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Alexandros Dimitropoulos

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Abstract

Parking policies have significant environmental and economic implications, which have often been left unconsidered. This paper reviews the relevant literature to provide a deeper understanding of the main environmental and economic consequences of common parking policies, and suggest policy options to protect the environment and increase social welfare.

The environmental consequences of parking manifest themselves in open space and biodiversity losses caused by the construction of parking space, and in emissions of greenhouse gases and air pollutants occurring while cars are cruising for parking. Economic consequences are reflected in the time costs incurred while cruising for parking, and in time losses from traffic congestion caused by cruising. These costs come on top of construction and maintenance costs, as well as the opportunity costs of alternative land uses. As long as these environmental and economic costs are not reflected in parking prices and decisions over parking supply, they cause social welfare losses. This is a common failure, which also induces individuals to underestimate car use costs and, thus, travel more kilometres and cause more emissions of greenhouse gases and air pollutants, and more congestion. In the absence of road pricing schemes internalising these externalities, this additional travel inflates welfare losses.

The environmental problems and welfare losses associated with parking are largely caused by policies encouraging parking space oversupply and parking prices set lower than the social costs of provision. This paper discusses policies in the context of on-street parking, parking allocated to residents, parking provided by employers to employees, and parking in shopping malls and commercial downtown areas. The discussion focuses on the environmental, economic and social effects of these policies, as well as on examples of good parking policy practices from a number of OECD cities.

Based on this discussion, the paper provides a set of suggestions for the development of more efficient and environmentally sustainable parking policies. Key suggestions pertain to: (i) appropriately pricing on-street parking and residential parking permits to prevent both cruising and capacity underutilisation; (ii) reviewing, and if possible removing, minimum parking restrictions for new residential and office buildings to eliminate parking overprovision and increase housing affordability; (iii) reconsidering exemptions of employer-paid parking from income taxation; and (iv) encouraging employers to offer the cash equivalent of the parking subsidy to employees who do not receive free (or subsidised) parking. Such policy changes may not only lead to economic efficiency gains and environmental improvements, but also to higher government revenue. Most of the suggested changes are also likely to lead to distributional benefits. In the cases where vulnerable population groups are negatively affected by some of these changes, these groups can be compensated through targeted complementary measures.

Keywords: Parking pricing, environmental impact, welfare effect, parking requirement, employer-provided parking.

JEL codes: Q58, R48, R52.

Résumé

Les politiques de stationnement ont des implications environnementales et économiques importantes, qui ont souvent été négligées. Ce document de travail passe en revue la littérature pour mieux comprendre les principales conséquences environnementales et

économiques des politiques de stationnement et suggère des options politiques pour protéger l'environnement et accroître le bien-être social.

Les conséquences environnementales du stationnement se manifestent dans les pertes d'espaces verts et de biodiversité causées par la construction de places de stationnement, ainsi que dans les émissions de gaz à effet de serre et de pollution atmosphérique se produisant lorsque les voitures roulent pour se garer. Les conséquences économiques se reflètent dans les coûts en temps liés à la recherche de place de stationnement, ainsi que dans la perte de temps due à la congestion du trafic provoquée par cette recherche. Ces coûts s'ajoutent aux coûts de construction et d'entretien, ainsi qu'aux coûts d'opportunité d'autres utilisations de l'espace. Tant que ces coûts environnementaux et économiques ne sont pas reflétés dans les prix de stationnement et les décisions de fourniture de places de stationnement, ils entraînent des pertes de bien-être social. Il s'agit d'une défaillance de marché courante, qui pousse les individus à sous-estimer les coûts liés à l'utilisation de la voiture et, par conséquent, à parcourir plus de kilomètres, à générer davantage d'émissions de gaz à effet de serre et de polluants atmosphériques et davantage de congestion. En l'absence de systèmes de tarification routière internalisant ces externalités, ces déplacements supplémentaires gonflent les pertes de bien-être.

Les problèmes environnementaux et les pertes de bien-être associées au stationnement sont en grande partie causés par des politiques encourageant la surabondance de places de stationnement et par des prix de stationnement inférieurs aux coûts sociaux de leur fourniture. Ce document traite des politiques dans les domaines du stationnement sur la voie publique, du stationnement attribué aux résidents, du stationnement fourni par les employeurs aux employés et du stationnement dans les centres commerciaux et les zones commerciales du centre-ville. La discussion porte sur les effets environnementaux, économiques et sociaux de ces politiques, ainsi que sur des exemples de bonnes pratiques en matière de politique de stationnement dans plusieurs villes de l'OCDE.

Sur la base de cette discussion, ce document fournit un ensemble de suggestions pour l'élaboration de politiques de stationnement plus efficaces et plus respectueuses de l'environnement. Les principales suggestions concernent: (i) la tarification appropriée de stationnement sur la voie publique et des permis de stationnement résidentiels afin d'éviter à la fois l'effort de recherche d'une place de stationnement et la sous-utilisation des capacités existantes; (ii) revoir et, si possible, supprimer les restrictions de stationnement minimales pour les nouveaux immeubles résidentiels et de bureaux afin d'éliminer la surproduction de places de stationnement et d'accroître l'abordabilité du logement; (iii) Intégrer les avantages réels procurés par les employeurs à leurs employés en matière de stationnement dans le revenu imposable ; et (iv) inciter les employeurs à donner le choix à leurs employés d'avoir une place de parking ou un paiement forfaitaire équivalent au loyer de stationnement. De tels changements de politique peuvent non seulement conduire à des gains d'efficacité économique et à des améliorations de l'environnement, mais également à une augmentation des recettes publiques. La plupart des modifications suggérées sont également susceptibles de générer des effets distributifs. Quand ces mesurent affectent négativement la catégorie de population à faible revenus, il faut envisager des mesures compensatoires complémentaires.

Mots clés: prix du stationnement, impact environnemental, effet de bien-être, besoin de stationnement, stationnement fourni par l'employeur.

Codes JEL: Q58, R48, R52.

Foreword

This report has been authored by Antonio Russo (ETH Zurich), Jos van Ommeren (VU University Amsterdam) and Alexandros Dimitropoulos (OECD Environment Directorate). The authors are grateful to delegates to the Working Party on Integrating Environmental and Economic Policies for helpful comments on earlier drafts of this paper. They would also like to thank Shardul Agrawala, Aimée Aguilar-Jaber, Elisabetta Cornago, Wei-Shiuen Ng and Walid Oueslati for input and comments on previous versions of the paper. Katjusha Boffa and Aziza Perrière provided editorial assistance. The authors are responsible for any remaining omissions or errors. Work on this paper was conducted under the overall responsibility of Shardul Agrawala, Head of the Environment and Economy Integration Division.

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1. Introduction

Car travel causes important negative externalities, including emissions of greenhouse gases and air pollutants, road congestion, noise and traffic accidents.[1] While the environmental and other external costs of car travel have been the object of numerous research efforts, much less attention has been paid to the investigation of the negative externalities associated with another important dimension of car use: *parking*.

This is probably surprising given that the average car is parked roughly 95% of the time and large amounts of land are consumed by parking (Inci, 2015[1]). For instance, in the United States, the land allocated to parking is roughly equal to the size of the state of Massachusetts (Jakle and Sculle, 2004[2]). The estimated social cost of a parking spot varies significantly across space, but it is particularly high in urban areas.

Provided its importance in terms of land use and its decisive role in car ownership and travel decisions, parking deserves a much higher level of scrutiny than the one it has thus far received. This also holds for parking policies: despite usually being developed at the local level, their implications often extend beyond local – and sometimes also national – administrative boundaries.

The objective of this paper is to fill this gap by providing a better understanding of the environmental and economic consequences of parking policies in different parts of the world, and propose a set of policy changes to tackle these consequences and increase social welfare. To achieve this objective, the paper relies on an extensive review of the relevant literature, drawing, as much as possible, on real-world policy examples from Europe, North America, Oceania, and East and Southeast Asia. Despite most of the discussion focusing on OECD cities, examples from parking policies in countries outside of the OECD, such as Brazil, Singapore and Thailand, are also provided.

The environmental and economic consequences of parking occur through land-use change and increased car use. Paving land to provide parking spaces entails open space and biodiversity losses, which can be particularly important in suburban areas. Furthermore, drivers parking in busy downtown areas cause a negative externality to other users who have to continue driving around the vicinity of their destination in search of a vacant parking spot. This activity, denoted by the term *cruising for parking* (Shoup, 2005[3]), implies significant time costs, aggravates congestion and pollution, and increases greenhouse gas emissions. However, cruising is not the only channel through which parking induces more car use, and therefore more congestion and emissions: abundant supply of parking at low prices reduces the costs of car travel and induces more individuals to drive – instead of using other transport modes – to reach their destinations.

The environmental and economic problems associated with parking are largely the result of policies encouraging the oversupply of parking space and parking tariffs set at levels lower than the social costs of parking provision. Common parking policies – and policy failures – are reviewed in this paper along four types of parking: on-street (curbside)

[1] External costs occur when a production or consumption activity imposes costs on others which are not reflected in the prices of goods or services being produced or consumed. For example, in the absence of corrective taxes, the emissions produced by a car are an external cost, as the environmental and health damages they cause are typically ignored by the car driver.

parking; parking allocated to residents (e.g. through special permits); parking provided by employers to employees; and parking in shopping malls and downtown commercial areas. The review also briefly alludes to interactions between parking and car-sharing, alternative transport modes, street design, vehicles with low CO_2 emissions and autonomous cars.

The remainder of the paper proceeds as follows. Section 2 describes the main environmental and economic consequences of parking. Section 3 reviews common parking policies in urban areas, and discusses their main implications for the environment and social welfare. Section 4 concludes and provides a set of suggestions for the development of more economically efficient and environmentally sustainable parking policies.

2. The effects of parking on the environment

This section discusses the main environmental implications of parking. It first explains the relationship between parking, car ownership and car use and describes its implications for congestion and emissions of greenhouse gases and pollutants. The discussion then turns to the effects of the provision of parking space for land use and the associated loss of open space and biodiversity.

2.1. Effects of parking on car ownership and use

Parking accounts for a substantial share of the costs of car ownership and use. For example, the total private costs of parking provision for a typical vehicle in U.S. urban areas have been estimated to be about half of the annual generalised costs of car ownership and use. These are the costs that drivers would incur in the absence of parking subsidies – without taking into account the external costs of parking. However, drivers pay directly only 20-25% of private parking costs (Litman and Doherty, 2018[4]). Employer-paid parking, on-street parking subsidies, and parking provided for free at shopping malls and downtown commercial areas induce them to underestimate the costs of owning and using a car by about 40%. Parking subsidies, or alternatively the incorporation of parking costs in lower wages, higher rents or higher product prices, have a simple adverse implication: individuals buy more cars and use them more. So do also regulations requiring a generous supply of parking spaces in residential and office buildings: excessive parking supply stimulates car ownership and use.

Empirical evidence suggests that parking space availability has a significant impact on car ownership. For example, residential parking space availability in New York City has been shown to be a more important determinant of car ownership than income and other household characteristics (Guo, 2013[5]). At the same time, the residential parking price elasticity of car ownership in central Amsterdam has been estimated to be around -0.8: a 10% increase in residential parking prices is associated with an 8% reduction in car ownership (De Groote, van Ommeren and Koster, 2016[6]). Even though the elasticity may be lower in cities where parking is cheaper and where travelling by other transport modes, such as public transport and bicycles, is not as a close substitute to car travel as in

Amsterdam, this finding suggests that the underpricing of parking significantly contributes to car ownership.

Some back-of-the-envelope calculations can provide further insights into the relevance of implicit subsidies to parking for car ownership. For concreteness, it is useful to focus on parking provided for free by employers to their employees. The costs incurred by firms to provide parking in typical European and North American urban areas have been estimated to be between EUR 5 and 10 per day per parking spot (Litman and Doherty, 2018[4]). To be conservative, one can take the lower bound of this interval. Assuming 200 working days per year, the implicit subsidy to a car commuter is EUR 1000 per year. Considering an average vehicle lifetime of 10 years (and for simplicity neglecting discounting), the total implicit subsidy is EUR 10 000. This value is almost as high as the retail price of a small car. In fact, it is comparable to the size of taxes that many countries impose on car ownership. In principle, these taxes serve the purpose of internalising some of the external costs of car ownership, among other possible objectives. However, the above calculation suggests that some of the implicit parking subsidies, such as the ones on employer-provided parking, can completely undermine this purpose.

In addition to increased car ownership, the underpricing of parking space induces more car travel. As already mentioned, a common cause of additional car travel is cruising for parking, with estimates of the share of cars cruising in downtown traffic ranging from 8 to 74 percent depending on the city (Shoup, 2006[7]). Cruising is the result of an unpriced (or underpriced) external cost: the time cost that a driver occupying a parking space imposes on those who are in search of a vacant space in that vicinity. This external cost varies across space and its magnitude increases with the attractiveness of the location where the parking space is located (Small and Verhoef, 2007[8]).

Cruising does not only imply more vehicle-kilometres travelled: cars cruising for parking contribute to congestion and pollution disproportionately, as they slow down other vehicles (Inci, 2015[1]). These additional vehicle-kilometres travelled in slow speeds and congested streets of urban areas have significant environmental costs. They considerably increase CO_2 emissions and cause outdoor air pollution exactly where it is most harmful for human health: at the core of urban areas.

The underpricing of parking space also leads to more car trips. For example, car owners in New York City are more likely to commute by car when they have access to free parking in proximity of their home (Weinberger, 2012[9]). Again, a simple calculation suggests that the effect is important. Taking the conservative cost estimate of EUR 5 per day per parking spot that was used above, and assuming that the cost of a commuting trip by car (excluding parking) is about 2.4 times that value,[2] the supply of free parking to employees implies a subsidy equal to around 30% of the private costs of the trip. Considering also a demand elasticity of car use with respect to private costs equal to -0.5 (Litman, 2017[10]), the demand for car commuting is inflated by about 15% due to the provision of free parking at the workplace.

2 This approximate calculation assumes an average length of a commuting trip of 18 kilometres and duration of 25 minutes, consistent with the study by Pasaoglu et al. (2012[15]) and the data provided in United States Census Bureau (2017[61]). It also assumes a value of in-vehicle travel time of USD 13 per hour, equal to about 50% of the average gross hourly wage (Bureau of Labor Statistics, 2018[63]; Parry and Small, 2009[57]), an average fuel economy of 24 miles per gallon (Federal Highway Administration, 2016[13]) and a retail price of gasoline of USD 0.63 per litre (IEA, 2018[62]).

It is also possible to try to evaluate the environmental consequences of the supply of free parking to employees, focusing e.g. on CO_2 emissions. Commuting trips account for about 21% of vehicle miles travelled in the United States and 95% of car commuters park for free (American Association of State Highway and Transportation Officials, 2013[11]; Shoup, 2005[12]). In 2016, passenger cars and light-duty vehicles travelled around 1.614 trillion urban miles with an average vehicle fuel efficiency of 24 miles per gallon (mpg) (Federal Highway Administration, 2016, pp. Table VM-1[13]). This implies that commuting trips in 2016 were responsible for 338.9 billion miles travelled and for the consumption of about 14.1 billion gallons of gasoline. Taking into account the estimate of 15% provided in the previous paragraph, free parking at the workplace is responsible for the emission of at least 17 million tonnes of CO_2 annually in the United States alone.[3]

Given the lower fuel consumption of cars in Europe, the size of the effect of subsidised parking on CO_2 emissions is likely to be smaller, but far from negligible. For instance, assuming average passenger car emissions of 160 grams CO_2 per kilometre (Fontaras, Zacharof and Ciuffo, 2017[14]), an average length of a (one-way) commuting trip of 18 kilometres (Pasaoglu et al., 2012[15]) and 200 working days per year, the average European car used for commuting emits about 1.15 tonnes of CO_2 per year. Assuming a demand elasticity of car use of -0.5, free parking at the workplace is responsible for the emission of around 0.17 tonnes of CO_2 per car parking for free annually.[4]

The calculations above take under consideration only environmental consequences in terms of greenhouse gas emissions. However, car travel is also responsible for the emission of air pollutants, which poses important health risks, particularly in urban areas. Health risks from additional car travel will be higher where population density is higher and cars are more polluting. Given the popularity of (more polluting) diesel cars in Europe and the higher density of European urban areas compared to American ones (OECD, 2018[16]), the air pollution and health consequences of free parking at work are likely to be larger in Europe.

Parking policies interact with other instruments aimed at addressing the negative externalities of car travel. Economic efficiency and environmental effectiveness require that greenhouse gas emissions, air pollution, congestion, noise and road accidents from car travel are internalised through targeted policy instruments, such as road pricing and motor fuel taxes. However, road pricing has only been implemented in very few urban areas - and in most cases in a way that does not fully account for the spatial and time variation of the costs of car travel, while motor fuel taxes are in many cases set at lower than optimal levels. In the absence of (optimal) road pricing and/or motor fuel taxes, parking tariffs can serve

3 Every litre of gasoline consumed creates about 2.32 kilograms of CO_2.

4 This calculation further assumes a value of in-vehicle travel time of EUR 10 per hour (Eurostat, 2018[65]; Parry and Small, 2009[57]), a fuel efficiency of 6.9 litres/100 km (the equivalent of average CO_2 emissions of 160 grams per kilometre), and a gasoline price of EUR 1.3 per litre (IEA, 2018[62]).

the purpose of internalising the external costs of car travel to some extent.[5,6] By the same token, the implicit subsidies to parking aggravate the distortions related to excessive car travel where road pricing and motor fuel taxes have not been introduced or are set at suboptimal levels.

2.2. Effects of parking on land use

Parking is responsible for the consumption of enormous amounts of land worldwide. Road infrastructure, including parking, covers between 1.8% and 2.1% of total land area in France, Germany, and the United Kingdom, and 3.5% in Japan (Kauffman, 2001[17]; Litman, 2012[18]). On-street parking space typically represents 20-30% of urban road space (Litman, 2012[18]). As any other type of land use, parking implies opportunity costs of unpursued alternative land uses, such as residential or commercial development, that are typically reflected in land prices.[7] These costs are prominent in many cities and are compounded by the loss of potential revenue for local governments that alternative land uses would generate. This stresses the importance of pricing public parking space (e.g. on-street or in public garages) at its marginal social costs of provision, of which the opportunity costs of land use are an important component.

Building parking spaces has important environmental costs which, in the absence of corrective taxes, are neglected by developers and not reflected in land prices. These costs are due to the loss of open space and biodiversity and can be particularly high in certain areas. For example, allocating large amounts of land at the edge of urban areas to parking development can lead to important welfare losses if parking prices do not reflect the value of the lost open space and biodiversity. More importantly, such development plans may have never been realised, had these external costs been taken into account from the outset.

As will be discussed in more detail in Section 3, the costs of land consumption associated with parking are to some extent related to inefficient policies. Generous minimum parking restrictions are among the most important reasons behind the overallocation of land to parking space. Such restrictions are often designed to cover peak demand for *free* parking, entailing that developers have to provide much more parking than what they would under efficient market conditions. Another policy leading to overconsumption of land to construct parking spaces is the provision of free parking permits to residents of urban centres. As a majority of parking spaces is allocated to permit holders, additional land needs to be

5 This holds mainly for the external costs of car travel at the very local level, i.e. in the vicinity of the parking space. Nevertheless, parking tariffs cannot account for the distance driven by each car to reach the parking space, and therefore for its exact contribution to congestion and pollution. Furthermore, parking tariffs cannot be used to price the negative externalities caused by pass-through trips (Glazer and Niskanen, 1992[64]; Small and Verhoef, 2007, p. 154[8]). Last, the effectiveness of parking tariffs in internalising the external costs of car travel also depends on the availability and price of parking spaces in locations nearby the driver's destination. If parking supply in the neighbourhood (e.g. in private garages) is high, parking tariffs will be even less effective in internalising these costs.

6 For a comparison of the effectiveness of an increase in daily parking fees and a hypothetical cordon-based congestion charge in reducing car trips in Chicago, see Miller and Wilson (2015[66]).

7 Other alternative land uses in busy downtown streets are, for instance, manifested in the concept of *parklets*, i.e. pavement extensions covering multiple parking spaces, which are intended to facilitate the activities of pedestrians (e.g. walking or resting) or cyclists (e.g. if bike-parks are installed on them), or to provide other urban amenities (e.g. green spaces).

converted to accommodate demand from non-residents (e.g. shoppers). That space is costly to build and is profitable only because the willingness to pay per hour of non-residents is high.

Not only do parking subsidies and minimum parking restrictions have direct effects on land consumption, they also indirectly lead to the conversion of more land. By inducing commuters to underestimate the costs of car trips, such policies encourage households to move further away from their job locations and live in low-density areas. This entails a sprawled urban development and more land being converted to artificial areas (OECD, 2018[16]; Willson, 1995[19]).

3. Parking policies

This section provides a review of parking policies commonly implemented in urban areas and their implications for the environment and social welfare. It focuses on policies for on-street (curbside) parking and parking in shopping centres and downtown commercial areas, the provision of parking by employers to employees, and residential parking policies. The discussion revolves around a number of parking policy instruments in the hands of local and national (or state / provincial) governments, presented in Table 1. The table classifies instruments by type, i.e. command-and-control regulation vs. pricing instruments, and shows the parking type to which they apply. The section also briefly discusses interactions between parking and car-sharing, alternative transport modes, street design, autonomous cars and incentives for vehicles with low CO_2 emissions.

Table 1. Summary of discussed parking policies

	On-street parking	Residential parking	Employer-provided parking	Parking in malls and downtown commercial areas
Command-and-control regulatory policies				
On-street parking supply	✓	✓		✓
Minimum and maximum parking restrictions		✓	✓	✓
Maximum duration restrictions	✓			✓
Market-based policies				
Parking pricing	✓	✓		✓
Residential parking permits		✓		
Fringe benefit taxation			✓	
Parking cash-outs			✓	

3.1. On-street parking

One of the most important aspects of parking in urban areas is its interaction with road congestion, primarily due to cruising for parking (see Section 1 for a definition). A survey

of early studies on cities in the United States and elsewhere finds that a non-negligible share of cars in downtown traffic are searching for a parking spot, spending on average about 8 minutes cruising for parking per trip (Shoup, 2006).

Cruising for parking is essentially a side-effect of parking space underpricing. When the price of parking is too low, demand for on-street parking exceeds supply and saturation of parking space occurs. Thus, some cars must drive around looking for a free spot. This is inefficient for two reasons. First, not only is cruising a negative externality per se, but it also aggravates externalities from driving. In addition to the time costs incurred by drivers searching for a vacant spot, cruising increases road congestion and environmental costs. As cruising cars tend to drive slower than in-transit traffic, they contribute disproportionately to congestion, greenhouse gas emissions and air pollution. Using data from Istanbul, Inci, van Ommeren and Kobus (2017[20]) show that the time costs of cruising for parking can be of the same order of magnitude as the congestion costs generated in transit from origin to destination. Second, parking users pay with their time, rather than with their money, thus depriving governments of a non-distortionary source of revenue. Governments are then more likely to seek to collect these forgone tax revenues from distortionary sources, such as labour.

Analytical work based on stylised models provides further insights into the determining role of efficient parking pricing for cruising. In their theoretical framework, Arnott and Inci (2006[21]) make a simple recommendation: because curbside parking capacity is fixed in the short run, the optimal parking price should be so high that at least one parking spot is always available. In other words, no cruising should take place in equilibrium. Inci and Lindsey (2015[22]) analyse the interaction between curbside parking pricing and parking garages. The issue is important because garages provide additional capacity that can alleviate curbside parking congestion. However, privately owned garages have market power, and may therefore charge inefficiently high tariffs. Nevertheless, under the assumption of inelastic parking demand, the government does not need to regulate parking garages if it sets curbside parking prices optimally.

In most cities around the world, on-street parking in busy downtown areas is saturated, indicating that prices are too low. This is typically the case in North American cities, although these cities impose certain maximum duration restrictions (e.g. one-hour parking). In principle, optimal space- and time-varying pricing would make duration limits unnecessary. However, when pricing of parking spaces is not optimal, duration limits can eliminate cruising by discouraging long-term parking users (Arnott and Rowse, 2013[23]). Recently, the city of San Francisco implemented a pilot system employing space- and time-varying parking prices, called *SFpark*: the system is described in more detail in Box 1.

Box 1. The SFpark system in San Francisco, CA, USA

The *SFpark* is a system for managing on-street parking, run by the San Francisco Municipal Transportation Agency. It employs smart parking meters that change prices according to location, time of day, and day of the week. Parking usage is monitored via sensors placed in the asphalt, and users can check the availability of parking and prices via the internet and on mobile apps. Prices are designed with the objective of keeping an average occupancy rate between 60 and 80% in any given block. The idea is to eliminate cruising by ensuring that drivers are always able to find a parking spot.

In April 2013, prices ranged from USD 0.25 to USD 6 per hour during morning and afternoon hours. In addition to on-street parking, fourteen city-owned garages are included in the program (see (Pierce and Shoup, 2013[24]) for a detailed description of the scheme). Ex-post evaluations of the programme not only indicate that parking tariffs marginally decreased on average, but also that cruising declined by about 50% in the first two years of implementation (Millard-Ball, Weinberger and Hampshire, 2014[25]). This means that, overall, drivers are better off thanks to the introduction of the system.

The experiment has attracted attention from other cities (e.g. Mexico City and Milan). Similar demand-response pricing approaches based on target occupancy rates have been implemented in various areas of the cities of Calgary (Canada), Rotterdam (the Netherlands), Auckland (New Zealand), and Los Angeles and Seattle (United States) (GIZ and SUTP, 2016[26]).

Sources: GIZ and SUTP, 2016; Millard-Ball, Weinberger and Hampshire, 2014; Pierce and Shoup, 2013.

The low curbside parking prices in American cities contrast sharply with the policy adopted in several Asian cities (e.g. Seoul, Singapore, Tokyo), where on-street parking is severely restricted (Asian Development Bank, 2011[27]). Box 2 briefly draws on some aspects of parking policy in Japanese cities. Curbside parking prices are also higher in several European cities. For instance, in central Amsterdam, non-resident parking users pay between EUR 20 to 40 per day for curbside parking.

Several cities try to coordinate the on-street and off-street parking prices and supply. The French city of Strasbourg, for example, has implemented a harmonised pricing structure with curbside parking in the inner city charging the highest hourly tariffs, and off-street parking in the outer city charging the lowest ones. The implementation of the policy required extensive negotiations and the establishment of public-private partnerships with garage owners (Kodransky and Hermann, 2011[28]).

From a political economy perspective, increasing on-street parking tariffs is a challenging task, likely to encounter the opposition of local communities. To increase public acceptability of parking fee rises, it is possible – even though generally economically inefficient – to earmark a part of the parking revenues for projects improving quality of life in neighbourhoods facing parking tariff increases (Inci, 2015[1]). This idea underlies, for example, the implementation of the *ecoParq* programme in central Mexico City, where 30% of on-street parking revenues are set aside for projects aiming at the regeneration of local neighbourhoods. Projects are selected through a public consultation process (OECD, 2015[29]; Ríos Flores, Vicentini and Acevedo-Daunas, 2015[30]).

Box 2. Japan's proof-of-parking rule

Japanese law requires motorists to prove that they have access to a local parking space when registering a car, or when changing address. In both cases, motorists need to obtain a "parking space certificate" ("garage certificate") from the local police. The rule was enacted in 1962 and initially applied only to large cities (Steiner, 1965[31]). However, it has gradually been extended also to smaller ones. On top of requiring proof of parking, Japanese law puts stringent restrictions on on-street parking. It essentially bans parking on streets. Exceptions allow some daytime and evening on-street parking, but not overnight parking. Although these measures are effective at curbing car use and ownership, their stringency may have unintended consequences. For example, a side-effect of Japan's proof-of-parking regulation was that it encouraged a market for off-street parking places for lease (Asian Development Bank, 2011[27]).

Sources: Asian Development Bank (2011), Steiner (1965).

Enforcement of on-street parking policies

On-street parking regulation and pricing can only be effective if they are properly enforced. Yet, enforcement is a challenge in many cities, owing to the lack of sufficient resources or of strong incentives for local authorities. Where parking revenues are collected and managed by local authorities, enforcement incentives are strong; in contrast, where revenues are obtained by higher levels of government, incentives for enforcement are weaker.

Better enforcement of parking policies can be achieved through a closer and more frequent monitoring of parking space use, as well as through the establishment of higher fines for violators. Closer monitoring implies devoting more resources to enforcement, which might be very challenging for smaller and less affluent cities. Where resources are particularly scarce, it might be worth concentrating efforts on areas where non-compliance causes the greatest problems, such as arterial roads and busy downtown streets (Litman, 2016[32]). Higher fines can be effective in discouraging parking violations in the short run, but long-term compliance can only be ensured if the likelihood of being fined is perceived as substantial by potential violators.

Some countries in Asia and Europe, such as Japan and the United Kingdom, have recently taken measures towards better enforcement. These include outsourcing of enforcement duties to private contractors and reforming the local public finance system to allow local governments to keep a larger share of the revenue collected from parking, in a bid to strengthen incentives. Some cities have adopted more direct enforcement mechanisms. For example, Amsterdam has implemented a system where a van photographs and scans license plate numbers using Automated Number Plate Recognition technology (Kodransky and Hermann, 2011[28]). Such measures increase the efficiency of parking enforcement by reducing, sometimes dramatically, the costs of monitoring parked vehicles.

3.2. Residential parking

Minimum and maximum parking requirements

In numerous OECD cities, minimum parking requirements apply to residential and office buildings. Historically, residential buildings had to include at least one parking space per residential unit, and commercial and office buildings had to have a minimum number of parking spaces per square meter. In the United States, minimum parking requirements have usually been established with a view to satisfy peak demand for free parking (Shoup, 1997[33]; Shoup, 1999[34]). Instead of being tailored to the needs of the neighbourhood where they would be applied, minimum parking requirements were widely determined by consulting requirements in neighbouring cities (see e.g. Jakle and Sculle, 2004[2]).

Unfortunately, minimum parking requirements create a perverse incentive for developers to build more parking than the market requires and stimulate car use. Empirical evidence from Los Angeles and New York confirms that they lead to a higher parking supply, more vehicles on the road and a lower population density (Cutter and Franco, 2012[35]; Manville, Beata and Shoup, 2013[36]). On top of distorting commuters' mode choices, they cause excessive land consumption (Brueckner and Franco, 2017[37]). Minimum parking requirements also harm housing affordability, as they decrease the costs of driving at the expense of increasing development costs (Litman, 2016[38]; Manville, 2013[39]; Shoup, 1999[34]). The effect can be significant, as it has been estimated that parking accounts for about 10% of the development costs of a typical building (Litman and Doherty, 2018[4]).

Minimum parking requirements are ubiquitous in OECD countries, but also in emerging economies. For example, the cities of Bangkok, Kuala Lumpur, Rio de Janeiro and São Paulo have high requirements, averaging above 2 spaces per 100 square meters of floor space (Asian Development Bank, 2011[27]; Ríos Flores, Vicentini and Acevedo-Daunas, 2015[30]). However, these are still much lower than the very high requirements in some suburban areas of Australia or the United States, which are in the order of 3 to 4.3 spaces per 100 square meters (Asian Development Bank, 2011[27]; Shoup, 2005[3]). A likely explanation for such requirements is the concern over possible parking shortages (Shoup, 2005[3]), which is also related to the management of on-street parking spots. Cities that handle on-street parking effectively, e.g. by providing it at prices high enough to ensure low saturation levels, should also be less concerned about shortages of residential parking. Therefore, they should be less prone to adopting high minimum parking requirements.

Instead of regulating minimum parking supply, several major OECD cities, including Chicago, London, New York City, Paris, Seoul, Sydney and Toronto, have moved towards adopting *maximum* parking requirements for particular land uses (Guo and Ren, 2013[40]). Empirical evidence of the effectiveness of replacing minimum parking requirements with maximum ones comes from London's 2004 major parking policy reform. The reform led to a remarkable 49% reduction of parking spaces in new residential developments, freeing up space for other uses. The largest part of this reduction was attributed to the removal of minimum parking requirements, particularly affecting developments in the area of Inner London. Maximum parking restrictions were more impactful in suburban developments (Li and Guo, 2014[41]). In 2017, Mexico City also replaced its minimum with maximum parking requirements, which amount to a maximum of three parking spaces per housing unit for residential parking (Government of Mexico City, 2017[42]; Institute for Transportation and Development Policy, 2017[43]).

Residential parking permits

Many cities provide residents with preferential access to curbside parking space. Specifically, they issue parking permits to residents (in the area in proximity to their home) at much lower prices than the curbside rates charged to non-residents. Differences between the two rates can be very large, especially in cities that charge high curbside parking fees, such as London. For example, in the borough of Kensington and Chelsea, 86% of the 34 000 on-street parking spaces are allocated to residential permit holders only, and the number of permits exceeds the number of street parking spaces (Royal Borough of Kensington and Chelsea, 2014[44]). While residents pay on average slightly more than GBP 0.30 per day for a parking permit, the parking costs for non-residents are at least 40 times higher, i.e. GBP 15 per day or GBP 1.2 per hour.[8]

Offering parking to residents at lower prices is often justified in residents' financial contribution to the construction and maintenance of local road infrastructure through local taxes. However, incorporating parking provision costs in local taxes is both economically inefficient and potentially regressive. This holds because resident households without cars have to incur part of the financial burden of providing parking space to resident car users. In such cases, revenue-neutral tax reforms where increases in the prices of residential parking permits are accompanied by reductions in local taxes may lead to both economic efficiency gains and distributional benefits.

There are at least two sources of inefficiency associated with underpriced residential permits. First, in areas that attract substantial non-residential traffic, discounted residential parking implies that parking space is potentially misallocated: residents' willingness to pay for parking might be much lower than the opportunity cost of occupying the parking space (including the willingness to pay of non-residents and the external costs of cruising). However, residents' willingness to pay most likely exceeds the price they pay for permits. For example, empirical evidence from Amsterdam shows that residents are willing to pay, on average, about EUR 10 per day for a reserved curbside parking spot, although they pay only EUR 0.4. Furthermore, the tariff charged to non-residents is much higher: between EUR 20-40 per day (van Ommeren, Wentink and Dekkers, 2011[45]). Given the presence of cruising for parking in many areas, this implies that visitors are willing to pay much more than residents for curbside parking. The reason is that visitors stay only for a few hours, so their marginal willingness to pay per hour is larger than that of residents.

The second inefficiency caused by underpriced residential parking permits is that they drive up the costs of providing parking space. Because curbside parking is granted to residents for a very low price, additional parking space is needed to accommodate non-residents (e.g. shoppers). Local authorities and private firms invest in downtown parking garages that are costly to build and thus profitable only because of the extra demand by non-residents (whose willingness to pay is high). Empirical evidence from Dutch shopping districts show that residential permits are responsible for a 15% increase in parking provision costs, on average, and the associated social loss is about EUR 275 per permit per year (van Ommeren, de Groote and Mingardo, 2014[46]).

8 See www.rbkc.gov.uk/parking-transport-and-streets/residents/permit-charges, and www.rbkc.gov.uk/pdf/Pay%20and%20Display%20Parking%20Tariff%20map-%20April%202015-%2030010%20.pdf (accessed on 19 January 2018).

Some European cities have pioneered radically different approaches to manage, rather than accommodate, residential parking. An interesting example of such an approach comes from Zurich, Switzerland, and is described in Box 3.

Box 3. Parking caps in Zurich

Since 1996, the city of Zurich in Switzerland, has adopted the "Historic parking compromise". This policy encompasses a series of measures, including a progressive increase in on-street and off-street parking tariffs. However, perhaps its most notable aspect is the overall cap on parking spaces inside the city centre: some publicly accessible on-street parking spaces are allocated to other purposes (e.g. bikeways) and replaced with an equal number of off-street spaces (in parking garages). The total number of parking spaces may not be changed.

In less central areas, the city recognises the connection between parking management and overall transport policy. Locations with good public transport access must reduce the number of parking spaces allowed in new developments. Furthermore, developers are allowed to construct new parking spaces only if it is assessed that surrounding roads can bear additional car traffic without getting congested. Parking caps are also considered as long as air pollution exceeds annual limit values (Kodransky and Hermann, 2011[28]).

Source: Kodransky and Hermann, 2011.

3.3. Employer-provided parking

In most countries, employers provide parking to their employees for free or at very low rates (Shoup, 2005[12]; van Ommeren and Wentink, 2012[47]). For example, data from the 1995 U.S. Nationwide Personal Transportation Survey reveal that 95% of car commuters in the United States park for free at work (Shoup, 2005[12]). Estimates for cities in other OECD countries are below this number, but it is rare that more than half of car commuters pay for parking at work. In New Zealand, for example, stated preference data show that 76% of car commuters park for free in Auckland, 73% in Christchurch, and 58% in Wellington (O'Fallon, Sullivan and Hensher, 2004[48]). Furthermore, the fringe benefit of free (or subsidised) parking at work is usually exempt from income taxation (Shoup, 2005[12]).[9]

Just as for curbside parking, economics suggests that free provision (or provision at very low rates) is inefficient. Although employers pay for the provided parking spaces, they give them out at a cost that often exceeds commuters' willingness to pay. This implies a welfare loss, as parking spaces are developed at costs higher than consumers' willingness to pay for their use.

In addition, tax-exempt subsidised parking at the workplace distorts commuter choices and encourages commuting by car. Employer-paid parking is a subsidy that commuters are

[9] Employers have incentives to provide part of employees' compensation in the form of such fringe benefits, as they usually do not have to pay social security contributions on them, while employees have incentives to welcome such benefits as they might be exempt from taxation or be taxed at lower rates than their income.

eligible for only if they drive to work. Furthermore, the benefit from the parking subsidy decreases with the number of passengers in the car. Employer-paid parking not only encourages commuting by car; it also discourages car-pooling for the benefit of single-occupant driving. Results from case studies in the United States and Canada show that employer-paid parking increases on average the number of cars driven to work (per 100 employees) by about 36% and the share of commuters driving to work by 60% (or 25 percentage points) (Shoup, 2005[12]). Drawing on the results of a mode choice model estimated on data for commuters to downtown Los Angeles (Willson, 1992[49]) and assuming a parking price of USD 5 per day, Shoup (2005[12]) estimates that untaxed employer-paid parking leads to an additional 1 311 vehicle miles travelled (VMT) per employee per year.

Commuters drive to work instead of using more environmentally friendly transport modes (e.g. public transport), increasing, thus, greenhouse gas emissions, air pollution, noise and congestion. Unless all these external costs are internalised, this induced demand for car travel aggravates the welfare loss discussed above.

Free provision of workplace parking is also encouraged by minimum parking requirements for office buildings and other workplaces. The binding nature of such restrictions implies that there is an excess supply of parking, incentivising free provision (Shoup, 2005[3]). Van Ommeren and Wentink (2012[47]) quantify welfare losses from the exemption of employer-paid parking from income taxation, and from minimum parking requirements, using Dutch real estate data. They show that the tax exemption of employer-paid parking induces deadweight losses equal to about 10% of parking resource costs. In addition, hypothetical minimum parking requirements of the levels applied in the United States would induce deadweight losses of around 18% of resource costs.

Recognising that perverse incentives may cause overprovision of parking, several cities have considered taxing companies that provide free parking to employees. For instance, the city of Nottingham in the United Kingdom recently adopted a tax of up to GBP 250 per year per parking space provided by companies to their employees. Other cities are revising their minimum parking regulations. For example, the city of Hamburg in Germany reduces minimum parking requirements for companies that provide public transport passes to employees (Kodransky and Hermann, 2011[28]).

Parking cash-outs

From a policy perspective, removing free parking at work or its exemption from income taxation is a challenging endeavour. Free parking at work is entrenched in commuters' minds and policies to remove the relevant subsidies are likely to encounter opposition from employees. A related policy often praised for its potential effectiveness and acceptability is requiring employers to provide *parking cash-outs*. The idea behind parking cash-outs is simple: instead of providing a subsidy (in the form of a rented parking space) only to commuters who drive to work, provide the subsidy to all commuters and let them choose whether they want to spend it on parking or other goods. In terms of implementation, a parking cash-out policy requires employers to offer the cash equivalent of the parking subsidy to employees who do not receive free (or subsidised) parking (Shoup, 2005[12]). California's parking cash-out requirements, briefly described in Box 4, are probably the most extensively studied cash-out programme.

Box 4. California's parking cash-out requirements

California passed a law in 1992 requiring employers who provide free or subsidised parking to their employees to also offer a cash-out programme. The law specifies that the value of the cash-out should be equal to the value of the parking subsidy provided by the employer (Shoup, 1992[50]). Cash-out requirements apply only to firms with more than 50 employees, and parking spaces which are rented – not owned – by the firm (Shoup, 2005[12]).

Sources: Shoup (1992, 2005[12]).

Parking cash-outs have multiple advantages discussed extensively in Shoup (2005[12]). A first advantage is that they make salient the costs of free parking to commuters who drive to work, therefore inducing them to make an explicit trade-off between free parking and its cash equivalent. As a result, it is very likely that at least some commuters will shift from driving alone to public transport, car-pooling, or even cycling or walking when commuting distances are short. This will lead to a reduction of vehicle-kilometres travelled and to environmental benefits in terms of reduced emissions of greenhouse gases and air pollutants.

Results from case studies in eight firms in Southern California show that commuting behaviour shifts can be important: cash-outs led on average 13% of driving-alone commuters to shift to other modes and to a decline of 12% in VMT. The latter translated into a reduction of 652 VMT (about 1050 vehicle-kilometres travelled) per employee annually (Shoup, 1997[51]). Estimates of the corresponding annual savings of emissions of CO_2 and air pollutants per commuter are presented in Table 2. The estimates shown in the table are based on the motor vehicle technology in 2017 and emission factors for gasoline passenger cars provided by California Air Resources Board (2018[52]).[10] Considering that there are about six million parking spaces which could be cashed-out without major difficulties in the United States alone (Shoup, 1997[51]), the table also presents an illustration of the potential annual emission savings from a hypothetical U.S.-wide parking cash-out programme. The emission reductions from such a programme could be significant, amounting to 1.25 million tonnes CO_2, 402 tonnes NO_x, 78 tonnes $PM_{2.5}$ and 186 tonnes PM_{10}. These estimates are based on the assumption that the findings of Shoup's (1997[51]) case studies in Southern California could be generalised to other U.S. states and firms in other sectors, so they should be treated with caution.

A second advantage of parking cash-out policies is that they are likely to be considered equitable and therefore be welcomed by employees. A cash-out policy may well be viewed as a step towards treating all commuters equally regardless of their income, possession of a car, and commuting preferences. Parking subsidies may be considered particularly unfair by low-income employees without access to a car. Not only do cash-outs address such equity concerns, they also provide these employees with a valuable source of additional income. Furthermore, cash-outs are not exempt from income taxation (as is usually the case with parking subsidies) and in progressive tax systems the after-tax benefit will be higher for employees with a lower taxable income.

[10] Estimates of emission savings are much higher in (Shoup, 1997[51]; Shoup, 2005[12]) as they are based on emission factors for 1995, when cars were less fuel efficient and multiple times more polluting.

Parking cash-outs can also lead to welfare gains and increases in tax revenues. Some commuters are better off by obtaining the after-tax benefit of the cash-out instead of the parking subsidy. The absence of a parking cash-out programme entails in these cases a welfare (deadweight) loss, equal to the difference between the parking costs paid by the employer and the employee's willingness to pay for the parking space. A parking cash-out programme eliminates this welfare loss and provides a valuable source of tax revenues, which may be more difficult to obtain from other, potentially distortionary, sources.

An obvious concern with parking cash-outs is that they might lead to significant increases in costs for employers. This ultimately depends on the number of employees driving alone to work when the programme is offered, which is contingent, among other things, to urban form, and the price, accessibility, comfort and quality of alternative modes. Commuters are more likely to use public transport in areas where urban development is concentrated around major transport nodes and where public transport is more affordable and comfortable and the service is more frequent. In car-dependent cities, however, the share of employees driving alone to work is very high. In the United States, for example, 91% of workers commute by car. In such cases, increases in employer costs are not expected to be substantial, especially if they already provide some form of public transport subsidy to employees who do not commute by car. In addition, parking cash-outs may also make the firm attractive to more workers, leading to possible benefits in terms of increased productivity for the firm. Firms also have the option to reform their parking subsidy in a way that the impact of parking cash-outs is cost-neutral to them. For example, if parking cash-outs are offered to the 10% of the employees who do not drive to work, the firm can reduce its parking subsidy to 90% of what it offered before (Shoup, 2005[12]).

Table 2. Potential savings of VMT and vehicle emissions from parking cash-outs

United States, 2017

	Potential annual savings per commuter	Potential annual savings for 6 million cashed-out parking spaces
Vehicle-miles travelled (VMT)	652	3 912 million
CO_2 emissions (tonnes)	0.208	1.25 million
PM_{10} emissions (kg)	0.031	183 000
$PM_{2.5}$ emissions (kg)	0.013	77 000
NO_x emissions (kg)	0.067	404 000
CO emissions (kg)	0.731	4.39 million

Note: Estimates of the potential VMT savings per employee are based on the findings of eight firm case studies in Southern California. Estimates of savings of emissions of CO_2 and air pollutants per commuter are derived by multiplying the VMT and round-trip savings (for 252 trips per year) by the relevant emission factors provided by the California Air Resources Board for gasoline passenger cars in 2017. Estimates of PM_{10} and $PM_{2.5}$ emission savings also include non-exhaust emissions, i.e. emissions from tyre and brake wear. Multiplying the potential savings per commuter by six million parking spaces (the number of parking spaces which could be cashed-out without major difficulties) provides the estimates in the right column of the table.

Source: (Shoup, 1997[51]) for VMT, and own calculations based on California Air Resources Board (2018[52]) and (Shoup, 1997[51]) for emission savings.

3.4. Parking in shopping malls and downtown commercial areas

Shopping is one of the main activities associated with parking. As Hasker and Inci (2014[53]) argue, "other than money and credit cards, parking is probably the most important

intermediate good in the modern economy". Shopping malls are among the largest contributors to the stock of parking space. For example, a typical shopping mall in the United States (where there are over 100 000 shopping malls) has four to six parking spaces per 1000 square feet of gross leasable area. This suggests that there is more parking space in the average mall than space for stores (International Council of Shopping Centers and Urban Land Institute, 2003[54]). At the same time, most malls provide free parking, whose costs are embedded in the prices of the goods they sell. Can this behaviour be rationalised? It has been shown that free parking in suburban malls is justified when consumers are uncertain about the availability of the goods they are looking for (Hasker and Inci, 2014[53]). The authors also provide a rationale for minimum parking requirements for such commercial buildings.

Although suburban malls are important, in European cities a substantial share of retail activity takes place in downtown shopping districts. There are important issues with downtown commercial parking. While in some cities parking tariffs for non-residents are high, in many other cities they are low enough to generate substantial cruising. In downtown shopping areas, this is often the result of local businesses' lobbying efforts to protect themselves from shopping malls (Inci, 2015[1]). De Borger and Russo (2017[55]) rationalise these inefficiencies in a political economy framework: they show that the conflicting interests of downtown retailers (who lobby for low parking charges) and downtown residents can explain inefficient parking pricing.

To ensure high parking occupancy rates and prevent capacity saturation in main downtown shopping areas in an efficient manner, parking should be allocated to shoppers through time-varying parking tariffs (Small and Verhoef, 2007[8]). By contrast, cities usually employ too low time-invariant parking prices and set maximum limits on the allowed duration of curbside parking in those areas. While time limits can discourage drivers with long visits from searching for on-street parking in the area, their design should ensure that capacity does not end up being underutilised or saturated. Too lax duration limits, for example, do not prevent long-term visitors from parking in the area and therefore do not provide much relief to saturated capacity. On the other hand, introducing parking duration limits in areas where capacity is not saturated (and therefore cruising is not an issue) or employing too stringent limits can lead to capacity underutilisation, which also implies social welfare losses.

3.5. Additional policy issues

Car-sharing

A sensible strategy to reduce the need for parking spaces is to decrease the number of cars on the road. Car-sharing offers some promise in this sense. There is a two-way connection here because several cities are using parking to incentivise car-sharing. In Amsterdam, as in many other cities, car-sharing companies get dedicated parking spaces. In Antwerp, Belgium, residents who are members of car-sharing schemes receive the equivalent of a residential permit so that they can park shared vehicles near their residence. In London, shared cars are permitted to park for free on the street (Kodransky and Hermann, 2011[28]). In the German state of Baden-Württemberg, the owners of buildings where the installation of the required car parking spaces is not possible or too difficult, have the opportunity to pay a fee to the municipality which will be used to finance the provision of dedicated car-sharing parking spaces (European Environment Agency, 2017[56]).

Public and non-motorised transport

Shortages in parking capacity can also be dealt with by providing alternatives to car travel. These include public transport and cycling. Many of the cities mentioned in this paper are gradually redesigning their transport systems in this direction. Although this topic is too large to be treated exhaustively in this paper, it is worth noting that the economic literature suggests that, while monetary subsidies are effective in stimulating a modal shift towards public transport (Parry and Small, 2009[57]), non-monetary incentives, such as the provision of dedicated lanes for buses, trams and bicycles, can also be very important (Basso and Silva, 2014[58]).

Street design

Parking policies can also lend themselves to instruments for controlling urban road traffic flow and improving road safety. For example, some cities have leveraged parking to improve the safety of cyclists and pedestrians. Amsterdam has zones called woonerfs where the layout of parking spaces forces vehicles to move at a very slow pace. Another example comes from many neighbourhoods of Paris and Copenhagen where parked cars are used as a barrier between cyclists and moving traffic.

Encouraging the use of vehicles with low CO_2 emissions

Some cities have started providing parking at preferential rates to drivers of cars with lower tailpipe emissions. For example, the boroughs of Islington, Richmond, and Kensington and Chelsea in London have adopted a policy of charging for residential permits according to the type-approval CO2 emissions of the applicant's car (Kodransky and Hermann, 2011[28]; Royal Borough of Kensington and Chelsea, 2014[44]). Richmond also experimented with charging curbside parking fees based on CO2 emissions (Kodransky and Hermann, 2011[28]). The city of Amsterdam uses free parking as an incentive for the adoption of electric cars. Parking a conventional car in front of an electric charging point is not allowed, while electric vehicle users can park their car at any charging location, as long as their vehicle is plugged in (City of Amsterdam, 2015[59]). In addition, they are granted priority for residential parking permits which is particularly valuable given the lack of parking spaces within the city (the waiting time for a parking permit can be of several years for conventional cars). Although these policies incentivise residents to choose cars with lower tailpipe emissions of CO_2, they do not address directly the problem of parking oversupply in central areas, and their net effect on CO_2 emissions is not *ex-ante* clear. Indeed, it is possible that, by making access to parking cheaper, some of these policies induce car owners to drive more, and cause more congestion and emissions.

Parking and autonomous cars

Automation of specific driving features is becoming increasingly common in new cars and autonomous vehicles are expected to become widespread in the not-too-distant future. It is hard to predict how this radical change will affect parking, and this is another topic that would deserve a dedicated treatment. Nevertheless, it is possible to briefly discuss some of the possible implications. Self-driving cars should essentially reduce the value of cruising time to zero, because drivers would leave their car after reaching their destination, letting the car find a parking spot on its own. On the other hand, autonomous cars should reduce the need for parking space close to highly demanded destinations (e.g. office buildings), because they could drive themselves to parking locations far from drop-off points. This change could dramatically reduce the costs of providing parking, freeing up highly valuable

space in cities. However, it may also increase the volume of traffic, with possible negative consequences on congestion and the environment.

Future transport could also be based on shared autonomous cars, whose allocation to individual trips would be based on smart mobility management systems. Shared autonomous cars can lead to massive reductions of parking space needs. For example, simulations based on a large-scale uptake of shared autonomous cars in a mid-sized European city show that the need for on-street parking capacity could be completely eliminated, while also up to 80% of off-street parking capacity could be freed up for other uses. These estimates are based on relatively strong assumptions, i.e. that shared autonomous cars would completely replace the whole fleet of cars and buses, and that their uptake would have no effect on trip origin, destination and timing, but they illustrate the potential of shared autonomous cars to reduce parking space needs (ITF, 2015[60]).

4. Conclusions

This paper provided an extensive discussion of the external costs of parking and the implications of various parking policies for the environment and social welfare. The implications of existing parking policies were analysed along four types of parking: on-street (curbside) parking; parking allocated to residents (e.g. through special permits); employer-provided parking; and parking in shopping malls and downtown commercial areas. Interactions between parking and car-sharing, alternative transport modes, street design, low-emission vehicles and autonomous cars have also been briefly considered.

Drawing on the lessons learned from experiences with various parking policies around the world, the paper suggests a set of policy options to achieve environmental improvements and social welfare gains. Providing parking policy recommendations for certain cities is beyond the scope of the paper: a different set of policy options will be relevant in different cities. It is important to note, however, that urban form, accessibility to public transport and frequency of public transport service, and quality of infrastructure for non-motorised transport vary significantly across cities and are important determinants of the effectiveness, efficiency and distributional effects of parking policies. Parking policies should be tailored to the specificities of the local context, but the suggestions outlined below can help achieve more environmentally sustainable and cost-effective outcomes.

First, the prices of curbside – and, where applicable, public garage – parking should be set at levels reflecting the social costs of parking provision. Parking prices should at least account for the costs of parking space construction, the opportunity costs of alternative land uses, and the external costs of open space and biodiversity losses and of time losses due to cruising. Especially in busy downtown areas, setting efficient parking tariffs is necessary to prevent parking capacity saturation and avoid cruising for parking, while also ensuring high occupancy rates (80-90%). Given fluctuations in demand, achieving these rates requires a dynamic parking pricing system, where tariffs vary over space and time using information on occupancy in surrounding areas. For a smooth introduction of efficient on-street parking pricing, a necessary condition is that local communities are well-informed about the expected environmental and economic benefits of the policy.

The second suggestion concerns the treatment of employer-provided parking, which is mostly offered for free or at highly subsidised rates to employees and is exempt from their taxable income. Employer-paid parking is essentially a subsidy for driving to work, which strongly encourages commuting by car and has important consequences for congestion, pollution and greenhouse gas emissions. It is thus important that exemptions of employer-paid parking from employees' taxable income are removed. It is also worthwhile to consider requiring employers who rent parking spaces for their employees to offer parking cash-outs, i.e. the cash equivalent of the parking subsidy, to employees who do not receive free (or subsidised) parking. Parking cash-out policies are attractive, because in addition to leading to welfare gains and environmental benefits, they are likely to be acceptable by employees and increase tax revenues (as cash-outs are not exempt from income taxation).

Third, it is worth reviewing, and in many cases removing, minimum parking requirements for new residential and office buildings. The review of minimum requirements should follow a proper assessment of the actual parking needs of residents and account for the perverse effects of overprovision on car ownership and use. Setting curbside parking prices at levels achieving the occupancy targets mentioned above is likely in many cases to render minimum parking requirements redundant. Maximum parking requirements can also be leveraged to prevent excessive car use in some areas.

Another suggestion is related to the provision of free or underpriced parking permits to residents of city centres. Free or underpriced residential parking permits have substantial costs for society, as they increase the costs of parking supply and land use. They also induce the provision of additional parking capacity for non-residents, thus entailing that funds which could possibly be directed to improve the transport system are consumed for parking. Residential parking permits should generally be priced at rates approximately equal to those charged to visitors, with price discounts reserved only for a few special cases. When the costs of parking permit provision are financed by local tax revenues, it is worth considering implementing a revenue-neutral tax reform where increases in parking permit prices are accompanied by reductions in local taxes.

Instead of using space-and time-varying parking tariffs to allocate parking to users in downtown commercial areas, many cities employ low time-invariant parking prices and set maximum parking duration restrictions. Maximum duration restrictions can be useful when parking capacity is saturated and cruising for parking is substantial, as they prevent long-term visitors from parking in the area. A critical factor for duration restrictions' efficiency is the length of duration allowed. Maximum duration restrictions should be set at levels allowing users just enough time to carry out the activities normally undertaken at the parking location (e.g. shopping).

Appropriate enforcement is key for the effectiveness of on-street parking regulation and pricing. However, insufficient resources and incentives for local authorities often hamper parking enforcement. To improve it, cities could leverage advances in digitalisation (e.g. licence plate recognition technologies) which enable a close monitoring of parking space use at lower costs. Higher fines for parking violations can also help increase compliance with parking regulation. In public finance systems where parking revenues are collected by state or national governments, it may be worth considering providing larger shares of the revenues to local authorities to strengthen enforcement incentives.

Policies determining parking supply and pricing strongly influence developers' decisions on how much land to provide for parking, and individual choices of how many vehicles to own and which transport modes to use to cover their daily travel needs. Those choices have important implications for land use and open space conservation, traffic congestion, air

pollution and greenhouse gas emissions. In that sense, parking policies are a key toolbox in the hands of policy makers to achieve more environmentally sustainable urban mobility patterns, protect valuable open space, and increase social welfare. Efficient parking tariffs are also an important source of revenue for local governments, which can be used to finance the supply of public goods and services, including public transport and infrastructure for non-motorised transport. Additional income tax revenues from parking cash-outs and the appropriate fiscal treatment of employer-paid parking can further contribute to state and national government budgets.

Finally, it is important to highlight that many of the existing implicit subsidies to parking, as well as minimum parking requirements, are regressive, in the sense that their benefits are mainly reaped by higher-income groups. Efficient pricing and removal of implicit subsidies might on average increase parking prices, but lower-income households will probably incur only a small part of this burden. Where lower-income households and other vulnerable population groups are negatively affected by parking policy changes, they can be compensated through targeted complementary measures, financed by part of the revenues raised from parking tariffs and parking cash-outs.

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