2025. Supply: •Total Graduates Active and inactive % (2006) •Active •Inactive •Working outside pharmacy workforce Forecast on Demand: •Community pharmacist •Hospital pharmacist	•Unidentified variables; •Insufficient magnitude of change for some variables, e.g. global financial crisis. Assumption: •2.48% population growth; Community pharmacist: •Ratio of technicians to pharmacists would increase to 0.3 by 2025; •Scripts to persons increase by 0.5% per annum; •Dispensing productivity stays constant. Hospital pharmacist: •Highest estimates of future growth; •With declining ratio of separations to hospital pharmacists (ceases in 2012)

Author, year	Design Model type/ analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Fraher, et al. 2002 (123)	Trend analysis Dynamic model.	Demand: Population growth and ageing; Insurance (prescription drug coverage); Direct-to-consumer (dtc) advertising; Supply: Age; Gender; Working hour; Graduates	Demand: •Prescriptions dispensed per population Working hour per week (1989-1998) •Male •Female	•Not projection model
Health Resources and Services Administration. (HRSA) 2008 (121)	Demand/utilisation base Dynamic model	Demand: Population growth and aging; New and more complex pharmaceuticals; Evolving societal attitudes; Increased affordability and Availability of generic drugs; Increase in pharmaceuticals for Chronic conditions; Role of pharmacist; Supply: Number of graduates (local and overseas); Male-female ratio; Working hour; Attrition	•FTE shortfall projection •Examine the adequacy of previous pharmacist supply projection. •Projection for total pharmacist supply. •Projected male-to-female ratio in workforce.	Assumption: •Moderated prescriptions /capita growth; •No growth in educational capacity •Factors such as technology development and the number of graduates are uncertain.

Author, year	**Design Model type/ analysis**	**Parameters included** **(population level or individual level)**	**Outcomes**	**Assumptions & Limitations**
Health Resources and Services Administration. (HRSA) 2000 (126)	Trend analysis	Demand: Volume of prescription medication dispensed (in different settings); Population growth and aging; Increased third-party prescription coverage; Growth of the economy; Expending roles; Introduction of new and innovative drug therapies; Direct-to-consumer marketing; Increased number of prescription providers Supply: Graduates; Male-female ratio; Losses due to death, retirement and leaving practice; Region; Working hour	•Supply of Active Pharmacists (pharmacists per 100,000 resident U.S. population) •Per cent of female active pharmacists	•No projection of the demand for pharmacists.
Knapp, et al. 2002 (187)	Trend analysis Dynamic model	Demand: Unemployment rates; Retail prescription growth rate Supply: Number of graduates	•Looked at ADI trend from year 1999=2010 •Pearson Correlation between ADI and below factors: •Unemployment •Graduates •Prescription growth rate	•Data unavailability, e.g. retail prescription data for 2010 and actual graduate data for 2010.

Author, year	Design Model type/ analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Knapp, et al. 2005 (124)	Trend analysis	ADI (5-point rating system): 5= high demand for pharmacists, difficult to fill positions, 4 = moderate demand, some difficulty filling positions, 3 = demand in balance with supply, 2 = demand is less than the pharmacist supply available, and 1 = demand is much less than the pharmacist supply available.	•Rating distribution among different regions:	•The usefulness of the ADI is limited by the fact that panellists may choose different ratings for the same scenario. •Replacement panellists may not rate the severity of the shortage the same as did the original panellists within the same organization.
Knapp. 2002 (125)	Dynamic model	Graduation; Working hour; improvement of therapy; growth of distance therapy; increased intensity of hospital; growth in size and complexity of hospital system; Functional area (order fulfilment, primary care, secondary & tertiary care and non patient care)	•Current use of FTE pharmacist 2001 •Projected need for FTE pharmacist 2020 •Total estimated FTE supply •FTE pharmacist shortfall	•Mainly about the factors needed to be considered; •Projection model was not clearly described.
Koduri, et al. 2009 (120)	Benchmark Dynamic model Design Model type /analysis	Pharmacist to population ratio Expanded roles; Prescription volumes growth; Population growth and aging; Insurance coverage; DTC Marketing; Expiring drug patents;Attrition Number of graduates; Working hour; Gender FTE adjustment	•Projected future trends for FTE demand and supply. Outcomes	Assumptions: •79 pharmacists would enter the field each year (in Utah); •Each female pharmacist provides 0.79 FTE of pharmacy services;

Radiographer

Author, year	Design Model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply model				
Reiner, et al. 2002 (188)	Supply description	Type of facility; Facility size; Modality;	•Average FTEs •Average number of FTE for different modalities •Radiography •CT •Ultrasonography •MRI •Nuclear medicine •Mammography •Interventional/angiography	Limitations: •Only give out the average FTE numbers in different types of facilities; •Do not have a trend of FTE numbers.
Wing, et al. 2009 (146)	Age cohort flow model	Population growth; New entrants; Attrition; Age; Working hour;	•Projection of FTE Supply of Radiologic Technologists •Status Quo Projection •Projection on radiologic Technologists per 100,000 Women	Assumptions: •Future resource inputs proportional to current practitioner-to-population ratio. Limitations: •Do not account for productivity increase; •Only focus on mammography.
Mixed model				
Bingham, et al. 2002 (189)	Demand: Trend analysis Supply: Trend description	Demand: Extension of NHS Breast Screening Programme from females; skill mix (radiographer assistant); population ageing and growth; WTE Supply: Graduates; Working part-time and work-life balance; Retirement; Student attrition; Career progression	•Projection of overall radiography workforce demand (2002-2006 plan): •Diagnostic •Therapeutic Projection in Supply: •overall radiographers •diagnostic radiographers •therapeutic radiographers •Projected supply against projected demand (2002-2006)	Assumptions: •8% of attrition rate for radiographer students; •All radiographers would retire on earliest eligible retirement age (60 years); •Workforce capacity lost due to increase of part-time working and work-life balance (1.75%), would increase to 2.15% (0.1% per annum.

Author, year	Design Model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Centre for Workforce Intelligence. 2012 (147)	Trend analysis	Data from DH: Age; Graduates; Field of practice; Training attrition; Retirement; Ageing population; Increased demand in related groups;	•Project increase in demand •Projection available workforce supply from 2010 to 2016 in headcount and FTE	Limitations: •Only focus on diagnostic radiographers.
Patterson, et al. 2004 (190)	Demand: Population projections Supply: Trends description	Demand: Aging workforce and population; Hospital radiographer employees and vacancies Supply: Total license grows; Retirement; Proportion of active licensees currently practicing; Aging workforce and population; Education capacity	Supply: •Active licensees (currently practicing) •Projection on retirement •Demand (Vacancies)	Assumptions: •A demand of 69.0 providers per 100,000 populations. Limitations: •Scarcity of data related to the state's radiographer workforce; •Size of radiographer workforce is small, making the projections more volatile. •Unavailable data, e.g. FTE, migration in and out of state. •The data of demand projection was based on hospital radiographer only. •Active license may not be able to represent the active practitioners.
Victorian Department of Health. 2010 (191)	Demand: demand/utilisation model Supply: Stocks and flow model	Working hour; Graduates; Attrition; Immigration; Adjusted training requirement;	•Projected FTE Demand: 2009 - 2030 •Projected number of graduates: 2010-2029 •Projected FTE Shortage (based on current trends in workforce supply)	Limitations: •Assuming that no significant changes in radiation technology;

Optometrist

Author, year	Model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply models				
Bellan, et.al. 2007 (192)	Dynamic (Stock and flow) model	Retirement; Death; Emigration; Age; Sex; Graduates; Population.	•Number of FTEs; •FTEs per 100000 populations; •Percentages of female FTEs.	•Assumes a status quo scenario in terms of attrition and gain factors.
Demand based utilisation models (includes 'need', 'requirement' etc.)				
Tuulonen, et.al. 2009 (137)	Computer simulation model using system dynamics approach	Number of cataract, glaucoma, diabetic retinopathy, and macular degeneration; Cost of those disease; Number of ophthalmologists; Number of physicians; Population data	•Number of patients; •Service increase (e.g. Cataract surgery and Bilateral surgery)	•Different number of assumptions based on what kind of disease they are looking at, have various scenarios
Mixed models				
Australian Institute of Health and Welfare. 2000 (193)	Trend analysis	Age; Number of optometrists; Number of optometrists; Migration; Sex; FTE; Population demographics; Graduates; Utilisation of services;	Supply: •Number of FTEs optometrists; Demand: •Number of FTEs needed;	•Assume that there will be no significant change from the current pattern of use of optometrist services, the number of graduates, workforce participation and average number of services per optometrist.

Author, year	Model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Kiely, et al 2010 (194)	Supply: Dynamic model Demand: Utilisation-based model	Graduates; Retention rates; Immigration; Age; Attrition; Population; Service utilisation rates	Supply: •Number of FTEs; •Percentage of female optometrists. Demand: •Number of FTEs required	•Assumes different scenarios for practice and how it affects supply and demand.
Lee, et.al 1998 (195)	Supply: Unclear Demand: Need-based model	Subspecialty; (not very specific on how they calculated)	•Number of FTEs by subspecialty	•Does not specifically show how the FTE were calculated with certain parameters
Pick, et.al. 2008 (141)	Trend analysis	Retirement age and rates; Graduates; Retention rates; Number of ophthalmologists; Service hours; Population	Supply: •Total number of ophthalmologists Demand: •Require number of ophthalmologists	•Assumes no change to working hours or the number of trainees, lack full-time equivalent data for the workforce, did not collect gender-specific data for the workforce, did not consider overseas

Medical Laboratory Technician

Author, year	Model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply models				
Canadian Institute for Health Information (CIHI) 2010 (131)	Supply description	Graduates; Working hours; Age; Gender; Pass rate of the certification examinations; Field of practice; Place of employment;	•FTE of active registrations in the previous years; •Proportion of professions by field of practice.	Assumptions: •Standard full-time weekly hours of 37.5 hours.
Mixed models				
Health Resources & Services Administration2005 (196)	Supply and demand:	Supply: Population; Graduates; Career attraction (wages and career growth); Demand: Demographics; Changing biomedical and information technologies; Utilisation of laboratory test;	•Shortages by types of workers and geographic area.	Limitations: •No numbers of supply and demand.

Chiropractor

Author, year	Model type /analysis	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply models				
Davis, et al. 2012 (129)	Supply description	Geographic variation; Age; Adult population; Population educational levels;	•Total number of Chiropractors; •Chiropractors per capita.	Limitations: •Lack of information about working hours; •Only included the chiropractors in Medicare.
Davis, et al. 2009 (130)	Supply description	Age; Adult population; Graduates;	•Total number of chiropractors; •Chiropractors per 10,000 adult population (age>18).	Limitations: •Lack of information about working hours and number of visits.
Mixed models				
Institute for Alternative Futures 2005 (128)	Supply: stock and inflow Demand: need-based model	Ageing; Adult population; Graduates; Retirement; Technology; Conditions treated (e.g. low-back pain, neck pain); Types of practice (e.g. solo private practice)	•Percentage of using chiropractic care annually (age>18); •Percentage of chiropractic care provided to patients below 18 annually; •No. of practicing chiropractors; •Patient visits per week.	Assumptions: •Four alternative future scenarios were being described and used for projection.
Whedon, et al. 2012 (127)	Supply and utilisation description	Geographic variations; Population (aged 65 to 99);	•Chiropractors per 100,000 population (2008); •Annual services per chiropractic user; •Chiropractic users per 1000 Medicare beneficiaries.	Limitations: •The chiropractic use may be underestimated due to the availability of chiropractic service in veteran's administration health service.

Physiotherapist

Author, Year	Design (Model/type analysis)	Parameters included (population level or individual level)	Outcomes	Assumptions & Limitations
Supply models				
WRHA, 2002 (135)	Dynamic Model	Position/vacancy data; Retirement data; Graduates; New registrants	•Vacancy percentage by Equivalence of Full Time	•The calculation of FTE, it assumed that all persons employed were full time. •It is not known whether any of the positions are filled by therapists working at more than one location.
Mixed models				
Breegle, 1982 (144)	Supply: Dynamic Model Demand: Trend Analysis Need Model	Population; Number of patient visits a year; Average admissions; average length of stay; Possible outpatient visits per year; Estimated home-bound patient visit needs Practitioners; Graduates;	•Ratio of PT per 10,000 Population	•Trend analysis: assuming factors influencing the historical trend remain constant. •Health-Needs Method: assuming one third of the possible visits were physiotherapy related, non-institutionalized people received 0.87 home visits. •Supply based on the historical data.
American Physical Therapy Association, 2012 (197)	Supply: Dynamic Model Demand: Linear Regression Analysis	Number of licensed PT; Graduates; International PT; Attrition/retirement rate; Working hour per week; Population with insurance; Vacancy rate	•Full Time Equivalent	•Number of international PT will remain constant. •Constant attrition rate. •The percentage of insured population is based on current rate. However the percentage can change based on the Affordable Care Act. •Vacancy rate only reflects the situation in 2010.
Zimbelman, 2010 (142)	Supply: Dynamic Model Demand: Linear Regression Analysis	Number of PT available job vacancy; Projected population; Personal healthcare expenditure(PHE); Likelihood of being employed; Population; Baseline number of PT	•Shortage ratios per 10,000 people	•The demand model is determined only by age and population growth. 2. Assumption of linear growth was made; •Does not incorporate workplace settings, part-time or full-time employment status;

Occupational Therapist

Author, year	Design (Model type/analysis)	Parameters included	Outcomes	Assumptions & Limitations
Supply models				
Salvatori et al, 1992 (134)	Dynamic Model	Population level data: Actual 1988 employment data; annual inactivity rate; Graduates; Immigration; Re-entry figures; A part-time to full-time FTE ratio	•Number of Occupational Therapists	•Numbers may not be accurate. •Many rates kept constant over years.
WRHA 2002 (198)	Dynamic Model	Individual level data: Current position and vacancy, predicted new graduates, Past retention rate for new graduates, new registrants over the past 5 years, retirement rate.	•Vacancy rate by Equivalence of Full Time	•Information was based on previous data and representing status at one point in time, and only based on requirements for the year of 2001. •Difficult to measure the impact of the availability of work within private sector, with the possibility of improved benefits and flexibility.
Demand based utilisation models (includes 'need', 'requirement' etc.)				
Mirkopoulos et al, 1989 (133)	Demand Analysis by growth per year	Population level data: Current number of paid full-time and part-time OT's, Vacancy numbers, Attrition rates in physiotherapy, hospital average growth rate, Home care average growth rate for OT.	•Full Time Equivalent	•It was assumed that the factors affecting attrition would be very similar for physiotherapy and occupational therapy. •Baseline data didn't represent the whole picture, therefore there was underestimate of the true requirement projection.
Mixed models				
Morris 1989 (136)	Supply: Dynamic Model Demand: Analysis by growth per year	Individual level data: Predicted number of additional positions by respondents from different sectors, Projected population in Georgia, national population ratio, Average annual number of graduates between 1980-1986.	•Full Time Equivalent	•Future demand was based on professions prediction. •All Georgia graduates accept employment within the state, and no separations from the work force occur.