The Tax Consequences of Legal Cannabis

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Les auteurs analysent les répercussions de la légalisation relative à la consommation de cannabis à des fins récréatives au Canada sur les recettes fiscales. Ils construisent, calibrent et simulent un modèle de demande imbriqués à double niveau dans lequel le cannabis légal et le cannabis illégal sont des produits différenciés et qui incorpore des estimations économétriques de paramètres cruciaux. Premièrement, les auteurs constatent qu'il est possible que les recettes provenant de la taxe de vente et de la taxe d'accise par suite de la légalisation ne compensent pas entièrement la baisse des recettes tirées de la consommation d'alcool et de tabac. Deuxièmement, et par opposition aux recettes provenant de la taxe de vente et de la taxe d'accise, de nouvelles recettes seront tirées des impôts sur le revenu des particuliers et sur les bénéfices des sociétés. À l'aide des renseignements disponibles sur la structure salariale des sociétés productrices de cannabis, et en appliquant une distribution de Pareto aux revenus dans le secteur d'activité, les auteurs obtiennent une estimation des recettes tirées de l'impôt sur le revenu des particuliers. Pour calculer les recettes tirées de l'impôt sur les bénéfices des sociétés, ils utilisent les données antérieures sur la main-d'œuvre et les parts de capital et simulent les résultats découlant des hypothèses relatives au levier d'endettement. Ils estiment également la valeur monétaire de la légalisation dans le secteur privé pour les particuliers au moyen d'une fonction d'utilité. Leurs résultats par utilisateur tendent à indiquer une valeur annuelle avoisinant 500 $. Les conclusions de l'étude peuvent être transposées aux économies dont les taxes sur le tabac et l'alcool sont élevées et qui songent à la légalisation.

Mots clés : bien-être, cannabis, élasticités croisées, légalisation, marijuana, préférences, prix, taxes

We explore the tax revenue consequences of legalizing recreational cannabis in Canada. We build, calibrate, and simulate a two-level nested demand model in which legal and illegal cannabis are differentiated products and that incorporates econometric estimates of critical parameters. First, we find that sales tax and excise tax revenues accruing from legalization may be fully offset by declines in revenues from alcohol and tobacco. Second, and in contrast to excise and sales tax revenue, new revenue will accrue from personal income and corporate profits taxes. Using some available information on the wage structure of cannabis-producing corporations and imposing a Pareto distribution on incomes within the industry, we obtain an estimate of personal income tax revenues. To compute corporate profits tax revenue, we use priors on labour and capital shares and simulate the results of assumptions of debt leverage. We also estimate the private dollar value of legalization to individuals using a utility function approach. Per user, our results suggest a value roughly equal to $500 per annum. The results of this study may carry over to high-sin-tax economies contemplating legalization.

Keywords: cannabis, cross-elasticities, legalization, marijuana, preferences, prices, taxes, welfare

Introduction and Objectives

This article explores the consequences of cannabis legalization on aggregate tax revenues in Canada. Several arguments support legalization, and tax revenue generation is just one.[1] The tax revenues accruing from legalization depend, broadly, on two responses. First is the response of cannabis users in the illegal cannabis sector. The price difference between legal and illegal product, in conjunction with the strength of preferences for the legal product, determine the extent to which the legal market dominates (or does not dominate) the illegal market after legalization. Second, the markets for alcohol and tobacco

doi:10.3138/cpp.2019-062

(which, along with cannabis, we term "sin" or "recreational" goods) will be affected. Because these markets yield substantial tax revenues, estimates of the changes in consumption in these markets are critical. A meaningful estimate of the tax revenues pursuant to legalization thus requires, initially, a model of recreational goods consumption. A comprehensive view of tax generation also involves the supply side of the economy: revenues will accrue from payments to the factors of production—labour and capital.

Although some studies have explored the effects of medical marijuana laws (MMLs) on specific behavioural responses (including Dills, Goffard, and Miron 2017 on alcohol and tobacco consumption, Anderson, Hansen, and Rees 2013 on driving fatalities, and Powell, Pacula, and Jacobson 2015 on the use of opioids), because legalization of recreational marijuana is so recent just a few research papers (cited later) have studied the demand responses of the alcohol and tobacco markets.

The popular conceptualization of legalization is that substantial excise and sales (indirect) tax revenues should accrue as a result of bringing a large segment of the underground economy into the legal sphere. This has been the US experience in the early-to-legalize states (Colorado Department of Revenue 2019; Davis, Hill, and Phillips 2019). In some of these states, excise revenues from cannabis now exceed excise revenues from beer, wine, or liquor (in part because the excise rates on alcohol products are low).

In this article, we explore the tax environment surrounding legalization in Canada, and we find that the overall additional tax revenue generated from recreational goods may not be positive. This is because Canada is a high-sin-tax economy, and if expenditures are diverted to legal cannabis from other sin goods such as alcohol and tobacco, then the secondary decline in tax revenues from these goods may be sufficient to counteract the first-round positive tax revenue impact of legalization.

From the standpoint of income taxes, the story is different: a formerly illegal product that is produced legally sees a shift of resources from the underground sector of the economy, where taxes are evaded, to a legal sector where taxes are paid in the form of both a profits tax on corporate income and an income tax on personal earnings. In some new economic production activities, little additional net direct tax revenues may be generated, because resources arrive from other legal sectors of the economy where income and profits taxes are already being paid. In the case of cannabis, however, resources are ultimately arriving from the illegal sector where taxes are mostly avoided.

Our methodological approach to computing sales and excise taxes is to develop and calibrate a two-level utility-based demand-side model. At the lower level, cannabis is defined as a composite of legal and illegal cannabis. At the upper level, cannabis is one good along with other recreational goods—alcohol and tobacco—and these three are substitute goods in consumption.

Beyond tax revenue, there is the question of the degree to which consumer well-being increases. The lifting of a binding constraint on the consumption of a good that has mass appeal has the potential to raise welfare substantially. Given that the model used here for tax revenue prediction is utility based, it can also be used to estimate potential welfare or surplus measures of gain associated with legalization. To our knowledge, the literature has not yet addressed this question.

Although this article is developed for the Canadian marketplace, it should be relevant to other economies considering legalization. Western economies exhibit a remarkable range of tax rates on recreational goods. As a generalization, rates in Northern Europe are elevated; in Southern Europe, not so much. Some US states choose high alcohol and tobacco tax rates; others do not. Jurisdictions with elevated alcohol and tobacco tax rates may lose tax revenues from these goods if cannabis is legalized, whereas jurisdictions with lower tax rates should not.

The article has the following structure: next, we briefly describe the Canadian and US marketplaces for marijuana. Then we describe the model used to simulate excise and sales tax revenues from consumers; the technical presentation of the model is contained in Appendix A. In the "Tax Revenue Estimates" section, we explore tax revenues from cannabis, alcohol, and tobacco combined. The "Personal Income and Corporate Income Taxes" section explores taxes from personal and corporate incomes; the model underlying personal income tax generation is developed in Appendix B. The sixth section, "Consumer Welfare," contains consumer welfare estimates resulting from legalization; the formalities are developed in Appendix C. In the final section, we analyze the generalizability of the results and offer conclusions.

The Marketplace

Recreational cannabis has had a quasi-legal status in specific US states—initially Colorado, Washington, and Oregon—only since 2014. In contrast, almost 30 US states, and several other developed economies, have legalized medical cannabis or decriminalized the possession of non-medical-purpose cannabis. The decision to legalize cannabis consumption in Canada is a federal decision, but the retailing of cannabis falls within the jurisdiction of each province. In the tax domain, the federal government levies an excise rate of $1 per gram, with the provinces receiving 75 percent of that excise revenue. The choice of a relatively low federal rate reflects the objective of reducing the share of the illegal market. In addition, provincial governments may, and do, levy sales taxes on top of the excise-inclusive price.

Legalization in specific US states, or specific Canadian or European provinces within a federation, differs from

 doi:10.3138/cpp.2019-062

legalization at the federal level. For example, in the United States, some of the supply from the early-to-legalize states was diverted to out-of-state users in the form of recreational tourism and illegal cross-border shipment (Hansen, Miller, and Weber 2017; Orens et al. 2018). This smuggling pattern is also well documented in the tobacco literature, with prices differing significantly between adjoining states (Agaku et al. 2016). With federal legalization, cross–province-border purchases are likely not important in our analysis.

Non-price characteristics, such as quality and convenience in the form of easy access to retail outlets, are critical to the success of legalization. In particular, the retail structures in cannabis-legal US states have seen several hundred outlets spring up in each of the three states mentioned.[2] Our demand model of the cannabis market is one in which preferences are hedonically dependent on product traits. In particular, a mature market with easy access to multiple legal retail outlets yields a higher utility value to the consumer than a legal market in which access is limited because of a lack of retail outlets.

Cannabis Quantity Measurement

Cannabis comes in a variety of forms: In addition to the dry flower, there exist a number of edibles and oil-based, or non-flower, products. Oil may be infused into edibles or liquefied so that it can be vaped. Schedule 3 of Bill C-45—the *Canadian Cannabis Act* (2017a)—provides some equivalencies between dried and liquid product. A scientific basis for equivalencies can be found in Orens et al. (2015). Oil-based cannabis products are important on account of the growth of the e-cigarette market. The US Department of Health and Human Services (2016) reports that, among high school students who consume nicotine, the probability of vaping far exceeds the probability of smoking.

For the purpose of modelling the tax structure and consumer choice, we define cannabis as being either legal or illegal and define non-flower products in terms of dried flower quantity equivalences. Home-grown product is considered to form part of the illegal aggregate.[3]

Market Structure

The cannabis market structure in the United States is highly decentralized, with several hundred producers in states where it has been legal for just a few years. These are almost perfectly competitive markets despite some product variety, in that entry and exit are relatively free. Wholesale prices are reported at https://www.cannabisbenchmarks.com.[4] In Canada, most provincial governments have adopted a highly centralized system at both the retail and the wholesale levels. The province-owned retail monopolies are monopsonists in turn: they form the sole legal transit for product from producer to retailer. Some provinces permit private-sector retailing and, in all but Saskatchewan, province-owned monopsonies control purchases from producers. This may limit the number of producers the monopsonists choose to deal with. Online sales are in the hands of government agencies alone.

The monopolization of provincial cannabis procurement and distribution may lead to a more elevated cost structure on account of the higher wage structure (Glassdoor 2020) and less vigorous competition at the retail level. The mark-up over wholesale price for cannabis in the United States is typical of most retail: 100 percent or more. Caulkins et al. (2015) and Hansen et al. (2017) estimate even larger markups. With additional taxes, the resulting legal retail tax-inclusive price may place the product at a price disadvantage relative to the illegal sector.

Entry

At the production level, few barriers to entry exist in either Canada or the United States. Health Canada is responsible for licensing and, given past rates of issue, there should be 300 operative permits by mid-2020. Although this is a miniscule number compared with the number of producers in Oregon, Washington, or Colorado, some individual Canadian producers are national in their scope and hence much larger than their US counterparts. Although entry is theoretically free, it places significant demands on potential entrants (see Statistics Canada 2018b). Most production in Canada is indoor, with a small component in greenhouses.

Product Access

The abundance of retail outlets in cannabis-legal US states has been critical to the growth of the legal market. Washington State initially restricted retail outlets strictly by population using a lottery system, and it seemed to neglect the issue of distance, despite a trade-off depicted in the research (Caulkins 2013). It subsequently eliminated the quota or lottery approach to licensing retail outlets and switched to a Colorado-style system that evaluated applications on the basis of merit and need. Regulated market sales increased by 200 percent the following 12 months (Washington State Liquor and Cannabis Control Board 2015). This restrictive scheme, in addition to the elevated tax structure, contributed to the initial failure in Washington State to transition the market from an illegal one to a primarily legal one.

It is difficult to predict the success of government-owned online sales stores in Canada, given the reluctance of some users to place their use history in a government data bank. The current delays in developing a dense network of retail outlets in Canada (resulting from individual provinces assuming complete ownership of retailing) will prolong the transition period to a mature market. Nonetheless, the assumption of a mature market underlies our estimates.

doi:10.3138/cpp.2019-062

A Model of the Cannabis Market

We formally model the demand side of the market. The pervasiveness of retail monopolies means that we accept a retail price that is determined by a de facto single seller and simulate the demand-side reaction of the market. We do not impose profit maximization on the supply side; that would require an elastic demand for the product. The retail market equilibrates through the quantity decisions of buyers, and the producer side of the market equilibrates through free entry and exit in the longer run.

The demand side is represented by an aggregate consumer who has preferences over, or gets utility from, the consumption of cannabis, C, and all other goods. The details of the model are presented in Appendix A. A utility-based model has several advantages: First, it provides a means of developing a credible set of own- and cross-price elasticities in the current era, where econometric estimates are scarce. Second, it ensures that budgeting rules are not violated (total expenditure on all goods must remain constant) when prices or taxes in the system vary. Third, it facilitates modelling the pre-legal environment. Finally, it provides a means of computing the private dollar value of legalization (consumer surplus) to an average user.

It is useful to write a single equation to illustrate how expenditures vary after legalization. Utility V is obtained from consumption of recreational goods R and all other goods Z. Recreational goods include alcohol, A; tobacco, T; and cannabis, C. Cannabis has two forms, legal, C_L, and illegal, C_I, and the legal product is not available pre-legalization.

$$\text{Utility } V = V(Z, R(A, T, C(C_L, C_I))). \quad (1)$$

Post-legalization, expenditure is directed to the legal product as well as the illegal product, which continues to be purchased at a lower level in the market. Total expenditure on cannabis increases: users are willing to pay a higher price for the legal product because it does not involve breaking the law, and its quality is more reliable. Legalization thus channels some buyers from the illegal market and may also induce some new users. The degree to which the legal market establishes itself depends on the degree to which users are willing to substitute between the two products, on the relative prices of legal and illegal products, and on the ease of access to the legal product. The simulations we present envisage a long-run equilibrium in the market, that is, where numerous retail outlets are present, where a stable price differential between legal and illegal cannabis has been established, and where consumers are fully informed of the characteristics of the broad market. We choose parameters for the model that (in time) generate a financial market share of about 70 percent for the legal market. This share corresponds to Canada's Parliamentary Budget Office (2016) estimates and to estimates from some US states in which cannabis has been legal for several years. Caulkins et al. (2019) find that the legal share of cannabis expenditures in Washington State after three years of legalization stood at about 70 percent. Table A.1 presents market shares for different model parameters described in Appendix A, as well as different relative prices for legal and illegal product. A detailed discussion of the operation of the model and the content of Table A.1 are given in Appendix A. The results can be understood without exploring Table A.1. The tax estimates are presented in Table 1.

The operation of the demand model is as follows: expenditure on cannabis increases post-legalization. That generates new tax revenue, which we estimate. When expenditure on cannabis increases, expenditures elsewhere must decline to respect the global budget constraint. That redirection involves reduced tax revenues from these other goods. Critical parameters in the system are the elasticities of expenditure on alcohol, tobacco, and other goods with respect to legalization.[5] They determine the degree to which expenditures are redirected. The tax component of the prices of other goods determines the potential offsetting tax losses in the markets for these other goods.

Tax Revenue Estimates

Elasticity Priors

Estimates of tax revenues from cannabis legalization in Canada to date are limited to estimates in the cannabis market alone (see, e.g., Sen and Wyonch 2018 for estimates and a review). Impacts of legalization on taxes from complementary or substitutable products do not yet exist. A first step is to establish whether cannabis is a complement or substitute for other tax-generating goods and services and to recognize a global budget constraint on consumer expenditures. Several articles explore this relationship, and reviews are provided in Baggio, Chong, and Kwon (2018) and Choi, Dave, and Sabia (2017). Baggio et al. conclude that cannabis has a substitutability relationship with both alcohol and tobacco. They examine sales data by US county that link changes in alcohol and tobacco sales to MMLs for the period 2006–2015. They find that the implementation of a MML reduces alcohol sales by approximately 13 percent and tobacco sales by between 2 percent and 4 percent. Choi et al. examine the relationship between MMLs and tobacco consumption. Using three different data sets, they find strong substitution effects running from the presence of a MML to tobacco reduction. Including the impacts at both the extensive and the intensive margins together, the effect is on the order of 10 percent.

To our knowledge, there exists just a single econometric study for the United States that explores the impact of recreational marijuana legalization on alcohol and tobacco (Miller and Seo 2018). This study finds large cross-elasticities for the State of Washington: that is, their estimates indicate that sales of alcohol and tobacco decline substantially and significantly after recreational legalization, *ceteris paribus*.

Evidence from the chemistry literature supports a negative relationship between cannabis and tobacco if the cannabis has enough of a CBD component, because CBD is an antagonist to nicotine.[6] Thus, if legalization increases total cannabis use in the economy, then nicotine consumption should decline.

The tax revenue estimates reported in Table 1 take two forms. The first panel of results uses econometric estimates of own- and cross-price elasticities to compute the implied tax revenue changes. The second panel uses our demand model to simulate initial and final values of budget shares and tax revenues, subject to a global expenditure constraint. Estimates of effective tax rates are required.

Effective Tax Rates

Alcohol Effective Tax Rate

In addition to excise and sales taxes imposed by Canada's federal and provincial governments, revenues accrue to provincial governments in the form of dividends from their retail monopoly operations. For example, in Ontario, wine and liquor sales are through the Liquor Control Board of Ontario. Because the dividends remitted to their governments by these provincial agencies are a monopoly tax on alcohol, they must be included along with the pure tax components of recreational goods taxes. These dividends, in conjunction with excise duties and sales tax revenues accruing to both levels of government, are given in Statistics Canada (2018a). As a percentage of sales value to the consumer, the effective rate of taxation from alcohol is set at $11.9 billion/$22.5 billion = 0.53, or $t_A = 0.53P_A$.[7]

Tobacco Effective Tax Rate

The tax take per carton of 200 cigarettes for each year and province is reported by the Non-Smokers Rights Association (2018). We use their estimate of each province's retail carton price to convert this to an *ad valorem* tax rate and then calculate the population-weighted average over all provinces for 2017. The resulting rate is $t_T = 0.65P_T$; that is, of every dollar expended, $0.65 goes to government. Total expenditures on tobacco, net of sales taxes, are taken from CANSIM Table 36-10-0432-01. The result is an annual expenditure of $16.5 billion. Significant illegal sales characterize the tobacco market in some provinces. However, because the illegal sector yields no tax revenues, the change in tax revenues for the complete tobacco market is based on the change in the legal quantity of tobacco transacted.

Collectively, expenditures on the aggregate R are thus $43.8 billion from a total of approximately $1.200 billion, or 3.7 percent of total household expenditures. This includes an expenditure of $4.8 billion on cannabis, which we develop in the following section.

Other-Goods Effective Tax Rate

The effective rate on all other goods is less easy to compute, both because provincial sales tax rates vary considerably and because some goods and services are excluded, for example, food. The combined maximum of federal and provincial rates (goods and services tax, harmonized sales tax, and provincial tax rates for provinces that are not harmonized) is 15 percent and the lowest is 5 percent. Alberta has a zero provincial rate, meaning that just the federal rate of 5 percent applies (see Cherniak 2017). Accordingly, we simply use a rate of 7.5 percent for taxes on other goods Z in the simulations. The results are largely invariant to fluctuations around this value. The reason is that the difference between this rate on Z, on the one hand, and the rates on alcohol and tobacco (and to a lesser extent cannabis), on the other, is extremely large—almost an order of magnitude, and any variation in the assumed 7.5 percent leaves that difference relatively unaffected.

Tax Revenues Based on Econometric Estimates

After legalization, as noted earlier, the quantity C is predicted to increase. The econometrics literature has little to provide in the form of estimated quantity increases, however. Several studies point to a stationary rate of consumption for youth during the legalization phase (see Drug Policy Alliance 2018).[8] Our approach is to start with an assumed increase of 10 percent in volume. This is slightly ad hoc, but it is consistent with Dills et al. (2017), who find very small increases in use after the legalization of medical marijuana in 29 US states. Post-legalization, we use a legal expenditure share of 0.681 from the simulations reported in the third panel of Table A.1.

Several estimates of the value of the Canadian cannabis market pre-legalization fall in the neighbourhood of $5 billion (reviewed in Parliamentary Budget Office 2016). Accordingly, we specify the pre-legalization annual market to be composed of 800 tonnes of cannabis, with each gram selling at a price of $6, yielding a $4.8 billion market. Post-legalization, using the preferred estimates from the model described in the previous paragraph and assuming a 10 percent volumetric increase in cannabis, expenditures on illegal cannabis amount to $2.471 billion and expenditures on legal cannabis amount to $5.267 billion, for a combined market value of $7.738 billion. Because we set the tax rate on cannabis at 25 percent of the net-of-tax price, 20 percent of the $5.267 billion tax-inclusive expenditure is in the form of tax revenue, which amounts to $1.053 billion. This is consistent with the estimate proposed by Sen and Wyonch (2018), and it is the first numerical element in Table 2. It is the estimate of revenue when the market equilibrates, that is, when all planned retail outlets are in place.

We do not present tax revenue estimates in the table based on the findings of Choi et al. (2017) because they provide no alcohol impacts. Accounting for tobacco alone results in revenue declines that are approximately the same size as the increase in revenues from cannabis.

1. MS estimate that in Washington State, legalization led to a reduction of 20 percent in the quantity of tobacco demanded and a reduction of 12 percent in the quantity of alcohol demanded. Applied to the Canadian data, these estimates would imply a fall in expenditures on alcohol of approximately \$3.3 billion and in tobacco of \$2.7 billion, which lead to a reduction in tax revenue, using the rates described earlier, of almost \$3.6 billion combined. This is offset by a gain in tax revenue from all non-sin goods, *Z*, of \$0.225 billion. These estimates form the first numerical row of Table 1. They are not completely plausible for Canada because they imply a reduction in expenditure on alcohol and tobacco that exceeds the increase in expenditure on cannabis.
2. The second row of the table is based on BCK, who estimate a 13 percent decline in alcohol sales and a 3 percent decline in tobacco sales. The secondary losses here are smaller than the losses implied by the MS estimates, but they again nullify the gains in the primary cannabis market.

Tax Revenues Based on Model Simulations

We first calibrate the model such that base (pre-legalization) expenditure values on *C, A, T,* and *Z* are produced. Cannabis is then legalized, and expenditure on the cannabis aggregate *C* increases. As detailed in Appendix A, if the quantity of cannabis *C* increases, this can be modelled as a decline in its price, and this in turn reduces the price of the aggregate good *R*. Because the price of *R* declines, it is necessary to choose a value of the price elasticity of demand for *R* to determine how expenditures on it respond. If it is inelastically demanded, then expenditure on *R* must decline; the converse occurs if it is elastically demanded. Consider now the four rows of estimates in the second panel of Table 1. A full set of elasticity values for the components of *R* are generated in the model once it is parameterized to satisfy base-year quantity predictions for *C, A, T,* and *Z*.

1. The estimates in the first row are based on η_R = –0.5, necessitating a fall in expenditures on *R* in response to a decline in its price. Because expenditures on *C* increase, expenditures on *A* and *T* decline substantially. As a corollary, expenditure on *Z* increases, and this produces some additional tax revenue. The overall tax revenue change is –\$1.47 billion. The second row in the table produces qualitatively similar results, given that the demand for recreational goods remains inelastic. The change in overall tax revenue is –\$0.835 billion.
2. The third row in Panel 2 sets η_R = –1.0, meaning that total expenditure on *R* remains approximately constant in the face of a change in its price.[9] Hence, the increase in expenditure on *C* comes from *A* and *T*. Accordingly, the positive tax revenue figure associated with cannabis is offset by the tax revenues losses resulting from a decline in the consumption of *A* and *T*. The decline in expenditures on these goods results in a tax revenue decline of \$1.642 billion combined. The net impact here is a loss of \$0.201 billion in tax revenue.
3. The final row of the table contains estimates based on η_R = –1.25. In this case, the changes in tax revenues reflect the fact that, despite an increase in expenditure on *R*, within the *R* aggregate expenditures are shifted away from the higher-tax goods *A* and *T* to the lower-tax good *C* on account of the changes in relative prices within *R*. Hence, although legalization still generates substantial new tax revenues from cannabis, the reallocation due to relative price changes in the system reduces that new tax revenue substantially.

Table 1: Tax Revenues after Legalization (\$Billion)

Scenario	Cannabis	Tobacco	Alcohol	Other	Net
Econometric basis					
MS[a]	1.07	–2.18	–1.43	0.225	–2.32
BCK[b]	1.07	–0.322	–1.55	0.257	–0.55
Model basis					
η_R = –0.5	1.271	–1.364	–1.671	0.294	–1.470
η_R = –0.75	1.316	–1.051	–1.287	0.186	–0.835
η_R = –1.0	1.362	–0.738	–0.904	0.079	–0.201
η_R = –1.25	1.408	–0.425	–0.520	–0.029	0.434

Notes: MS = Miller and Seo (2018) elasticity estimates; BCK = Baggio, Chong, and Kwon (2018) elasticity estimates; η_R = elasticity of demand for recreational products *R*.

Sources: Baggio et al. (2018); Miller and Seo (2018); and authors' calculations.

In sum, the only scenario in which systemwide tax revenue does not fall is that in which the elasticity of demand for the aggregate of recreational goods is greater than unity. In this instance, the primary increases generated in the legal market are reduced to approximately one-third of the first-round impact as a result of the declines from alcohol and tobacco. However, this scenario is improbable given that the bulk of econometric price elasticity estimates for alcohol and tobacco are less than unity in absolute value. Fogarty (2010) provides a review of alcohol estimates, and Galbraith and Kaiserman (1997) and Gruber, Sen, and Stabile (2003) find tobacco estimates for Canada of less than one-half, which are consistent with estimates in international meta-analyses. It is straightforward to illustrate algebraically that, for the aggregate

R, if each component's own-price elasticity is less than unity in absolute value and goods are substitutes, then the elasticity of demand for the aggregate C must also be less than unity in absolute value. This is consistent with Nelson's (2013) meta-analysis of demand studies, in which he reports a price elasticity of demand of –0.5 for the alcohol aggregate. Accordingly, the tax revenue estimates corresponding to inelastic values of the η_R parameter are most credible.

It is important that the cross-price elasticities implicit in the model approximate econometric estimates. Analytical expressions are easily derived for these elasticities among A, C, and T and are similar in form to Equations (7) in Appendix A. The values in the final two rows of the table yield cross-elasticities in the range {0.01, 0.04}. These values are small relative to the average values reported by Miller and Seo (2018) and Baggio et al. (2018), yet they are sufficient to provide strong negative tax revenue countereffects to the positive cannabis-related tax revenues. This is because, even though the declines in the quantities A and T are modest, they each have unusually large tax wedges. With η_R = –0.5, the cross-price elasticities are larger—of the order of +0.13. In this case, the large tax wedge effect is compounded by a more substantial quantity effect. The choice of different η_R values thus implicitly places bounds on the cross-price elasticity parameters and produces a quasi–confidence interval around a mid-range value.

Tax Reform

We next explore the impact of a change in the tax rate t_L on tax revenues (TR) when the model is set to the post-legalization equilibrium. Technically, we compute $(\delta(TR)/\delta t_L)dt_L$ after legalization. In particular, we consider the impact of abolishing the assumed provincial sales tax component of the total tax wedge on cannabis. The federal excise component is left in place. This amounts to a price ratio of the legal to illegal products of 1.67, corresponding to the second panel in Table A.1. The precise outcome depends on the chosen elasticity value for the parameter η_R, but for each value used in Table 1, there is a decrease in systemwide tax revenue relative to where both elements of the cannabis tax are in place. The reason is that when the sales tax on C_L is eliminated, the effective tax rate is approximately halved. This implies a substantial decline in tax revenues from cannabis. The expenditure changes on C are relatively small, however, so the corresponding expenditure changes on A and T are also small when moving to the lower tax on C. Hence, total tax revenue declines slightly relative to when the sales tax is in place.

This result implies, conversely, that a small increase in the tax rate would increase tax revenue. However, this comes at the cost of reducing legal market share, which is an equally, or more, important target for the Government of Canada.

Personal Income and Corporate Income Taxes

The legal employment of labour and capital generates personal and corporate income taxes. When a new legal product supplants (in large part) an illegal product, employment is ultimately redirected from a tax-evading sector to a tax-generating sector. Consequently, both personal and corporate income taxes in the cannabis sector represent genuine new revenue, not offset by migration of labour and capital from other legal sectors.

A limited amount of data exist in 2019 that enable the computation of somewhat reliable estimates of personal income taxes. Firm-level wage data for some of the larger cannabis producers are obtainable from a search of https://www.glassdoor.ca (e.g., Glassdoor 2020). Combined with a form for the distribution of wages, these wage data yield an estimate of total wages and taxes paid, once the tax function is modelled. On the corporate side, the challenge is greater on account of the complete lack of corporate tax payments as of 2020: producers are running large operating losses and have incurred substantial up-front capital costs. Our approach is to use a prior on the breakdown of revenue as between capital and labour and to compute what corporate tax payments on domestic revenues might ultimately be, using different assumptions on depreciation and debt leverage.

Personal Income Taxes

Two ingredients are required to generate personal income tax estimates. The first is the form of the marginal income tax revenue function, and the second is a prior on the distribution of wages within the industry.

Because income tax rates in most federations vary by jurisdiction, our approach is to model the tax function for the province of Ontario. It accounts for about 40 percent of Canada's population and has a disproportionate share of registered cannabis producers. As explained in Appendix B, we combine the federal and provincial rates and then establish a top and bottom rate, and a curvature for the underlying marginal step function, by fitting a three-parameter form for the marginal tax rate. We assume that the income distribution in the cannabis-producing sector follows a Pareto distribution and obtain estimates of lower-end wages from Glassdoor (2020). These values and assumptions result in a tax take from the cannabis-producing sector that is almost 27 percent of labour income generated.

In the preceding section, we estimated that expenditure on legal cannabis would be about \$5.27 billion and that \$1.05 billion of this would be in the form of tax revenue. This means that \$4.22 billion accrues to production and distribution. If capital and labour incomes are such that two-thirds go to labour (Gomme, Ravikumar, and Rupert 2011), and 0.27 of the labour income goes to taxes, then personal income taxes should yield revenues of \$763 million.

Referring to Table 2, the estimate of excise and sales tax revenue, corresponding to the value η_R = –0.75, is –$835 million. Accordingly, employment-based tax revenues almost suffice to offset those losses.

Corporate Income Taxes

Corporate tax revenue estimates for this new industry are of necessity speculative. Stock market valuations of listed corporations fluctuate enormously and reflect potential earnings in both domestic and international markets several years into the future. Accordingly, starting from an asset value to infer likely earnings on which corporate taxes would be paid is hazardous. An alternative is to use the same approach as in the preceding subsection—that is, to infer payments to capital, make allowance for depreciation and debt payments, and apply the corporate profits tax rate to the remaining amount. Again, using the two-thirds/one-third split in corporate income and using the $4.22 billion figure from the previous section as income, then payments to capital are $1.41 billion. Of this amount, depreciation and payments on debt are netted out before applying the corporate tax rate. In Ontario, the provincial rate is 11.5 percent. The federal rate is 26.5 percent, making for a combined rate of 38 percent. Consequently, if half of payments to capital are taxable, then $268 million of revenue is generated (38% × 0.5 × $1.41 billion). If one-third or two-thirds of capital income is deductible in the form of depreciation and interest, then corporate tax revenues come to $359 million or $177 million, respectively.

These are admittedly back-of-the-envelope calculations, but they accord well with official estimates in the Government of Canada's Budget Plan (Canada 2018). Corporate tax revenues for 2018 are 30 percent of personal income tax revenues. Our baseline estimate of that ratio is 35 percent ($268 million/$763 million). In addition to this tax revenue, Health Canada levies a 2 percent fee on revenue to cover the cost of regulating the industry. This amounts to about $80 million. This might be considered as tax revenue or simply as a cost of legality.[10]

In addition, it is a slight exaggeration to say that zero corporate income tax comes from illegal supply. Some illegal product is grown indoors, and property taxes are paid, implicitly, on the space used for cultivation. To the extent that some of the capital used to grow indoor product continues to be used in the new equilibrium, some property taxes are being generated that are attributable to the capital used in illegal production. The capital no longer used (basements turned from a grow-lab to a den or home space) continues to generate tax revenue in a legal form. Consequently, there is no loss in property tax revenue from the capital used to produce illegal product pre-legalization, even though its allocation between legal and illegal activity may change.[11]

There is a twofold take-away from this: first, taxes on corporate income in a mature industry form a modest fraction of personal income tax revenues. Second, and as a result, although our estimates indicate that corporate and personal tax revenues combined are likely to generate a sum in the region of $1 billion, that sum will just be sufficient to counteract the substantial negative revenue from indirect taxes and result in a small positive tax contribution systemwide.

Consumer Welfare

Surplus measures of consumer well-being are not focal points for criminologists or politicians, but much of public economics evaluates policy measures using this concept. By *surplus,* we mean an estimate of the private dollar value accruing to users as a result of legalization. To our knowledge, the estimation of potential surplus value accruing from cannabis legalization has not yet been attempted. The model developed here can be used to generate estimates because it is utility based. The estimate we arrive at is large: approximately $500 per annum per cannabis user. Its development is described in Appendix C. The dollar value we arrive at provides an answer to the following question: "Given the dollar expenditure on cannabis pre-legalization, how much less expenditure would be required post-legalization to attain the same level of utility as was obtained pre-legalization?" The answer is that the reduction in expenditure would amount to $2.5 billion and, when this sum is averaged over Canada's five million users, each user could thus gain $500. Although this estimate depends on the model's parameter estimates, it is consistent with the tax results developed earlier in that each result uses similar parameter values. There may be a further social dividend from a reduction in crime (because criminal activity has been reduced) and a reduction in policing costs.

Generality and Conclusions

High- and Low-Tax States

The simulation results generated for Canada have consequences for economies that tax sin goods at a high rate. Although the United States has lower tobacco and alcohol taxes on average than Canada, most of Scandinavia, Britain, Ireland, and some other European economies have excise and sales taxes that are sufficiently high to result in outcomes similar to what we obtain (European Commission 2018a, 2018b). Table 2 contains sin-tax differentials that characterize some European economies. Scandinavian economies (Denmark, Finland, and Sweden) and Anglo-Saxon-Celtic economies (United Kingdom and Ireland) have the highest combined excise and value-added taxes on alcohol, whereas other large economies bordering the Mediterranean (Italy, Spain, and France) have just a fraction of those rates. Tobacco taxes are more uniform, and all of them are comparable to the rate used in this article for Canada. The table indicates that tax outcomes in Europe,

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should its economies embark on recreational legalization, will differ significantly.

Australia has the highest tobacco taxes in the developed world. Each cigarette is taxed (as of September 2018) at a rate of $0.80, which puts the cost of a pack of cigarettes in the $20–$30 range (Scollo and Bayley 2020). Alcohol excise taxes vary by type: beer carries a rate of $50.4 per litre of alcohol, spirits carry a rate of $85.4 per litre of alcohol, and wine carries a wine equalization tax (Australia 2020). The alcohol rates are lower than the high excise rates listed in Table 3, and the tobacco rate is higher. This indicates that some negative secondary tax consequences would materialize after recreational cannabis legalization in Australia.

Excise taxes across US states differ enormously. Tobaccofreekids (2019) reports state excise rates per pack of $0.30 in Virginia, $0.45 in North Carolina, $0.57 in South Carolina, and $0.62 in Tennessee. In contrast to these low-tax states, New York levies a rate of $4.35, the District of Columbia a rate of $4.50, and Rhode Island a rate of $4.25. Sales taxes and local taxes are also levied. Equally large differences apply to alcohol taxes. The federal rate depends on whether the beverage is a beer, a wine, or a spirit. Per gallon of alcohol content, the federal rate is $13.50 on spirits, $1.07 on wine, and $18.00 on beer. When corrected for alcohol content, this means that spirits are charged a rate about three times as large as that for beer and wine. Variations in taxes by place of purchase are due to variations in state excise taxes. Spirits rates vary from a couple of dollars in low-tax states such as Arkansas, Colorado, Maryland, North Dakota, Texas, and West Virginia to more than $20 in Washington and Oregon (Tax-rates.org 2019).

Low-Tax Simulation

To determine the impact of tax rates on alcohol and tobacco, we re-simulated the demand model, using the same tax rates on cannabis but excise and sales tax that are closer to the low-sin-tax economies of Southern Europe. Specifically, the values for excises and VAT in Table 2 for these countries suggest that the taxes applicable to alcohol and tobacco are less than one-half of the Canadian rates.[12] Accordingly, we reduced the alcohol and tobacco taxes to one-half of their values in the simulations reported in Table 1. We imposed a mark-up value of unity on pricing, meaning that a decline in taxes is fully reflected in the retail price. Second, we adjusted the value-added tax (VAT) upward to reflect the reality of the European tax structure, setting it at 15 percent rather than 7.5 percent. The standard European Union rate varies between 20 percent and 25 percent, but lower rates are imposed on a variety of necessities, in particular food (see avalara.com).

Base-year quantities were determined by assuming an elasticity of demand for alcohol of –0.5 and for tobacco of –0.4. Hence, a drop of x percent in the retail price, when scaled by the elasticity, yields a new counterfactual base-year quantity, expenditure, and tax revenue. We then follow the same procedure as in the main simulations and generate the tax revenue changes that accrue as a result of changes in the quantities demanded of the goods A, T, and Z after cannabis legalization. The results are given in Table 3.

As predicted, the declines in revenue from alcohol and tobacco are reduced, and the compensating rise in revenue from other goods Z increases on account of the higher VAT rate on Z. Despite the lower alcohol and tobacco taxes, net revenues remain modest in the two

Table 2: Alcohol and Tobacco Taxes in the European Union

	Wine		Beer		Spirits		Tobacco	
Country	Excise	VAT, %	Excise	VAT	Excise	VAT, %	Tax, %	Price
High-tax economies								
Denmark	156	25	7.5	25	2,016	25	79	274
Finland	383	24	35.6	24	4,785	24	86	284
Sweden	273	25	21.0	25	5,378	25	78	280
United Kingdom	326	20	21.6	20	3,250	20	84	525
Ireland	425	23	22.6	23	4,257	23	84	484
Low-tax economies								
France	3.8	20	7.4	20	1,741	20	81	337
Italy	0	0	0.0	22	1,036	22	77	233
Spain	0	21	2.8	21	959	21	84	525

Notes: Excise on wine = euros per hectolitre of wine not exceeding 15 percent alcohol content; excise on beer = euros per hectolitre; excise on spirits = euros per of ethyl alcohol; tax on tobacco = excise plus VAT as percentage of price; price of tobacco = weighted average price in euros per 1,000 cigarettes. VAT = value-added tax.

Source: European Commission (2018a, 2018b, various tables).

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Table 3: Tax Revenues after Legalization in Low Alcohol- and Tobacco-Tax Environment ($billion)

	Tax Revenue Scenario				
Model Basis	Cannabis	Tobacco	Alcohol	Other	Net Tax Revenue
η_R = –0,5	1.199	–0.929	–1.109	0.591	–0.249
η_R = –0.75	1.251	–0.730	–0.871	0.391	0.041
η_R = –1.0	1.304	–0.530	–0.633	0.190	0.331
η_R = –1.25	1.356	–0.330	–0.395	–0.010	0.620

Notes: Simulated base tax revenue pre cannabis legalization = $12.06 billion. η_R = elasticity of demand for recreational products *R*.

Source: Authors' calculations.

most credible scenarios—in which the demand elasticity for recreational goods as an aggregate lies in the range of –0.5 to –0.75. Hence, even with an optimistic recreational goods elasticity value of η_R = –1.0, the change in excise and sales tax revenues is just mildly positive: Row 3 in Table 3 indicates that of the $1.304 billion generated in cannabis tax revenue, when the decline in alcohol- and tobacco-based tax revenue is netted out, the addition of VAT revenue of $0.19 billion results in a net positive revenue of $0.331 billion.

To summarize, these simulations indicate that economies with alcohol and tobacco taxes that are about one-half the rates of the high-tax economies referenced in Table 3 experience a neutral indirect (excise and sales) tax impact and a positive direct (personal and corporate income) tax impact from cannabis legalization; in contrast, economies with high alcohol and tobacco taxes will gain revenue from income taxes alone while suffering losses from indirect taxes.

Conclusions

To our knowledge, this is the first article to analyze the consequences of legalization of cannabis on total tax revenues from indirect and direct taxes, in which the indirect taxes are computed on the basis of a multi-market recreational goods model. Simulations indicate that legalizing cannabis could result in negative systemwide indirect tax revenues in Canada and in specific European economies in which tax wedges on substitute goods are large. Moreover, a legal cannabis market that absorbs more expenditure, as a result perhaps of a highly successful legal market, results in a greater decline in alcohol- and tobacco-based tax revenues. In the United States, these results are unlikely to reflect the experiences of most jurisdictions on account of the low excise rates on sin goods. In Canada, taxes on cannabis are low relative to taxes on alcohol and tobacco (the reverse is more generally true in the United States), and so just a small decline in alcohol and tobacco sales may produce negative overall recreational goods tax revenue changes.

On the income tax front, we find that although taxes from employment and corporate profits should be sufficient to offset the best-estimate losses that accrue in the markets for recreational goods, the overall net tax revenue from legalization will be limited. This should warn advocates of legalization who base their case on the belief that legalization necessarily generates substantial new revenues that can be used for "virtuous" purposes. If legalization generates social value, then it should be based primarily on the case that a legal market for marijuana represents an improvement over a pervasive illegal market and that legalization generates a substantial surplus to consumers. The central message of the Le Dain report presented to Canada's federal government in 1972 ("Canadian Government Commission of Inquiry" 1972) was that criminalizing the use of soft drugs was negative for society. It was rejected or neglected by the Trudeau (Senior) government at the time but was embraced by the Trudeau (Junior) government 46 years later.

The importance of institutions cannot be overstated. Alvin Roth (2018) has stressed that if market design is substandard, then black markets may result, or black markets may be unnecessarily large. Much of the marijuana legalization policy debate among economists has focused on product pricing. Economists have emphasized that the cross-price demand elasticity between legal and illegal cannabis is high. However, this preoccupation with price has led some provincial governments in Canada to develop market structures that de-emphasize access and convenience. This is detrimental to the goal of transforming a substantial component of the total market to a legal form. Our model stresses that hedonic product characteristics, as represented in the model parameters, are as important as price values. A recent report on the Colorado marijuana market (Orens et al. 2018) finds that the combination of modest tax rates and numerous retail outlets has led to a dominant legal market. Colorado, Washington, and Oregon are states with small populations, yet each has approximately 500 bricks-and-mortar retail outlets. Hence, government policies aimed at increasing the legal market share must come to terms with having a substantial number of legal retail outlets, and this may require a change in culture in some communities.

We have not confronted the question of what constitutes an optimal cannabis excise or sales tax rate in the context of a game-theoretic approach involving higher- and lower-level governments. Specifically, provincial or state governments that have low alcohol and tobacco rates have little to lose in tax revenues as a result of a decline in demand for these products after the legalization of cannabis. Optimization at the lower level for such a state will result in a different tax rate than one applied by states with large state-level alcohol and tobacco excise rates.

Finally, we have not attempted to address either the obvious externalities that attend recreational goods or

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the impact of cannabis legalization on the health of users. Reduced alcohol and tobacco consumption bring health benefits, in both the area of tobacco use and where binge drinking specifically is reduced. These benefits are experienced both by the individuals whose consumption declines and by the social contacts of those individuals. As for cannabis itself, the potential range of health and safety outcomes in Canada is unlikely to be wide. Evidence suggests that, because Canada has had one of the highest rates of illegal cannabis use in the world, legalization per se will have a limited impact on health. We have indicated in this article that the impact of legalization on the quantity of cannabis consumed should primarily fall on low-dose users and on a limited number of new users. High-dose users account for three-quarters of all consumption, and those users were well provisioned by the illegal market before October 2018. Legalization will reduce crime, because crime has been redefined, and policing costs will fall correspondingly.

Concern has been raised regarding the potential for cannabis use to rise among teens post-legalization (Cyrenne and Shanahan 2018). The youth nicotine market has changed dramatically in the most recent five years, and particularly since 2018, when Juul arrived in the Canadian marketplace. The vaping prevalence rate in 2020 stands at a multiple of the smoking rate for teens, but the price of nicotine ingested through vaping is at most one-half the price of that ingested through cigarettes. This price decline will affect the allocation of recreational goods expenditure. The cohorts that have embraced vaping most vigorously are the teen cohort and the 20s cohort. Vaping is a new technology, and its adoption has diverted young cohorts away from cigarettes. Insufficient data are available at this time to determine whether nicotine vaping and cannabis vaping (now legal) may have a complementary component.

Notes

1 Other reasons are that police forces will be better able to direct their resources to more serious crime; that many societies now view cannabis consumption as no more dangerous or undesirable than gambling or alcohol consumption, and therefore the legal playing field should be levelled; and that legalization will facilitate the expunging of many cannabis-related felony convictions that have placed heavy penalties on those individuals affected.

2 Data are available from the annual reports of the respective regulatory bodies; for example, in Colorado the Marijuana Enforcement Division of the Department of Revenue produces annual statistics on production, processing, and retail licenses.

3 Technically, home-grown, up to a limit, is legal under federal legislation, although some provinces have outlawed it. Whether legal or illegal, this product generates no tax revenue.

4 Individual transaction volumes are typically small; the average for 2017 was just ten pounds (Schaneman, Sacirbey, and Nichols 2018), although the weighting used affects this number. Outdoor-grow product prices are lower than those for greenhouse or warehouse product (see https://www.cannabisbenchmarks.com). Smart et al. (2017) report that scale economies characterize production.

5 As a technical matter, in the model we treat the pre-legalization price of legal cannabis as being so high that it is not purchased. When cannabis is legalized, we can model that as a reduction from a near-infinite price for legal cannabis to a finite price. This interpretation means that the price of cannabis (legal and illegal combined) falls. Hence, we can then progress to use price elasticity estimates rather than elasticities of expenditure on tobacco and alcohol with respect to a change in a law.

6 Morgan et al. (2013) conducted a treatment–control experiment in which the subjects were smokers who intended to quit smoking. The treatment group was given an inhaler with CBD, and the control group was given a placebo inhaler. Subjects were asked to take a puff when they experienced a craving for nicotine. The treatment group experienced a 40 percent decline in cigarettes consumed, and the control group experienced a small and insignificant decline.

7 "Liquor stores, agencies and other retail outlets sold $22.5 billion worth of alcoholic beverages during the fiscal year 2017. Net income and other government revenue derived from the control and sale of alcoholic beverages, including excise taxes, retail sales taxes, specific taxes on alcohol, and licence and permit revenues, was $11.9 billion in the year ending March 31, 2017" (Statistics Canada 2018a).

8 Kerr, Lui, and Ye (2018) find that the increase in marijuana use among adults from 2000 to 2015 is primarily attributable to changing attitudes rather than legalization. This suggests that the 10 percent increase is in the true range.

9 We say *approximately* because discrete changes in price occur. Expenditure is exactly constant for just infinitesimally small price changes.

10 We are grateful to a referee for drawing our attention to this.

11 Again, we are grateful to a referee for drawing our attention to this.

12 Note that the apparently high rates on tobacco in Table 3 for Southern Europe are less than one-half of the Canadian rates. The effective Canadian rate is almost 200 percent, given that the tax wedge accounts for 65 percent of the retail tax-inclusive price. Rates of 80 percent for Europe are rates on top of the wholesale price.

13 We use the terms *aggregator* and *utility* interchangeably. Any utility function represents a means of aggregating products. Hence, we can think of utility as a monotonic transformation of the simple aggregator, and we normalize that transformation to unity without loss of generality.

14 This assumption allows some consumers to prefer the illegal product: they may have a special relationship with their supplier or have found a particular blend of tetrahydrocannabinol and cannabidiol (CBD) that is to their liking. In turn, this means that with equal prices for legal and illegal cannabis, a minority of consumers will continue to consume the illegal product. Technically, strictly convex preferences produce that result. This in turn implies that even though we have an aggregate consumer, preference heterogeneity is in the background.

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15 Because Canada has one of the highest prevalence rates among developed economies (Macdonald and Rotermann 2017), this is a reasonable assumption.

16 For example, consider an official price, inclusive of a $1 federal excise tax, of $10. If a province imposes a sales tax of 12.5 percent on top of that $10, the selling price becomes $11.25. In conjunction with this, if the street price is $6, then the price ratio is 1.875. This ratio is consistent with prices reported on Statistics Canada's Cannabis Hub (https://www150.statcan.gc.ca/n1/pub/13-610-x/13-610-x 2018001-eng.htm).

17 We assume a work year of 1,800 hours and a personal income deduction of $12,000, which yields a lower taxable income bound (z) of $16,800.

18 The distribution of wages there is likely flatter, but in provinces in which retail is the responsibility of provincial monopolies, workers are unionized, and an Internet search indicated that the wages of retail workers start in the neighbourhood of $20.

Acknowledgements

The authors have no conflict of interest. We are grateful to Fred O'Riordan for advice on income tax, to participants at the Volteface Cannabis Conference (Toronto 2019), and to three referees who provided numerous comments on the first draft. Any remaining errors are our own responsibility.

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Appendix A: Demand Model

We adopt a standard multi-level budgeting process of the Strotz–Gorman type (Gorman 1959; Strotz 1957): at the top level, the consumer allocates a budget between recreational goods R and other goods Z depending on relative prices. R contains cannabis, C; alcohol, A; and tobacco, T. At the lower level, the consumer allocates cannabis expenditure M_C between legal cannabis C_L and illegal cannabis C_I, depending again on relative prices and preferences.

Utility is thus

$$V = V\left(Z, R\left(A, T, C\left(C_L, C_I\right)\right)\right). \tag{2}$$

We denote P_C as the price index for cannabis and P_R as the price index for recreational goods; the price of Z is set to 1. We use constant elasticity of substitution (CES) aggregators for both cannabis C and recreational goods R.[13]

To satisfy a budget constraint at each level of aggregation, a price index is required such that the price index multiplied by the quantity aggregate equals expenditure on the aggregate. The form of the price index is obtained by deriving demand equations for each good in the utility or aggregator function, substituting them back into the function and then solving an equation that states price × quantity = expenditure for the price term.

We illustrate the optimization only for the lower level. The upper-level optimization for the components of R follows the same pattern. Accordingly,

$$C = \left(\alpha_L C_L^{-\beta} + \alpha_I C_I^{-\beta}\right)^{-\frac{1}{\beta}}. \tag{3}$$

Demand and share equations (C_i and s_i) subject to a fixed budget $\Sigma_j p_j C_j = M_C$ are of the form

$$C_i = \alpha_i^{\frac{1}{1+\beta}} p_i^{\frac{1}{1+\beta}} M_C \left(\sum_j \alpha_i^{\frac{1}{1+\beta}} p_i^{\frac{\beta}{1+\beta}}\right)^{-1} \tag{4}$$

$$s_i = \alpha_i^{\frac{1}{1+\beta}} p_i^{\frac{1}{1+\beta}} \left(\sum_j \alpha_i^{\frac{1}{1+\beta}} p_i^{\frac{\beta}{1+\beta}}\right)^{-1}.$$

Substituting C_i into C and solving for the identity $P_C \times C = M_C$ yields the price index

$$P_C = \left(\sum_j \alpha_i^{\frac{1}{1+\beta}} p_i^{\frac{\beta}{1+\beta}}\right)^{\frac{1+\beta}{\beta}}. \tag{5}$$

The alpha parameters define preferences, and consumers prefer the legal over the illegal product on account of its characteristics, not simply its taste.[14]

Products here are hedonic, so the legal product is preferred because its traits differ from the illegal product: for example, greater certainty is likely associated with the legal product's quality and production environment. Canada's Cannabis Survey (2017b) finds that users place a high degree of importance on knowing the product quality. The strength of preference for the products also depends on the relative ease of access: if there are few legal outlets and many illegal outlets, then the relative consumption experience associated with the legal product is diminished. We assume that cannabis is always available, although it may be difficult to access.[15]

The legal product is further preferred because the purchaser has no risk of being apprehended by police for acting illegally. The beta parameter implicitly defines the elasticity of substitution: $\sigma = (1/(1 + \beta))$. A necessary condition is that $\beta > -1$ for $\sigma > 0$. In addition, if the indifference set is to yield a zero value for one of the goods, it is necessary that $\sigma > 1$, meaning that $\beta < 0$; hence, $-1 < \beta < 0$.

The price index P_C is a "true" cost-of-living index that measures the price of a utility-of-cannabis level. It is homogeneous of degree one in the component prices. The standard approach to this modelling is to choose a set of parameter values, subject to existing prices, that generate the observed initial market shares or quantities. Then prices change, and new quantities and budget shares emerge. Our model has the feature that only one of the two goods exists in the pre-policy phase: the "legal" good is not yet legal. We solve the "non-existing good" problem by means of a virtual price. The canonical approach is that of Neary and Roberts (1980), who analyze binding (non-marginal) constraints on demand. The details are given next.

In a multi-stage budgeting model, partial effects of price or policy changes involve a reallocation of the expenditure on an aggregate M_C between the legal and illegal components. Changes in individual cannabis prices, however, also affect the overall cannabis price index P_C, which in turn affects the allocation of total income Y between C and other goods. The response of M_C is determined by imposing a prior value on the demand elasticity for C. The demand for any good (legal or illegal cannabis) is thus composed of a conditional demand, assuming expenditure M_C is constant, plus a component reflecting a change in expenditure on C, that is,

$$C_i = C_i(p_L, p_I, M_C(P_C(p_L, p_I), Y)). \tag{6}$$

The price elasticities ε_{ii} and ε_{ij} incorporate both the effect of changes in relative prices within the cannabis aggregate and the impact of a change in the price of cannabis on expenditure M_C allocated to cannabis. The elasticity formulas that emerge are

$$\begin{aligned} \varepsilon_{ij} &= (\sigma - 1)s_j + (1+\eta)s_j = (\sigma + \eta)s_j \\ \varepsilon_{ii} &= (\sigma - 1)s_i - \sigma + (1+\eta)s_i = (\sigma + \eta)s_i - \sigma. \end{aligned} \tag{7}$$

η (≤ 0) is the own-price elasticity of demand for C.

 doi:10.3138/cpp.2019-062

We examine an assumed long-run equilibrium state in the cannabis market. The actual market in 2020 is in a state of flux, and just a small component is legal in part because of a shortage of retail outlets. In the scenarios we consider, we imagine a marketplace in which outlets are plentiful, prices are set by vendors, and consumers quantity adjust in accordance with their tastes. The potential market shares for the legal and illegal products that emerge from the model depend on prices (and taxes) and the parameter values. Some combinations of these prices and parameter values result in post-legalization quantities and shares that are predicted in the literature (e.g., Parliamentary Budget Office 2016).

Table 1 contains simulated (long-run) legal expenditure shares for different sets of prices, taste parameters, and substitution elasticities. The ratio s_L/s_I for a given set of model values is obtained from the share in Equations (7):

$$S=\left(\frac{s_L}{s_I}\right)=\left(\frac{\alpha_L}{\alpha_I}\right)^{\sigma}\left(\frac{p_L}{p_I}\right)^{1-\sigma}, \qquad (8)$$

where $p_L > p_I$. M_C is not being held constant here; because the Engel curves for C_L and C_I are parallel, the ratio $S = s_L/s_I$ is invariant to M_C. We maintain the weak inequality $\alpha_L \geqslant \alpha_I$ in the simulations. The first panel in Table A.1 sets the relative price ratio to a value of 1.5; the second panel sets it to 1.67; the third panel sets it to 1.875. The 1.5 value describes those provinces in which the street price is high; the 1.875 ratio describes those provinces in which the street price is low relative to an official price.[16]

Reading across any row in the table's top panel, with preferences for the legal product increasing, the legal market share increases for each value of the elasticity of substitution. Where the average buyer has a modest willingness to substitute in response to relative price changes ($\sigma = 1.1$ is almost Cobb Douglas), the legal market share ranges between 49 percent and 67 percent. As the willingness to substitute between legal and illegal products increases, however, the legal share drops substantially for any given value of a_L/a_I. Where $\sigma = 3$, the legal share is less than one-third where consumers are balanced in their preference parameters ($a_L = a_I$). The simulations indicate that a strong preference premium for the legal product is required for its market share to be more than two-thirds, even in the presence of just a 50 percent price premium for the legal product. As consumers are more willing to substitute between sectors (larger σ), it is progressively more difficult to secure a larger market share.

The second and third panels contain estimates based on two further price ratios. With higher prices for the legal good, its share declines correspondingly; hence every entry is less than the corresponding entry in the first panel. The price ratio may evolve as a result of the legal sector being able to take better advantage of returns to scale than the illegal sector. This would favour a ratio of 1.67 over a ratio of 1.875. In contrast, illegal prices may be competed down after legalization.

Equation (8) indicates that preferences are in a sense more important than prices in determining market shares when the elasticity of substitution exceeds unity. The degree to which tastes dominate prices depends on σ. When σ is small, consumers are less willing to substitute between legal and illegal products. Consequently, the power of prices diminishes. Algebraically, the absolute value of the share elasticity with respect to preferences exceeds the value with respect to prices, but this excess relative impact diminishes with increases in σ:

$$\left|\frac{\delta \ln S}{\delta \ln\left(\frac{\alpha_L}{\alpha_L}\right)}\right| = |\sigma| + \left|\frac{\delta \ln S}{\delta \ln\left(\frac{p_L}{p_I}\right)}\right| = |(1-\sigma)|.$$

Because preferences in this model include product characteristics such as quality and accessibility, then policies designed to influence preferences, such as accessibility (in the form of the frequency of retail outlets), should not take second place to policies designed to choose the "right" price.

As already stated, a price index P_R is developed for R in the same manner as for C. Expenditure on R is determined by overall income Y, the value of P_R relative to the price of Z (unity), and the price elasticity of demand for R with respect to P_R. At the higher level, we parameterize the CES function for R so that expenditure shares for alcohol, tobacco, and cannabis reflect actual shares. In conjunction with effective tax rates on each recreational good, we compute base-year tax revenues and revenues after legalization.

Legalization necessarily increases the quantities C and R: with legal cannabis unavailable, then $C_L = 0$. In a utility framework, this is equivalent to a virtual legal price p_L that is high enough to drive C_L toward zero. Legalization effectively relaxes this virtual price; that is, $dp_L < 0$, $dP_C < 0$, and $dP_R < 0$. Hence, quantities C and R increase if demand curves slope downward.

For tax purposes, the critical behaviour is expenditure on C and R. If expenditure on C rises, then expenditure must be redirected from other goods, in the presence of an unchanged savings rate by households. The source of this expenditure transfer is critical: whether it comes from other highly taxed recreational goods A and T or lower-taxed other goods Z. The transfer of expenditures from a high-tax sector to a lower-tax cannabis sector has secondary tax revenue impacts that may severely moderate the first-round impacts.

The budget constraint is

$$Y = P_C C + P_A A + P_T T + P_Z Z. \qquad (9)$$

doi:10.3138/cpp.2019-062

The change in expenditure on cannabis must equal the negative of the change in expenditure on all other goods. Hence the budget balance equation is

$$-\Lambda(P_C C) = P_A \Lambda A + P_T \Lambda T + P_Z \Lambda Z. \quad (10)$$

The change in tax revenue after legalization is

$$\Lambda\ tax\ revenue = (\tau + t_L(\bar{p}_L + \tau))C_L + t_A \Lambda A + t_T \Lambda T + t_z \Lambda Z, \quad (11)$$

where p_L denotes the net-of-tax per gram price of legal cannabis C_L, t_L is the percentage sales tax rate on legal cannabis (there is a zero tax on illegal cannabis), and τ is the excise tax applied per gram, which is \$1, as described earlier. With tax rates on alcohol, tobacco, and other goods unchanged, Equation (9) requires that expenditure changes on C be balanced by compensations in (at least some of) the quantities demanded of A, T, and Z.

Legalization is treated as a large change in the virtual price of legal cannabis, C_L. With cannabis not legal, that is, $C_L \approx 0$, the cannabis aggregate contains just C_I. The true cannabis price indices in Equation (5) remain finite when one component of the price index goes to infinity, provided $\sigma > 1$. They are not fixed-weight indices like Paasche or Laspeyres indices. When a single price heads toward a limiting value, buyers still maximize utility by varying their consumption bundle, and that de facto permits them to purchase zero of that good. For example, with $\sigma = 2$ and $p_L \rightarrow \infty$, the price index for cannabis, Equation (5), becomes $P_C = (p_I/(a_i)^2)$.

Numerically, we set $p_L/p_I = 100.0$ when cannabis is illegal and set $p_L/p_I = 1.875$ when it is legal to maintain consistency with the simulations reported in Table A.1. The price ratio of 1.875 accords with the research in Cannabis Benchmarks (2019). The price ratio of 100.0 drives C_L almost to zero. The reduction in the shadow price of C_L reduces the price of the cannabis aggregate and, in turn, the price index for R. We specify a set of parameter values for the CES aggregator for R to generate base-year values. Using these parameter values in the price index for R (P_R) that has an analogous form to Equation (5), the result is ΔP_R = –13 percent. This modest decline in P_R, resulting from a large price reduction for C_L, reflects the small weight associated with C in the aggregate R relative to A and T.

Table A.1: Simulated Legal Market Expenditure Share s_L

p_L/p_I =	α_L/α_I →			
1.5				
$\sigma\downarrow$	1.0	1.25	1.5	2.0
1.1	0.500	0.551	0.600	673
2.0	0.400	0.510	.0600	0.727
3.0	0.308	0.456	0.600	0.780
1.67				
$\sigma\downarrow$	1.0	1.25	1.5	2.0
1.1	0.487	0.548	0.597	0.671
2.0	0.375	0.483	0.574	0.705
3.0	0.264	0.412	0.548	0.741
1.875				
$\sigma\downarrow$	1.0	1.25	1.5	2.0
1.1	0.484	0.546	0.595	0.668
2.0	0.348	0.455	0.545	0.681
3.0	0.221	0.357	0.500	0.695

Notes: σ is the elasticity of substitution in the utility function. The greater σ is, the more substitutable are legal and illegal products. The greater the ratio α_L/α_I is, the greater is the relative preference for legal cannabis for a given price ratio.

 doi:10.3138/cpp.2019-062

Appendix B: Personal Income Tax Payments

We combined the federal and provincial rates for the province of Ontario and then established a top and bottom rate, and a curvature for the underlying marginal step function, by fitting the three-parameter form for the marginal tax rate (MTR):

$$MTR = C - e^{-(\alpha+\beta y)}. \tag{12}$$

The parameter symbols used here bear no relation to those in Appendix A. It follows that the tax paid by an employee with a taxable income z is given by

$$Tax\ per\ employee = \int_0^z \left(C - e^{-(\alpha+\beta y)}\right) dy. \tag{13}$$

The calibrated values are $\{C = 0.5, \alpha = 1.204, \beta = 0.000010525\}$. We then follow Alvaredo et al. (2013) and impose a Pareto distribution on the form of incomes earned or generated; that is,

$$f(z) = \frac{y z_{\min}^{y}}{z^{(y+1)}}. \tag{14}$$

Hence, total income tax paid by all employees is

$$\int_{z_{\min}}^{z_{\max}} \int_0^z \left(C - e^{-(\alpha+\beta y)}\right) dy \frac{y z_{\min}^{y}}{z^{(y+1)}} dz \tag{15}$$

and total employee income is

$$\int_{z_{\min}}^{z_{\max}} \frac{y z_{\min}^{y}}{z^{(y+1)}} dz. \tag{16}$$

To operationalize this, estimates of the upper and lower bounds are required for z and an estimate is required for γ. Glassdoor (2020) indicates that cannabis-producing corporations have a heavy mass of employees involved in production who earn between \$15 and \$20 per hour. These are the lowest paid employees, so we set $z_{\min}$ to \$16.[17] The γ parameter defines the rate of decline in the distribution, and the mean income is given by $(\gamma/(\gamma-1))z_{\min}$. Alvaredo et al. suggest a value for γ of 1.5, which makes for a high skewness in the distribution and a correspondingly higher share of the top 1 percent of the economy's distribution. However, cannabis is a production sector without many of the economy's highly paid professionals. Accordingly, we set $\gamma = 2.0$. Experimentation with the upper limit indicates that whether it is set at infinity or some large constant such as \$1 million makes very little difference to the calculations because the distribution is very sparse beyond a certain point. The upper limit we arbitrarily set at \$1,000,000.

These values produce a tax take from employment in cannabis of almost 27 percent of labour income generated. We assume that the proportion of income going in the form of income taxes in the retail side is similar.[18]

doi:10.3138/cpp.2019-062

Appendix C: Consumer Welfare Estimates

Figure C.1 depicts an initial consumer equilibrium at point A. Legal cannabis has an almost infinite price, and this is reflected in the almost vertical budget constraint BC_0. U_0 represents the level of cannabis utility obtained. The legal price then falls to a finite value. If the same expenditure is directed to cannabis, the budget constraint becomes BC', and it permits an equilibrium at E corresponding to the utility level U'. The somewhat vertical profile of the indifference curves reflects a preference for the legal good, *ceteris paribus*. One measure of the monetary value of the price decline (legalization) is the difference between the monetary value of the budget constraint BC_0 and the amount required to reach the same level of cannabis indifference U_0 at the new prices, that is, post-legalization.

The amount required to attain U_0 initially is $M(U_0, P_0)$ (which is BC_0), and the amount required to attain the same level of cannabis utility following the lower price is $M(U_0, P')$. The price indexes are readily calculable using Equation (5) and depend on the parameter values of the model; heuristically, the value to the consumer of the price decline from almost infinite to finite will depend on how substitutable the legal and illegal products are. If they are almost perfect substitutes, the price decline is worth less than if they are strongly imperfect substitutes. To illustrate, consider the set of parameter values associated with the share value 0.681 in the third panel of Table A.1. Here the post-legalization price ratio is 1.875; the elasticity of substitution is set at $\sigma = 2$, and the preference for the legal product is twice as strong as for the illegal product. This results in $M(U_0, P') = 0.47 \times M(U_0, P_0)$; that is, the consumer would require just 0.47 of the pre-legalization budget (\$4.8 billion) to attain the same level of utility. Because the pre-legalization expenditure was \$4.8 billion, the surplus using this measure amounts to \$2.544 billion (0.53 × \$4.8 billion). Because there are approximately five million users in Canada (Statistics Canada's Cannabis Hub), this amounts to a per user gain of about \$500 per annum. This measure would be even greater with a smaller substitution elasticity. There may be a further social dividend from a reduction in crime (because criminal activity has been redefined), and a reduction in policing costs.

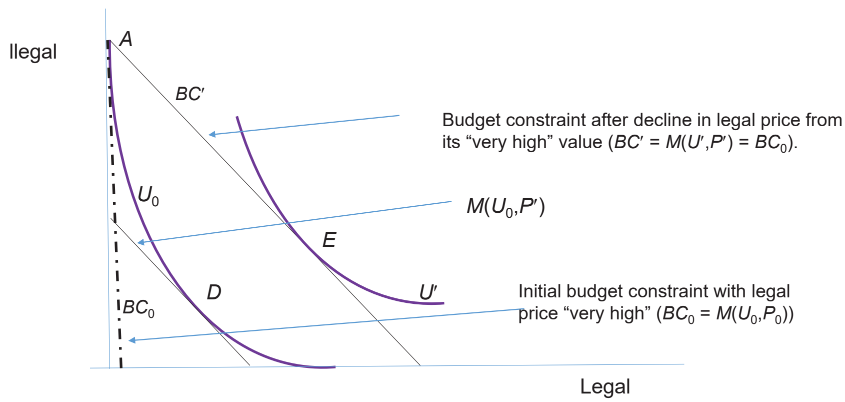

Figure C.1: Consumer Welfare Impact of Legalization

The initial equilibrium with an almost infinite price for legal cannabis is at A, with the budget constraint BC_0. The legal price falls to a finite value, and the new budget constraint is BC'; this yields an equilibrium at E. The somewhat vertical profile of the indifference curves reflects a preference for the legal good, *ceteris paribus*. One measure of the monetary value of the price decline (legalization) is the difference $M(U',P') - M(U_0,P')$, which is identical to $M(U_0,P_0) - M(U_0,P')$.