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Measuring the Effects of Demand and Supply Factors on Service Sector Productivity

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ABSTRACT

Economic activities in the service sector have been increasingly important in developed countries. Despite the importance of the service sector, there are several drawbacks with a conventional way of measuring service sector productivity. This paper proposes an alternative methodology in which we can separate demand and supply factors that influence service transactions. An empirical framework is constructed based on the model of Johnson and Myatt (2003) and allows us to identify cost factors separately from demand factors. This paper also demonstrates that demand factors significantly influence the conventional measure of service sector productivity.

Keywords: Productivity, Service quality, Market structure, Mixed logit model
JEL classification: L10, L80

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1. Introduction

Economic activities in the service sector have been increasingly important in developed countries. According to World Develop Indicators of the World Bank, the percentage of service sector's values in GDP is 78 percent for the United States, 73 percent for Japan, and 68 percent for Germany in 2012. Given a large share of economic activities of the service sector, it is a primal interest of policy makers to spur economic growth through the improvement of service sector's productivity. Despite its significance in policy formulation, it remains challenging to conceptualize and measure service sector's productivity. Value-added per worker is often used to measure service sector's productivity mainly because of its convenience. This approach however has several drawbacks. First, this productivity measure contains price effects arising from demand conditions or market structures. Unlike goods, production and consumption of services occur simultaneously (Morikawa, 2011), implying that value-added can be substantially influenced by demand-side factors. This productivity measure therefore may fail to capture technical changes in the service sector and may end up with capturing a change in underling demand conditions. Second, it does not take roles of quality into account, although quality is a critical determinant for service transactions, and quality varies significantly even within a narrowly defined service industry. Finally, this productivity measure cannot distinguish whether productivity improvement is due to an increase in resources employed, improvement of labor efficiency or that of capital efficiency. Even if we take multi-factor productivity approach, there remain the first two problems unresolved. In short, measuring service sector's productivity by a conventional approach is insufficient to understand changes in technological and demand conditions in the service sector as well as to formulate fine-tuned economic growth policies.

In this paper, we propose an alternative methodology in which we can measure service sector's productivity by separating demand and supply factors that influence service transactions. Given the availability of data about consumers' choice, prices and qualities of a service, our methodology identifies a firm's marginal cost with respect to quality, which enables us to examine how a firm's cost structure differs over time and across firms and regions. In particular, based on estimates of the marginal cost, we can investigate the evolution of firm's capability of supplying a better quality of services as well as regional differences in service sector's productivity. Our methodology also allows us to decompose value-added into direct and indirect effects of costs. While the direct effect of costs captures an impact of cost reduction on value-added independently of demand conditions, the indirect effect of costs is largely affected by the underlying demand/market structure. Taking it into consideration that the simultaneity of production and consumption restricts service transactions to a certain geographical area or time dimension, separating the indirect effect from the direct one informs us of a relative impact of geographical and time factors on value-added, a widely used service sector's productivity measure.

Our estimation strategy is to estimate firms' marginal costs by using a structural model estimation. More specifically, we utilize the model of Johnson and Myatt (2003) in which both consumers and firms take a quality of services into consideration when they decide their optimal behaviors. Given prices and qualities of the service, consumers choose a particular quality of the service that gives them their highest utility level. On the other hand, facing the demand for each quality of the service, firms decide which quality of the service and what quantity of a particular quality of the service to supply. A derived first order condition from the model is then used to identify each firm's marginal costs. Unlike the conventional measure of productivity in the service sector, the estimated marginal costs reflect only supply-side factors. These estimated marginal costs are also incorporated into our decomposition analysis, which enables us to investigate how firm's value-added is affected by demand-side and supply-side factors.

The contributions of this paper are three-fold. First, in comparison with the conventional approach of using value-added, our estimation approach singles out a firm's cost structure, and it allows us to directly estimate a marginal cost of producing a higher quality of service. By viewing firm's capability of producing a better quality from a given set of inputs as firm's productivity, we are able to investigate firm's productivity dynamics in the service sector. Second, our approach permits us to relate value-added to two sets of factors; One set of factors captures a contribution of cost reduction to a change in value-added and the other set measures a contribution of demand conditions or market structures. This decomposition allows us to empirically examine relative importance of demand conditions/market structures on variation in value-added of the service sector. Since productivity changes are usually decomposed from the viewpoint of resource allocation among various types of firms in past studies about productivity dynamics (e.g., Baily et al., 1992; Foster et al., 2001), this decomposition is expected to shed a new light on determinants of productivity changes in the service sector. Finally, our decomposition analysis can provide policy makers with a clue about whether an economic policy aiming to raise value-added per worker should target towards supply-side factors such as the efficient use of ITC technology or demand-side factors such as the formation of densely populated areas.

The rest of the paper is organized as follows. Section 2 briefly reviews the literature on the measurement of service sector's productivity. In Section 3, we lay out the model proposed by Johnson and Myatt (2003) in order to prepare for presenting our estimation strategy. While Section 4 describes our strategy of estimating marginal cost functions, Section 5 presents our decomposition methodology. In Section 6, we demonstrate our methodology by using artificially generated datasets. Section 7 concludes.

2. Brief literature review

In general, productivity is defined as a ratio of a volume measure of output to a volume measure of input use (Diewert and Nakamura, 2007). This concept of productivity is unambiguous in the context of the manufacturing industry and has proved useful to answer many important questions in the industrial organization research. As Syverson (2011) summarizes, this concept of productivity has been used to examine several issues ranging from market structures, managerial practices, learning by doing to spillovers.

The general concept of productivity however becomes ambiguous when we turn our attention to the service sector. One important aspect of service transactions is that consumers perceive quality differences even in a narrowly defined service category and these quality differences are a critical determinant for the purchase of services. To distinguish services from goods, Hill (1977) defines a service as "a change in the condition of a person, or of a good belonging to some economic unit." When we look at a service from this viewpoint, both quantity and quality of a service determine the extent to which consumers receive these changes through a service transaction. Thus it may not be appropriate to use a physical unit of services simply as an output measure, though the physical unit measure of outputs is a critical component in the general concept of productivity. Manufacturing products are also differentiated in several dimensions, but data limitations make it more difficult for the service sector to guarantee homogeneity conditions that are needed to empirically examine firm-level and plant-level productivity. Another important aspect of service transactions is the simultaneity of production and consumption, so that firms in the service sector cannot keep finished outputs as inventory (e.g., Morikawa, 2011). In other words, demand-side factors can significantly affect a ratio of output to input, and this may result in failing to capture the rate of transformation of total input to total output.

Partly because of such measurement issues, value-added per person is often used as a measurement of service sector productivity. The multi-factor approach is sometimes employed to correct for some biases arising from the one factor approach. Although this approach has several merits, it faces several challenges when we examine productivity issues in the service sector. Since value-added is basically measured by a monetary unit, it cannot avoid involving price effects in service output measures. Foster et al. (2008) discuss that revenue productivity, a widely used measure of productivity, is not able to cleanly measure a rate of transformation of total input to total output and they show that revenue productivity and physical productivity differ greatly. This is simply because revenue productivity contains price components. As mentioned above, quality and the simultaneity of production and consumption are discerning features of service transactions. When the value-added approach is applied to the service sector, it may work as adjusting quality differences because these quality differences are partially reflected in prices. But prices also reflect other aspects of service transactions such as market structures and consumers' willingness to pay. Therefore, the value-added approach does not tell us whether a change in value-added per person is due to technical changes of firms or taste changes of consumers.

To summarize, the value-added approach has been often used to measure productivity in the service sector, but that measure of productivity is unable to distinguish technology-driven productivity changes from demand-driven productivity changes.

3. Model

In this section we present the model of Johnson and Myatt (2003) to help illustrate potential problems of using the conventional approach when we try to measure technical changes in the service sector as well as understand our estimation strategy for measuring firm's productivity in the service sector. In the model, a service is differentiated with quality, and consumers differ in tastes of quality of the service. We derive an inverse demand function of the service with a particular quality in the form of cumulative demand for the services with that quality and above. By transforming the inverse demand function of the service in this way, a solution from the firm's profit maximization problem boils down to the second-degree price discrimination case for each quality of the service. Although the model can deal with the case of a multiple service industries, we focus on the case of a single service with different qualities throughout this paper to illustrate our main points.

3.1 Consumers

We consider a model where each consumer purchases one unit of a service from a set of *n* different qualities of the service. These *n* different qualities of the service are differentiated vertically in the sense that all consumers agree to order these *n* services from the highest quality to the lowest quality. For convenience, let q_j denote the *j*-th quality level of the service, and assume that $q_1 < q_2 < \cdots < q_n$.

Consumers have a different taste over qualities of the service, and their utility from the service depends on a quality of the service and its price. Formally, consumer *i*'s utility from the purchase of the service with quality q_j is specified as

$$v_{ij} = \theta_i q_j - p_j \qquad (1)$$

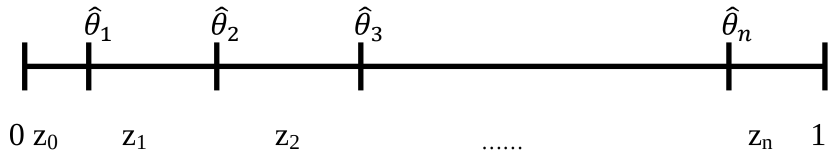
where θ_i is consumer *i*'s taste parameter, and p_j is a price of the service with quality q_j. The marginal valuation of quality increases with θ so that this utility function satisfies the single-crossing property. The taste parameter θ is distributed according to a distribution function *F*.

Given that a consumer's utility is normalized to zero when she does not purchase the service at all, the consumer with $\hat{\theta}_1$ is indifferent between buying the q_1 quality service and not buying any service, where $\hat{\theta}_1$ satisfies $\hat{\theta}_1 q_1 = p_1$. Similarly, the consumer with $\hat{\theta}_j$ is indifferent between buying q_j quality service and buying q_{j-1} quality service, where $\hat{\theta}_j$ satisfies $\hat{\theta}_i(q_i - q_{i-1}) = p_i - p_{i-1}$. Denoting a demand for q_j quality service by z_j, we can write

$$\hat{\theta}_j = 1 - \sum_{k=j}^{n} z_k \qquad (2)$$

Figure 1 shows a relationship between θ and *z* graphically.

Figure 1



A fraction of "potential" buyers of the service with quality q_j is given by

$$\sum_{k=j}^{n} z_k = 1 - F\left[\left(p_j - p_{j-1}\right)/\left(q_j - q_{j-1}\right)\right] \quad (3)$$

Using equation (3), an inverse demand function of q_j quality service is written as

$$p_j - p_{j-1} = \left(q_j - q_{j-1}\right)H\left(Z_j\right) \quad (4)$$

where

$$Z_j = \sum_{k=j}^{n} z_k \quad (5)$$

and

$$H\left(Z_j\right) = F^{-1}\left(1 - Z_j\right) \text{ for } Z_j \in (0,1) \quad (6)$$

The cumulative variable Z_j is interpreted as the total demand at quality q_j and above. Equation (4) suggests that a price of quality upgrade from q_{j-1} to q_j is $p_j - p_{j-1}$ and the price of upgrade depends only on the cumulative variable Z_j. A benefit of this approach is that we do not need to pay attention to how Z_j consists of z_is.

A service with quality q_j is in positive supply in an equilibrium if $Z_j - Z_{j+1} > 0$, and it is in zero supply if $Z_j - Z_{j+1} = 0$. If q_j is the minimum quality in positive supply, we have that $Z_k = Z_j$ for $k < j$. Using this fact and $p_j = \sum_{i=1}^{j}(p_i - p_{i-1})$, we must have

$$p_j = H\left(Z_j\right)q_j \quad (7)$$

Equations (4) and (7) characterize the demand system for different qualities of the service.

3.2 Firms

This section examines firm's optimal choice of service supply. We consider a case where there are *M* firms in a service industry and these firms compete through the quantity of service supplied to the market. We assume that labor is only an input for producing and providing the service and specify the production function of quality q_j service as

$$z_j = a\left(q_j\right)l$$

where $a\left(q_j\right)$ represents a technical efficiency and l is the amount of labor employed. A simple cost minimization calculation implies the unit cost of providing quality q_j service is

$$c_j = \frac{1}{a(q_j)}$$

where c_j is a unit cost and a constant marginal cost of providing quality q_j service. This equation shows that the standard notion of productivity is inversely related to the unit cost parameter.

Firm m chooses $(z_{m,1}, \dots, z_{m,n})$ so as to maximize its profit $\Pi^m = \sum_{j=1}^{n} z_{m,j}(p_j - c_{m,j})$. Using equation (7), the maximization problem of firm m can be formulated as

$$Max \ \sum_{j=1}^{n} Z_{m,j}\left[(q_j - q_{j-1})H\left(\sum_{k=1}^{M} Z_{k,j}\right) - (c_{m,j} - c_{m,j-1})\right]$$

$$\text{subject to } \ Z_{m,j} \leq Z_{m,j-1} \ \text{ for each } \ j.$$

This formulation greatly simplifies the optimization problem since we do not need to consider how each of $(z_{m,1}, \dots, z_{m,n})$ is combined to maximize the profit.

Differentiating the objective function with respect to each $Z_{m,j}$, we obtain first order conditions for this optimization problem as

$$H\left(\sum_{k=1}^{M} Z_{k,j}^*\right) + Z_{m,j}^* H'\left(\sum_{k=1}^{M} Z_{k,j}^*\right) \geq \frac{c_{m,j} - c_{m,j-1}}{q_j - q_{j-1}} \qquad (8)$$

with equality if $Z_{m,j}^* < Z_{m,j-1}^*$.

Define a "marginal" productivity index as

$$\omega_{m,j} \equiv \frac{c_{m,j} - c_{m,j-1}}{q_j - q_{j-1}} \qquad (9)$$

When $\omega_{m,j}$ increases with j, the inequality that $Z_{m,j}^* < Z_{m,j-1}^*$ is guaranteed under regularity conditions. Therefore, equation (8) holds with equality:

$$H\left(\sum_{k=1}^{M} Z_{k,j}^*\right) + Z_{m,j}^* H'\left(\sum_{k=1}^{M} Z_{k,j}^*\right) = \omega_{m,j} \qquad (10)$$

In this case, a firm provides all levels of qualities of the service, $(z_{m,1}, \dots, z_{m,n})$. On the other hand, when $\omega_{m,j}$ decreases with j, we must have $Z_{m,j}^* = Z_{m,j-1}^*$ for any j. The firm therefore provides only the highest quality of the service, $z_{m,n}$.

To proceed further, we assume that $\omega_{m,j}$ increases with j for all m so that equation (10) holds for any j and m. As in the Cournot model, a Nash equilibrium consists of $(Z_{1,1}^*, \dots, Z_{1,n}^*, \dots, Z_{M,1}^*, \dots, Z_{M,n}^*)$ that satisfy a system of equation (10). Once we obtain $(Z_{1,1}^*, \dots, Z_{1,n}^*, \dots, Z_{M,1}^*, \dots, Z_{M,n}^*)$, we can derive an equilibrium supply of each firm, $(z_{1,1}^{*}, .., z_{1,n}^{*}, ..., z_{M,1}^{*}, .., z_{M,n}^{*})$, from equation (5).

3.3 Relationship between ω_j and Conventional Productivity Measures

To see how $\omega_{m,j}$ is related to a conventional productivity measure, use equation (7) and write a revenue of firm *m* from the *j*-th quality of the service as

$$R_{m,j} = z_{m,j}^{*} H\left(\sum_{k=1}^{M} Z_{k,j}^{*}\right) q_{m,j}$$

Combining it with the first-order condition (10), we have

$$R_{m,j} = z_{m,j}^{*} q_{m,j} \left(\omega_{m,j} - Z_{m,j}^{*} H'\left(\sum_{k=1}^{M} Z_{k,j}^{*}\right)\right) \qquad (11)$$

Equation (11) shows that the value-added approach is problematic when we are interested in measuring cost changes (i.e., productivity changes) realized by productivity improvement.[2] A change in R_j can be caused by demand conditions, embedded in $H(\cdot)$, even if ω_j is held constant. For example, an introduction of a new service may cause a change in the distribution of tastes, and this results in changing R_j, even though there is no change in ω_j. Similarly, equation (11) implies that rivals' productivity improvements affect the measurement R_j through a change in $Z_{k,j}^{*}$. Overall, the value-added approach captures a mixture of demand and supply effects, and cannot isolate ω_j from other factors.

4. Estimation Strategy

4.1 Estimation when Quality and Price Data Available

In this section, we describe our estimation strategy when data about prices and qualities of a service are available along with data about consumers' service choices. An objective measure of quality is available for some services, and different qualities of such services are vertically ordered in the ordinal sense. Our data requirement is similar to the one by Train and Winston (2007) who study consumers' vehicle choices using a random sample of consumers who acquired a new vehicle.

Our estimation strategy is to estimate $\omega_{m,j}$ by estimating the left hand side of equation (10). To make our analysis tractable, assume that a taste parameter θ is distributed normally with mean μ and variance σ^2. Let $f(\theta; \mu, \sigma^2)$ denote the normal density function of θ. When quality q_j and price p_j are available, a consumer's choice can be modeled as a mixed logit model. That is, consumer *i*'s

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[2] In this discussion, we assume that material costs are negligible in the service sector.

probability of choosing j-th level quality of the service is given by

$$Prob_{ij} = \int L_{ij}(\theta)\, f(\theta; \mu, \sigma^2) d\theta \tag{12}$$

where

$$L_{ij}(\theta) = \frac{e^{v_{ij}(\theta)}}{\sum_{k=1}^{n} e^{v_{ik}(\theta)}} \tag{13}$$

These equations can be derived by specifying an individual utility function as equation (1), $v_{ij}(\theta) = \theta q_j - p_j$, and assuming that a random term follows the i.i.d. Type-I extreme value distribution. See Train (2009) for the details of the mixed logit model.

We estimate parameters of the taste distribution, mean μ and variance σ^2, by taking the standard procedure of the mixed logit model estimation. Once we obtain estimates $\hat{\mu}$ and $\hat{\sigma}^2$, we can recover the cumulative density function

$$\hat{F}(\theta) = \frac{1}{\sqrt{2\pi\hat{\sigma}^2}} \int_{-\infty}^{\theta} e^{-\frac{1}{2\hat{\sigma}^2}(x-\hat{\mu})^2}\, dx \tag{14}$$

Using $\hat{F}(\theta)$, we obtain the empirical function of $H(\cdot)$:

$$\hat{H}\left(\sum_{k=1}^{M} Z_{k,j}\right) = \hat{F}^{-1}\left(1 - \sum_{k=1}^{M} Z_{k,j}\right) \text{ for } Z_{k,j} \in (0,1) \tag{15}$$

Our remaining task is to find an expression for $H'(\cdot)$. This can be done by using the fact that $H'(x) = \frac{1}{F'(H(x))}$. That is, we have

$$\hat{H}'\left(\sum_{k=1}^{M} Z_{k,j}\right) = -\frac{1}{\hat{f}\left(1-\sum_{k=1}^{M} Z_{k,j}\right)} \tag{16}$$

Since $Z_{k,j} = \sum_{i=j}^{n} z_{k,i}$ for any k and j, we can use a market share $s_{k,i}$ as an estimate of $z_{k,i}$ and estimate $Z_{k,j}$ as

$$\hat{Z}_{k,j} = \sum_{i=j}^{n} s_{k,i} \tag{17}$$

Finally, we get

$$\sum_{k=1}^{M} \hat{Z}_{k,j} = \sum_{k=1}^{M} \sum_{i=j}^{n} s_{k,i} \tag{18}$$

We are now in a position to estimate the left hand side of equation (10). While equations (15) and (18) determine the first component of the left hand side of equation (10), equations (16) and (17) pins down the second component. As a result, we obtain an estimate for $\omega_{m,j} \equiv \frac{c_{m,j} - c_{m,j-1}}{q_j - q_{j-1}}$. Unlike the conventional value-added approach, this estimate is independent of demand factors.

4.2 Quality Estimation when Quality Data are not Available

When quality data are not available, we use the random coefficient model proposed by Berry (1995) and Khandelwal (2010) to estimate a quality of the service. After obtaining an estimate for a quality of the service, we can take the same procedure outlined in Section 4.1.

We first specify equation (1) as

$$v_{ijkt} = \tilde{q}_{jkt} - \alpha p_{jt} + \zeta_{ijt} + (1-\sigma)\epsilon_{ijkt} \tag{19}$$

where *j* indicates firm *j*, *k* is category *k* in the service, and *t* is time *t*. Decomposing q_{jkt} as

$$\tilde{q}_{jkt} = q_{jk} + q_t + q_{jkt} \tag{20}$$

we can write (19) as

$$v_{ijkt} = q_{jk} + q_t + q_{jkt} - \alpha p_{jt} + \sum_{j=1}^{N} d_{jk}\zeta_{ijt} + (1-\sigma)\epsilon_{ijkt} \tag{21}$$

where $d_{jk} = 1$ if firm *k*'s service to the *j*th category, and $d_{jk} = 0$ otherwise.

Under the assumption that ϵ_{ijkt} is distributed Type-I extreme value, we obtain the following estimating equation:

$$ln\left(s_{jkt}\right) - ln(s_{0t}) = q_{jk} + q_t - \alpha p_{jt} + \sigma ln(s_{kt}) + q_{jkt} \tag{22}$$

where s_{jkt} is firm *k*'s share of category *j* in the service industry at time *t*, s_{kt} is firm *k*'s share in the category *j*. Given that panel data about prices and market shares are available, we can estimate equation (22) and obtain an estimate for $\tilde{q}_{jkt}$.

5. Decompositions

In this section, we show a way of decomposing value-added into direct and indirect effects of costs. While the direct effect of costs is independent of demand or market conditions, the indirect effect of costs is dependent on these conditions and it therefore varies from one market to another market. Furthermore, we decompose the indirect effect into effects of a market structure and consumers' tastes. It is worthwhile pursuing this way of decomposition in order to understand what the conventional measure of service sector's productivity actually measures because both value-added and economic activities in the service sector are largely influenced by demand/market conditions.

Using the revenue function (11), we can write

$$\frac{VA_{m,j}}{z_{m,j}^{*} q_{m,j}} \equiv va_j = \omega_{m,j} - Z_{m,j}^{*} H'\left(\sum_{k=1}^{M} Z_{k,j}^{*}\right) \tag{23}$$

where value-added of firm *m* from *j*th quality of the service, $VA_{m,j}$, is $R_{m,j}$ less material costs. The first term of equation (23) is the direct effect of costs on the value-added and it is independent of demand/market conditions. The second term captures the indirect effect of costs since $Z^*_{k,j}$ is a function of ω.

We can further decompose the second term of equation (23). In particular, we can show that the second term varies through the function $H(\cdot)$ that summarizes consumers' tastes and through the number of competitors in the service industry. To see this, assume that that *F* is a normal distribution function and that an equilibrium is symmetric (i.e., $Z^*_{k,j} = Z^*_j$ for *k=1,..,M*). We then have

$$H'\left(MZ^*_j\right) = \sqrt{2\pi}\sigma^2 exp\left[\frac{1}{2}\left(\frac{MZ^*_j - \mu}{\sigma}\right)^2\right]$$

With this expression, the second term is expressed as

$$ln\left[Z^*_j H'\left(MZ^*_j\right)\right] = lnZ^*_j + ln\sqrt{2\pi} + ln\sigma^2 + \frac{1}{2\sigma^2}\left(M^2 Z^{*2}_j - 2\mu M Z^*_j + \mu^2\right)$$

Based on estimates $\hat{\mu}$, $\hat{\sigma}^2$, $\hat{Z}^*_j$, and $\widehat{M}$, we can quantify the following relationships[3]:

$$\frac{\partial ln\left[Z^*_j H'\left(MZ^*_j\right)\right]}{\partial M} = \frac{1}{\hat{\sigma}^2}\left(\widehat{M}Z^{*2}_j - \hat{\mu}\hat{Z}^*_j\right) \tag{24}$$

$$\frac{\partial ln\left[Z^*_j H'\left(MZ^*_j\right)\right]}{\partial \mu} = \frac{1}{\hat{\sigma}^2}\left(2\hat{\mu} - \widehat{M}\hat{Z}^*_j\right) \tag{25}$$

and

$$\frac{\partial ln\left[Z^*_j H'\left(MZ^*_j\right)\right]}{\partial \sigma^2} = \frac{2\hat{\sigma}^2 - \left(\widehat{M}^2 \hat{Z}^{*2}_j - 2\hat{\mu}\widehat{M}\hat{Z}^*_j + \hat{\mu}^2\right)}{2\hat{\sigma}^4} \tag{26}$$

Equation (24) represents a change in value-added when the number of competitors increases. As equation (24) shows, this effect depends on taste parameters. Equations (25) and (26) capture a change in value-added when there is a change in the distribution of consumers' tastes. These decompositions will give us additional insights regarding the composition of value-added.

6. Simulations

6.1 Comparative Statics

In this section, we do comparative static exercises to examine how consumers' tastes and firms' costs affect a price of the service and a volume of service transaction of each quality. To achieve this purpose, we numerically compute an equilibrium price and quantity of the service for a given set of taste and cost parameters. For these

[3] We assume here that the second order effects are negligible.

comparative static exercises, we assume that there are three levels of quality of the service and focus on outcomes arising from a symmetric equilibrium.

6.1.1 Number of Firms

Table 1 presents an equilibrium price and an aggregate share of each quality of the service for different sets of parameters for the number of firms and the distribution of consumers' tastes. As we can easily expect from the model, other things being equal, an equilibrium price of each quality falls as the number of firms increases. In the first three rows of Table 1 (see Regions 1, 2, and 3), for example, the equilibrium price of high quality is 53.3 when the market is monopolized, and it is 47.4 and 45.1 when the number of firms increases to 5 and 100 respectively. We can also see that an equilibrium price rises as quality level goes up from low, middle to high.

Results in Table 1 show that these two qualitative features apply to other categories of quality and different sets of taste parameters. An increase in the number of active firms lowers an equilibrium price of the service.

6.1.2 Taste parameters

We now turn our attention to effects of taste parameters on an equilibrium price of the service and a volume of service transaction. A population size is one of the main focuses in the standard argument when we consider roles of demand in the service sector. Our comparative static exercises focus on examining a change in the distribution of consumers' tastes, and intends to capture the reality that consumers' taste differ from region to region. It is often mentioned that residents of a large city tend to seek for high quality and diversifying services, compared with those of a small city. In our analysis, the mean of a consumers' taste distribution intends to capture a desire of residents for high quality, whereas the standard deviation intends to capture the diversity of consumers' tastes.

We can obtain a general insight regarding a desire for high quality (i.e., mean parameter) by comparing Region 3 and Region 9 in Table 1. The mean of taste distribution of Region 9 is larger than that of Region 3, and other parameters of the model are identical. Both equilibrium price levels and aggregate shares for all the categories in Region 9 are higher than those in Region 3. This suggests that consumers' willingness to pay for a given quality of the service becomes higher as the consumers' taste distribution shifts to the right, and this contributes to the expansion of service transactions.

We next investigate effects of the diversity of consumers' tastes (i.e., standard deviation parameter). According to Table 1, the effects on equilibrium prices are mixed. When the numbers of firms is 1 or 5, a price of high quality service rises as the standard deviation parameter becomes larger. This suggests that a price of high quality is likely high when individuals' tastes are diverse. However, this pattern does not necessarily hold when the number of active firms in the market increases to 100 (Compare Regions 3, 6, 9, and 12).

Our comparative static exercises reveal that an equilibrium price level is high when the mean of the taste distribution is high, and that an equilibrium price level for a given quality of the service can be higher or lower as consumers' tastes spread out.

6.1.3 Cost parameters

Table 2 shows results of comparative static exercises for firms' costs. We can see a clear pattern that cost reduction leads to price decline and the expansion of service transactions. The model of this paper also suggests that productivity improvement is a key determinant for the growth of the service sector.

6.2 Estimations

We generate two datasets artificially based on the model described above to demonstrate our estimation procedure and to raise potential problems of a conventional method of measuring service sector's productivity. We contextualize this exercise by trying to examine differences in productivity across regions. To see how demand factors affect a measure of productivity, one data (dataset 1) set is generated by holding cost parameters constant across regions. We generate the other data set (dataset 2) by allowing both consumers' taste and cost parameters to vary across regions. We conduct simulations at 500 times and report the mean and the standard deviation of each estimated coefficient.

6.2.1 Cost Parameters Estimations

We use value-added (revenue) as the dependent variable in the value-added approach, and regress it on regional dummies. This replicates research that uses the conventional measure of the service sector's productivity. On the other hand, we estimate cost parameters in our approach by taking the procedure described in Section 4, and regress estimated cost parameters on regional dummies. Since the dataset is generated based on the model, our approach should serve just as the benchmark case to gauge how good the value-added approach can perform when estimating productivity differences resulting from supply-side factors (i.e., cost differences).

We first use the dataset 1 in which cost parameters are held constant across regions but consumers' taste parameters differ across regions. In theory, an appropriate estimation procedure should produce the outcome that regional dummies are not statistically different from zero if we aim to measure underlying supply-side productivity differences across regions.

Table 3A presents regression results from the dataset 1.[4] We can see that the value-added approach is very imprecise to capture cost differences across regions. First, the mean value of estimated coefficients for Region 1 is 0.69 for the high quality category, 0.35 for the middle quality category, and 0.38 for the low quality category. Since the base is the Region 1 dummy (i.e., constant term) in the regression, its coefficient should reflect the underlying cost parameters 15, 8, and 2 of the corresponding quality categories (See Table 3B). The estimated coefficients are however far from reflecting these numbers of the parameters. Second, our estimation results from the value-added approach show that regional dummies are different across regions. This property can be seen in our approach too, but the magnitude of all the estimated coefficients is much larger in the value-added approach than in our approach. Finally, the value-added approach tends to over-estimate productivity measures for a region where consumers have a taste for higher quality.

We next use the dataset 2 in which both cost parameters and consumers' taste parameters vary across regions. In theory, an appropriate estimation procedure should capture cost differences across regions even in this case. We present regression results from the dataset 2 in Table 4A.[5] Again, our estimation results indicate that the value-added approach is very imprecise to capture cost differences across regions. A value of the cost parameters decreases as we move down (i) Regions 1, 2 and 3, (ii) Regions 4, 5 and 6, to (iii) Regions 7, 8 and 9 (See Table 4B), but this pattern is not captured by the value-added approach. In fact, we observe the opposite pattern for the high quality service. Again, the value-added approach over-estimates productivity

[4] See Table 3B for a value of parameters we set for generating the dataset 1.
[5] See Table 4B for a value of parameters we set for generating the dataset 2.

measures for a region where consumers have a taste for higher quality.

Overall, our exercise shows that the value-added approach measures firms' costs imprecisely when consumers care about quality of the service and when firms are involved in Cournot-type competition. In such a situation, our approach can estimate firms' costs with greater accuracy than the value-added approach.

6.2.2 Decompositions

Table 5 presents estimation results about effects of entry and taste on the value-added. These numbers are calculated by using equations (24) to (26). Estimated effects of entry are all negative, suggesting that the value-added decreases as more firms enter a market. In general, the magnitude of this effect is larger when a few firms dominate a market. Effects of the mean of taste parameter on the value-added are positive, and the magnitudes increase with the mean value. This suggests that a taste for a better quality has enhancing effects on the value-added. Effects of the standard deviation of taste parameter on the value-added are positive for most cases, but they can be negative. This implies that the diversification of consumers' tastes may increase or decrease the value-added.

7. Conclusions

In this paper, we demonstrated that a conventional measure of service sector's productivity can be problematic, and we suggested the alternative way of measuring service sector's productivity. Compared with the conventional approach, our estimation approach can identify the cost parameters independently of demand factors, and it can relate the value-added to cost factors and demand factors. It is important to distinguish how each of these two different types of factors affects productivity measures. An economic policy for promoting service sector's productivity should be designed to target the supply side if cost factors are a primal source for slow productivity growth. On the other hand, such an economic policy should target the demand side if consumers' preferences are the main reason for slow productivity growth. In this paper we argued that the cost and demand factors are entangled in the conventional approach. This paper suggested a methodology of drawing useful policy implications by distinguishing cost and demand factors cleanly.

A limitation of this paper is lack of a welfare analysis.[6] A taste parameter enters the utility function of each consumer and a shape of the taste parameter distribution affects an aggregate welfare of the consumers. Firms are also heterogeneous in terms of cost structures. Under such a circumstance, maximizing productivity growth is not necessarily equivalent to maximizing the total welfare of an economy. Due to the heterogeneity of both consumers and firms, the effectiveness of an economic policy depends on how these economic actors respond to demand-side and supply-side incentives provided by the economic policy. This puts us in a difficult position to draw a general conclusion about whether a demand targeting policy or a supply targeting policy maximizes the total welfare of an economy. Despite this difficulty, it is worthwhile examining such welfare questions further and trying to draw general insights. The task of welfare analysis is left as a future task.

[6] The author of this paper would like to thank the participants of a RIETI DP workshop, especially Prof. Fukao, for pointing out the importance of a welfare analysis.

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Tables

Table 1: Effects of Number of Firms and Taste Parameters

	No. of firms	Taste parameters		Price			Aggregate share		
				Quality level			Quality level		
Region		Mean	S. D.	High	Middle	Low	High	Middle	Low
1	1	5	10	53.3	26.9	10.2	10.1	19.9	30
2	5	5	10	47.4	19.5	4.8	14.0	31.8	50.8
3	100	5	10	45.1	16.2	2.2	15.8	37.8	61.0
4	1	5	20	71.5	39.6	16.5	17.3	23.0	28.3
5	5	5	20	53.1	23.5	6.8	26.3	36.8	46.5
6	100	5	20	45.6	16.5	2.3	30.5	43.5	55.4
7	1	15	10	76.0	45.7	21.0	15.1	21.6	27.4
8	5	15	10	58.6	30.3	11.4	32.5	49.5	64.0
9	100	15	10	46.1	17.1	2.7	48.5	74.0	89.1
10	1	15	20	89.5	52.8	23.6	22.9	28.4	33.4
11	5	15	20	60.6	29.2	9.9	39.8	50.8	60.1
12	100	15	20	45.9	16.7	2.4	49.4	63.0	73.5

Note: Cost parameters are fixed. S.D. stands for standard deviation.

Table 2: Effects of Cost Parameters

	Cost parameters			Price			Aggregate share		
	Quality level			Quality level			Quality level		
Region	High	Middle	Low	High	Middle	Low	High	Middle	Low
1	30	15	8	90.0	30.1	8.1	0.6	15.8	37.8
2	25	13	7	75.1	26.2	7.1	2.3	20.9	41.5
3	20	10	5	60.0	20.2	5.1	6.7	30.5	49.5
4	15	8	4	45.1	16.2	4.1	15.8	37.8	53.5
5	10	5	3	30.3	10.3	3.2	30.5	49.5	57.3
6	5	3	1	15.4	6.3	1.1	49.5	57.3	65.0

Note: Taste parameters are fixed.

Table 3A: Comparison of Value-Added Approach with Our Approach 1

	I. Value-Added Approach					
	Quality level					
	High		Middle		Low	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Region 1	0.6915	0.0014	0.3511	0.0060	0.3836	0.0083
Region 2	-0.5472	0.0016	-0.2806	0.0065	-0.3081	0.0087
Region 3	-0.6194	0.0015	-0.1120	0.4790	-0.3464	0.0085
Region 4	0.6236	0.0021	0.1007	0.0085	0.0118	0.0119
Region 5	-0.4174	0.0016	-0.2627	0.0065	-0.3121	0.0091
Region 6	-0.5511	0.0015	-0.3083	0.0063	-0.3489	0.0087
Region 7	1.3912	0.0022	0.1748	0.0102	0.0245	0.0146
Region 8	-0.2441	0.0016	-0.2602	0.0067	-0.3271	0.0093
Region 9	-0.4657	0.0015	-0.3426	0.0060	-0.3785	0.0083
	II. Our Approach					
	Quality level					
	High		Middle		Low	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Region 1	14.9542	0.0141	8.0364	0.0995	1.9842	0.0896
Region 2	-0.0980	0.0342	-0.0546	0.2142	0.0108	0.1930
Region 3	-0.0542	0.0468	0.5197	1.8411	0.0605	0.2783
Region 4	-0.0019	0.0180	-0.0017	0.1326	0.0411	0.1374
Region 5	0.0597	0.0263	0.0123	0.2064	-0.0067	0.2571
Region 6	-0.1150	0.0316	-0.0158	0.2796	-0.0213	0.3706
Region 7	0.0853	0.0176	-0.0066	0.1499	0.0196	0.1671
Region 8	-0.0058	0.0239	-0.0828	0.2568	-0.0688	0.3755
Region 9	-0.0531	0.0293	-0.0187	0.3473	0.0473	0.5603

Note: The base category is Region 1 for which an estimated coefficient for the constant term is reported. S.D. stands for standard deviation.

Table 3B: Parameters for Artificial Dataset 1

	Parameters					
	Cost			Taste		No. of firms
	Quality level			Mean	sigma	
Region	High	Middle	Low			
1	15	8	2	5	10	10
2	15	8	2	5	10	50
3	15	8	2	5	10	100
4	15	8	2	10	10	10
5	15	8	2	10	10	50
6	15	8	2	10	10	100
7	15	8	2	15	10	10
8	15	8	2	15	10	50
9	15	8	2	15	10	100

Table 4A: Comparison of Value-Added Approach with Our Approach 2

	I. Value-Added Approach					
	Quality level					
	High		Middle		Low	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Region 1	0.0540	0.0027	0.4427	0.0098	0.5981	0.0137
Region 2	-0.0450	0.0028	-0.3495	0.0108	-0.4683	0.0153
Region 3	-0.0450	0.0028	0.0094	0.6789	-0.5320	0.0142
Region 4	1.2612	0.0031	0.0093	0.0115	-0.2020	0.0159
Region 5	0.2202	0.0027	-0.3541	0.0100	-0.5270	0.0139
Region 6	0.0864	0.0027	-0.4000	0.0099	-0.5632	0.0139
Region 7	2.0230	0.0029	-0.3532	0.0110	-0.5192	0.0161
Region 8	0.2490	0.0027	-0.4342	0.0099	-0.5912	0.0137
Region 9	0.0871	0.0027	-0.4398	0.0098	-0.5952	0.0138
	II. Our Approach					
	Quality level					
	High		Middle		Low	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Region 1	30.1101	0.1754	14.9460	0.1445	8.0376	0.0998
Region 2	0.6976	0.5229	-0.0793	0.3392	-0.0719	0.2214
Region 3	-1.8261	0.4063	-7.3530	10.5661	-0.0795	0.2848
Region 4	-15.1581	0.1757	-6.9149	0.1693	-6.0266	0.1456
Region 5	-15.0975	0.1750	-6.9160	0.2338	-6.0424	0.2503
Region 6	-15.2715	0.1771	-6.9136	0.2893	-6.0926	0.3540
Region 7	-25.1577	0.1765	-11.9945	0.1906	-7.0011	0.1817
Region 8	-25.1082	0.1774	-12.0420	0.3565	-7.2160	0.4247
Region 9	-25.2804	0.1807	-11.8885	0.5063	-7.1321	0.6439

Note: The base category is Region 1 for which an estimated coefficient for the constant term is reported. S.D. stands for standard deviation.

Table 4B: Parameters for Artificial Dataset 2

	Parameters					
	Cost			Taste		No. of firms
	Quality level			Mean	Sigma	
Region	High	Middle	Low			
1	30	15	8	5	10	10
2	30	15	8	5	10	50
3	30	15	8	5	10	100
4	15	8	2	10	10	10
5	15	8	2	10	10	50
6	15	8	2	10	10	100
7	5	3	1	15	10	10
8	5	3	1	15	10	50
9	5	3	1	15	10	100

Table 5: Decomposition of Indirect Effects

	Entry Effect			Taste Effect					
				Mean			Sigma		
	Quality level			Quality level			Quality level		
Region	High	Middle	Low	High	Middle	Low	High	Middle	Low
1	-0.000030	-0.0007	-0.0016	0.1000	0.0992	0.0983	0.0088	0.0088	0.0089
2	-0.000005	-0.0002	-0.0003	0.1000	0.0998	0.0996	0.0088	0.0088	0.0089
3	-0.000005	-0.0001	-0.0002	0.1000	0.0999	0.0998	0.0088	0.0088	0.0089
4	-0.002700	-0.0048	-0.0065	0.1973	0.1950	0.1930	0.0053	0.0055	0.0057
5	-0.000600	-0.0011	-0.0014	0.1994	0.1989	0.1985	0.0053	0.0055	0.0057
6	-0.000300	-0.0005	-0.0007	0.1997	0.1994	0.1992	0.0053	0.0056	0.0058
7	-0.009900	-0.0106	-0.0112	0.2896	0.2889	0.2882	-0.0002	-0.0002	-0.0001
8	-0.002300	-0.0024	-0.0025	0.2976	0.2974	0.2973	-0.0001	0.0000	0.0001
9	-0.001200	-0.0012	-0.0013	0.2988	0.2987	0.2986	0.0000	0.0000	0.0001