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Implications of long-term care capacity response policies for an aging population: A simulation analysis

John P. Ansah[a,*], Robert L. Eberlein[a], Sean R. Love[a], Mary Ann Bautista[a], James P. Thompson[b], Rahul Malhotra[a], David B. Matchar[a,c]

[a] Program in Health Services and Systems Research, Duke-NUS Graduate Medical School, 8 College Road, Singapore 169857, Singapore
[b] Department of Social Science and Policy Studies, Worcester Polytechnic Institute, 100 Institute Road, Worcester, MA 01609, USA
[c] Department of Medicine, 3703 Duke University Medical Center, Durham, NC 27710, USA

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ABSTRACT

Introduction: The demand for long-term care (LTC) services is likely to increase as a population ages. Keeping pace with rising demand for LTC poses a key challenge for health systems and policymakers, who may be slow to scale up capacity. Given that Singapore is likely to face increasing demand for both acute and LTC services, this paper examines the dynamic impact of different LTC capacity response policies, which differ in the amount of time over which LTC capacity is increased, on acute care utilization and the demand for LTC and acute care professionals.
Methods: The modeling methodology of System Dynamics (SD) was applied to create a simplified, aggregate, computer simulation model for policy exploration. This model stimulates the interaction between persons with LTC needs (i.e., elderly individuals aged 65 years and older who have functional limitations that require human assistance) and the capacity of the healthcare system (i.e., acute and LTC services, including community-based and institutional care) to provide care. Because the model is intended for policy exploration, stylized numbers were used as model inputs. To discern policy effects, the model was initialized in a steady state. The steady state was disturbed by doubling the number of people needing LTC over the 30-year simulation time. Under this demand change scenario, the effects of various LTC capacity response policies were studied and sensitivity analyses were performed.
Results: Compared to proactive and quick adjustment LTC capacity response policies, slower adjustment LTC capacity response policies (i.e., those for which the time to change LTC capacity is longer) tend to shift care demands to the acute care sector and increase total care needs.
Conclusions: Greater attention to demand in the acute care sector relative to demand for LTC may result in over-building acute care facilities and filling them with individuals whose needs are better suited for LTC. Policymakers must be equally proactive in expanding LTC capacity, lest unsustainable acute care utilization and significant deficits in the number of healthcare professionals arise. Delaying LTC expansion could, for example, lead to increased healthcare expenditure and longer wait lists for LTC and acute care patients.

* Corresponding author. Tel.: +65 6601 1215; fax: +65 6534 8632.
E-mail addresses: john.ansah@duke-nus.edu.sg (J.P. Ansah), bob@astutesd.com (R.L. Eberlein), sean.love@duke-nus.edu.sg (S.R. Love), maryann.bautista@duke-nus.edu.sg (M.A. Bautista), jpthompson@wpi.edu (J.P. Thompson), rahul.malhotra@duke-nus.edu.sg (R. Malhotra), david.matchar@duke-nus.edu.sg (D.B. Matchar).

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1. Introduction

Between now and 2050, the number of individuals 65 years of age and older in Singapore is projected to rise from less than half a million to over one and a half million [1,2]. As the population of older individuals grows, the demand for long-term care (LTC) services, consisting of home- and community-based services and institutional care, is expected to increase considerably [3]. Already, Singapore is experiencing a shortage of healthcare professionals across care venues [4,5], and the wait list for nursing homes is sizeable [6].

Keeping pace with rising healthcare demand poses a key challenge for policymakers, and the Singapore Ministry of Health (MOH) and the Agency for Integrated Care (AIC; the agency responsible for the placement of individuals with LTC needs) are looking for ways to address the growing demands. In order to minimize LTC costs, Singapore has adopted a LTC policy that encourages individuals to "age in place" [7,8]. As a result of this policy preference, it is estimated that, by 2030, about 90 percent of elderly individuals with disabilities will reside at home without LTC services due to inadequate nursing home beds supply and relatively low uptake of home- and community-based services [9], partly due to the availability of less costly albeit untrained foreign domestic workers (FDWs). Given the disproportionately high healthcare utilization rate of older individuals [10–15], especially for those with disabilities [16], the demand for acute care services is expected to rise as greater numbers of older individuals rely on inpatient hospital stays, outpatient services, and emergency room visits to meet their LTC needs.

Accordingly, Singapore is planning a rapid expansion of its acute care sector, including tripling the number of community hospital (i.e., hospitals that provide short-term therapy and treatment following discharge from an acute hospital) beds and increasing the number of acute hospital (i.e., those intended for intense medical treatment and surgeries) beds by 30 percent by 2020 [6]. However, the expansion of the LTC sector is occurring more slowly. Although the AIC is working on developing a range of home- and community-based services, including day rehabilitation centers, day care centers for dementia patients, and home medical and nursing care, the capacity of these services remains low given the number of Singaporeans aged 65 years and older. In addition, relative to the projected number of individuals with nursing home care needs [17], the Singapore government has proposed only modest increases in the number of nursing home beds between now and 2020 [6].

Given that Singapore is likely to face increasing demands for both acute and LTC services, this paper examines the dynamic impact of different LTC capacity response policies (i.e., based on the amount of time taken to increase LTC capacity) on acute care utilization and the demand for LTC and acute care healthcare professionals. Although this study focuses on the Singapore context, the general insights presented herein are potentially broadly applicable to other countries undergoing a similar demographic transition, including, among others, Japan, South Korea, and Taiwan [18,19].

2. Methods

Based on discussions with healthcare planners from the Singapore MOH as well as care providers, patient placement agencies and representatives of LTC services, a System Dynamics (SD) model [20,21] was developed to capture and represent the interaction between persons with LTC needs and the capacity of the healthcare system to provide care. SD offers a practical approach to engaging stakeholders in understanding the behavior of real-world systems over time in a way that allows alternative policies and scenarios to be tested systematically in order to answer both "what if" and "why" questions [22].

A substantial and expanding academic literature supports SD models as being useful in assisting policy formulation in healthcare and addressing the dynamic complexity that characterizes many public health issues [22–27]. SD modeling has been applied to issues of population health since the 1970s [22] and, more recently, has also been applied to human resource issues in healthcare. For example, Barber and López-Valcárcel [28] used an SD model to simulate the evolution of supply and demand of medical specialists in Spain, and Masnick and McDonnell [29] used an SD model to link population and medical needs to the workload of a clinical workforce.

2.1. Model structure

The model structure used in this paper represents the demand and supply of LTC services which is key to understanding the impact of a demand–supply gap on acute care utilization and the demand for healthcare professionals (Fig. 1; see Appendix, Table 1 for a complete list of model equations and inputs). The use of care services by LTC patients (i.e., persons with LTC needs) is the main interest in this model. Evidently, acute care services are also used by other patients. However, having assumed that the demand for acute care by persons without LTC needs would not change over the simulation period and that the focus of the work was on the changes in outcomes (i.e., total acute care visits, total professionals needed, deficit of LTC professionals, and deficit of acute care professionals) attributable to LTC capacity response policies, the demand for acute care by persons without LTC needs did not vary in the model. Given this assumption, the numbers derived from the SD model present the best-case scenario since any 'competition' or increase in demand from persons without LTC needs will result in an even graver situation. Results are presented on a per-year basis; however, the model is simulated in continuous time with a solution interval of 1/16 year.

In the model, the population of interest (i.e., persons with LTC needs) is comprised of elderly individuals (aged 65 years and older) who have functional limitations that require human assistance. Naturally, admission to LTC facilities depends on the availability of such facilities and can increase only when LTC capacity increases. LTC capacity (supply) is modeled as a delayed response (reflective of the time required to change capacity) to the number of persons with LTC needs (demand). In the model, a shorter

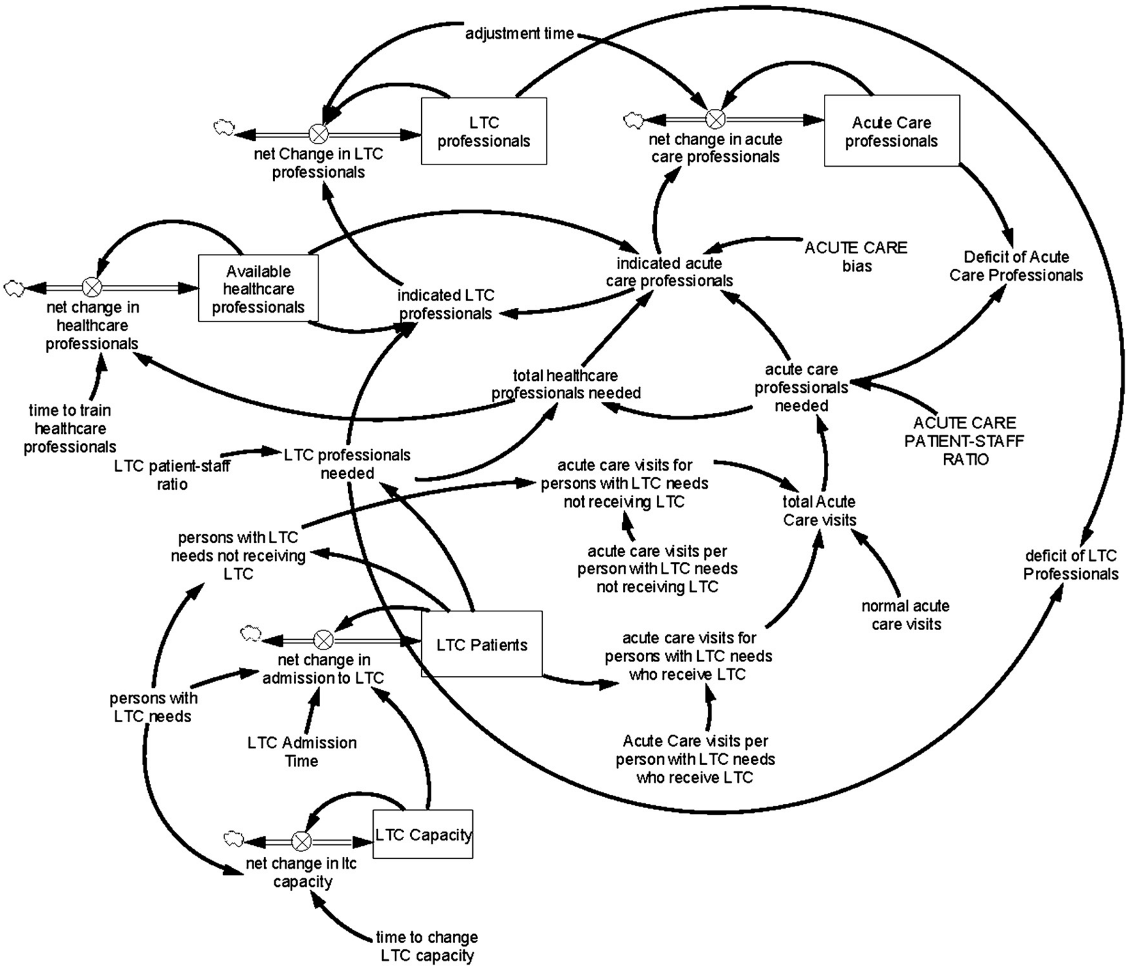

Fig. 1. Simplified model structure. Boxes signify stocks (i.e., state variables that represent an accumulation), arrows into stocks represent flows (i.e., generally rate variables that cause stocks to change over time), and all other arrows represent casual links.

delay results in a quick increase in LTC capacity and a longer delay leads to a slower increase.

Acute care visits are modeled as the sum of acute care visits by persons with LTC needs and are receiving such care, and persons with LTC needs but are not receiving LTC services. The acute care visits refer to inpatient stays, outpatient services including visits to the general practitioner's clinic and polyclinic, and emergency room visits. The number of acute care visits by persons with LTC needs and are receiving such care and persons with LTC needs but are not receiving LTC services is a function of the number of persons in the respective groups and how often individuals within these groups utilize acute care services. For both groups, acute care visits occur at specified, constant rates.

The number of LTC professionals needed is modeled as a function of the number of LTC patients and the LTC patient–staff ratio. In contrast, the number of acute care professionals needed is calculated by dividing the total acute care visits by the acute care patient–staff ratio. The total number of healthcare professionals needed is modeled as the sum of the number of acute care professionals needed and LTC professionals needed.

Healthcare professionals are distributed to venues according to demand. Those venues with the highest demand for healthcare professionals receive the greater proportion of those available to be allocated. Based on input concerning professional preferences from individuals familiar with the healthcare system in Singapore, when availability in both the acute and LTC sectors exist, healthcare professionals prefer working in acute care over LTC. This is represented in the model as an acute care bias, reflecting the relative flow of healthcare professionals to acute care versus LTC. Meanwhile, the availability of healthcare professionals' changes in response to demand (total healthcare professionals needed) and the time required to train healthcare professionals.

2.2. Assumptions

In the model, the LTC patients (i.e., persons with LTC needs who receive LTC services) are presumed to have relatively low acute care utilization (0.5 visits per person per year; Table 1) [16], whereas persons with LTC needs but not receiving LTC services have a relatively high acute care

Table 1
Model parameter values and ranges for sensitivity analysis.

Parameter	Value	Range	Unit	Distribution
Time to change LTC capacity	10	5.0–15	Year	Uniform
LTC admission time	1	0.5–1.5	Year	Uniform
Acute care visits per person with LTC needs who receives LTC	0.5	0.25–0.75	Visit/patient/year	Uniform
Acute care visits per person with LTC needs not receiving LTC	2	1.0–3.0	Visit/patient/year	Uniform
Acute care patient–staff ratio	5	2.5–7.5	Patient/worker	Uniform
LTC patient–staff ratio	5	2.5–7.5	Patient/worker	Uniform
Time to train healthcare professionals	2	1.0–3.0	Year	Uniform
Acute care bias	1.2	0.6–1.8	Dimensionless	Uniform
Adjustment time	1	0.5–1.5	Year	Uniform
Persons with LTC needs*	100	–	Patient	–
Normal acute care visits*	10	–	Visit/year	–

* Sensitivity analysis not performed.

utilization (2.0 visits per person per year). Persons with LTC needs but are not receiving LTC services due to capacity constraints are assumed to reside at home without formal external services, receiving care from informal sources (usually family members, often with a foreign domestic worker) [9,30] and also make use of acute services for needs that LTC might address more appropriately (i.e., effectively and at lower cost) [31–33]. In addition, it is assumed that there is no constraint to the supply of healthcare professionals other than training delay, which is a blended value that averages across physicians, nurses, and support staff and includes both hiring from abroad and education.

2.3. Steady state

Because this model is intended for policy exploration, stylized numbers are used for the population and their care needs. To make it easier to discern policy effects, the model is initialized in a steady state (i.e., a hypothetical situation in which LTC and acute care demand and supply are equal). To initialize the model in a steady state, the following three assumptions are made: first, the number of persons with LTC needs remains constant over the simulation time; second, all persons with LTC needs receive LTC services; and third, the number of available healthcare professionals is equal to the total number of healthcare professionals needed. It is important to note that the initialized steady state is a dynamic equilibrium. The steady state is numerically sensitive to model parameters but typically consequent model behavior is not.

2.4. Policy experimentation

The steady state is disturbed by gradually increasing the number of persons with LTC needs from 100 to 200 by year 30 starting from year five, a scenario likely reflective of a country with an aging population. Under this demand change scenario, the effects of four LTC capacity policies are studied.

(a) “Static”—keeping LTC capacity constant and making the time to change LTC capacity parameter unresponsive to changes in LTC demand;
(b) “Slow adjustment”—adjusting LTC capacity slowly and assuming an adjustment time of 10 years;
(c) “Quick adjustment”—adjusting LTC capacity quickly and assuming an adjustment time of 2.5 years; and
(d) “Proactive adjustment”—anticipating the likely demand for LTC in the future, and adjusting LTC capacity assuming an adjustment time of one year and healthcare professionals adjustment time of 0.075 years.

These hypothetical policies were selected to cover the range of possibilities expressed by stakeholders and may be supported by previous studies that considered similar policies in a relevant setting. A “static” policy [34] is implausible in the current context in which LTC services are indeed being expanded; however, it is selected to serve as a reference point for evaluating the alternatives. Both the “slow adjustment” and “quick adjustment” policies – which only differ in their time to change LTC capacity – reflect the official eldercare policy of “aging in place” which emphasizes: the family as the principal support system for older adults [35,36]; the role of LTC in containing healthcare expenditure by encouraging the frail elderly to remain at home; and the desire to avoid overbuilding which is accomplished by expanding capacity only in the face of an evident gap [37]. Finally, the “proactive adjustment” policy involves preemptive action seeking to achieve long-term sustainability or a desired stated goal [38,39].

2.5. Parameter sensitivity analysis

Sensitivity analysis was performed to identify how changes in each of the model parameters affected the model outputs. Using one-way sensitivity analysis [40], the value for each model parameter was varied by ±50 percent, and a uniform distribution for each parameter range was assumed. The model was run 100 times for each parameter. Each run drew a parameter value from a uniform distribution. Next, a linear regression model using outcomes from the sensitivity analysis was used to estimate the effect of each parameter change on the outcome variables (i.e., total acute care visits, total healthcare professionals needed, deficit of LTC professionals, and deficit of acute care professionals). For the outcomes related to deficits, a value closer to ‘1’ approaches the perfect scenario, where demand equals supply.

3. Results

The results as shown in Fig. 2A–D depict the impact of the different LTC capacity response policies on total acute care visits, the total number of healthcare professionals needed, and the deficits of LTC and acute care professionals, respectively.

In the “static” LTC capacity scenario, the total acute care visits per year and the total number of healthcare professionals needed will increase by 333 and 125 percent, respectively (Fig. 2A and B). A significant deficit of healthcare professionals in the LTC and acute care venues is also observed over the short and long terms (Fig. 2C and D). Alternatively, in the “slow adjustment” LTC capacity, total acute care visits per year and the number of healthcare professionals needed increase by a smaller percentage, 183 and 106 percent, respectively (Fig. 2A and B). Although a deficit of LTC and acute care professionals is observed over the simulation time, the deficit is smaller compared to the “static” policy (Fig. 2C and D). However, in the “quick adjustment” policy, the number of patients in LTC increases, and the total acute care visits per year and the total number of healthcare professionals needed increases by just 102 and 94 percent by year 30 (Fig. 2A and B); which is on par with the increase in the number of elders. Moreover, a smaller deficit in LTC and acute care professionals is observed over both the short and long terms (Fig. 2C and D). The smallest percentage increases in total acute care visits and total healthcare professionals needed are observed in the “proactive adjustment” (Fig. 2A and B); total acute care visits and total healthcare professionals needed increase by 93 and 95 percent, respectively—a smaller percent rise than the percent increase in elders. The smallest deficits of LTC and acute care healthcare professionals are observed under this response policy (Fig. 2C and D).

In addition, the outcomes of the “quick adjustment” and “proactive adjustment” policies at year 30 were compared with that of the “slow adjustment” policy. At year 30, the “quick adjustment” policy is projected to decrease acute care services utilization and the number of total healthcare professionals needed by 23 percent and four percent, respectively. In this scenario, the deficit of acute care professionals is expected to remain unchanged, whereas a two percent improvement is projected for the deficit of LTC professionals. Likewise, the “proactive adjustment” policy tested in the simulation model is projected to decrease the number of acute care visits by 32 percent at year 30, with an equivalent reduction of six percent in the total healthcare professionals needed. Although the small improvement (1.4%) observed for the deficit of acute care professionals is likely not significant for policy purposes, the deficit of LTC professionals is projected to improve by 11 percent. Along these lines, compared with the “slow adjustment” policy, the cumulative reduction in total acute care visits is estimated to be 17 percent for the reactive policy and 26 percent for the proactive policy. For the total healthcare professionals needed, the reactive and proactive policies are estimated to have a cumulative gain of three and four percent, respectively, in addition to a corresponding 20 and 25 percent reduction in workload.

Based on the sensitivity analysis, regression results (Table 2; Appendix Fig. 1A–H) show the standardized coefficients that estimate the effect of one standard deviation change in each model parameter on the outcome variables at year 30. For example, a one standard deviation decrease in the number of acute care visits per person with LTC needs will decrease the number of total acute care visits by 0.41 standard deviations. To facilitate concise reporting of results, the two most responsive parameters were compared with the third most sensitive parameter within each of the four outcomes; thereby obtaining the relative magnitude of effect to inform policy action.

Primarily, total acute care visits was found to be sensitive to three parameters namely: the LTC admission time (see Appendix, Table 1), the number of acute care visits per person with LTC needs who receives LTC, and the number of acute care visits per person with LTC needs not receiving LTC, identifying the latter two as the most responsive parameters in projecting this outcome. In terms of standard units, the regression results suggest that decreasing the number of acute care visits per person with LTC needs who receives LTC and that of person with LTC needs not receiving LTC is 19.4 (0.408/0.021) and 15 (0.321/0.021) times more effective, respectively, in decreasing the total acute care visits, compared to decreasing LTC admission time (i.e., the third most sensitive parameter). The outcome of total healthcare professionals needed, on the other hand, was sensitive to all model parameters except for LTC admission time, time required to train healthcare professionals, acute care bias, and adjustment time, with the parameters related to patient–staff ratio for both acute care and LTC showing the strongest effect. In terms of relative magnitude, increasing the patient–staff ratio of acute care and LTC is 1.8 (0.531/0.289) and 1.9 (0.560/0.289) times more effective than decreasing acute care visits per person with LTC needs who receives LTC in decreasing the number of total professionals needed. Likewise, the deficit of LTC professionals is sensitive to all model parameters except for LTC admission time; among the statistically significant parameters, time to train healthcare professionals and acute care bias are the most important parameters in projecting the potential behavior of this outcome. Comparing the coefficients also suggests that decreasing the time to train healthcare professionals and reducing acute care bias are 1.1 (0.365/0.317) and 1.7 (0.550/0.317) times more effective than increasing acute care patient–staff ratio in improving the deficit of LTC professionals. Lastly, the deficit of acute care professionals is sensitive to half of the parameters (i.e., acute care visits per person with LTC needs who receives LTC, acute care visits per person with LTC needs not receiving LTC, acute care bias, and adjustment time), of which acute care bias and adjustment time have the highest magnitude of effect. Increasing acute care bias and decreasing adjustment time are 5.2 (0.762/0.145) and 2.2 (0.313/0.145) times more effective than decreasing acute care visits per person with LTC needs not receiving LTC in improving deficit of acute care professionals. Importantly, at ±50% perturbation of all model parameters, the foregoing results of the sensitivity analysis suggests that the model is numerically sensitive but

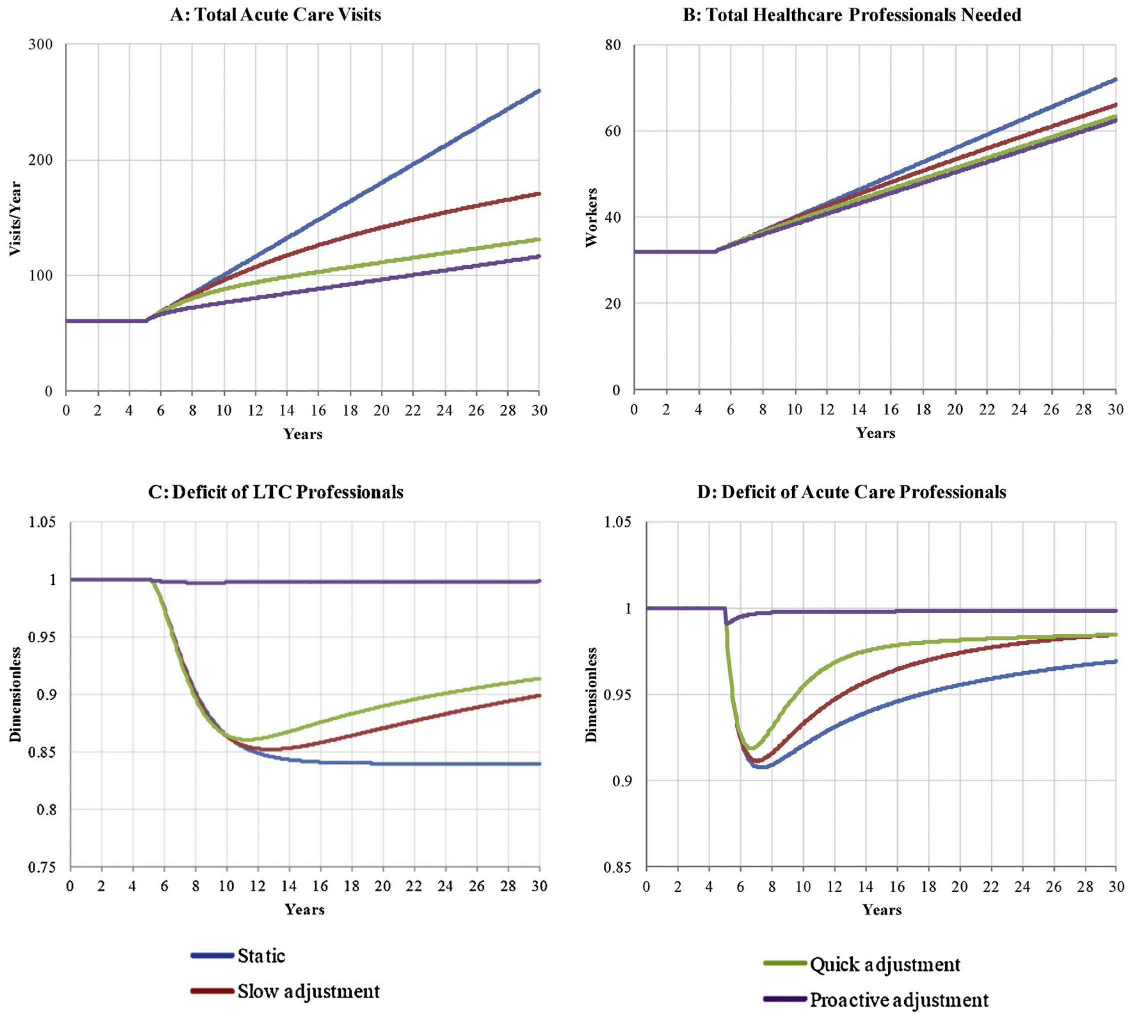

Fig. 2. Effects of long-term care capacity response policies on: (A) Total acute care visits, (B) Total healthcare professionals needed, (C) Deficit of LTC professionals, (D) Deficit of acute care professionals.

Table 2
Regression results.

Parameter	Outcome			
	Total acute care visits	Total professionals needed	Deficit of LTC professionals	Deficit of acute care professionals
LTC admission time	0.0211*	0.0047	−0.0094	−0.0102
Acute care visits per person with LTC needs who receive LTC	0.4080*	0.2893*	−0.0675*	0.1114*
Acute care visits per person with LTC needs not receiving LTC	0.3207*	0.2256*	−0.2302*	−0.1448*
Acute care patient–staff ratio	1.29e − 18	−0.5306*	0.3166*	1.37e-07
LTC patient–staff ratio	1.29e − 18	−0.5599*	−0.2897*	2.13e-18
Time to train healthcare professionals	−2.18e − 18	4.69e − 17	−0.3650*	4.47e-18
Acute care bias	−2.23e − 18	−2.41e − 17	−0.5504*	0.7618*
Adjustment time	−2.18e − 18	4.69e − 17	−0.0507*	−0.3132*

* $p < 0.01$; standardized coefficients of the regression are shown; unstandardized coefficients and tests of significance are available in Appendix, Table 2.

the ensuing behavior is not. This finding demonstrates the robustness of the main conclusion drawn from the model: that inadequate supply of LTC capacity tends to shift care demand toward acute care facilities and increase total care needs.

4. Discussion

The health system consists of multiple interconnected components. Specifically in this study, the simplified model of the reciprocal relationships between supply and demand for LTC and acute services demonstrates that by not increasing LTC capacity (i.e., static), the demand for acute care and the total number of healthcare professionals needed increases disproportionately to the population growth. Meanwhile, large deficits of LTC and acute care professionals are observed. If LTC capacity is increased slowly (i.e., slow adjustment), then increases in acute care visits and healthcare professionals needed is moderated, while the deficits of LTC and acute care professionals observed is less severe. If the "quick adjustment" LTC capacity is adopted, the increases in the number of acute care visits and healthcare professionals needed remains smaller relative to the first two scenarios, as are the deficits of LTC and acute care professionals. By implementing the "proactive adjustment" LTC capacity (i.e., shorter time to change LTC capacity and increasing allocation of healthcare professionals), the rate of increase in acute care visits and healthcare professionals needed is reduced, and the deficits of LTC and acute healthcare professionals are effectively eliminated over the long-term. While certain outcomes are particularly sensitive numerically to parameter changes, changing the model parameters over wide ranges does not affect the general mode of behavior of the outcomes of interest nor the general model conclusion: that failure to respond proactively to LTC needs tends to shift care toward acute care facilities and increase total care needs. Meanwhile, total acute care visits and total professionals needed were found to be most sensitive to acute care utilization and manpower efficiency (i.e., manpower use, here reflected in patient–staff ratio for acute and LTC) respectively. Aside from acute care bias, the deficits of LTC professionals and acute care professionals were also found to be most sensitive to the training duration of healthcare workers (time to train healthcare professionals) and the time to reallocate healthcare professionals (adjustment time) respectively.

These results can be explained by the interaction of capacity adjustment and healthcare professional movement. For example, increases in total acute care visits are primarily due to the increase in the number of older persons with LTC needs who reside at home due to inadequate LTC capacity. By not responding to the demand for LTC proactively, the LTC sector will be unable to generate the capacity necessary for the appropriate allocation of elderly individuals with LTC needs to the LTC venue. As assumed, individuals who have LTC needs but do not receive LTC have a higher acute care utilization rate compared to LTC patients. Shortages of acute care healthcare professionals, on the other hand, are due to increasing care needs and the delay in training new healthcare professionals. Since the supply of healthcare professionals is a delayed function of the healthcare professionals needed, supply always lags demand. Meanwhile, several factors can explain the shortages of healthcare professionals in the LTC sector. For example, training delays can affect the availability of healthcare professionals, whereas the rising demands in the acute care sector may lead to the allocation of healthcare professionals from the LTC to the acute care sector. Finally, expanding LTC capacity may increase the number of patients in LTC and the corresponding demand for LTC professionals. Again, the dynamic interaction between LTC availability and acute care utilization shown in this study demonstrates how LTC planning delays may contribute to increased acute care utilization and significant deficits of LTC and acute care professionals.

The key study finding, that inadequate supply of LTC capacity tends to shift care demands to acute care facilities and increase total care needs, has policy implications. Overall, this finding suggests that if policymakers place more emphasis on the demand for acute care than that of LTC, they are likely to over-build acute care facilities and fill them with persons with LTC needs. Policymakers must then be proactive in responding to LTC demand, lest acute care utilization and significant deficits of healthcare professionals arise. A delayed response could, for example, lead to increased healthcare expenditure and longer wait lists for LTC and acute care patients.

The outcome of total acute care visits was shown to be sensitive to the number of acute care visits per person with and without LTC needs. Given that early empirical studies [13–15,31,32] have reported a disproportionately high acute care utilization among elderly individuals living at home with LTC needs, this finding lends support to the need to implement evidence-based healthcare interventions that are proven to reduce acute care utilization among persons with LTC needs, thereby promoting the appropriate use of healthcare services. For example, right-siting patients with diabetes in an integrated care setting, ensures that "patients are treated in the most appropriate location by medically competent teams at the lowest possible cost" [41,42]. Likewise, the outcome of total professionals needed was shown to be sensitive to the patient–staff ratio for both acute and LTC services. In this regard, policymakers can leverage on technological advances in improving manpower utilization. On the surface, the automation that comes with new technology can be seen as a substitute for human workforce; however, innovation and technology would still generally require more skills and technical expertise from well-trained professionals [28]—especially increasing the demand for healthcare manpower trained in the effective use of new technology and methods. Thus, the efficient deployment of available workforce and the implementation of policies that increase the productivity of healthcare workers are more critical than ever.

A further insight is that elimination of acute care bias is one of the most important considerations in reducing deficits of LTC and acute care professionals. Increasing the attractiveness of LTC venues for healthcare professionals by providing them with attractive compensation and an interesting career path can contribute to the elimination of this bias. Ultimately, eliminating acute care bias can prevent over-expanding acute care services for patients whose actual needs are better addressed by LTC services. This contention underscores the value of redirecting a portion of the available resources to LTC services; an effective intermediate level step-down care transition to home- and community-based LTC may also be useful [43]. Finally, reducing the deficits of LTC and acute care services is also sensitive to the time to train healthcare professionals and the adjustment time. Thus, in anticipating future demands for LTC capacity, LTC policies should consider supporting well-designed training programs that can help decrease the time spent to train healthcare professionals, and a shorter adjustment time that allows for a prompt, balanced, and realistic response to healthcare needs [38,39].

The model presented herein has several limitations. First, the model assumes a higher acute care utilization rate among older individuals who have LTC needs. The extent to which this is true depends on technology and treatment options, which may improve over time. In fact, one of the mandates of the AIC is to develop interventions that increase the efficiency of LTC delivery, the evaluation of which is the subject of ongoing research. It is also possible that in jurisdictions where access to acute care is limited, the provision of LTC may actually increase the utilization of acute care services to the extent that they facilitate connections or referrals to other forms of care. The model also assumes that there is no constraint to the supply of healthcare professionals; however, in Singapore, this is not the case, as people often have competing career options, limitations on employing foreign workers exist, and training facilities (e.g., nursing and medical schools) are generally unable to adjust quickly to changes in demand for healthcare workers. An additional limitation is that the allocation of healthcare professionals in the model does not account for any change in the organization of services; thus, the demand for care is assumed proportional to the demand for healthcare professionals.

Despite these limitations, the models presented remain useful for policymakers, particularly in forward planning. For instance, the models can be used as an exploratory tool to search for leverage policies and evaluate the impact of future policy on specific outcomes of interest, more importantly increasing awareness of the conditions for successful policy implementation. It must be emphasized however, that the value of the models in the current study does not merely lie in their capacity to predict the impact of the LTC capacity response policies of an aging population. Above all, building and using these models improves insights. Primarily, simulating the implications of different response policies provides a learning environment for policymakers to distinguish critical policy effects. The insights gained from the Singapore setting may be a relevant starting point for other aging populations faced with similar needs and challenges. Besides generating insights, these models also help policymakers design, communicate, and implement effective policies, by identifying the relevant parameters to which specific outcomes of interest are sensitive. We further argue that understanding the interactions between older persons with disabilities and the capacity of the healthcare system to provide care is essential to effective policy design. Moreover, using a relatively small model allows for an exhaustive experimentation through parameter changes, which facilitates learning from the sensitivity analysis and examining interactions among different parameters; thus, more easily identifying important leverage points in the system. Models of this nature could be used as a boundary object—a framework to promote better communication with stakeholders, sharing dynamic insights and improving understandability for consensus building [44–46]. Ultimately, the study findings fill important research gaps on the impact of LTC capacity response policies for an aging population. Researchers acknowledge the limited published works on LTC capacity planning [43]. A previous study investigated the structural adjustments associated with an ageing population, largely focusing on the implications of population aging on economic policies [47]; in reporting the effects of the demand–supply interactions, the study provided the means toward a more rational policy discussion. Though this exercise did not consider the implications of specific LTC policy scenarios on the outcomes relevant to particular issues, which may vary across different settings, these considerations are natural extensions of the current work.

5. Conclusions

This paper provides a clear explanation of why healthcare professional shortages might exist in LTC facilities regardless of what the policy for expanding these facilities may be. This is important to understand because, if policymakers choose to restrict the expansion of LTC facilities due to staffing concerns, they are likely to exacerbate difficulties in staffing within the LTC sector.

In light of these results, policymakers should consider the dynamic relationship that exists between the LTC and acute care sectors. Policymakers should understand that, when implementing policies designed to affect LTC directly, such policies tend to affect acute care venues as well. In addition, these results highlight the importance of forecasting future LTC demand and scaling up capacity quickly so as to avoid deficits of healthcare professionals. Finally, policymakers should also consider the likely impact that placing constraints on LTC service expansion may have on factors not represented in the model, such as the increased burden that family caregivers for older individuals with disabilities may experience.

Authors' contributions

All authors have contributed substantially to the design, analysis, discussion and results and have approved the final version of this paper.

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