Productivity and Customer Satisfaction -A DEA Network Model*

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Abstract

This paper presents a network model incorporating customer satisfaction into efficiency and productivity measures. The network consists of a production node and a consumption node and offers flexibility in modelling the production and consumption process. Allocation of input resources to production and customer oriented activities is allowed. In the consumption process inputs and output characteristics result in customer satisfaction. The model solution identifies optimal allocation of resources between production and customer oriented activities. Data envelopment analysis estimators of the defined theoretical measures of efficiency and productivity are presented. An empirical application using data from a sample of Swedish pharmacies is included. Results from the network model and a direct productivity model indicate increased average productivity, although the productivity progress is somewhat lower in the network model.

Key-words: Customer satisfaction, Data envelopment analysis, Distance function, Malmquist productivity index, Network model.

JEL-Classification: D11, D12, D24.

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1. Introduction

Customer satisfaction has become an important performance indicator for both private and public firms as discussed in Fornell (1992). Customer satisfaction barometers can often be regarded as complementary to productivity measures since the latter seldom take customer perceived quality into consideration. If customer satisfaction is an explicit objective for a firm, the inclusion of such measures into productivity indices leads to more valid measures of productivity. The purpose of this paper is to present an approach to include customer satisfaction in productivity measures. The proposed model allows estimation of efficiency and productivity taking both qualitative and quantitative (productivity) aspects into account. The estimates can be obtained using data envelopment analysis (DEA).

DEA is a non-parametric linear programming (LP) approach to estimate production characteristics such as technical efficiency and productivity (see, e.g., Charnes, Cooper and Rhodes (1978) and Banker, Charnes and Cooper (1984)). An appealing property of the DEA-approach is that multiple-input, multiple-output technologies readily can be modeled without revenue or cost data. This is important in efficiency and productivity measurement in public production, where price or cost data are often unavailable.

We propose the use of a network model where the fundamental idea is that the production and consumption processes can be represented as separate nodes. This approach extends the network model in Färe and Grosskopf (1996), where a network model for productivity measurement with intertemporal products is specified.

The network approach is flexible in the sense that production and consumption can be jointly modeled along with a broad representation of customer satisfaction. The network model allows an allocation of resources between customer oriented activities (x^C) and traditional production (x^P). A subvector of the outputs (y^C), representing characteristics and quality attributes, is treated as an intermediate input in a consumption technology. Moreover, quality assessments (q) as well as the "ordinary" outputs (y^P) are considered as final exogenous production from the consumption and the production node, respectively. The quality assessments are here represented by data from Customer Satisfaction Barometers (CSB), see e.g., Fornell (1992). It can be noted that the idea of a consumer technology is similar to the model in Lancaster (1991) where it is assumed that "consumption is an activity in which goods, singly or in combination, are inputs and in which the output is a collection of characteristics", Lancaster (1991: p. 12).

The technology is represented by distance functions which also define the efficiency and productivity measures. The distance functions can be estimated by DEA using only primal production data without imposing a functional form for the technology. The LP solutions allow identification of optimal allocation of production resources. Furthermore, the optimal level of the characteristics and attributes subvector (y^C) can also be identified.

An alternative approach to incorporate customer satisfaction in productivity indices is given in Färe, Grosskopf and Roos (1996). Their approach is based on a preference indirect distance function defined as a distance function incorporating a utility restriction. Quality assessments are used as weights in a (linear) utility function defined over attributes (and outputs). One disadvantage with this approach when using DEA is that a functional form of the utility function has to be specified and that there has to be a one-to-one relation between the assessments and the outputs to allow an interpretation of the assessments as utility function weights. In the network model the utility restriction is exchanged by a distance function defined for the consumer technology and the relation between the assessment dimensions in the CSB and the outputs (and quality attributes) does not have to be one-to-one. This implies that a broad representation of consumer satisfaction can be incorporated in the network productivity model.

The paper includes an empirical application where the network model and a direct productivity model is estimated using a sample of Swedish pharmacies. The outlined model is an appropriate model of the pharmacy technology since a large proportion of labor time is devoted to customer related activities such as information and counselling.

The paper unfolds as follows: *Section* 2 presents the network model and the distance function representation of the technology. This section also defines the Malmquist productivity index for the network and the production node. DEA estimators of firm specific distance functions and Malmquist indices are presented in *Section* 3. *Section 4* presents the empirical application and *Section* 5 contains a summary and some concluding remarks.

2. The Network Model

We use a network technology that consists of two nodes as a representation of the production and consumption process. In the production node, firms use inputs $x^P \in R_+^N$ to produce outputs $y = \left(y^P, y^C\right) \in R_+^{M+J}$. The subvector y^P represents traditional, marketable (final) outputs whereas the subvector y^C represents non-marketable characteristics and attributes of the production. The characteristics and attributes are then considered as intermediate inputs, together with inputs $x^C \in R_+^N$ in the consumption node, resulting in customer quality assessments $q \in R_+^L$. The total inputs $x = x^P + x^C$ and the vector $\left(y^P, q\right)$ are treated as exogenous. The network model is illustrated in Figure 2.1 adapted from Färe and Grosskopf (1996).

2.1. The production technology (P-node)

The production technology is represented by an input distance function (Shephard (1970)) defined as:

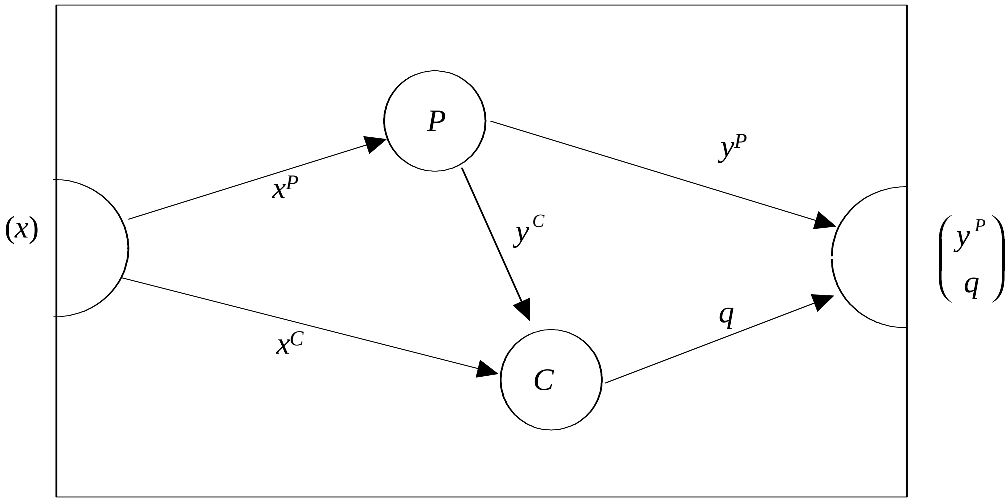

Figure 2.1: The Network Technology

$$D_i^{P,t}\left(x^P,\left(y^C,y^P\right)\right)=\max\left\{\lambda:\frac{x^P}{\lambda}\in L^t\left(y^C,y^P\right)\right\}, \tag{2.1}$$

where $L^t\left(y^C,y^P\right)=\left\{x^P:\ x^P \text{ can produce } \left(y^C,y^P\right) \text{ at time } t\right\}$ is the period t input requirement set. The production technology is assumed to satisfy a set of axioms. In short: (i) inactivity is allowed, (ii) "free lunch" is not allowed, (iii) strong disposability of inputs and outputs and (iv) the output set is a compact and convex set. See Färe, Grosskopf and Lovell (1994) for a presentation of these axioms. The input distance function takes on values larger than one if and only if $x^P\in L^t\left(y^C,y^P\right)$. Technical efficiency is achieved when the distance function equals one.

2.2. The network technology

Färe and Grosskopf (1996) define a network technology for the P-node. Here we specify a network model as joint production and consumption technology in an analogous manner. The network technology in Figure 2.1 can be represented by the network distance function

$$\mathcal{D}_i^t\left(x,\left(y^P,q\right)\right)=\max_{\widetilde{x}^P,\widetilde{x}^C,\widetilde{y}^C}\left\{\lambda:\frac{x}{\lambda}\in\mathcal{L}^t\left(\left(\widetilde{y}^C,y^P\right),q\right),x\geq\widetilde{x}^P+\widetilde{x}^C\right\}, \tag{2.2}$$

where $\mathcal{L}^t\left(\left(y^C,y^P\right),q\right)=\left\{x:\ x^P\in L^t\left(y^C,y^P\right),q\in Q^t\left(x^C,y^C\right),x\geq x^P+x^C\right\}$ is the network grand input set. $Q^t\left(x^C,y^C\right)=\left\{q:x^C \text{ and } y^C \text{ can give } q \text{ at time } t\right\}$ is the quality assessment set in the consumption technology in time period t representing the set of quality assessments attainable from $x^C$and y^C.

The distance function measures the maximum proportional contraction of the inputs given that an output vector can be produced that still allows the quality assessments to be attained. The network distance function thus constitutes a measure of technical efficiency that incorporates consumer satisfaction represented by the quality assessments in the consumption node.

Note that the optimal values of the choice variables $\tilde{x}^P, \tilde{x}^C$ and $\tilde{y}^C$ in (2.2) identify an optimal allocation of the inputs (x^P and x^C) and the output attributes/characteristics (y^C). It is of course possible that one or more elements in the input vector x only goes to one of the two nodes. This can easily be taken into consideration in the model. Since $x_n = x_n^P + x_n^C$, $n = 1, ..., N$, we simply set, for example, $x_{n'}^P = 0$, if input n' is entirely used in the C-node.

Two properties of the network distance function can be noted. $\mathcal{D}_i\left(x, \left(y^P, q\right)\right)$ is homogenous of degree 1 in inputs, i.e., $\mathcal{D}_i^t\left(\theta x, \left(y^P, q\right)\right) = \theta \mathcal{D}_i^t\left(x, \left(y^P, q\right)\right)$, for $\theta > 0$ and nondecreasing in q (and y^P), i.e., $\mathcal{D}_i^t\left(x, \left(\gamma y^P, \gamma q\right)\right) \leq \mathcal{D}_i^t\left(x, \left(y^P, q\right)\right)$, for $\gamma \geq 1$.

2.3. P-node productivity

Caves, Christensen and Diewert (1982) showed that productivity changes can be measured by Malmquist indices, defined in terms of ratios of distance functions. Following Färe, Grosskopf and Roos (1996) an input-based Malmquist productivity index can be defined for the production technology (P-Node) as

$$M_i^{t,t+1}\left(x^{P,t}, x^{P,t+1}, y^t, y^{t+1}\right) = \left[\frac{D_i^{P,t}\left(x^{P,t+1}, y^{t+1}\right)}{D_i^{P,t}\left(x^{P,t}, y^t\right)} \frac{D_i^{P,t+1}\left(x^{P,t+1}, y^{t+1}\right)}{D_i^{P,t+1}\left(x^{P,t}, y^t\right)}\right]^{\frac{1}{2}}. \qquad (2.3)$$

Productivity improvement is signaled by a Malmquist index less than one and a negative change in productivity is signaled by an index greater than one. The Malmquist index can be decomposed into two components as in Färe, Grosskopf and Roos (1996)

$$M_i^{t,t+1}(\cdot) = \underbrace{\frac{D_i^{P,t+1}\left(x^{P,t+1}, y^{t+1}\right)}{D_i^{P,t}\left(x^{P,t}, y^t\right)}}_{E_i^{P,t,t+1}} \underbrace{\left[\frac{D_i^{P,t}\left(x^{P,t}, y^t\right)}{D_i^{P,t+1}\left(x^{P,t}, y^t\right)} \frac{D_i^{P,t}\left(x^{P,t+1}, y^{t+1}\right)}{D_i^{P,t+1}\left(x^{P,t+1}, y^{t+1}\right)}\right]^{\frac{1}{2}}}_{TC_i^{P,t,t+1}}. \qquad (2.4)$$

The term outside the brackets, E_i, measures change in efficiency which can be interpreted as a "catching up" (to the production frontier) effect. The TC_i term measures change in technology in terms of shifts in the production frontier.

2.4. Network productivity

A network Malmquist productivity index based on the network distance functions can be defined analogously to the P-node index in (2.4) as

$$\mathcal{M}_i^{t,t+1}\left(x^t, x^{t+1}, y^{P,t}, y^{P,t+1}, q^t, q^{t+1}\right) = \underbrace{\frac{\mathcal{D}_i^{t+1}\left(x^{t+1}, y^{P,t+1}, q^{t+1}\right)}{\mathcal{D}_i^t\left(x^t, y^{P,t}, q^t\right)}}_{\mathcal{E}_i^{t,t+1}} \times \tag{2.5}$$

$$\underbrace{\left[\frac{\mathcal{D}_i^t\left(x^t, y^{P,t}, q^t\right)}{\mathcal{D}_i^{t+1}\left(x^t, y^{P,t}, q^t\right)} \frac{\mathcal{D}_i^t\left(x^{t+1}, y^{P,t+1}, q^{t+1}\right)}{\mathcal{D}_i^{t+1}\left(x^{t+1}, y^{P,t+1}, q^{t+1}\right)}\right]^{\frac{1}{2}}}_{\mathcal{TC}_i^{t,t+1}},$$

where $\mathcal{E}_i$ reflects the change in technical efficiency or "catching up" and $\mathcal{TC}_i$ reflects technology change as a shift in the network production frontier.

3. Data Envelopment Analysis

Using a sample of K firms the distance functions and the Malmquist productivity indices can be estimated using DEA. The data are collected in matrices: $X^P = (x_1^P, ..., x_K^P)$ and $X^C = (x_1^C, ..., x_K^C)$ which are $(N \times K)$ matrices of inputs, $Y = \begin{pmatrix} Y^P \\ Y^C \end{pmatrix} = \left(\begin{pmatrix} y_1^P \\ y_1^C \end{pmatrix}, ..., \begin{pmatrix} y_K^P \\ y_K^C \end{pmatrix}\right)$ which is a $((M+J) \times K)$ matrix of outputs and finally $Q = (q_1, ..., q_K)$ is an $(L \times K)$ matrix of quality assessments.

3.1. DEA estimators of distance functions

The estimate of the P-node input distance function (2.1), under constant returns to scale (CRS), is given by the solution to the linear program (c.f., Färe, Grosskopf and Roos (1996))

$$\left[\widehat{D}_i^{P,t}\left(x_k^{P,t}, y_k^t\right)\right]^{-1} = \min_z \left\{\theta : \theta x_k^{P,t} \geq X^{P,t} z, y_k^t \leq Y^t z, z \in R_+^K\right\}. \tag{3.1}$$

By adding an additional restriction on the intensity variables, z, alternative returns to scale restrictions can be imposed on the distance function estimate. The restriction $\sum_{k=1}^K z_k = 1$ imposes variable returns to scale (VRS) and the restriction $\sum_{k=1}^K z_k \leq 1$ imposes non increasing returns (see, e.g., Färe, Grosskopf and Lovell (1994)).

The network distance function (2.2), under CRS, is estimated by the following LP problem (c.f., Färe (1991), Färe and Grosskopf (1996))

$$\left[\widehat{\mathcal{D}}_i^t\left(x_k^t, y_k^{P,t}, q_k^t\right)\right]^{-1} = \min_{\widetilde{x}^C,\widetilde{x}^P,\widetilde{y}^C,z_1,z_2} \{\lambda : \quad \lambda x_k^t \geq \widetilde{x}^C + \widetilde{x}^P,$$

$$\widetilde{x}^P \geq X^{P,t} z_1, y_k^{P,t} \leq Y^{P,t} z_1, \widetilde{y}^C \leq Y^{C,t} z_1, \tag{3.2}$$

$$\widetilde{y}^C \geq Y^{C,t} z_2, \widetilde{x}^C \geq X^{C,t} z_2, q_k^t \leq Q^t z_2,$$

$$z_1 \in R_+^K, z_2 \in R_+^K \Big\} .$$

3.2. DEA estimators of the Malmquist productivity index

Given repeated observations on the sample of K firms, the Malmquist index can be estimated with DEA. In addition to (2.1) and (2.2), cross-period distance functions have to be estimated.

The P-node cross-period distance function $D_i^{P,t}\left(x^{P,t+1}, y^{t+1}\right)$ used in the Malmquist index in (2.3) is estimated analogous to (3.1) as

$$\left[\widehat{D}_i^{P,t}\left(x_k^{P,t+1}, y_k^{t+1}\right)\right]^{-1} = \min_z \left\{\theta : \theta x_k^{P,t+1} \geq X^{P,t} z, y_k^{t+1} \leq Y^t z, z \in R_+^K\right\} . \tag{3.3}$$

In (3.3) observations from period $t+1$ are evaluated against an estimate of the input requirement set $L^t\left(y_k^{t+1}\right)$, using observations from period t. The cross-period distance function $D_i^{P,t+1}\left(x^{P,t}, y^t\right)$ is estimated analogously, with the time indices t and $t+1$ interchanged.

Similarly, the network cross-period distance function $\mathcal{D}_i^{t+1}\left(x^t, y^{P,t}, q^t\right)$ used in (2.5) is estimated similarly as (3.2)

$$\left[\widehat{\mathcal{D}}_i^{t+1}\left(x_k^t, y_k^{P,t}, q_k^t\right)\right]^{-1} = \min_{\widetilde{x}^C,\widetilde{x}^P,\widetilde{y}^C,z_1,z_2} \{\lambda : \quad \lambda x_k^t \geq \widetilde{x}^C + \widetilde{x}^P,$$

$$\widetilde{x}^P \geq X^{P,t+1} z_1, y_k^{P,t} \leq Y^{P,t+1} z_1, \widetilde{y}^C \leq Y^{C,t+1} z_1, \tag{3.4}$$

$$\widetilde{y}^C \geq Y^{C,t+1} z_2, \widetilde{x}^C \geq X^{C,t+1} z_2, q_k^t \leq Q^{t+1} z_2,$$

$$z_1 \in R_+^K, z_2 \in R_+^K \Big\} .$$

The network cross-period distance function $\mathcal{D}_i^t\left(x^{t+1}, y^{P,t+1}, q^{t+1}\right)$ is estimated analogously, with the time indices $t+1$ and t interchanged.

4. Empirical Application

4.1. Data

An empirical application is included to illustrate the method and the types of conclusions that can be made from a comparison of a standard productivity model with the network model. The data consist of a sample of 31 Swedish pharmacies in 1993 and 1994. Färe, Grosskopf and Roos (1995, 1996) use similar type of data, but other subsamples of Swedish pharmacies. One novelty with the data set we use is that we have data available on the allocation of one of the two input dimension (the labor hours) to the two nodes. This implies that we can estimate the complete network model specification which allows differences in allocation of inputs to the P-node (traditional production) and the C-node (customer oriented). The allocation of inputs (labor hours) to the C- and P-node, is based on budget data in terms of ratios of total labor hours. Due to data limited availability we have to use the same allocation ratio (x^C/x^P) in both years.

The dataset include two inputs, three outputs, two quality attributes and five quality assessment dimensions. The following set of variables are used:

Two inputs (x^P) *and* (x^C)*:*

LABOR-P and LABOR-C (hours of pharmacist and technical staff services in the P-node and C-node, respectively),

COSTO (the value of other inputs, SEK 1000)

Three outputs (y^P)*:*

NUMPRE (number of outpatient prescriptions),

OTC (number of over the counter transactions),

OEXP (number of other types of expeditions).

Two output attributes (y^C)*:*

OPEN (number of business hours open per week),

PRESERV (percent of prescriptions filled within one day).

Five CSB quality assessments (q):

AVAIL (availability of the pharmacy service),

PREMI (the pharmacy premises),

QPRESERV (service on prescription drugs), PREFREE (service on prescription free drugs),

QUE (que service).

The five assessments dimensions represent impact transformed estimates of the different quality dimensions in the Customer Satisfaction Index (CSI). The data used in the estimation of the CSI are obtained from pharmacy specific customer satisfaction barometer surveys. The CSI is estimated using a Partial Least Square (PLS)-algorithm where the rating and the impact of the different quality dimensions on the CSI are estimated. In the analysis the transformation is simply a multiplication of the rating of each dimension of q with the corresponding impact estimate (see, e.g, Fornell (1992) for a discussion of the CSI-estimation procedure). Descriptive statistics of the data are given in Table 1.

Table 1
Descriptive statistics for the inputs, outputs, attributes and CSB-data

	Mean		**Min.**		**Max.**	
	1993	*1994*	*1993*	*1994*	*1993*	*1994*
Inputs:						
LABOR-P	3,754	3,863	408	426	11795	11703
LABOR-C	6,849	7,045	669	713	20969	20806
COSTO	588,40	670,70	148.10	174.40	1691.40	1804.90
Outputs:						
NUMPRE	46,763	45,197	10,313	9,074	129,640	134,260
OTC	52,584	51,361	9,438	8,938	174,601	173,567
OEXP	3995	8350	527	1184	14207	27329
Attributes:						
OPEN	44	44	26	27	62	62
PRESERV	86	89	0	0	98	98
CSB Data:						
AVAIL	36.7	39.3	7.4	8.0	130.5	84.0
PREMI	84.6	71.1	37.2	16.8	148.2	132.0
QPRESERV	54.6	44.3	0.0	0.0	133.5	136.0
PREFREE	55.5	41.1	8.9	0.0	109.2	77.4
QUE	36.9	44.6	15.6	17.2	62.4	106.6

From Table 1 we see that input use have increased on average. The average values of the quality attributes are nearly the same in both years. Data on outputs and quality assessments show no clear pattern although a high increase in other types of expeditions (OEXP) can be noted. This is caused by a change in technology for some pharmacies resulting in increased other types of expeditions partly accounted for by a decrease in outpatient prescriptions.

4.2. Results

We present (geometric) average results for the network Malmquist index and its components. Note that restrictions are imposed on the attributes $\left(y^C\right)$ since opening hours and the service level are bounded above by 168 and 100, respectively. Furthermore, results based on a "standard" model of the technology using the approach in Färe, Grosskopf and Roos (1995) are also presented. This (direct) model does not account for customer satisfaction. Quality attributes are, however, included as a subvector of the output vector, i.e., the output is given by the output from the P-node as $y = \left(y^P, y^C\right)$. The inputs are aggregated into a single input vector, consisting of the total (exogenous) inputs in the network model, i.e., the inputs $x = x^P + x^C$ are used.

Qualitative and quantitative comparisons of these results indicate how the inclusion of customer perceived quality (based on the network model) affect the estimated productivity scores. Implicit adjustment terms can be defined as the ratio of the network Malmquist index to the standard Malmquist index, i.e., $\widehat{AP} = \widehat{\mathcal{M}}_i^{t,t+1}(\cdot) / \widehat{M}_i^{t,t+1}(\cdot)$. If $\widehat{AP} < 1$ (> 1), the effect of accounting for customer satisfaction is positive (negative) and productivity growth is higher (lower) when accounting for customer satisfaction.

Results from the two models are given in Table 2. Results on optimal values of the choice variables x^P, x^C and y^C in the estimation of the network distance functions (3.2) are given in Table 3.

Qualitatively, the two models give similar results in terms of sample averages. The network model, however, indicates a lower (average) productivity progress than the standard model. Both the efficiency and technical change components in the Malmquist index decomposition indicate progress in productivity.

The results show 13 (18) cases where the estimated productivity (change) is higher (lower) in the network model compared to the standard model. Although there are equally many cases with productivity progress, the pharmacies with increased productivity are not the same in the two models. Three pharmacies experienced increased productivity in the network model, but decreased productivity in the standard model and consequently there are three cases with the opposite results. We note that the models also give similar results in terms of rank comparisons. Six units are in the group with ten highest productivity scores in both models and seven units are in the group with ten lowest scores in both models.

Table 2
Summary results: Malmquist index, decompositions and implicit adjustment terms[1]

	Network Model	Standard Model	Adjustment terms
Productivity change:			
geometric mean	0.949	0.914	1.038
progress (counts)	21	21	13
regress (counts)	10	10	18
no change (counts)	0	0	0
Efficiency change:			
geometric mean	0.97	0.979	0.99
progress (counts)	16	18	16
regress (counts)	12	5	12
no change (counts)	3	8	3
Technical change:			
geometric mean	0.978	0.934	1.048
progress (counts)	20	21	17
regress (counts)	11	10	14
no change (counts)	0	0	0
# Efficient units	7 / 7	11 / 10	

On average the adjustment term is greater than one for the productivity and technical change, whereas it is less than (but very close to) one for the efficiency change component. We thus draw the conclusion that the inclusion of customer perceived quality lowers the estimated productivity and technical change for this sample.

The number of efficient units is less in the network model compared to the standard model, both in 1993 and 1994. The number of units with progress and regress in efficiency also differs between the two models.

Table 3
Descriptive statistics of optimal values of x^C, x^P and y^C

	Mean		**Min.**		**Max.**	
	1993	*1994*	*1993*	*1994*	*1993*	*1994*
Inputs:						
LABOR-P	4,294	5,238	409	506	26,876	23,608
LABOR-C	4,254	3,316	794	713	20,969	10,003
Attributes:						
OPEN	52	46	25	27	168	112
PRESERV	74	89	0	0	100	100

[1]In column 3 progress = # cases where $\widehat{AP} < 1$ and regress = # cases where $\widehat{AP} > 1$.

The results for optimal values of x^C, x^P and y^C in Table 3 reveal that the optimal levels of labor time allocated to customer activities are for both years, on average, less than the actual observed levels. The opposite results is obtained for labor time allocated to production. Equivalently, the ratio of optimal allocation to production activities over optimal allocation to customer oriented activities (i.e., x^P/x^C) is higher than the observed values. One interpretation of this is that more resources should be allocated to production activities and less to consumer activities.

For the output attributes the average results show that the optimal values of the open times exceed the observed values for both years. The optimal value of the service level is below the observed level in 1993 and equal to the observed level in 1994. An interpretation of this is that the pharmacies should substitute opening hours for service level. It can also be noted that the optimal values attain maximum values of both attributes in 1993 for one pharmacy.

5. Summary and Concluding Remarks

This paper proposes a network model which gives flexibility in the modeling of productivity and customer satisfaction. The model allows inputs to be allocated to customer oriented activities or traditional production activities. The inputs directed to customer activities, together with quality attributes of the production is assumed to give customer satisfaction, here represented by quality assessments from customer satisfaction barometer surveys. If these data are available, optimal allocation of the inputs to the production- and consumption nodes in the network can be estimated using DEA.

For firms with an objective to achieve a high degree of customer satisfaction, the approach gives valid measures of efficiency and productivity. This can be important for organizations with quality objectives and incentive structures based on productivity measures.

We present an empirical application using a sample of Swedish pharmacies. Similar qualitative results are obtained from the network model and a standard productivity model. In both models the estimated (average) productivity change is positive. The network model, however, shows a lower (average) productivity progress than the standard model. Both the efficiency and technical change components in the Malmquist index decomposition indicate progress in productivity. The technical change component accounts for most of the progress, although this is more clear in the standard model than in the network model. There are, however, some differences regarding which pharmacies are experiencing progress and regress in productivity in the different models. Furthermore, the results indicate that more resources should be allocated to the production activities and less to the consumer activities and that the pharmacies should substitute opening hours for service level.

To conclude, this paper has presented an approach to account for customer satisfaction in estimation of efficiency and productivity. For firms with customer satisfaction as a stated objective this type of model provides a way to obtain more valid measures of efficiency and productivity than traditional approaches where customer perceived quality are often ignored. Furthermore, important results for management decisions regarding both allocation of resources and quality attribute prioritations are provided.

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