Equilibrium Model of Waiting Times for Non-Emergency Procedures in the NSW Public Hospitals*

Olena Stavrunova, *University of Technology Sydney*
and
Oleg Yerokhin, *University of Wollongong*

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Abstract

This paper studies the determinants of waiting times for elective non-emergency procedures in the NSW public hospitals by estimating a model in which waiting times serve as a mechanism which equilibrates demand for and supply of hospital treatments. The model is estimated on the level of postal code areas using data on all New South Wales (NSW) public hospital admissions in 2004-05, selected postal code area characteristics and area-level provisions of public and private hospital beds. Spatial interactions methods are used to estimate the levels of provision of hospital beds to each geographical area. We find that, consistent with the predictions of the theoretical model, demand for elective hospital procedures is affected negatively and supply of treatments is affected positively by the expected waiting times. Compared to the estimates from other countries, the demand for elective procedures is highly responsive to waiting times.

1 Introduction

In countries with publicly-funded health care systems waiting lists for elective (non-emergency) public hospital treatments serve as an allocation mechanism which equilibrates demand and supply in the absence of rationing by money prices. Consequently, issues related to the length of waiting for elective hospital procedures and associated costs figure prominently in the public debates in these countries. In Australia, where a publicly-funded universal health care system coexists with the private health care sector accounting for 30% of nation's health

*PRELIMINARY AND INCOMPLETE

care expenditures (Australia's Health 2006, AIHW) a number of policies were implemented during the last decade which aimed to reduce the demand for public hospital treatments by subsidizing the private health insurance. Recently the focus of the policy has shifted to financing expansion of public health care sector capacity, with the Australian government announcing $150 million in additional funding to the states and territories to be spent on reducing elective surgery waiting lists (Hospital Waiting Lists Explained, Parliament of Australia Background Note, March 2008). Despite the prominence of the waiting times for the elective hospital procedures in public policy debate, there exists little empirical evidence on the effects of the demand and supply side policies on the waiting times associated with these procedures in the Australian public hospitals.

This paper attempts to quantify the responsiveness of the demand for and supply of elective procedures to the waiting times in the Australian public hospitals. To achieve this goal we estimate an equilibrium model of the market for elective hospital procedures using data from the NSW public hospitals from 2004-05. The starting point of our analysis is the theoretical model of rationing by waiting lists proposed by Martin and Smith (1999, 2003), which we use to obtain the empirical specifications of the demand and supply equations for the waiting list procedures. The resulting demand function specifies the relationship between the hospital utilization rate and waiting times in a given market conditional on the set of demographic characteristics and the cost of access to private treatments which we proxy by the provision of private hospital capacity, while the supply function relates hospital utilization to waiting times and the provision of public hospital capacity. The resulting model is estimated using variation in the relevant variables across small geographic areas (postal code areas of New South Wales) under the assumption that observed waiting times and utilization rates correspond to the market equilibrium in each area.

Estimation of the demand and supply model on the level of a small geographical area necessitates construction of the measures of the quantity of public and private hospital capacities in a given area. We use the spatial interaction method to obtain measures of the area-level provisions of public and private hospital beds. This methodology allows one to construct measures of the provision of hospital beds to an area which take into account not only the hospital capacity in the area but also capacities in other areas discounted by distance and influences of the competing populations in hospitals's catchment areas. In contrast to previous studies which specify the parameters on the distance decay function in ad hoc fashion, we estimate these parameters in the context of a gravity model of patient flows.

The estimation results imply that there exists a negative relationship between the quantity demanded of non-emergency elective procedures and the waiting time and that the demand is highly responsive to the waiting times with the estimated elasticity equal to -2. We also find a positive relationship between waiting times and supply of the non-emergency procedures, with supply elasticity approximately equal to 1. We do not find any significant effect of provision of private hospital capacity to an area on the demand for non-emergence procedures. Comparison of these results to those obtained by Martin and Smith (1999, 2003) for the UK public hospital sector suggests that the demand for elective procedures is much more responsive to waiting times in Australia than in the UK. The high elasticity of demand implies that an exogenous increase in the supply of elective procedures will have relatively small impact on the equilibrium waiting times associated with these procedures.

2 Empirical Specification

To obtain the empirical specifications of the demand and supply functions for elective hospitals procedures we use the conceptual framework proposed by Martin and Smith (1999), which combines earlier theoretical models of rationing by waiting (Lindsay and Feigenbaum, 1984; Cullis and Jones, 1986) and agency models of managerial supply (Propper, 1995). In this model each patient decides whether to join the waiting list for a given procedure by comparing the utility of public treatment to the utility from the two other alternatives: private treatment and no treatment. The model assumes that the utility of public treatment decreases in waiting time with a constant decay factor which reflects time discounting, loss of earning and the reduction in the quality of life arising as a result of the delay of treatment. Under these assumptions the propensity to choose public treatment over the other alternatives is affected negatively by the length of the waiting period, magnitude of the decay factor, cost of private treatment and the fixed cost of seeking care. The supply of elective surgery is determined by the behaviour of the hospital managers who seek to maximize a utility function which depends on the waiting times, efficiency with which resources devoted to surgery are used and the resources devoted to non-surgical activity subject to the overall resource constraint. The solution to the utility maximization problem results in the supply function for the elective surgery which is increasing in the amount of total resources available to the manager and waiting time. This theoretical model can be used to obtain the specifications of the empirical demand and supply equations for the elective hospital procedures which can be estimated using variation in the relevant variables across small geographic areas. The empirical demand equation specifies the relationship between hospital utilization, which measures the quantity of elective procedures performed, expected waiting time for these procedures and a set of demand shifters which capture (i) the effects of need and preferences on the demand for public treatment emanating from a particular geographical area (e.g. index of disability, education and income levels); and (ii) the cost of access to private treatment, which can be proxied by the provision of the private hospital beds to the area. Formally the empirical demand equation takes the following form:

$$\begin{aligned}\text{Hospital Utilization}^d &= g(\text{Waiting times (-)}, \text{Need (+)}, \text{Education(-)}, \text{Income(-)}, \\ &\quad \text{Access to private treatment (-)}).\end{aligned}$$

The supply equation relates hospital utilization to the waiting time and the measure of the provision of the public hospital beds to the area which proxies for the amount of the total hospital resources allocated to the area:

$$\text{Hospital Utilization}^s = g(\text{Waiting times (+)}, \text{Provision of public hospital beds (+)}).$$

The demand and supply equation are linked by the equilibrium condition of equality of supply and demand:

$$\text{Hospital Utilization}^d = \text{Hospital Utilization}^s.$$

The resulting system of the demand and supply equations is estimated using the variation across postal code areas under the assumption that equilibrium has been attained in each area. This assumption implies that resources devoted to the area are sufficient to keep the waiting time stable given the arrival rate of new patients to the area. Because the demand and supply equations are linked by the market equilibrium condition, waiting times are endogenous in both equations and estimation of the equations by OLS will produce biased results. To avoid this problem the simultaneous equations estimation technique such as two-stage least squares should be used.

3 Data

We estimate the model at the level of postal code areas of New South Wales. To construct the estimation sample we utilize the following data sources.

1. All planned (waiting list) public hospital admissions in NSW for 2004-2005:
   - time spent on waiting list before the admission
   - hospital of treatment
   - patient age, sex and postal code of residence
2. Public and private hospitals and day procedure centers geographic locations and number of acute beds. There are a total of 203 public hospitals, 87 private hospitals and 87 day procedure centers in our sample
3. Socio-demographic characteristics of postal code areas of New South Wales taken from the Australian Census.

Figure (1) presents the map of postal code areas of New South Wales, which is our main unit of analysis. There are 605 postal code areas with population ranging between 50 and 85,333. We have amalgamated 93 postal code areas with population of less than 1000 people into adjacent areas so that no area in our analysis have population of less than 1000 people. The resulting estimation sample contains 520 geographical areas.

There are two endogenous variables in our analysis - hospital utilization and public hospital waiting times. Following Martin and Smith (1999) we construct the *standardized* by gender and age utilization rate U_i for every postal code in our data set as follows:

$$U_i = \frac{\text{Actual Admissons}_i}{\text{Expected Admissions}_i|\text{age}_i, \text{sex}_i}$$

where

$$\text{Expected Admissions}_i = \sum_{j=1}^{21}\sum_{k=1}^{2} M_{jk}P_{ijk},$$

M_{jk} is the state of NSW utilization rate in age group j and sex group k, P_{ijk} is the population of the area i in age group j and sex group k. The standardized utilization rate is the ratio of actual public hospital admissions emanating from the postal code area to the number of expected admissions given area's population distribution of gender and age. Standardization by sex and age obviates the need to include these variables in the regression analysis.

In our analysis we use the following four measures of waiting times:

- Average waiting times in the area (average of the waiting times of all patients residing in a given postal code area);

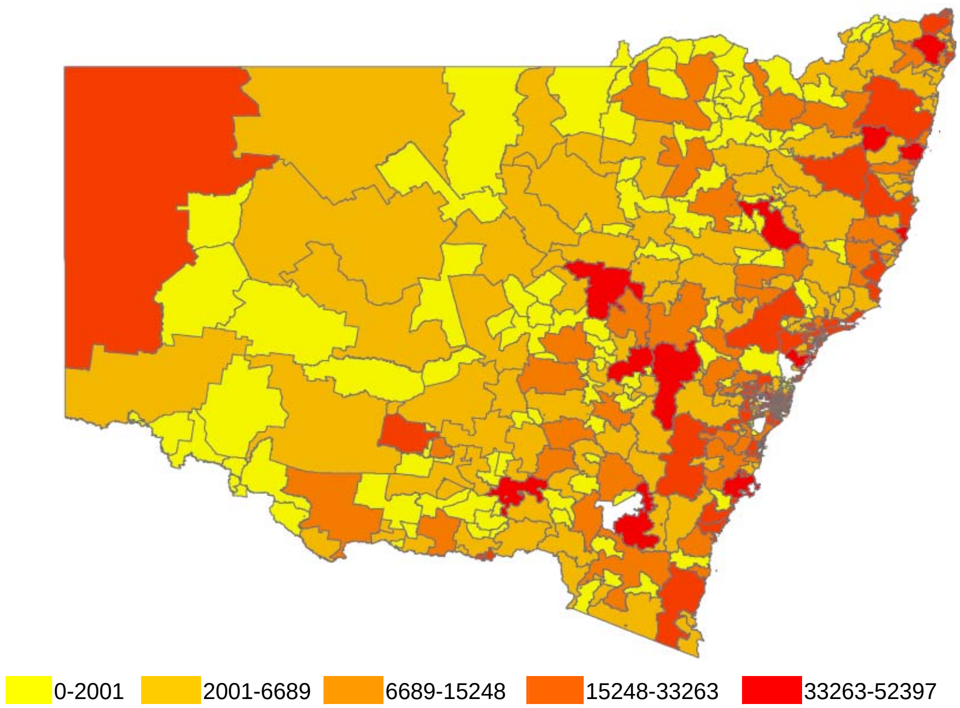

Figure 1: Postal code areas of New South Wales, boundaries and population

- Median waiting times in the area (median of the waiting times of all patients residing in a given postal code area);
- Standardized average waiting times in the area (ratio of the average actual waiting times to the expected waiting times given area's population distribution of gender and age);
- Proportion of patients in the area who waited longer than recommended by their urgency category (typically when a specialist assesses the patient she indicates whether the admission is recommended within 7, 30, 90 or 365 days depending on severity of patient's condition and overall state of health).

Figures (2) and (3) show variation in various measures of utilization rates for public hospital elective procedures and waiting times for these procedures across the postal code areas of NSW.

When estimating the demand for elective hospital procedures we control for a number of the postal code area characteristics which capture variation in the preferences and need for public hospital treatments. In particular, the set of demand shifters consists of area's unemployment rate (UR), labour force participation rate (LFP), proportion of people who need assistance with core activities [1] (PropNeedAssistance), proportion of indigenous population (PropIndig), proportion of people with advanced degrees such as diploma, advanced diploma, bachelor or postgraduate degree (PropAdvDegree), median weekly family income (medinc) and a number of general medical practitioners per 1000 people.

The specification of the empirical demand equation also includes a measure of the accessibility of private health care services in the area, which is expected to have a negative affect on the demand for public hospital services. We proxy this measure by the area-level provision of private hospital beds and day procedure centers. Similarly, the supply equation includes a measure of public hospital capacity to capture the effect of the hospital budget constraint on the total supply of the elective hospital procedures. This variable is proxied by the provision of public hospital acute beds to the area. In principle, one can measure these provision variables by computing the ratio of hospital beds (or day procedure centers) located in the area to area's population. However, this method is valid only under the assumption that people never cross area borders to get a hospital treatment. While such an

[1] This variable has been developed by the Australian Bureau of Statistics to measure the number of people with disability. A person is classified as one who needs assistance with core activities if she requires help in at least one of the three core activity areas of self-care, mobility and communication due to old age, disability or long term health condition.

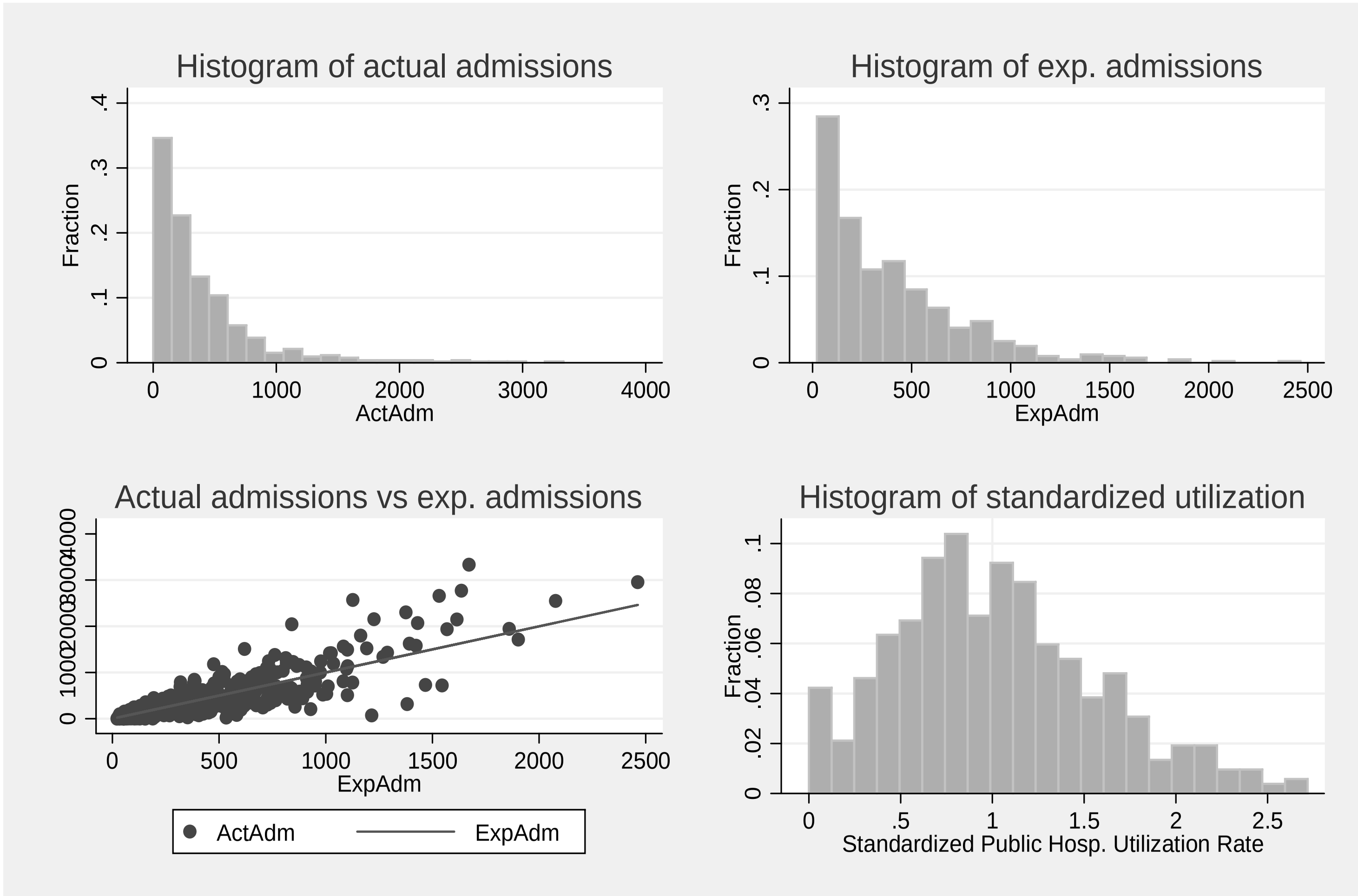

Figure 2: Public hospital utilization, postal code areas of NSW

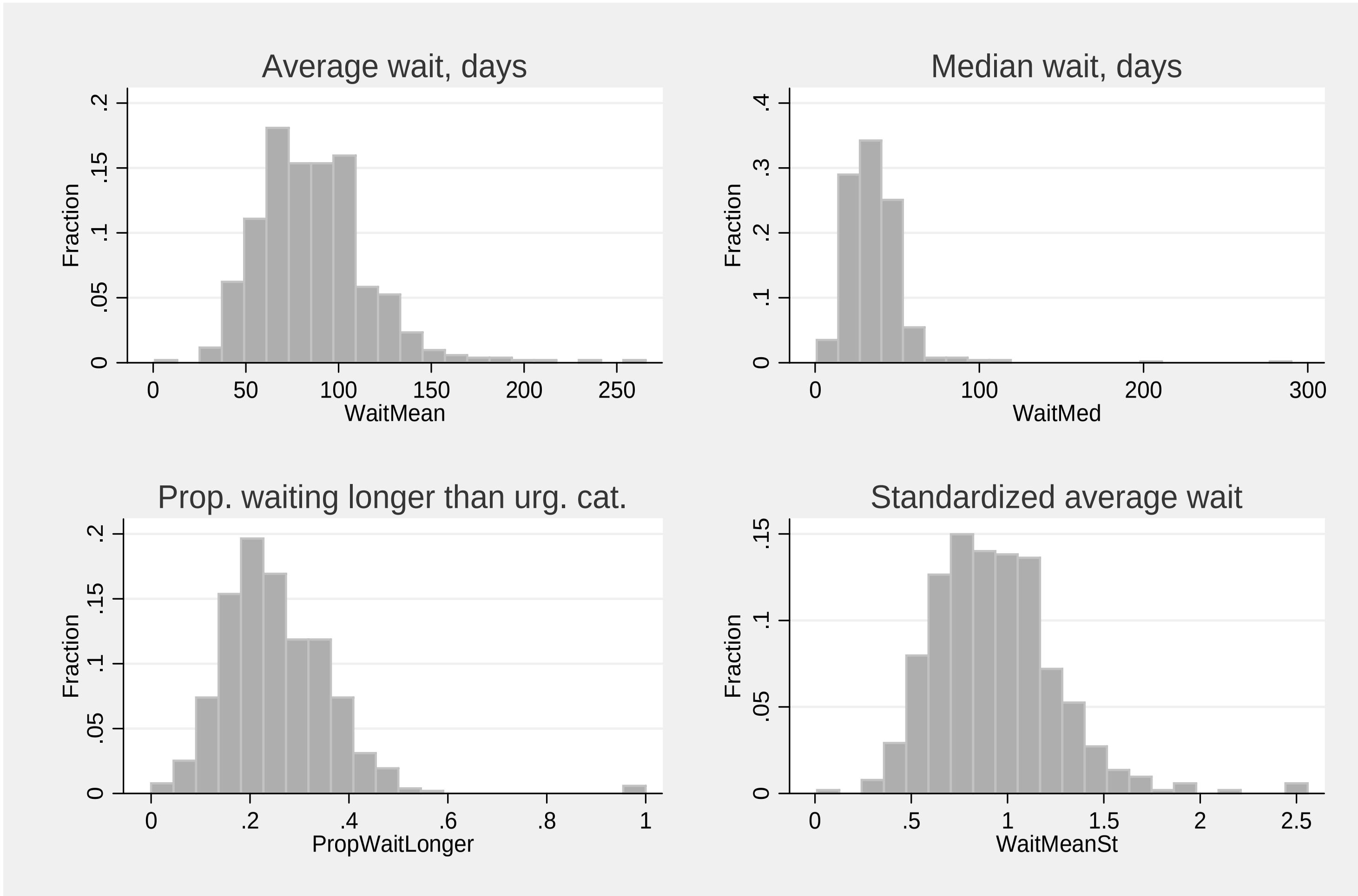

Figure 3: Public hospital waiting times, postal code areas of NSW

assumption can be justifiable if the unit of analysis is a large geographical area, it is not applicable to situations in which the unit of analysis is a small geographical area, such as postal code. Hence, the measure of capacity provision must take into account capacity in a given area as well as in the neighboring areas which are close enough to permit traveling to receive a hospital treatment. The spatial interactions modeling approach (Wilson, 1974) provides a convenient way to do this. In particular, we construct the accessibility measure derived from a gravity model of patient flows which takes the following form:

$$T_{rh} = \alpha P_r \cdot B_h \cdot f(d_{rh}), \tag{1}$$

where T_{rh} is the number of hospital episodes between area r and hospital h in a given period, P_r is population of area r, B_h is the number of beds in hospital h, d_{rh} is a measure of distance between area r and hospital h and $f(d_{rh})$ is a distance decay function. Then the accessibility of hospital beds to area r is defined as the ratio of the total number of hospital episodes originating in area r to this area's population:

$$A_r = \frac{\alpha P_r \sum_h B_h f(d_{rh})}{P_r} = \alpha \sum_h B_h f(d_{rh}).$$

The "attraction constrained" version of this measure (A_r^*) takes into account competition from the neighboring populations and can be interpreted as the distance-adjusted beds to population ratio:

$$A_r^* = \sum_h B_h \frac{f(d_{rh})}{\sum_r P_r f(d_{rh})}. \tag{2}$$

To compute A_r and A_r^* one needs to specify the distance decay function (d_{rh}) and obtain estimates of its parameters. Martin and Smith (1999, 2003), who also used the spatial interaction method to compute provision of hospital capacity to the areas in their study, could not estimate parameters of this function due to data limitation and thus resorted to choosing the functional form and parameters in an ad hoc way. Our data set contains information on the hospital of treatment for each public hospital episode, as well as the postal code of each patient's residence. This data together with the information on geographic location of the postal code areas and hospitals allows us to estimate the gravity model (1) for public hospital non-emergency admissions in NSW. We take the straight line distance between the locations of centroids of postal code areas of a patient residence and a hospital as our measure of distance d_{rh}. Using this measure we estimate two alternatives specifications of the the distance decay function: exponential ($f(d_{rh}) = \exp(-\beta \cdot d_{rh})$)) and power ($f(d_{rh}) = d_{rh}^{-\gamma}$))).

Table 1: Results of estimation of the gravity model with exponential distance decay function.

	Cf	**Std.Error**	**t-stat**	**p-value**	**R sq**
α	0.0004	0.00000852	46.71	0	
β	0.75	0.02	40.71.02	0	0.14

Table 2: Results of estimation of the gravity model with power distance decay function.

	Cf	**Std.Error**	**t-stat**	**p-value**	**R sq**
α	0.0002	0.00000149	124.6	0	
γ	1.23	0.012	96.90	0	0.15

Tables (1) and (2) present the results of fitting the gravity model with these two specifications of the distance decay function by non-linear least squares to the data on hospital trips of patients of public hospitals. The estimation results suggest that the power function provides a better fit to the hospital trips data. Consequently, we use equation (2) and the distance decay function of the form $f(d_{rh}) = \frac{1}{d_{rh}^{1.23}}$ to compute the accessibility of public and private hospital beds and day procedure centers to the postal code areas.

Figure (4) shows a scatter plot of the number of hospital trips and distance for all 105560 pairwise combinations of 520 postal code areas and 203 public hospitals of NSW in 2004-2005, as well as the fitted distance decay functions. Scatter plots of the resulting beds and day procedure centers provision versus simple capacity to population ratios are shown in Figure (5). As expected, the spatial interactions measure of accessibility assigns positive hospital capacity to areas in which no hospital is located by taking into account availability of hospital capacity in the neighboring areas. On the other hand, it assigns lower hospital capacity to areas with high capacity to population ratios by taking into account the influences of the competing populations from the neighboring areas. The descriptive statistics of all of the variables used in the analysis are shown Table (3).

4 Results

We have experimented with several specifications of the demand and supply equations and found that linear specification provides the bets fit to the data. The provision of public beds enters as a third degree polynomial in the supply equation. We estimate the following model:

$$U_i^d = \alpha_0 + \alpha_1 \cdot \mathrm{W}_i + \boldsymbol{\alpha}_2 \cdot \mathbf{DS}_i + \alpha_3 \cdot \mathrm{PrivBeds}_i + \alpha_4 \cdot \mathrm{DPC}_i + \alpha_5 \cdot \mathrm{GP}_i + \varepsilon_{1i}$$

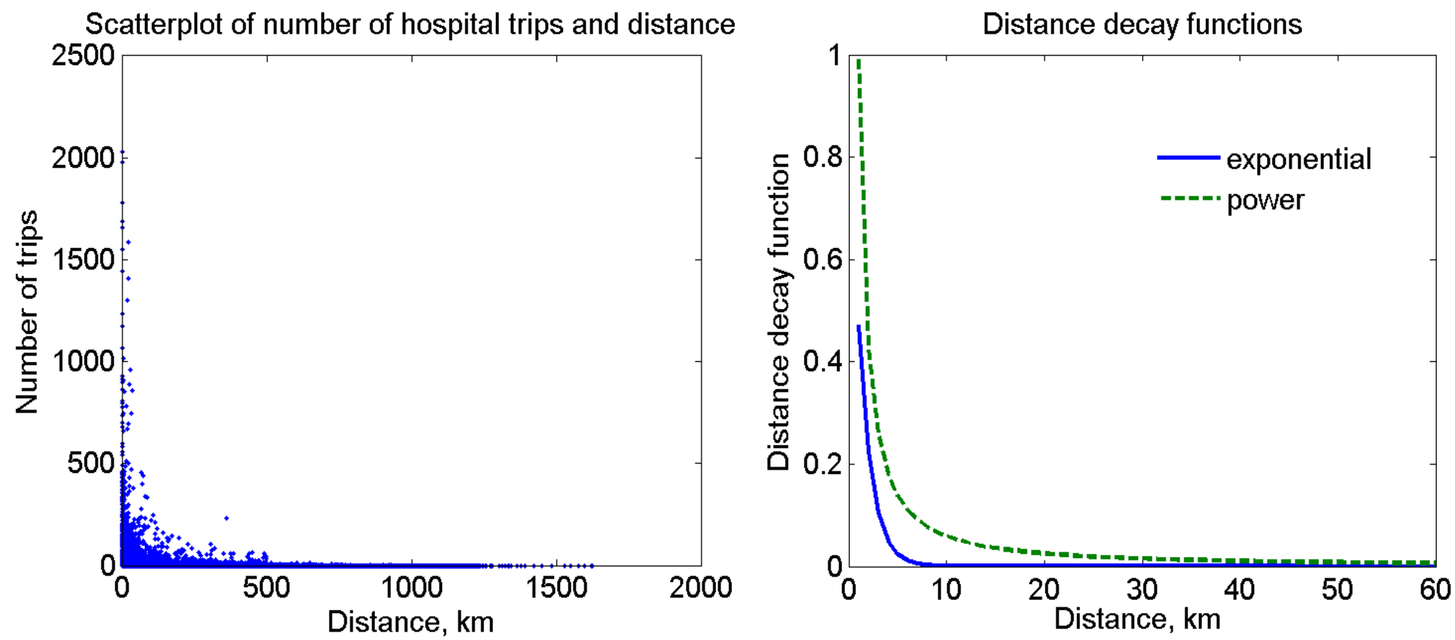

Figure 4: Public Hospital trips, NSW

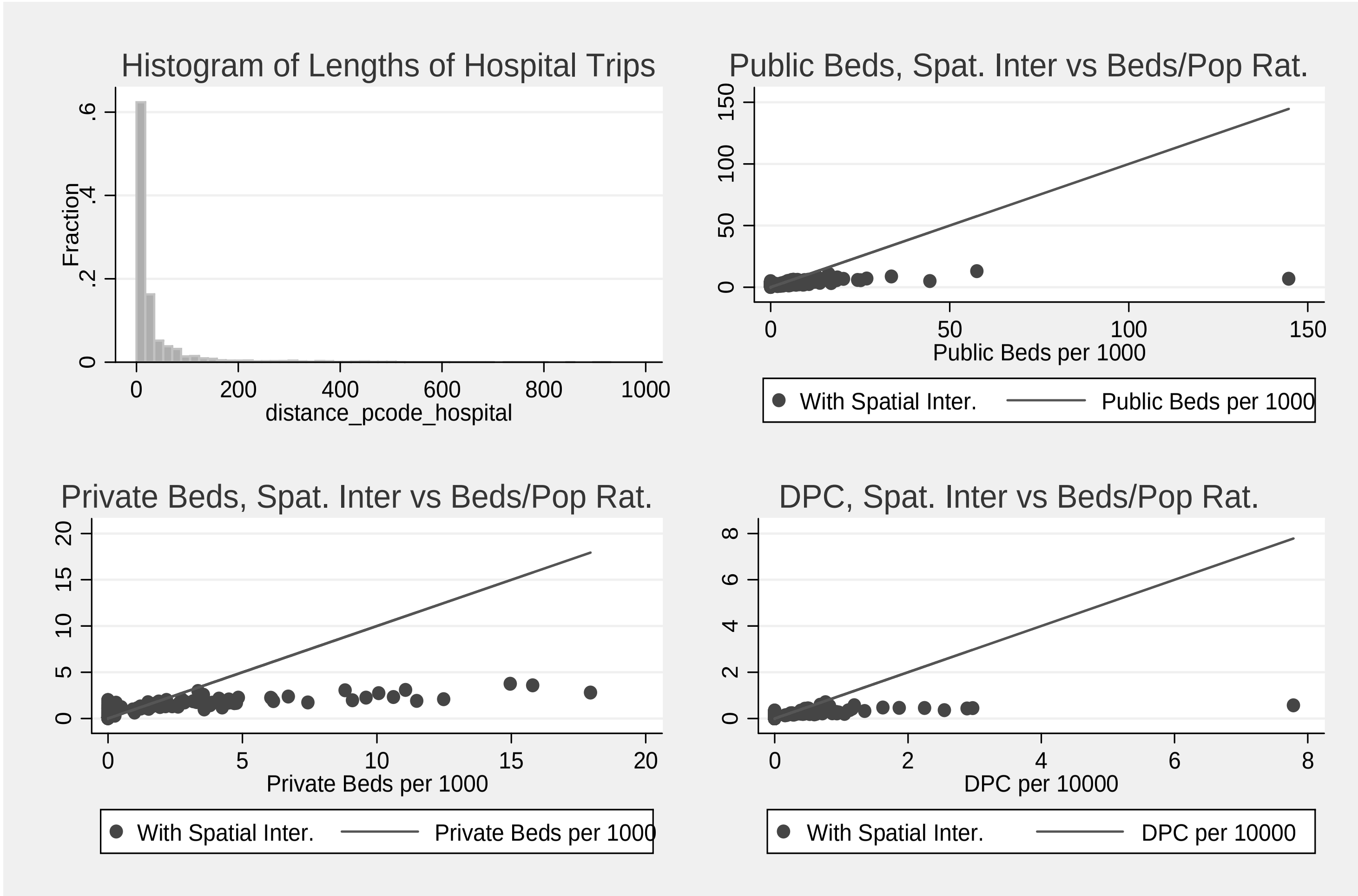

Figure 5: Provision of hospital beds using spatial interactions method

Table 3: Sample descriptive statistics.

Variable	Description	Mean	Std.Dev.	Min	Max
U	Public hospital utilization rate standardized by age and gender	1.03	0.54	0.005	2.72
WaitMean	Average waiting time	85.75	29.203	1.000	240.941
WaitMed	Median waiting time	34.98	16.19	1	207
PropWaitLonger	Proportion of patients who waited longer than recommended by their urgency category	0.25	0.10	0.000	0.56
WaitMeanSt	Average waiting time standardized by age and gender	0.93	0.31	0.01	2.54
PropLoneOld	Proportion of households consisting of people older than 65 years and living alone	0.040	0.017	0.003	0.106
UR	Unemployment rate	0.061	0.031	0.016	0.261
LFP	Labour force participation rate	0.626	0.082	0.325	0.867
PropNeedAssistance	Proportion of people who need assistance with core activities of daily living (disability)	0.046	0.017	0.012	0.179
PropIndig	Proportion of indigenous people	0.030	0.043	0.000	0.405
PropAdvDegree	Proportion of people with advanced degree (diploma and higher)	0.222	0.121	0.027	0.549
medinc	Median family weekly income, AUD	1259.507	475.57	543.800	2716.400
PrivBeds	Provision of private hospital beds to postal code area computed using spatial interactions method	0.75	0.67	0.03	3.74
DPCSupply	Provision of day procedure centers to postal code area computed using spatial interactions method	.1008877	.1122358	.0029337	.7016987
PubBeds	Provision of public hospital beds to postal code area computed using spatial interactions method	2.530351	1.58095	.2276443	12.98248
GPtoPop	Number of general practitioners per 1000 of population	1.165219	.3178864	.6571429	3.59273

$$U_i^s = \beta_0 + \beta_1 \cdot \mathrm{W}_i + \beta_2 \cdot \mathrm{PubBeds}_i + \beta_3 \cdot \mathrm{PubBeds}_i^2 + \beta_4 \cdot \mathrm{PubBeds}_i^3 + \varepsilon_{2i}, \qquad (3)$$

where i indexes postal code areas, W_i denotes $\mathrm{WaitMean}_i$, $\mathrm{WaitMed}_i$, $\mathrm{PropWaitLonger}_i$ or $\mathrm{WaitMeanSt}_i$ and a vector of area characteristics $\mathbf{DS}_i$ includes the following demand shifters: PropLoneOld, UR, LFP, PropNeedAssistance, PropIndig, PropAdvDegree, medinc and GPtoPop.

We conduct the over-identifying restrictions test of a hypothesis that additional instruments are exogenous for both demand and supply equations. We do not find an evidence of instrument endogeneity in the demand equation, while the supply equation does not pass the over-identifying restrictions test. Because of the possible misspecification of the supply equation, estimates of the coefficients on waiting time and provision of public beds in this equation must be interpreted with caution.

Table (4) presents estimation results for the four different definitions of the waiting time variable. The demand and supply equations were estimated by two stage least squares squares, and postal codes were weighted according to the number public hospital admissions so that postal codes with fewer admissions received smaller weight in the estimation. The results are broadly consistent with theoretical predictions for all four definitions of waiting times. The demand for waiting list procedures is negatively affected by waiting times, with the elasticity of demand with respect to average waiting time at the sample averages of the utilization and the waiting time equal to -2. This effect is approximately 10 times bigger than the one found by Martin and Smith (1999) for the UK public hospitals. We also find a positive and significant effect of the unemployment rate and negative and significant effects of the proportion of population with advanced degree, median income and the provision of general medical practitioners on the demand for waiting list procedures. We do not find any effects of geographical accessibility of private health care services on the demand for public waiting list procedures. Turning to the supply equation, estimation results imply that supply of waiting list procedures is positively affected by waiting times. We also find a positive effect of the provision of public beds on the supply in the specification which includes the median waiting time.

These results have important implications for the effectiveness of the supply side policies in reducing waiting times in public hospitals. In particular, the high responsiveness of the demand for public non-emergency treatments to the expected waiting times implies that a decrease in queue brought about by the increased efficiency or capacity in the public sector (increase in supply) will be offset by the additional demand for elective surgery as

Table 4: Results: demand and supply equations. Triple, double and single asterisk indicate significance at 1%, 5% and 10% levels, respectively.

Variable	WaitMean	WaitMed	PropWaitLonger	WaitMeanSt
Demand Equation				
WaitMean	-0.0138***			
WaitMed		-0.0312***		
PropWaitLonger			-5.3875***	
WaitMeanSt				-1.3022***
PropLoneOld	5.1213***	1.0185	0.5074	4.0631**
UR	7.0461***	6.9073***	8.0728***	7.3956***
LFP	0.5453	0.2383	0.4756	0.7289
PropNeedAssistance	-3.3581	-1.6116	-1.4913	-3.2873
PropIndig	0.6704	2.8129***	-1.5855	0.6543
PropAdvDegree	-2.1670***	-1.9598***	-1.8145***	-2.2359***
medinc	-0.0003**	-0.0003**	-0.0004**	-0.0003**
PrivBeds	0.0071	-0.0736**	-0.0390	0.0109
DPC	0.1740	0.0991	0.3774	0.1631
GP	-0.3975***	-0.4479***	-0.2919***	-0.3951***
cons	2.8561***	2.9655***	3.0535***	2.7981***
Supply Equation				
WaitMean	0.0110***			
WaitMed		0.0324***		
PropWaitLonger			1.0554**	
WaitMeanSt				0.9797***
PubBeds	0.1107	0.1950*	-0.0800	0.0877
PubBeds2	-0.0151	-0.0318	0.0272	-0.0105
PubBeds3	0.0001	0.0010	-0.0023*	-0.0001
cons	0.0552	-0.1853	1.0030***	0.1194

consumers switch from private to public sector in response to the decrease in the expected waiting times. This finding suggests that policies which increase supply of the elective public hospital procedures might not be effective in decreasing waiting times for these procedures.

5 Conclusions

Recently a number of policies aimed at reducing waiting times for elective hospital procedures have been proposed in Australia. There exists however little empirical evidence on the responsiveness of the consumers' behaviour to changes in the expected waiting times which could be used to evaluate the effectiveness of these policies. This paper uses data on the provision of hospital services and waiting times in postal code areas in NSW to estimate an equilibrium model of demand and supply for the elective hospital procedures in which waiting time serves as a rationing device. We estimate a gravity model of patient flows between geographical areas in order to construct measures of provision of public and private hospital beds to each area which are then used in the estimation of the demand and supply model. We find that demand for elective procedures is affected negatively by the waiting time and that elasticity of demand is relatively large. The supply of elective procedures increases in waiting time but is less sensitive to variation in waiting times compared to the demand response. These findings are consistent with the results of studies of the market for elective hospital procedures in other countries (Martin and Smith, 1999 and 2003). However, in contrast to the results on the demand responses to waiting times in other countries we find that that the demand for elective treatments is much more elastic with respect to waiting times which might be explained by the larger degree of substitutability between private and public sectors in Australia.

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