

## Defensive spending on tap water substitutes: the value of reducing perceived health risks

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### ABSTRACT

We examine factors that explain consumer spending on tap water substitutes using information from a national survey undertaken with a representative set of Canadian respondents. We develop a model to predict the percentage of households that undertake such spending for the purpose of reducing perceived health risks from tap water consumption. Using results from the model we estimate the magnitude of defensive expenditures to be over half a billion dollars (2010 US\$) per year for Canada, as a whole. This is equivalent to approximately \$48 per household per year or about \$19 per person per year. Residents of Ontario, the province in which an *Escherichia coli* incident took place in 2000, have the highest willingness-to-pay of approximately \$60 per household per year.

**Key words** | boil water advisories, bottled water, defensive expenditures, health benefits, tap water

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### INTRODUCTION

Safe drinking water is every Canadian's expectation. Until 11 years ago, a majority of Canadians believed that consumption of tap water did not cause health problems (Auslander & Langlois 1993; Levallois *et al.* 1999). This belief was challenged by two events early in the first decade of the new millennium. First, in April 2000 the presence of *Escherichia coli* O157:H7 in the tap water of Walkerton, a rural community in the province of Ontario, ultimately led to seven deaths and illness for over 4,000 people (Livernois 2001). A year later *Cryptosporidium* in the tap water of North Battleford, Saskatchewan caused many illnesses but no fatalities. A position paper from the Canadian Council of Ministers of the Environment (CCME) called for a concerted 'source to tap' approach in order to prevent tap water contamination through the adoption of multiple barriers for contaminants (CCME 2002). Nonetheless, drinking water quality problems continued to plague many parts of Canada. While their severity never reached the level of Walkerton or North Battleford, they have been serious enough for local public health authorities to issue a large number of boil water advisories – recommendations made to the public about the advisability of boiling tap water prior to drinking (Health Canada 2009) – for communities across Canada. Eggertson (2008)

reports that, as of March 31, 2008, there were 1,766 boilwater advisories and that Ontario had the highest number (679).

Better management of water sources to ensure quality tap water is an important goal for governments to pursue, however, some citizens may view these actions as insufficient in either scope or timeliness. Over the past decade the number of Canadians who have chosen to use home water filtration devices with their tap water and/or to drink bottled water in place of tap water has increased. Thirty percent of respondents in a 2007 Federal Government sponsored survey say that bottled water is their primary source of drinking water while more than half say that they treat their home tap water with some kind of filtration device prior to drinking it (Statistics Canada 2009). Such behaviour is not solely a Canadian phenomenon. Doria (2006) notes general trends towards increased consumption of bottled water and Doria *et al.* (2009) report that 34% of British respondents and 53% of Portuguese respondents in their cross-country survey use bottled water as their main source of drinking water at home.

While some individuals may purchase bottled water or filter tap water at home for reasons of convenience or

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taste, others may do so because they perceive bottled water/filtered tap water to be safer than water straight from the tap. [Doria et al. \(2009\)](#) find that tap water consumption is influenced negatively by risk perceptions of poor quality. [Statistics Canada \(2009\)](#) reports that 43% of respondents who treat their tap water prior to use with some form of home filtration device do so in order to remove possible bacterial contamination; 40% say it is to remove metals or minerals, and 51% indicate they do so to remove water treatment chemicals such as chlorine. Common home filtration devices are marketed as providing water that is free from impurities by removing contaminants that may be bad for a person's health. To the extent that discretionary expenditures on tap water substitutes are defensive in nature – that is, they are intended to provide protection to the purchaser – they reveal a willingness to commit one's own resources in order to achieve reductions in one's own perceived health risks from tap water consumption.

An examination of the magnitude of out-of-pocket spending on tap water substitutes is one approach that has been adopted for the purposes of measuring the health benefits that consumers may attribute to being able to consume safer drinking water ([Grossman 1972](#); [Harrington & Portney 1987](#)). The underlying behavioural model is the household production model ([Grossman 1972](#); [Courant & Porter 1981](#); [Bockstael & McConnell 1983](#)). It assumes that an individual combines market or purchased goods with non-market goods or services (for example, one's time or the overall quality of one's environment) in order to produce health services that are valuable to the individual. In the case of water quality and health benefits, expenditures on bottled water and/or home filtration devices are substitutes for tap water; expenditures are assumed to arise from motives of self-protection designed to avoid or reduce adverse outcomes.

An alternative approach for estimating the perceived benefits from health risk reductions is stated preference methods, such as contingent valuation ([Mitchell & Carson 1989](#)). The researcher describes a specific, hypothetical health improvement situation and then asks survey respondents to state whether they would be willing to pay a given amount of money in order to obtain the improvement. This approach has the advantage that policy analysts can describe scenarios that are outside the range of current experience and, in this way, provide future insights.

However, the hypothetical nature of such scenarios has been criticized ([Diamond & Hausman 1994](#)).

The majority of the literature on the valuation of health benefits associated with water quality has adopted the first or revealed preferences approach identified as either defensive behaviour or averting behaviour, although some authors noted that this may not be defensive behaviour when individuals drink bottled water for reasons related to perceived health benefits from the presence of certain minerals ([Doria 2006](#)). [Abdalla et al. \(1992\)](#) estimate the reduction in economic benefits (in the form of increased expenditures) of groundwater degradation in southeastern Pennsylvania using data from a mail survey. They look at increases in defensive expenditures (bottled water purchases, installation of home water treatment systems, water hauled from other sources and the boiling of water for other than hot beverages) due to a specific incident involving trichloroethylene (TCE) contamination. The range of estimated annual additional per household spending to deal with the TCE incident is between \$23 and \$49 (these and all subsequent values noted in the paper are converted to 2010 US\$ for comparison purposes). [Traoré et al. \(1999\)](#) survey a sample of Québec households to determine which factors encourage defensive spending behaviour intended to reduce risks from unspecified, endemic groundwater contamination. People with higher incomes and those who express concerns about environmental degradation are more likely to spend on tap water substitutes. The authors estimate that each household spends about \$265 annually in order to self-protect against perceived bacterial and mineral contaminants in tap water. [Abrahams et al. \(2000\)](#) examine drinking water choices of Georgia residents and find that individuals who perceive health risks from tap water consumption are more likely to adopt averting behaviour actions (filtering their tap water at home or purchasing bottled water). Average annual spending on bottled water is approximately \$164 per person. [Janmaat \(2007a\)](#), surveying households in Nova Scotia's Annapolis River watershed, finds that those who believe that water has made them ill in the past is a key factor in predicting perceived health risks. [Janmaat \(2007b\)](#) uses the data to estimate a model to explain whether households engage in some form of water treatment. Respondents who perceive a worsening of water quality are significantly more likely to treat, however,

more highly educated individuals are significantly less likely to undertake defensive actions. The average annual per household savings in defensive expenditures associated with a small improvement in water quality for those on municipally supplied systems is calculated to be approximately \$20.

As the preceding discussion highlights, there is repeated evidence in the literature over the last twenty years that some people hold strong beliefs that their tap water may represent a risk to their health. Further, there are fairly widespread beliefs that the purchase of tap water substitutes such as bottled water or home filtered water may reduce these personal health risks. It is tempting to view these values directly as measuring health benefits that consumer could obtain if they had greater confidence in their publicly supplied water and did not feel the need to spend on tap water substitutes. There are two opposing views on this matter. On the one hand, [Courant & Porter \(1981\)](#) argue that the values obtained from these revealed preference types of actions do not include the amount of money that individuals would be willing to pay to avoid pain associated with illnesses. However, as such pain avoidance values can only be obtained through hypothetical survey methods, revealed preference methods are viewed as capable of providing valuable information on the lower bounds of health benefits. [Breshnahan & Dickie \(1995\)](#) make a counter argument that actual defensive expenditures may in fact overstate health benefits since some part of the motivation for their purchase may arise for reasons unrelated to achieving health risk reductions. If these purchased goods provide utility beyond better health – for example, consumers may simply like the taste or convenience of bottled water – then reported expenditures will tend to overstate health benefits.

[Abrahams \*et al.\* \(2000\)](#) suggest a method that researchers may use to adjust observed defensive expenditures on bottled water and/or home filtration systems to remove the non-health-related component such as pleasant taste/smell and/or convenience, leaving behind an estimate of health-related benefits from better water quality. For their data they find that consumers purchase bottled water for health and non-health reasons, thereby requiring bottled water expenditures to be adjusted in order not to overstate health benefits. Their findings are instructive. For example,

[Traoré \*et al.\* \(1999\)](#) actual spending values are likely to be an over-estimate of the potential savings (or health benefits) since they do not include any adjustment in total spending on bottled water and/or water treatment devices for non-health or non-contamination reasons and the values do not pertain to a specific incident. This is less likely to be the case for [Abdalla \*et al.\* \(1992\)](#) since they examine behaviour arising from a particular contamination episode and so expenditures are likely to be a reliable measure of the health benefits.

Each of the examples cited above give an incomplete picture since they use relatively small sample sizes and respondents come from single communities. These results may not be relevant for a more geographically and possibly socio-demographically diverse sample. In the current paper we first present estimates of the magnitude of aggregate observed defensive expenditures on both bottled water and home filtered water for Canada, as a whole, and by each of four different geographic regions within Canada. We then present a model to separately predict the probabilities that these two different types of spending are being undertaken for defensive purposes, as opposed to other purposes. The explanatory variables in our model include not only socio-demographic characteristics that have been found relevant in the previous literature but also a subjective risk perception measure for each individual, as well as an objective risk measure in the form of information about the presence or absence of boil water advisories in communities. Using the estimated probabilities from this model we adjust actual bottled and home filtration expenditures in order to remove the non-health-related portions. These adjusted expenditures are then used to measure the value that Canadians hold with respect to the health benefits associated with better quality tap water.

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## METHODS

The data used in our analysis come from an Internet-based survey undertaken in 2004. The survey was designed to obtain data on the views that Canadians hold with respect to tap water and its substitutes, as well as their drinking water consumption choices, experiences with tap water and their health concerns about tap water ([Adamowicz](#)

*et al.* 2004; Dupont *et al.* 2010). E-mail invitations were sent to members of an Internet-enabled, Canada-wide representative panel maintained by Ipsos-Reid (<http://www.ipsos.ca/en/products-tools/ipsos-panels/>). The panel contained more than 100,000 members who have been recruited primarily over the telephone using random digit dialing. The survey was put on a secure website maintained by Ipsos-Reid. Respondents were given the choice of doing the survey in either French or English and 1,633 completed responses were obtained. We wanted approximately 1,600 completed responses from internet-enabled Canadians representative of gender and geographical (provincial) populations. Therefore, a total of 4,563 e-mail invitations were made to a random sample of the members of the Internet panel. From this 2,520 respondents started the survey. Of this number 419 quit before completing it and 466 were screened out of the sample since they were on septic systems or private wells. We included only individuals on municipal water systems because of other questions asked in our survey about such systems. Finally, 2 responses were deleted due to server errors. Our overall response rate is 35.8%, similar to that obtained by Pintar *et al.* (2009).

Respondents were asked to provide information about the percentage of water consumed at home from each of three sources: water directly from the tap, bottled water, and tap water that is treated with some type of home filtration device prior to use. We classify each respondent's household as consuming primarily direct tap water, bottled water, or home filtered tap water if the household's consumption is 75% or more of one type. Table 1 reveals that a majority of households drink tap water that has been filtered with some type of home filtration system – either a container style (water pitcher or jug that has a removable filter) or an on-tap filtration device. In addition, a substantial number – more than one in ten households – use bottled water as their primary source of drinking water. This value is lower than the one of 33% reported by Statistics Canada (2009) in their survey undertaken in 2007; however, the difference may lie in the meaning of 'primary use'. Statistics Canada does not define primary in their survey, so their measure may include respondents who consume between 51 and 100% of their drinking water from bottled water. Our choice of 75% or more consumption to define primary usage is in accordance with

**Table 1** | Descriptive statistics: survey and census comparison

	Survey	2001 Census
Primarily tap water consumption (% households)	34%	n.a.
Primarily bottled water consumption (% households)	13%	n.a.
Primarily filtered home water consumption (% households)	53%	n.a.
Average household income (2010 US\$1,000)	67	67
Average household size	2.6	2.6
Age	48	46
Females (%)	50	50
Educated beyond high school (%)	80	55
English is first language (%)	76	73

<sup>a</sup>Primarily is defined as consuming 75% or more of a particular type of water. n.a. not applicable because the Census did not ask this question.

other literature that looks at tap water choices (Jones *et al.* 2006). However, since respondents in our sample specify exact percentages of water choices consumed, we note that 18% of households in our sample consume bottled water according to a definition of 50% or more.

Respondents who answer that they filter their tap water are also asked a series of questions about the type of system (e.g., container or on-tap), its purchase price, frequency of filter replacement and filter costs. Respondents who indicate that they purchase bottled water are asked to state the monthly household expenditure. Further, each respondent is asked a series of questions about whether she/he has experienced colour, sediment, taste or smell problems with tap water and to answer a 4-point Likert scale question designed to elicit a subjective perception of health risk associated with consuming tap water in the home (see below for question details). Separate from the survey, we collected data on whether a respondent's community has experienced a boil water advisory since the *E. coli* event in Walkerton, Ontario in 2000 (The Water Chronicles National Water Advisory Map).

Finally, socio-demographic information is collected from respondents. As Table 1 shows our sample is representative of the Canadian population according to the 2001 Census of Canada. The only socio-demographic variable for which we observe a difference between the Census and our sample population is the percentage of people educated

beyond high school (55% in the 2001 Census and 80% in our 2004 survey). We do know, however, that Canada experienced a rapid expansion of more highly educated individuals over the period. A comparison of the 2001 Census results with the 2006 Census results shows that the number of respondents with education beyond high school increased by 24% over the five year period (Statistics Canada 2006b).

Two aspects about the data are noteworthy. First, two-thirds of households undertake spending on one or other of tap water substitutes in order to supply the majority of their drinking water needs. Our data provide estimates of the magnitude of this spending on a per household basis. In order to obtain Canada-wide estimates of defensive spending to obtain better quality drinking water, we can use the number of households in the sample who make these expenditures to calculate the proportion of the total Canadian population doing so. We can then obtain estimates of aggregate Canadian spending on bottled water and home water filtration operations. Second, as discussed in the previous section expenditures calculated in this way may provide an over-estimate of defensive spending if people buy bottled water and/or filter their tap water for reasons other than those relating to health concerns about tap water. However, it is possible to adjust actual expenditures from our survey using an approach suggested by Abrahams *et al.* (2000). Step one requires that we determine the proportion of households who are predicted to be undertaking the two types of defensive spending (bottled water purchases and home filtration device expenditures) for health reasons alone. Step two uses these predicted proportions along with per household expenditures to obtain adjusted expenditures that can be attributed only to health concerns.

For step one we develop an empirical model to predict each household's primary drinking water choice. By classifying each household into one of the three categories identified above (direct tap water, home filtered tap water, and bottled water), we have three mutually exclusive choices. Under this circumstance a multinomial logit model can be used to better understand each household's choice, given socio-demographic characteristics and other explanatory factors (Greene 2008). We are interested in identifying those factors ( $F$ ) that lead a household ( $i$ ) to make a single choice ( $j$ ) from more than two mutually

exclusive alternatives (where  $J$  is the set of alternatives; this is three in our case). In Equation (1) we define the probability ( $\pi_{ij}$ ) of household  $i$  choosing alternative  $j$ . Given socio-demographic characteristics and other key explanatory factors, each household is assumed to choose the most desired alternative from amongst the three alternatives. Explanatory factors are represented by the vector,  $F$ , with corresponding coefficients to be estimated,  $\alpha$ 's.

$$\pi_{ij} = \frac{e^{\alpha_j F_i}}{\sum_{j=0}^J e^{\alpha_j F_i}} \quad (1)$$

The previous literature guides our choices of which factors to include in our vector,  $F$ . They are: income, age, gender, presence of young children (under 6) in the household, urban dweller, and university education. We also include marital status as a separate explanatory factor. In addition, we include information about the primary language of the household since the water contamination incidents discussed earlier both took place in predominantly English-speaking areas and were covered extensively by the English-language press. In addition, given Canada's experience with water contamination in different regions, we include household's geographic locations as explanatory variables. The regions are defined as: the Eastern provinces (Nova Scotia, New Brunswick, Newfoundland, and Prince Edward Island), the province of Quebec, the province of Ontario, and the Western provinces (Manitoba, Saskatchewan, Alberta, and British Columbia). It is important to note that relative prices of these choices may also be important factors, however, bottled water data are not available at the disaggregated level required. Insofar as tap water is concerned, the relevant price (marginal cost) to the household for one more litre is effectively zero. According to recent data from a survey of municipal water prices for Canada (2008 Municipal Water Pricing Report), the average domestic consumer pays \$1.26 for 1,000 L or \$0.00126 per litre. If we use an average recommended daily amount of water consumed of 3.2 L as recommended by the National Academies of Science (2004), then the daily cost of drinking water is \$0.00378. Over the course of a month, the cost per person would be 11 cents. In light of these very small numbers, the price for tap water is not included.

In addition to conditioning household water choices on socio-demographic factors in the vector  $F$ , we also include a variable relating to tap water aesthetics and two variables that may be relevant to households in their assessment of potential health risks associated with tap water. The first variable (POOR TAP AESTHETICS) is defined to be categorical denoting previous tap water experience with four types of events: rusty water, sediments in water, unpleasant smells and unpleasant water taste. We assign the variable a value of 0 if a household indicates that it has had no experience with any of these events in the past year and a value of 1 if a household has experienced any one of these. If the household indicates that it has experienced any two of these events, then it is assigned a value of 2, and so on, up to a possible maximum of 4 for such types of experiences. In our sample, 49% indicate no experience with any of these events, while 24% have experienced one and 18% have experienced two and 7% have experienced three.

The second variable is intended to measure a household's subjective perception of possible health risks associated with tap water (SUBJECTIVE RISK PERCEPTION). Respondents are asked: 'which of the following statements best reflects your personal opinion about the health concerns you might have with the tap water in your home?' The four possible responses are: (a) drinking tap water does not pose a problem for my health or my family's health; (b) drinking tap water poses a minor problem for my health or my family's health; (c) drinking tap water poses a moderate problem for my health or my family's health; or (d) drinking tap water poses a serious problem for my health or my family's health. For the purposes of categorizing households as either having no health concerns or having health concerns, we code responses as a binary variable. If the household says that tap water poses no health problem, then this variable is assigned a value of zero. If tap water poses either a minor, moderate or serious problem to health, then the variable is given a value of 1. In the entire sample, 39% of households have a value of 1 for this variable, indicating that they are concerned about the health risks associated with their tap water. Interestingly, when we restrict attention to households that primarily drink water directly from the tap without personal intervention, only 20% indicate some degree of concern about health risks. This result suggests that individuals who are more

concerned take defensive actions to mitigate these risks through the use of bottled and/or home filtered tap water.

The third variable identifies whether there is an objectively measured level of health risk from tap water by identifying whether the household lives in a community that has been subject to a boil water order since the first water contamination incident in 2000. The BOIL WATER ADVISORY variable is binary: a value of 1 indicates that a boil water advisory has been given (19% of respondents) within the past year and a value of 0 indicates the absence of boil water advisories for the community in which the household lives.

The construction of these variables merits discussion. Aggregation of responses from several variables and/or dichotomization of variables may lead to a loss of detail. However, this must be balanced against the gains of greater degrees of freedom arising from the inclusion of fewer explanatory variables. In each case, our choices are informed by responses obtained from focus group discussions. For example, respondents viewed different kinds of water events (rusty colour, smell and taste events, etc.) as being similar in annoyance level. Thus, we add together the number of these occurrences in order to describe the extent of experiences and to better understand how this might affect water consumption choices. In the case of the subjective health risk variable, we felt it important to be able to distinguish between those individuals for whom tap water posed no health concern and those for whom it posed a health concern. Our focus group discussions suggested that this was an important distinction for making water consumption choices.

In order to estimate the parameters of the model we define the log-likelihood function to be maximized in Equation (2). This is the joint probability distribution of the  $N$  household observations in the data, expressed as a function of the parameters (the  $\alpha$ 's). We use NLOGIT to obtain the parameter estimates that we employ in our second step (Greene 2008).

$$LLF = \sum_{i=1}^N \sum_{j=0}^J c_{ij} \ln \pi_{ij} \quad (2)$$

where  $c_{ij} = 1$  if individual  $i$  chooses alternative  $j$  and 0 otherwise.

## RESULTS AND DISCUSSION

### Actual expenditures on tap water substitutes

Table 2 shows the information from our survey on per household actual average expenditures on bottled water purchases, use of container devices to home filter tap water, and use of on-tap home filtration systems (for comparison purposes with other studies, all values have been converted to 2010 US\$). While average annual spending on bottled water per household is \$249, there is variation across regions: from a high of approximately \$277 by residents of the Western provinces and the Eastern provinces and a low of about \$189 by residents of the province of Quebec. In order to obtain comparable annual home filtration expenditures, we calculate the annual costs of using two different systems. For container systems, annual household costs include the amortized share of the purchase price to account for depreciation, as well as operating costs relating to the purchase of replaceable filters. Since container systems are expected to last for approximately three years (evidence based on focus group discussions), the amortized annual cost is assumed to be one-third of the initial purchase price. Annual operating costs are obtained by multiplying the average cost of a filter times the number of times it is replaced within a year. As Table 2 shows, the average annual expenditures on container filtration devices range from \$37 for respondents in Ontario to \$49 for respondents in the Western provinces.

Overall, the average amount spent per household per year in Canada to operate container filtration devices is \$44. The annual expenditures associated with using on-tap

filtration devices are calculated in a similar fashion using a longer amortization period for the capital cost. Um *et al.* (2002) consider the useful life of a tap filtration system to be 10 years. This means that the amortized annual cost is 10% of the initial purchase price. To this are added the annual filter replacement costs. Annual spending on this form of in-home filtration system is greater than that of container systems. This is not surprising since these systems require much larger initial purchase prices and filter replacement is also more expensive. Ontario is the province with the largest annual spending per household (\$136) while residents of Quebec spend the least (\$76).

### Model to predict household choices

Results from step one (the empirical model used to predict household proportions) are presented in Tables 3 and 4. Table 3 provides the estimated coefficients for each of the explanatory variables included in the model of household water choice and Table 4 presents the estimated proportions of households in the sample that are predicted to use the different types of water choices. These predictions are obtained by using estimates from the empirical model. Turning to the results in Table 3, we note that, since the three water choices are modeled as mutually exclusive for the purposes of this paper and we define the reference choice to be water consumed direct from the tap, the parameters indicate how different factors affect the choice of home filtration or bottled water purchases over direct tap water consumption. A positive sign means that an increase in the explanatory factor increases the probability of choosing one of the tap water substitutes over the option of using tap water directly.

**Table 2** | Annual average per household expenditures (2010 US\$) on tap water substitutes, number of households surveyed, and total number of households in Canada

	Canada	Western provinces	Ontario	Quebec	Eastern provinces
Bottled water <sup>a</sup> Expenditures (# households)	\$249 (764)	\$277 (222)	\$260 (335)	\$189 (175)	\$276 (32)
Container filter devices expenditures (# households)	\$44 (618)	\$49 (203)	\$37 (261)	\$44 (114)	\$41 (40)
\$ on tap filter devices (# households)	\$77 (139)	\$94 (56)	\$136 (61)	\$76 (16)	\$84 (6)
Total number of households surveyed	1633	515	624	411	83
Total number of households from census (millions) <sup>b</sup>	12.4	3.7	4.6	3.2	0.9

<sup>a</sup>An estimate of the annual per household average expenditure on tap water for drinking water purposes is \$3.43. This is found by taking the monthly estimate of \$0.11 per person times 12 months times 2.6 persons per household.

<sup>b</sup>Statistics Canada 2006, Census Data (2006a).

**Table 3** | Parameter estimates for multinomial logit model

Variable name	Factors affecting the probability of choosing bottled water		Factors affecting the probability of choosing home filtered water	
	Estimated coefficient	Estimated standard error	Estimated coefficient	Estimated standard error
Age	-0.0102	0.0061	-0.0072 <sup>b</sup>	0.0035
English-speaker	1.4656 <sup>a</sup>	0.4091	0.6337 <sup>b</sup>	0.2251
Income	0.944E-05 <sup>a</sup>	0.225E-05	0.149E-05	0.168E-05
University education	-0.7160 <sup>b</sup>	0.2239	-0.5252	0.1564
Children under six	0.4424	0.4937	0.3025	0.3320
Male	0.0059	0.1902	0.1006	0.1200
Male with children under six	-0.3199	0.7188	-0.3620	0.5123
Married	0.1723	0.2036	-0.0040	0.1271
Urban resident	-0.0233	0.1872	0.1212	0.1233
Resident of the Eastern provinces	-0.5811	0.4310	-0.3333	0.2764
Resident of Quebec	0.4716	0.3876	0.1019	0.2327
Resident of the Western provinces	-0.4751 <sup>b</sup>	0.2147	-0.2470	0.1448
Poor tap aesthetics	0.5193 <sup>a</sup>	0.0870	0.2628 <sup>a</sup>	0.0639
Subjective risk perception	2.1732 <sup>a</sup>	0.2852	1.3399 <sup>a</sup>	0.2419
Boil water order	0.6114 <sup>b</sup>	0.2378	0.2212	0.1640
Constant	-2.6349 <sup>a</sup>	0.5783	0.2480	0.3288

Chi-squared statistic for overall fit is 252.5456 ( $p = 0.000$ )

<sup>a</sup>Coefficient significant at 1% level.

<sup>b</sup>Coefficient significant at 5% level.

A negative sign decreases this probability. As Table 3 shows, factors leading to a statistically higher probability of a household choosing to be primarily a bottled water drinker include: income, being English-speaking, poor tap aesthetics, subjective health risks held with respect to direct tap water, and the presence of a boil water order in the community. Other factors that have potentially positive impacts include being younger, not having a university education, and not living in a Western province. Similar factors lead to a higher probability of choosing to use home filtration devices, although income is no longer significant.

The results show clearly that households are more likely to either purchase bottled water or use home filtration systems if they feel that their tap water may pose health risks (positive and significant coefficients for subjective risk perception that direct tap water poses a health risk). In addition, households in communities that have been subject to boil water orders are also more likely to respond by being bottled water users. Both findings suggest that money spent on these tap water substitutes can be viewed as defensive

expenditures undertaken in order to reduce the perceived health risk from consuming tap water; as such, they could be used to measure the amount of health benefits that respondents believe they may gain from having made these choices. The results also show that consumers who are not satisfied with some of the aesthetics of tap water, such as unpleasant smell and/or taste, are also more likely to purchase bottled water and filter their tap water. This means that some portion of the money spent on these choices may be for purposes other than that of protecting one's health and we need to adjust observed spending to remove this component.

We modify an adjustment approach suggested by Abrahams *et al.* (2000) to determine the proportion of observed spending on bottled water and/or home filtration that is not related to tap water aesthetics and, therefore, can be attributed to motivations related to defensive behaviour. We do so in order to avoid making an over-estimate of the potential health benefits that might be used in infrastructure decision-making (Provins 2011). The approach first

**Table 4** | Estimated proportions of water choices: Status quo and adjusted

	Bottled water user	Home filtered water user	Direct tap water user
Canada			
Status Quo	10.83	57.58	31.58
Adjusted	8.10	54.23	37.67
Western provinces			
Status Quo	11.38	57.57	31.05
Adjusted	8.22	53.89	37.89
Ontario			
Status Quo	13.58	60.42	26.00
Adjusted	10.22	57.89	31.89
Quebec			
Status Quo	7.14	51.77	41.09
Adjusted	5.65	48.53	45.82
Eastern provinces			
Status Quo	9.57	56.08	34.35
Adjusted	6.62	51.39	41.99

establishes the predicted status quo proportions of primarily bottled and/or home filtered water household users. We use the estimated parameters from [Table 3](#) with the average level of observed tap water aesthetics and sample average values for all other explanatory variables in order to obtain status quo proportions. These proportions reflect choices under the existing set of conditions about tap water aesthetics. We then use the model parameters to predict the proportions of households that would still choose to be primarily bottled or home filtered water users if tap water aesthetics (taste, smell, and appearance) were at their highest quality value (which we call the adjusted proportions). This adjustment process removes the aesthetics quality differential between tap water and the other choices, so the adjusted proportions indicate only the defensive rationale for choosing either bottled or filtered water in preference to tap water.

[Table 4](#) shows both the predicted status quo and adjusted proportions of households for Canada and each region. For example, it is predicted that under current

status quo conditions 10.83% of Canadian households choose to be primarily bottled water users, 57.58% choose to be primarily home filtration water drinkers, and 31.58% choose to be direct tap water drinkers. These predicted status quo proportions are very close to the observed proportions in the sample, as noted above. Therefore, we have confidence in the ability of the model to predict the adjusted proportions. [Table 4](#) also provides detail on the predicted status quo proportions by region. In particular, Ontario is predicted to have the highest proportion of households that use home filtration devices (60.42%), as well as the highest proportion of primarily bottled water using households. Given that the Walkerton *E. coli* incident took place in the province of Ontario, these results are not surprising.

[Table 4](#) also shows the predicted adjusted proportions. They are calculated using average values for all explanatory variables as before but assuming that tap water aesthetics are of the highest quality. If households spend on bottled water and/or home filtered water for reasons related to both health concerns and those related to aesthetics, then under this set of improved water aesthetics conditions our model should predict reductions in the proportions of households spending on bottled and/or filtered water and an increase in the proportion of households consuming tap water as their primary source. This is indeed what we observe in [Table 4](#). The adjusted proportions of households that would choose tap water is predicted to rise to 38% for Canada, as a whole, and to 32% for residents of Ontario. The adjusted proportion of households across Canada predicted to purchase bottled water primarily falls to 8% and to 10% for Ontario residents. Similar results are observed regarding predicted reductions in proportions of households consuming home filtered water primarily.

### Calculation of defensive expenditures

Our second and final step for obtaining estimates of the magnitude of defensive expenditures takes average expenditures on bottled and home filtered water per household from [Table 2](#) and uses them with the adjusted proportions of households spending for defensive purposes from [Table 4](#). In order to aggregate up to the Canadian population we use data on the number of households in Canada and

each of the four regions. We multiply average annual defensive expenditures per household on a specific defensive option by the proportion of households who are predicted by the model to choose that specific defensive option. For example, Table 4 shows the model predicts that 8.1% of all Canadian households in the sample choose to purchase bottled water for health reasons alone if tap water quality is seen as being completely satisfactory in terms of its aesthetic attributes of taste/smell, etc. From Table 2 we note that average annual spending on bottled water per household is \$249 for Canada, as a whole. Therefore, aggregate annual defensive expenditures on bottled water in Canada are calculated to be approximately \$251 million per year. This value is shown in Table 5, along with a breakdown of estimated defensive spending on bottled water by region. Estimates for each region are calculated using region-specific components for the adjusted proportions and average spending. The sums of the values for the four regions in this table do not equal the values for Canada, as a whole, since population weightings differ under the two approaches.

We use a similar calculation to obtain defensive expenditures associated with undertaking home filtration of tap water. However, since households do have a choice of two types of home filtration systems, we first split the total proportion of households choosing home filtration into those

using container systems versus those using on-tap home filtration systems. For the sample as a whole, 81% of Canadians who do home filtration use a container and 19% use an on-tap system; these values vary marginally across the sample with 78% of the Western provinces residents using containers and 87% of the Eastern provinces residents doing the same. We then multiply the average spending per household on each of the two types of filtration by the specific proportion of users in a region. So, for example, 58% of the entire sample of Western respondents is predicted to use home filtration devices. Of this sub-set of households, 78% are observed to be using containers. Thus, our proportion of Western households using containers is 45%. Similarly, of the entire sample of Western households, 22% are observed to use on-tap filters, so, 13% of the entire number of households in that region have expenditures related to this type of defensive behaviour. In summary, the total proportion of Western households using one of the two types of home filtration devices is 58%, split between 13% using on-tap and 45% using containers. We repeat this approach using each region's observed split of container versus on-tap filtration proportions applied to that region's proportions of households choosing to be primarily users of home filtration devices.

Having constructed estimates for each of the three types of defensive expenditures that can be made, we add up the

**Table 5** | Annual aggregate unadjusted and adjusted defensive expenditures (millions 2010 US\$)<sup>a</sup>

	Canada	Western provinces	Ontario	Quebec	Eastern provinces
Adjusted defensive expenditures					
On bottled water	251	85	121	34	17
On container filter devices	241	77	78	59	17
On tap filter devices	98	41	71	15	5
Total value of health benefits = sum of adjusted defensive expenditures	590	204	271	108	39
Unadjusted defensive expenditures					
On bottled water	336	118	161	43	24
On container filter devices	256	82	82	63	19
On tap filter devices	104	44	74	16	6
Total unadjusted defensive expenditures	696	244	317	122	49

<sup>a</sup>Estimates for Canada are calculated using average Canadian spending estimates from Table 2 and estimated proportions for Canada as a whole from Table 4. Estimates for each region are calculated using region-specific components in the same way. The sums of the values for the four regions in this Table do not equal the values for Canada, as a whole, since population weightings differ for the two approaches.

amounts spent on bottled water, on container systems, and on on-tap systems in order to obtain an estimate of the total amount of defensive spending on tap water substitutes. This approach does not involve any double-counting as each household has been identified as belonging to only one of these defensive spending groups. This out-of-pocket spending made by Canadians to avoid health risks perceived to be present in tap water reveals what they are willing to do in order to protect themselves. As such, these values provide useful insight into the extent of perceived potential health benefits that consumers may attribute to being able to consume safer tap water for drinking purposes (Grossman 1972; Harrington & Portney 1987). For Canada, total potential health benefits per year using the information from our survey are estimated to be \$590 million. This figure is equivalent to approximately \$48 per household per year or about \$19 per person per year.

Our estimate for Canada falls within the range of values obtained by Abdalla *et al.* (1992)'s study to estimate the loss of health benefits (as measured by defensive spending on bottled water and/or home filtered water) associated with a water contamination event in Pennsylvania. This suggests that our estimates are successfully capturing health concerns that Canada have with respect to tap water quality and the extent to which they are willing to spend money on water, in addition to the amounts they pay their local water supplier for tap water delivered to their homes. Our estimate also falls within the range of the two previous estimates available using data from Canadian residents. Janmaat (2007b) obtains an estimate of approximately \$20 per household from residents of the Anapolis Valley in Nova Scotia who obtain their water from a municipal supplier. Our survey respondents are all on municipal water systems. His approach differs from ours in that he had limited information on individual choices and expenditures, so he used a stylized comparison of expenditures obtained from industry sources. As well, he examines a partial improvement in tap water quality. However, his findings are consistent with our observation that residents of Eastern provinces are less likely to either purchase bottled water or employ home filtering systems. Our estimate is lower than the Traoré *et al.* (1999) estimate of \$265 per household per year spending on avoiding bacteria and chemical contamination for several communities in Quebec. There are, at

least, two reasons for the high values they obtain. First, their survey respondents obtain tap water mostly from private wells that are subject to groundwater contamination from nearby agricultural activities. Second, and more relevant to our paper, however, is that Traoré *et al.* (1999) do not adjust for non-health related considerations. If we had used aggregate unadjusted expenditures, our estimate of the health benefits from better quality tap water would have been overstated by about 18% on average. Our estimate of aggregate annual expenditures undertaken for both health and non-health reasons – identified in Table 5 as unadjusted defensive expenditures – is calculated using the status quo proportions of households from Table 4 times spending per household and equals approximately \$696 million. The difference between the unadjusted and adjusted measures provides an estimate of the non-health-related spending on these tap water substitutes.

Our data and model also allow us to investigate the extent of regional differences in defensive spending. We find that residents of Ontario are predicted to be willing to pay the highest amount of money for self-protection: about \$60 per household per year while residents of Quebec are willing to pay about \$34 per household per year. Such differences are more likely to be the norm than the exception. For example, Doria *et al.* (2009) find differences in the way tap water quality and risks are perceived in the UK and Portugal. Both their work and ours point to the need to collect data at a finely disaggregated level in order to better understand individual motivations and choices. Aggregate values may mask important regional differences.

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## CONCLUSIONS

We examine factors that lead Canadians to undertake defensive spending on tap water substitutes and develop a model to predict the proportions of Canadians who do so for the purposes of reducing perceived health risks from tap water consumption. Our case study results using cross-Canada data with sensitivity to regional differences demonstrates that households are willing to spend significant amounts of money out of their own pockets to obtain water for drinking that they believe to be safer and cleaner than water direct from their tap. We find that the magnitude of these defensive

expenditures for Canada, as a whole, is almost \$600 million per year. In order to put this into context we look at the most recent data from Environment Canada on typical spending on water supply services from municipal water utilities. These data come from Environment Canada's 2004 survey of consumption and pricing. Using these data we construct the average annual household water bill to be \$434 (Environment Canada 2008). Environment Canada also reports that about 10% of the total water use in the home is for drinking/cooking purposes. This finding suggests that the drinking/cooking component of a household's water bill is about \$43 per year. When viewed in this context, our estimate of \$48 per household per year as the amount of defensive spending undertaken by Canadians on tap water substitutes provides evidence of a strong latent demand for good quality drinking water. This willingness to protect one's health by choosing to spend on tap water substitutes instead of using one's income for other purposes reveals more importantly the value of health benefits that Canadians attribute to having good quality water for drinking purposes.

These efforts that many households are willing to undertake to obtain high quality water for consumption confirm the importance of recommendations given to water utility managers by Means *et al.* (2002). He urges them to become better informed about their customers' views on water quality and the types of future water improvements they view as desirable. There are some interesting potential implications for the future of household water delivery and treatment systems. These may include technological changes associated with the delivery of different qualities of water to households in the future, as is currently done with dual reticulation systems in a number of communities in Australia and the USA.

The evidence provided in this paper on the magnitude of expenditures that Canadians are willing to make in order to have access to what they consider to be better, safer water can also be an important input into informed public sector decision-making regarding the timing and location of water infrastructure upgrades. A recent report for OFWAT (the United Kingdom Water Services Regulation Authority that regulates water services providers) recommends companies to '... consider the use of averting behaviour surveys to understand better the substitution and mitigation actions customers take ...' (Provins 2011, p. iii). The amount of

investment money that the Canadian Water and Wastewater Association estimated more than a decade ago for water treatment systems infrastructure needs alone over the period 1997–2012 was just over \$2 billion per year (CWWA 1998). Given the public sector's constrained capital budgets, it seems timely that greater use of the types of evidence estimated in this paper relating to consumer values be applied to future investment and infrastructure decision-making.

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