Exploring the Feedback Effects of Reconfiguring Health Services: The Case of Cardiac Catheterization Procedures

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The reconfiguration of health care, shifting services 'closer to home', is a well established trend, which has been motivated by the desire to improve the provision of services. However, these efforts may be undermined by the improvements in access stimulating demand. Existing analyses of this trend have only considered isolated parts of the system and have led to recommendations to control demand with stricter clinical guidelines or to meet demand with capacity increases. By failing to appreciate the underlying feedback mechanisms, these interventions may only have a limited effect. We demonstrate the contribution offered by system dynamics modeling by presenting a study of two cases of the shift in cardiac catheterization services in the U.K. We describe several mechanisms by which demand is stimulated and clarify the roles for stricter clinical guidelines and capacity increases. We also demonstrate the potential benefits of changing the goals that drive activity.

INTRODUCTION

The reconfiguration of health care is a well established trend whereby services are being shifted towards the primary level and 'closer to home' [1,2]. This trend has been motivated by the broad desire to improve the provision of services by expanding services and by improving service quality. However, the efforts to improve services overall may be undermined by the unintended consequences of service shifts, in particular, by the improvements in access stimulating demand. This general feedback phenomenon has been frequently reported in the health care literature [3-8].

The evidence of shifts in services influencing demand has tended to be anecdotal or unsubstantiated assertions with existing analyses limited to isolated parts of the system, based upon economic appraisals and surveys. Insufficient attention has been given to the underlying feedback mechanisms. Furthermore, existing analyses have led to calls to control demand by introducing stricter clinical guidelines or to meet demand with capacity increases [9-11]. However, these interventions may only have a limited impact due to the complexity of the underlying feedback mechanisms. System dynamics [12] is specifically designed for the analysis of feedback. Therefore, the application of this method could provide a better appreciation of the consequences of service shifts and thus offer useful insight into ensuring that service shifts actually improve the provision of services overall. In this paper, we describe a system dynamics modeling study [13] of a specific service shift across the patient referral chain in the U.K. health care system, the National Health Service (NHS).

The patient referral chain runs from the primary level (care by general practitioners or GPs) to the secondary level (district general hospitals) and from there on to the tertiary level (more specialized hospital-based care carried out at specialist centers). Our study considered the case of the shift in cardiac catheterization (CC) services from the tertiary level to the secondary level for low risk investigations. A CC investigation is an invasive procedure used to diagnose heart disease. The majority of elective (non-emergency) investigations are low risk. Whilst a few patients who present at hospital as emergencies will subsequently stabilize and become elective referrals for a CC investigation, elective referrals typically arise from patients first seen at a hospital outpatient appointment. We considered the development of CC services at two English district general hospitals. For reasons of confidentiality, they are referred to as ‘Veinbridge Hospital’ and ‘Ribsley Hospital’.

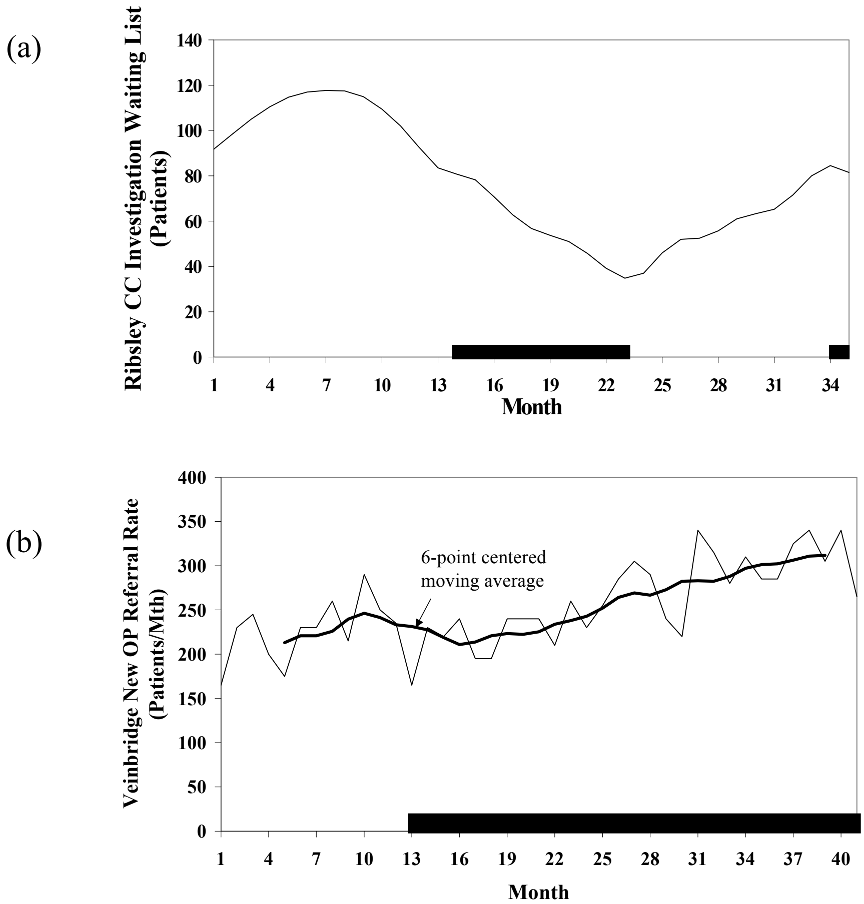
CARDIAC CATHETERIZATION SERVICES AT RIBSLEY AND VEINBRIDGE

Prior to the introduction of district services, cardiologists from Ribsley and Veinbridge Hospitals developed and maintained their CC skills, by using tertiary facilities to conduct CC investigations. They both worked at the same tertiary center. The level of both Ribsley and Veinbridge’s CC activity was determined by the contracts between the individual tertiary centers and the Ribsley and Veinbridge purchasing authorities. The elective demand for Veinbridge’s patients was met. However, there was a persistent problem of under-capacity for Ribsley’s patients. Consequently, temporary capacity increases had been provided at the tertiary level.

Improving Access with District Services

District CC services were originally introduced, using a mobile catheter laboratory, to compensate for the temporary closure of one of the tertiary-based catheter laboratories for repairs. Geographical considerations dictated that separate mobile sessions were required at Ribsley and Veinbridge Hospitals. At Ribsley, the district service sustained the capacity increases and thus produced dramatic improvements in access to elective services (Figure 1a). However, this trend was reversed when the tertiary laboratory reopened and the district service was withdrawn. A further temporary service was offered at a later date to compensate for a second period of construction work at the tertiary center and to provide additional capacity. This achieved further temporary improvements in access.

Figure 1. Consequences of District Services: Improving Access and Stimulating Demand



Black blocks indicate the use of district services

At Veinbridge Hospital, the district CC service formed part of a long-term strategy to expand capacity and to develop cardiac services at Veinbridge. Consequently, after the tertiary laboratory re-opened, the district CC service continued and was developed into a permanent service, with an integrated catheter laboratory.

Improvements in Access Stimulating Demand

The collaborators described several different mechanisms by which the improvements in access stimulated demand. These mechanisms involved the influences of a number of factors, in particular, the average waiting time, knowledge of patients and GPs of CC and the new CC service, and the skills of the CC operators. We refer to these effects as the waiting time, knowledge and skills effects on demand. The stimulation of demand was also reflected in the hospital data. No other changes occurred during the 40-month observation period that could have accounted for the changes in demand.

In both cases, there was sufficient supply to meet the CC investigation waiting time goals whilst the district CC services were in place. However, in the Veinbridge case, the increase in demand for an outpatient appointment (Figure 1b) produced severe detrimental effects on access to this service. This loss in access had not been anticipated.

THE SIMULATION MODEL

The model conceptualization process involved collecting archival data, observational work, informal discussions with junior hospital staff, and formal interviews with senior health professionals including consultant cardiologists, hospital managers and health service purchasers.

The simulation model was constructed using the *STELLA* software [14]. The model contains nearly 300 variables including 18 stocks (or levels) in the main structure and 52 overall. The main patient flows are shown in Figure 2.

Figure 2. The Main Patient Flows

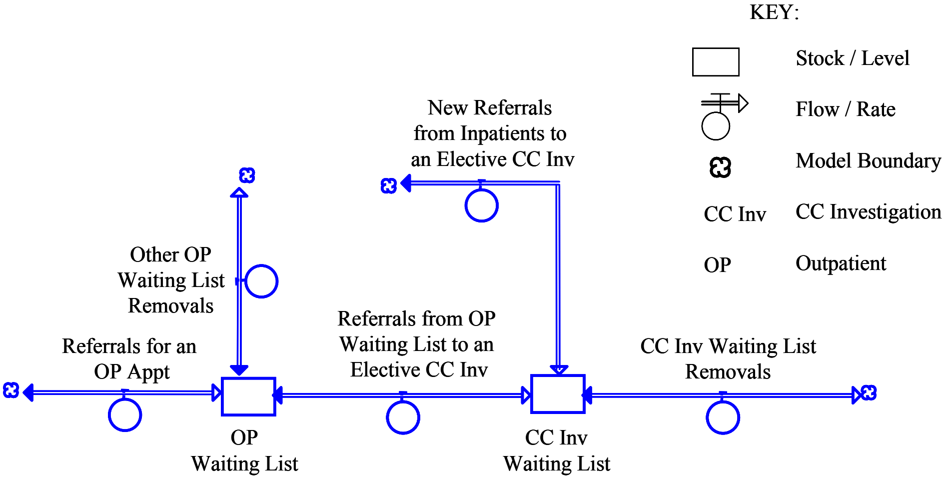
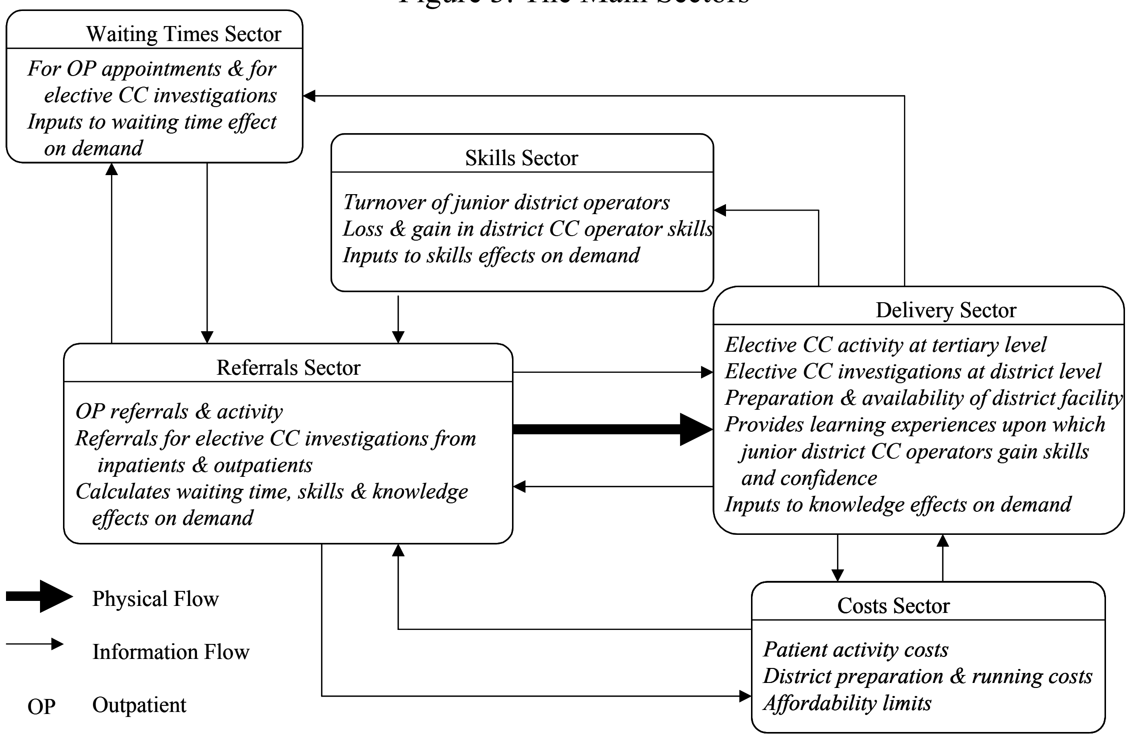


Figure 3. The Main Sectors



The model is divided into five main sectors (Figure 3). The endogenous variables include several referral multipliers, the waiting list lengths, average waiting times and patient activity rates. Beyond the model's explanatory boundary are a number of exogenous factors including the service capacities. This arose from the model purpose, which was to examine the consequences of the shifts in services and associated feedback effects and not the policy decisions to introduce a district service. Other exogenous variables reflected simplifying model assumptions. These included the base demand for an outpatient appointment that aggregated demand for new and follow-up appointments, and certain referral multipliers.

The modeling perspective of system dynamics is on continuous, aggregate phenomena. However, there have been calls to modify the system dynamics paradigm by incorporating discrete and stochastic elements into its models and by disaggregating further. This has been to extend the range of feedback phenomena that may be studied and to satisfy clients' desire for further detail [15-17]. In our study, it was necessary to make some modifications, for the former reason, as the emphasis was on decisions and processes at the local (individual hospital) level rather than the national level. This resulted in the introduction of discrete elements into the model including appropriate built-in STELLA functions. For example, to model the arrival and departure of trainee CC operators, a function was used which generated a pulse input of a specified size at a specified time.

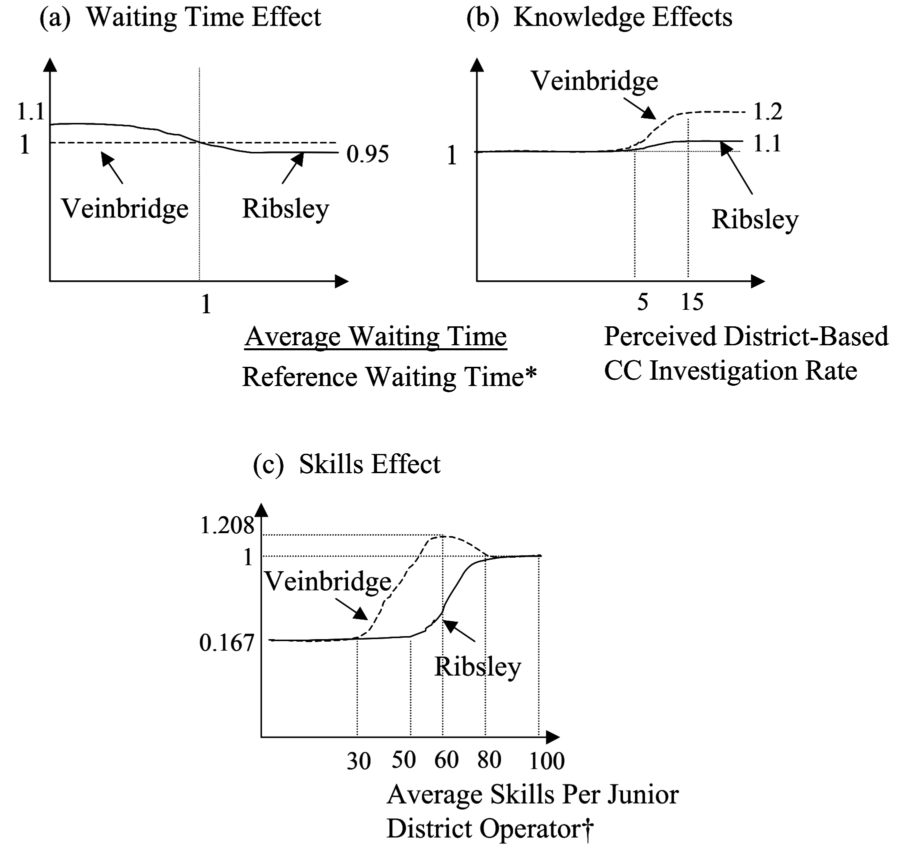
Calculation of the Elective CC Investigation Referral Rate

The elective CC investigation referral rate is the rate of referrals from the inpatient route (from patients who were admitted into hospital and subsequently stabilized) added to the rate of referrals arising from patients seen in outpatient clinics. The former was assumed to be constant and the latter is a fraction of the outpatient activity rate. This referral fraction is a reference referral fraction (described later) adjusted multiplicatively by several referral multipliers.

The model contains five base case referral multipliers. The first three are endogenous variables (Figure 4). The first multiplier involves the influence of the average waiting time (Figure 4a). This reflects how low waiting times could stimulate demand and how high waiting times could suppress demand. For the Veinbridge case, the waiting time was not considered a factor in referral decisions, which was consistent with the more 'aggressive' (confident and enthusiastic) referral behaviour at Veinbridge. This multiplier is set to a default value of 1 (zero effect).

The second multiplier concerns the influence of the knowledge of patients and GPs of the benefits of CC and the new CC service (Figure 4b). By developing a local CC service, GPs and patients became more knowledgeable about the benefits of CC and overcame anxiety about the risks, and thus more demanding for this service. The extent of this effect on demand increased as the district service grew generating more publicity and, through 'word of mouth', more reports of patients who had benefited. This effect was delayed as GPs and patients perceived changes in the availability of district services. Subsequently, this multiplier is modelled as a function of the perceived district CC rate. The effect was greater at Veinbridge because the CC service was permanent and heavily marketed.

Figure 4. Base Case Waiting Time, Knowledge and Skills Referral Multipliers



* - Neither stimulates nor suppresses demand; † - 100 represents a fully skilled CC operator;

Values above 1 - Stimulation of demand; Values below 1 - Suppression of demand

The third multiplier depicts how changes in the skill base of those who select patients for a CC investigation could alter demand (Figure 4c). We expand on the reports of Hamblin *et al* [18] who described how when staff gain new skills, as a result of taking on new duties, they identify more patients in need of treatment. We considered the *rate* of the gain in skills and the *loss* in skills associated with staff turnover. The effect of skills on demand is a weighted average of the skills multipliers of three categories of staff: expert CC operators; junior trainee CC operators; and, non-CC operators. Experts and non-CC operators were assumed to make referrals at constant rates with the former referring more than the latter due to their higher enthusiasm for CC and their greater skills in identifying patients in need (non CC operators will often be general physicians rather than cardiologists). The referral multiplier represents the changes in referrals of junior trainee CC operators as they climbed up the learning curve gaining specialist knowledge and confidence. The two functions reflect the different referral patterns, one representing Ribsley, involving a period of under-confidence and the other, representing Veinbridge, also involving a period of over-confidence. The multiplier reflects the greater confidence 'spilling over' during the learning process. Periodic skills effects were introduced by the existence of training programmes and the rotation of junior staff between hospitals.

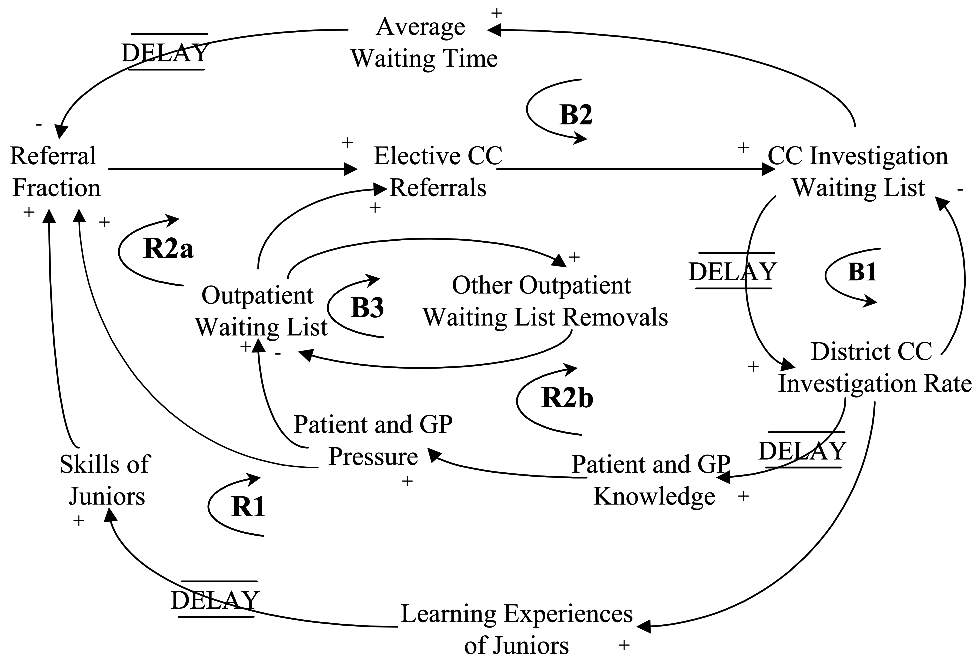
The model contains two other referral multipliers that are, for simplicity, modelled exogenously. The first is the effect of significant capacity losses on referrals. It was assumed that a significant loss of capacity in the Ribsley case (e.g. the withdrawal of the district service) resulted in a reduction in referrals of the lowest priority, lowest risk cases as a 'knee jerk' reaction. For the Veinbridge case, as there were no significant capacity losses, this multiplier is set to a default value of 1 (a zero effect). The second multiplier is the effect of other factors on referrals. For the Veinbridge case, it reflects how introducing a permanent CC service and opening the integrated laboratory prompted shifts of higher risk cases to the district level. For the case of Ribsley, this multiplier is set to the default value of 1, as the district service was only temporary.

The reference referral fraction represents periods where: there was no district service; normal capacity levels existed at the tertiary level; all district screeners were fully skilled; and, there was neither stimulation nor suppression of demand due to the waiting time or knowledge effects. This would correspond with a situation for which GPs' and patients' knowledge of CC relied totally on that derived from a tertiary-based service. An expert estimate applies to the case of Ribsley and for the case of Veinbridge, this figure is subjected to a multiplier to account for the more 'aggressive' referral environment. The formulation chosen for the referral fraction reflects the assumption that the 'knee jerk' reaction to the capacity losses dominated over the effects of waiting times, knowledge and other factors on referrals for an elective CC investigation. This avoids double counting patient referrals [19].

The Basic Mechanisms

The basic feedback mechanisms represented in the model are shown in Figure 5.

Figure 5. Basic Feedback Structure



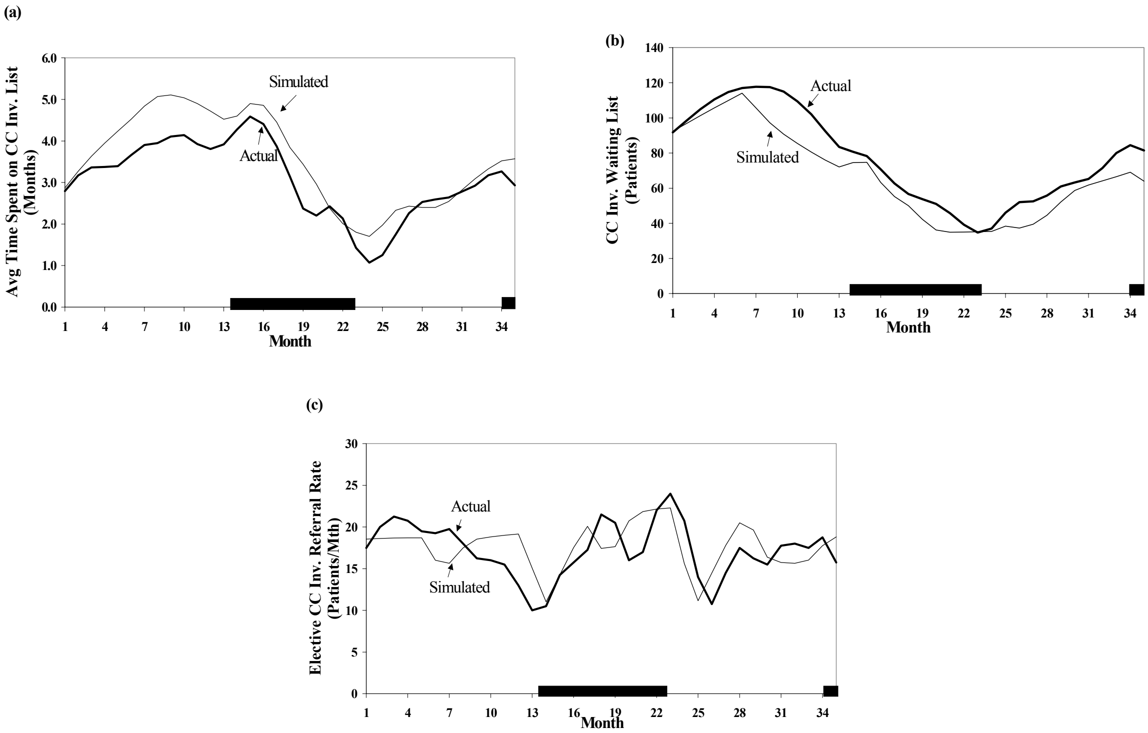
B1 - Activity adjustment; B2 - Waiting time effect on demand; B3 - Other outpatient waiting list removals; R1 - Skills effect on demand; R2a & R2b - Knowledge effect on demand for elective CC investigations and outpatient appointments respectively; For the Veinbridge case, loops B2 and R1 remained inactive. The average waiting time was not considered in making referral decisions and referrals were not influenced by changes in juniors' skills and confidence because the expert operator made all final decisions about referrals.

Model Parameterization and Testing

The justification underlying the model parameters varied as efforts were made to utilize all the available data, as recommended by Homer [20]. The approximations and assumptions made served for the purpose of the model. Various parameters arose from archival data provided by the collaborative centers. Other parameters were based upon estimates given by the study collaborators including some of the nonlinear referral multiplier functions. There was insufficient numerical data to estimate these functions econometrically, as described by Sterman [21]. In several cases where numerical data did not exist, parameter values were derived from simple calculations using the actual activity rates and by assuming that parts of the system were in equilibrium and the desired waiting time goals were maintained. Values of parameters were also obtained from the preliminary simulation runs.

Confidence was gained in the model via established methods [19,22]. In testing the ability of the model to replicate the patterns of historical behavior there was a good qualitative fit in both cases. Figure 6 shows some selected graphs for the Ribsley case.

Figure 6. Selected Graphs of Historical Fit for the Ribsley Case



Actual data is smoothed with a 2 point-centered moving average. Black blocks indicate the use of district services during month 14 to month 23 and month 34 to month 38; Avg - Average; CC Inv - CC Investigation

For the Veinbridge case, hypothetical reference modes were constructed due to the absence of suitable real data. These modes, which were based upon the descriptions of the interviewees, were verified during the base case analysis.

MODEL-BASED EXPERIMENTS

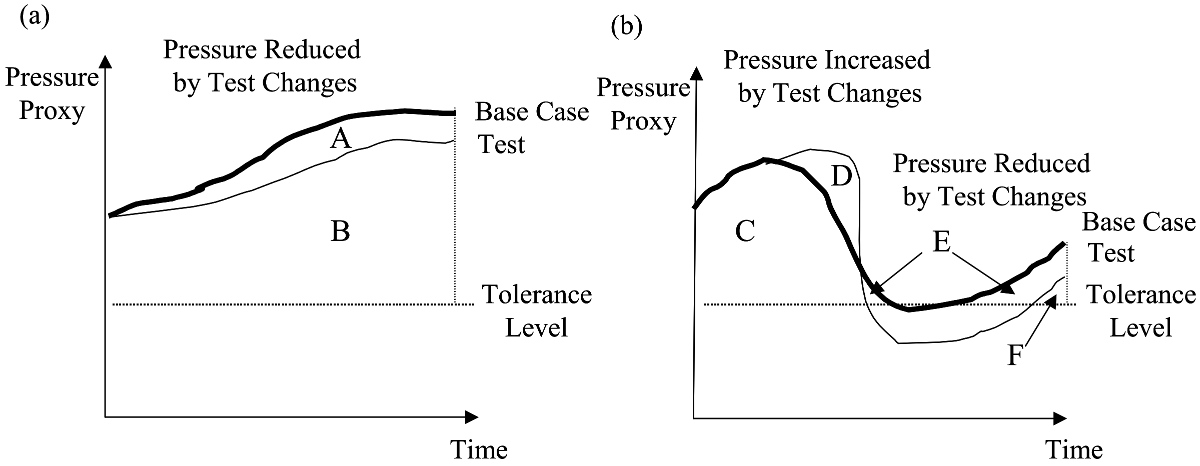
Insight into the basic causes of the base case scenario was gained via a series of partial model test simulations and sensitivity analyses. A series of policy experiments followed which showed how the senior health professionals *could have* effectively intervened to improve the provision of services. Sensitivity analysis confirmed the insights generated by the various experiments. We provide an overview of the experiments and present the results of the key policy experiments.

The key model outputs were: the cumulative referrals, cumulative patient activity, cumulative overall costs, and the basic trends displayed by the average waiting times and waiting lists. Waiting times and waiting lists were both considered as each reflect different aspects of pressure on the system, respectively, the delay for services and the number of patients waiting. In our case studies, whilst the focus was on meeting waiting time goals, those concerned about costs were also interested in the length of the waiting list. For example, if the waiting time target was met, an increase in the waiting list would indicate that increases in patient activity were necessary to prevent the average waiting time rising above its target.

In interpreting the results of the experiments, we considered the varying needs of the different senior health professionals [8,23,24]. Firstly, the need to improve health i.e. identify patients in need of treatment, provide health care promptly and appropriately, direct resources towards the most urgent cases, and increase activity and thus meet higher activity targets. Secondly, the need to control the overall costs incurred i.e. whilst agreeing to the district service set up costs, ensuring that services were used appropriately. Thirdly, the need to improve efficiency i.e. deliver care at the lowest cost/case. We thus refer to *health improvement*, *overall cost control* and *efficiency improvement perspectives*.

To summarize the graphical output of different simulation runs, for several variables, a simple ‘pressure summary index’ was defined by the area between each graph and a tolerance level as specified by the relevant goal (Figure 7). We assumed that pressure would only be exerted if the goal were exceeded. Comparing areas thereby quantified the degree to which improvements had been made over the duration of the simulation run, accounting for short-term and longer-term effects and changes in expectations, which would be reflected by adjustments in the tolerance level.

Figure 7. Using a Pressure Summary Index to Measure an Improvement Under Test Conditions



For (a):	PSI for Base Case	= Area A+ Area B
	PSI for Test Case	= Area B
	Improvement with Test Conditions	= Area A
For (b):	PSI for Base Case	= Area C + Area E + Area F
	PSI for Test Case	= Area C + Area D + Area F
	Improvement with Test Conditions	= Area E – Area D

PSI - Pressure summary index; Pressure Proxy - Waiting list length or average waiting time

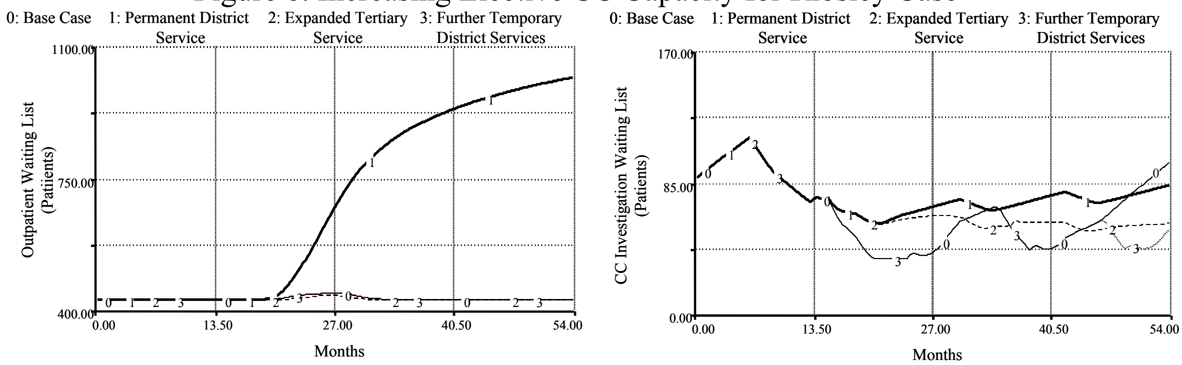
Ribsley Case

The Need for Capacity Increases

The Ribsley experiments indicated that the extent of the under-capacity was such that demand management strategies alone, even the use of the most stringent clinical guideline, could not have altered the undesirable rise in the CC waiting list and average waiting time. Frequent capacity increases were necessary. However, it would be sensible to coordinate capacity increases with efforts to manage demand to ensure that the benefits of increasing supply were not cancelled out by stimulated demand.

Different approaches to capacity increases would have produced different effects (Figure 8 and Table 1). An obvious approach to increasing capacity would have been to provide a permanent district service, as this would have been expected to maintain the access targets permanently. However, from an *overall cost control perspective*, the benefits of increasing the supply would have been cancelled out by stimulated demand. The CC investigation waiting list would have exhibited a gradual rise thus indicating the need for further increases in the elective CC investigation rate in order to maintain the desired waiting time. Furthermore, the stimulated demand would have created a new problem, as outpatient capacity shortages would have arisen. This would have been unanticipated and it would have then called for further resources in an attempt to control access to outpatient services. From a *health improvement perspective*, the reduction in the CC waiting times and increases in activity associated with a permanent district service would have been attractive, but these benefits would have been undermined by the loss in access to outpatient services.

Figure 8. Increasing Elective CC Capacity for Ribsley Case



The outpatient waiting list graphs for runs 0 and 3 are the same.

Table1. Selected Summary Statistics of Ribsley Policy Runs

Performance Measure	Base Case	% Change from Base Case: Permanent District Service	Expanded Tertiary Service	Further Temporary District Services
PSI for outpatient waiting list	155	>+8000	-44	0
PSI for CC waiting list	891	+1.6	-40.5	-10.6
Cumul. referrals for an outpatient appt	19,937	+9.7	-0.2	0
Cumul. referrals for a CC investigation	947	+13.4	+4.7	-1.4
Cumul. outpatient activity	18,784	+3.5	-0.2	0
Cumul. CC investigations	848	+14.9	+9.4	+4.3
Cumul. Costs	2,439,461	+6.4	+1.7	+1

Cumul. - Cumulative; PSI - Pressure summary index

By using new referral guidelines, it might have been possible to suppress demand and generate considerably lower costs. However, whilst the use of new moderate guidelines would have enabled the access to CC services to be maintained, strict new guidelines would have been necessary to eliminate the outpatient capacity shortages. The feasibility of introducing strict new guidelines would have been doubtful even in a modest referral environment such as Ribsley. Therefore, even with realistic safeguards in place to control demand, a permanent district service could not have led to significant improvements from either an *overall cost control* or *health improvement perspective*.

Limiting the Use of District Services

The access problems generated by a permanent district service suggests that a more effective approach to increasing supply would have been to limit the use of district services. In theory, this could have involved either expanding the tertiary-based service, and just using the district service to compensate for tertiary facility closures, or offering further temporary district services. (i.e. a continuation of the base case scenario). Compared to a permanent district service, carrying out the same capacity increases at the tertiary level would have generated fewer costs because by lowering demand and reducing expectations on the service, it would not have been pushed as far. Therefore, this option would have been more attractive from an *overall cost control perspective*. However, in practice, expanding the supply for elective services at the tertiary level would have been difficult whilst meeting the demands for more urgent cases. Expanding the supply at the district level would have been easier to achieve, as the service would have been solely devoted to elective care. Those pursuing an overall cost control agenda would have favored further temporary district services over the same overall capacity increases translated into a permanent expansion at the tertiary level. This would apply because the former would have generated lower costs due to the 'knee jerk' reductions in referrals in reaction to the capacity losses.

The preference from a *health improvement perspective* would have been less clear. The greater use of a district service would have provided more opportunities to devote tertiary resources to more complicated cases. It would also have led to the stimulation of more demand for outpatient services. Bringing more patients forward for assessment could have led to the identification of further high-risk patients and also supported higher activity targets. However, fewer referrals would have been made for CC services, as by introducing more capacity losses there would have been more 'knee jerk' reductions in referrals in reaction to these losses. It could be assumed that these reductions would have referred to lower risk patients. However, their assessment as lower risk patients would have been based on incomplete information i.e. without the benefit of the CC investigation, which was the most accurate diagnostic tool available. It would have been possible that some high-risk cases that presented minor symptoms would have slipped though the net. Therefore, from a health improvement perspective, further temporary district services would have involved trade-offs. Nevertheless, it could be assumed that those pursuing this agenda would have conceded that, on balance, further temporary district services would have been the only practical way to achieve improvements in access.

The attractiveness of further temporary district services would have been subject to district services being efficient. Based upon the limited data provided, the district service provided investigations at a lower cost/case compared to tertiary-based investigations. However, some patients needed to undergo a second CC procedure for treatment as synchronous investigation and treatment was only permitted at the tertiary level. Taking this factor into account, a district service would only have been attractive from an *efficiency improvement perspective* if it had avoided a high proportion of patients undergoing their CC investigation as an inpatient. If that were not the case, from an efficiency improvement perspective, the desire would have been to restrict the district service and to achieve improvements in access to CC services via an expanded tertiary-based service if possible.

Veinbridge Case

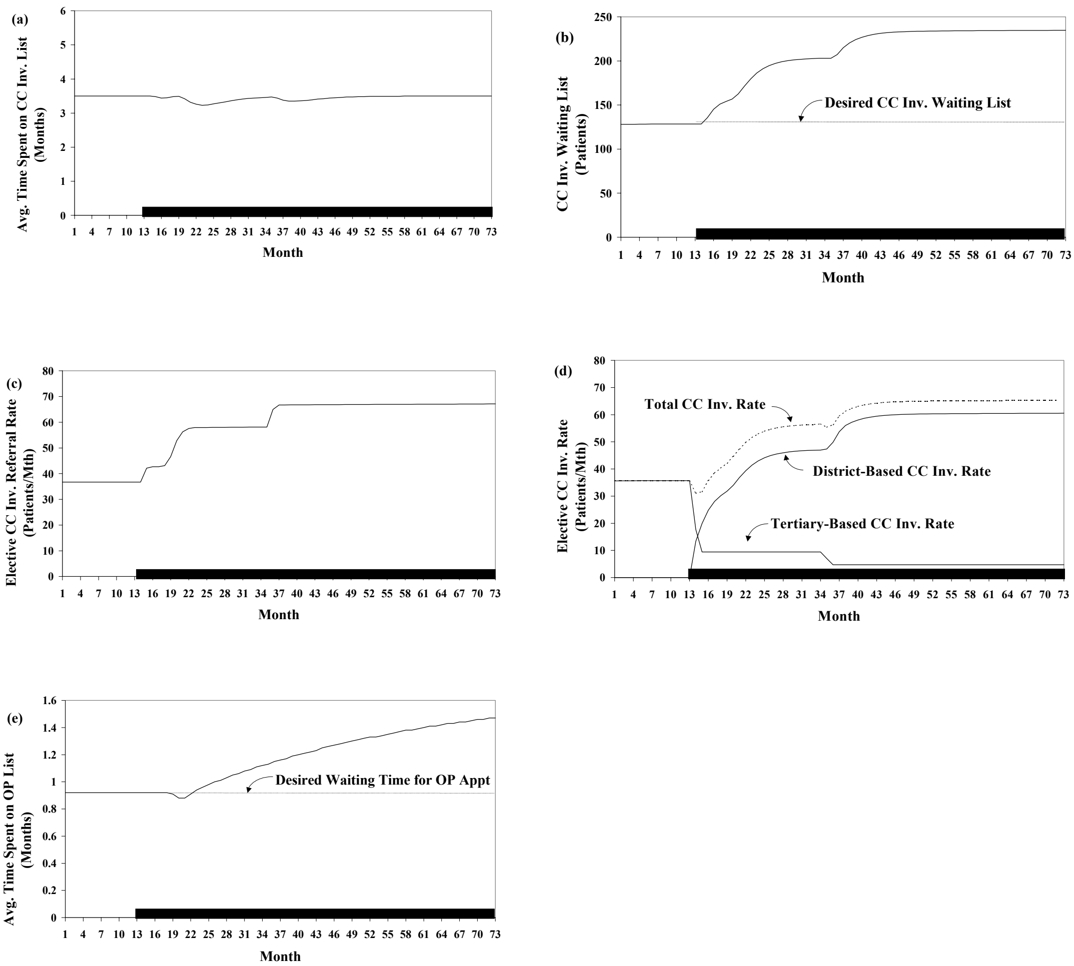
The Need to Control Demand

The Veinbridge base case analysis indicated that whilst the long-term strategy to expand CC services at Veinbridge Hospital relied upon increases in demand, the strategy would be undermined unless it was coordinated with controls to limit the stimulated demand. Demand for outpatient services (where patients are screened for a CC investigation) would have to be controlled. Significant increases in the Veinbridge outpatient activity were not essential to support the expansion of CC services at Veinbridge. Demand for the CC service also arose from elsewhere (cardiologists from the surrounding districts also used the Veinbridge facilities). The Veinbridge purchasers were concerned that the increases in demand for outpatient services indicated a rise in inappropriate referrals. Consequently, they were unwilling to provide unlimited funding for outpatient services.

Combining Controls on Demand with New Forces Driving Activity

Whilst the desired waiting time for CC was met, the CC waiting list exhibited increases (Figure 9). The base case analysis suggested that with sufficient slack in the system, the waiting time and waiting list goals could have been met simultaneously by changing the forces that drive activity rates - seeking a desired waiting list length rather than a desired waiting time. There was spare capacity for elective CC services and introducing controls on demand would have produced some spare capacity for outpatient services.

Figure 9. Selected Variables for the Veinbridge Base Case Scenario



Black blocks indicate the use of district services (introduced at month 13 and with integrated catheter laboratory opened at month 34); Avg - Average; CC Inv - CC Investigation; OP - Outpatient

The policy analysis thus considered the use of stricter clinical guidelines in combination with changes to the goals that drive activity. The use of stricter guidelines was modeled by assuming that the maximum degree to which demand could be stimulated was cut by 50%. This was considered to form a reasonable adjustment. The factors limiting a further reduction were the acceptability of such guidelines in such an 'aggressive' referral environment, and for the case of CC services, the need to ensure sufficient demand to justify the development of a permanent district service at Veinbridge. For comparative purposes, a further experiment considered the use of stricter guidelines alone, and another experiment investigated the effects of a 10% increase in outpatient capacity.

The experiments demonstrated that, the outpatient and CC waiting list and waiting time goals could have been simultaneously (and feasibly) met only by using stricter clinical guidelines in combination with seeking a desired waiting list length (Figure 10 and Table 2). In fact, this policy would have overcompensated by producing an average waiting time that was lower than required. The use of stricter new referral guidelines alone would have led to some improvements but fewer than those derived from the combined policy. Increasing outpatient capacity would have generated increases in the overall costs and CC costs in particular as further patients were pushed along the referral chain.

Figure 10. Meeting the outpatient Waiting List and Waiting Time Targets for Veinbridge Case

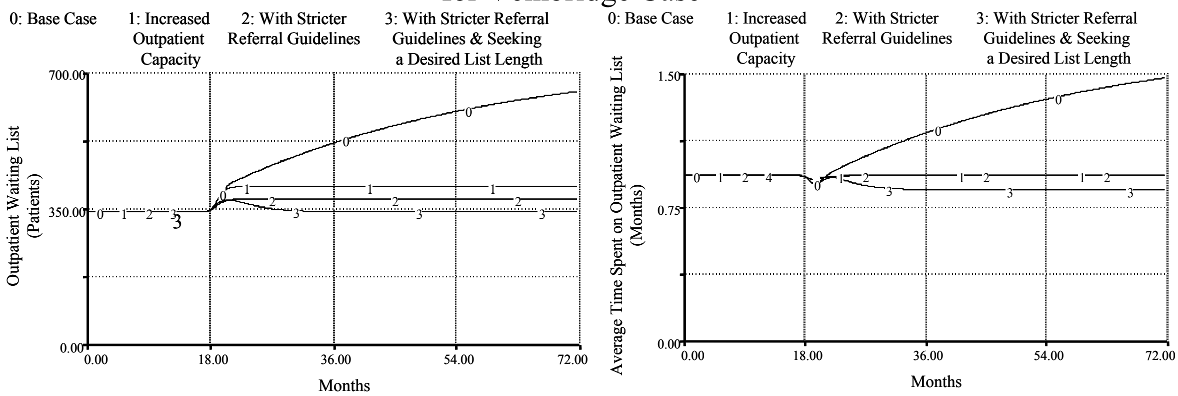


Table 2. Selected Summary Statistics of Veinbridge Policy Runs

Performance Measure	Base Case	% Change from Base Case: Increased Outpatient Capacity	With Stricter Referral Guidelines	With Stricter Referral Guidelines & Seeking a Desired List Length
PSI for outpatient waiting list	11,263	-68.4	-84.2	-98
PSI for time spent on outpatient waiting list	17	-100	-100	-100
PSI for CC inv. Waiting list	5,043	+2.4	-52.2	-96.6
Cumul. referrals for an outpatient appt	30,295	0	-6.5	-6.4
Cumul. referrals for a CC inv.	4,140	+0.9	-19.6	-19.5
Cumul. outpatient activity	29,092	+1.5	-5	-4.7
Cumul. CC investigations	3,922	+0.9	-18.6	-16.8
Cumul. Costs	6,801,121	+1	-10.2	-9.3

CC inv. - CC investigation; Cumul. - Cumulative; PSI - Pressure summary index; * - Division by zero;

Achieving Significant and Sustainable Improvements

Therefore, the implementation of the long-term strategy to expand CC services could have been improved by coordinating the shift in CC services with the use of new referral guidelines and changes to the forces that drive activity rates. This would have produced significant and sustainable improvements in behavior that would have been attractive from both an *overall cost control* and a *health improvement perspective*. The effects of this policy would have been particularly attractive from an overall cost control perspective, as it would have led to improvements in access and reductions in costs. For those pursuing a health improvement perspective, there would have been trade-offs. They would have valued the improvements in access to outpatient services and reduction in the CC investigation waiting list but the reductions in referrals and activity would have been in conflict with the desires to meet higher activity targets and identify more high risk patients.

As with the case of Ribsley, taking into account the need for some patients to undergo further CC, a mobile-based district service at Veinbridge was only more *efficient* than a tertiary-based service if it avoided a large proportion of patients being catheterized as inpatients. When the integrated catheter laboratory at Veinbridge opened, it provided the opportunity to improve the efficiency of the district service as the cost/case declined with the volume of patient activity. This eliminated any conflict there might have been in considering both a *health improvement* and an *efficiency improvement perspective*.

DISCUSSION AND CONCLUSIONS

Little attention has been given to the actual mechanisms of feedback effects associated with service shifts. This is in spite of the increasing emphasis in health care on the need for 'joined-up' or 'whole systems' thinking where different parts of the system and their interactions are considered [9,25,26]. This paper has demonstrated the contribution system dynamics modeling can provide. Our study offers a plausible causal framework to support the hypothesis that shifting services can stimulate demand. Also, in offering empirical evidence of this phenomenon, we argue that such policies should be coordinated with other policy changes to control demand and to ensure that suitable forces drive patient activity.

As with all models, this model is based upon certain simplifying assumptions. For example, in reality, there would be additional feedback mechanisms. Nevertheless, the model still successfully replicated the problematic behavior for both cases. Furthermore, the findings of this research are not specific to the subject or timing of the case studies as the interactions between supply and demand are widely generalizable. Therefore, a number of broad policy lessons and recommendations may be derived.

Policy Lessons and Recommendations

It has been previously argued by Wolstenholme [27] in a community care setting, that increasing capacity is not necessarily the most effective way of improving access. Our study provides further evidence of this paradox. Wolstenholme highlights the greater leverage of flow (rate) variables compared to that of stock variables. The Veinbridge case showed that capacity increases (a stock variable) and stricter referral guidelines (flow variables) would have provided similar leverage in improving behavior in terms of reducing the waiting list and average waiting time. Furthermore, significantly better leverage could have been obtained by combining stricter guidelines with changes to the goals that drive activity (both flow variables). This result arose from the existence of spare capacity and was not specific to the case of the shift in CC services. It was a general consequence of the interplay between supply and demand variables that determine the waiting list length and average waiting time. Although discussions of spare capacity may seem incongruous with reports of long NHS waiting lists and waiting times, some spare capacity is often released by service shifts, by their ability to provide additional capacity and/or by prioritizing patients. By contrast, the Ribsley case demonstrated that in cases of extreme imbalance between supply and demand, only capacity increases could have provided the necessary leverage. However, demand management strategies could still have played an important role by improving the leverage of capacity increases.

Our study challenges the persistent tendency in health care towards a narrow focus on isolated events, short-term results and single performance measures with calls made to shift the emphasis from the waiting list length on to the waiting time [18]. For example, the Veinbridge analysis showed that maintaining a waiting time goal did not necessarily mean that the system was free from pressure. The rise in the waiting list suggested that it was under pressure and that the waiting time goal was only being maintained because more money was being poured in to raise activity levels.

The case studies also illustrated the influence of pressure by patients on clinical decisions and the problems that can arise from the inability to cope with this pressure and the poor management of demand. It has been argued that clinical and policy decisions should be driven by the preferences of patients and the public [28,29]. Questions thus arise about how the shift in the balance of care can continue whilst providing high quality care to patients whose expectations for health care are traditionally high.

Generalizations

Whilst the NHS formed the context to our case studies, our research findings have implications for health service reconfigurations in other countries in spite of the differences between their health systems. The NHS is a publicly funded system. Other types of health systems are privately funded or insurance-based. The stimulation of demand in response to improved access is a common response in the NHS and it is a consequence to services being free at the point of delivery. However, it could be argued that services in other health systems are all free in one sense or another. The individual feedback mechanisms that we have discussed can be generalized to other health systems. Even the impact of waiting times on referrals can be generalized in spite of the fact that waiting lists are a typical characteristic of the NHS; the waiting time can translate to other health systems into the price customers pay for services.

Potential Changes in Health

In both cases, the stimulated demand prompted increases in activity. The question of whether or not the increase in the CC investigation rate actually improved health was not fully addressed as serial data of clinical events and long-term patient outcomes were not monitored. However, several comments could be made. In the Ribsley case, the reduced waiting time for catheterization contributed to shorter delays for those requiring invasive treatment (coronary angioplasty or coronary bypass surgery). This could offer the potential for health benefits as treatment delays can lead to some patients deteriorating.

The fraction referred on for a CC investigation increased in both cases. As the case mix of the patient populations did not change, this meant that the threshold for a CC investigation had changed towards less severe cases (defined without the benefit of a CC investigation). Catheterizing more of these patients could lead to improvements in health if it identified further patients in need of invasive treatment; some patients with severe heart disease only display minor symptoms and these patients may thus fail to be identified by other diagnostic methods. The fraction of patients referred on for invasive treatment remained constant so, associated with the increased catheterization rate was an increased invasive treatment referral rate. This would suggest that, from the less severe cases, further patients in need of such treatment had, indeed, been identified. However, for even less severe cases, it might be better to delay bypass surgery until the disease is more advanced as repeat bypass surgery, which can occur given the progressive nature of heart disease, carries higher risks. Therefore, delaying catheterization (and therefore delaying bypass surgery) could, paradoxically, be beneficial in the long-term management of the disease.

Further Work

There are several possibilities for further work. The model could be employed to explore other service shifts, of which there are numerous examples. The model boundary could be extended to endogenize the follow-up process of patients after their discharge from an outpatient appointment and the process of changes in the referral threshold for CC and district CC as the district service evolves. The model could be disaggregated to elucidate the dynamics of changes in clinical priority between routine and urgent elective cases. Finally, the pressure summary indices could also be investigated further.

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