Economics of Transportation 3 (2014) 166–174

Contents lists available at ScienceDirect

Economics of Transportation

journal homepage: www.elsevier.com/locate/ecotra

Time-varying parking prices

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ARTICLE INFO

Article history:
Received 17 August 2012
Received in revised form
15 May 2014
Accepted 15 May 2014

Keywords:
Parking pricing
Employer parking
Deadweight loss

ABSTRACT

According to welfare-maximising principles, the price of parking must vary per day given shifts in daily demand. We study the economic consequences of not doing so by estimating the employees' parking demand at an organisation that varies the price of parking by day of the week. We estimate the effect of the employees' parking price on demand using a difference-in-differences methodology. The deadweight loss of free parking due to overconsumption of parking is about 10% of the organisation's parking costs (excluding welfare costs due to increased travel externalities). Charging a fixed price per day induces a welfare loss of at least 4% of the organisation's parking costs.

1. Introduction

It is rather well-known that parking is usually provided free to users (Shoup, 2005). There is however surprisingly little information to what extent not charging for parking creates welfare losses, although this is the central theme in the economics of parking literature (Vickrey, 1954; Roth, 1965; Arnott et al., 1991; Arnott and Inci, 2006, 2010; Anderson and De Palma, 2004; Kobus et al. 2013; Van Ommeren et al., 2011, 2012). One recent paper concluded that underpricing of parking for workers may create substantial welfare losses (Van Ommeren and Wentink, 2012). This loss is induced by non-optimal fringe benefit taxation, because the provision of parking is not taxed as income, whereas wages are taxed as income, which stimulates organisations to offer parking below its cost price, or even free, which increases the demand for parking. As far as we are aware only in Singapore, free employer-provided parking is taxed as income and, in line with theory, most employees pay for employer parking (ADB, 2010).

We continue on this theme by estimating the welfare loss of non-optimal pricing of parking of hospital workers in the Netherlands. Vickrey (1954) recommended to use *time-varying parking tariffs* to deal with variation in demand for parking.[2] This is in line with the more general principle that the price of a good must be vary with time-shifts in demand when changes in supply are costly.[3] It is unknown to what extent efficiency losses in the parking market are substantial when time-invariant parking tariffs are applied. Hence, we will estimate the deadweight loss of using a time-invariant parking tariff as well as the deadweight loss of free parking. In this way, we are able to understand the importance of applying time-of-day parking pricing compared to time-invariant pricing as well as compared to general underpricing of parking.

Hospitals operate on a 24-h a day basis, hence within-day parking variation in demand is related to the timing of nurses' and doctors' shifts (one peak between 7 and 8 am and another one between 2 and 3 pm), the arrival of administrative staff (at around 9 am) and of patients scheduled for treatment.[4] Parking demand on weekdays far exceeds the demand on weekends, but, as we will document later on, there also is quite some variation *between* weekdays, a characteristic which is ignored in the literature.

Now let us consider the case where the hospitals' weekly marginal resource cost of parking is given, which is plausible because hospitals are not able to vary the number of parking spaces within the week. Furthermore, consider the case where the demand for parking varies per day of the week (e.g. on Monday demand is higher than on Wednesday). Let us suppose that the hospital may freely choose the number of parking spaces (per week) as well as the parking price for each day. In line with principles already discussed almost 100 years ago by Pigou (1920), the *welfare-maximising* parking price to be paid by workers, i.e. the

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[1] Jos van Ommeren would like to thank Netherlands Organisation for Scientific Research (NWO) for funding. We would like to thank two anonymous referees, the editor Marvin Kraus, Richard Arnott for detailed comments, Bronovo hospital for providing data and Daan van Egeraat for advice.

[2] Vickrey's (1954) vision is applied in many circumstances. For example, day and evening curbside parking fees are usually different.

[3] The classical example is the electricity industry where changes of supply within a day are expensive, so peak load pricing within the day (nights are cheaper) is common (Steiner, 1957).

[4] Visitors are a relatively small group who predominantly use parking spaces that are left vacant by workers/patients who have left earlier.

http://dx.doi.org/10.1016/j.ecotra.2014.05.001
2212-0122/

price that induces efficient use of parking space, must vary per day. To be more precise, it must vary such that for the *marginal* parking space, the sum of the (inverse) parking demand functions for each day of the week is equal to the weekly parking costs (Steiner, 1957).[5]

When shifts in demand between days of the week are substantial, there will be excess supply on some days of the week, which will be labelled as *slack days*. Given optimal parking pricing, the parking price is zero on slack days and positive on the remaining days—the peak days. Given identical demand functions on peak days, the optimal peak day parking price is equal to the weekly fixed costs divided by the number of peak days. We estimate the deadweight loss of not using the optimal parking price on slack and peak days.

For the welfare calculations it does not matter why organisations do not use optimal pricing. These reasons include for example the presence of distortionary fringe benefits taxation which reduces the incentives to charge for parking, and therefore also reduces the incentive to vary the price over the day of the week.[6] Another reason might be that it requires specialised parking equipment which induces a fixed cost, particularly for organisations that do not charge visitors. This reason is less likely to be applicable for hospitals – including the hospital we focus on – because hospitals use parking prices for patients (and visitors) to regulate demand for parking and to recover parking expenses.[7] Another reason is that it induces transaction costs (e.g. it requires the payroll administration to have data about parking usage) that only recently have fallen due to improvements in computer technology.

To determine the welfare loss of nonoptimal pricing of parking, we will estimate the price effect on parking demand for a single hospital that varies the parking pricing regime in several ways. In particular, it varied the parking price over the days of the week, after a period when it varied only with workers' commuting distance. To vary price per day is rather unique – we are not aware of any other organisation employing this practice – and in line with economic theory to deal with variation in demand (Vickrey, 1954). Importantly, for the current paper, charging on a daily basis is useful as a quasi-natural experiment to identify the *causal* effect of pricing on workers' parking demand.

In our welfare calculations, we will assume that parking demand is deterministic, but we will show that allowing for stochastic demand shocks does not fundamentally change the welfare calculations.[8] We will also discuss the possibility that the hospital adjust wages due to distortionary taxation, which complicates the welfare calculation. The case where parking is productive for the hospital, in the sense that workers use hospital parking for cars used for purposes (e.g. visit to patients at home), is discussed as well. Furthermore, we discuss the welfare consequences that underpricing of parking will increase travel demand and therefore creates travel externalities as well as interactions with the parking market for patients.

The structure of the paper is the following: Section 2 describes the underlying assumptions of the welfare analysis. Section 3 contains the data description. Section 4 presents the empirical results. Section 5 discusses the deadweight loss of non-optimal pricing. The final section offers concluding remarks.

2. Theoretical foundations of the welfare calculations

2.1. Main assumptions

We assume a hospital which offers N parking spaces to one representative worker, where $N \leq 1$. So, N can be interpreted as the ratio of parking spaces to workers. We focus on a representative week. Each worker produces revenue R per week and obtains utility from income (wages minus payments for parking) and utility from parking at the hospital. For convenience, but this is not essential, we assume that their utility U is additive in income and utility from parking. The worker must receive (at least) the utility level that she could have received through alternative use of employment, U^*. The hospital consequently faces the following labour supply constraint: $U = U^*$.

The marginal cost of parking for one week is equal to c. The hospital is free to choose the supply of parking, but, conditional on that choice, supply is given for all days of the week.[9] The hospital is free to vary the parking price per day. We will denote total weekly revenue from parking per worker by $S(N)$.

Workers differ in the benefit from parking (e.g. some may walk to work, whereas others live far away). This implies that for a representative worker, we have a downward sloping inverse parking demand function, denoted by $D(N)$. When $D(N) = 0$ for a value of N, then $D(n) = 0$ for $n > N$.

Demand for parking differs between days of the week. We distinguish between n_p days of the week with high demand, which will be labelled *peak days*, and n_s days of the week with low demand which will be labelled *slack* days. The corresponding inverse parking demand functions on these days are denoted by D_s and D_p, respectively. Demand for parking is higher on peak days than on slack days, hence $D_p(N) > D_s(N)$.

The hospital will maximise profits by choosing a wage level W and parking quantity N. The following profit function is maximised

$$\text{profit} = R - W - cN + S(N), \tag{1}$$

given the constraint that

$$W - S(N) + n_s \int_0^N D_s(n)dn + n_p \int_0^N D_p(n)dn = U^*, \tag{2}$$

where the third and fourth terms on the left-hand side of the equation denote the worker benefits of parking on slack days and peak days, respectively. The solution to this maximisation problem can be written as:

$$n_p D_p(N^*) + n_s D_s(N^*) = c, \tag{3}$$

where N^* denotes the chosen quantity of parking. This solution is identical to the problem when the firm maximises *the welfare*

[5] The demand for parking is a derived demand, and this has some surprising consequences. For example, Hasker and Inci (2014) show that free parking may be optimal when a car driver visits a shopping mall and does not know with certainty whether the desired good is available.

[6] For example, hospitals charge workers a price for the use of parking that is much lower than their (long-run) marginal resource cost – the (annualised) expenses to increase the hospital's parking with one unit – so parking for workers is implicitly subsidised (in line with the observation that workers pay a fraction of the cost paid by patients/visitors).

[7] Indeed it appears that a substantial proportion of hospitals charge workers for parking. This is true in the Netherlands (about one third), but also, for example, in the US (National Parking Association, 2009).

[8] In general, cruising for parking in the Netherlands is almost absent, particularly for workers. In general, cruising for parking is relevant when focusing on street parking, particularly when street parking is underpriced (Arnott and Inci, 2006). In the hospital we focus on, cruising for parking does not occur during the period of observation.

[9] Note that over a long period (e.g. of more than one year), parking supply is not fixed. For example, ground parking can be converted to multi-storey parking. In the US, construction costs of such a parking, excluding the cost of land or of any special foundations are about € 10,000 per space (Parking Consultants Ltd, 2010). According to the management of the hospital will focus on, the hospital chooses the parking quantity and adapts the parking price. For example, after the period analysed in this paper, the hospital has expanded parking capacity by building a garage further away from the hospital and has set the parking price for this garage such that demand equals supply on peak days.