Is it time to raise the gas tax? Second-best optimal gasoline taxes for Ontario and the Greater Toronto-Hamilton Area

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Abstract

This paper uses a representative agent model and Canadian data to calculate the optimal gasoline taxes for Ontario and the Greater Toronto-Hamilton Area (GTHA) in a second-best setting with pre-existing distortionary income taxes. The results suggest a second-best optimal gasoline tax of 40.57 cents per litre in 2006 Canadian dollars for the GTHA that is much higher than the current tax rate of 24.7 cents per litre, and also higher than recently proposed increases. The resulting value is insensitive to whether the additional revenue is used to reduce taxes on income or to incrementally fund increased public transit infrastructure (The Big Move plan). However, in the absence of a regional tax, the second-best optimal gasoline tax for Ontario as a whole of 28.51 cents per litre in 2006 Canadian dollars is slightly higher than the current tax rate and in-line with proposed increases. *JEL: Q5, Q58, H23; Keywords: Gasoline tax, externalities, Ramsey rule of taxation, Ontario, Toronto;*

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1 Introduction

Currently proposed methods of raising revenue to fund public transit infrastructure in the Greater Toronto-Hamilton Area (GTHA) largely avoid addressing the externalities that result from automobile use.[1] The provincial government originally tasked Metrolinx, the regional transportation authority, to recommend instruments to raise the required revenue.

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Policy instruments, such as congestion pricing, carbon taxes, and pay as you drive insurance would provide optimal solutions to these externalities but are viewed as politically infeasible, and were therefore ignored. One of the proposed new revenue tools, a regional gasoline tax, would internalize these externalities while raising revenue to fund public transit. However, in the 2014 provincial budget, the government reaffirmed its unwillingness to increase the tax on gasoline in Ontario or impose an additional regional level gasoline tax on the GTHA.

Although unpopular, gas taxes exist in Canada at the federal, provincial, and regional levels. Most notably, the province of British Columbia levies a regional gasoline tax ($0.17/L) on Metro Vancouver in addition to the existing provincial ($0.1517/L)[2] and federal ($0.1/L) taxes. The revenues from this regional tax are specifically earmarked to funding Translink, the regional transportation authority. The existence of the Metro Vancouver gasoline tax suggests that a regional gas tax is politically feasible in Canada and a possible policy option for the GTHA.

An optimal gasoline tax can be broken down into two major components: A Pigouvian component accounting for the numerous externalities related to gasoline use, and a Ramsey component reflecting the efficiency from raising revenue from a tax on a relatively inelastic commodity. The Pigouvian component includes climate damages, the cost of traffic congestion, traffic accident externalities, and local air pollution damages.

Parry and Small (2005) develop a representative agent model to calculate the optimal tax based on estimates of the value of each of these parameters (with the Ramsey component endogenously determined) in a second-best setting with pre-existing distortionary taxes on income. They input data from the United Kingdom and the United States to the model and conclude that gasoline taxes in the UK are slightly too high, and gasoline taxes in the US are much too low. Lin and Prince (2009) add energy security costs to the Parry and Small (2005) model and use data from California to conclude that the second-best optimal gasoline tax for California is three times larger than the current tax. Most recently, Lin and Zeng (2014) apply the Parry and Small (2005) model to calculate the gasoline tax for China.

The purpose of this paper is to calculate the second-best optimal gasoline tax for the GTHA and for Ontario as a whole. Estimates of the various externality parameters for the GTHA and Ontario are gathered from various data sources and are then applied to an adjusted version of the Parry and Small (2005) model. The calculated values are then compared with the current and recently proposed levels of gasoline taxation. A sensitivity analysis is conducted to ensure the results are robust to uncertainty in the selected parameter values. The results suggest that a regional gasoline tax in excess of the existing \$0.247/L tax (\$0.10/L federal and \$0.147/L provincial) is economically justified; and that it should be higher than the \$0.05/L tax proposed by Metrolinx. However, if there is no regional gasoline tax implemented, the second-best optimal gasoline tax for Ontario is higher than the current tax, but slightly lower than the proposed 5 cent increase.

This paper innovates on the Parry and Small (2005) model in several ways. First, unlike Parry and Small (2005), who do not include a lump sum tax, a lump sum tax is introduced to reflect the Harmonized Sales Tax (HST) implemented by the federal and Ontario governments. Second, unlike Parry and Small (2005), who assume the revenue from gasoline taxes are used to decrease labour taxes, in a later section of this paper, the model is adjusted so that the new revenue is used to pay for public transit infrastructure investment by increasing the level of exogenous government spending by the annual investment required to finance the Metrolinx Big Move transit plan. Third, the model is applied to Ontario and Toronto unlike Parry and Small (2005), Lin and Prince (2009), and Lin and Zeng (2014), who apply the model to the US and UK, to California, and to China, respectively.

Section 2 outlines a theoretical model of the economy and driving decisions. Section 3 reviews Canadian data and lays out the chosen parameter values for model calibration. Section 4 presents the results from numerically solving the model. Section 6 concludes the paper.

2 Analytical Framework

In order to calculate the second best optimal gasoline tax for the United States and the United Kingdom, Parry and Small (2004; 2005) develop a static model that reflects the various decisions involved with driving. The representative agent's utility function is given by

$$U = u(\psi(C, K, T, G), N) - \varphi(P) - \delta(A), \tag{1}$$

where C is a numeraire consumption good, K is vehicle kilometers traveled (vkt), T is time spent driving, G is government spending, and N is leisure; all in per capita terms. The functions $u(\cdot)$ and $\psi(\cdot)$ are both quasi concave. Pollution, P and traffic accidents, A from driving are aggregately determined and enter as disutility through weakly convex functions $\varphi(\cdot)$ and $\delta(\cdot)$.

The amount of vehicle kilometers traveled (vkt) is determined by a homogeneous, pseudo production function

$$K = K(F, H), \tag{2}$$

where F is the amount of gasoline and H is a monetized representation of all other driving costs, e.g., comfort, trunk space, etc. This pseudo production function captures the tradeoff between fuel economy and other vehicle characteristics.

Time driving is determined by the following function

$$T = \pi(\bar{K})K \tag{3}$$

where π is traffic congestion (e.g., the inverse of the average speed), and $\bar{K}$ is aggregate vkt per capita.

Two forms of pollution from driving are included; carbon dioxide emissions (P_F) and local air pollutants (P_K). Carbon dioxide emissions depend on aggregate gasoline use per capita; whereas, because of gram per km vehicle emission standards, local air pollutants are assumed to depend on aggregate vkt per capita.

$$P = P_F(\bar{F}) + P_K(\bar{K}) \tag{4}$$

Severity adjusted accidents depend on aggregate vkt per capita and are determined by

$$A = a(\bar{K})\bar{K} \tag{5}$$

where $a(\bar{K})$ is the average external cost per vkt. Congestion, pollution, and accidents all depend on aggregate behavior because they are external effects.

The production side of the model is relatively abstract and consists of competitive firms producing all market goods from labour with constant marginal products. q_F denotes the producer price of gas; all other prices and the wage rate are assumed fixed and normalized to one.

Government revenue comes from a tax on labour, t_L, a tax on gasoline, t_F, and a lump sum tax, S. Parry and Small (2005) did not include a lump sum tax, however, a constant lump-sum tax is introduced here to reflect the Harmonized Sales Tax (HST) implemented by the federal and Ontario governments in Canada. The HST is a value added tax levied on most goods and services (including gasoline) with exemptions for several politically sensitive products such as many grocery items. Because the HST is a consumption tax applied so broadly, I make the assumption that it is applied to both the numeraire consumption good and gasoline, and therefore can be modeled as a lump-sum tax to reflect its efficiency.[3] When calibrating the model to the data, the GST/HST is included in the producer price of gasoline, q_F. The government budget constraint is

$$G = t_L L + t_F F + S, \tag{6}$$

where L is total labour supplied. Government spending in the Parry and Small (2004,

2005) model is exogenous, so increased gasoline tax revenues are recycled through decreases in labour tax. However, this may not be the case in Ontario since politicians have been vocally eager to find new revenue sources to pay for a major investment in public transit infrastructure. For example, speaking to reporters in 2013, Premier Wynne stated “its not whether were going to create a revenue stream,... its which of those tools were going to use” (Alcoba 2013). Therefore, in a later section of the paper, the level of exogenous government spending will be increased by the annual investment required to finance the Metrolinx transit plan ($2 billion annually).

The budget constraint of the representative agent is

$$C + (q_F + t_F)F + H + S = I = (1 - t_L)L. \tag{7}$$

Note that $(q_F + t_F)$ is the consumer price of gasoline.

The agent's time endowment is fixed at $\bar{L}$, and is split between labour, leisure and time spent driving

$$L + N + T = \bar{L}. \tag{8}$$

The representative agent chooses C, N, F, and H to maximize equation (1) subject to equations (2) to (8). Parry and Small (2004) provide the maximization problem as

$$\begin{aligned} V(t_F, t_L, P, A, \pi) = \max_{C,K,N,F,H} & \; u(\psi(C, K, \pi K, G), N) - \varphi(P) - \delta(A) + \mu\{K(F, H) - K\} \\ & + \lambda\{(1 - t_L)(\bar{L} - N - \pi K) - C - (q_F + t_F)F - H - S\}. \end{aligned} \tag{9}$$

Parry and Small (2004) show that the first order conditions of the representative agent's maximization problem can be rearranged to provide the following equation representing the second best optimal gasoline tax (assuming that G and S are constant)

$$t_F^* = \frac{MEC_F}{1+MEB_L} + \frac{(1-\eta_{KI})\epsilon_{LL}^c}{\eta_{FF}}\frac{t_L(q_F+t_F^*)}{1-t_L} + \beta\frac{K}{F}E^C[\epsilon_{LL}-(1-\eta_{KI})\epsilon_{LL}^c]\frac{t_L}{1-t_L}. \tag{10}$$

The first expression on the right hand side (RHS) of equation (10) represents the "Adjusted Pigouvian" component of the tax. The second expression on the RHS of equation (10) is the Ramsey portion of the tax. The last expression on the RHS of the tax equation is described by Parry and Small (2005) as the congestion feedback portion of the tax.

Equation (10) has many new notations which are defined and described as follows. β is the ratio of the elasticity of vkt with respect to the gasoline price ($\eta_{KF} = -dK/dt_F \cdot P_F/K$) and the own price elasticity of demand for gasoline ($\eta_{FF} = -dF/dt_F \cdot P_F/F$) (i.e., $\beta = \eta_{KF}/\eta_{FF}$). The term ϵ_{LL}^c is the compensated labour elasticity and is equal to $\partial L^c/\partial t_L \cdot (1-t_L)/L$. ϵ_{LL} is the uncompensated labour supply elasticity. The term η_{KI} is the income elasticity of vkt and is equal to $\partial K/\partial I \cdot I/K$ where $I = (1-t_L)L$.

The Adjusted Pigouvian portion of the tax is broken down as

$$MEC_F = E^{P_F} + (E^C + E^A + E^{P_K})\frac{\beta K}{F} \tag{11}$$

$$MEB_L = \frac{-t_L\frac{\partial L}{\partial t_L}}{L+t_L\frac{\partial L}{\partial t_L}} = \frac{\frac{t_L}{1-t_L}\epsilon_{LL}}{1-\frac{t_L}{1-t_L}\epsilon_{LL}}, \tag{12}$$

where $E^{P_F} = \varphi P_F'/\lambda$, $E^{P_K} = \varphi P_K'/\lambda$, $E^C = \upsilon\pi K'$, and $E^A = \delta A'/\lambda$. The pure Pigouvian tax (i.e., MEC_F) is adjusted by MEB_L, which is the excess burden of labour taxation, reflecting the fact that labour taxation is more efficient due to its broader base.

Fuel economy (K/F) also depends on the level of t_F; therefore, Parry and Small (2005) define fuel economy as

$$\frac{K}{F} = \frac{K^0}{F^0}\left(\frac{q_F+t_F^*}{q_F+t_F^0}\right)^{-(\eta_{KF}-\eta_{FF})} \tag{13}$$

where the superscript 0 indicates current values. Similarly, fuel consumption is calculated as

$$F = F^0 \left(1 - \eta_{FF} \left(\frac{t_F^* - t_F^0}{q_F + t_F^0}\right)\right). \tag{14}$$

Let F be gasoline sold at the optimal tax, t_F^* and $\hat{F}$ be gasoline that continues to be sold at the current tax t_F^0. When looking for the optimal gasoline tax at the metropolitan level, F and $\hat{F}$ represent gasoline bought inside and outside the GTHA respectively. But when focused on a provincial level optimal tax, F represents all gasoline purchased in Ontario as a whole and $\hat{F}$ is equal to zero. Adjusting the government budget constraint (equation (6)) to reflect both F and $\hat{F}$, subbing Y in for L, and solving for t_L gives the following expression for the labour tax rate

$$t_L = (G/Y) - (S/Y) - t_F^0(\hat{F}/Y) - t_F^*(F/Y). \tag{15}$$

In this sense, the labour tax rate is assumed to be the share of government expenditures as a percentage of output that is not financed by gasoline taxes or the HST.

Assuming that all elasticities are constant and values for all fixed parameters, t_F^* can be solved for numerically using equations (10) to (15).

3 Parameter Values

This section reviews Canadian data and lays out the chosen parameter values for model calibration. Due to data availability limitations (discussed throughout), the parameter values are selected to be close to the year 2006. The research question ultimately becomes, what was the optimal gasoline tax for the GTHA in 2006. Due to the relevance of the research topic to current public policy decisions, more recent data would obviously be preferred; however, a sensitivity analysis is conducted on key parameter values and reported in a later section.

3.1 Fuel Economy, K^0/F^0

According to Natural Resources Canada (2009) the average fuel economy in Ontario for light-duty vehicles in 2007 was 10.9 litres per 100km. This corresponds to 9.17 km per litre or 21.57 miles per gallon. Data on the number of vehicle kilometres traveled in the GTHA on an annual basis were difficult to find. AECOM (2013) uses a value of 55.9 billion vkt for the GTHA in 2009. Using 55.9 billion for K^0 and assuming the average fuel economy is similar in the GTHA as for all of Ontario (9.17 km/L), produces a value for F^0 of 6,096 million litres. All parameters and their selected values are displayed in Table 1.

For Ontario as a whole in 2006 there are data on the total number of vkt from the Canadian Vehicle Survey. In 2006 K^0 for Ontario was 120,465 million vkt (Statistics Canada, 2007). Assuming average fuel economy of 9.17 km/L, produces a value for F^0 of 13,137 million litres. The amount of gasoline purchased outside the GTHA is just the difference between 13,137 million litres and 6,096 million litres.

Table 1: Selected Parameter Values

Parameter	GTHA	Ontario	Unit
Fuel economy, K^0/F^0	9.17	9.17	km/Litre
Fuel consumption, F^0	6,096	13,137	million litres
Climate damages, E^{P_F}	0.051	0.051	\$/Litre
Local air pollution damages, E^{P_K}	0.015	0.0135	\$/km
External cost of accidents, E^A	0.038	0.042	\$/km
External cost of congestion, E^C	0.12	0.051	\$/km
Elasticity of gasoline demand, η_{FF}	-0.654	-0.654	-
Elasticity of vkt to gasoline price, η_{KF}	-0.1	-0.1	-
Total output, Y	560,576	560,576	million \$
Government expenditures, G	211,898	211,898	million \$
Lump-sum Tax, S	28,906	28,906	million \$
Producer price of gas, q_F	0.694	0.694	\$/L
Current tax on gas, t_F^0	0.247	0.247	\$/L
Elasticity of vkt to income, η_{KI}	0.6	0.6	-
Uncompensated labour supply elasticity, ϵ_{LL}	0.2	0.2	-
Compensated labour supply elasticity, ϵ_{LL}^c	0.35	0.35	-

Notes: All monetary values in 2006 Canadian dollars. For the actual numerical calculations the elasticity parameters η_{FF} and η_{KF} are in absolute value following Parry and Small (2005).

3.2 Air Pollution, E^{P_F} and E^{P_K}

Greenstone, Kopits, and Wolverton (2013) suggest a value of \$21 per ton of CO2 for the Social Cost of Carbon in 2010. Converted to 2006 Canadian dollars this value is \$23.09 per ton of CO2. This value corresponds to \$0.051 per litre of gasoline or \$0.19 per gallon. Greenstone, Kopits, and Wolverton (2013) recommend \$5 and \$65 as values for sensitivity analysis.

Zhang et al. (2005) provide an estimate of the external costs of local air pollution in Canada from urban vehicles per passenger km (pkt). They report their preferred estimate in pkt, but mention that they converted the value to pkt from vkt using a conversion factor of 1.4 passengers per vehicle. Their estimate assumes a value of a statistical life (VSL) of \$4.25 million, but they also calculate estimates using VSL's of \$2.5 million and \$7 million. A VSL of \$4.25 million is quite low. Anderson and Aufhammer (2014) use the US department of Transportation's suggested VSL of \$5.8 million USD which is also relatively close to the \$5 million value recommended for cost benefit analysis by Boardman et al. (2011). If the \$5.8 million USD VSL estimate is adjusted for Canada/US income differences[4] and converted to Canadian dollars using the average exchange rate for 2006, a VSL value of \$5.8 million (2006 CAD) results. A value of the external costs of local air pollution from urban vehicle use per pkt is obtained by fitting a regression for the three three estimates provided by Zhang et al. (2005) and finding the point on that line corresponding to a VSL of \$5.8 million. When converted to vkt, the selected value for the GTHA in the present analysis is \$0.015 per vkt. For Ontario as a whole, this value will be scaled down by 10% (\$0.0135) because some of Ontario's vkt occur outside of the Windsor-Ottawa corridor. Pollution concentrations are quite high by Canadian standards in the Windsor-Ottawa corridor, but quite low in the northern areas of the province (Wood, 2012). Unfortunately a more specific regional breakdown is not possible since disaggregated vkt data from the Canadian Vehicle Survey is not publicly available.

3.3 Traffic Accidents, E^A

Zhang et al. (2005) provide three estimates of the average external costs of traffic accidents. Their highest Canadian estimate reported is \$0.038 per km when converted to 2006 dollars. This estimate is similar to the parameter value of \$0.03 per mile selected by Parry and Small (2005) and Lin and Prince (2009). Zhang et al. (2005) also cite a number based on European research of \$0.09 per km.

Parry (2004) estimates the average external costs of accidents in the US to range between \$0.022 per mile (\$0.0354 per km) to \$0.066 per mile (\$0.1062 per km) in USD. The Zhang et al. (2005) estimate is close to Parry (2004)'s lower bound. However, Parry (2004) uses a relatively low Value of a Statistical Life (VSL) of \$3 million, whereas Zhang et al. (2005) use a value close to \$4.5 million. More recently, Anderson and Auffhammer (2014) provide an estimate of the external costs of accidents for the US that takes into account the vehicle weight externality. Drivers select heavier vehicles for private safety benefits, and ignore the extra damage a heavier vehicle imposes on others in an accident. Anderson and Auffhammer (2014) provide an estimate of \$0.048 per mile (\$0.078 per km) that accounts for this vehicle weight externality. However, they only consider the VSL cost of fatalities and omit external costs from injuries and other external costs related to fatalities.

However, it may be that the US estimates are not applicable to the GTHA or Ontario. Table 2 displays vehicle accident statistics for the GTHA and Ontario averaged between 2006 and 2011. The probability of an accident in the GTHA calculated as the number of accidents divided by the number of registered vehicles is 2.9% (author's calculation); however, for the US this probability is 3.6% (Anderson and Auffhammer, 2014).

Table 2: Accident Statistics: 2006-2011

	GTHA	Ontario
Accidents	106,526	214,636
Fatalities	187.67	634.33
Injuries	33,395	64,634
Registered vehicles	3,678,541	7,607,387

Notes: Values are from annual data collected from Ontario Road Safety Annual Reports and averaged over the years 2006, 2007, 2008, 2009, 2010, 2011. The number of registered vehicles in Ontario is from Statistics Canada (2014).

Another estimate for the external cost of traffic accidents in the GTHA can be estimated using the accident statistics in Table 2 and detailed injury and fatality cost data from Parry (2004). Given the total external costs in Table 3 and the average annual accident data from Table 2, the total external costs of accidents in the GTHA is $1.79 billion a year. Divided by the total vkt in the GTHA produces an average external cost estimate of $0.032 per vkt. For sensitivity analysis, this estimate will be used as a lower bound, and the high estimate of Parry (2004) converted to Canadian dollars will be used as an upper bound.

For Ontario as a whole, applying the external costs in Table 3 to the Ontario accident statistics in Table 2 provides an estimate of total external costs of accidents of $5.08 billion. Dividing by total Ontario vkt produces an average external cost estimate of $0.042 per vkt. For the Ontario gasoline tax calculations, $0.042 per vkt will be used as the preferred parameter value.

Table 3: External Costs Per Accident

Category	Fatality	Injury
Medical	21,297	4,494
Legal	98,451	878
Property Damage	2,912	1,026
Police & Fire	803	78
Travel Delay	5,950	902
Employer Costs	0	544
VSL/QALYs	5,800,000	12,447
Total	5,929,414	20,368

Notes: These values are taken from Table 2 in Parry (2004) which displays total social costs of accidents. They are then adjusted to external costs following the directions in Parry (2004) and converted to Canadian dollars using the average exchange rate in 2006 (1.134). The injury costs are for injuries of unspecified severity.

3.4 Traffic Congestion, E^C

HDR (2008) calculates the total external costs of traffic congestion for the GTHA in the AM peak traffic period for 2006. However, what is required for the current analysis is the marginal external cost of traffic congestion rather than the total. Given the information provided in the HDR study, it was possible to back out the marginal cost of traffic congestion for the whole GTHA using their assumed demand curve, assumed parameters, and provided results. This provides an estimate of the marginal external cost in the AM peak period of $0.44 per vkt. A simple approach to getting an estimate of the cost of congestion throughout the day is to assume this level of congestion two times a day, five days a week, 52 weeks a year, minus 9 statutory holidays, and no congestion at other times of the day, the value is $0.123 per vkt. This assumes that peak vkt is around 28% of total GTHA vkt[5]. The value selected for the current analysis is $0.123 per km.

Assuming no congestion costs at non-peak times suggests this may be an underestimate, but it is substantially higher than the values chosen by Parry and Small (2005) and Lin and Prince (2009). Furthermore, the estimate ignores agglomeration externalities that are foregone because of traffic congestion. The agglomeration externalities foregone by traffic congestion relate to labour market pooling, face-to-face learning, consumer amenities, and input sharing (Dachis 2013, 9). Dachis estimates that these foregone positive externalities increase the total external cost of congestion for the GTHA by "at least $1.5 billion and as much as $5 billion per year" (2013, 1). The total external cost of traffic congestion in the GTHA is estimated to be $6 billion in 2006 by HDR (2008). If $1.5 billion is added to this estimate and divided by the total vkt for the GTHA, we get an estimate of the average external cost of congestion of $0.134 that is close to the selected value of $0.123. If the higher estimate from Dachis (2013) is chosen, we get an estimate of the average external costs of congestion of $0.197 per vkt. For an upper bound in the sensitivity analysis $0.197 per vkt will be used.

On the other hand, the selected value may be too high. The congestion costs may be higher during the AM peak than during the PM peak, e.g., lost time in the morning may be valued at the rate of foregone wages, whereas lost time in the evening may be valued at the rate of foregone leisure. Furthermore, as noted by Anderson (2013) when studying traffic congestion in Los Angeles, the PM peak is twice as long in time frame as the AM peak. If the traffic volume of the two periods is similar, congestion in the PM peak period would be expected to be less. The HDR (2008) estimates assume the value of time is $26.57 an hour, but they mention a lower estimate recommended by a Transport Canada model of $10.50 an hour. Using this lower estimate for the PM peak period produces an estimate of the cost of congestion of $0.22 per vkt during the PM peak period. Assuming $0.44 per vkt in the AM peak and $0.22 per vkt in the PM peak, 5 days a week, 52 weeks a year, minus 9 holidays, provides an estimate of $0.092 per vkt. This estimate will be used as a lower bound in the sensitivity analysis.

For Ontario as a whole, information on traffic congestion was less available. The total external cost of traffic congestion in the GTHA is estimated to be $6 billion in 2006 by HDR (2008). Transport Canada (2006) does provide an estimate of the total external cost of traffic congestion for the Ottawa metropolitan area of \$88.6 million; however, this estimate is based on 1995 data. Scaling the value up by the change in the CPI and the change in the number of vehicle registrations in the Ottawa area produces a value of \$121 million. Assuming no external costs of congestion outside the GTHA and Ottawa metro area, the total external costs of congestion are \$6,121 billion. Dividing this by K^0 for Ontario produces an estimate of the average external cost of congestion of \$ 0.051 per vkt.

3.5 Gasoline Price Elasticities, η_{FF} and η_{MF}

Studies estimating the own price elasticity of demand for gasoline for many developed countries generally find estimates ranging between -1.1 to -0.3. A recent study by Chang and Serletis (2014) using Canadian data and sophisticated econometric techniques suggest estimates ranging between -0.738 and -0.57. The Chang and Serletis study is particularly interesting because their approach accounts for transportation modes other than driving and their model specification ensures concordance with microeconomic theory. For the analysis, the midpoint of the Chang and Serletis (2014) estimates is selected as the preferred value for η_{FF}, with the range being used in a sensitivity analysis.

At first glance, the selected value may seem high in absolute value to some readers; however, a high value is justified because there is evidence that consumers respond more strongly to gasoline tax increases than they do to non-tax gasoline price increases. Li, Linn, and Muehlegger (2014) provide two reasons why consumers might respond more strongly to changes in gasoline taxes than to other changes in gasoline prices: Persistence and salience. First, consumers may change their behaviour more because they view gasoline tax increases as being more persistent or permanent than market driven increases to prices. Second, gasoline tax increases may garner more media coverage than market driven price increases, making the increase more salient to consumers. Li, Linn, and Muehlegger (2014) quantify media coverage of gasoline price changes and gasoline tax changes and find that tax changes garner media coverage that is significantly larger than for price changes. Overall, Li, Linn, and Muehlegger (2014) find that a 5 cent per gallon increase in gasoline tax reduces gasoline consumption by 0.86%. Rivers and Schaufele (2014) study the introduction of the British Columbia Carbon Tax and find that a 5 cent per litre increase in the tax on gasoline reduces gasoline consumption by 12.5%. Given the elasticity of demand for gasoline value selected for the current study and the q_F value, a 5 cent increase in the existing Ontario gas tax would only reduce gasoline consumption by 3.5%.

Barla et al. (2009) use provincial level panel data from the Canadian Vehicle Survey over the period 1990 to 2006 to estimate the elasticity of vehicle travel with respect to gasoline price, η_{KF}. They find a short run estimate of -0.08 and a long run estimate of -0.2. Parry and Small (2005) cite a few US sources and decide on -0.22 as their preferred value. Lin and Prince (2009) use data for California to actually estimate the parameter; their estimated value is -0.065. For the current analysis, -0.1 is selected as the preferred value of η_{KF}. Sensitivity analysis will be conducted on the range -0.04 and -0.22. The selected values for η_{KF} and η_{FF} imply a value for β of 0.153 (Note: Original published version reported 0.214).

For the actual numerical calculations given the equations in Section 2, the elasticity parameters η_{FF} and η_{KF} are entered in absolute value following Parry and Small (2005).

3.6 Other Parameters

The labour tax rate is endogenously determined through combining and rearranging equations (6) and (7). Y is assumed to be total Ontario GDP for 2006 ($560,576 million) and G is the consolidated expenditures of all levels of government in Ontario in 2006 ($211,898 million)[6] (Statistics Canada, 2011).

Ontario only moved to the HST in 2010, so the value for S is calculated for 2006 as follows. The Ontario retail sales tax was 8% in 2006 and generated $16,228 million in revenue in fiscal year 2006/07 (Ontario Ministry of Finance, 2007). Although the retail sales tax was not a VAT and had different coverage than the current HST, I use this value as a proxy estimate of the revenue an 8% HST would have raised. With no available estimate of the GST revenue collected from Ontario in 2006, I am forced to proxy this as well. The value of $12,678 million is calculated using the Ontario retail sales tax revenues from 2006/07 at 8% and the GST rate of 6.25% since the GST was lowered from 7% to 6% on July 1st 2006. Therefore, the total value of S is $28,906 million.

The average producer price, q_F of gasoline in Toronto in 2006 was $0.694/L (Natural Resources Canada, 2011). For Ontario as a whole, the population weighted average producer price of gasoline was also $0.694 (Natural Resources Canada, 2011; author's calculations). The current tax rate on gasoline, t_F^0 in Ontario is $0.247/L. Values for η_{KI}, ϵ_{LL}, and ϵ_{LL}^c are taken from Parry and Small (2005) and are 0.6, 0.2, and 0.35 respectively.

4 Results

4.1 Second Best Optimal Gasoline Tax

Given the assumed parameter values, the second best optimal gasoline tax for the GTHA is calculated as $0.4057 per litre (2006 CAD) of gasoline which is much higher than the existing tax of $0.247. The five cent a litre regional gas tax proposed by Metrolinx would bring the total gasoline tax in the GTHA closer to, but still over ten cents below, the calculated value. Interestingly, the calculated value is only two cents lower than the current total gasoline tax in Metro Vancouver, $0.4217. If no regional tax is implemented for the GTHA, the optimal tax for Ontario is calculated as $0.2851 per litre. The calculated value is slightly higher than the existing tax of $0.247, but much lower than the value calculated for just the GTHA. The difference is largely driven by the difference in the congestion externality. Seventeen cents of the regional tax is from the congestion externality whereas at the province level the congestion externality gets diluted to just 6.6 cents. Furthermore, most of that 6.6 cents is due to the congestion in the GTHA. This result supports the idea that a regional tax could be economically justified, while leaving the provincial tax at its current rate or even at a lower rate.

Table 4 displays a breakdown of the different tax components for the GTHA and Ontario alongside the results from Parry and Small (2005) and Lin and Prince (2009). The second best optimal gas tax for the GTHA is similar to that calculated for California. The tax is larger than the value Parry and Small (2005) calculated for the US and smaller than the value they calculated for the UK. The value calculated for Ontario as a whole is much smaller than all of the other values, which is surprising because both the other studies use a very small value of the social cost of carbon. The social cost of carbon assumed by Parry and Small (2005) only accounts for climate damages at the national level; whereas, the value in the current study includes global climate damages. Despite a low value for the social cost of carbon, the value calculated for California by Lin and Prince (2006) is mainly higher than the estimate for Ontario due to the fact they assumed a lower elasticity of demand for gasoline (leading to a higher Ramsey tax component), higher local air pollution costs, and non-zero costs associated with oil dependence. The very high estimate of the tax for the UK by Parry and Small (2005) is mainly driven by a relatively high value of congestion costs (they contribute almost half of the calculated tax).

For the GTHA tax, the Adjusted Pigouvian component accounts for 71.5% of the total tax; more than half of which is due to traffic congestion. The Ramsey component makes up 27.2% of the tax, and at around \$0.11/L is itself smaller than the current gasoline tax. The congestion feedback component is inconsequential at 1.3% of the total tax, which corresponds to around half a cent per litre.

When looking at a regional gasoline tax for the GTHA, the labour tax rate, t_L is calculated to be 31.94 per cent. When considering an Ontario-wide gasoline tax instead, t_L is slightly higher at 31.97 per cent.

Table 4: Optimal Gasoline Taxes for the GTHA, Ontario, and Other Jurisdictions, $/Litre

Tax Components	Toronto-Hamilton	Ontario	California	United States	United Kingdom
Adjusted Pigouvian Tax	0.29	0.185	0.25	0.26	0.36
Pollution - fuel	0.046	0.046	0.02	0.02	0.02
Pollution - distance	0.021	0.018	0.04	0.06	0.06
Congestion	0.17	0.066	0.08	0.10	0.21
Accidents	0.053	0.055	0.05	0.08	0.07
Oil Dependence	0	0	0.06	0	0
Ramsey Tax	0.11	0.099	0.16	0.09	0.08
Congestion Feedback Tax	0.005	0.002	0	0	0.02
Total Gasoline Tax	**0.4057**	**0.2851**	**0.41**	**0.35**	**0.46**

Notes: All numbers are in 2006 CAD per litre. The US and UK values from Parry and Small (2005) were adjusted to 2006 USD using the US CPI. Both the Parry and Small values and the California values from Lin and Prince (2009) were converted to CAD using the average CAD/USD exchange rate for 2006. Some values may not sum properly due to rounding.

4.2 The Big Move

The Big Move transportation plan proposed by Metrolinx requires an investment of $2 billion annually into public transit infrastructure. A permanent exogenous shock to government spending of $2 billion is assumed to reflect this investment. Adding $2 billion to Ontario's 2006 government expenditures only has a negligible effect on the calculations, and the second best optimal gas tax increases by only five 100ths of a cent.

It should be noted that the improved public transit investment is assumed to only improve welfare through the representative agent's consumption of government services, not through reduced traffic congestion. This assumption is supported by the work of Duranton and Turner (2011) who find no empirical evidence that investments in public transit reduce freeway vehicle miles traveled, and thus congestion. However, this may not be the case for congestion on arterials. Anderson (2013) finds that a transit strike in Los Angeles increased congestion on arterial roads, but it is not clear that the natural experiment of a transit strike (a short run phenomenon) is reflective of the change in behaviour resulting from a long-term increase in public transit infrastructure. Furthermore, more recent work by Beaudoin, Farzin, and Lin (2015) examines the relationship between public transit capacity and traffic congestion in metropolitan areas across the US. They find that a 10% increase in transit capacity leads to a 0.8% reduction in congestion when controlling for a host of other factors such as income and population growth. More interestingly, they find that the effect on congestion can be as large as a 4% decrease in congestion for densely populated regions with well-developed transit systems. If investment to increase public transit capacity reduces congestion and therefore congestion costs, the value of the optimal gasoline tax would be expected to be lower. However, the effect may not matter significantly for the current analysis for two reasons. First, presumably there is a lag time for the building of the transit infrastructure and the current analysis is static in nature. Therefore, the absence of an effect on congestion costs in the current model can be justified by the gap between when a project is planned and when it is completed. The optimal value of the tax could be re-evaluated at a later date following the completion of portion of the Big Move plan. Second, the model in this paper is calibrated, for the most-part, using 2006 data; growth in population, incomes, and registered vehicles since 2006 would likely outweigh the relatively small effect on congestion from enlarging transit capacity in the GTHA.

5 Sensitivity Analysis

A similar approach to that taken by Lin and Prince (2009) is used to determine how sensitive the results are for changes in the assumed parameter values. Table 5 displays low and high values for the most important parameters. The optimal tax is calculated for each high and low value for an individual parameter while holding all other parameter values constant. It is clear that the results are robust to changes in individual parameters, with one exception, the elasticity of vehicle kilometers traveled with respect to the price of gasoline, η_{KF}. The 'low' value (in absolute value) for this parameter results in an optimal tax that is one cent less than the current tax in the GTHA. While holding all other parameters constant, the optimal tax for the GTHA is lower than the current tax for values of η_{KF} less than 0.047 in absolute value. Both the short run and long run estimates of this parameter, -0.08 and -0.2 respectively, provided by Barla et al. (2009) using Canadian data fall outside this threshold.

Table 5: Sensitivity Analysis Results for GTHA Tax

Parameter	Low Value	Low Tax		High Value	High Tax
E^{P_F}	0.011	0.36		0.145	0.52
E^{P_K}	0	0.38		0.021	0.42
E^{A}	0.032	0.40		0.12	0.56
E^{C}	0.092	0.35		0.197	0.55
η_{FF}	-0.738	0.36		-0.57	0.47
η_{KF}	-0.04	0.23		-0.22	0.81
q_F	0.568	0.39		0.841	0.42
Low Scenario	0.14		High Scenario	2.01	

Notes: All values in 2006 Canadian dollars. The Low Tax column indicates the optimal tax with the low value for that parameter while holding all other parameters constant; the High Tax column is similar except using each high value. At the bottom of the table, the Low Scenario is the optimal tax when all parameters have their low values. Similarly, the High Scenario is the optimal tax when all parameters have their high value.
Source: Author's calculations.

A further sensitivity analysis is undertaken by calculating the optimal tax when all parameters have low values and when all parameters have high values. The results are displayed at the bottom of Table 5. In the high scenario the tax is $2.01 per litre. In the low values scenario, the optimal tax is only $0.14 per litre, which is well below the current tax of $0.247. Using R to make 10,000 random draws from a triangular distribution with a minimum of 0.14, maximum of 2.01, and mode of 0.4057, 220 (2.2 percent) of the draws are less than or equal to 0.247. This suggests that although there are parameter combinations which produce an optimal tax that is less than the current value in Ontario, these combinations are not very likely. For the proposed increased tax rate of $0.297, 472 (4.72 percent) of the draws are below this value. Clearly a gasoline tax in the GTHA should be higher if the tax is imposed at the metropolitan level.

Table 6: Sensitivity Analysis Results for Ontario Tax

Parameter	Low Value	Low Tax	High Value	High Tax
E^{P_F}	0.011	0.24	0.145	0.39
E^{P_K}	0	0.26	0.021	0.30
E^{A}	0.038	0.28	0.12	0.42
E^{C}	0.025	0.24	0.09	0.35
η_{FF}	-0.738	0.25	-0.57	0.33
η_{KF}	-0.04	0.19	-0.22	0.50
q_F	0.568	0.27	0.841	0.30
Low Scenario		0.095	High Scenario	1.32

Notes: All values in 2006 Canadian dollars. The Low Tax column indicates the optimal tax with the low value for that parameter while holding all other parameters constant; the High Tax column is similar except using each high value. At the bottom of the table, the Low Scenario is the optimal tax when all parameters have their low values. Similarly, the High Scenario is the optimal tax when all parameters have their high value.
Source: Author's calculations.

The sensitivity analysis results for the Ontario gasoline tax, in the absence of the regional tax, are displayed in Table 6. The optimal tax is calculated for each high and low value for an individual parameter while holding all other parameter values constant. The low values for only three out of the seven parameters lead to tax rates below the current tax ($0.247/L): The low values for the social cost of carbon, congestion cost, and the elasticity of vkt to gasoline price. And the low values for the social cost of carbon and traffic congestion produce tax values very close (the difference is in tenths of a cent) to the current tax value.

The Low Tax Scenario has a value of $0.095 per litre that is much lower than the current tax rate. The High Tax Scenario results in a tax rate of $1.32 per litre. Making 10,000 draws from a triangular distribution with a mode of 0.285, a minimum of 0.095, and a maximum of 1.32, only 1,009 (10 percent) of the draws are less than the current tax rate ($0.247). This is suggestive that, in the absence of the implementation of a regional specific gasoline tax for the GTHA, the Ontario tax on gasoline should be raised.

6 Conclusions

Recent debate in Ontario about how to fund the expansion of public transit infrastructure in the GTHA has led to a proposal for a regional gasoline tax of 5 cents per litre, bringing the total tax on gasoline to 29.7 cents. The provincial government has instead chosen to keep the gasoline tax at its current level. This paper determines what the tax on gasoline in the GTHA ought to be. When accounting for the external costs of vehicle travel (congestion, air pollution, and accidents) the second-best optimal gasoline tax for the GTHA is calculated to be 40.57 cents a litre (2006 CAD). This value is much higher than both the current gasoline tax rate in Ontario, and the regional gasoline tax proposed for the GTHA by Metrolinx. The level of the tax is insensitive to whether The Big Move public transit plan is funded through incremental government spending or not.

The resulting value is similar to estimates for California, the United States, and the United Kingdom. Interestingly enough, the calculated value for the optimal tax in the GTHA is less than two cents lower than the total of gasoline taxes levied in Metro Vancouver. And this difference would become smaller if the optimal tax for the GTHA was converted from 2006 CAD to 2015 CAD. The existence of this tax level in Metro Vancouver suggests that a regional gasoline tax of this level can be politically feasible in Canada.

If no regional tax is implemented for the GTHA, the optimal gasoline tax rate for Ontario as a whole is calculated as 28.51 cents per litre (2006 CAD). The calculated value is higher than the existing tax rate of 24.7 cents, but much lower than the value calculated in this study for just the GTHA. The difference is largely driven by the difference in traffic congestion between the regional and provincial levels. Seventeen cents of the regional tax is from the congestion externality whereas at the province level the congestion externality gets diluted to just 6.6 cents. Furthermore, most of that 6.6 cents is due to the congestion in the GTHA. This result supports the idea that a regional tax could be economically justified, while leaving the provincial tax at its current rate or even at a lower rate.

It is also interesting to consider what would have happened to the existing gasoline tax rate if it was indexed to increase with inflation. Ontario's current provincial gasoline tax rate (14.7 cents per litre) was set in 1992 and the current federal excise tax on gasoline (10 cents per litre) was set in 1995. If these taxes had been indexed to increases in the Ontario Consumer Price Index, the combined tax rate would have been $0.318/L in 2006 and $0.368/L in 2014 (author's calculations). The value for 2006 is only 3 cents greater than the optimal value for Ontario calculated in the present study (28.51 cents/L). Drivers in Ontario have paid gasoline taxes that were higher in real terms in the past than what they currently pay.

This study provides evidence that according to economic efficiency, the gasoline tax in the GTHA should be higher regardless of what is done with the revenues. However, the overall impact on equity is important to consider. Williams (2006) predicts that an equity neutral optimal gasoline tax for the United States is lower than the one calculated by Parry and Small (2005). However, if the revenue from the optimal tax is used to fund increases in public transit infrastructure, that may benefit poorer households relatively more, it is unclear what the net effect of the policy on equity will be. Targeting the revenue from a regional gasoline tax to increasing transit capacity may help build political support for the tax by mitigating regressive effects. There also may be gains in political support if the earmarking is done in a transparent manner so tax payers can see that the money is not going into general revenues. On the other hand, gasoline tax revenue is not necessarily the best option for funding long-term infrastructure plans. Steadily improving fuel efficiency has the potential to reduce the effectiveness of the gasoline tax as an instrument to reduce the vkt related externalities from driving. That said, the value of the tax and the use of other policy instruments, such as congestion pricing or a tax on vkt, can be revisited in the future.

Two potential limitations of the study are with respect to the model and provide several opportunities for future research. First, it is a closed economy model and future research could focus on adjusting the model to be more reflective of the behavioural changes having a gasoline tax at the metropolitan level might produce. Some drivers will be able to shift a portion of their gasoline purchases to stations located outside the border of the metropolitan area. Also, a tax at the metropolitan level may impact the location choices of businesses and households on the fringe of the metro area. To capture these responses, a core-periphery aspect would need to be included in the model. Furthermore, empirical work (likely focused on the Metro Vancouver area) would be needed to identify and quantify the size of these responses. Second, government expenditure is exogenous in the model. To endogenize the public transit investment decisions of the provincial government requires a much more complex model with larger data needs. Parry and Small (2009) evaluate the optimal funding levels of public transit in US cities, but the data requirements are much higher than what is currently available for the GTHA.

Notes

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[1]I refer here to the proposed methods to raise the revenue to fund the investment in public transit infrastructure. Beaudoin, Lin, and Farzin (2015) provide a second-best model that indicates building public transit infrastructure in itself is a way to reduce congestion when first-best pricing policies are politically impossible.

[2]The provincial tax portion in British Columbia consists of a \$0.085/L excise tax and a \$0.0667/L carbon tax.

[3]Two alternative approaches could arguably be used within the current model instead of treating the HST as a lump-sum tax. One approach would be to assume the HST applies only to the numeraire good and thus could be included in the overall tax on labour. Including the HST in the labour tax rather than as a lump-sum tax results in a higher estimate of the optimal gasoline tax. A second approach would be to apply the HST only to gasoline and not to the numeraire good. Applying the HST only to gasoline would result in a lower estimate of the optimal gasoline tax.

[4]Following Zhang et al. (2005), the US estimate is multiplied by Canadian income/US income.

[5]Total annual vkt in the GTHA in 2009 was reported as 55.9 billion vkt by AECOM (2013).

[6]Total consolidated expenditures by all levels of government in Ontario are available from Statistics Canada no more recently than 2008 due to the change away from the Financial Management System.

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