Price elasticity of on-street parking demand—a case study from Seattle

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MOTIVATION AND OBJECTIVES

In the central areas of many cities, on-street parking pricing touches upon a set of inter-connected issues ranging from individual travel choices to area-based congestion, air pollution, and economic vitality. Because of these concerns, on-street parking pricing remains a sensitive, politically (un)popular, and yet must-be-tackled issue [1, 2].

On-street parking fees, as part of the out-of-pocket costs, play into the decision making of every driver's choices. These decisions concern the generation of a trip, the alternative destinations of a trip, and the mode of travel. Basic economic theory tells us that low parking price likely induces travel and encourages driving [3].

The aggregate of individual travelers' responses to parking policies has a direct impact on an area's congestion level and air quality [4]. Demand for on-street parking is usually the greatest in the commercial cores of a city [5]; when on-street parking is underpriced, available parking spots are hard to find, resulting in people spending time cruising for an available spot, contributing to both congestion and pollution. Shoup [6] found that about 8-74% of the traffic in central business districts is cruising for parking and the time searching for a space ranged from 3.5 to 14 minutes.

On the other hand, overpricing of on-street parking may potentially hurt an area's economic vitality, since where on-street parking demand is the greatest, or the commercial core, is often the most economically vital part of a city. Business owners as well as city officials often fear that on-street parking pricing, if too high, can either divert trips to other areas where parking is cheaper, or simply eliminate trips, thus causing a drop in business revenues. These concerns are often first heard whenever an increase on on-street parking is proposed [7].

The central point of these various concerns is that on-street parking must be rightly priced to achieve a parking occupancy level that discourages cruising and, at the same time, maintains or even stimulates an area's economic activities. Existing studies point out that an optimal parking occupancy level of a block falls between 80% and 90% [3, 5, 6, 8, 9]. Shoup [3] suggested that the optimal parking occupancy rate should be around 85% or leaving at least one or two open parking spots per block. To accomplish that, a performance-based parking pricing should be applied; parking fee is raised if the parking occupancy is higher than target occupancy, and is decreased if the occupancy is below the target occupancy. Further complicating the matter is that the demand for on-street parking varies by time of day, by day of week and by location. Thus, a well-implemented parking policy would need to change during a day to respond to different levels of parking demand in different neighborhoods [10].

"How should on-street parking be priced to achieve the desired occupancy level?" remains a critical question for many city officials. The answer to this question requires direct knowledge of the elasticity of on-street parking demand in response to pricing. While there have been a large number of travel behavior studies that investigated individual responses to changes in parking fees, surprisingly few studies have looked at how parking pricing affects on-street parking demand [11]. Consequently, scarce evidence exists on the price elasticity of on-street parking demand in response to on-street parking fees. It is this on-street parking demand that directly concerns city officials when pricing decisions for on-street parking are made.

This study takes advantage of a recent parking pricing adjustment implementation in 14 neighborhoods in Seattle[1]. Between January and April 2011, the city of Seattle adopted a performance-based pricing strategy [8] by adjusting on-street parking fees for a total of 10 neighborhoods surrounding the commercial core, based on their previous peak-occupancy rates — those areas with higher rates had their fees increased and those areas with lower rates saw their rates reduced. Another four neighborhoods had their parking rates unchanged as parking occupancy rates in these neighborhoods were within the target range that the city had determined. In the study, we calculate pricing elasticities of block-level parking occupancies in neighborhoods with increased rates and decreased rates. In the process, we hypothesize that pricing elasticities vary by time of day and by neighborhood characteristics. We also hypothesize the presence of asymmetric behavior—parking demand sensitivities in neighborhoods with increased rates differ from those in neighborhoods with decreased rates.

METHODOLOGY

To quantify how parking demand changes in response to the change in parking price, we developed two models. In model 1, we hypothesize that the price elasticity varies by time of day, but not neighborhood characteristics:

$$\ln(y_{i,t}) = \propto + \beta \cdot \ln(y_{i,t-1}) + \lambda \cdot D(NoChange) + \gamma_k \cdot \ln(P_{i,t}) \cdot D_k(Hour) + \varepsilon_{i,t}$$

where,

$y_{i,t}$ refers to the demand for on-street parking (measured as occupancy level) on i^{th} block at time t after the rate changes,

α is the constant,

$y_{i,t-1}$ is included to capture unobserved block-level effects and refers to the demand for on-street parking on i^{th} block at time $t-1$ before the rate changes,

β is the partial adjustment parameter,

D(NoChange) is a dummy variable and is equal to one for all blocks in a neighborhood with no rate changes,

λ is the parameter that captures the differences between blocks that had changes in rates and blocks that did not have changes in rates,

$P_{i,t}$ is the parking price on i^{th} block at time t,

$D_k(Hour)$ is a vector of dummy variables and is equal to 1 when it is k^{th} hour of the day,

γ_k is the price elasticity of the demand for on-street parking at k^{th} hour with respect to on-street parking rates.

In model 2, we further hypothesize that the pricing elasticity varies by time of day and neighborhood characteristics:

[1] Actually 23 neighborhoods had parking pricing implementation. However, we only studied areas within the downtown boundaries of Seattle, total of 14 neighborhoods.

$$\ln(y_{i,t}) = \propto + \beta \cdot \ln(y_{i,t-1}) + \lambda \cdot D(NoChange) + \gamma_k \cdot \ln(P_{i,t}) \cdot D_k(Hour) + \varepsilon_{i,t}$$
$$= \alpha + \beta \cdot \ln(y_{i,t-1}) + \lambda \cdot D(NoChange) + \left[\sum_j \gamma_{k,j} \cdot X_j(BE)\right] \cdot \ln(P_{i,t}) \cdot D_k(Hour) + \varepsilon_{i,t}$$

where,

$\gamma_{k,j}$ is the parameter associated with j^{th} neighborhood characteristic for k^{th} hour, and

X_j is a vector of BE (Built environment) related variables for i^{th} block.

DATASET

New Parking Rates

In the months of February to April in 2011, a change in the regulation of on-street parking in Seattle was implemented which resulted into both an increase and a decrease of the hourly parking rate. The rate change was based on *performance based parking prices* [12] where rates are adjusted according to the peak parking occupancy within the boundaries of every neighborhood[2]. These occupancy rates were based on manually counted data that was gathered in a citywide parking study that was conducted a few months before the implementation and the city determined a target occupancy range of 71-86% [13]. The new rates and the parking price change of each neighborhood business district can be seen in Figure 2. In total, four neighborhoods experienced an increase in parking rates; six neighborhoods had a decrease; and four had their rates unchanged.

[2] Before the rate was changed, the neighborhood boundaries were adjusted to account for significant concentrations of parking demand that sometimes occur in and around the business and retail core of the these neighborhoods.

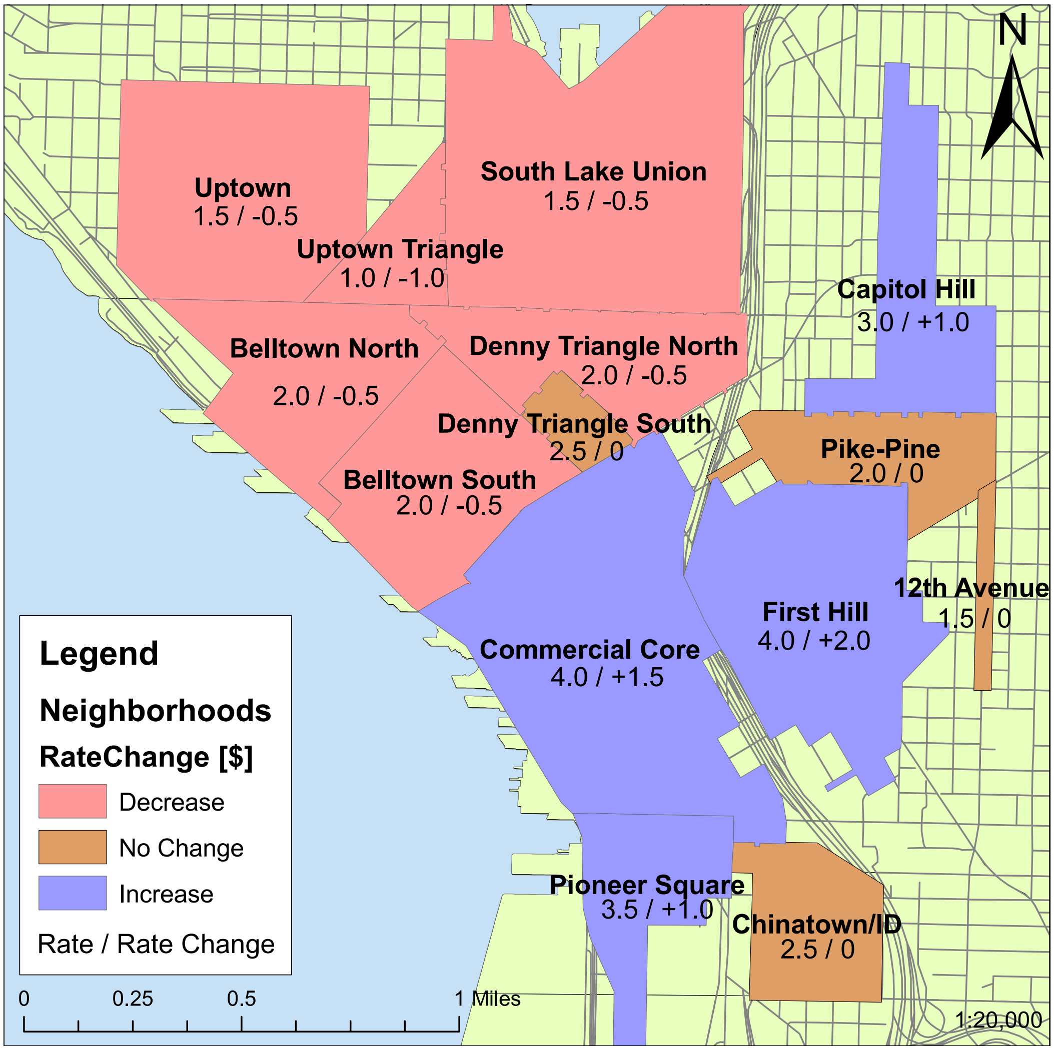

FIGURE 1 New rates and rate changes in each neighborhood within the study area in Seattle. Numbers before the 'slash' represents the new rate, the number after the 'slash' represents the rate change.

RESULTS

Price elasticities of parking occupancy

We first discuss estimated price elasticities[3] from model 1. Figure 2 shows these elasticities by hour of day as well as corresponding occupancies in 2011. By looking at Figure 2, it can be seen that the price elasticity of the parking occupancy is inelastic (their absolute values are less than 1). For neighborhoods with decreased rates, the elasticity ranges from -0.53 to -0.02; it is significant and highest at 8 a.m. (-0.53), decreasing gradually until noon when it becomes very low (-0.06) and insignificant and continues that trend through the afternoon period. In contrast, for neighborhoods with increased rates, the elasticity ranges from -0.43 to -0.24 and is relatively constant during the day; it is the highest in the morning (-0.43) but lowest at the noon hours

[3] Due to word limit constraints, estimates from model 1 and 2 are not presented in this paper. For interested readers, please contact the corresponding author directly by email.

(0.24-0.25) but then it rises slightly in the afternoon before having a turning point at 4 p.m. (-0.31). These elasticities suggest that, in both cases, on-street parking demand appears most sensitive in the morning. In addition, while the increasing rates certainly affect demand, decreasing rates appears less so, especially in the afternoon hours. On average, elasticity for blocks with increased rates is higher (-0.304) than that for blocks with decreased rates (-0.103), suggesting that parking demand is more sensitive to rate increases than decreases, in other words, it indicates asymmetric behavior.

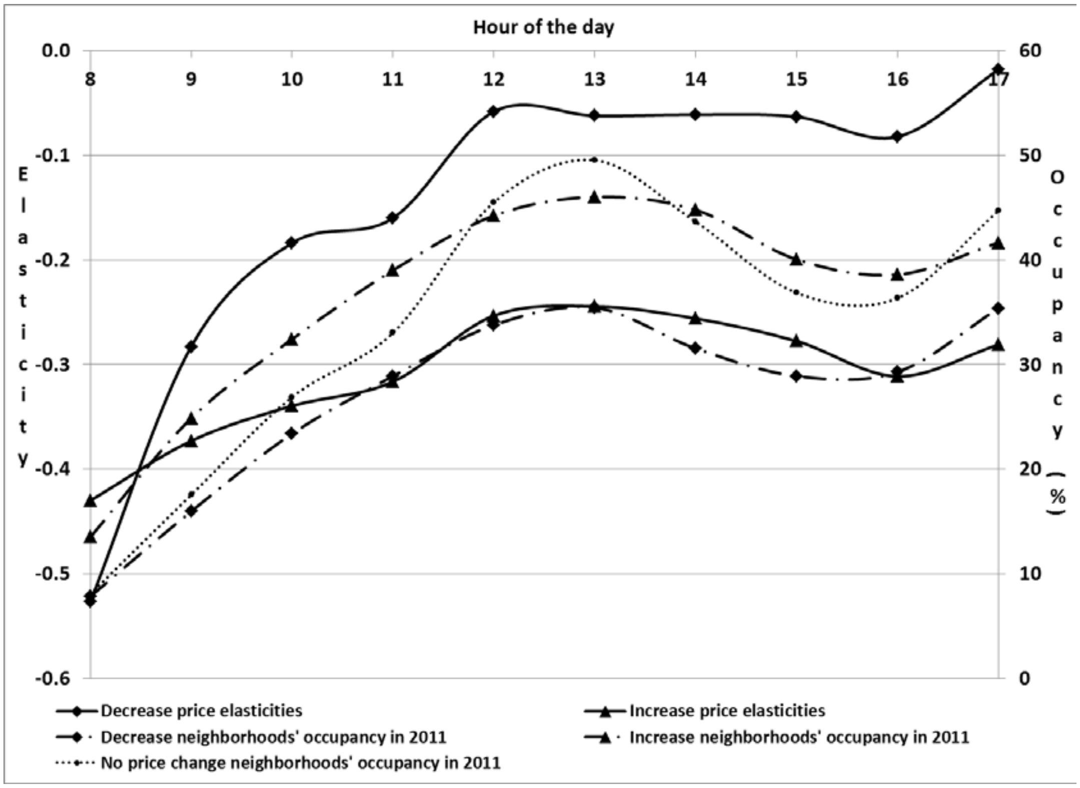

FIGURE 2 Price elasticity by the hour of day from model 1. Average parking occupancy rates of 2011 (i.e. after the rate change) in neighborhoods with a decrease, no change and an increase in rates are also displayed in this figure.

In model 2, we expressed price elasticity as a function of neighborhood characteristics. The fact that there are significant neighborhood variables throughout the day supports our hypothesis that neighborhood characteristics matter[3].

To better understand how neighborhood characteristics affect price elasticity, we created Table 1. Table 1 shows calculated price elasticity by neighborhood based on model 2 results. We can make three observations from Table 1. First, price elasticity varies by neighborhood. Second, for each neighborhood, the elasticity is expressed as a range (see min and max values), meaning that different blocks are associated with different elasticities for the same hour, given their different characteristics. Third, consistent with the results from model 1, the elasticities for neighborhoods with increased rates are on average higher than those neighborhoods with decreased rates.

TABLE 1 Mean, min. and max. price elasticities per block by neighborhood. Also, parking rates in 2010 and 2011 (after the rate change) are displayed. This table is based on model 2 results.

Neighborhood	Rate 2010 ($)	Rate 2011 ($)	Rate Change ($)	Decrease price elasticities			Increase price elasticities		
				Mean	Min	Max	Mean	Min	Max
Belltown North	2.5	2.0	-0.5	-0.18	-0.42	0			
Belltown South	2.5	2.0	-0.5	-0.11	-0.27	0			
Denny Triangle North	2.5	2.0	-0.5	-0.15	-0.30	0			
South Lake Union	2.0	1.5	-1.0	-0.22	-0.65	0			
Uptown	2.0	1.5	-0.5	-0.29	-0.62	0			
Uptown Triangle	2.0	1.0	-1.0	-0.20	-0.37	0			
Capitol Hill	2.0	3.0	+1.0				-0.31	-0.70	-0.21
Commercial Core	2.5	4.0	+1.5				-0.24	-0.61	-0.02
First Hill	2.0	4.0	+2.0				-0.28	-0.60	-0.10
Pioneer Square	2.5	3.5	+1.0				-0.28	-0.60	-0.14
All neighborhoods with price changes				-0.19	-0.65	0	-0.27	-0.70	-0.02

IMPLICATIONS FOR SCIENCE AND PRACTICE

The study results confirm our hypothesis that the price elasticity of on-street parking demand varies by time of day and by location. The parking demand appears to be most responsive in the morning at 8 and 9 a.m. Our hypothesis on asymmetric behavior is also confirmed—parking demand is more sensitive to rate increases than to rate decreases.

The elasticities derived from the study can be used for performance-based pricing—calculating the optimal pricing for on-street parking to achieve a desired level of occupancy. The method demonstrated in the study can be readily implemented in any city that is interested in applying performance-based pricing and has data from automatic pay stations or manual surveys.

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