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Estimating determinants of dentist productivity: new evidence

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Abstract

Objective: Productivity (output per unit of input) is a major driver of dental service capacity. This study uses 2006-2007 data to update available knowledge on dentist productivity.
Methods: In 2006-2007, the authors surveyed 1,604 Oregon general dentists regarding hours worked, practice size, payment and patient mix, prices, dentist visits, and dentist characteristics. Effects of practice inputs and other independent variables on productivity were estimated by multiple regression and path analysis.
Results: The survey response rate was 55.2 percent. Dentists responding to the productivity-related questions were similar to dentists in the overall sampling frame and nationwide. Visits per week are significantly positively related to dentist hours worked, number of assistants, hygienists, and number of operatories. Dentist ownership status, years of experience, and percentage of Medicaid patients are significantly positively related to practice output. The contributions of dentist chairside time and assistants to additional output are smaller for owners, but the number of additional dentist visits enabled by more hygienists is larger for owners.
Conclusion: As in earlier studies of dental productivity, the key determinant of dentist output is the dentist's own chairside time. The incremental contributions of dentist time, auxiliaries, and operatories to production of dentist visits have not changed substantially over the past three decades. Future studies should focus on ultimate measures of output – oral health – and should develop more precise measures of the practice's actual utilization of auxiliaries and their skill and use of technology.

Introduction

Dental services are an important and growing sector of the economy. From 1980 to 2005, annual dental expenditures increased at an average annual rate of 7.2 percent; and, as of 2005, at $86.7 billion, dental expenditures exceeded annual expenditures on coronary heart disease and cancer treatment, respectively (1). Of the annual growth in dental expenditures, almost one-third of the 7 percent increase (2.3 percent) is attributable to dental price increases in excess of general inflation. Moreover, in 2004, more than one-third of the US population over age 1 year did not visit the dentist, a proportion that has barely changed since 1997 (2).

These figures highlight the size and growth of expenditures on dental care, but they also suggest a challenge for population health – gaps in access to dental care that have not been ameliorated in the past decade and excess dental price inflation. To address these shortfalls in dental care sector performance, a variety of tools in public policy and practice innovation might be employed. For example, federal and state programs might a) loan forgiveness programs for dentists practicing in underserved areas; b) increase the scope of independent practice of dental hygiene in areas with compromised access; and c) collaborate with the dental profession to encourage reduced prices and enhanced access to dental insurance for underserved populations.

Since it is beyond the scope of this paper to examine the full range of policy and practice instruments, the authors have chosen to focus on one practical mechanism for improved dental care performance – dentist productivity.

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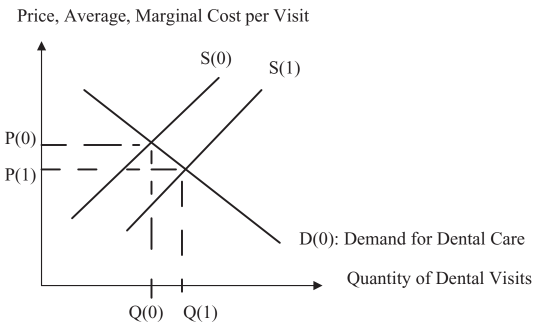

Logic: Increased output per unit of input → Reduced cost per unit of output (visit) → Increased supply of services at any given price {S(0) shifts to S(1)} → Reduced price per visit {P(1) < P(0)} → Increased number of visits at a given level of demand {Q(1) > Q(0)}

Figure 1 Relationships between value, cost, efficiency, and productivity.

Over the period 1960-1998, dentist visits per unit time worked increased 1.4 percent annually on average. However, in spite of this positive absolute trend – with the exception of the time frame 1960 to 1974 when dentist productivity grew by almost 4 percent per year – annual productivity growth lagged overall growth in the US economy (1).

Figure 1 illustrates the logical relationship between dentist productivity and other parameters of interest. An increase in productivity, defined as increased units of output of dental visits per unit of input (practice personnel and capital), leads to reduced cost per unit of output, other things being equal. Improved productivity correspondingly implies that more dental services could be produced with the same level of dentist workforce (3). Reduction in unit cost (improved *efficiency*), in turn, increases the dentist's willingness to supply services at any given price, represented pictorially as a shift from S(0) – the original number of visits supplied at any given price – to S(1) – the new, potentially greater number of visits at the lower unit cost attained through increased productivity. In order to equilibrate supply and demand in the dental marketplace, price is now reduced from P(0) to P(1), and the aggregate quantity of visits delivered to patients rises from Q(0) to Q(1). The implication for oral health is that increases in dental output potentially result in improved access to dental care.

The preceding reasoning follows standard economic theory. While dental market behavior might not adhere precisely to this model because of the special professional, social, and regulatory aspects of dentistry, we do submit that this logic offers an accurate qualitative portrait of the impact of productivity on other parameters of interest to dental practitioners, patients, and policymakers. Even if dental practice is not perfectly competitive, improved productivity helps to contain the cost of dental services and thereby to increase the supply of those services. The relationships in Figure 1 concentrate on price, unit cost per visit, and number of visits (quantity). Accordingly, the model's implications for the effect of increased dentist productivity assume that other supply-side factors (e.g., dental workforce policy, input prices) and demand-side influences (e.g., levels of income, dental insurance) stay the same and should be judged in that context.

Changes over time in relative dental price, dentist productivity, utilization per capita are broadly consistent with the model in Figure 1 (3). During 1960-1974, when productivity (output per dentist) rose by 3.95 percent per year, relative dental prices increased by 0.87 percent per year. In contrast, during 1991-1998 dentist productivity rose by only 1.05 per year, while relative dental prices rose by 2.22 percent. This comparison, while based solely on correlation, is suggestive of the hypothesized inverse relation between productivity and dentist prices. The same data (3) suggest an inverse relation between the rate of increase in relative dental prices and utilization per person, which is consistent with the logic of Figure 1: reduced prices lead to increased demand. Put differently, reductions in price (other things equal) are associated with improved access.

Benefits of increased productivity are realized initially by the owner dentist and the dental practice (4,5), but – to the extent that private practice productivity benefits are passed through to patients and the larger society – there are potential long-run gains to a broader set of stakeholders. For example, increased productivity would allow dentists to expand services to patients for the same input of time while improving returns on investments in dental education made by individual dentists and by states and federal government. The extent to which such improvements accrue to patients and the public versus to the private dental practice will depend on market and regulatory forces: ease of entry into dentistry and dental auxiliary professions; availability of comparative information on access, pricing, and quality of dental services; and the extent to which dental insurance insulates patients from the cost consequences of their dental treatment choices.

Prior empirical work on dentist productivity, including the impact of expanded function auxiliaries, is more than three decades old and potentially out of date with respect to current patterns of dental practice (6-9). The vintage of this empirical work supplies one important rationale for our paper: to ascertain whether relationships appear to have altered appreciably over the past 30 years. The earlier papers show that output, measured in visits, is largely a function of the number of dentist hours worked; smaller increases are contributed by increased use of dental assistants and hygienists, and a greater number of operatories. These studies consistently find a positive relationship between dentist experience and productivity (6-9). While positive, the slope of the relationship with productivity decreases with experience – thus exhibiting diminishing marginal returns analogous to those of labor and capital.

In the current study, the authors examine the production of dental visits as influenced by: labor inputs (dentist time, and number of dental assistants and hygienists), capital inputs (number of operatories), practice characteristics (ownership status and payer mix), and years of dentist experience. The empirical model of production is based on theory (10,11) and previous empirical studies of dental (6-9) and physician services (10,11). In selecting dentist visits as the measure of output, we follow the general convention of previous studies, while acknowledging that general dentist visits represent an *intermediate* output on the way to the ultimate goal of improved population oral health.

Methods

Study population and setting

This research is part of the larger project to explore the knowledge, attitudes, and practices of general dentists in relation to the care of pregnant women. Questionnaires were mailed in 2006 and 2007 to 1,604 general dentists in Oregon identified through the master file of the American Dental Association, including members and nonmembers.

Survey methods

The survey was administered by the Social and Economic Sciences Research Center at Washington State University. Following the protocol of the Tailored Design Method (12), an initial survey and cover letter were mailed to the sampling frame of all general dentists in the state of Oregon. The first mailing was followed by a postcard reminder within 10 days. If the survey was not received within 2 weeks of its initial mailing, a follow-up cover letter and identical replacement survey were mailed to the practice. Remaining nonrespondents after 5 weeks were contacted with one final request for survey completion. The Institutional Review Board of the University of Washington approved the study. We included the elements of informed consent in cover letters accompanying the survey.

Measures

The dependent measure of output, dentist visits, is defined by the dentist's answer to the question, "In a typical week, how many patients do you see in your primary practice?" Variables included in the production model are: years of dentist experience, number of operatories available for restorative care, number of dentist chairside hours worked per week, number of assistants and hygienists available to the dentist, ownership status (owner versus nonowner), and payer mix (percentage of patients on Medicaid). In this study, ownership is dichotomized as a sole proprietor, partner, or shareholder versus associate or employee. Dentist productivity is measured as dentist visits per unit of input. Since production of dental output requires multiple inputs of labor and capital, the incremental contribution of each input to the number of dentist visits per week is estimated statistically, holding constant all other parameters. The methodology for capturing these incremental effects – referred to as the marginal product of each input – is delineated in the next section.

Analysis

We used SPSS (version 14.0) to manage the data. Ordinary least squares regression analysis (OLS) of a Cobb–Douglas production function (14), expressed as $Y = AL_1^{\alpha 1}L_2^{\alpha 2}L_3^{\alpha 3}K^{\beta}$, was used to estimate the relationship of output to inputs, where Y = dental visits per week, L_1 = dentist chairside hours worked per week, L_2 = number of full-time equivalent (FTE) assistants, L_3 = number of FTE hygienists, K = number of restorative operatories available to the dentist, and A = an intercept term capturing levels of total factor productivity.

The a and β are output elasticities, which represent the proportionate change in output for a proportionate change in each input, holding constant all other inputs and variables in the model. The Cobb–Douglas production function assumes positive, but diminishing marginal returns to labor and capital inputs (13). This implies that, as use of any one input (e.g., dentist chairside time) increases while holding other inputs (e.g., number of assistants, hygienists, and operatories) constant, more output is produced but at a diminishing rate.

The owner variable is included because the owner's assumption of economic risk for the practice is expected to result in increased output, other things equal. Similarly, the payer variable is included in order to capture potential differences in service mix or remuneration among patients insured by different payers, which in turn might affect number of visits.

A second set of regressions using path analysis (14) examined determinants of dentist productivity separately for owner and nonowner dentists. We propose that, in contrast to owners, employees and associates have less control over work hours, number of assistants and hygienists and operatories, and thus may utilize labor and capital inputs somewhat differently.

Path analysis provides information that complements the OLS regression analyses. Specifically, path models distinguish between the direct effect of a given independent variable on dental output and its indirect effects through other independent variables which, in turn, directly affect output. Path models are best interpreted as tests of selected hypotheses regarding nonrecursive relationships in dental production (in one direction only – from variable x to y, not from y to x). Total effects of a given independent variable are calculated by adding the path coefficient for its direct effect on output to

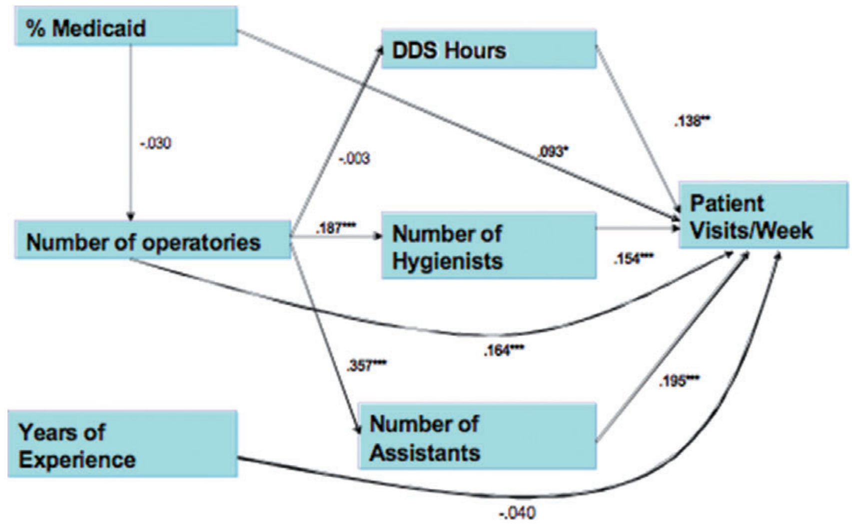

Figure 2 Path diagram of dentist productivity for practice owners. Standardized betas are expressed as z-scores ($N = 519$).

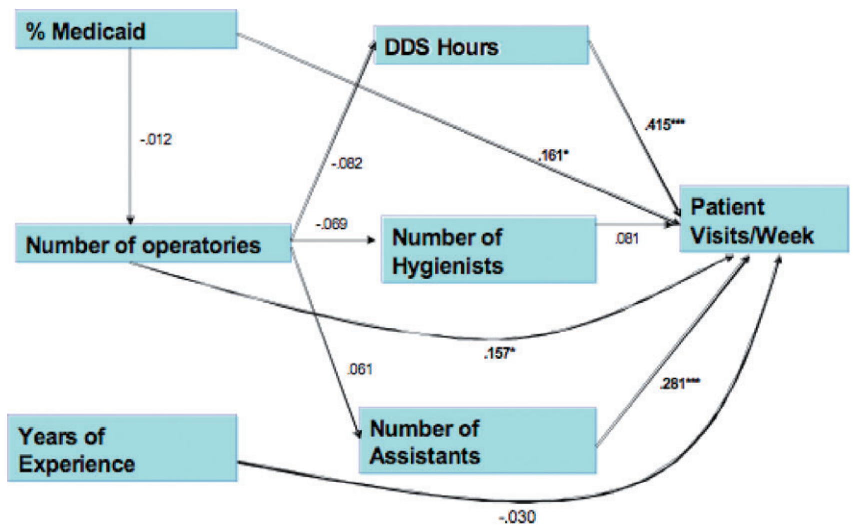

Figure 3 Path diagram of dentist productivity for nonowners. Standardized betas are expressed as z-scores ($N = 226$).

the multiple of its coefficients along (indirect) paths through other variables. The path analyses thus allow one to explore the mechanisms through which different factors ultimately affect dental output.

Figures 2 and 3 for owner and nonowner dentists, respectively, illustrate a set of hypothesized path relationships. Payer mix (percentage of Medicaid) is postulated to directly affect output of visits and influence the practice's capital inputs (restorative operatories), which will be organized to accommodate the service mix and oral health needs of patients served. In turn, number of operatories is directly positively related to expected dentist output, other things equal. The path model also implies that the number of operatories affects the level of labor inputs (dentist chairside time, assistants, and hygienists).

As in the OLS regression, dentist chairside work hours and number of assistants and hygienists are expected to be positively and directly related to the level of dentist output. Similarly, dentist experience is posited to affect productivity directly, not through other variables.

Results

Questionnaires were received from 829 general dentists, for an adjusted response rate of 55.2 percent, after eliminating retired and inactive dentists from the study-eligible population. The average number of patients seen by the dentist per week is 51.9 [standard deviation (SD) = 30.2]. The large SD reflects significant variability among the respondents in production levels. Over two-thirds (69.7 percent) are owners (sole proprietors, partners, or corporate shareholders); the nonowner dentists in our sample are either associates or employees. Over 80 percent are male. The average age of respondent dentists is 47 (SD = 11.9) years with, on average, 18.9 (SD = 12.5) years of experience since graduation. Most dentists reported working approximately 35 hours a week (SD = 7.7). The average number of dental assistants and hygienists per dentist is 2.7 (SD = 1.7) and 2.0 (SD = 1.4), respectively. Dentists typically reported having three operatories available for restorative care (SD = 1.2). The average percentage of patients with Medicaid insurance is 8.4 percent (SD = 20.1).

OLS regression analyses of productivity relationships

We estimated the effects of ownership, labor input (dentist hours work, number of assistants and hygienists), capital input (number of operatories), and dentist characteristics (years of experience) on output (number of dentist visits per week) using OLS regression. Table 1 shows the regression results. As predicted by previous empirical work and production theory, dentist visits per week are a positive function of dentist chairside hours worked, number of assistants and hygienists, and number of operatories. The proportionate effect of dentist chairside hours on dentist visits is substantially above that of number of assistants, hygienists, and restorative operatories. Ownership, years of experience and payer mix are significant positive predictors. Overall, the model has a good fit; about 33 percent of variability of dentist output is explained.

Path analyses of owner and nonowner productivity

The path analyses include 519 owners and 226 nonowners. The final path model of direct productivity effects for owners and nonowners is specified in the following equation:

Table 1 OLS Regression Analysis of Dentist's Productivity by Ownership, Dentist Hours Worked, Number of Assistants, Number of Hygienists, Number of Operatories, Percentage of Medicaid Patients, and Years of Experience

Variables*	Coefficient	S.E.	*P* value
Constant	0.330	0.276	0.231
Ownership	0.227†	0.053	<0.001
Dentist hours worked	0.872	0.074	<0.001
Number of assistants	0.095	0.015	<0.001
Number of hygienists	0.036	0.011	0.001
Number of operatories	0.126	0.051	0.015
Percent of Medicaid patients	0.024	0.005	<0.001
Year of experience	0.050	0.023	0.032

Adjusted R^2 = 0.327, N = 829.

* All independent and dependent variables, except ownership, have been converted to their natural logarithm.

† The proportionate difference in dentist visits per week between owners and nonowners can be calculated by exponentiating the coefficient of 0.227 and subtracting 1, which = 0.2548.

OLS, ordinary least squares regression analysis.

$$\begin{aligned}\text{Dentist Visits} = {} & (\beta_1)\text{ DDS hours} + (\beta_2)\text{ \% Medicaid} + \\ & (\beta_3)\text{ \# of Operatories} + (\beta_4)\text{ \# of Assistants} + \\ & (\beta_5)\text{ \# of Hygienists} + \\ & (\beta_6)\text{ Years of Experience} + \text{Error}\end{aligned}$$

Figure 2 illustrates the analytical model in our path diagram for dentist owners. Figure 3 displays the path analysis diagram for dentist nonowners. The Beta values are standardized *z*-scores derived by subtracting the population mean for variable from the raw score and then dividing by the SD, allowing comparison of the effects of different variables on the same scale. A larger value indicates a stronger influence.

As expected, results of the owner and nonowner analyses differ. For owners, the numbers of assistants and hygienists are somewhat more strongly associated with number of patient visits to the dentist than dentist chairside hours worked, but the latter is significant, too. For nonowners, number of dentist chairside hours worked and number of assistants available are the strongest predictors, while number of available operatories has less impact and the effect of number of hygienists is not significant. Dentist experience is not significantly related to productivity in either sample. The proportion of patients with Medicaid insurance seen in the practice is significantly related to productivity; this is true within the owner and the nonowner samples; the magnitude of effect is approximately double in the nonowner sample. Among owner dentists, number of operatories is strongly associated with available number of assistants and, to a lesser extent, hygienists; this is not true among nonowners.

Discussion

This is the first scholarly work in several decades to examine dentist productivity. Consistent with previous work, labor (dentist chairside hours worked per week and number of assistants and hygienists) and capital (number of operatories available for restorative dentistry) were strong predictors of dentist output (dentist visits per week). The OLS regression elasticities (Table 1) imply that for a 10 percent increase in dentist time worked per week, there is an increase of almost 9 percent in the number of dental visits that occur in a week. A 10 percent increase in the number of operatories leads to a much smaller, but significant increase in dentist visits: 1.2 percent. A 10 percent increase in number of assistants and hygienists is associated with an increase in visits of less than 1.0 and 0.4 percent, respectively.

Other things equal, owners are approximately 25 percent more productive than nonowners. In the OLS regression model, a 10 percent increase in years of experience leads to a significant productivity rise of 0.5 percent. The latter finding contrasts with the magnitude of the coefficients for associated with the dentist experience observed in the path models –

most likely due to the differences in functional form between the path and OLS specifications.

The study is the first in recent scholarly literature to analyze productivity for owners and nonowners separately. Over 30 percent of our survey respondents were nonowner dentists. Although the models are similar overall, it is striking that the number of assistants plays a much stronger role in the productivity of nonowners than of owners. The direct effect of the number of operatories on the number of hygienists and assistants is much stronger and statistically significant only for owner dentists, and the impact of number of operatories on dentist chairside hours is negligible for owner and nonowner dentists.

Oregon general dentist survey respondents appear typical of general dentists in the United States. 2008-2009 Bureau of Labor Statistics data reveal that 80 percent of all dentists are solo practitioners with small support staffs (15). Most full-time dentists work 35 to 40 hours per week; dentists in new practices work more hours than more-experienced dentists. The sample used for the analysis reported here is similar also to the general dentist population responding to the American Dental Association's 2005 Survey of Dental Practice (16,17). In the latter sample, for example, average independent dentist hours worked per week was 35.7 and patient visits per week 57.2 – quite close to our Oregon sample – auxiliaries per dentist in the two samples were comparable, as were payer mix and patient age distribution.

In the current study, not all dentists completed all survey questions related to productivity. However, comparing those who did to the larger group who completed other aspects of the survey, the mean responses for the two groups (production analysis subgroup versus total sample) were very similar: percent male (82.5 versus 82.7), dentist years experience (18.9 versus 19.1), percent sole proprietors (44.6 versus 45.3), percent shareholders or partners (26.4 versus 25.7), percent production-based compensation (50.0 versus 46.8), payer mix (percent Medicaid: 8.1 versus 10.5; percent private insurance: 60.8 versus 61.8), and patient age (percent 45 years and above: 22.6 versus 22.6). Of course, these data represent characteristics of dentists in a single state. Although circumstances in other states may differ, our within-state analysis holds constant the regulatory, political, and legal context of dental practice otherwise might confound results of multistate analyses.

Our findings suggest that the dentist's own time is the key determinant of dentist productivity. The effect of assistants and hygienists is less overall and is more strongly associated with the output of nonowners. This likely reflects differences between owners and nonowners in utilization of dental auxiliaries. The survey measures in this study reflect availability of auxiliaries, but not their specific use by the individual dentists. If more fine-grained measures of personnel skill level, auxiliary utilization, and dental technology were used in lieu of our general measures of labor and number of operatories, it is possible that findings regarding input effects on dentist output might be different. Also, this study focused on individual dentist visits, not total practice visits, so the estimated effects of dental auxiliaries capture only the effects of the availability of assistants and hygienists on the dentist's own output.

Both path analyses and OLS regression models showed that dentists who cared for a higher proportion of Medicaid patients produced more visits. This difference was more pronounced for nonowners than for owners. No doubt, this reflects the way owner dentists assign patients within the practice and the capacity of practices with associate and employee dentists to see Medicaid patients at all. For nonowner dentists, the proportion of Medicaid patients in their practice was, on average, 20 percent. For owners, it was less than 4 percent.

Conclusion

This study has addressed a purposefully narrow question: the effect of labor and capital inputs on dentist visits. Our estimates of the incremental effect of the dentist's own chairside time and of the available number of assistants, hygienists, and operatories are generally within the range of earlier studies of dental productivity, conducted 30 or more years ago. The analyses reveal interesting differences between owner and nonowner dentists in productivity: number of auxiliaries significantly increases output only for nonowners, and owner dentists produce substantially more visits than nonowners, other things equal. The estimates further highlight the positive effect of dentist experience on productivity.

This research tackled a focused technical question; in that sense, it has contributed new information – including comparisons to an earlier evidence base. For dental productivity studies to move to the next level of influence on professional policy and practice, we recommend that:

- Output be measured in terms of contribution to oral health, not visits;
- Use of dental auxiliaries and their skill level be measured, not just their availability;
- Utilization of dental technology and space utilization be measured more precisely; and
- Patient mix (demography and oral health) be included in production models.

These refinements of productivity measurement would require more intensive, real-time data collection, but would yield significant payoff in improved understanding of dental practice and its contribution to oral health.

Acknowledgments

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