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SIMULATION MODELING FOR PRIMARY CARE PLANNING IN SINGAPORE

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ABSTRACT

Singapore is undergoing an epidemiological shift and has to provide services for an aging population with a higher burden of chronic disease. In order to address this challenge, enhancing the provision of primary care by improving the ability of more primary care providers to offer care to more complex patients over the continuum of needs is seen as a promising solution. Developing capabilities and capacities of primary care services is far from straightforward and requires careful analysis of how increasing the number of primary care providers with enhanced capabilities influences the multiple objectives of the health care system. The paper demonstrates how group model building can be used to facilitate this planning process, and provides potentially valuable initial insights regarding the tradeoffs engendered by policies aimed at meeting the health care needs of a more complex population.

1 INTRODUCTION

Singapore, like many other countries, is aging rapidly. Less than a decade ago, the proportion of the resident population aged 65 years and older was less than 10%; this is expected to nearly triple by 2030 (Singapore Department of Statistics 2015; Singapore Department of Statistics 2016; National Population and Talent Division 2012). Accompanying this demographic shift is a growing number of people with illnesses requiring chronic care, such as diabetes and hypertension (Ministry of Health 2015a). These conditions can progress to become complex as complications, such as heart disease and stroke, become manifest. A consequence is that the acute hospitals and specialist services that have been the focus of a health system designed for a younger population have been showing signs of systemic stress. This is evident in the high bed occupancy rates in acute hospital (Lam 2014; Ministry of Health 2016a), overburdened specialty outpatient clinics (SOCs) (Ministry of Health 2001), increasing emergency department (ED) utilization (Anantharaman 2008), long waiting times for admission to acute hospital wards (Ministry of Health 2016c), as well as workforce shortages (Ministry of Health 2012; Kang and Leong 2012). Hospital admissions due to diabetes, for instance, are much higher in Singapore (432 per 100,000 population) than in countries such as the United Kingdom (64 per 100,000) or the United States (149 per 100,000) (OECD 2016).

To adapt to the evolving needs of a population with chronic conditions, many countries have been reassessing their healthcare system to focus on chronic care management by the "front line" providers, namely primary care physicians and teams (World Health Organization 2002). The various models of healthcare delivery that have been adopted include changes in the role and incentives of the private sector

and general practitioners (GPs), changes in subsidies and the use of empanelment to assign individual patients to designated primary care providers or care teams (Department of Health 2014; Grumbach and Olayiwola 2015; Ham 2009). These are among the dominant policy alternatives under consideration in Singapore.

The challenge of meeting the needs of a rapidly changing population is complicated by the many moving parts with complex interactions (e.g., hospital services, outpatient services, private and public providers, and so on), and the many stakeholders whose interests must be considered if a major policy change is to be successful.

In this paper, we describe our strategy for approaching the challenge of meeting the growing need for chronic care through enhanced primary care, as a dynamic problem. We focus on initial work completed, in which we have worked in partnership with community stakeholders to begin a facilitated discussion on how investments in primary care services and regulatory changes will potentially affect overall health system success. A summary model is presented which illustrates potentially important insights that can inform the policy discussion.

2 CONTEXT: PRIMARY CARE SERVICES IN SINGAPORE

Singapore is an island city-state with a total population of 5.5 million people, of which 3.9 million are citizens or permanent residents. To serve their needs, the healthcare system in Singapore is a hybrid of public and private elements that deliver primary, acute and step-down care in various institutions island wide. An estimated 80% of acute hospital care is in the government hospitals; in contrast, 80% of primary outpatient services are provided by private practitioners (Ministry of Health 2016b). Eighteen public polyclinics and about 1,500 private GP clinics largely operating as solo or small group practices provide the primary care services and people are free to choose venue of care (Ministry of Health 2015b). Polyclinics act as "one-stop" healthcare centers, offering comprehensive range of services, including outpatient medical care, health screening, education and vaccinations, and x-ray and laboratory services (Ministry of Health 2015b); however, their capacity to address a full range of needs of an individual with multiple health problems can be limited by high volume and relatively short consultation times. Private GP clinics are generally run by solo practitioners and usually do not possess a full range of services. On the other hand, patients in a private clinic usually see the same physician whereas in polyclinics patients are in most cases assigned any available doctor each time they visit (Khoo, Lim, and Vrijhoef 2014). Not infrequently, patients seek care at multiple sites.

Not only are more hospitalizations occurring in the public sector, public polyclinics also get a disproportionate share of patients requiring complex, chronic care. While 20% of primary care attendees are seen by public polyclinics, nearly half of patients with conditions requiring chronic care are seen in the public sector (Sng 2010). This may be attributed to healthcare financing in Singapore, which encourages transition to public services as needs become more complex. Healthcare financing in Singapore is a combination of out-of-pocket payments, payments from a personal medical savings account (Medisave) and subsidies. Public polyclinics are highly subsidized by the government. Singapore citizens referred to specialty care from a polyclinic will also continue to receive subsidized treatment and medication, up to 75 percent of the bill (Ministry of Health 2014). While private GP services have historically not been subsidized, there is a move to make chronic care in the private sector more affordable. In the past 10 years, individuals have been able to use their Medisave accounts to pay for specific chronic conditions, subject to the GPs' participation in the Chronic Disease Management Programme introduced by the Ministry of Health (MOH). More recently, Singaporeans from lower-to middle-income households eligible for the Community Health Assist Scheme (CHAS) receive subsidies for medical care at participating GP clinics (CHAS 2016). The concern remains that patients with greater needs continue to migrate to the public sector due to the larger range of services available (e.g., a patient with previously mildly symptomatic heart failure will tend to go to the ED with the first onset of severe

shortness of breath as all X-rays and lab tests are available and highly subsidized; thereafter they are likely to remain within the public polyclinics and/or SOCs).

3 APPROACH

3.1 The Objective: What is a Successful Health System?

As a first step in this exercise to project the impact of various policies intended to enhance primary care, we established the key outcomes for measuring success of a health care system. We chose to apply the "Quadruple Aim" framework developed by the Institute for Healthcare Improvement (Institute for Healthcare Improvement 2016). That is, policy options are assessed in terms of the degree to which alternatives achieve an optimal mix of service effectiveness (to improve population health), patient satisfaction, service efficiency (to minimize need for expensive services, reducing per person costs), and provider satisfaction (to minimize staff burnout and turnover).

3.2 Preliminary Work: Group Model Building

We applied group model building (GMB) to gain insights into the dynamic forces that promote or inhibit the development and uptake of enhanced primary care, which in turn could be useful in guiding actions that would make enhanced primary care effective and sustainable. GMB is a participatory method for involving stakeholders in the process of understanding and changing systems using the methodology of system dynamics (Vennix 1992; Scott, Cavana, and Cameron 2016; Forrester 1961; Homer and Hirsch 2006). System dynamics is a simulation modeling method used to represent the structure of complex systems in an analytic framework to facilitate understanding systems behavior over time. The involvement of various stakeholders with vast knowledge in the continuum of care, particularly in primary care, in the development of a system dynamics model increases the relevance and usefulness of the model. This provides a strong framework for analytic deliberation and testing of various hypotheses (Scott, Cavana, and Cameron 2016; Sterman 2000). Examples of its application in healthcare include the work of Vennix and Gubbels (1992), and Homa et al. (2015).

To better understand the dynamics of chronic disease management in a primary care setting, a 2-day roundtable workshop was organized around a GMB exercise. The workshop was comprised of 50 stakeholders and experts providing chronic care to patients or with an interest in chronic care management, including private GPs, polyclinic doctors, hospitals administrators, and government policy makers, as well as academic health services researchers. Patient groups were not involved in this stage, but will be engaged in the following stages of model development.

Day 1 of the workshop began with 11 interactive presentations covering a wide range of experience on enhanced primary and chronic disease care in the United States, United Kingdom and Singapore. After this, a panel discussion consisting of three local GPs was conducted. The presenters and stakeholder participants generally agreed that primary care capacity and capability is not adequate to serve the local population over the medium- to long-term and that the essential features of enhanced primary care would include: (1) providing the first point of contact for patients, (2) offering a broad range of services for patients with chronic conditions, and (3) coordinating patient care across venues.

On day 2, participants were divided into breakout sessions consisting of 6-8 individuals with a mix of backgrounds. Each breakout group had a facilitator, modeler, recorder, and reflector. Their task was to identify key causal relationships that impacted the ability of enhanced primary care to affect health, cost, and satisfaction of patients and providers. They were encouraged to use causal loop diagrams to represent their hypotheses, and these diagrams were then presented to all the participants and examined in an often highly animated plenary discussion. A summary model capturing the various insights gained from the GMB exercise was later developed by the research team. For purposes of the current presentation, we describe a simplified version of the summary model, which captures major issues that might promote or

inhibit the successful development of an enhanced primary care sector (i.e., one that achieves the declared aims of a modern healthcare system).

3.3 Model Structure

In this section, we describe the simplified summary model illustrating key insights from the workshop. Specifically, it reflects the hypothesized causal relationship between the provision of services and the "quadruple aims" of a health care system, noted above (Figure 1). Since the two types of primary care services (normal and enhanced) are represented in identical structures, for clarity only the single common structure is shown; technically the separation is accounted for using variable subscripting. Table 1 shows the parameter values used to initialize the model.

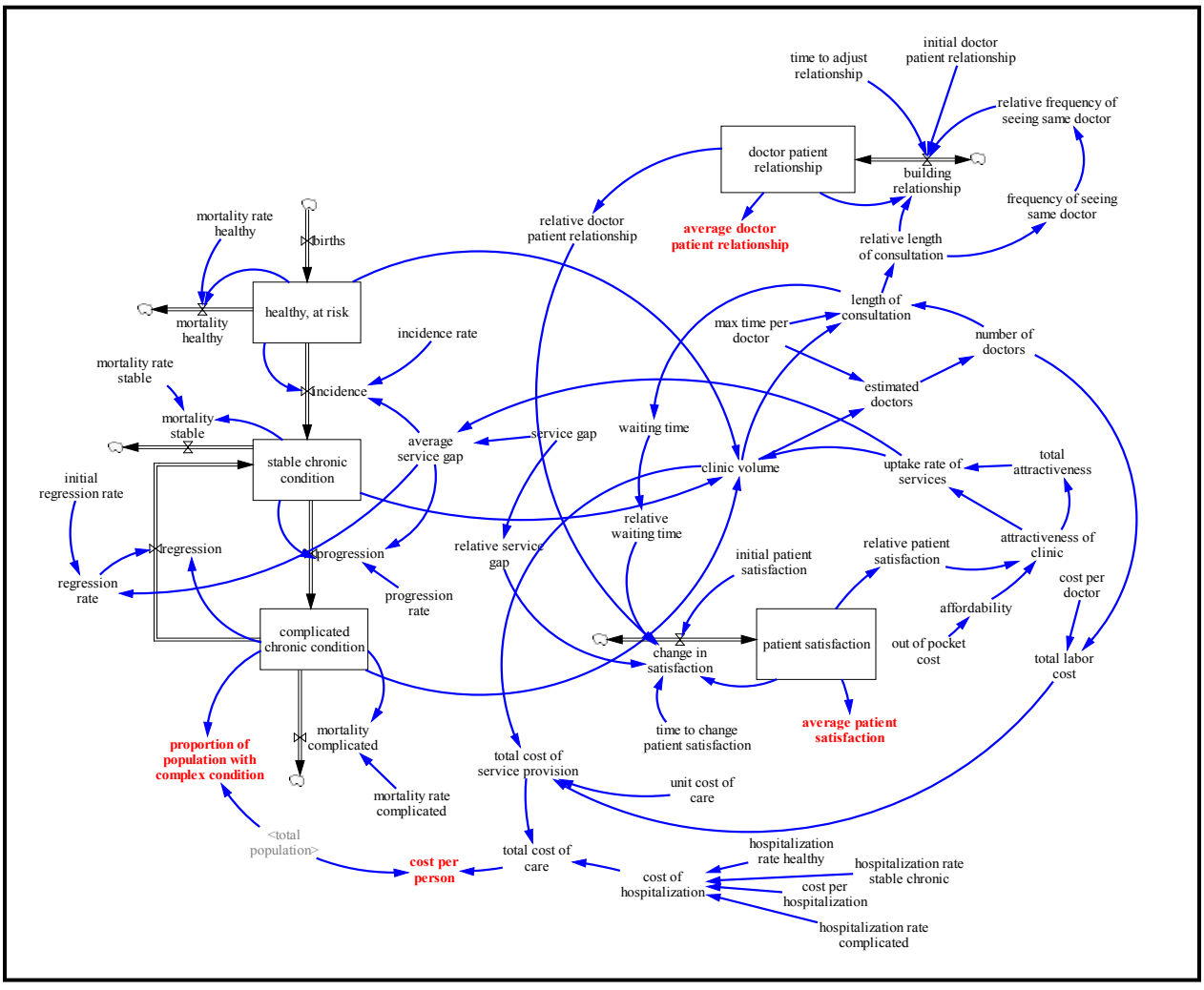

Figure 1: Causal diagram. Boxes indicate accumulations (stocks), black arrows are flows into or out of stocks. Blue arrows indicate causal relationships. The quantities in red indicate the "quadruple aim" of the healthcare system: population health (here represented by the proportion of the population with complex conditions), patient satisfaction, service efficiency (cost per person in the total population), and provider satisfaction (here represented by the doctor-patient relationship).

3.3.1 Population Health

In considering how primary care relates to population health, the participants agreed on the notion that individuals can be considered as occupying health states of increasing levels of severity (Homa et al. 2015). This is reflected in Figure 1 by the three stocks: (a) healthy, at risk; (b) stable chronic condition; (c) complicated chronic condition. Each stock corresponds to the nature (type and intensity) of medical service needs that would be expected to inhibit progression into or regression from more symptomatic or disabling health states (represented by black "flows"). Chronic conditions are taken to be an aggregate of all types of chronic diseases. This "needs-based" (as opposed to "disease-based") perspective reflects the fact that many health conditions are associated with similar type and level of needs (e.g., care of patients with chronic obstructive pulmonary disease (COPD) and heart failure both entail close longitudinal follow up by a physician, chronic medications, and the potential for sudden, life-threatening exacerbations requiring emergency care). Moreover, the majority of individuals with chronic conditions have several conditions and these occur in a myriad of combinations, many of which can be treated in groupings (e.g., asymptomatic diabetes, hypertension, and mild chronic kidney disease often occur together, and require similar levels of management skills and intensity (how often seek medical care).

Progression refers to the transition into health states with higher needs, with greater instability, untoward impact on quality of life, and higher costs (particularly hospitalization), while regression refers to the reverse The rates of flow are represented by "valves" (here by double triangles) which are influenced by the degree to which service needs are met. Specifically, service gaps lead to higher rates of progression and lower rates of regression.

3.3.2 Patient Satisfaction

In the lower right section of the causal diagram indicates the relationships influencing patient satisfaction. Patient satisfaction is represented as a stock that can increase or diminish. Stakeholders deemed that the main determinant of satisfaction is out-of-pocket-cost; this is consistent with published literature (Derose and Petitti 2003; Himmel, Dieterich, and Kochen 2000; Kulu-Glasgow, Delnoij, and de Bakker 1998). Additional factors influencing change in patient satisfaction with care is waiting time for care (Sloan and Kasper 2008), quality of the doctor-patient relationship (Anderson, Camacho, and Balkrishnan 2007), and perceived quality of care by patients (Williams, Weinman, and Dale 1998). For simplicity, this last factor is assumed to be directly related to meeting medical needs (i.e., as service gaps diminish, change in patient satisfaction becomes more positive. This section of the diagram also includes a feedback loop: all things being equal, patients who are satisfied with care are more likely to find the venue attractive which leads to higher patient volume, and, in turn, longer waiting times and lower patient satisfaction. This is a balancing loop, inducing a constraining force on clinic growth.

Patient satisfaction was deemed to be related, in part, to the quality of the doctor-patient relationship. This relationship is importantly related to the number of doctors relative to demand for services (Alrubaiee and Alkaa'ida 2011) since relationships are established through longer consultation time (Murray 2007), and the consistency of the relationship over time (i.e., ability to see the same doctor) (Howie 1991). Stakeholders felt that current consultation time are too short and thus consistent doctor-patient relationships are not possible in local public polyclinics. Note that this establishes another feedback loop that balances clinic growth: if a clinic becomes more attractive by increasing consultation time and access to the same doctor, resulting increased clinic volume forces consultation times to be reduced and decreases the chance that a person's doctor will be available when needed and so will need to see other doctors, reduces patient satisfaction and clinic attractiveness.

3.3.3 Service Efficiency

Overall costs of chronic care services include two major components. The first is the cost of providing

clinic services, a cost that is dominantly driven by numbers of providers. The second component of cost is services that may be reduced by high-quality care. As noted above, filling service gaps reduces progression of chronic conditions. This progression not only has a profound effect on quality of life, it is also expensive. More medically complex individuals are more likely to use emergency services, be hospitalized, and require expensive specialty care.

Evidence suggests that as length of consultation decreases, fewer of the needs of patients with chronic conditions can be addressed during a visit, which impacts quality of care (Fan 2005). In addition, integration of chronic care services among various providers, and capability of care providers influence quality of care (Murray 2007; Campbell 2001). While addressing these problems with chronic disease management has immediate costs, the question is whether it will ultimately reduce net costs, or at least lead to extra costs deemed worth the health benefits.

3.3.4 Provider Satisfaction

Here the level of the doctor-patient relationship is used as an indicator of provider satisfaction. This stock represents crucial characteristics our stakeholder physicians valued in their day-to-day work life: the ability to have an adequate amount of time to see patients, and the opportunity to follow the same patient over time.

3.4 Model Inputs

3.4.1 Model Parameters

Steady state:

Because the model is intended for policy exploration, stylized numbers are used to initialize the model. To make it easier for policy analysis, the model is initialized in a steady state (i.e. a hypothetical situation in which population, service gap, cost of care, patient satisfaction and doctor-patient-relationship are equal and constant across the two care venues — normal and enhanced primary care). To initialize the model into steady state the following assumptions were made: (1) the population in the three health state are assumed to remain constant; (2) there is no difference in the effectiveness of care (a proxy for service gap) provided across the two venues; (3) both care venues have the same number of providers (medical staff) to care for patients; and (4) the out-of-pocket cost for patients across the care venues are the same. It is important to note that the initial steady state is a dynamic equilibrium and is numerically sensitive to model parameters, but typical consequent behavior is not. The parameters used in the model are shown in Table 1.

3.4.2 Policy Experimentation

To illustrate the potential impact of policy changes, the simulation was run under four scenarios in which the steady state was perturbed by changing three main model parameters (i.e. service gap, out-of-pocket cost, and number of doctors) stepwise under the following scenarios:

I. Equilibrium: All key policy variables were kept constant. Under this scenario, effectiveness of normal and enhanced primary care was assumed to be equal and remain unchanged over the simulation time. Likewise, out-of-pocket cost, and number of doctors were assumed to be equal across the two care venues and remain constant over the simulation. All outputs were expected to remain constant at their steady state values and provide a reference trajectory.

II. Effective enhanced primary care: The effectiveness of receiving care at an enhanced primary care venue was assumed to be significantly higher to that of normal primary care. This was implemented by reducing service gap from 0.5 to 0.1 at time 5 while the service gap for normal primary care remained at 0.5 over the simulation time.

III. Reduced out-of-pocket costs for primary care: In addition to introducing enhanced primary care that could favorably affect clinical course, in this strategy the out-of-pocket costs for such care was assumed to be half of normal care, in order to increase the attractiveness of seeking care in enhanced care venues.

IV. Proactive increase of enhanced primary care providers: This scenario was the same as scenario III except that number of providers of care at the enhanced primary care (here indicated by number of doctors) is proactively increased as demand for enhanced primary care increases.

Table 1: Model Parameters.

Model Parameter	Unit
$Service\ gap[normal] = 0.5$	Dimensionless
$Service\ gap[enhanced] = 0.5 + step(-0.4,5)$	Dimensionless
$Hospitalization\ rate\ healthy = 0.1$	Visit/person
$Hospitalization\ rate\ stable\ chronic = 0.3$	Visit/person
$Hospitalization\ rate\ complicated = 1$	Visit/person
$Number\ of\ doctors[normal] = 10$	Doctor
$Number\ of\ doctors[enhanced] = IF\ THEN\ ELSE(SWITCH = 1 : AND : TIME \geq 5, estimated\ doctors[enhanced], 10)$	Doctor
$Cost\ per\ doctor = 15$	$/doctor/year
$Cost\ per\ hospitalization = 100$	$/year/visit
$Births = 350$	Person/year
$Initial\ complicated\ chronic\ condition = 2500$	Person
$Initial\ doctor\ patient\ relationship[providerType] = 1$	Dimensionless
$Initial\ healthy, at\ risk = 10000$	Person
$Incidence\ rate = 0.05$	Dimensionless/year
$Unit\ cost\ of\ care[normal] = 50$	$/visit
$Unit\ cost\ of\ care[enhanced] = 100$	$/visit
$Initial\ regression\ rate = 0.025$	Dimensionless/year
$Max\ time\ per\ doctor = 22500$	Min/doctor/year
$Mortality\ rate\ complicated = 0.07$	Dimensionless/year
$Mortality\ rate\ healthy = 0.01$	Dimensionless/year
$Mortality\ rate\ stable = 0.015$	Dimensionless/year
$Out\ of\ pocket\ cost[normal] = 50$	$/visit
$Out\ of\ pocket\ cost[enhanced] = 50 + STEP(-25,5)$	$/visit
$Progression\ rate = 0.12$	Dimensionless/year
$Initial\ stable\ chronic\ condition = 5000$	Person
$Time\ to\ adjust\ relationship = 5$	Year
$Time\ to\ change\ patient\ satisfaction = 5$	Year
$Visit\ per\ year\ complicated = 12$	Visit/person/year
$Visit\ per\ year\ healthy = 3$	Visit/person/year
$Visit\ per\ year\ stable\ chronic = 6$	Visit/person/year

4 RESULTS

Figure 2 shows the impact of the four scenarios on the quadruple aim of the health care system — population health (proportion with complex conditions), per person cost, patient satisfaction, and provider satisfaction (doctor-patient-relationship).

As expected, in scenario I, "equilibrium", given the assumptions, all the outcome variables remained constant over the simulation period.

Under scenario II, "effective enhanced primary care", where enhanced primary care was assumed to be 40% more effective than normal primary care, the proportion of the population with complex conditions decrease by 88% over the simulation time. Initially, per person cost of care increased following the sudden increase in effectiveness for enhanced primary care and decreased gradually over time. While average patient satisfaction increased with improved quality of care, the average doctor-patient-relationship actually decreased.

Under scenario III, "reduced out-of-pocket costs for primary care" is the same as scenario II with the elimination of out of pocket costs to patients (thereby enhancing the attractiveness of enhanced primary

care to patients), the behavior of the outcome variables are similar to that of the effectiveness of care scenario. Again, average patient satisfaction increased, now enhanced by a somewhat higher proportion of the population receiving higher quality services and with this increase is seen a diminished doctor-patient relationship as enhanced primary care venues become more crowded.

Lastly, under scenario IV, "proactive increase of enhanced primary care providers", also includes a provision for the increase in providers to meet growing service demand. Of all the alternative scenarios, this leads to the best population health (i.e., lowest proportion of the population with complex conditions) and highest costs. Notably it maintains high patient satisfaction as well as average doctor-patient-relationship.

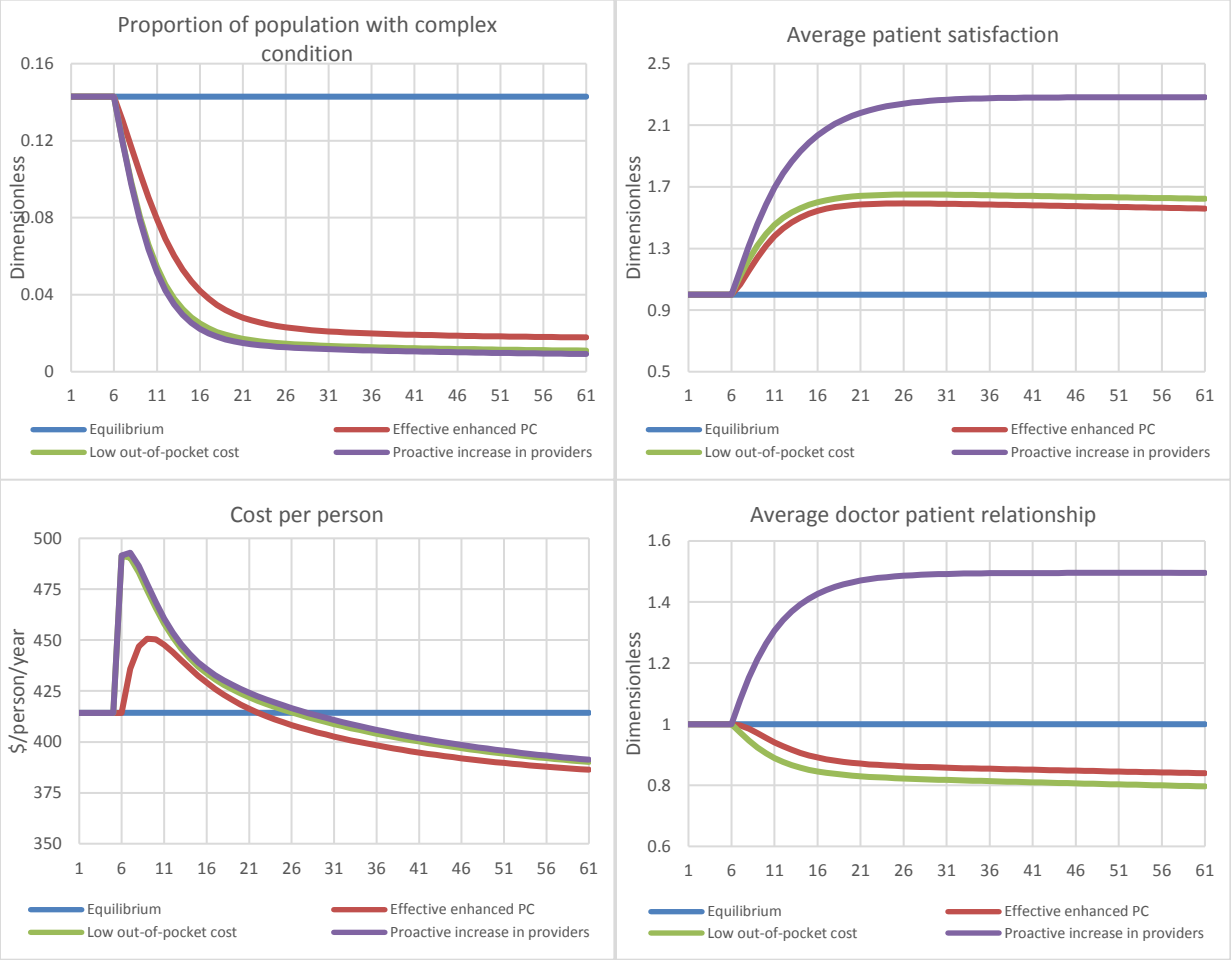

Figure 2: Impact of the four scenarios on the quadruple aim of the health care system.

5 DISCUSSION

In this exercise, we demonstrated the application of simulation modeling incorporating GMB to address a complex social issue involving potentially substantial change to the organization of crucial services. In addition to engaging stakeholders, the resulting model provided some preliminary insights into the dynamic impact of introducing a new model of primary care services intended to serve the needs of a broader range of patients than typically provided in the current system. It reinforced the general intuition that enhanced primary care services could improve outcomes, and that costs may, at least partially, be offset by the reduced utilization induced by better population health. Reducing the out-of-pocket costs to

patients had minor effects on population health or per person costs (not unexpected as costs were merely shifted from the patient to the government); however, since patients are quite price sensitive, this reduction did improve patient satisfaction by promoting their use of higher quality services. Moreover, changing the model of care without increasing the number of providers in this illustration had the undesirable consequence of decreasing doctor satisfaction as new venues become overwhelmed with patients seeking enhanced services, reducing continuity of providers and consultation time, and thus detracting from the doctor-patient relationship.

There are several limitations to the simple summary model. In particular, it represents only two key players: the normal primary care providers and enhanced primary care providers. In reality, chronic care services can be provided in multiple venues, including private GP offices, enhanced private sector clinics, public sector polyclinics, and specialty clinics. Each sector will offer a different mix of services and thus have different capacities to reduce service gaps, as well as different levels of attractiveness to patients. Thus, a practical set of policy options will not merely include the expansion of existing services (in this case, public polyclinic services) but also the encouragement through funding and regulation to promote enhanced primary care in the private sector. Thus, a realistic causal model must account for the tendency for individuals to vote with their feet: for doctors to participate in alternative models of chronic care service. Further, particularly in a system involving a mix of public and private sectors providers, quality of care will depend on their ability to integrate (i.e., share the care of the same patient) which requires a level of trust and communication.

A second limitation is the dearth of available data on current patterns of health service use, and the factors likely to influence both doctors and patients to participate in alternative care venues. The conclusions based on more complete evidence may very well be quite different. Indeed, we see this work as a first step in a coherent sequence of activities to promote informed decision-making regarding the development of enhanced primary care in Singapore. Based on the current exercise, we identified two areas where reliable information would be crucial to plausible projections of the impact of policy change and for which existing data are not available: (1) epidemiological data on the proportion of the population in various health needs segments and the rate of transition between segments, as a function of their patterns of care; and (2) the desirability of venues of care for patients and primary care providers based on characteristics of those venues which emerge from policy options. Thus, we are proceeding with collecting these data via a population-based survey and a discrete choice experiment with a broadly representative group of primary care physicians and individuals in various health needs segments. Since patient groups were not represented in the first GMB exercise, we will seek input from patient groups in the refinement of the model. In addition, we have engaged multiple representatives of the Regional Health Systems (RHSs); the RHS serve as the units responsible for planning the public response to expanding population health needs. The RHSs have agreed to partner with the research team to tailor the model to unique conditions in each region.

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