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A geography of moral hazard: Sources and sinks of motor-vehicle commuting externalities

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ABSTRACT

Motor-vehicles are responsible for harms to health that are not directly experienced by individual drivers – such as air pollution and risk of injury to pedestrians. In addition to their direct effects on health, these harms also represent a moral hazard since drivers are not required to consider their effects as part of their decision to drive. We describe an approach for estimating sources of motor-vehicle commuter externalities as a means of understanding the geography of moral hazard, and in particular, the spatial displacement of negative health externalities associated with motor-vehicle commuting. This approach models motor-vehicle commuter traffic flow by trip origin for small geographic areas within the City of Toronto, Ontario. We find that most health-related externalities associated with motor-vehicle commuters are not locally generated, with a large share coming from outside Toronto. Low income is associated with externalities originating outside the municipal boundary, but not with locally sourced externalities. We discuss the impact of geographical moral hazard on the agency of citizens as well as policy options aimed at addressing motor-vehicle externalities.

1. Introduction

Individuals make decisions to drive, at least to some extent, based on personal assessments of benefits and costs. Most benefits of motor-vehicle use are experienced by individuals, both instrumentally and psychosocially (Ellaway et al., 2003; Lois and Mercedes López-Sáez, 2009), however the costs of motor-vehicle use are both individual (private) and public. Private costs include the purchase cost of vehicles, the price of fuel and private insurance and the personal risks of injury from collisions. Public costs include building and maintenance of transportation infrastructure, traffic congestion, and air pollution. Since the public costs of motor-vehicle commuting are shared irrespective of individual benefits, they are often characterised as negative externalities – costs that an individual driver does not have to fully include in his private cost-benefit analysis when choosing whether or not to drive. Without offsetting policies that internalise these costs, there emerges a well-known moral hazard in which individuals (in this case, motor-vehicle drivers) make decisions that may be individually beneficial, but collectively harmful (Hardin, 1968).

Of the many public costs associated with motor-vehicle use, three have been widely studied for their direct effects on the health of human populations: air pollution, noise pollution and motor-vehicle injury. Emissions from motor-vehicles make up sizeable shares of the total quantity of nitrogen oxides and volatile organic compounds in urban areas, substances which also contribute to the formation of the secondary pollutants ozone and PM_{10} (Wang et al., 2009). There is considerable evidence that exposure to motor-vehicle pollution directly harms health. For example, living near freeways appears to increase risk of acute and chronic respiratory problems (Gowers et al., 2012), cardiovascular disease (Hoffmann et al., 2009; Campen et al., 2012), mortality (Hoek et al., 2002) and diabetes in children (Thiering et al., 2013). Motor-vehicle pollution has secondary consequences as well – increasing air pollution exposure for those who use active transportation modes and engage in outdoor physical exercise (Carlisle and Sharp, 2001; Briggs et al., 2008) and adversely affecting perceptions of place and local environment (Bush et al., 2001; Williams and Bird, 2003; Mullan, 2003).

Health concerns associated with exposure to noise pollution include sleep disturbances (Bluhm et al., 2004), hypertension (Bluhm et al., 2007; Bodin et al., 2009), cardiovascular disease (Babisch et al., 2005) as well as general quality of life (Dratva et al., 2010). While the precise pathology is unknown, some of the negative effects of acute traffic noise exposure may be related to responses of the endocrine system, such as raised levels of cortisol and adrenaline (Stansfeld and Matheson, 2003). Other evidence

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suggests that long-term exposure to traffic noise can be responsible for higher levels of anxiety. In children, chronic noise exposure may affect various cognitive tasks, including memorisation, speech perception and reading ability (Stansfeld et al., 2005).

Motor-vehicle injuries remain a leading cause of death worldwide, and are projected to account for 3.6% of all human deaths by 2030 (World Health Organization, 2009). Most motor-vehicle related injuries and mortality result from collisions involving two or more vehicles, but collisions with cyclists and pedestrians account for roughly 16% of motor-vehicle fatalities in the U.S. and Canada (U.S. Department of Transportation, 2013; Transport Canada, 2013). The risks to pedestrians and cyclists are also noteworthy since the consequences of motor-vehicle collisions involving cyclists/pedestrians are asymmetrical – with almost no risk of physical harm to the drivers themselves. Furthermore, while motor-vehicle occupant fatalities have almost halved over the last decade, the risks to pedestrians and cyclists remain largely unchanged (U.S. Department of Transportation, 2013; Transport Canada, 2013).

One of the ways in which these negative health externalities are understood is in terms of source apportionment – that is, the total quantity of the externality at a location or in a population can be apportioned to a particular source or class of sources. Source apportionment is useful when trying to assign legal responsibility for or regulate an externalised harm. In the case of motor-vehicle collisions, this is a relatively simple exercise, as motor-vehicles are the immediate cause of motor-vehicle collisions (though there remain noteworthy differences by size of vehicle (Broughton, 2008; Cooper et al., 2009)). In the case of air pollution, source apportionment has been estimated for different compounds across sectors of the economy, with reliable regional estimates of motor-vehicle pollution as a proportion of total pollution concentration (Thurston et al., 2011) as well as air pollution by vehicle type (Lemp and Kockelman, 2008) and noise pollution by vehicle type (Lewis, 1973).

There is comparatively little research on source apportionment of motor-vehicle externalities in geographical terms, and in particular, little is known about how different geographical source locations may contribute different concentrations of externalities at sink locations. This is important because the bulk of direct health effects of all three motor-vehicle externalities described above are local; in the case of air and noise pollution, usually within a few hundred metres of roadways (Brugge et al., 2007), and for motor-vehicle collisions, on or immediately adjacent to the road. Yet, the geographical source of these motor-vehicle trips is not likely to be local. For example, according to the 2009 U.S. National Household Travel Survey, the average motor-vehicle trip in the U.S. is roughly 15 km (U.S. Department of Transportation, 2011). Trips of this length suggest that drivers spend much of their drive time outside their local neighbourhoods, so it follows that the externalities produced are also experienced between the origin and destination of their trips where drivers may spend little time.

In this research we describe a method for understanding the sources and sinks of motor-vehicle commuter externalities, with application to the City of Toronto, Ontario, Canada. We employ journey-to-work data collected from the 2006 Canadian Census to estimate concentration of exposure to traffic for small geographic areas in Toronto. The estimates of flow are broken down into source locations to make it possible to estimate local traffic externalities by geographic source. This allows us to understand the net local and non-local contributions to motor-vehicle externalities. In addition to describing this method, we also characterise dynamics of exposure to motor-vehicle commuter externalities in the study area. This involves modelling the concentration of exposure as well as the degree to which the levels of exposure are spatially displaced. Our aim is to identify areas of the city that are sinks of motor-vehicle commuter externalities, and identify areas that endure an inequitable share of spatially displaced externalities.

2. Geographic source externalities

At small geographic scales – where the effects of many transportation-related negative health externalities are most immediately felt – one might envision the source of externality not only as the motor-vehicle itself, but as the geographical origin of the motor-vehicle trip. Under this framework, motor-vehicles can be seen as externalities 'emitted' from the sources of geographical origin (e.g., neighbourhoods), and the sinks are the neighbourhoods they pass through on route to their destination. Depending on the geographical origin and destination of the driver and the structure of the road network, the distances between source and sink can be great or small. This distance not only approximates the total volume of externalities produced (with longer trips resulting in more negative externalities than shorter trips) but also describes the spatial displacement of these externalities from source locations to sink locations – a geographical form of moral hazard.

This framework has several advantages. First it enriches how the inequalities of motor-vehicle externalities are understood, particularly with respect to questions of responsibility. A number of studies have shown considerable small-scale variations in the concentration of motor-vehicle externalities at sink locations (Kingham et al., 2000; Jerrett et al., 2007; Birk et al., 2011). Such studies are essential for understanding potential health impacts on the population, but overlook the role of local responsibility (or absence of it) for these externalities. For example, a sink-focused approach would treat two neighbourhoods with equal concentration of total externalities and equally vulnerable populations the same even if in one most of the externality is locally generated, and in the other most of the externality is not locally generated. Yet the responsibility for the externalities does not seem the same; residents in a neighbourhood with fewer drivers but a high burden of motor-vehicle externalities seem less responsible for their exposure than a neighbourhood with the same burden of externalities but more drivers. Understanding the role of source location and the linkages between source and sink geographies could help inform imbalances between sources and sinks in urban areas – particularly in cases where economically marginalised communities are net sinks for motor-vehicles originating from affluent communities. This is particularly important since the former would more typically lack the resources to change their personal or neighbourhood circumstances in a way to reduce levels of exposure.

Second, this framework is useful for understanding policy options that are meant to incentivize more environmentally friendly uses of the transportation system. Road pricing has been suggested as a tool for managing growth in use of the motor-vehicle transportation system, but also as a way to reduce pollution and encourage public transit. Through combining source and sink information it would be possible to estimate the net externalities for geographic areas – such as municipalities or neighbourhoods – which could then be used to allocate road pricing revenues as compensation to net sink neighbourhoods. Information about sources and sinks could help address the economic and political challenges facing the implementation of road pricing schemes which often face strong opposition from subsets of the population (Litman, 1996). So in addition to helping ameliorate the effects of externalities proportional to the burden, the linkage of geographical sources and sinks could also make road pricing more