The production of dental care and the measurement of output[*][†]

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1 Introduction

Faced with increasing demand for services many countries have considered ways to improve productivity and encourage substitution of expensive medical specialist personnel with less expensive health care workers (Sibbald et al., 2004; Duckett, 2006; Gallagher et al., 2010; Health Workforce Australia, 2011). In dental services a small number of empirical studies to date in Europe and the USA have suggested that there are economies of scale in dental production and a positive marginal product from auxiliary personnel (Sintonen and Linnosmaa, 2000). However the use of cross-sectional data to investigate economies of scale and the contribution of auxiliaries, has limited inferences about the gains that can be made from increasing hours worked by dentists and substitution by auxiliaries. Furthermore, the output of dental practices can be measured in different ways and little is known about the sensitivity of findings to the choice of output measure. The current paper uses panel data to estimate a production function for dental services and compares results for different measures of output, thereby making more precise and robust predictions on proposed policies to expand subsidised services.

The particular policy context of the empirical work in this paper is the need to expand adult dental services in response to a perceived gap in the provision of services relative to need in Australia, and the proposed policy response of an expansion of public finance for dental services (Health and Commission, 2009). A number of recent government

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reports have suggested an expansion in public funding, at least for selected services for disadvantaged groups in the population, either through a subsidy to private dentists who currently provide 80% of services, or an expansion of public service provision that currently provides services mainly to lower income disadvantaged adults. A number of commentators have suggested that any increase in public insurance or funding for public delivery of services would most likely be ineffective in reducing the need for services at least in the short to medium term if there is insufficient supply capacity. The argument is that capacity constraints, particularly on the number of dentists and their working hours, limit the ability to respond to increasing demand[1]. In this paper we use production functions to identify the effect of dental production factors on different measures of output and to assess ways in which production could be increased to meet the expected changes in demand in the Australian private dental sector. These include increases in scale or changes to the mix of inputs as far as technically feasible with the current production technology.

We find that expanding services would not be constrained by decreasing returns to scale. However there is limited scope for substitution of inputs; especially substitution of dentists' own labour for dental hygienists or therapists. These results are robust to the measures of output used - a significant finding given the range of measures used in this area. In policy terms these are important findings in terms of increasing coverage for dental services in Australia as well as in many other developed countries that face similar calls for increased subsidies and similar supply side constraints.

2 Measuring dental practice output

Measuring the output of health care providers is a challenging task and constitutes a central problem in productivity studies (Atkinson, 2005; Castelli et al., 2005). Health care is consumed by patients presenting with different medical conditions and underlying severity. Certain patients will require more attention and resources than others because they suffer from more severe conditions or differ with respect to other relevant factors that determine treatment decisions, such as age, gender, or comorbidities. Health care providers must adapt treatment processes to the patients' individual needs and provide, at the margin, different services to each patient (Bradford et al., 2001). As a consequence, overall output consists of a mixture of distinct output categories.

The analysis of the dentists' production process requires a means of integrating these different outputs into a common metric. The question then arises which weights should be used. Ideally, one would like to measure the effect of dental care on each patient's outcome, i.e. the change in oral health trajectory induced, or averted, by treatment. The

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[1] A direct assessment of this argument would provide evidence on how the market supply and price would together respond to a subsidy for each service type. The main issue in any empirical strategy to estimate the impact of a subsidy or increase in public service provision on the market is that even assuming the exogeneity of price in this imperfectly competitive market there are no data on prices facing individual dentists for services that might be covered either in cross section or over time to allow us to estimate the parameters of the demand and supply functions.

rationale is that patients rarely seek dental treatment because of the care process itself. Instead, they consult a dentist to restore their health or prevent imminent deteriorations. Health improvement describes *"the 'value-added' to health as a result of the contact with the health system"* (Jacobs et al., 2006, p.23) and constitutes an ideal measure of output that combines aspects of quality and quantity of care provided.

Unfortunately, comprehensive measures of oral health are not routinely collected. Indeed, given the dominance of preventive care and the importance of personal hygiene for preventing tooth decay, it remains far from clear how the impact of dental care provision on oral health can be accurately assessed. Hence, the current literature on dental production (and cost) functions focuses on other weighting systems as summarised in Table 1. Loosely speaking, these weights are based on activity, time or monetary value (Mitry et al., 1976; Sintonen and Linnosmaa, 2000), each of which is based on different assumptions about outputs.

Table 1 about here

Activity-based measures are by far the most predominant means of describing output. 7 out of 10 surveyed studies use measures such as 'number of patients treated' or 'number of patient contacts' to summarise the activity of dental practitioners. The implicit weights used are equal across output categories. Accordingly, check-up visits are treated as equivalent to complicated tooth extractions.

The advantage of the activity-based approach lies in its simplicity and the quality of data available. Activity numbers can be easily retrieved from routine documentation such as medical records, claim files or practice schedules, or obtained as part of a survey. In the context of an expansion of insurance coverage there may be some relevance in evaluating the change in the number of patients seen since this may be a policy relevant parameter. However, activity is an inherently blunt measure of output and assumes homogeneity across dental practices with respect to patient need (i.e. oral health) as well as mix and quality of procedures (Sintonen, 1986).

Time-based measures are derived from the idea that more severely ill patients will, in general, require more attention than their healthy counterparts and therefore receive more time-consuming procedures. By specifying the time requirements of each procedure and using these as weights, one can generate a measure of output which takes account of the particular mix of procedures and, by extension, the underlying case-mix of the production unit. Furthermore, time-based measures help to control for some of the variability in technical efficiency inherent to the production of health care (Hollingsworth, 2008).Bentley et al. (1984) uses weights derived from an expert panel to study the costs of dental care delivery in school children, whereas Mitry et al. (1976) use the average observed time per procedure as weights in a simulation model of dental productivity. However, while the time-based approach improves over a simplistic activity-based approach, it shares several limitations: First, one cannot take account of variation in quality and might falsely deem time spent in excess of the benchmark as inefficient when it really reflects better care (Sintonen, 1986). Second, the approach does not take account of intermediate, non-labour inputs that are used in the production process. Some procedures might not primarily require time (i.e. labour input) but costly prosthesis or implants. Equating a simple consultancy with an implantation will consequently result in overestimated outputs for labour-intense practices.

Value-based weights provide alternative means of integrating heterogeneous output and are a natural choice in economic studies. Here, the value of a procedure or a treatment continuum is taken to be the monetary valuation as represented by its market price or the less commonly known patients' willingness to pay. The advantage of price weights is that they capture some of the variation in quality as valued by the patient. Further, assuming perfect information and allocative efficient markets, market prices are equivalent to the consumers' willingness-to-pay for dental care and can be used to study the welfare effects of changes in production processes. The downside is that prices may be heavily distorted by market power if this assumption does not hold and that perceived and real quality of care may be substantially different. In addition price weights may be little different from time weights if the price is closely related to the agreed work effort among dentists of a particular procedure.

3 Estimating a dental production function

The unit of analysis in this study is the office-based, self-employed dentist who acts as owner-manager of the dental practice. Following the literature on physician production functions (e.g. Reinhardt, 1972), we assume that dentists maximise utility and trade off revenue from their practice activities with own leisure time. They make decisions about capital and labour (own or auxiliary) inputs to pursue their objective but are constrained by the available production technology, medical and legal standards, the characteristics and requirements of the patient population as well as own abilities and tastes. Given that some of these constraining factors are inherently unobservable, our approach builds on panel data techniques to account for time-invariant heterogeneity and obtain unbiased estimation of the coefficients of interest (Mundlak, 1961).

Output is assumed to be determined by the quantities of homogeneous input factors utilised as well as by characteristics of the dentist and the dental practice, so that

$$Y = f(C, L, D, \Gamma) \tag{1}$$

where Y represents the relevant measure of output and C and L denote vectors of capital and labour inputs. Some characteristics of the dentist and his practice are observed by the researcher, here denoted by the vector D, whereas others remain unobserved, Γ. Examples include the mix of patients seen (often observed) and the tastes and abilities of the dentist (usually unobserved).

In order to study the relative importance of each production factor in determining output, one must specify the function f. In this paper, we choose an augmented Cobb-Douglas production function with

$$y_{it} = \alpha_0 + D_{it}^{'}\beta + l_{it}^{'}\delta + c_{it}^{'}\theta + \phi_t + \gamma_i + \epsilon_{it} \tag{2}$$

where individual dentists are denoted as $i = 1, \ldots, I$ at time $t = 1, \ldots, T$. Observed dentist characteristics, D, enter on the linear scale, whereas output and other inputs are expressed as logarithms. Unobserved heterogeneity is represented by γ_i, the dentist-specific derivation from the common intercept α_0. We allow for a time trend ϕ_t that is common to all dentists. The random error term is denoted as ϵ_{it} and assumed to be serially uncorrelated and distributed as $\epsilon_{it} \sim \mathcal{N}\left(0, \sigma_\epsilon^2\right)$.

Two issues surrounding the estimation of this dental production function warrant further consideration: First, inputs can be classified as either being 'essential' or 'non-essential' to the production of dental services (Scheffler and Kushman, 1977). The dentists own labour and certain capital inputs (e.g. surgery rooms, equipment) are unarguably most important and essential production factors in a dental practice. Without these inputs, overall output is bound to be zero; independently of the way output is measured. In contrast, auxiliary labour provided by dental assistants, hygienists or therapists is not (strictly) essential to the production process and while recent years have seen a growing trend in delegation of tasks to these specially trained assistants, it is not uncommon to observe dentists that do not employ one or another type of auxiliaries.

Non-essential inputs pose problems for the estimation of the specified Cobb-Douglas production functions because the logarithm of zero is not defined. Several workarounds have been proposed in the literature, including Box-Cox transformation (Caves et al., 1980), entering non-essential inputs in linear form (Reinhardt, 1972), and substituting arbitrarily small, positive numbers. In this paper, we follow the approach proposed by Battese (1997) to obtain unbiased estimates of slope parameters. For each non-essential input $k = 1, \ldots, K$ in vector c and l, we create an indicator variable E_{kit} that takes the value of 1 if the relevant input is not used by dentist i at time t and 0 otherwise. We then replace the value for the relevant input with 0 if $E_{kit} = 1$, or retain its original value if $E_{kit} = 0$. This approach separates intercepts and slope parameters for members of the distinct groups defined by $E_{kit} \in [0, 1]$ as shown in Figure 1. We interpret the coefficient on the dummy variable as differences in production technology.

Figure 1 about here

The second issue refers to the way in which the unobserved, time-invariant heterogeneity parameters γ_i are modelled. The econometric literature emphasises three types of models that can be applied in the context of unobserved heterogeneity (Wooldridge, 2002). Fixed effect (FE) models are common in panel data econometrics and treat γ_i as individual-specific parameters that are to be estimated from the data. Random effects (RE) models make the additional assumptions that all γ_i are identically distributed random variables and are uncorrelated with the explanatory variables. Pooled models assume that unobserved heterogeneity is does not exist or is ignorable, so that $\gamma_i = 0$ for all i.

Fixed effect estimators provide consistent estimates of the regression parameters independently of the distribution of the unobserved heterogeneity term or its correlation with other explanatory variables. The price for this consistency is that the FE estimator only utilise within-cluster information. This may be a potentially serious limitation for the estimation of the described production functions because major input factors, such as working hours or number of surgery rooms, are unlikely to vary substantially over time. In contrast, the RE estimator exploits both within- and between-cluster variation and are thus generally more efficient, especially when there is only limited within-unit variation. However, the RE estimator is biased when the assumed exogeneity of explanatory variables conditional on the unobserved effect does not hold. In order to test the sensitivity of our results to the choice of modelling approach, we estimate fixed and random effect models as well as pooled models with cluster-robust standard errors. We use the Hausman test as a screening device to detect potentially serious bias[2]. All time-trends are treated as fixed effects.

4 Data

Our study uses data from the Longitudinal Study of Dentists' Practice Activity (LSDPA) survey for the period of 1993 to 2003. The survey is conducted in 5-year intervals and covers a representative sample of all dentists working in each state/territory of Australian. At each wave, the sample is supplemented with dentists that are new to the dental registry to account for attrition and retain the cross-sectional characteristics. We extract data on 584 dentists[3]. However, not all dentists report in each wave of the LSDPA and the resulting panel of 896 observations is unbalanced.

The LSDPA contains information on production factor inputs as well as on characteristics of the dentist and the general set-up of the practice. The data are reported at the level of the dentist where shared resources in group practices are broken down according to their individual usage[4]. We extract data on the number of hours per week worked by the dentist (`hours`), dental hygienists (`dhygien`), dental therapists (`dtherap`) and other auxiliaries (`assist`) as well as the number of operation theatres utilised (`chairs`). The latter is intended to capture capital investment and is hypothesised to affect output positively by allowing for simultaneous preparation and treatment of patients. Furthermore, to characterise the dentist and the practice set-up, we record the dentist's age and gender, whether the dentist reports working part-time or in a multi-owner group practice. For 'non-essential' inputs, missing responses were interpreted as zero.

We link this information to several other data sources. First, we obtain information on patient characteristics and procedure codes for a random subsample of dentists that participate in the LSDPA. The data are collected via a patient log where dentists

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[2] As pointed out by e.g. Clark and Linzer (2012), the Hausman test may not be an appropriate tool to decide between fixed and random effects estimators because it lacks power and puts an infinite weight on unbiasedness compared to efficiency. Instead, the test should only be used as an additional decision aid.

[3] We only use data from non-employed dentists with complete responses for all 'essential' inputs or output fields. Furthermore, we have delete several influential observations identified in preliminary analysis (initial sample: 612 dentists, 912 observations). The exclusion decision is based on the DFITS statistic and we decided *a priori* to exclude 10 observations for each of the output measures. There was some overlap across models.

[4] The dataset allows for such adjustment because the survey specifically asks for the number of surgeries or labour input of auxiliary staff associated or working with the surveyed dentist.

document number and type of procedures carried out, oral health status of the patient (here: number of remaining teeth) as well as other patient characteristics (e.g. age, gender, insurance status and reason for encounter) for all patient contacts that occur on a randomly selected day. We use this information to construct measures of average medical need at dentist level and account for differences in the patient population across dentists (Sintonen, 1986; Grytten and Rongen, 2000).

Second, we obtain average fee data for a comprehensive set of procedures for the year 2008 and link these to the procedure codes reported in the patient log file. Fee data are provided by two sources: The Australian Dentist Association (ADA) collects average fee data for 80 common dental procedures through an annual survey of their members and makes these publically available. Because these data cover only about 77% of procedure codes documented in the patient log file, we supplement them with fee data imputed by the Australian Research Centre for Population Oral Health (ARCPOH). In some cases, fees cannot be imputed because they are not performed sufficiently frequent to allow for meaningful imputation. Thus, the final fee schedule available to us remains incomplete, albeit significantly improved (coverage: 94% of the reported procedure codes).

Third, we approximate the deprivation profile of the practice neighbourhood through the Socio-economic Indexes for Areas (SEIFA) developed by the Australian Bureau of Statistics. We use scores from the 2006 census (Australian Bureau of Statistics, 2008).

Following the previous discussion, we construct three measures of output:

1. *Activity* - the number of patients treated by the dentist
2. *Time* - the number of procedures multiplied by their average, observed time requirement (see Mitry et al. (1976))
3. *Value* - the number of procedures multiplied by their respective average fee

All outputs are calculated on a weekly basis. We multiply the observed output per day (from patient log files) by the reported number of working days per week (LSDPA). This adjustment is necessary to account for dentists working part-time, i.e. less than five working days per week.

5 Results

5.1 Descriptive statistics

Table 2 presents descriptive statistics. There is considerable variation in number of patients treated by each dentist in the sample (mean=63, sd=39). This is reflected in the variation in hours worked (mean=35.7, sd=12.1). We also observe substantial variation in the time- and value-weighted output (mean=1,930, sd=1,204 and mean=17,682, sd=13,384).

Table 2 about here

The different output measures show substantial correlation as presented in Table 3 and Figure 2. The highest correlation is observed between time- and value-weighted measures of output (corr=0.81), indicating that fees charged by dentists are closely related to the time-requirements of the procedures. The lowest, albeit still substantial, correlation is observed for the two output measures based on raw and value-weighted activity (corr=0.50). This suggests that there is some (limited) heterogeneity in the revenue generated by a patient contact.

Table 3 and Figure 2 about here

The vast majority of dentists had at least one assistant. In contrast, the use of either dental therapists or dental hygienists was less common with only 4% and 9% of dentists using these labour inputs. In terms of capital inputs most dentists worked with 2 surgery rooms (median=2, mean=2.47) but there were some who report utilising multiple rooms within their practice. This leads to a skewed distribution of the number of surgery rooms, with a mean of 2.47 and a maximum of up to 7 chairs.

The dentists in the sample had an average age of 42 (similar to their patients) and practised mostly full time (73%) and in group practices (58%). They were located in areas evenly distributed across the range of socio-economic advantage. Not surprisingly in a health system with complementary insurance the share of patients with private dental insurance (55%) was higher than the percentage of the general Australian population with general private health insurance, although over two thirds of consultations were not emergencies. Only 44% of patients received routine checkups.

5.2 Regression results

Tables 4-6 show the estimated regression coefficients and their standard errors for each of the output measures. Output, measured as time-, value-, or unweighted activity, is statistically significantly associated with the number of hours worked by the dentist, the number of chairs and the number of assistants. The results suggest that there are constant returns to scale from capital and the two labour inputs with an elasticity of output close to one. The size of the coefficients on dentist hours is very similar across specifications. A 1% increase in hours worked by the dentist leads to an about 0.8% increase in output in terms of the raw number of patients seen per week, the time weighted number of procedures, or the value weighted number of procedures. These results are consistent with optimising behaviour among dentists. In other words, if dentists are able to optimise the use of their time, they would only work an extra hour if the change in the value of output to them in terms of % revenue is equal to the cost to them in terms of time and other factor costs. Similarly the value of output from having an extra chair or surgery is positive across all models and output specifications, albeit not always statistically significant. The results are consistent with the ability of the dentist to allocate their time and capital so that an extra hour with a patient has a value that does not exceed the value to the dentist of that extra time.

The contribution of auxiliary labour inputs to output is positive and statistically significant for assistants, but not for dental hygienists or therapists. A 1% increase in assistant labour inputs is estimated to lead to about 0.1% increase in output (RE models), independent of the way in which output is measured. Also, dentists that do not employ assistants utilise a different production technology than those that rely on assistant labour. This is reflected in the larger intercept (*E_assist + constant*), but overall lower level of output. Dentists that employ dental hygienists or therapists treat (statistically insignificantly) fewer patients but generate (statistically insignificantly) larger amounts of valued output.

Some characteristics of the practice patient population also influence output levels. Dentists that treat, on average, more elderly or healthier patients (i.e. more remaining teeth) see fewer patients per week. More patients are seen and more time-weighted services are produced in practices that perform more check-ups. However, our results also suggest that dentists seeing more emergency patients produce more activity-based and time-weighted output. While it seems intuitively correct that check-ups are less time consuming, thus allowing the dentist to see more patients, it is somewhat counterintuitive that practices with more emergency patients can also treat more patients overall.

With respect to the choice of estimator, we find that FE, RE and pooled models produce qualitatively similar results. However, while the coefficient estimates obtained from the RE and pooled models are comparable in size, direction and significance, the coefficients obtained from the FE model are often substantially different in terms of magnitude and statistical significance. We believe that this is a reflection of the limited within-unit variability and the relatively short length of our panel (three waves). The results of the Hausman test suggest that the bias in the RE estimates is substantial for the activity-based and time-weighted output models (p=0.001; p=0.043) but does not reject the choice of the RE estimator for the value model (p=0.131).

6 Discussion and conclusions

This paper presents a first assessment of the production of dental services in Australia. We utilise data obtained as part of the Longitudinal Study of Dentists' Practice Activity, which covers a representative sample of Australia dentists and provides information on their individual productivity and their choice of factor inputs. The estimated results are consistent with the observation that expansion of the scale of dental services in Australia would not be constrained by decreasing returns. An expansion of private practice on average could produce a larger number of services by incentivising dentists to provide more labour. On the other hand there seem to be limited scope for substitution of inputs in the production process given their limited contribution to activity.

Production studies in dental services to date have used a limited range of output measures. A significant finding in this study is that the results on productivity are robust to the measure of output used; whether it is patient volume, time spent on patients, or the price-weighted value of activity. The estimated coefficients on capital and labour inputs are broadly the same across output specifications, show the expected sign, and are similar with respect to statistical significance. This is particularly noticeable for the dentist's own labour input where the estimated elasticity of output with respect to hours of dental work is in the range of 0.79 to 0.87, irrespective of the output measure or the choice of estimator. The robustness of the result suggests that the mix of patients and the allocation of time by dentists to procedures and patient types are similar across dentists and that the price of procedures is proportional to their time requirement. One reason for this may be that dentists work in similar ways with fixed appointment time slots arranging patients and procedures through the day to create a similar pattern of work at given prices. In short, common elasticity across output measures suggests a fixed pattern of working with a stable mix of patients. The similarity of the results across the choice of panel data estimators suggests that there is a degree of homogeneity across dentists in their work practices and not much variation in unobserved tastes or abilities.

In contrast to dental production inputs, patient clinical characteristics do have different effects depending on the measure of output. Emergency patients are more time consuming to treat compared to regular appointments but they tend to receive less expensive treatment so that the value of a visit is not different. A check-up is more common than other appointments but adds little to the dentist's revenue. This may be because check-ups are produced at higher time costs than other types of appointment. The age of the patient affects is a statistically significant but small determinant of output. Dentists do not seem to see more patients with insurance but there is some evidence that those that they do see have procedures that take more time, and are of higher value to the dentist.

In light of these findings, we would like to encourage a general discussion about the productivity of dentists as well as a more focussed discussion about some specific points. These are:

1. Are the output measures we use useful/indicative of real activity?
2. Are our methods useful in this context? In particular, how should the difference between fixed and random effects estimates be interpreted?
3. Are our results on scale and labour input realistic and generalisable?
4. Are the similarities in output elasticities across measures of output and specifications credible and how should this be interpreted?
5. Could dentists really change their practice patterns to accommodate therapists more?
6. Should we establish other criteria to drop unrealistic observations / outliers? For example, the maximum value of weekly output observed in our sample is about \$92k or £57k. Given the activity rates observed for this dentist, this would be equivalent to about \$2,000 revenue per patient.
7. What forum should we look to publish this in?

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Authors	Country	N	Measure of output			Cost function	Functional form
			Activity	Time	Value		
Beazoglou et al. (2009)	US	154	X		X	no	CD
Conrad et al. (2010)	US	829	X			no	CD
DeVany et al. (1982)	US	447	X			no	TC
Gray (1982)	UK	266			X	no	TC
Grytten and Dalen (1997)	Norway	1754	X			yes	TL
Grytten and Rongen (2000)	Norway	14 / 84[a]	X			no	CD
Mitry et al. (1976)	US	128[b]		X		no	TC
Scheffler and Kushman (1977)	US	29000	X			no	CD, TL
Shuman et al. (1992)	US	31		X	X	no	L
Sintonen (1986)	Finland	98	X		X	no	TC

CD = Cobb-Douglas, TL = Translog, TC = Transcendental, L = Linear

[a] Pooled over time.

[b] Number of computer simulations with different combinations of input factors and case-mix.

We only include published studies (in English) that estimate a cost or production function. This excludes some earlier work, most notably the unpublished PhD theses by Maurizi (1967); Boulier (1974) and Crakes (1984).

Table 1: Overview of published studies on dental cost/production functions

Variable	Description	Mean	Std. Dev.	Min	Max
Measures of output					
volume	Number of patients treated per week	62.39	39.2	4	247.5
time_total	Time-weighted volume of procedures per week	1930.34	1203.5	131.2	8289.6
value	Value of procedures per week	17682.19	13384.6	676.5	91573.3
Production factors					
hours	Number of dentist's hours per week	35.74	12.1	2	77
chairs	Number of surgery rooms	2.47	1.2	1	7
assist	Number of assistants' hours per week	69.14	49.0	0	294
dhygien	Number of dental hygienists' hours per week	2.04	7.6	0	48
dtherap	Number of dental therapists' hours per week	0.85	5.6	0	96
E_assist	=1, if no assistant employed	0.09	0.3	0	1
E_dhygien	=1, if no dental hygienist employed	0.91	0.3	0	1
E_dtherap	=1, if no dental therapist employed	0.96	0.2	0	1
Characteristics of the dentist					
age	Age of dentist	42.16	10.6	23	81
seifa_cat1	=1, if practice is located in high socio-economic area (upper third)	0.33	0.5	0	1
seifa_cat2	=1, if practice is located in medium socio-economic area (middle third)	0.33	0.5	0	1
seifa_cat3	=1, if practice is located in low socio-economic area (lower third)	0.33	0.5	0	1
parttime	=1, if dentist works part-time	0.27	0.4	0	1
group	=1, if dentist works in group practice	0.58	0.5	0	1
female	=1, if dentist is female	0.43	0.5	0	1
Characteristics of the patient population (averaged at practice level)					
pat_age	Average age of practice pop	41.46	8.2	9	73
pat_female	Share of female patients	0.55	0.2	0	1
pat_teeth	Average number of remaining teeth in practice pop	24.60	2.7	0	31
pat_insurance	Share of patients covered by private insurance	0.55	0.2	0	1
pat_emergency	Share of patients treated as emergencies	0.28	0.2	0	1
pat_checkup	Share of patients receiving routine check-ups	0.44	0.2	0	1

Table 2: Descriptive statistics

	Activity	Time-weighted	Value-weighted
Activity	1.00		
Time-weighted	0.61	1.00	
Value-weighted	0.50	0.81	1.00

Table 3: Correlation between different output measures

	Pooled		FE		RE	
Variable	Beta	SE	Beta	SE	Beta	SE
log_hours	0.791	0.04 ***	0.869	0.06 ***	0.820	0.04 ***
log_chairs	0.092	0.03 **	0.140	0.06 *	0.104	0.03 **
log_assist	0.121	0.02 ***	0.032	0.03	0.108	0.02 ***
log_dhygien	-0.009	0.05	-0.062	0.10	-0.005	0.05
log_dtherap	-0.085	0.05	-0.019	0.14	-0.104	0.08
E_assist	0.406	0.10 ***	0.226	0.14	0.392	0.10 ***
E_dhygien	0.027	0.16	-0.306	0.30	-0.006	0.14
E_dtherap	-0.193	0.16	-0.025	0.43	-0.244	0.24
yr1998	-0.588	0.03 ***	-0.537	0.08 ***	-0.592	0.03 ***
yr2003	-0.580	0.04 ***	-0.445	0.14 **	-0.580	0.03 ***
age	0.029	0.01 **	0.021	0.02	0.030	0.01 ***
age2	0.000	0.00 **	0.000	0.00	0.000	0.00 ***
seifa_cat1	0.018	0.03	-0.106	0.12	0.016	0.03
seifa_cat3	-0.109	0.03 **	0.095	0.11	-0.098	0.03 **
parttime	-0.138	0.04 **	-0.033	0.06	-0.097	0.04 *
group	0.017	0.03	-0.014	0.05	0.011	0.03
female	-0.040	0.03	.	.	-0.057	0.03
pat_age	-0.010	0.00 ***	-0.012	0.00 ***	-0.011	0.00 ***
pat_female	0.021	0.09	0.060	0.11	0.033	0.07
pat_teeth	-0.019	0.01 ***	-0.021	0.01 **	-0.019	0.00 ***
pat_insurance	-0.043	0.06	-0.031	0.09	-0.021	0.06
pat_emergency	0.133	0.08	0.349	0.11 **	0.187	0.07 **
pat_checkup	0.167	0.08 *	0.131	0.10	0.159	0.06 **
constant	1.392	0.35 ***	1.949	0.80 *	1.364	0.37 ***
Test statistics [a]						
Wald test of $\gamma_i = 0$	2.14/0.000					
Hausman test	48.06/0.001					

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] statistic/p-value

Table 4: Regression result - Activity

	Pooled		FE		RE	
Variable	Beta	SE	Beta	SE	Beta	SE
log_hours	0.820	0.05 ***	0.862	0.07 ***	0.828	0.04 ***
log_chairs	0.078	0.03 *	0.138	0.07	0.093	0.03 **
log_assist	0.124	0.02 ***	0.053	0.04	0.115	0.02 ***
log_dhygien	0.008	0.04	-0.143	0.11	0.001	0.05
log_dtherap	-0.029	0.06	-0.075	0.16	-0.045	0.09
E_assist	0.353	0.11 ***	0.250	0.17	0.339	0.10 ***
E_dhygien	0.121	0.12	-0.372	0.35	0.094	0.15
E_dtherap	-0.049	0.20	-0.104	0.49	-0.090	0.26
yr1998	-0.551	0.03 ***	-0.488	0.09 ***	-0.556	0.03 ***
yr2003	-0.510	0.04 ***	-0.332	0.16 *	-0.517	0.03 ***
age	0.028	0.01 ***	0.017	0.02	0.028	0.01 ***
age2	0.000	0.00 ***	0.000	0.00	0.000	0.00 ***
seifa_cat1	-0.016	0.03	-0.071	0.14	-0.012	0.03
seifa_cat3	-0.018	0.04	0.114	0.13	-0.011	0.04
parttime	-0.149	0.04 ***	-0.052	0.07	-0.132	0.04 **
group	0.019	0.03	-0.047	0.06	0.011	0.03
female	-0.023	0.03	.	.	-0.033	0.03
pat_age	-0.004	0.00	-0.007	0.00 *	-0.004	0.00 *
pat_female	0.013	0.09	0.042	0.12	0.030	0.08
pat_teeth	-0.010	0.01	-0.014	0.01	-0.010	0.01
pat_insurance	0.110	0.07	0.047	0.11	0.120	0.06 *
pat_emergency	0.260	0.09 **	0.398	0.13 **	0.283	0.08 ***
pat_checkup	0.186	0.08 *	0.027	0.12	0.157	0.06 *
constant	3.926	0.36 ***	5.382	0.92 ***	3.983	0.39 ***
Test statistics [a]						
Wald test of $\gamma_i = 0$	1.68/0.000					
Hausman test	33.32/0.043					

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

[a] statistic/p-value

Table 5: Regression result - Time-weighted activity

	Pooled		FE		RE	
Variable	Beta	SE	Beta	SE	Beta	SE
log_hours	0.843	0.06 ***	0.877	0.09 ***	0.848	0.06 ***
log_chairs	0.085	0.05	0.220	0.10 *	0.106	0.05 *
log_assist	0.108	0.03 ***	0.069	0.05	0.105	0.03 ***
log_dhygien	0.088	0.05	-0.082	0.15	0.071	0.07
log_dtherap	0.170	0.10	0.178	0.21	0.166	0.11
E_assist	0.330	0.14 *	0.395	0.22	0.346	0.14 *
E_dhygien	0.287	0.13 *	-0.159	0.46	0.252	0.20
E_dtherap	0.316	0.32	0.359	0.65	0.330	0.35
yr1998	-0.602	0.05 ***	-0.501	0.11 ***	-0.610	0.04 ***
yr2003	-0.574	0.05 ***	-0.277	0.21	-0.572	0.04 ***
age	0.023	0.01 *	-0.006	0.03	0.024	0.01 *
age2	0.000	0.00 *	0.000	0.00	0.000	0.00 *
seifa_cat1	-0.037	0.05	0.210	0.19	-0.020	0.05
seifa_cat3	-0.025	0.05	0.356	0.16 *	-0.010	0.05
parttime	-0.207	0.06 ***	-0.113	0.10	-0.194	0.06 ***
group	-0.016	0.05	-0.101	0.08	-0.016	0.04
female	-0.049	0.04	.	.	-0.069	0.05
pat_age	0.002	0.00	0.001	0.00	0.002	0.00
pat_female	-0.082	0.12	-0.033	0.16	-0.060	0.11
pat_teeth	-0.031	0.01 ***	-0.040	0.01 ***	-0.032	0.01 ***
pat_insurance	0.169	0.09	0.098	0.14	0.159	0.08 *
pat_emergency	-0.022	0.11	0.047	0.17	-0.033	0.10
pat_checkup	-0.012	0.10	-0.338	0.16 *	-0.062	0.09
constant	6.201	0.50 ***	7.760	1.22 ***	6.192	0.52 ***
Test statistics ^{a}						
Wald test of $\gamma_i = 0$	1.76/0.000					
Hausman test	28.32/0.131					

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$
^{a}statistic/p-value

Table 6: Regression result - Value-weighted activity

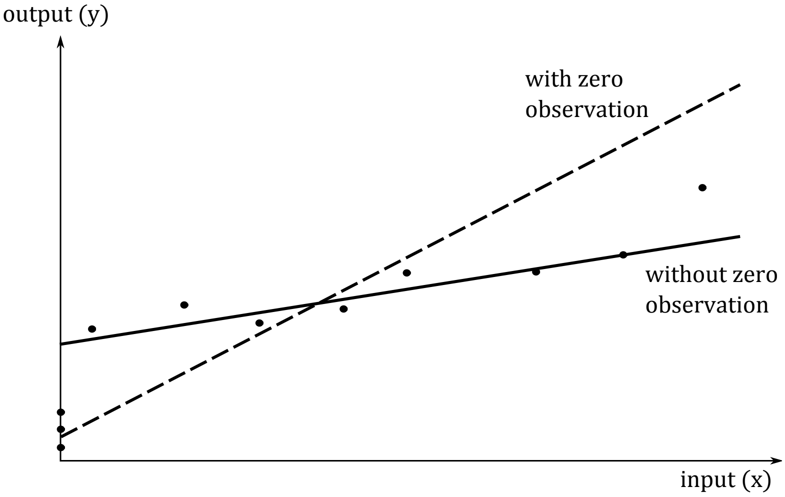

Figure 1: The estimation of a production function with zero inputs for some observations (Battese, 1997)

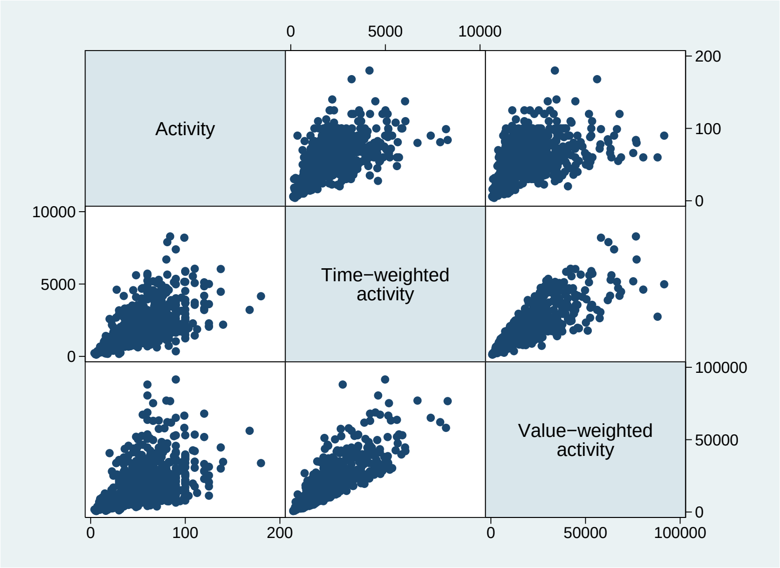

Figure 2: Scatter plots of three different output measures