

Productivity Modelling: A Health Systems Focus in Small Island Developing States

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Abstract: This paper explores the various dimensions of measuring productivity in health systems in Small Island Developing States (SIDS). The authors seek to unearth the difficulties which arise when measuring the productivity in these systems, identifying the various forms of productivity which are applicable to health systems and determining the best means of measuring productivity in these health systems. The findings show that the development of partial productivity measures is difficult, but it is best for decision making and improvement of performance of the health systems. The paper concludes by proposing the use of a composite measure, $C_i = \alpha_1 P_{i1} + \alpha_2 P_{i2} + \dots + \sum_j \alpha_j P_{ij}$ which is based on the partial productivity measures as a more robust measure of productivity in the health systems in SIDS. The overall productivity of elements of the health system, or the entire health system itself, can be measured, monitored and disaggregated for identifying areas for productivity improvement through management intervention.

Keywords: Productivity, efficiency, health systems, partial-productivity, whole-productivity, composite measure

1. Introduction

From an economic perspective, there is a direct relationship between productivity improvement and economic growth. In Small Island Developing States (SIDS) of the Caribbean, economic growth is usually dependent upon export capacity, for raw materials and agriculture products, or service delivery, mainly in the tourism sectors. With the advent of the Covid-19 Global Pandemic, the tourism sector of most SIDS has been wiped out. For those countries where tourists have been allowed, there has been the risk of the upsurge of cases of Covid-19 which have the potential of causing economic collapse. It is therefore necessary to consider how well health systems can cope with the impact of this global pandemic, and how productivity measurement and improvement can aid in this process.

One of the simplest ways to increase productivity is to improve the operations of any system. This may involve the development on new methods of using the available resources to provide outputs at higher quantity and quality and at a lower cost. Sometimes in high-pressure, continuous operating systems, some resources tend to exist with excess capacity, as focus is paid to serviceability and reliability. Being able to measure productivity rapidly and with high accuracy would allow for better tracking and utilisation of resources, while also improving the quality and reliability of health systems.

2. Literature Review

Measuring productivity can be used to improve health care delivery. Assessing the individual processes of the patient flow can assist in measuring individual productivity levels for these departments. By assessing all the processes in the model, we can compare the units and calculate productivity for the entire system. In this review of relevant literature, productivity and productivity measurements would be discussed in relation to health care: the purpose of productivity measurement, types of productivity measures and systems, variables, traditions, challenges, and advancements would be discussed.

2.1 Definition and Purpose of Productivity

Productivity can be defined as the ratio of the given outputs to the given inputs of a system for a specific period of time (Finkler, 2007). Output per labour hour has deemed to be the most common measure of productivity. As for hospital productivity, it can be measured in terms of hospital expenditures, physician practice or health systems utilising the outputs that contribute to health care (McKellar, 2011). Productivity analyses are subjective since there are different definitions of output and input that vary across different hospitals. These differences are explained by production technology, scale differences, efficiency differences and environmental characteristics (Nazarian, 2014). Productivity is commonly referred to as cost per patient day and increases with length of stay. One factor

considered is the changes in inputs which, when decreased, can be beneficial to hospitals by increasing the number of patients per day and increasing earnings per employee whilst maintaining the quality of services provided (Scott, 2008).

2.2 Difference between Productivity and Efficiency

The terms productivity and efficiency are often used interchangeably. However, they have different applications. Productivity is associated with working smarter; it is doing new things or improving ways things are done to create value and results. While efficiency is about doing more with less, and is concerned with lowering the cost of the status quo (Heizer et al., 2017).

2.3 Productivity Measurement

Productivity measurement is needed to assess productivity growth. Low productivity growth rate is a result of productivity measurement pitfalls (Sheiner and Malinovskaya, 2016). Correct measurements of output and productivity, especially in the health sector, are necessary to track resources. In the healthcare system, there is a concern as to whether improved health comes at higher costs or increase in resources.

In today's environment, characterised by increased demands on the health system and inflation, the cost of healthcare is increasing. Healthcare providers have signaled their concern and are trying to improve productivity. Productivity hinges on the valuing of the efforts placed into improvement of a system. It can be seen as health created per dollar spent, by delivering services that produce health and production of these services using less resources where possible. It is therefore necessary to measure productivity as a means of supporting stakeholders in their decisions to promote betterment in the healthcare system.

2.4 Outputs and Inputs

Determining outputs is the main problem in measuring productivity. Much of the focus has been on the difficulty of measuring outputs (Sherwood 1994; Scott 2008). However, by observing the way that outputs are defined and by assessing how they are created, it may provide clues for making their measurement easier. There is a direct relationship between the quantity of inputs and the quantity of outputs produced. The measure of cost per hospital day is viewed as a measure of resources, but may vary in value for different healthcare facilities, due to the characteristics of each facility. This measurement may differ as the number and availability of beds, the number of doctors employed at the facility and/or the number of wards that the facility has vary. It is therefore necessary to develop a more robust technique to measure the outputs in healthcare systems.

Process metrics are used to identify the services provided to a patient; while outcome metrics focus on the characteristics of materials or objects which the

organisation consumes. In medical services, the inpatient period is measurable. The total services received can be determined by the service quantity, duration and length of stay. These components can be used to derive metrics such as hospital charges per patient which can be used for productivity measurement.

According to Scott (2008), there has been an increase in the productivity levels of hospitals. From the medical services perspective, both the higher costs being charged and increased health outcomes are associated with more elaborate and diverse medical services. Metrics such as in-hospital deaths limit outcome measurement. However, metrics such as morbidity at days post-surgery can be used to evaluate the quality of care being provided by a hospital. Scott (2008) advocates that there should be no premature selection or foreclosing of any of the metrics of healthcare system outputs simply because one does not know enough about the processes.

In medical services, the defining of outputs is challenging when compared to the defining of inputs. There are many ways to measure outputs. Van Hulst (2016) suggests that output metrics should be aggregated by assigning weights to each output of the system. McKellar (2011) suggests that the measuring of the improvement in healthcare productivity is challenging, purporting that healthcare systems consume time and resources abundantly, and that it is possible to correlate health improvement through the improvement of productivity whilst conserving the inputs and thus cost. He cautions that given that the resulting improvement in the health of a patient takes place over time, it is often difficult to relate this health improvement to improvements in productivity which may have taken place prior to the patient's receiving treatment, as there is a lag between the improvements and the effects of the improvement.

Productivity can be affected by policy tools or reactionary interventions. Before developing the productivity metrics, it is necessary to understand the terms average and marginal productivity. The relationship between total output to total amount of any given inputs is referred to as average productivity. Marginal productivity is a measure of incremental output for an incremental investment in additional resources. Both can be used to measure total productivity, and it must be noted that productivity is highly dependent on the price and availability of inputs, as well as the process(s) required to generate outputs. The main services which are identified in most healthcare systems are the number of first-time visits and the number of discharges, length of stay and whether patients had surgery. The inputs for the productivity measurement include the number and cost of staff, administrative, nursing, paramedical and other personnel, as well as material supplies which include food and medical supplies. When aggregated, they provide the total cost of the health system inputs.

2.5 Traditions of Productivity Measurement

Traditionally, healthcare productivity has been determined by expenses on health products (goods and services) deflated by a price index. If the prices are incorrect, then so are the measures. It is apparent that healthcare itself can be adjusted for quality changes. However, this raises the issue of how to measure this intangible aspect of healthcare. According to Sheiner and Malinovskaya (2016), quality and price indices are used as separate measures. These metrics can be derived by adopting a cost-of-living approach which measures improved life expectancy. Sheiner and Malinovskaya (2016) redefined the approach to successful productivity measurement interventions by including a cost of quality improvement approach which is often used to compare the cost of goods over a period. Moreover, the Affordable Care Act, in the United States of America, recommends the use of cost per unit of quality adjusted healthcare which contributes to health care productivity (Dogra and Dorman, 2016).

There are international bodies which provide guidance in healthcare output measurement. The work covered by Sharpe (2007) discusses the guidance from the Eurostat handbook which adopts the terminology shown in Figure 1. The terminology recommends weighting output by cost of production and facilitates the assumption that higher cost treatment indicates higher quality. For several reasons, the measurement of healthcare output is not straightforward. Not only this, but medical services are continuously changing, making productivity challenging to measure.

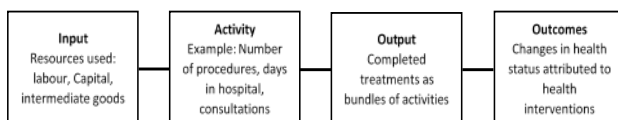


Figure 1. Terminology for the Healthcare Sector
Source: Adapted from Sharpe (2007)

Gross Domestic Product (GDP) is one measure of economic output. There has been a trend in healthcare, especially in communities with social assistance, to measure output firstly using real GDP, and secondly, by employment. These are then used as the inputs to measure labour productivity. According to Sharpe (2007), there have been trends in productivity estimates that include the Centre for the Study of Living Standards (CSLS) productivity estimates where real GDP per worker is measured.

Official figures of output and inputs can underestimate productivity, while using price indices can overestimate them. Therefore, better metrics are needed to determine productivity. According to McKellar (2011), what is needed is not just better estimates of output and productivity, but also of the comprehensive

documentation of procedures and processes used in delivering health services.

Most productivity measures track utilisation of healthcare services, which include measures that integrate the patient. These metrics include cost per patient discharged, cost per outpatient visit, relative value units per physician per month, patients visit per physician per month, and average length of stay per discharged.

2.6 Multifactor Productivity

Some traditional measures of productivity in healthcare include labour productivity and multifactor productivity. Multifactor productivity can be used to provide the costs needed to deliver services. This is considered as being residual, meaning it is the remainder after much of the quantity of measures is subtracted (ONS, 2017). It is known that multifactor productivity measurements are not accurate, as the traditional approach for deriving multifactor productivity consists of price measures and quality measures independently. One solution is to incorporate both cost-of-living and the cost of quality improvement approach and redefine the good approach as espoused by McKellar (2011).

2.7 Throughput and Productivity

Not all medical services are created equally. Therefore, the metrics of throughput, the maximum rate of production of a system as a productivity measure in health systems can be flawed. Healthcare is not a good for consumption. It can lead to an increase of other outputs of the healthcare system, thus indicating that it is vital to measure the outputs that add value to health.

Quality, effectiveness, and relevance of treatment to patients could help identify useful metrics of healthcare value. Noting that throughput measures fail to represent quality of care provided, some metrics can still be effectively used to measure productivity. Of the input measures identified, only a few were connected to patient welfare. According to Hussey et al. (2009), wrong metrics have been used in the determination of the value of healthcare. Although throughput metrics are inappropriate for measuring the value of healthcare, they provide information for medical staff. Faced with resources constraints, different hospitals may aim at delivering different services with different aims for efficiency. It would be infeasible to use throughput as a productivity measure.

2.8 Patient Flow

Patient flow is basically a reflection of how well the hospital can deliver and move a patient through its systems. Patient flow models allow us to look at healthcare from a hospital's perspective.

As in most economic sectors, there is an increasing concern for health care services to achieve higher levels of performance in both the quality and quantity of service

being delivered, while using limited resources. Recall that productivity is established when the outputs are generated with sufficient quality and quantity by maximising the inputs of the system. To support this increase in productivity, models of patient flow can be used to identify any constraints or bottlenecks in the health system. Models have different uses and can be representative of the flow between departments or whole system models. According to the KTA Evidence Summary (2011), the key to productivity is not in treating patients but rather in utilising the extra time and materials between patient periods.

Health care is a major part of the economy and as expenditure in this sector increases, there is the imperative to increase productivity. Karagiannis (2012) writes that productivity changes can be broken down into scale, efficiency, and technical change.

The optimal sizes of hospitals are rarely mentioned in studies. A proxy which is often used is the number of beds in a hospital. Identification is also made of the fact that economies of scale turn into diseconomies of scale when parametric and non-parametric studies are used. Parametric studies do not incorporate the optimal scale but rather the scale elasticity which can be used to determine the types of scales. This is important as many hospitals are either undersized or oversized which can drastically affect the productivity and these values can be misinterpreted with respect to other hospitals. Hospitals that are undersized or oversized are operating at diseconomies of scale, since many are increasing in size.

Efficiency can be used to identify productivity changes. Efficiency is a measure of a hospital's productivity compared to a best practice hospital. If both hospitals are in sync, then they have 100% efficiency. Anything lower than 100%, the remainder represents how much productivity could be improved. One method of measuring hospital efficiency is data envelopment analysis. Apart from the size of the hospital, government characteristics make it difficult to assess what affects efficiency (Osei et al., 2005).

Lastly, technical change can be used as a measure for productivity change that also affects the mix of inputs and outputs. According to KTA Evidence summary (2011), technology indices are used, and innovations are collected and aggregated which are measured by means of a set of technology index numbers. Some innovations have been shown to increase productivity while other innovations which are designed to improve quality do not.

According to MacLean (1991), the metric, cost per patient day, is frequently used to measure hospital productivity. Cost of outpatient services is used as an input in productivity measurement, but it does not seem to contribute much to the health system, and thus it is recommended that there must be some sort of separation between inpatient and outpatient services to capture total patient services which can be done by using inpatient cost per patient day and outpatient cost per outpatient

visit. MacLean (1991) showed that there has been a decline in cost of running the Canadian Public Hospital using this measure simply because outpatient costs were not included. As a result, the real productivity value was not being captured.

Given that productivity is such a concern in health care, financial accounting can be used to improve health services, while cost accounting focusses on productivity measurement problems which are related to quality and outcome measures. In addition to cost accounting, workers' actions contribute to the total productivity of the organisation (Finkler et al., 2007). The inputs needed to create outputs, are difficult to determine, and these are what are needed to define productivity. Although output is hard to define, some common measures include visits, treatments per patient day and discharges. Productivity of direct and indirect measures affect the overall productivity of the organisation.

3. Direct and Indirect Measures with Productivity

3.1 Productivity Measure and Indirect Cost

Apart from the cost ratio of outputs to inputs, another measure of productivity could be based on direct and indirect costs. Some departments, like surgery, use both direct and indirect patient care, which can be used since there is inactive time existing between the processes. Thus, to determine the productivity status in the organisation, one can determine if there exists a relationship between the time taken for direct and indirect patient care.

Hypothetically, if 50% of the direct time required for patient care is not spent with the patient, then a standard can be developed and when summed the total patient care hours can be determined. The productivity level can be obtained when the ratio of productive hours (which includes both direct and indirect hours) to total hours is derived. Productivity is expressed as a percentage and 100% is considered as perfect (Finkler et al., 2007).

A drawback to this approach is the omission of holidays. When holidays are included, it has been demonstrated that the level of productivity increases. An increasingly high productivity, caused by the generation of similar outputs when some support staff are absent on holidays, would be recorded, especially for those employees whose vacation hours are not included but substituted with allowance hours. The decision is made to remove vacation hours and just use sick leave in the calculations, if consistency is maintained by reducing slack time and overstaffing, 100% productivity can be achieved.

3.2 Productivity Measures and Direct Cost

Direct costs are challenging to measure since they have no input-output relationship making productivity difficult to achieve for example, administration. According to Finkler et al. (2007) health care costs can be classified in three ways, which would assist in determining a right

budget for each department. These include engineered costs, committed costs, and discretionary costs.

Engineered costs are for specific input-output relationships, while discretionary costs are incurred annually and are approved as part of the normal budget. Both efficiency and effectiveness can be used to increase productivity. It is however, of great concern as to how these costs are controlled and compared to engineering costs. This can be done by using the zero-based review, zero base budgeting, and work measurement. There is a need to control these costs, since there exist problems with how these costs are derived, and to deal with these differences, efficiency and effectiveness can be applied while including the zero-base review.

Additionally, monitoring tools for efficiency and effectiveness can be used. The measures obtained should be compared with the various departments to measure its usefulness. Another way of controlling this direct cost is to subject them to market forces; the health organisation can use various departments forcing other departments to become more efficient. Moreover, leadership is needed to generate hard work and maintain these costs. Given that both direct and indirect hours are considered, the following formula can be used to calculate productivity on a labour level:

$$\text{Productivity level} = \frac{\text{Productive hours}(\text{direct} + \text{indirect}) + \text{vacation, holidays, etc}}{\text{Total hours}} \times 100 \quad [\text{Eq. 1}]$$

3.3 Productivity Today

For those resources that are consistent in production, productivity will increase if the cost per unit can be reduced. This can be derived by dividing the total inputs and their cost by the total units produced which will provide the cost per unit, which however will be subject to the nature of the product. One drawback of this traditional approach is the cost allocation for specific departments. The resources per patient will never be equal which makes them incapable of indicating the productivity changes such as cost per patient day, including patient visit, number of surgeries, or discharges.

With respect to health care services, there are several measures available, these include total productivity and partial productivity measures. Total productivity for a health care organisation can be measured as the outputs into the sum of supplies, labour, capital and overhead inputs. Improved productivity is given in terms of dollars when this ratio is used. Partial productivity is a measure for one department and is dependent on the cost per patient and the cost per labour hour. However, one may change faster than the other and this ratio does not account for this change, for example, labour cost may increase more than the number of patients treated. This ratio allows there to be a comparison between the monetary value of outputs and inputs.

To avoid output accumulation in health care organisations, it is assumed that the number of unbilled patients is the same as billed ones, which allows the ratio to be define as:

$$\text{Total Productivity} = \frac{\text{Operating revenue}}{\text{Supplies} + \text{Labour} + \text{Capital} + \text{Overhead}} \quad [\text{Eq. 2}]$$

For there to be a comparative productivity measure, the unit of evaluation must be kept constant over time. However, inflation occurs when dollar amounts are used, but this is needed when developing comparable measures. Inflation is not the only problem, so too is quality changes, as it too, is assumed to be held constant. These factors make the total productivity ratio inadequate because it is unable to separate the impact of case mix from productivity changes.

The partial productivity ratio on the other hand is the measure of total output with a partial input, e.g. patients treated per labour hour. Unlike total productivity, partial productivity allows one to focus on individual departments. The basis for partial productivity is a given baseline for measuring the output, and current measure for the period under consideration. The use of partial productivity can be best represented by consideration of the steps outlined in Equations [3], [4] and [5];

Step 1:

$$\text{Index of Output} = \frac{\text{Actual output hours}}{\text{Baseline output hours}} \times 100 \quad [\text{Eq. 3}]$$

Step 2:

$$\text{Index of Labour Hours} = \frac{\text{Actual labour hours}}{\text{Baseline labour hours}} \times 100 \quad [\text{Eq. 4}]$$

Step 3:

$$\text{Index of Output/Labour Hours} = \frac{\text{Index of Output}}{\text{Index of Labour hours}} \times 100 \quad [\text{Eq. 5}]$$

Once information is available, the above steps would allow the computation of a concrete measure of partial productivity. In addition, this allows the creation of various measures like this throughout any health care organisation, with the additional capacity to move measures towards the use of total productivity. When revenue is included as a factor in the measurement of productivity, it is more difficult to determine partial productivity as compared to deriving total productivity. Notwithstanding this limitation, partial productivity measures are used for monitoring the operational efficiency of and in identifying opportunities for operational improvements in health care organisation.

There may be the prevailing impression that there are no correct measures of productivity which can be used for system comparison and to direct improvement. These measures of total and partial productivity can be measured in terms of dollars or physical units (Finkler et al., 2007). An understanding of partial and total productivity requires an appreciation of the traditional way of measuring productivity. Historically, products are

made in fixed processes. Therefore, it is easy to determine system inputs. A forgotten measure of Productivity is:

$$\text{Productivity} = \frac{\text{Total inputs and their monthly costs}}{\text{Total number of units produced}} \quad [\text{Eq. 6}]$$

This measure is no longer in vogue because of product mix and quality variation. The resources in health systems organisations may not be uniformly assigned.

4. Composite Indicators Productivity Measurement: A Proposal

From the previous discussion, it is evident that most measures of productivity in the health system are flawed in the context of SIDS. To compensate for the obvious inaccuracies which the traditional productivity measures may have, we propose the use of a composite productivity indicator. Composite indicators can be utilised for assessing the performance of a system, specifically in areas of efficiency, public assurance and managerial competence (Smith, 2010). A composite indicator can be linear which can be demonstrated using the formula:

$$C = \alpha_1 P_1 + \alpha_2 P_2 + \dots + \alpha_n P_n \quad [\text{Eq. 7}]$$

Where, α_j is the weight attached to the constituent performance indicators j . P_{ij} is the score of unit i (health system i) on the indicator j and C_i is the resultant composite score of unit i .

Jacobs et al. (2007) indicate that the lack of composite performance measurement systems has led the public to assess the quality of health care because of their convenience, henceforth encouraging public sector managers to achieve high ratings. These are mostly used in service areas. A composite measurement summarises the performance and determines the institution's consequences to be faced as a result (Jacobs et al., 2007).

The composite measurement system is within managerial control and is easy to understand. Thus, the following steps can be used in the development of a composite measurement system:

1. Choosing the organisations to be assessed,
2. Choosing the organisation objectives to be encompassed,
3. Choosing the indicators to be included,
4. Transforming measured performance on individual indicators to be aggregated,
5. Combining the individual indicators using the addition or other decision rules,
6. Specifying an appropriate set of weights for aggregation purposes,
7. Adjusting for environmental or other uncontrollable influences on performance, and
8. Using sensitivity analysis to test the robustness of the composite score.

The difference between a composite measure to other measures is that the composite measure is more methodological which can be challenging. Some of the data which are normally used include star ratings and performance ratings. These are usually sorted into the four themes which are essential in the selection of a composite measurement system. These are:

1. *Uncertainty* - the use of simulations to calculate the range of composite scores that the organisation obtains which estimates the degree of uncertainty of the composite measure.
2. *Real Performance Variation* - assume that performance is within managerial control. For each indicator, it estimates the proportion of variation caused by factors such as measurement errors; thus, the remainder represents genuine variations. Variations depend on the performance targets, data collection methods, operational components and interactions between components.
3. *Alternative Aggregation Methods* - weights can be objective so a decision rule system can be used, that is: 0-3 stars, excellent, poor etc. A differential weighting can be applied to the indicators.
4. *Composite Indicators over Time* - can be achieved through aggregation methods, weightings or decision rules: this must have a constant methodology of application over time.

The use of publishing composite measures can both be rewarding and punishing. Thus, it is necessary to consider the potential risks involved in these practices. The most important implications made about composite measure and its incorporation into systems are that variations and fluctuations exist. However, a reduction in uncertainty can result in a more robust composite measure. In constructing the measures, the sensitivity to methodological choices must be considered, since the weightings chosen have significant impact and caution must be applied to decision rules. The methodology may change as time progresses, and most notably, the measures must be published with a degree of uncertainty.

Health system performance is multi-dimensional. The indicators which are derived show how the system behaves but is partial and hence can be misleading. If management has a strong interest in system performance, there may be a preference to provide a composite measure as opposed to partial measures.

Although hospitals aim to improve their quality of health care, there is tremendous uncertainty as to how performance is linked to operational principles. As a result, partial indicators should be compiled to attain a correct representation of the system's performance as the partial indicators are not able to do so.

There are four elements of a composite indicator. These include:

1. Separate dimensions to be measured,
2. Selection of operational indicators to be used,
3. Transformation of indicators to common units, and

4. Weights to be applied to derive the composite indicator.

To obtain a meaningful composite measure, weights must be applied to the partial indicators which take the following form:

$$C_i = \alpha_1 P_{i1} + \alpha_2 P_{i2} + \dots + \sum_j \alpha_j P_{ij} \quad [\text{Eq. 8}]$$

Where, C is the composite measure, P is the productivity and α is the indicator weighting.

The corresponding weights to attach to the indicators must be found. These demonstrate the importance of the indicators. Development of a composite indicator exhibits that management wants to move towards a more comprehensive measure of system performance: thus, the most important aspects of health care should be included in this measure (OECD, 2002). The lack of data can affect the credibility of the resources. Since health results are products of years of service, there is much concern as to whether health status is an accurate indicator of current health performance.

Smith (2010) presents four examples which examine the use of composite measures. In example one, the United States Medicare was examined. Clinical topics were selected in accordance with five criteria from which the twenty-two (22) process measures were developed for the areas selected. Each state was ranked using a scale and thus a composite measure was obtained by finding the states' average rank. However, these examples have included various problems to arrive at the final composite measure.

The measures used in productivity measurements are constrained by the availability of data and often, if there is no relative importance of factors, equal weights were assigned to each indicator. In the development of a composite indicator, the analyst should assess the components to be measured, the collinearity of components, their composite weights, transforming the constituent indicators assessing the environmental influences on the system and any analytical approaches to inferring efficiency (and or productivity).

A mathematical productivity model was derived with the findings mentioned above; the entities of the model are shown below which were utilised by the Organisation for Economic Co-operation and Development (2002).

For general treatment, consider an additive composite indicator of the form:

$$C_i = \sum_j^n \alpha_j P_{ij} \quad [\text{Eq. 9}]$$

Where, α_j is the weight attached to the constituent performance indicators j . P_{ij} is the score of unit i (health system i) on the indicator j , and C_i is the resultant composite score of unit i .

Suppose that each health care system i is seeking to maximise its composite score subject to a budget constraint X_i . Then, if all the n performance measures were independent, the first order conditions require that:

$$\alpha_j \frac{\delta P_{ij}}{\delta x} = \gamma_1 \quad [\text{Eq. 10}]$$

For each performance measure j . That is the unit i should invest in improving measure i up to the point where the marginal benefit is inversely proportional to the weight α_j attached to the indicator j .

In practice, any initiative to improve health care performance is likely to have an influence on more than one performance indicator. That is, the performance indicators cannot be independent. Suppose then that there are k possible programs designed to improve performance, then the optimisation problem for health system i is to choose how much expenditure X_{jk} to assign to programme k , leading to the first order conditions:

$$\sum_j \alpha_j \frac{\delta P_{ij}}{\delta x} = \gamma_1 \text{ for each programme } k. \quad [\text{Eq. 11}]$$

In the special case of constant returns to scale, the composite score is optimised by solving the following linear programme.

$$\begin{aligned} &\text{Maximise } C_i = \sum_j \alpha_j P_{ij} \\ &\text{Subject to } P_{ij} = \sum_k \beta_{kj} x_k \text{ for } j = \dots, N \\ &\sum_k x_k = X \end{aligned}$$

Which can be rewritten as:

$$\begin{aligned} &\text{Maximise } C_i = \sum_j \sum_k \alpha_j \beta_{kj} x_k \\ &\text{Subject to:} \\ &\sum_k x_k = X \end{aligned}$$

This is a linear programme with one constraint. It will therefore have an optimal solution with only one non-zero x_k ; namely that which maximises the value of:

$$\sum_k \alpha_j \beta_{kj}$$

5. Conclusion

The measurement maxim “You cannot manage what you cannot measure”, which is attributed to Peter Drucker, when applied to the assessment of productivity in hospitals, implies that the way healthcare can be improved, is by measuring the productivity of the healthcare system. According to Kang et al. (2017), the improvement of the productivity, and therefore efficiency of hospitals, result in an improved quality of service to the patients. Thus, being able to measure the productivity in hospitals is useful as it will demonstrate how well the inputs are utilised to generate outputs.

Since hospital productivity is focused on customer satisfaction, the utilisation of patient flow can be used to measure productivity. This will capture both outpatient and inpatient services. Additionally, patient flow allows the creation of a patient flow model, thus ensuring that the main resources are easily tracked.

If the processes in the healthcare system would exist at the executive, management, knowledge works and

operational levels of the hospital, while also being separated by departments and or clinics, then it is not difficult to imagine the existence of various measures of productivity in the hospital. Using the throughput measure of productivity is inefficient, since services are not equally provided. Therefore, the traditional measure of cost per output, or in this case cost per patient, does not capture the true essence of the hospital's productivity. Contrariwise, through measuring partial productivity could allow us to calculate productivity of the individual departments, so that we can identify constraints in the system.

One best way to measure overall productivity for hospitals is to use a composite measure. A composite productivity measure would capture the performance of individual departments, different processes, and even individual levels in the organisation hierarchy, thus making it easier to manage the healthcare system, and improve the quality of service delivered to patients. In Trinidad and Tobago, the Eric Williams Medical Sciences Complex possesses functions which go beyond the direct treatment of patients. This provides an example for measuring productivity in hospitals. The case would allow the robustness of the composite model to be demonstrated, while directly moving the model from theory to practice.

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