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Cross-border casino competition, Externalities and Optimal Tax Policy: A Unified Theory with Quantitative Analysis

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ABSTRACT

We develop a framework on cross-border competition in markets for goods with negative externalities and provide evidence for optimal fiscal policy with a special focus on taxation. We build the case of two bordering casinos with city governments setting taxes to maximize social welfare. Analytically, we show that cross-border casino gambling makes aggregate casino demand more elastic. By calibrating the model to fit the Detroit-Windsor market, our welfare analysis shows that cross-border competition induces both cities to lower casino taxes, while the optimal tax mix features a shift from the casino revenue tax to the good and service surcharge on gambling in Detroit but a reversed shift in Windsor. We also find a casino buy-out deal to not be credible because Windsor's willingness to pay Detroit to ban Michigan casinos is far below Detroit's willingness to accept giving up its casinos.

1. Introduction

Cross-border competition has become increasingly fierce for capturing external sources of revenues. It is particularly prominent in the casino industry where sizable externalities prevail. Across Europe, casino gambling revenues have increased from €8.03 billion in 2016 to €8.55 billion in 2017 with France, Great Britain, Germany and Switzerland being the largest markets. In North America, casino gambling is even larger with a sharp increase over the past two decades: revenues increased by 233% from \$11.2 billion in 1993 to \$37.3 billion in 2012 in the U.S. and in Canada from \$6.4 billion in 1995 to \$15.1 billion in 2010–2011. Both in Europe and in North America, casinos are often either government run or heavily taxed and thus play an important role for public households, providing, for example \$8.6 billion in the U.S. and \$13.5 in Canada.

Today there are 2021 casinos in Europe, 508 in the U.S. and 71 in Canada. Interestingly, many casinos were built along various borders across states and countries. Such cross-border settings are especially relevant in Europe due to the many borders and large number of casinos. Prominent examples include the setting in Lugano, Mendrisio, and Campione near the Switzerland-Italy border; Basel near the Swiss-French-German border; Baden-Baden near the France-Germany border; Rozvadov near the Germany-Czech border and the planned three new casinos in Liechtenstein. The likely best known example in the cross-border setting is in Detroit, U.S., and Windsor, Canada. While there have been some case studies on cross border casino-competition, a *systematic* study – especially including welfare implications and optimal taxation for casino regulatory policies – remains completely unexplored. We deem such a study not only an important contribution for gambling regulators but also a perfect example for cross-border competition with externalities in general.

City or national boundaries are locations of economic opportunity, especially if the existence of the border is itself the source of a monopoly situation that favors one side over the other (Krakover, 1997). Indeed, the border is a favorite site for the development of casinos, if an untapped, large market exists on the other side.[1] The monopoly situation, however, can turn into a highly competitive one, when casinos are positioned for new competition from the other side of the border. Once

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[1] For example, casinos in Windsor, Canada, are directed at the Detroit market (Deloitte-Touche, 1995). While the Nevada casinos (outside of Las Vegas) target the large population concentrations of Northern California (Eadington, 1995), the riverboats of Northeast Indiana feed off the Chicago market (Thompson and Gazel, 1997; Przybylski and Littlepage, 1997). Similarly, the Macau casinos service the China and Hong Kong markets (Hobson, 1995).

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the border turns into a relentlessly competitive battleground, not only is the cake of the casino market redistributed, but each side of the border has to deal with the negative externalities generated by gambling casinos on both sides.[2] While bordering casinos generate demand from the other side of the border and create local jobs and other businesses, they also represent the import of tax income and the re-exportation of negative externalities that accompany the gamblers as they return to their home city (i.e., the export of external disorder costs). Such undesirable consequences have led many governments to use various taxes and/or regulations as a social guardian to control the social cost of gambling despite the revenue generating power of casinos. Casino externalities are an important factor that is often neglected in economic analyses of the casino market, despite the important role that it plays in institutionalizing relevant regulations.

Just how would the relentless competition in this growing industry affect recreational (regular) and problem (addicted) gamblers both on the intensive margin and on the extensive margin via cross-border gambling? What are the underlying driving forces influencing the intensity of cross-border gambling and the bordering casinos' pricing, possibly preferences for gambling, casino taxes, the population of gamblers of different types, and commuting cost, among others? How would the bordering governments' casino tax policies depend on the extent of cross-border gambling and the associated negative (social disorder) and positive (income creation) externalities? Would it be better to impose a tax on casino revenue (i.e., a wagering tax) or to impose a good and service tax (GST) surcharge on gambling? How would the fiscal competition outcome in turn affect cross-border casino competition? We address these interesting questions with a systematic study of cross-border casino competition.

We develop a theoretical model of cross-border casino competition highlighting the following salient features that are important but largely ignored in the existing literature. First, we model separately the behavior of *recreational* and *problem* gamblers and analyze their differential decisions on cross-border gambling. Second, we, on the one hand, allow the bordering casinos to compete with each other for the source of demand from both sides of the border. On the other hand, we permit the two competing cities' governments to be active, where they can set their optimal tax policy (the casino revenue tax on casino operators and the GST surcharge on gambling) to achieve the highest local welfare. In other words, we analyze *cross-border casino competition for both casino gambling revenues and tax revenues*, as observed in the real world. Third, for the normative analysis, we consider that "travel to use" casino services may generate *local externalities*, possibly negative (social disorders) or positive (income creation). Thus, by engaging in tax competition, both governments take into account the "import" of tax revenues and the "export" of external disorder costs. Finally, we provide the first attempt to quantitatively conduct positive and normative analyses by calibrating the theoretical model to fit the Detroit-Windsor data.

The study of Detroit-Windsor casino competition is an example that is well-suited to our analysis for several important reasons (to be fully elaborated in Section 4 below). Briefly put, such competition reflects the historically relentless rivalry of two cities over one of the busiest commercial borders between the U.S. and Canada.[3] In addition, it is of a large scale, with participation rates at 71% and 66% in Michigan and Ontario, respectively, and with large cross-border gambling consisting of 80% of customers in Windsor originating in Detroit. Moreover, such competition is accompanied by an active city government competition policy in the form of various tax incentives. Furthermore, the data are very rich, featuring significant cross-city heterogeneities with regard to population size and preferences towards gambling, thus permitting various policy analyses, including *city-specific* optimal casino taxation that is valuable to policymakers. In addition, two sharp events – the increased commuting costs due to 911 and the decreased population size in Detroit due to the declining automobile industry – have caused external shocks to the setting and allow for interesting analyses.

We solve the equilibrium backward. We first solve the optimization problem of individual gamblers of each type (recreational and problem), obtaining individual demand as well as cross-border gambling decisions. We then determine the (Bertrand) price competition of the two bordering casinos. We further pin down the optimal tax policy imposed by the two competing cities' governments. The competition between the two bordering casinos is subsequently affected by the tax policy, in addition to the commuting cost of border crossing, the heterogeneous preferences for casino gambling and the differential population size of the two cities. That is, a full equilibrium of casino gambling involves both cross-border casino competition and cross-border casino tax competition. In particular, upon fully calibrating the border casino competition between Detroit and Windsor, we quantitatively assess the casino tax effects and determine the optimal casino tax policy for each city in the presence of cross-border casino competition.

Among many theoretical results, we choose to highlight three sets of findings that are all related to cross-border gambling. First, we show that under a reasonable assumption the demand elasticity for casino gambling is greater than one for recreational gamblers but less than one for problem gamblers, both rising with the preset payout ratio. While a higher commuting cost discourages cross-border gambling, the overall cross-border gambling intensity (for both problem and recreational patrons) is increasing in the own city's casino price and GST surcharge on gambling. Second, the presence of cross-border casino gambling provides an outside option to gamblers, thus leading to an *elastic aggregate demand* for casino services despite the addictive nature of gambling. Interestingly, in a city whose residents have stronger preferences for casino gambling, the net flows of cross-border gambling are more pronounced. As a consequence, a lower commuting cost that encourages agents to cross the border to gamble would reduce this city's casino monopoly power, thereby making its aggregate demand for casinos more elastic. On the contrary, a lower commuting cost makes the price elasticity of casino demand in a city inhabited by people with weaker preferences for casino gambling less elastic. In short, *a lower commuting cost favors cross-border casino business in a city with a weaker taste for gambling*. Third, a larger population size in the rival city makes the local city's price elasticity of casino demand less elastic. This may raise local casino prices and induces cross-border gambling. While an increase in the local population may make the local city's price elasticity of casino demand more elastic and local casino prices lower, the resulting *negative effect on cross-border gambling* is offset by the *positive population scale effect*, thereby leading to an ambiguous outcome.

By calibrating the model to fit the casino competition between Detroit and Windsor, we obtain additional findings from positive analysis. First, if a larger city whose residents have stronger preferences for casino gambling (Detroit) raises its casino tax (either a casino revenue tax or a GST surcharge on gambling), the cross-border consumption of Detroit would exhibit an *extensive margin response* in the sense that the proportion of the cross-border gamblers would increase, although the cross-border casino consumption per gambler would decrease. While the competition brought about by Detroit's casinos hurts neighboring gambling revenues, such a loss in Windsor is less than Detroit's gain, leading to an expansion in the *overall* Detroit-Windsor casino market. Second, a higher wagering tax is more effective in reducing the casino disorder cost than a GST surcharge on gambling. It exhibits *nonequivalence* in the tax burden between the casino revenue tax and the GST surcharge on gambling. Third, in contrast to the responses to tax shifts, a higher commuting cost leads to an *intensive margin response* whereby the cross-border gamblers from Detroit to Windsor decrease, but each gam-

[2] Casino gambling generates various attendant externalities including compulsive addictions, productivity losses and other social pathologies, increased drug and alcohol abuse, and the committing of crimes. See Eadington (1999), Grinols and Mustard (2001), and Chang et al. (2010) for the details.

[3] For example, the value of trade between the U.S. and Canada is about $1.2 billion per day and 27 percent of all merchandise trade crosses the Ambassador Bridge connecting Detroit and Windsor.

bler consumes more. When a rising commuting cost discourages cross-border gambling, the city with stronger preferences and a larger population absorbs greater demand and tax revenue, which are accompanied by higher disorder costs. Fourth, the drop in Detroit's *overall gambling population* hurts its neighboring casino, Windsor, more severely. By contrast, Detroit's casino demand and revenue, tax revenue, and disorder costs are more responsive to its *proportion of problem gamblers*. Fifth, while individual demand for gambling is *more responsive* to the wagering tax than the GST surcharge on gambling, the government's tax competition tends to make the cross-border casino competition *more intense* regardless of the instruments of the casino tax.

Our quantitative welfare analysis also leads to several interesting findings regarding the optimal casino tax policy. First, we establish the optimal policy based on a single casino tax instrument of a city, given the alternative tax instrument and its rival's tax policy at the benchmark values. We find that cross-border competition induces both city governments to *lower* each tax compared to the pre-existing rate. The relentless competition pushes cities to tolerate problem gamblers to visit their casinos; it is more pronounced in Windsor as it relies more on cross-border gamblers and has lower disorder costs. Second, we conduct a tax incidence exercise, solving the optimal tax mix in a city given its rival's tax policy at the benchmark values. We find that while Detroit has a favorable tax mix *away from the casino revenue/wagering tax*, Windsor has one *away from the GST surcharge on gambling* to attract cross-border gamblers. Third, we perform a welfare-based pairwise casino competition in one tax instrument, fixing the other tax policy at the benchmark values. We find that, in order to better compete with the neighboring casino, it is optimal for both cities to *lower* casino revenue tax rates and GST surcharges on gambling compared to those where the rival's tax policy is given (i.e., the optimal policy of a single casino tax or a tax mix obtained above). More interestingly, it is optimal for Detroit to set relatively high casino taxes to control the social cost of gambling by preventing Windsor's problem gamblers from crossing the border. By contrast, it is optimal for Windsor to aggressively set lower casino taxes to enhance casino and tax revenues and income creation by pulling in the cross-border visitor, including some problem gamblers from Detroit. Finally, we find that Windsor's willingness to pay Detroit in order for Detroit to ban its casinos is far below Detroit's willingness to accept giving up its casinos. Thus, such a casino buy-out deal in this cross-border rival scenario is not credible.

This paper is a first attempt to develop a model that is rich enough to capture the central features of cross-border casino and tax competition, but simply tractable to yield valuable insights toward addressing the interesting questions mentioned above. In both our analytical and quantitative methods, we have developed a richer framework of fiscal competition with "travel to use" services generating local externalities that could be negative or positive, or, from a different angle, a richer framework of spatial competition with competing governments that are active in setting their optimal tax policy. There is a lack of a comprehensive analysis of casinos in both positive and normative aspects because of the paucity of theoretical modeling in this field. Among rare exceptions, Sauer (2001) develops a political competition model to study how gambling restrictions lower the level of gambling, whereas Chang et al. (2010) study the entry and tax regulation of oligopolistically competitive privately-run casinos and government-run casinos in the presence of casino gambling externalities. Neither examine cross-border casino competition, which is the primary focus of our paper. Quantitatively, our welfare analysis provides policy implications to the casino policymakers of the bordering cities and offers new insights into the sparse economic literature on casino gambling. To date, efforts to consider optimal gambling taxation have been limited primarily to lottery games. In viewing a casino tax as a Pigouvian tax to correct for externalities, more research is needed to assess the size of the externalities involved and design optimal corrective taxes.

Our model-based quantitative approach offers such assessment in a systematic manner, which is valuable as well for other broader studies with limited data. For example, our paper may be applied to the literature on cross border shopping for goods by taking advantage of price differences between the bordering countries, such as the prices of tobacco and alcohol, due to different sales or sin/excise taxes (such as Delaware versus Pennsylvania or New Jersey). With different population sizes and preferences, we can differentiate between regular and heavy addicts, analyzing their consumption behaviors and their differential external impacts on welfare. Moreover, our framework may also be applied to the tourism literature, especially because the cross-border tourism competition is usually associated with sophisticated negative congestion or environmental externalities accompanied by positive income creation (such as the rivalry between Hong Kong and Macau).

2. The model

Consider two cities, called City 1 and City 2 ($i = 1, 2$), with populations of potential gamblers denoted by N_1 and N_2, respectively. To focus on cross-border casino competition, we assume that each city has a single casino firm ($j = 1, 2$) which can serve customers from both cities. Such a structure may capture, for example, Detroit (U.S.) vs. Windsor (Canada), Lugano and Mendrisio (Switzerland) vs. Campione (Italy), or Eilat (Israel) vs. Taba (Egypt). In each city, we distinguish two kinds of gamblers: problem (addicted) and recreational (regular) gamblers, given the fact that problem and recreational gamblers exhibit different demand for casino gambling. Recreational gamblers constitute n_1 and n_2 (normal) percent of the population in City 1 and City 2, respectively.

In the face of the casino prices and taxes of the two bordering cities, residents in City i decide whether to gamble locally at casino $j = i$, or to gamble across the border at casino $j \neq i$. Cross-border casino visitors incur a (symmetric) commuting cost $\varrho_{ij} = \varrho_{ji} = T$ ($j \neq i$), with the intracity commuting cost being normalized to zero ($\varrho_{ii} = 0$). Note that T may also capture the barriers to cross-border gambling. We assume that residents in City 1 have higher preferences for casino gambling than those in City 2, which is captured by the preference parameters $\gamma_H > \gamma_L$. In addition, residents in the two cities have different levels of income, denoted by I_1 and I_2, respectively.

Taxation is important in the highly-regulated casino industry. As for casinos, there is a casino revenue (variable) tax σ_i and a fixed licensing fee f_i (or operating permit) in each City i. In practice, the revenue tax (i.e., wagering tax) is the most common form of taxation (see Suits, 1979). As for gamblers, there is a GST imposed on gambling activities. The rate of GST on gambling goods/services is higher than that on non-gambling goods/services. Denote t as a general consumption tax rate on non-gambling goods and services and s_j as a GST surcharge on gambling, the GST on gambling is then $\left(1+s_j\right)t$. To focus on the gambling-related taxes, the general consumption tax rate t is assumed to be identical in both cities.

2.1. Gamblers' optimization

Each resident in City i derives utility from casino gambling x_i and from consuming a composite good q_i (which acts as a numéraire). Within a specific City i, residents only differ in their moral costs ε_i (in forms of disutility) with respect to gambling in their own city. The moral cost ε_i is uniformly distributed over $[0, N_i]$. Let m stand for the type of gamblers, i.e., $m = P$ (problem gamblers) or $m = R$ (recreational gamblers). It is natural to assume that problem gamblers are less sensitive morally, i.e., $\varepsilon_{i,P} < \varepsilon_{i,R}$. In addition to this *internal* moral cost, there are *attendant externalities* generated by casino gambling, which are referred to as *negative* disorder costs, denoted by DC_i, and *positive* income creations, denoted by IC_i. The disorder costs capture any social costs caused by compulsive addictions, productivity losses, the problems of alcohol/drug abuse and crimes, as well as other social pathologies and disturbances. The casino income creations are perceived to generate widespread economic benefits to local businesses and industries. Individuals are atomistic, taking these externalities as given, when they make decisions. We here focus on the behavior of the gambling population, while in the welfare analysis below, we will account for the negative and positive externalities of gambling on the entire society, inclusive of the non-gambling population.

By the nature of discrete choice, we can define an indicator function θ_i with $\theta_i = 1$ indicating gambling in the own city's casino and $\theta_i = 0$ indicating cross-border gambling. Accordingly, each agent's utility function, taking the quasi-linear form, can be specified as follows:

$$\varpi_{i\tau,m} = \gamma_\tau \ln(x_{i,m} - \eta_m) + q_{i,m} - \theta_i \varepsilon_{i,m} - DC_i + IC_i, \tag{1}$$

where $\tau = H$ if $i = 1$ and $\tau = L$ if $i = 2$ as well as $\eta_m = \eta_P > 0$ for problem gamblers and $\eta_m = -\eta_R < 0$ for recreational gamblers. The Stone-Geary utility function reflects the necessity nature of casino goods for heavily addicted problem gamblers, with η_R measuring the recreational gamblers' relative income elasticity of casino goods to the composite good. Each agent (for both problem and recreational gamblers) has a two-stage decision process. In Stage 1, he makes a discrete choice, deciding on which casino to visit; in Stage 2, he then chooses the amount of casino gambling, together with the quantity of composite good consumption. Using θ_i, we can thus define $k_{i,m}(\theta_i) = \theta_i k_{ii,m} + (1-\theta_i)k_{ij,m}$ for $k = x, q, \varrho$.

Solving backward, the Stage 2 optimization is given by,

$$\varpi_{i\tau,m}(\theta_i, \varepsilon_{i,m}) = \max_{x_{i,m};\, q_{i,m}} \gamma_\tau \ln(x_{i,m} - \eta_m) + q_{i,m} - \theta_i \varepsilon_{i,m} - DC_i + IC_i,$$

subject to

$$(1+t)\, q_{i,m}(\theta_i) + \left[1 + \left(1+s_j\right) t\right] p_j x_{i,m}(\theta_i) + \varrho_i(\theta_i) = I_i + \pi x_{i,m}(\theta_i). \tag{2}$$

Concerning casino pricing, p_j is the price per dollar gambled (including the gambling-related products and services) and π is defined as the return to player percentage (RTP).

In most forms of gambling, the price of the gamble is not easily observed by consumers. Yet, casinos usually reveal the RTP (or payout ratio) to their customers, serving as an indicator of the long-term expected payback percentage from wagers. In the empirical literature on casino demand, the price elasticities are estimated based on the percentage of each dollar wagered that is retained by casinos, or, in our notation, $1 - \pi$. However, most casinos have exercised other pricing strategies beyond this. For example, casinos usually provide hotel and dining discounts and other entertainment offers as well as free money for gambling (i.e., the so-called "house money"). On the contrary, some casinos may charge entry fees and/or impose withholds. While discounts, offers and free money lower the casino price, entry fees and withholds raise it. Thus, the win percentage in our model is more general, captured by $p_j - \pi$. Given that many games have fixed rules and the specific RTP cannot easily be altered (at least not in a continuous way as typical prices), we assume that π is an institutional constant not adjusting with prices and is set to be identical for both casinos.

In Stage 1 the optimization problem is simply:

$$v_{i\tau,m}(\varepsilon_{i,m}) = \max\{\varpi_{i\tau,m}(0, \varepsilon_{i,m}), \varpi_{i\tau,m}(1, \varepsilon_{i,m})\}.$$

Thus, the discrete choice is to gamble in the agent's own city if $\varpi_{i\tau,m}(1, \varepsilon_i) \geq \varpi_{i\tau,m}(0, \varepsilon_i)$; otherwise, cross-border gambling occurs. To an agent residing in City i, the discrete choice is captured by,

$$\theta_i^* = \arg \max_{\theta_i \in \{0,1\}} \varpi_{i\tau,m}(\theta_i, \varepsilon_{i,m}),$$

where $\varepsilon_{i,P} \in [0, (1-n_i)N_i]$ and $\varepsilon_{i,R} \in [(1-n_i)N_i, N_i]$ given that problem gamblers are less sensitive morally.

We are now ready to solve the gambler's optimization problem, starting with Stage 2. Let λ_i be the Lagrange multiplier associated with the agent's budget constraint (2). Thus, the first-order conditions with respect to the variables x_i and q_i in Stage 2 are:

$$\frac{\gamma_\tau}{x_{i,m} - \eta_m} - \lambda \left\{p_j \left[1 + \left(1+s_j\right) t\right] - \pi\right\} = 0, \tag{3}$$

$$1 - \lambda(1+t) = 0, \tag{4}$$

which can be combined to yield ($j \neq i$),

$$x_{i,m}(\theta_i) - \eta_m = \frac{\theta_i \gamma_\tau (1+t)}{p_i \left[1 + (1+s_i) t\right] - \pi} + \frac{(1-\theta_i)\gamma_\tau (1+t)}{p_j \left[1 + \left(1+s_j\right) t\right] - \pi}.$$

To solve the Stage 1 optimization problem, we use (2) to write:

$$\begin{aligned}\varpi_{i\tau,m}(\theta_i, \varepsilon_{i,m}) = {} & \gamma_\tau \ln(x_{i,m}(\theta_i) - \eta_m) \\ & + \frac{(I_i + \pi x_{i,m}(\theta_i) - \varrho_i(\theta_i) - (1 + (1+s_j)t) p_j x_{i,m}(\theta_i))}{1+t} \\ & - DC_i + IC_i - \theta_i \varepsilon_{i,m}.\end{aligned}$$

An agent residing in City i compares the values (indirect utilities) obtained in Stage 2 to choose his gambling location. Since all agents in a particular city are identical except for their moral costs, there must be a single cutoff $\varepsilon^*_{i,P}$ ($\varepsilon^*_{i,R}$) under which $\varpi_{i\tau,P}(0, \varepsilon^*_{i,P}) = \varpi_{i\tau,P}(1, \varepsilon^*_{i,P})$ ($\varpi_{i\tau,R}(0, \varepsilon^*_{i,R}) = \varpi_{i\tau,R}(1, \varepsilon^*_{i,R})$) for problem (recreational) gamblers. Thus, we have:

$$x_{i,P} = \begin{cases} x_{i,P}(1) = x_{ii,P} & 0 < \varepsilon_{i,P} \leq \varepsilon^*_{i,P} \\ x_{i,P}(0) = x_{ij,P} & \varepsilon^*_{i,P} < \varepsilon_{i,P} < (1-n_i)N_i \end{cases},$$

$$q_{i,P} = \begin{cases} q_{i,P}(1) = q_{ii,P} & 0 < \varepsilon_{i,P} \leq \varepsilon^*_{i,P} \\ q_{i,P}(0) = q_{ij,P} & \varepsilon^*_{i,P} < \varepsilon_{i,P} < (1-n_i)N_i \end{cases}$$

for problem gamblers and

$$x_{i,R} = \begin{cases} x_{i,r}(1) = x_{ii,R} & (1-n_i)N_i < \varepsilon_{i,R} \leq \varepsilon^*_{i,R} \\ x_{i,r}(0) = x_{ij,R} & \varepsilon^*_{i,R} < \varepsilon_{i,R} < N_i \end{cases},$$

$$q_{i,R} = \begin{cases} q_{i,R}(1) = q_{ii,R} & (1-n_i)N_i < \varepsilon_{i,R} \leq \varepsilon^*_{i,R} \\ q_{i,R}(0) = q_{ij,R} & \varepsilon^*_{i,R} < \varepsilon_{i,R} < N_i \end{cases}$$

for recreational gamblers.

To be more specific, we can write out City i residents' demands for the casino and composite goods, respectively, as follows:

$$x_{ij,m} = \frac{\gamma_\tau (1+t)}{p_j \left[1 + \left(1+s_j\right) t\right] - \pi} + \eta_m, \tag{5}$$

$$q_{ij,P} = \frac{I_i - \gamma_\tau (1+t) - \eta_m \left\{p_j \left[1 + \left(1+s_j\right) t\right] - \pi\right\}}{1+t}, \tag{6}$$

where $i,j = 1,2$; $\tau = H$ if $i = 1$ and $\tau = L$ if $i = 2$; and, $\eta_m = \eta_P > 0$ for problem gamblers (P) and $\eta_m = -\eta_R < 0$ for recreational gamblers (R). From (5), we can derive the demand elasticity of problem and recreational gamblers. Specifically, we obtain the demand elasticity for own ($e_{ii,m}$) and cross-border casino gambling ($e_{ij,m}$ for $j \neq i$):

$$e_{ij,m} = -\frac{p_j \partial x_{ij,m}}{x_{ij,m} \partial p_j} = \frac{p_j [1 + (1+s_j)t]}{p_j [1 + (1+s_j)t] - \pi} \left(1 - \frac{\eta_m}{x_{ij,m}}\right), \tag{7}$$

where $i,j = 1,2$; $\eta_m = \eta_P > 0$ for problem gamblers and $\eta_m = -\eta_R < 0$ for recreational gamblers.

Accordingly, we have:

Proposition 1. (***Demand Elasticity of Problem and Recreational Gamblers***) *The demand elasticity for casino gambling is smaller for problem gamblers than for recreational gamblers, both rising with the return to player percentage (RTP), π. It is greater than one for recreational gamblers and less than one for problem gamblers, if* $\eta_P > \pi \cdot \max\left\{\frac{x_{ii,P}}{p_i[1+(1+s_i)t]}, \frac{x_{ij,P}}{p_j\left[1+(1+s_j)t\right]}\right\}$ *which holds with high addiction (large η_P) and low RTP.*

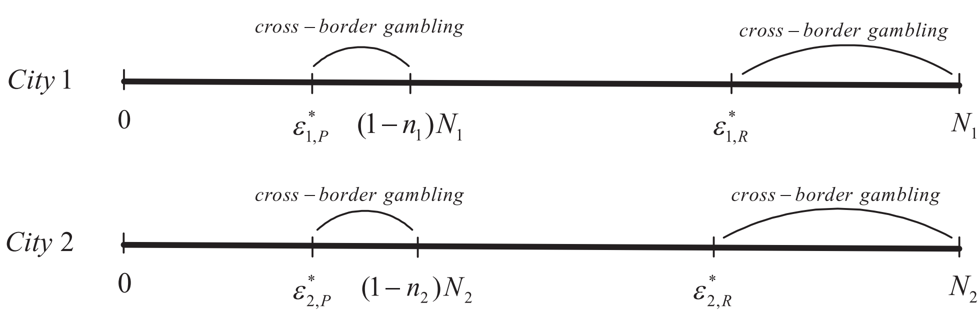
Proof. All proofs are relegated to the Online Appendix.

The overall demand for casino gambling comprises two quite different groups of gamblers, each with distinct demand characteristics (Philander, 2014). Problem gamblers, not being very responsive to price given their addictions and compulsions, may have very inelastic demand. Other gamblers without such addictions and compulsions may have much more elastic demand. The finding of Proposition 1 corroborates the argument.

We now solve the second stage problem which determines the gambling location. By focusing on City 1, substituting (5) and (6) into the resident's utility function (1) yields the respective values associated with gambling locations, $v_{11,m}(\varepsilon_{i,m})$ and $v_{12,m}(\varepsilon_{i,m})$ where $m = P$ or $m = R$. Thus, $\varepsilon^*_{1,m}$ solves $v_{11,m}(\varepsilon^*_{1,m}) = v_{12,m}(\varepsilon^*_{1,m})$. Similarly, the cutoff in City 2, $\varepsilon^*_{2,m}$ solves $v_{22,m}(\varepsilon^*_{2,m}) = v_{21,m}(\varepsilon^*_{2,m})$. We then have:

$$\begin{aligned}\varepsilon^*_{i,m} = {} & \gamma_\tau \ln\left(\frac{p_j\left[1+(1+s_j)\,t\right]-\pi}{p_i\left[1+(1+s_i)\,t\right]-\pi}\right) \\ & + \frac{\left\{p_j\left[1+(1+s_2)\,t\right]-p_i\left[1+(1+s_1)\,t\right]\right\}\eta_m+T}{1+t},\end{aligned} \tag{8}$$

where $i,j = 1,2, j \neq i$; $\eta_m = \eta_P > 0$ for problem gamblers and $\eta_m = -\eta_R < 0$ for recreational gamblers. These gambling locations are shown as follows.



Next, we characterize the schedules of the cross-border gambling intensities. To do so, we define the overall cross-border gambling intensity $\left(\mu_i^{CB}(p_i) = \frac{[(1-n_i)N_i-\varepsilon^*_{i,P}]+[N_i-\varepsilon^*_{i,R}]}{N_i}\right)$ as well as the cross-border gambling intensity for problem patrons $\left(\mu_{i,P}^{CB}(p_i) = \frac{(1-n_i)N_i-\varepsilon^*_{i,P}}{(1-n_i)N_i}\right)$ and for recreational patrons $\left(\mu_{i,R}^{CB}(p_i) = \frac{N_i-\varepsilon^*_{i,R}}{n_iN_i}\right)$ for City i. With these definitions, we establish the following proposition:

Proposition 2. (***Cross-border Gambling Intensity Schedules***) *Given $\eta_P > \eta_R$ (a sufficient but not necessary condition),*

(i) *the overall cross-border gambling intensity schedule ($\mu_i^{CB}(p_i)$) is upward-sloping in its own price (p_i) and shifts outward in response to a higher GST surcharge on gambling imposed in its own city (s_i), a lower GST surcharge on gambling in its rival city (s_j), or a lower commuting cost (T);*
(ii) *the cross-border gambling intensity for problem gamblers ($\mu_{i,P}^{CB}(p_i)$) is always upward-sloping, while that for recreational patrons ($\mu_{i,R}^{CB}(p_i)$) may not be;*
(iii) *the cross-border gambling intensities for both problem ($\mu_{i,P}^{CB}(p_i)$) and recreational patrons ($\mu_{i,R}^{CB}(p_i)$) are decreasing in the commuting cost (T).*

Under a reasonable condition $\eta_P > \eta_R$, the overall cross-border gambling intensities, $\mu_i^{CB}(p_i)$, are positively related to their own casino prices. A higher casino price p_i or GST surcharge on gambling s_i encourages city i's own gamblers to engage in cross-border gambling. Yet, due to substitution between casino goods and non-casino composite goods, recreational gamblers, in response to either form of consumer casino price increase (p_i or s_i), may be better off staying in their own casino rather than crossing the border to gamble, thereby resulting in the ambiguity effect of own prices on cross-border gambling. Interestingly, because there is no such substitution effect for problem gamblers, higher own prices always induce more cross-border gambling and such effects become the dominating forces driving the overall cross-border gambling intensity as long as $\eta_P > \eta_R$. With regard to commuting costs, a higher T unambiguously discourages cross-border gambling regardless of the type of gamblers.

2.2. Firms' optimization

The two bordering casinos are assumed to engage in Bertrand price-competition against each other for cross-border gambling. As noted above, the price of casino services is defined in a broader concept where casinos may exercise their pricing strategies in different forms, including the provision of house money or hotel and dining discounts and other amenities such as entertainment offers. The casino pricing game allows us to capture in a clean manner distinctive preferences (willingness to pay for gambling) for different gamblers (problem or recreational gamblers) in two different bordering casinos, thus shedding light on the cross-border competition with travel-to-use casino services.[4]

Let $\gamma \equiv \frac{\gamma_H}{\gamma_L}$ measure the extent of City 1's preference bias toward casino gambling. Thus, the aggregate demand for casinos in City i, X_i, can be derived from (5) and (8):

$$\begin{aligned}X_1(p_1) = {} & \frac{(1+t)\gamma_L}{p_1(1+(1+s_1)t)-\pi}\cdot\left\{\gamma[\varepsilon^*_{1,P}+\varepsilon^*_{1,R}-(1-n_1)N_1]\right. \\ & \left.+(2-n_2)N_2-(\varepsilon^*_{2,P}+\varepsilon^*_{2,R})\right\}+[\varepsilon^*_{1,P}+(1-n_2)N_2-\varepsilon^*_{2,P}]\eta_P \\ & -[\varepsilon^*_{1,R}+N_2-(1-n_1)N_1-\varepsilon^*_{2,R}]\eta_R,\end{aligned} \tag{9}$$

$$\begin{aligned}X_2(p_2) = {} & \frac{(1+t)\gamma_L}{p_2(1+(1+s_2)t)-\pi}\cdot\left\{\varepsilon^*_{2,P}+\varepsilon^*_{2,R}-(1-n_2)N_2\right. \\ & \left.+\gamma[(2-n_1)N_1-(\varepsilon^*_{1,P}+\varepsilon^*_{1,R})]\right\}+[\varepsilon^*_{2,P}+(1-n_1)N_1-\varepsilon^*_{1,P}]\eta_P \\ & -[\varepsilon^*_{2,R}+N_1-(1-n_2)N_2-\varepsilon^*_{1,R}]\eta_R.\end{aligned} \tag{10}$$

It is important to note that the aggregate demand schedule depends on both the intensive margin (via the term $\frac{(1+t)\gamma_L}{p_i[1+(1+s_i)t]-\pi}$) and the extensive margin associated with cross-border gambling (via $\varepsilon^*_{1,m}$ and $\varepsilon^*_{2,m}$).

[4] In practice, casinos may also engage in Cournot competition focusing on various capacities of services. As established in Kreps and Scheinkman (1983), Bertrand competition would yield Cournot outcomes if firms face capacity constraints, as most casinos do especially if they are in urban areas (see the discussion in Chang et al., 2010).

Due to cross-border gambling, the aggregate casino demand of a particular city is unambiguously increasing in the population of its neighboring city, $\frac{\partial X_i(p_1)}{\partial N_j} > 0$. This result is in accordance with empirical observations: the prevalence of state and national borders serving as a casino location is invariably the result of the presence of a large market across the border. For example, Windsor casinos have been targeted in the metropolitan market of Detroit (Deloitte-Touche, 1995; Eadington, 1999), Macau casinos in China and Hong Kong (Eadington, 1995; Hobson, 1995), and Taba casinos in Tel Aviv, Jerusalem and Beer Sheva (Felsenstein et al, 2002).

Assume that the casinos in either city have an identical constant marginal cost c, which allows us to focus on casino taxation. Faced with the casino taxation (the variable casino revenue tax σ_i and the fixed licensing fee f_i), the rival city's casino price p_j ($j \neq i$) and its own demand schedule X_i given above ((9) and (10), respectively), each casino firm sets its own price p_i to maximize its profit:

$$\max_{p_i} \ \Pi_i(p_i) = (1-\sigma_i)(p_i - \pi) X_i(p_i) - c_i X_i(p_i) - f_i. \tag{11}$$

The first-order conditions can be derived below:

$$\frac{\partial \Pi_i}{\partial p_i} = (1-\sigma_i) X_i \left[1 - \frac{(1-\sigma_i)(p_i-\pi) - c_i}{(1-\sigma_i)(p_i-\pi)} \cdot E_i\right] = 0, \tag{12}$$

where $E_i = -(\frac{\partial X_i}{\partial p_i}\frac{p_i}{X_i})$ is the price elasticity of aggregate casino demand in city i (in absolute value). We can rewrite the first-order condition as:

$$\frac{(1-\sigma_i)(p_i-\pi)}{c_i} = \frac{E_i}{(E_i - 1)}, \tag{13}$$

indicating that an interior solution requires that $E_i > 1$. Notably, with cross-border casino gambling, the aggregate demand for casino is affected by not only the intensive margin but also the extensive margin of casino consumption via the cutoffs of the travel-to-use-casino-service. This extensive margin makes the aggregate demand for gambling more responsive to price changes. That is, cross-border casino gambling provides an outside option to gamblers, thus leading to an elastic aggregate demand for casino services. Although the addictive nature of gambling makes the elasticity of demand for gambling become *less elastic*, our model is consistent with standard microeconomic theory in the sense that a monopolist can only maximize profit in the *elastic* range of the demand curve.

The aggregate price elasticities of casino demand are crucial to the cross-border casino competition: any variables that affect E_1 and/or E_2 will have direct consequences for the casino-competition outcomes. It is therefore useful to characterize these elasticity schedules which are rewritten as:

$$\begin{aligned} E_1 &= A_1(B_{1R}e_{11,R} + (1-B_{1R})e_{21,R} + C_{1R}) \\ &\quad +(1-A_1)(B_{1P}e_{11,P} + (1-B_{1P})e_{21,P} + C_{1P}), \end{aligned} \tag{14}$$

$$\begin{aligned} E_2 &= A_2(B_{2R}e_{22,R} + (1-B_{2R})e_{12,R} + C_{2R}) \\ &\quad +(1-A_2)(B_{2P}e_{22,P} + (1-B_{2P})e_{12,P} + C_{2P}), \end{aligned} \tag{15}$$

where $A_i = \frac{X_{i,R}}{X_i}$, $B_{iR} = \frac{[\varepsilon^*_{i,R} - (1-n_i)N_i]x_{ii,R}}{X_{i,R}}$, $B_{iP} = \frac{\varepsilon^*_{i,P}x_{ii,P}}{X_{i,P}}$, $C_{1\mathrm{m}} = \left[\frac{\gamma_L(\gamma x_{11,m} + x_{21,m})}{p_1[1+(1+s_1)t]-\pi} - \frac{\eta_m(x_{11,m}+x_{21,m})}{(1+t)}\right] \cdot \frac{p_1[1+(1+s_1)t]}{X_{1,m}}$ and $C_{2\mathrm{m}} = \left[\frac{\gamma_L(x_{22,m} + \gamma x_{12,m})}{p_2[1+(1+s_2)t]-\pi} - \frac{\eta_m(x_{22,m}+x_{12,m})}{(1+t)}\right] \cdot \frac{p_2[1+(1+s_2)t]}{X_{2,m}}$, for $i,j = 1,2$, $j \neq i$ and $\eta_m = \eta_P > 0$ for problem gamblers and $\eta_m = -\eta_R < 0$ for recreational gamblers. We can easily see that each elasticity is a weighted average of problem (with weights B_{1P} and B_{2P}) and recreational (with weights B_{1R} and B_{2R}) gamblers' individual elasticities adjusted by their "travel to use gambling services" C_{im} (all positive).

Using Propositions 1 and 2 and noting the independence of $\varepsilon^*_{1,m}$ and $\varepsilon^*_{2,m}$ of the population ($m \in \{P, R\}$), we obtain:

Proposition 3. **(*Aggregate Casino Demand Elasticities*)** *The price elasticity of aggregate casino demand (E_i) is*

(i) *increasing in the own city's casino price (p_i) and GST surcharge on gambling (s_i) and decreasing in the rival city's casino price and GST surcharge on gambling, but is independent of the fixed licensing fee (f_i);*
(ii) *decreasing in the population of the rival city (N_j, $j \neq i$), while ambiguously responding to the own city's population (N_i);*
(iii) *decreasing in the commuting cost (T) in City 1 with a stronger taste for gambling γ_H, but increasing in it in City 2 with a weaker taste for gambling γ_L.*

The aggregate demand schedule in each city, given by (9) and (10), depends on both the intensive and extensive margins. Both margins depend negatively on the own casino price and GST surcharge on gambling and their interplay leads to a more elastic aggregate demand for casino gambling. By contrast, there is an opposing response to an increase in either the price or the GST surcharge on gambling in the rival city. Under Bertrand competition, the price elasticities of demand and hence the casino prices are unaffected by the fixed licensing fee.

Due to cross-border gambling, a larger population size in one city (say, N_1) increases the aggregate demand for casino gambling in the neighboring city (say, X_2); hence, the price elasticity of aggregate demand for casino gambling in the rival city (say, E_2) becomes lower in response. It is intriguing to note that, as a result of cross-border gambling and different responses of recreational and problem gamblers, the effects of the own city's population on the aggregate demand and aggregate price elasticity are generally ambiguous. That is, *an increase in the local population results in a negative effect on cross-border gambling that may offset the positive population scale effect on casino demand.* Of particular interest, the price elasticities of aggregate demand in both cities have asymmetric responses to a lower commuting cost T. A lower commuting cost encourages agents to cross the border to gamble. Since City 1 residents have a stronger preference for casino gambling, the net flows of cross-border gambling from City 1 are more pronounced, making City 1's aggregate demand for casinos more elastic. Consequently, E_1 increases whereas E_2 decreases.[5] Thus, *a lower commuting cost favors cross-border casino business in a city with a weaker taste for gambling.*

3. Equilibrium

We now define the casino competition equilibrium, followed by outlining the welfare measures.

3.1. Equilibrium casino prices

The equilibrium concept adopted here is the Nash equilibrium. Specifically, a *casino competition equilibrium* (CCE) is a pair of casino prices (p_1^*,p_2^*) representing an individual casino firm's best responses given its rival city's casino pricing, i.e., (12). The CCE is called *non-degenerate* if the aggregate demands for casino services are strictly positive in both cities. Under the condition that each city's casino firm is more responsive to its own price changes, we are able to establish the existence and uniqueness of the casino competition equilibrium.

Theorem 1. **(*Existence and Uniqueness of a Non-Degenerate Equilibrium*)** *There exists a non-degenerate unique casino competition equilibrium set of casino prices (p_1^*,p_2^*).*

As shown in Fig. 1, the pair of equilibrium casino prices (p_1^*,p_2^*) is determined at point A, which is the intersection between the best response of Casino 1 ($R1$) and Casino 2 ($R2$). With a unique equilib-

[5] Notably, by construction, our comparative statics are restricted to responses to small changes. Should there be a large reduction in T causing an interior solution to become a corner solution with problem gamblers in City 1 no longer engaging in cross-border gambling, lower commuting costs may generate ambiguous effects on aggregate elasticities.

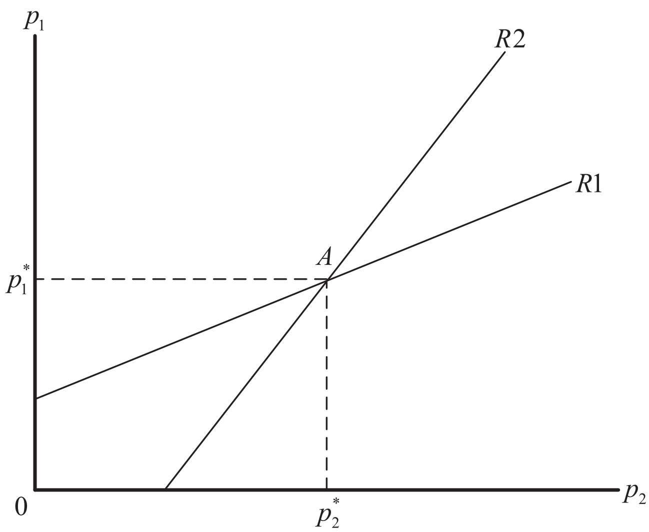


Fig. 1. Equilibrium Casino Prices.

rium established, we now examine the casino price effects which are summarized in the following proposition:

Proposition 4. (***Equilibrium Casino Prices***) *The equilibrium casino prices p_1^* and p_2^* increase with the casino revenue/wagering tax rate in either city (σ_1 or σ_2), while they have an ambiguous response to the GST surcharge on gambling s_i, the population size N_i, and the commuting cost T.*

It is clear from (12) that the revenue/wagering tax (the most common form of tax applied to casino games) has a most direct effect on the equilibrium casino prices and, therefore, increasing either σ_1 or σ_2 unambiguously raises both cities' casino prices p_1^* and p_2^*. Intuitively, when City 1 raises its revenue tax rate σ_1 imposed on its casino, the casino will pass the tax burden through to its consumers, resulting in a higher p_1^*. In addition, a higher σ_1 also leads the demand for its rival casino to become less elastic, allowing City 2 to raise its casino price p_2^*, too. Since a city's casino firm is more responsive to its own price change, the relative price of City 2 to City 1 p^* $(= p_2^*/p_1^*)$ decreases in response. In a way differing from the wagering tax, the GST surcharge on gambling s_i, the population size N_i, and the commuting cost T indirectly affect the equilibrium casino prices through their influence on the overall price elasticities of casino demand E_1 and E_2. As such, their overall effects are complicated, and will be studied numerically in Section 4 below.

3.2. Welfare measures and casino externalities

A standard measure of welfare consists of the consumer's surplus (CS_i), producer's surplus (PS_i), and tax revenues (TR_i). Specifically in relation to our casino competition model, tax revenues stem from gambling activities, whereas the consumer's surplus must add the casino income creation (IC_i) and subtract the social disorder costs (DC_i). Thus, the consumer's surpluses of City 1 and City 2 are given by, respectively:

$$\begin{aligned} CS_i = {} & [\gamma_\tau \ln(x_{ii,P} - \eta_P) - p_i(1+(1+s_i)t)x_{ii,P} - 1]\varepsilon_{i,P}^* \\ & +[\gamma_\tau(\ln x_{ij,P} - \eta_P) - p_j(1+(1+s_j)t)x_{ij,P} - T]\cdot[(1-n_i)N_i - \varepsilon_{i,P}^*] \\ & +[\gamma_\tau \ln(x_{ii,R} + \eta_R) - p_i(1+(1+s_i)t)x_{ii,R} - 1]\cdot[\varepsilon_{i,R}^* - (1-n_i)N_1] \\ & +[\gamma_\tau(\ln x_{ij,R} + \eta_R) - p_j(1+(1+s_j)t)x_{ij,R} - T]\cdot \\ & \times(N_i - \varepsilon_{i,R}^*) - DC_i + IC_i, \end{aligned} \tag{16}$$

where $i,j = 1,2, j \neq i$; $\tau = H$ if $i = 1$ and $\tau = L$ if $i = 2$.

Of the social costs that are attributed to gambling, problem (pathological) gambling is one of the most noticeable. While only a small percentage of gamblers may exhibit problem gambling behavior, such people cause significant social costs. Thus, the overall social disorder costs DC_i caused by both problem gamblers $DC_{i,P}$ and recreational gamblers $DC_{i,R}$ are given by:

$$DC_i = d_i(DC_{i,P} + z\cdot DC_{i,R}), \tag{17}$$

where $d_i > 0$ is a scaling parameter of the casino disorder costs for City i and $0 < z < 1$, indicating that, relative to recreational gamblers, problem gamblers generate more disorder costs to the society. To be more specific, the social costs caused by problem gamblers for Cities 1 and 2, respectively, are:

$$\begin{aligned} DC_{1,P} &= DC_{1,P}^1 + DC_{1,P}^2 + DC_{1,P}^3 \\ &= \{\varepsilon_{1,P}^* x_{11,P} + \phi_c[(1-n_2)N_2 - \varepsilon_{2,P}^*]x_{21,P} \\ &\quad +\phi_a[(1-n_1)N_1 - \varepsilon_{1,P}^*]x_{12,P}\}, \\ DC_{2,P} &= DC_{2,P}^1 + DC_{2,P}^2 + DC_{2,P}^3 \\ &= \{\varepsilon_{2,P}^* x_{22,P} + \phi_c[(1-n_1)N_1 - \varepsilon_{1,P}^*]x_{12,P} \\ &\quad +\phi_a[(1-n_2)N_2 - \varepsilon_{2,P}^*]x_{21,P}\}, \end{aligned} \tag{18}$$

and the social costs caused by recreational gamblers for Cities 1 and 2, respectively, are:

$$\begin{aligned} DC_{1,R} &= DC_{1,R}^1 + DC_{1,R}^2 + DC_{1,R}^3 \\ &= \{[\varepsilon_{1,R}^* - (1-n_1)N_1]x_{11,R} \\ &\quad +\phi_c(N_2 - \varepsilon_{2,R}^*)x_{21,R} + \phi_a(N_1 - \varepsilon_{1,R}^*)x_{12,R}\}, \\ DC_{2,R} &= DC_{2,R}^1 + DC_{2,R}^2 + DC_{2,R}^3 \\ &= \{[\varepsilon_{2,R}^* - (1-n_2)N_2]x_{22,R} \\ &\quad +\phi_c(N_1 - \varepsilon_{1,R}^*)x_{12,R} + \phi_a(N_2 - \varepsilon_{2,R}^*)x_{21,R}\}, \end{aligned} \tag{19}$$

where φ_c and φ_a are positive but less than one. To measure the social disorder costs, we need to differentiate between the local and the external gamblers – this leads to three distinct measures of casino externalities. First, as stressed by Eadington (1999) and Chang et al. (2010), the disorder costs associated with local gamblers should be viewed as much more severe. These disorder costs are captured by $DC_{1,m}^1$ for City 1 and $DC_{2,m}^1$ for City 2, where $m = P$ or $m = R$. Second, gamblers coming from the other city may also cause problems related to crime and drugs, which bring costs to this city. We capture these casino costs by specifying $DC_{1,m}^2$ for City 1 and $DC_{2,m}^2$ for City 2 with $\varphi_c < 1$ (i.e., less import-based disorder costs for external gamblers). Third, a specific city's residents who cross the border to gamble could also generate disorder costs for their own city, including the problems of compulsive addictions, productivity losses and other social pathologies. These costs are captured by $DC_{1,m}^3$ for City 1 and $DC_{2,m}^3$ for City 2 with again $\varphi_a < 1$ (i.e., less disorder costs for residents with cross-border gambling via exporting negative externalities).

The casino income creation IC_i for City i is assumed to be a proportion a_i of the casino's revenues:

$$IC_i = a_i\cdot[(p_i - \pi)X_i(p_i)], \tag{20}$$

which includes the job creation in the casino industry and in other casino-related industries.

The producer's surplus is simply measured by the casino firm's profits, reported in (11). In addition, the tax revenues of City i stem from the GST surcharge on gambling, revenue tax, and fixed fees:

$$TR_i = [(1+s_i)tp_i + \sigma_i(p_i - \pi)]X_i + f_i. \tag{21}$$

Of particular interest, included in this tax revenue measure are export-based tax revenues (EBT_i) collected exclusively from external gamblers:

$$EBT_i = (1 + s_i)tp_i\{[(1 - n_j)N_j - \varepsilon_{j,P}]x_{ji,P} + (N_j - \varepsilon_{j,R})x_{ji,R}\}, \tag{22}$$

for $i, j = 1, 2, j \neq i$.

We can then express City i's welfare as:

$$W_i = CS_i + PS_i + TR_i. \tag{23}$$

Due to more severe social disorder costs associated with local gamblers, Eadington (1995) argues that economic benefits are maximized when the city exports its gambling services to nonlocal gamblers. In our model, to maximize the social welfare, an active government attempts to export casino services and to capture external sources of tax revenues (EBT_i), as well as to "roll over" negative externalities (DC_i). To elaborate on the government's casino policy and derive policy implications, we shall further quantify the welfare measure from the border casino competition, to which we now turn.

4. Quantitative Analysis

In this section, we will quantitatively characterize the steady-state equilibrium, perform comparative statics exercises, and conduct welfare analyses, based on calibrated parametrization. In particular, we will calibrate the model to fit the cross-border casino competition between Detroit and Windsor. The study of Detroit-Windsor casino competition is interesting not only because of the historical rivalry between the two cities right on their respective borders but also because of the drastic changes in the commuting cost and the Detroit potential gambling population that influence their competition.

The Detroit and Windsor border is one of the most relentless forms of casino competition. Windsor, Ontario in the 1990s was an economically depressed area: a city of 200,000 people with population growth below the Canadian average and an unemployment rate 3% above average. Since its opening in 1998 (after winning the casino operation bid in 1994), Casino Windsor has been a booming sector, owing its success to the location on the US-Canadian border, and has become a catalyst for the creation of an urban business district. Casino Windsor is located on Windsor's riverfront overlooking the Detroit skyline near the Canadian end of the Detroit-Windsor Tunnel. Because of the border's favorable location, approximately four-fifths of the gambling business in the Windsor casino has been accounted for by metropolitan Detroiters. Detroit has observed Windsor's promising tax revenue windfalls and has subsequently enacted its own version of casinos to compete for casino dollars. Michigan approved plans to build three casinos in downtown Detroit (MotorCity Casino, MGM Grand Detroit, and Greektown Casino), which finally emerged in 2000 and have since then raised the stakes in the city's cross-border competition with Casino Windsor.

Windsor casino has experienced a large drop in cross-border business, due to the opening of Detroit casinos followed by the tighter restrictions on U.S. border controls after 911. Prior to the September 11, 2001 attacks, passage between Detroit and Windsor was quite easy, with only oral confirmation of identity generally providing enough to gain entry either to the United States or to Canada. After 911, the U.S. government tightened entry regulations by requiring passport or birth and identity documentation as well as extensive questioning and even random searches of vehicles (Ryan, 2012). Security hassles and long lines at the border led many Americans to stay home rather than travel abroad for gambling. In addition, the declining automobile industry, together with the financial tsunami, has seriously hit the Detroit economy. According to U.S. Census data, there has been a large reduction in Detroit's population; over the past 10 years, Detroit has lost about a quarter of its residents. Although Detroit's population and employment have significantly declined, the revenues of the casino industry have steadily increased. To overturn this disadvantage, in 2008 the Windsor Casino was rebranded and rebuilt as "Caesars Windsor," with an investment of over CAD $400 million.

As noted in Chang et al. (2010), most of the casinos in Canada are government run, including the Caesars Windsor. This implies that the Ontario Parliament sets tax rates and the Ontario Lottery and Gaming Corporation (OLG) administers the casino. To focus on our point, the possible agency problem between the Ontario Parliament and the OLG is abstracted from the analysis; instead, we view the Parliament and the OLG as making a collaborative decision. In the absence of the agency problem, a government run casino would be more likely to operate on a larger scale as long as the social disorder cost is not too high. Thus, the casino service in Windsor under our Bertrand competition setting is likely to be under-provided.

4.1. Calibration

We begin by obtaining relevant observations from Detroit and Windsor using data from various sources. The benchmark parameter values are summarized in Table 1.

The population size of potential gamblers is computed based on the average population over the age of 20.[6] Using data from the U.S. Census Bureau during the period 2000–2012, we calculate Detroit's average population over the age of 20 as $POP_1 = 629.087$ (in thousands); using data from Statistics Canada, the comparable figure (averaged over 2001–2011) for Windsor is $POP_2 = 239.820$ (in thousands). The relative population is about 2.6. Should we use metropolitan populations to capture a broader customer base, the relative population becomes 3.2.[7] Because the two cities are the bases for competition due to their direct involvements in setting relevant policies for their own residents, for welfare measures it is more appropriate to use city population. Nonetheless, one may view our benchmark effect of the population size in Detroit as a moderately conservative measure.

According to the reports of Gullickson and Hartmann (2006) and Dalton et al. (2012), the gambling participation rate is 66% in Ontario (based on at least one gambling activity in the past 12 months during 2007–2008), while it is around 71% in Michigan (based on the surveys on gambling behaviors in Michigan in 2001 and 2006). Thus, we can obtain the population sizes of the potential gamblers in Detroit and Windsor as $N_1 = 629.087 \times 0.71 = 446.652$ and $N_2 = 239.82 \times 0.66 = 158.283$, respectively. In each city, the population size of recreational gamblers is $n_i N_i$ and the population size of problem gamblers is $(1 - n_i)N_i$. Williams, Volberg and Stevens (2012) estimate the population of problem gamblers and show that about 2.1% of Michigan adults manifest a gambling disorder (based on the 2012 U.S. Census Bureau investigation for 7,234,755 persons aged 18 and above as well as four Michigan problem gambling prevalence studies in 1997, 1999, 2001, and 2006). The prevalence of problem gambling in the total population aged 18 and above ($2.1\% \times POP_1$) can be converted to around 3% of problem gambling in the population of potential gamblers, i.e., $(1 - n_1)N_1 = 3\% \times 446.652 = 13.4$ (in thousands). Similarly, Cox et al. (2005) estimate that problem gamblers constitute around 2% of the population in Ontario ($2\% \times POP_2$), so the population of problem gamblers in Windsor is computed as $(1 - n_2)N_2 = 3\% \times 158.283 = 4.784$. Over the period 2006–2011, the median household income is on average about $I_1 = \$29,526$ in Detroit and $I_2 = \$38,047$ in Windsor (all in US$).

Next, we compute the casino revenue tax (wagering tax) and GST surcharge on gambling. The wagering tax is levied based on the casino revenues, i.e., the Adjusted Gross Receipts (AGR, or casino win) of the game (see Suits, 1979; Combs et al., 2016). The AGR represent a

[6] The minimum casino gambling age is 21 in Detroit and is 19 in Windsor.

[7] Metro Detroit–Warren–Dearborn has about 3.2 million residents aged 20 or above. Because Windsor is not in a Census Metropolitan Area in Canada, we use the Chatham-Kent-Leamington area as a proxy, which has about 0.99 million residents aged 20 or above.

Table 1
Benchmark Parameter Values.

Observed Parameters	
Gambler size	$N_1 = 446.652$, $N_2 = 158.283$
Problem gambler rate	$1 - n_1 = 3\%$, $1 - n_2 = 3\%$
Population	$POP_1 = 629.087$, $POP_2 = 239.820$
Median income	$I_1 = 29526$, $I_2 = 38047$
Wagering tax rate	$\sigma_1 = 19\%$, $\sigma_2 = 20\%$
GST surcharge on gambling	$s_1 = 0.8$, $s_2 = 1.36$, $\widetilde{s}_1 = 0.0417$, $\widetilde{s}_2 = 0.071$
Consumption tax rate	$t = 5.5\%$
Licensing fee ratio	$f_1/AGR_1 = 1.25\%$, $f_2/AGR_2 = 1.30\%$
RTP percentage	$\pi = 0.9$
Casino income creation	$a_1 = a_2 = 0$
Relative AGR of Windsor to Detroit	$RR = 1.340$
Ratio of cross-border gamblers in Windsor	$FCWD = 0.610$
Relative disorder cost	$z = 1/10$
Calibrated Parameters	
Gambling preference	$\gamma_L = 1766.6$, $\gamma_H = 1802$
Marginal cost	$c_1 = 0.307$, $c_2 = 0.282$
Commuting cost	$T = 191.67$
Overall casino disorder cost	$d_1 = d_2 = 1.5$
Relative income elasticity	$\eta_P = 4061$, $\eta_R = 12$
Weight of casino disorder cost	$\varphi_c = \varphi_a = 0.5$
Equilibrium Variables	
Casino (relative) prices	$p_1^* = 1.285$, $p_2^* = 1.260$, $p^* = 0.981$
Moral cost cutoffs	$\varepsilon_{1,P}^* = 13.400$, $\varepsilon_{2,P}^* = 4.748$, $\varepsilon_{1,R}^* = 224.132$, $\varepsilon_{2,R}^* = 140.058$
Casino demands	$x_{11,P}^* = 7776.018$, $x_{12,P}^* = 7689.232$, $x_{22,P}^* = 7618.154$, $x_{21,P}^* = 7703.239$, $x_{11,R}^* = 3703.018$, $x_{12,R}^* = 3616.232$, $x_{22,R}^* = 3545.154$, $x_{21,R}^* = 3630.239$
Aggregate demands	$X_1^* = 950701.021$, $X_2^* = 1320553.125$
Demand elasticities	$e_{11,P}^* = 0.831$, $e_{12,P}^* = 0.815$, $e_{22,P}^* = 0.807$, $e_{21,P}^* = 0.822$, $e_{11,R}^* = 1.745$, $e_{12,R}^* = 1.734$, $e_{22,R}^* = 1.734$, $e_{21,R}^* = 1.745$

casino's gross revenue (the price of a \$1 wagering handle p_i times the total amount wagered by gamblers X_i) minus the payout (the amount of winnings paid out to gamblers, i.e., the return to player (RTP) percentage π times the total amount wagered by gamblers X_i), that is, $AGR_i = (p_i - \pi)X_i$. In practice, the RTP varies for different casino games. As for casino slot machines, the RTP percentage π can vary from 82% to 98%.,[8,9] We take averages and choose $\pi = 0.9$ for both casinos. In Detroit, casinos are required to pay a $\sigma_1 = 19\%$ tax on their gross gambling revenues (AGR) and a fixed fee, which is about $\frac{f_1}{AGR_1} = 1.25\%$ of the gross gambling revenues (see the 2013 (American Gaming Association (AGA), 2013) Survey of Casino Entertainment). In Windsor, casinos are required to pay the government of Ontario a "win contribution" (i.e., gambling tax) of $\sigma_2 = 20\%$ of the gambling revenue, along with a municipal hosting fee which is around $\frac{f_2}{AGR_2} = 1.3\%$ of the gross gambling revenues (see the report Potential Commercial Casino in Toronto, 2012).[10] Since the sales tax rates are 6% in Detroit and 5% in Windsor, we take averages to set $t = 5.5\%$. Thus, in Detroit the GST surcharge on gambling s_j could result in a 4.4% gaming excise tax, so the effective GST surcharge on gambling is $\widetilde{s}_1 = \frac{1+(1+s_1)t}{(1+t)} - 1 = \frac{s_1 \cdot t}{1+t} = 0.0417$. In Canada there is a 7.5% harmonized good and service tax imposed on gambling activities and the effective GST surcharge on gambling of Windsor is $\widetilde{s}_2 = \frac{0.075}{1+5.5\%} = 0.071$. These imply that $s_1 = 0.8$ and $s_2 = 1.36$.

We turn to the commuting cost computation, containing time costs, gasoline costs and tolls and depending crucially on the average number of trips for cross-border gambling. According to the 2006 (AGA, 2006) Survey, more than one quarter of the U.S. adult population (52.8 million) visited a casino in 2005, making a total of 322 million trips, with 6.1 trips per gambler on average. In our model, the fraction of the cross-border gamblers is: $FRAC = \frac{[(1-n_1)N_1-\varepsilon_{1,P}^*]+(N_1-\varepsilon_{1,R}^*)+[(1-n_2)N_2-\varepsilon_{2,P}^*]+(N_2-\varepsilon_{2,R}^*)}{N_1+N_2}$. With the average number of casino trips per gambler being 6.1 per year, the average cross-border trips are $ACBT = 6.1 \times FRAC$. The Detroit-Windsor Tunnel charges a toll (per round-trip) of \$9.25. To calculate the time cost of commuting, we use an observed average hourly wage for Detroit and Windsor of \$23.5 over the period 2006–2012.[11] Based on an average commuting time per trip of 3 h, the time costs per trip become \$23.5 × 3. Using an average gasoline cost of \$2.43 per hour of driving, we obtain the gasoline cost per trip of \$2.43 × 3.[12] Thus, on average the cross-border commuting cost is given by:

$$T = [3(23.5 + 2.43) + 9.25] \cdot ACBT. \tag{24}$$

We now compute the fraction of cross-border gambling activities. Before the opening of the Detroit casinos (before 2000), it is estimated that approximately four fifths of the gambling business in the Windsor casino was accounted for by metropolitan Detroiters (Wacker, 2006). Similarly, Canadian officials' estimates show that 80% of Windsor's gamblers were U.S. residents (Ankeny, 1998). However, nowadays there has been a significant drop in such cross-border business, due both to the opening of Detroit casinos and to the tighter restrictions on U.S.

[8] Regarding the RTP percentages, the reader can refer to the website of the Online Casino Bluebook: https://www.onlinecasinobluebook.com/education/tutorials/slots/.

[9] The 2013 report of the Institute for American Values entitled "Why Casinos Matter" estimates that a typical casino derives about 62%–80% of its revenues from slot machines.

[10] The report is available at: http://www.toronto.ca/legdocs/mmis/2012/ex/bgrd/backgroundfile-51515.pdf.

[11] We use data from the U.S. Bureau of Labor Statistics and Statistics Canada.

[12] For the driving commute costs, the reader can refer to the Commuter Cost Calculator, for which the website is: http://www.ttc.ca/ridingTTC/costCalculator.action.

border controls. Since the September 11, 2001 attacks, the U.S. government has tightened entry regulations by requiring passport or birth and identity documentation as well as extensive questioning and even random searches of vehicles. The number of agents at the Ambassador Bridge, Blue Water Bridge and the Detroit-Windsor Tunnel has already doubled since 911. As a result, between 60% and 70% of the business of the Windsor casino currently comes from across the border (Duggan, 2009; Hall, 2009), while U.S. customers still represent a crucial portion of business for Caesars (Battagello, 2014).[13] To capture the downward trend, we set the fraction of the casino consumption of Windsor coming from Detroit (*FCWD*) as:

$$FCWD = \frac{\left[(1-n_1)N_1 - \varepsilon^*_{1,P}\right]x^*_{12,P} + \left(N_1 - \varepsilon^*_{1,R}\right)x^*_{12,R}}{\left\{\varepsilon^*_{2,P}x^*_{22,P} + \left[\varepsilon^*_{2,R} - (1-n_2)N_2\right]x^*_{22,R} + \left[(1-n_1)N_1 - \varepsilon^*_{1,P}\right]x^*_{12,P} + (N_1 - \varepsilon^*_{1,R})x^*_{12,R}\right\}} = 0.61. \quad (25)$$

In addition, further insight is needed in order to compute the relative gambling revenue. Notably, there are three casinos in Detroit city, while there is only one casino in Windsor. Based on the OLG (Ontario Lottery and Gaming Corporation) Annual Reports, on average the casino in Windsor (Caesars Windsor) generated around 556 million CAD in gross casino revenues per year during the period 2000–2012. Computed from the data of the Michigan Gaming Control Board, the average gross revenue of casinos per year in Detroit was around 1.209 billion USD during the period 2000–2012, implying around 403 million USD for each casino.[14] Given the fact that the average CAD to USD exchange rate is about 0.97, the relative gambling revenues of the Windsor casino to the Detroit casino $RR = \frac{AGR_2}{AGR_1}$ is about 1.34. By using (9) and (10), we can thus express the relative AGR of the Windsor casino to the Detroit casino (*RR*) as follows:

$$RR = \frac{AGR^*_2}{AGR^*_1} = \frac{(p^*_2 - \pi)X^*_2}{(p^*_1 - \pi)X^*_1} = \frac{(p^*_2 - \pi)\left\{\varepsilon^*_{2,P}x^*_{22,P} + \left[\varepsilon^*_{2,R} - (1-n_2)N_2\right]x^*_{22,R} + \left[(1-n_1)N_1 - \varepsilon^*_{1,P}\right]x^*_{12,P} + (N_1 - \varepsilon^*_{1,R})x^*_{12,R}\right\}}{(p^*_1 - \pi)\left\{\varepsilon^*_{1,P}x^*_{11,P} + \left[\varepsilon^*_{1,R} - (1-n_1)N_1\right]x^*_{11,R} + \left[(1-n_2)N_2 - \varepsilon^*_{2,P}\right]x^*_{21,P} + \left(N_2 - \varepsilon^*_{2,R}\right)x^*_{21,R}\right\}} = 1.34. \quad (26)$$

Moreover, we can rewrite the first-order conditions for the prices of both cities:

$$1 = \frac{(1-\sigma_1)(p^*_1 - \pi) - c_1}{(1-\sigma_1)p^*_1} \cdot E^*_1, \quad (27)$$

$$1 = \frac{(1-\sigma_2)(p^*_2 - \pi) - c_2}{(1-\sigma_2)p^*_2} \cdot E^*_2, \quad (28)$$

and accordingly obtain the equilibrium relative price ratio as follows:

$$p^* = \frac{p^*_2}{p^*_1} = \frac{\left(1 - \frac{1}{E^*_1}\right)(1-\sigma_1)[(1-\sigma_2)\pi + c_2]}{\left(1 - \frac{1}{E^*_2}\right)(1-\sigma_2)[(1-\sigma_1)\pi + c_1]}, \quad (29)$$

where E^*_1 and E^*_2 are the gross (pre-tax) price elasticities of (overall) demand for Casinos 1 and 2 in equilibrium. In the calibration, the price of a unit bet p_i is calculated by using the take-out withhold which is the fraction of wagers placed by bettors that is withheld by the casino. A reasonable range for the average take-out withholding rates is around 15.5%–26.4%. We thus set the withholding rate $(1 - \frac{1}{p^*_1})$ at around 22% for the Detroit casino, implying that the price paid for a \$1 wagering handle is $p^*_1 = 1.285$ and the *overall* house advantage is $(p^*_1 - \pi) = 0.385$.

Generally speaking, problem gamblers, not being very responsive to price given their addictions and compulsions, have inelastic demand, while regular gamblers without such addictions and compulsions may have much more elastic demand. The problem gamblers' demand curve, however, is nested within the demand curve for all gamblers but cannot be observed because problem gamblers do not declare themselves and the data cannot break down totals into money from problem gamblers and money from recreational gamblers (Forrest, 2010). Given this difficulty, we focus on the Detroit gamblers who visit their own casino and set the demand elasticity of problem gamblers as

$$e^*_{11,P} = -\frac{\partial x^*_{11,P}}{\partial p_1}\frac{p^*_1}{x^*_{11,P}} = 0.83, \quad (30)$$

and the demand elasticity of regular gamblers as

$$e^*_{11,R} = -\frac{\partial x^*_{11,R}}{\partial p_1}\frac{p^*_1}{x^*_{11,R}} = 1.74. \quad (31)$$

These demand elasticities are consistent with the estimates in Thalheimer and Ali (2003) and Landers (2008), covering both elastic (greater than one) and inelastic (less than one) demands.

With the derivatives of $\varepsilon^*_{1,P}$, $\varepsilon^*_{1,R}$, $\varepsilon^*_{2,P}$, and $\varepsilon^*_{2,R}$, (24)-(31) allow us to calibrate $\gamma_H = 1802$, $\gamma_L = 1767$, $\eta_p = 4061$, $\eta_r = 12$, $T = 191.67$, $c_1 = 0.307$, $c_2 = 0.282$, and $p^* = 0.981$ (implying $p^*_2 = 1.26$). As a consequence, $\gamma \equiv \frac{\gamma_H}{\gamma_L} = 1.02$, implying that on average Detroit gamblers have 2% higher preferences toward casino gambling than Windsor gamblers. Moreover, the degree of irresponsiveness due to addiction in Detroit and Windsor is almost identical: about 74.3% for problem gamblers and 0.2% for regular gamblers.[15] Thus, all other prices and quantities, namely, $\varepsilon^*_{1,P}$, $\varepsilon^*_{1,R}$, $\varepsilon^*_{2,P}$, $\varepsilon^*_{2,R}$, $x^*_{11,P}$, $x^*_{11,R}$, $x^*_{12,P}$, $x^*_{12,R}$, $x^*_{21,P}$, $x^*_{21,R}$, $x^*_{22,P}$, $x^*_{22,R}$, X^*_1, and X^*_2, can be computed (see Table 1). In the calibrated benchmark, all problem gamblers in both cities visit their own casino, i.e., $\varepsilon^*_{1,P} = (1-n_1)N_1$ and $\varepsilon^*_{2,P} = (1-n_2)N_2$. The evidence indicates that problem gamblers are frequent gamblers and often gamble in local casinos. People who live close to a casino are twice as likely to become problem gamblers as people who live more than 10 miles away.[16] In the next subsection, we will examine under what conditions these problem gamblers who give rise to significant social costs will cross the border to gamble.

The average ratio of the commuting costs to the income of the cross-border gamblers (i.e., $\frac{T\left\{\left[((1-n_1)N_1 - \varepsilon^*_{1,P}) + (N_1 - \varepsilon^*_{1,R})\right] + \left[((1-n_2)N_2 - \varepsilon^*_{2,P}) + (N_2 - \varepsilon^*_{2,R})\right]\right\}}{\left\{\left[((1-n_1)N_1 - \epsilon^*_{1,P}) + (N_1 - \epsilon^*_{1,R})\right]I_1 + \left[((1-n_2)N_2 - \varepsilon^*_{2,P}) + (N_2 - \varepsilon^*_{2,R})\right]I_2\right\}}$) is around 0.64%, which seems very reasonable. Moreover, the equilibrium proportion of the cross-border gamblers for Detroit ($\mu^{CB}_1 = \frac{[(1-n_1)N_1 - \varepsilon^*_{1,P}] + [N_1 - \varepsilon^*_{1,R}]}{N_1} = 49.8\%$) is larger than that for Windsor ($\mu^{CB}_2 = \frac{[(1-n_2)N_2 - \varepsilon^*_{2,P}] + [N_2 - \varepsilon^*_{2,R}]}{N_2} = 11.5\%$), which is consistent with common

[13] The Detroit-Windsor tunnel traffic decreased from 5.9 million vehicles in 2001 to 3.6 in 2010. Daily traffic has fallen from around 18,000 visitors before 9/11 to about 13,000 visitors now. Caesars Windsor, however, is not exactly certain how much of the local casino's business from across the border may have dropped recently.

[14] The website of the Michigan Gaming Control Board is: http://www.michigan.gov/mgcb.

[15] Note that the absolute value of individual demand elasticity for local casino services is given by $e^*_{ii,m} = \frac{\gamma_\tau}{p_{ii}x_{i,m}} = 1 - \frac{p_{ii}\eta_m}{p_{ii}\eta_m + \gamma_\tau}$, where $\frac{p_{ii}\eta_m}{p_{ii}\eta_m + \gamma_\tau}$ measures the degree of irresponsiveness due to addiction.

[16] See the website: http://profilemap.net/ADT/local-casinos/.

observations. The evidence also reveals that problem gamblers constitute a much larger share of the population of gamblers who enter a casino, contributing to 40–60% of slot machine revenue (Narayanan and Manchanda, 2011). In our parametrization, the casino consumption of problem gamblers is more than 2 times as high as that of regular gamblers. The house advantage refers to the mathematical edge maintained by gambling operators that ensures the house ends up making money over the long term. In our parametrization, the *overall* house advantage is $(p_1^* - \pi) = 0.385$ for the Detroit casino and $(p_2^* - \pi) = 0.36$ for the Windsor casino. Accordingly, the gross rate of profit is around 19.04% for the Detroit casino and 20.58% for the Windsor casino, which are empirically reasonable.[17] Thus, the under-provision issue mentioned above under Bertrand competition is likely to be modest.

In the empirical literature, the effects of casinos on employment and hence income creation are found to be ambiguous. Some studies find potentially positive income creations of casinos – particularly when casinos are established in deprived areas where they create more jobs and incomes. Other studies, however, refer to a statistically insignificant effect on employment and income creation due to the cannibalization within the gambling industry (e.g., lotteries and horse and dog racing). Using data from Canadian casinos, Humphreys and Marchand (2013) found that a new casino has significant beneficial effects in directly increasing the employment and earnings of the local gambling industry, and indirectly benefiting the related local industries of hospitality and entertainment within one to five years after the casino opening. The income creation effects, however, are insignificant in areas with existing casinos, suggesting that the beneficial effects of a new casino are likely to be short-lived. To reflect the fact, we consider a scenario without the income creation effect (i.e., $a_1 = a_2 = 0$) as the benchmark. The calculation of the disorder costs is complicated. The National Opinion Research Center (NORC), Productivity Commission (PC), and Reith (2006) investigated the relationship between problem and pathological gambling and general measures of social wellbeing. Using their estimates based on financial problems (bankruptcy and indebtedness), crimes (arrest and incarceration), health impacts, job losses, and family stability issues (divorce and impacts on children), we set the relative disorder cost of regular to problem gamblers as $z = 1/10$.[18] In the absence of empirical observations, we set the cross-border intensity parameters as being half of those facing local gamblers, i.e., $\varphi_c = \varphi_a = 0.5$. Moreover, we set the scaling parameters of distortion costs from casino gambling as $d_1 = d_2 = 1.5$ such that the external disorder cost in Detroit is about 19% in consumption equivalence. Thus, the disorder costs in Detroit (338, 658) are substantially larger than in Windsor (192, 654).

4.2. Comparative statics

With the calibrated parametrization above, we now quantitatively examine some interesting comparative statics, which are reported in Table 2. A complete set of tables summarizing all comparative statics results is relegated to Online Appendix Table A1.

We begin by studying the responses to the two tax instruments (see Table 2-a). When Detroit raises the revenue/wagering tax rate σ_1 on its casino, Detroit's casino raises its price p_1^* in order to pass the tax burden onto the gamblers. Meanwhile, a higher σ_1 also makes the demand for Windsor's casino become less elastic, allowing the Windsor casino to raise its price p_2^*. Since the casino prices are higher in both cities, the casino consumption per gambler ($x_{11,m}^*, x_{12,m}^*, x_{21,m}^*$ and $x_{22,m}^*$) decreases regardless of the gambler types ($m = P, R$). Given that the direct (former) effect dominates, the relative price of the Windsor casino $p^*(= p_2^*/p_1^*)$ decreases in response. This, on the one hand, encourages more of Detroit's recreational gamblers (and hence overall gamblers) to visit Windsor's casino ($\mu_{1,R}^{CB}$ and μ_1^{CB} increase) and, on the other hand, leads Windsor's recreational gamblers (and hence overall gamblers) to stay at their own casino ($\mu_{2,R}^{CB}$ and μ_2^{CB} decrease). Thus, the cross-border gambling of Detroit exhibits an extensive margin response to a higher revenue tax σ_1 in Detroit whereby the proportion of cross-border recreational gamblers ($\mu_{1,R}^{CB}$) increases, but the cross-border casino consumption per gambler ($x_{12,R}^*$) decreases.

Moreover, since more of Detroit's (fewer of Windsor's) residents cross the border to gamble, the total demand for the Detroit casino (X_1^*) and the casino revenue (AGR_1^*) decrease, but both the demand for the Windsor casino (X_2^*) and its casino revenue (AGR_2^*) increase. These subsequently decrease the Detroit export-based and total tax revenues (EBT_1^* and TR_1^*), but increase the Windsor export-based and total tax revenues (EBT_2^* and TR_2^*). In terms of the social disorder cost, since for Detroit a higher σ_1 leads to a decrease in both the local recreational gamblers ($[\varepsilon_{1,R}^* - (1 - n_1)N_1]x_{11,R}$) and cross-border recreational gamblers ($(N_2 - \varepsilon_{2,R}^*)x_{21,R}$) from Windsor, the disorder costs $DC_{1,R}^1$ and $DC_{1,R}^2$ decrease as well. Thus, the total social cost $DC_{1,R}$ becomes lower, even though the cost caused by the compulsive addiction of gambling ($DC_{1,R}^3$) could be higher. The results regarding an increase in Windsor's revenue tax rate (σ_2) are totally symmetric, and are thus not repeated here to save space.

Walker and Nesbit (2014) estimate the impact of a casino in the Missouri riverboat gambling market and find that a 1% increase in neighboring casinos' AGR leads to a 0.116% decline in a casino's AGR, if slots and table games are kept constant.[19] If neighboring casinos increase both slots and table games, there is a slightly bigger impact after the market adjusts: a 1% increase in slots and tables causes a 0.136% decline in the casino's revenue. Thalheimer and Ali (2003) show that a new casino (commercial or tribal) in the Missouri-Iowa-Illinois region decreases the slot handle of competing casinos by approximately 3%. By focusing on the Philadelphia-Northern Delaware-Atlantic City market, Condliffe (2012) finds that in the face of Pennsylvania's competition the loss of neighboring casinos was around 0.01% of their mean monthly revenues. Our numerical analysis shows that casino competition via wagering taxation (say, a 1% reduction in σ_1) increases Detroit's casino demand (X_1^* by 2.096%) and revenue (AGR_1^* by 1.891%), while it decreases Windsor's casino demand (X_2^* by 1.337%) and revenue (AGR_2^* by 1.368%). This implies that a 1% increase in the AGR of Detroit's casino leads to a 0.72% decline in those of Windsor's casino. Compared

[17] See the Casino City Times (http://www.casinocitytimes.com/news/) for the relevant discussion.

[18] As for the financial problem, almost 20% of pathological gamblers had filed for bankruptcy, compared with rates of 5.5% for low risk gamblers and gambling losses averaged around 20% of household income for problem gamblers, compared with only 1% for regular gamblers. Moreover, 40% of the severe and 52% of the problem gamblers had sold their possessions to pay gambling debts, compared with 2% of regular gamblers. As for crime, the rates of arrest and incarceration, respectively, were 32.3% and 21.4% for pathological gamblers, 36.3% and 10.4% for problem gamblers, 11.1% and 3.7% for low-risk gamblers, and 4.5% and 0.4% for non-gamblers. In addition, 46% of the severe and 25% of the problem gamblers had committed illegal acts to gamble and/or pay gambling debts, compared with only 1% of regular gamblers. As for the health impacts of gambling, 61% of non-problem gamblers rated their health as excellent or very good, compared to only 49% of low to moderate-risk gamblers and 33% of problem gamblers. As for job loss, rates of past-year job loss were higher for both pathological and problem gamblers (13.8% and 10.8%, respectively) than for low-risk or non-gamblers (5.8% and 5.5%, respectively). As for family stability, rates of divorce were 53.5% and 39.5% for pathological and problem gamblers, respectively, as compared with 29.8% for low-risk gamblers and 18.2% for non-gamblers. Besides, other costs which are difficult to quantify include comorbidities of other addictions (drug, alcohol, and mental health problems) and negative impacts on family (e.g., the children of problem gamblers have a higher than normal involvement with addictive substances and more psycho-social problems than others).

[19] Our study can apply to analyzing the riverboat gambling competition even when it is not fixed-location.

Table 2-a
Effects of Casino Revenue Tax (σ_i) and Casino Tax Surcharge (s_i).

(Benchmark)		(+1%)		(+1%)		(+1%)		(+1%)	
		$\sigma_1 = 0.1919$		$\sigma_2 = 0.202$		$s_1 = 0.808$		$s_1 = 1.3736$	
p^*	0.981	0.981	-0.051%	0.982	0.052%	0.981	0.011%	0.981	-0.017%
$x^*_{11,P}$	7776.018	7769.853	-0.079%	7775.081	-0.012%	7772.469	-0.046%	7775.138	-0.011%
$x^*_{12,P}$	7689.232	7688.341	-0.012%	7683.211	-0.078%	7688.720	-0.007%	7683.573	-0.074%
$x^*_{22,P}$	7618.154	7617.280	-0.011%	7612.250	-0.077%	7617.651	-0.007%	7612.605	-0.073%
$x^*_{21,P}$	7703.239	7697.195	-0.078%	7702.321	-0.012%	7699.759	-0.045%	7702.376	-0.011%
$x^*_{11,R}$	3703.018	3696.853	-0.167%	3702.081	-0.025%	3699.469	-0.096%	3702.138	-0.024%
$x^*_{12,R}$	3616.232	3615.341	-0.025%	3610.211	-0.167%	3615.720	-0.014%	3610.573	-0.157%
$x^*_{22,R}$	3545.154	3544.280	-0.025%	3539.250	-0.167%	3544.651	-0.014%	3539.605	-0.157%
$x^*_{21,R}$	3630.239	3624.195	-0.167%	3629.321	-0.025%	3626.759	-0.096%	3629.376	-0.024%
μ_1^{CB}	0.498	0.504	1.142%	0.493	-1.137%	0.501	0.657%	0.493	-1.069%
μ_2^{CB}	0.115	0.099	-13.675%	0.131	13.610%	0.106	-7.869%	0.130	12.791%
AGR_1^*	365581.306	358640.938	-1.898%	372671.399	1.939%	361104.919	-1.224%	372245.012	1.823%
AGR_2^*	475866.456	482398.272	1.373%	469633.276	-1.310%	479625.238	0.790%	468922.222	-1.459%
TR_1^*	194930.225	191830.816	-1.590%	198595.712	1.880%	193145.172	-0.916%	198375.303	1.767%
TR_2^*	317394.037	321616.295	1.330%	313931.893	-1.091%	319823.923	0.766%	314126.015	-1.030%
DC_1^*	338658.023	336918.278	-0.514%	339902.910	0.368%	337655.965	-0.296%	339828.007	0.345%
DC_2^*	192653.956	193906.010	0.650%	191098.997	-0.807%	193374.311	0.374%	191192.315	-0.759%

Table 2-b
Effects of Commuting Costs (T), Detroit's Total (N_1) and Problem Gambling Populations ($1 - n_1$).

(Benchmark)		(+1%)		(+1%)		(−1%)	
		$T = 193.5867$		$N_1 = 451.1158$		$n_1 = 0.9603$	
p^*	0.981	0.981	-0.00010%	0.9812	0.00580%	0.981	-0.00656%
$x^*_{11,P}$	7776.018	7776.013	-0.00006%	7775.8854	-0.00171%	7775.227	-0.01018%
$x^*_{12,P}$	7689.232	7689.237	0.00006%	7688.5329	-0.00910%	7689.118	-0.00149%
$x^*_{22,P}$	7618.154	7618.158	0.00006%	7617.4679	-0.00900%	7618.042	-0.00147%
$x^*_{21,P}$	7703.239	7703.234	-0.00006%	7703.1092	-0.00169%	7702.463	-0.01008%
$x^*_{11,R}$	3703.018	3703.013	-0.00013%	3702.8854	-0.00358%	3702.227	-0.02138%
$x^*_{12,R}$	3616.232	3616.237	0.00013%	3615.5329	-0.01935%	3616.118	-0.00316%
$x^*_{22,R}$	3545.154	3545.158	0.00013%	3544.4679	-0.01935%	3545.042	-0.00316%
$x^*_{21,R}$	3630.239	3630.234	-0.00013%	3630.1092	-0.00358%	3629.463	-0.02138%
μ_1^{CB}	0.498	0.494	-0.81432%	0.5025	0.87173%	0.499	0.14657%
μ_2^{CB}	0.115	0.104	-9.99421%	0.1169	1.51768%	0.113	-1.75437%
AGR_1^*	365581.306	365619.019	0.01032%	366582.526	0.27387%	371478.640	1.61314%
AGR_2^*	475866.456	475831.874	-0.00727%	480993.487	1.07741%	476704.404	0.17609%
TR_1^*	194930.225	194949.724	0.01000%	195447.891	0.26557%	197978.796	1.56393%
TR_2^*	317394.037	317371.680	-0.00704%	320708.329	1.04422%	317935.770	0.17068%
DC_1^*	338658.023	338676.961	0.00559%	341494.443	0.83755%	386557.960	14.14404%
DC_2^*	192653.956	192635.306	-0.00968%	193690.136	0.53784%	192814.510	0.08334%

to the empirical findings, our numerical results show a relatively high figure due to a more competitive Detroit-Windsor market. In spite of the negative adjacent city effect of casinos, there may be a positive agglomeration effect for the casino market as a whole. McGowan (2009) finds that due to Pennsylvania's entry, Atlantic City lost over \$110 million dollars, but the overall Atlantic City-Philadelphia market grew by over \$460 million. As for the Detroit-Windsor market, our analysis reveals that the competition from Detroit's casinos hurts neighboring gambling revenues, but the loss in the AGR of Windsor is less than Detroit's gain. As a result, in response to a 1% reduction in Detroit's wagering tax σ_1, the overall Detroit-Windsor casino market $(X_1^* + X_2^*)$ expands by 0.1%, which leads to a 0.05% increase in the aggregate casino revenues $(AGR_1^* + AGR_2^*)$.[20]

Next, we examine the effects of the GST surcharge on gambling. As indicated in Proposition 3(i), raising Detroit's GST surcharge on gambling (s_1) increases the price elasticity of demand for Detroit's casino, but decreases the demand elasticity for Windsor's casino. As a result, the equilibrium price in Detroit p_1^* declines and the equilibrium price in Windsor p_2^* goes up, resulting in a higher relative price of Windsor p^*. Nevertheless, the after-tax relative consumer price $p^* \frac{1+(1+s_2)t}{1+(1+s_1)t}$ declines with a higher GST surcharge on gambling s_1, and, accordingly, the GST surcharge on gambling generates effects qualitatively similar to those of the revenue tax rate. The quantitative effects, however, are different. Detroit loses more export-based and total tax revenues in response to the wagering tax, compared to the GST surcharge on gambling (−13.77% and −1.60% vs. −7.55% and −0.92% in response to a 1% increase in σ_1 and s_1). There is a natural trade-off between the casino export-based/total tax revenue and the import-based/total disorder costs when levying higher taxation on either the casino σ_1 or gamblers s_1. As a consequence, the numerical analysis also suggests that for Detroit, a higher wagering tax can reduce the casino disorder cost more significantly than a GST surcharge on gambling.

The tax incidence of the wagering tax is also different from that of the GST surcharge on gambling. In response to an increase in the wagering tax, the increase in Detroit's casino price implies that the casino passes its tax burden onto consumers. In response to an increase in the GST surcharge on gambling, the decrease in Detroit's casino price implies that the casino shares some of the tax burden with its patrons. Our numerical analysis shows that in response to a rise in the wager-

[20] Nonetheless, Condliffe (2012) examines the Philadelphia-Northern Delaware-Atlantic City market empirically, revealing that the aggregate gambling revenue among the three states has not increased with the introduction of Pennsylvania gambling venues.

ing tax consumers share a relatively high tax burden (a 5% increase in σ_1 results in about a 0.3% rise in p_1^*), while in response to a rise in the GST surcharge on gambling the casinos share a relatively low tax burden (a 5% increase in s_1 results in about a 0.02% fall in p_1^*). The nonequivalence in the tax burden between the casino revenue tax and the GST surcharge on gambling is particularly interesting because in simple demand analysis it does not matter whether the consumer or the producer pays the tax given the pass through. As can be seen in the welfare analysis below (Subsection 4.3), this will lead to rich optimal tax outcomes. In summary, we have:

Result 1. (Effects of Casino Revenue Tax and GST surcharge on gambling)

(i) *The cross-border gambling of the city with stronger gambling preferences and a larger population (Detroit) exhibits an* ***extensive margin*** *response to a higher revenue tax in Detroit whereby the proportion of cross-border recreational gamblers increases, but the cross-border casino consumption per gambler decreases.*

(ii) *The competition from Detroit's casinos hurts neighboring gambling revenues, but the loss in the casino revenue of Windsor is less than Detroit's gain.*

(iii) *In Detroit, a higher wagering tax reduces the casino disorder cost more significantly than a GST surcharge on gambling and there is nonequivalence in the tax burden between the two casino taxes.*

When do problem gamblers cross the border to gamble? In Online Appendix Table A2, we show that the problem gamblers in Windsor will cross the border to gamble when Windsor raises the wagering tax rate σ_2 (the GST surcharge on gambling s_2) by 16% (18%) or when Detroit lowers the wagering tax rate σ_1 (the GST surcharge on gambling s_1) by 18% (or 28%) from the benchmark level. Intuitively, increasing Windsor's casino taxation generates a push effect, pushing Windsor's problem gamblers out to the Detroit casino. By contrast, decreasing Detroit's casino taxation generates a pull effect, pulling Windsor's problem gamblers into the Detroit casino. Since problem gamblers are less sensitive morally with respect to gambling in their own city, problem gamblers will cross the border to gamble only when the casino taxation changes significantly. This is somehow consistent with evidence in the sense that problem gamblers frequently visit local casinos that offer easy access for them to gamble closer to home and more often. Our numerical study shows that, as an example, if Windsor raises the wagering tax rate σ_2 by 18%, Detroit's export-based tax revenue will increase sharply, by around 299.50%, because problem patrons gamble more intensively (a higher $x_{21,P}^*$). Similarly, if Windsor raises the GST surcharge on gambling s_2 by 18%, Detroit's export-based tax revenue will increase by 239.47%. The corresponding import-based disorder costs, however, also become large. As for the effects of the wagering tax, $DC_{1,P}^2$ increases from 0 to 18,246 and $DC_{1,R}^2$ increases by 243.62%, resulting in an increase of about 14.73% in the total disorder costs. As for the effects of the GST surcharge on gambling, $DC_{1,P}^2$ increases from 0 to 4,873 and $DC_{1,R}^2$ increases by 224.21%, resulting in a 8.3% increase in total disorder costs.

As noted in Subsection 4.1, since the September 11, 2001 attacks, the U.S. government has tightened entry regulations which have dramatically raised the commuting cost between Detroit and Windsor. Based on our parametrization, a higher commuting cost (T) has resulted in a drop in the proportions of the cross-border gamblers for both cities (μ_1^{CB} and μ_2^{CB} fall), as shown in Table 2-b. As indicated in Proposition 3, since Detroit has a stronger preference for casino gambling, in Detroit the price elasticity of demand E_1 responds negatively to the commuting cost, but in Windsor the price elasticity of demand E_2 responds positively to it. As a result, the casino price of Detroit (p_1^*) increases, while the absolute (p_2^*) and relative prices ($p^* = p_2^*/p_1^*$) of Windsor decrease. The price effect refers to a decrease in the casino consumption per gambler in the Detroit casino ($x_{11,m}^*$ and $x_{21,m}^*$), but to an increase in the casino consumption per gambler in the Windsor casino ($x_{12,m}^*$ and $x_{22,m}^*$). In addition, because the cross-border gamblers of both cities are discouraged by a higher commuting cost and the population size of Detroit is larger than that of Windsor, the aggregate demand (X_1^*), casino revenue (AGR_1^*), and total tax revenue (TR_1^*) for Detroit are higher, but for Windsor are lower.

The tightened restrictions on the U.S. side of the border have led Windsor's gambling revenues to fall significantly. To counter this drop, the new Caesars Casino Windsor has opened new hotel towers and expanded its products to include a sports book. In particular, Caesars Casino Windsor offers passport photo sessions, information on what documents are needed to cross the border and even keeps passport application forms in its customer relations offices (Hall, 2009; McArthur, 2009). Other promotions include various hotel, dining and entertainment discounts and offers, as well as free slot machine play for the first $100. This evidence also supports our finding that the relative casino price of Windsor decreases in response to a higher commuting cost.

Result 2. (Effects of Commuting Costs)

(i) *A higher commuting cost causes the cross-border casino consumption of the city with stronger gambling preferences and a larger population (Detroit) to exhibit an* ***intensive margin*** *response in the sense that the proportion of cross-border gamblers decreases, but the cross-border casino consumption per gambler increases.*

(ii) *While Detroit absorbs greater demand and tax revenue, it is accompanied by higher disorder costs.*

Notably, the main finding in Result 1 and Result 2 concerning the effects of casino taxes and commuting costs are robust to different problem gambling prevalence rates $(1 - n_1)$ in the range of $1\% - 5\%$.

There has been, as noted above, a large reduction in Detroit's population due to the decline in the automobile industry. It is therefore also interesting to examine the effects of a reduction in Detroit's population, N_1. A reduction in Detroit's population decreases the demand for gambling, which leads the equilibrium casino prices in both cities to fall. The dwindling population, as shown in Proposition 3(ii), is more unfavorable to Windsor's casino, making the overall demand for Windsor's casino more elastic. Thus, the relative price of the Windsor casino p^* decreases. A fall in the casino prices enhances the casino consumption per gambler. Nonetheless, due to a reduction in the size of the gambling market, the cross-border gambling, total casino demand, casino revenue, total and export-based casino tax revenues, and social disorder costs in both cities are all lower (see Table 2-b). There is an intensive margin response whereby the gambling market size decreases while the casino consumption per gambler increases. Of particular interest, a 5% reduction in Detroit's population can substantially reduce the cross-border gambling from Detroit to Windsor, resulting in a remarkable loss in Windsor's export-based tax revenue (9.35%), total tax revenues (5.22%), and AGR (5.38%).

Result 3. (Effects of Detroit's Population) *The drop in Detroit's population hurts its neighboring casino, Windsor, more severely.*

In a meta-analysis of gambling disorders among adults in the U.S. and Canada, Shaffer, et al (1997) and Shaffer and Hall (2001) concluded that the number of problem gamblers among the adult general population had increased due to the increased exposure to gambling and immense social acceptance of gambling. Although the percentage of problem gamblers is small, their gambling activities give rise to significant social costs. The effects of a rise in the proportion of problem gamblers in Detroit $(1 - n_1)$ are qualitatively identical to those of an increase in Detroit's total gambling population (N_1), while their impacts differ quantitatively. Intuitively, because the demand of the problem gamblers is stronger and less elastic, the price elasticity of aggregate demand for gambling decreases and the price effect is more pronounced in Detroit. The proportion of Detroit's cross-border gambling only rises marginally. As a result, Detroit gains from much higher total casino demand (X_i^*), casino revenue (AGR_i^*), and tax revenues (TR_i^*), at the expense of much higher disorder costs (DC_i^*). This is consistent with the evidence that problem gamblers contribute 40–60% of slot machine revenue for a casino which offers easy access to and tempts citizens to gamble. Our numerical results suggest that a 1% increase in Detroit's problem gamblers increases the disorder costs sharply by almost 15%. By contrast, such percentage gains and costs in Windsor are much larger in response to an increase in the general gambling population of Detroit.

Result 4. (Effects of Detroit's Problem Gambling Population) *While Detroit incurs large gains in casino and tax revenues from a rising proportion of **problem** gamblers in Detroit, Windsor gains more from an increase in the **total** potential gambling population of Detroit*.

A primary factor driving the expansion of gambling is its ability to raise tax revenue, and under cross-border casino competition, demand elasticities are crucial for revenue generation. We thus further examine the elasticities of individual demand for gambling with respect to various casino taxes and investigate how the price elasticities respond to these different taxes (see Tables A1-a – A1-d in the Online Appendix). By focusing on the tax elasticity of the demand for gambling, because casinos can pass more of their tax burden onto consumers in response to a higher wagering tax rate, the wagering tax (σ_i) elasticities of the individual demand for gambling ($x_{ij,m}^*$) are much larger than the GST surcharge on gambling (s_i) elasticities. Moreover, due to the addiction of problem gamblers, the tax elasticities of the demand for gambling are lower for problem gamblers than recreational gamblers, regardless of the wagering tax or the GST surcharge on gambling. Besides, fiscal competition in either the wagering tax (lowering σ_i) or GST surcharge on gambling (lowering s_i) raises the price elasticity of demand for gambling for both problem and recreational gamblers ($e_{ij,m}^*$) in both cities. This implies that the government's tax competition tends to make the cross-border casino competition more intense.

Result 5. (Demand Elasticity and Casino Tax) *Individual demands for casino gambling are more responsive to the wagering tax than the GST surcharge on gambling and the government's tax competition leads the cross-border casino competition to become more intense.*

4.3. Welfare analysis

Endowed with a fully calibrated model, we are able to determine the optimal casino tax policy. We are particularly interested in three exercises. First, we compute the optimal policy of a single casino tax instrument, either the casino revenue tax σ_i^* or GST surcharge on gambling s_i^*, of a reference City i, given the alternative tax instrument and its rival's tax policy (σ_{-i}, s_{-i}) at their pre-existing values. Second, we compute the optimal tax mix $(\sigma_i^{**}, s_i^{**})$ of City i, given (σ_{-i}, s_{-i}) at their pre-existing values. This is basically a tax incidence exercise for each city. Finally, we compute the welfare-based pairwise casino competition $(\sigma_i^{***}, \sigma_{-i}^{***})$ and $(s_i^{***}, s_{-i}^{***})$, respectively, fixing the other tax policy at the pre-existing rates.

Consider the first exercise. Given the rival's tax policy and the alternative tax instrument, the optimal casino revenue/wagering tax rate in Detroit involves a decrease from its pre-existing value of 0.19 to $\sigma_1^* = 0.15$ (Fig. 2-a), whereas that in Windsor involves a decrease from 0.20 to $\sigma_2^* = 0.146$ (Fig. 2-b). While the optimal GST surcharge on gambling in Detroit declines from its pre-existing value of 0.8 to $s_1^* = 0.57$ (Fig. 2-c), that in Windsor decreases from 1.361 to $s_2^* = 0.998$ (Fig. 2-d). Generally speaking, the main trade-off facing each of these tax instruments is that a higher tax rate raises the consumer's surplus by means of a reduction in the casino externality (disorder costs), but suppresses the producer's surplus and the government's tax revenues as a result of a weakening competitive advantage. The optimal tax rate is determined by balancing these components.

In the benchmark parameterization with mild disorder costs of gambling, each city should lower its casino taxation in order to attract more cross-border gamblers, thereby establishing a competitive advantage over its rival. This explains the downward trend of casino taxation in recent decades (see Smith, 2000). To better compete with neighboring cities (jurisdictions), local governments have increased gambling revenues by expanding the tax base, rather than by raising tax rates. Such casino competition becomes more intense if the import-based disorder costs $DC_{i,m}^2$ are abstracted from the model (by setting $\varphi_c = 0$). Numerous empirical studies have shown that crime and drugs as imported costs may play a minor role when the number of tourists visiting (the tourism effect) is controlled. Because casinos can collect export-based tax revenues (EBT_i) from cross-border gambling without much concern about the relevant social disorder costs associated with cross-border gamblers, casino competition becomes more intense, thus driving down their optimal tax rates. Of particular interest, the low casino tax rates induce some problem gamblers to cross the border for gambling, contrary to the benchmark case. Meanwhile, the relentless competition pushes cities (jurisdictions) to tolerate problem gamblers to visit their casinos. This effect is more significant for Windsor, because the disorder cost for Windsor is less severe than for Detroit and Windsor's casinos are more dependent on cross-border visitors than Detroit's casinos.

This scenario also provides an important implication for online gambling that was practically nonexistent in 2003, but has grown extraordinarily during the last few years and is now an important factor in the global gambling market. In terms of online gambling, the revenues are paid where the casino operates but all disorder costs are borne in the gamblers' home jurisdictions. Thus, the competition of online casinos is tougher compared to that of brick-and-mortar casinos. As a result, most online casinos have resided in low-tax jurisdictions and reached out globally (cf. Fiedler and Wilcke, 2012; McAfee, 2014).[21] In summary, we have:

Result 6. (Optimal Policy of a Single Casino Tax) *The optimal policy of a single casino tax instrument is to lower each tax to below the respective pre-existing rate in both cities. The relentless competition pushes cities to tolerate problem gamblers to visit their casinos, and it is more pronounced in the city which relies more on cross-border gamblers and has lower disorder costs (Windsor)*

We next turn to the second exercise with the optimal tax mixes depicted in Fig. 3. Given Windsor's existing tax policy $(\sigma_2, s_2) = (0.2, 1.36)$, Detroit's optimal tax mix is $(\sigma_1^{**}, s_1^{**}) = (0.049, 1.483)$. Given Detroit's existing tax policy $(\sigma_1, s_1) = (0.19, 0.8)$, Windsor's optimal tax mix is $(\sigma_2^{**}, s_2^{**}) = (0.279, 0.405)$. Thus, Detroit with stronger gambling preferences and higher disorder costs should decrease its pre-existing wagering tax to a lower level but increase its pre-existing GST surcharge on gambling to a higher level (the disorder costs of Detroit are almost twice as high as those of Windsor in the benchmark). By contrast, Windsor which relies more on cross-border visitors should increase its pre-existing wagering tax to a higher level but decrease its pre-existing GST surcharge on gambling to a lower level (the casino consumption of Windsor coming from Detroit is $FCWD = 0.61$, which is about seven times larger than Detroit's figure in the benchmark). It is interesting to note that, in response to a population drop in Detroit N_1, the aggregate Detroit-Windsor casino market shrinks and, as a result, both cities should lower their casino-related taxation, which will attract cross-border gamblers without needing to be seriously concerned about the disorder costs.

Result 7. (Optimal Tax Mix) *The city with higher disorder costs (Detroit) decreases its wagering tax below the pre-existing level but increases its GST surcharge on gambling above the pre-existing level. By contrast, the city*

[21] The number of licenses in the UK nearly exploded over the last three years making it by now the largest hub of online gambling. Interestingly, these online casinos do face very low taxes. See http://online.casinocity.com/jurisdictions/.

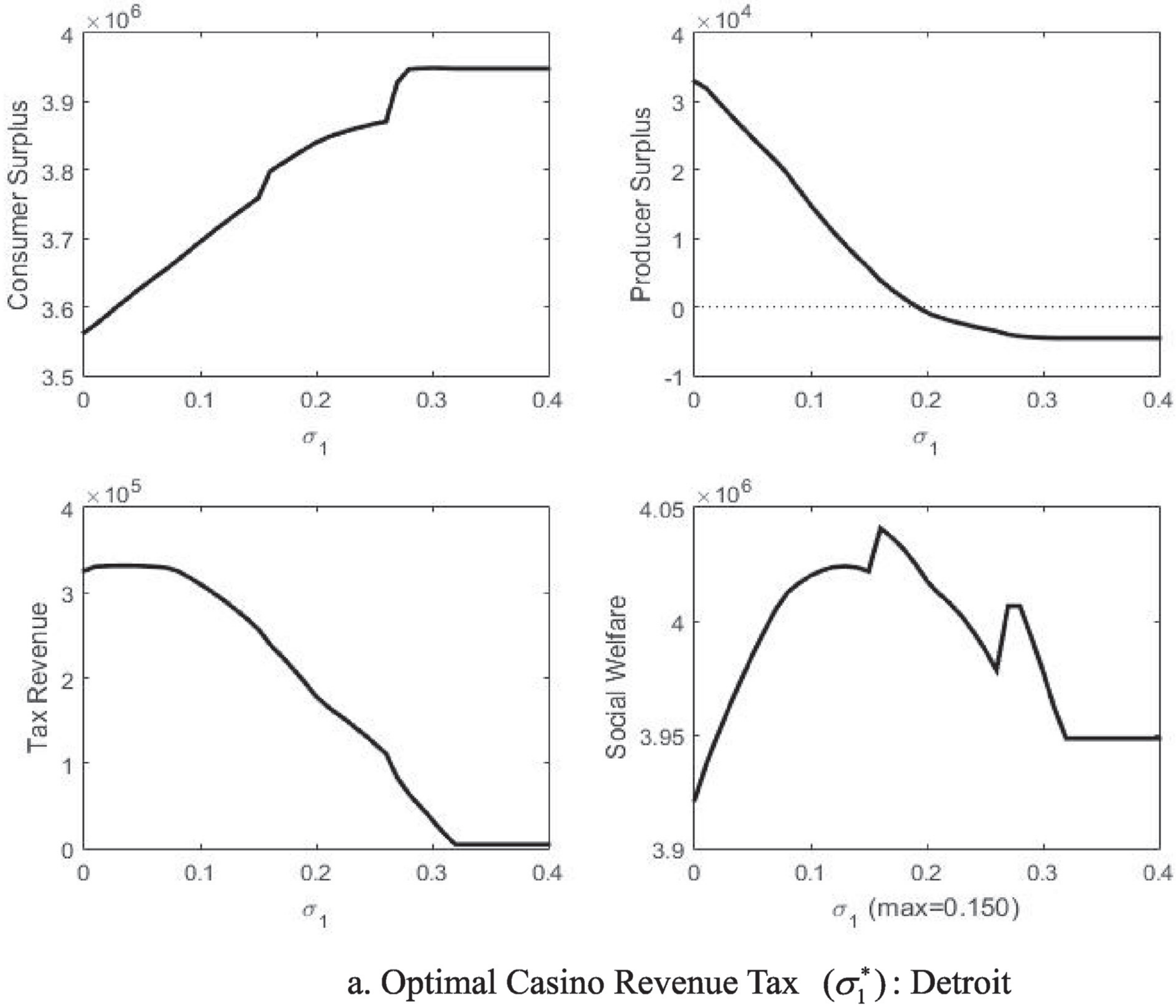


Fig. 2. a. Optimal Casino Revenue Tax (σ_1^*): Detroit. b. Optimal Casino Revenue Tax (σ_2^*): Windsor. c. Optimal Casino Tax Surcharge (s_1^*): Detroit. d. Optimal Casino Tax Surcharge (s_2^*): Windsor.

which relies more on cross-border visitors (Windsor) increases its wagering tax above the pre-existing level but decreases its GST surcharge on gambling below the pre-existing level.

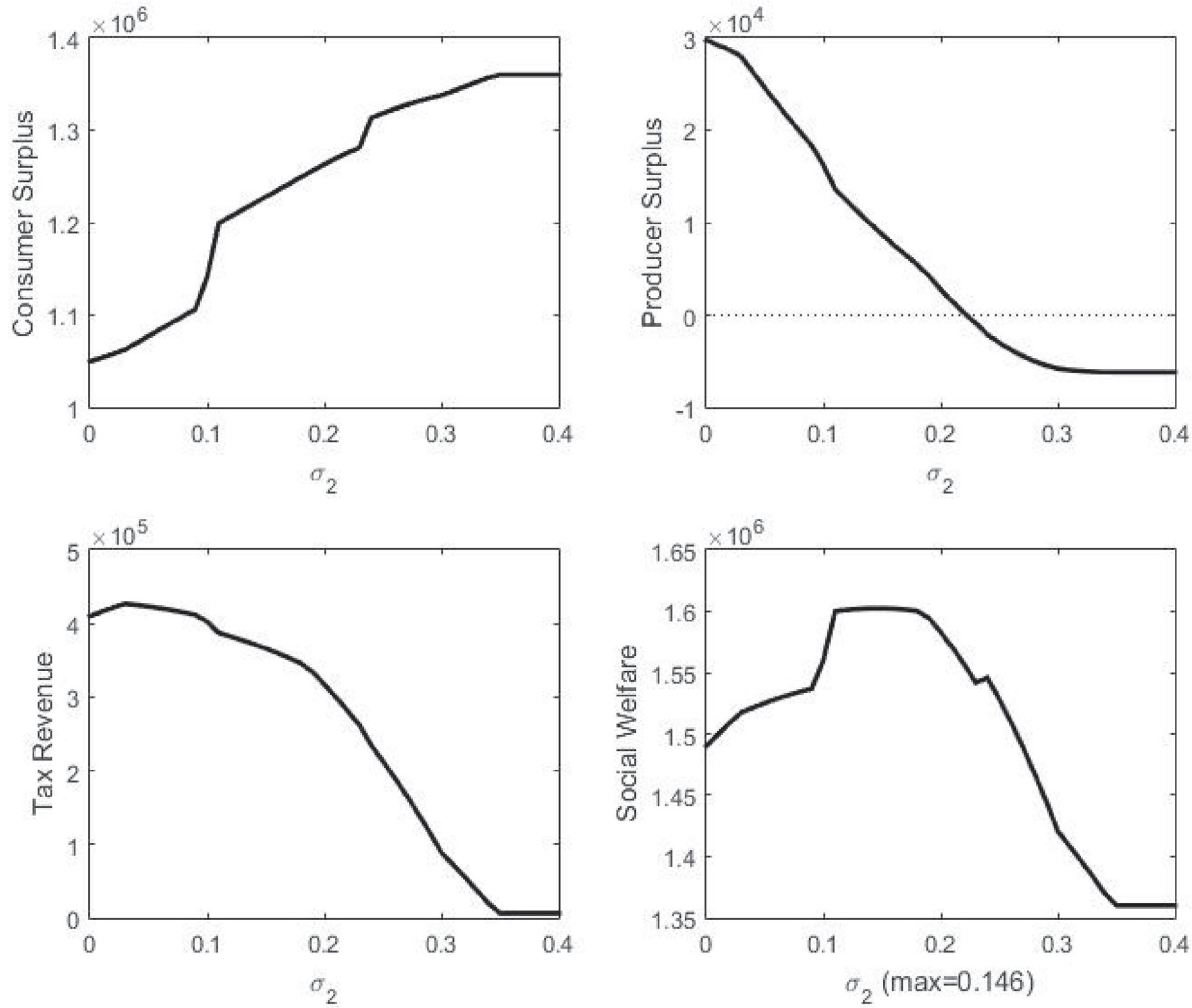
We now perform the third exercise concerning welfare-based pairwise casino competition. Given the alternative tax instrument, the welfare-based casino competition in terms of the wagering tax is $(\sigma_1^{***}, \sigma_2^{***}) = (0.043, 0.033)$, whereas the welfare-based casino competition in terms of the GST surcharge on gambling is $(s_1^{***}, s_2^{***}) = (0.021, 0.012)$. Compared with the pre-existing casino taxes (i.e., $(\sigma_1, \sigma_2) = (0.19, 0.2)$ and $(s_1, s_2) = (0.8, 1.36)$), both the optimal wagering taxes and GST surcharges on gambling are lower due to the intense cross-border casino competition. Moreover, in order to better compete with the neighboring casino, the welfare-based casino competition always features lower wagering tax rates and surcharges than those where the rival's tax policy is given (i.e., σ_i^{***} is lower than σ_i^* and σ_i^{**}, and s_i^{***} is lower than s_i^* and s_i^{**}).

Our calibration results also show that the casino-related taxes, regardless of the wagering tax or GST surcharge on gambling, are higher in Detroit than in Windsor (i.e., $\sigma_1^{***} > \sigma_2^{***}$ and $s_1^{***} > s_2^{***}$). As stressed above, Detroit has stronger gambling preferences and suffers more serious social disorder costs, while Windsor's casinos are more dependent on cross-border visitors from Detroit. Therefore, Detroit sets higher casino taxes in order to control the social cost of gambling by pushing Windsor's problem gamblers back to their own casino. By contrast, Windsor takes advantage of this to set relatively low casino taxes for enhancing casino and tax revenues. Accordingly, we conclude with the following:

Result 8. (Welfare-Based Pairwise Casino Competition)

(i) *To better compete with the neighboring casino, the welfare-based casino competition always features a lower wagering tax and GST surcharge on gambling than those where the rival's tax policy is given.*
(ii) *Accounting for the rival's tax policy, it is optimal for Detroit to set relatively high casino taxes to control the social cost of gambling by preventing Windsor's problem gamblers from crossing the border; by contrast, it is optimal for Windsor to aggressively set lower casino taxes to enhance casino and tax revenues by pulling in the cross-border visitors, including some problem gamblers from Detroit.*

Finally, one may also be interested in answering the following two questions: How much would Windsor be willing to pay (WTP) Detroit in order for Detroit to ban its casinos? How much would Detroit be willing to accept (WTA) in giving up its casinos? To calculate Windsor's WTP and Detroit's WTA, we set $\varepsilon_{1,P}^* = 0$ (hence, the population of Detroit's cross-border problem gamblers is $(1 - n_1)N_1$) and $\varepsilon_{1,R}^* = (1 - n_1)N_1$ (hence, the population of Detroit's cross-border recreational/regular gamblers is $n_1 N_1$), implying that all potential gamblers



b. Optimal Casino Revenue Tax (σ_2^*): Windsor

Fig. 2. *Continued*

in Detroit N_1 cross the border to gamble in Windsor's casinos. Moreover, we set $\varepsilon^*_{2,P} = (1 - n_2)N_2$ (hence, the population of Windsor's cross-border problem gamblers is 0) and $\varepsilon^*_{2,R} = N_2$ (hence, the population of Windsor's cross-border recreational/regular gamblers is 0), implying that all potential gamblers in Windsor N_2 gamble in their own casino. In addition, the intensive margin of casino consumption (the individual demand for casino services $x_{12,m}$ and $x_{22,m}$, where $m = P$ or $m = R$) can be easily derived from (5). Accordingly, from (10) we can re-derive the aggregate demand of the monopoly casino (Caesars Windsor) as:

$$X_2(p_2) = \frac{(1+t)\gamma_L(N_2 + \gamma N_1)}{p_2\left[1 + (1+s_2)t\right] - \pi} + \left[(1-n_1)N_1 + (1-n_2)N_2\right]\eta_P - (n_1 N_1 + n_2 N_2)\eta_R.$$

In line with the common definition (e.g., Hoffman and Spitzer, 1993), the WTP is defined as the maximum amount that Windsor is willing to pay for obtaining the position of a monopoly in the Detroit-Windsor area. Similarly, the WTA is defined as the minimum amount that Detroit is willing to accept in giving up its casinos. Thus, we calculate the WTP and WTA by comparing the case where Caesars Windsor operates a monopoly in line with the *status quo* case of casino competition, evaluated at the *status quo* price p_2^*. Compared with the *status quo* case of casino competition, if Caesars Windsor obtains the position of a monopoly, the welfare of Windsor will increase by 20%, i.e., $WTP = \Delta W_2 = 319,128$. The WTP is equivalent to the total amount of Windsor's tax revenue TR_2 (the ratio of the WTP to the total tax revenue is $\frac{WTP}{TR_2} = 1.1$). On the other hand, if Detroit bans its casinos, Detroit will lose all the welfare gain, i.e., $WTA = \Delta W_1 = 4,025,289$. Detroit's WTA is about 12 times as high as the amount of Windsor's tax revenue (the ratio of Detroit's WTA to Windsor's tax revenue is $\frac{WTA}{TR_2} = 12.5$). Because Detroit's WTA is much higher than Windsor's WTP, the deal would not be credible. Summarizing, we have:

Result 9. (Windsor's Willingness to Pay and Detroit's Willingness to Accept) *Windsor's willingness to pay Detroit in order for Detroit to ban its casinos is far below Detroit's willingness to accept giving up its casinos, so that such a buy-out deal is not credible.*

5. Further discussions

In this section, we consider four extensions by investigating the role played by the casino externality (social disorder costs and casino income creations), relative disorder cost between problem and regular gamblers, the winning tax, and the exchange rate in the cross-border casino competition, respectively.

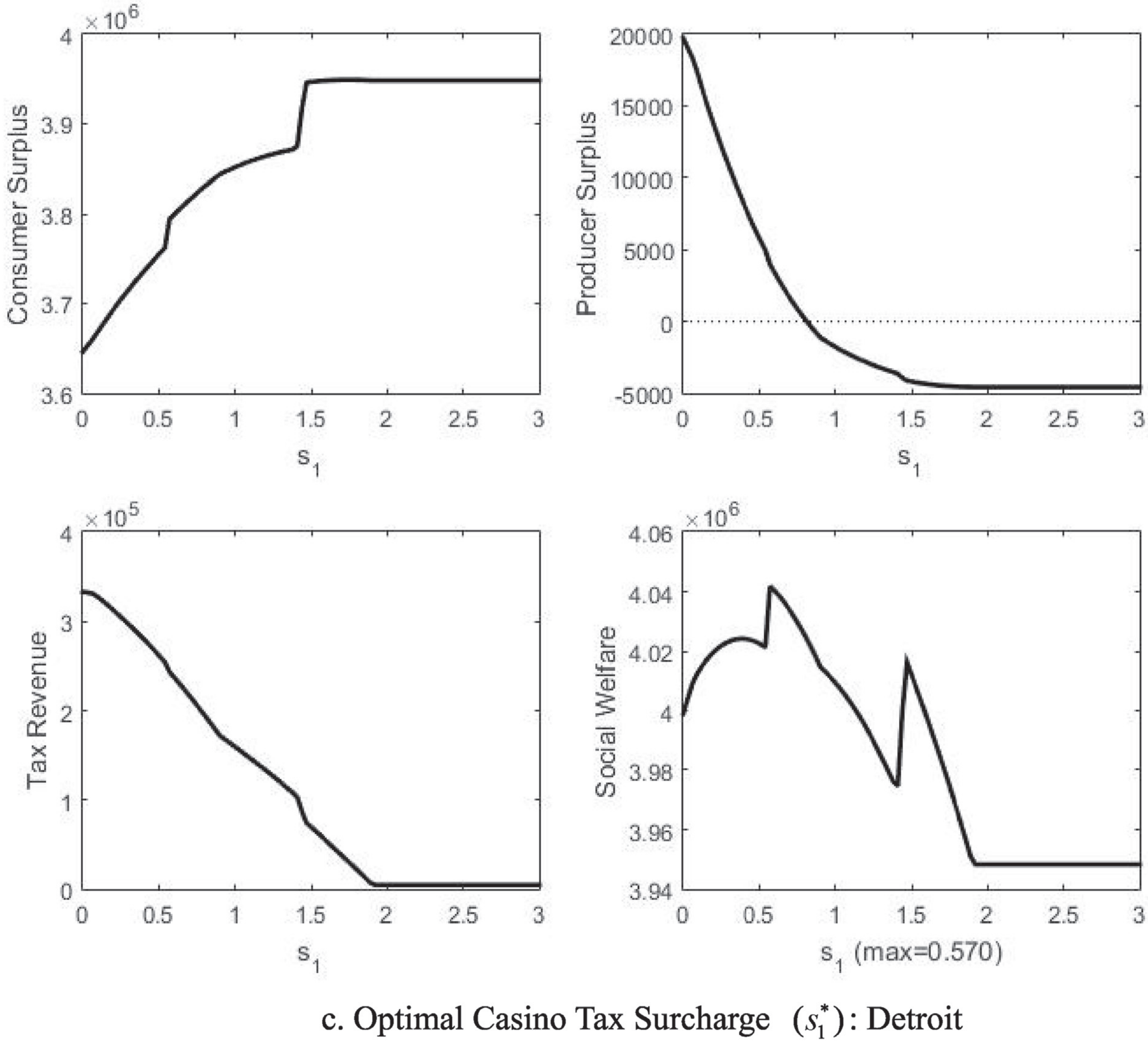


Fig. 2. *Continued*

5.1. Casino externalities: income creation and disorder cost

We now examine how the baseline results are sensitive to casino externalities – disorder cost (negative externality) and income creation (positive externality). While the qualitative findings in Table 2 remain the same, we would like to highlight a few welfare results.

We first consider a high-disorder-cost scenario by doubling the benchmark value ($d_1 = d_2 = 1.5$) of the disorder cost parameter to $d_1 = d_2 = 3$. Figure A1 in the Online Appendix shows that, if $d_1 = d_2 = 3$, the optimal casino wagering tax rate increases to $\sigma_1^* = 0.272$ in Detroit and $\sigma_2^* = 0.235$ in Windsor. The optimal GST surcharge on gambling increases to $s_1^* = 1.462$ in Detroit and $s_2^* = 1.62$ in Windsor. The casino-related taxes all become higher than their pre-existing values in the high-disorder-cost scenario. As for the optimal tax mix, Detroit's optimal taxation is $(\sigma_1^{**}, s_1^{**}) = (0.243, 1.043)$, while Windsor's optimal taxation is $(\sigma_2^{**}, s_2^{**}) = (0.228, 1.41)$. When we consider a higher disorder cost parameter $d_1 = d_2 = 3$, the optimal wagering tax in Detroit σ_1^{**} increases above its pre-existing level, whereas the optimal GST surcharge on gambling in Windsor s_2^{**} increases above its pre-existing level. Compared with the baseline results, for the tax mixes to be optimal, the GST surcharge (the wagering tax) decreases in Detroit (Windsor) in order to rebalance the trade-off between the casino disorder costs (via the consumer's surplus) and casino competitive advantage (the producer's surplus and the government's tax revenues). Moreover. the welfare-based casino competition in terms of the casino revenue tax is $(\sigma_1^{***}, \sigma_2^{***}) = (0.046, 0.028)$, whereas the welfare-based casino competition in terms of the GST surcharge on gambling is $(s_1^{***}, s_2^{***}) = (0.022, 0.012)$. Although the optimal casino-related taxes become higher than those in the baseline, the increments are quite limited because of the intense cross-border casino competition.

We further investigate a more interesting scenario where casino gambling features positive externalities (casino income creations $a_i > 0$), associated with high disorder costs ($d_1 = d_2 = 3$). To consider casino income creations, we need to calculate the multiplier of casino income creation a_i from (20). In the report for AGA, Bazelon et al. (2012) estimate an employment multiplier of 1.92 per casino job. With the median household income I_i, the multiplier of casino income creation a_i can be calculated by: $a_i = \frac{1.92(CE_i \cdot I_i)}{(p_i - \pi)X_i(p_i)}$, where CE_i is the casino employment in City *i*. The average number of the employed workers in Detroit's casino is $CE_1 = 2.657$ (in thousands) and in the counterpart in Windsor is $CE_2 = 2.833$. Accordingly, we obtain $a_1 = 0.414$ for Detroit and $a_2 = 0.437$ for Windsor.

By focusing on the optimal tax mix, Figure A2 in the Online Appendix shows that, given Windsor's existing tax policy, Detroit's optimal tax mix is $(\sigma_1^{**}, s_1^{**}) = (0.264, 0)$, and given Detroit's existing tax

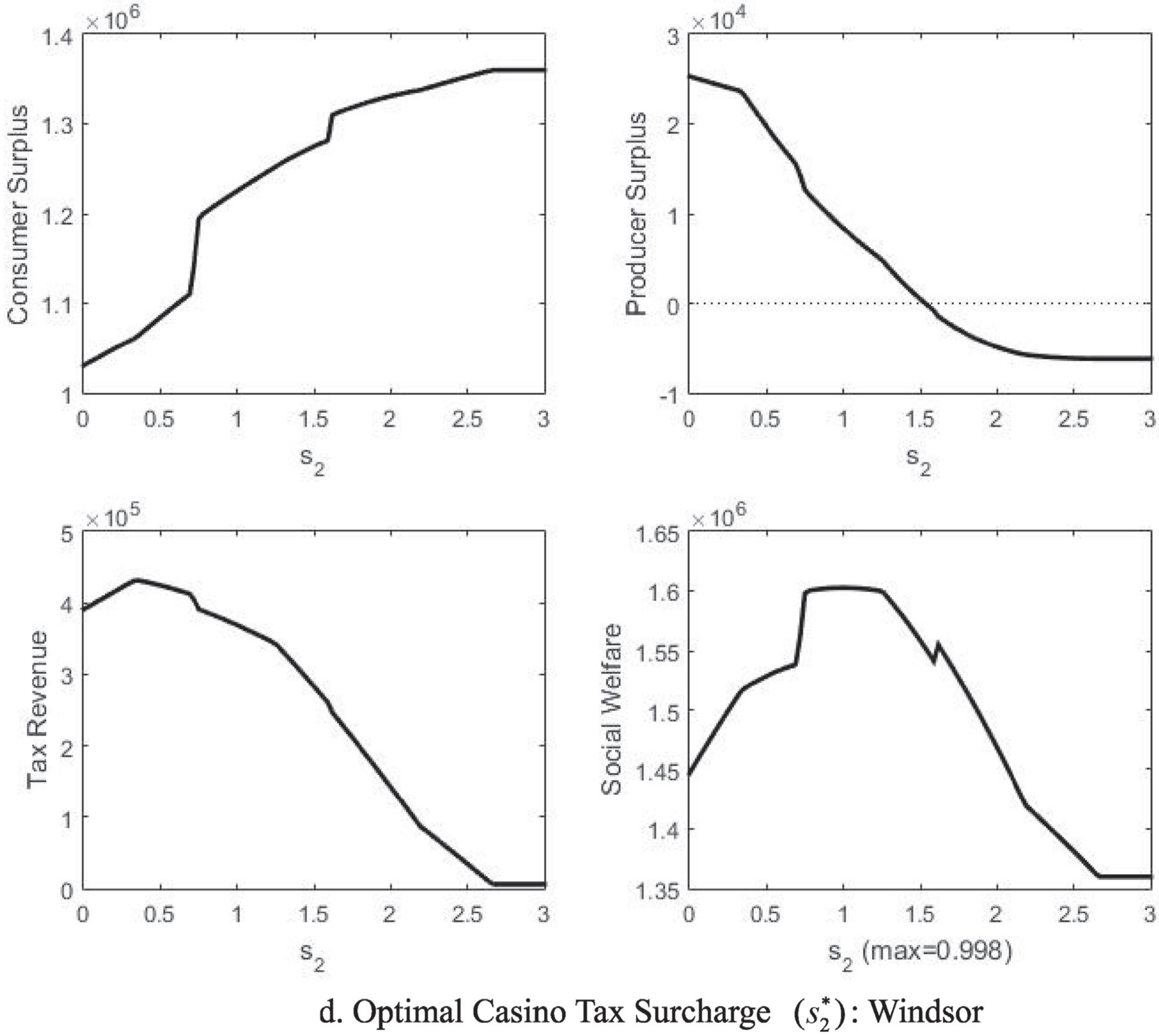


Fig. 2. *Continued*

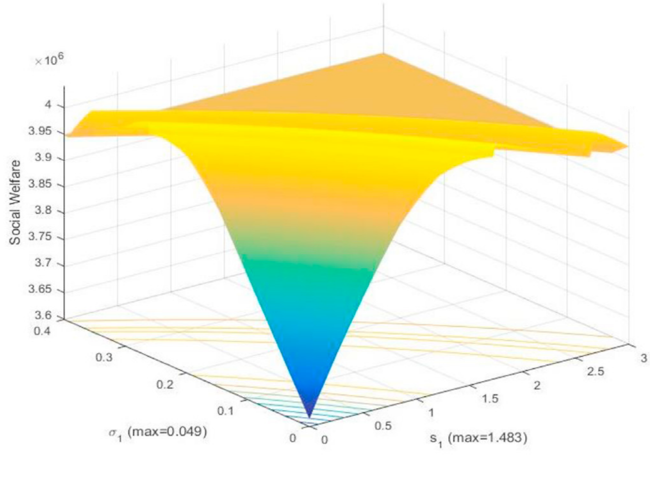
policy $(\sigma_1, s_1) = (0.19, 0.8)$, Windsor's optimal tax mix is $(\sigma_2^{**}, s_2^{**}) = (0.298, 0)$. In either city, *the optimal tax mix is in favor of taxing only the casino wagering tax* by fully exempting the consumers from a GST surcharge on gambling (i.e., a corner solution). Because the demand for gambling, as shown in Subsection 4.2, is more responsive to the wagering tax σ_i, the wagering tax can reduce the casino disorder cost more significantly than a GST surcharge on gambling. By contrast, both cities set the GST surcharge on gambling as low as possible in response to the positive casino externality – income creations. Such an optimal tax shift is more pronounced in Windsor when the income creation is greater (the casino income creation of Windsor is about 40% larger than that of Detroit). Regarding the welfare-based casino competition, the optimal casino-related taxes substantially decrease in this scenario because the existence of casino income creations triggers more intense cross-border competition.

5.2. Relative disorder costs of regular to problem gambling

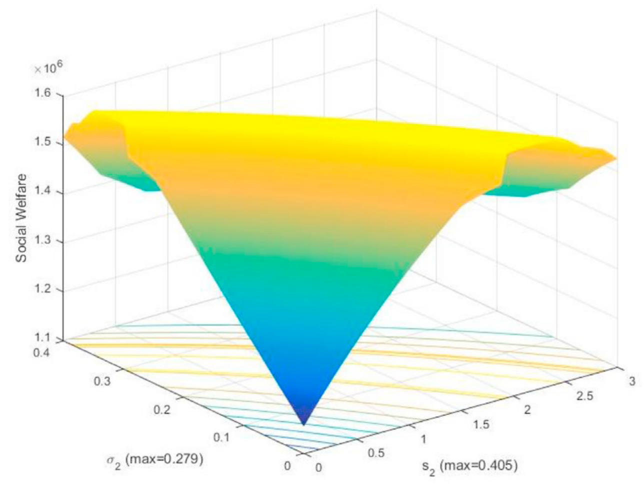
The relative social disorder costs of regular to problem gambling varies greatly. In the benchmark, such a ratio is set to be 1 to 10 ($z = 1/10$). One may inquire into what happens to the optimal taxation if problem gambling, relative to recreational/regular gambling, causes more serious social costs, entailing a lower relative disorder cost of regular to problem gambling (a decrease in z from $1/10$ to $1/50$).

Figure A3 in the Online Appendix shows that, if $z = 1/50$, the optimal policy of the single casino revenue instrument turns out to become lower for either Detroit or Windsor compared to the baseline results. In both cities, the population size is much larger for regular gamblers than for problem gamblers. Thus, when there are less serious social costs stemming from regular gamblers that account for a major portion of the population, both cities tend to set a relatively *low* tax rate on either the casino wager or surcharge to compete with their neighboring cities for more export-based tax revenues. This tendency is more pronounced for Detroit which has a serious gambling problem and a large population size. Thus, *measures of consumer protection that reduce the relative disorder costs of regular gamblers, such as self-limitation systems, indirectly lead to a lower tax rate on casino activities*.

Compared with the baseline results, Figures A3-e and A3-f show that, in the presence of a lower relative disorder cost of regular to problem gambling, the optimal tax mix for Detroit refers to a lower GST surcharge on gambling ($s_1^{**} = 0.276$), associated with a relatively high wagering tax rate ($\sigma_1^{**} = 0.161$) which prevents an excess of social damage caused by problem gamblers. By contrast, Windsor's tax mix involves a decrease in the wagering tax ($\sigma_2^{**} = 0.230$) but a slight increase in the GST surcharge on gambling ($s_2^{**} = 544$) in order to control the cross-border problem gambling from Detroit. Since Detroit has



a. Optimal Casino Tax Mix $(\sigma_1^{**}, s_1^{**})$: Detroit



b. Optimal Casino Tax Mix $(\sigma_2^{**}, s_2^{**})$: Windsor

Fig. 3. a. Optimal Casino Tax Mix $(\sigma_1^{**}, s_1^{**})$: Detroit. b. Optimal Casino Tax Mix $(\sigma_2^{**}, s_2^{**})$: Windsor.

a stronger gambling preference and more severe social disorder costs than Windsor, the tax shifting is more pronounced in Detroit and less pronounced in Windsor. Of particular note is that, if the social disorder cost of regular gambling is lower, the optimal GST surcharges on gambling in both Detroit and Windsor are lower than their pre-existing levels, although they favor different patterns of tax shifting.

5.3. Winning tax

Gambling winnings face distinct tax laws in the two countries. In Canada, gambling winnings are considered to be windfalls. Canadian tax law does not treat income from gambling as taxable income (except for professional gamblers) and does not allow for deductions from gambling losses either. By contrast, in the U.S. gambling winnings are regarded as taxable income and the Internal Revenue Service (IRS) requires certain gambling winnings to be reported on Form W-2G. The winnings are subject to (federal) income tax withholding at the rate of 25% regardless of where the gamblers come from, while gambling losses are also tax deductible (Greenlees, 2008). That is, for Detroit citizens, the winnings regardless of whether they are from Detroit or Windsor casinos have to be taxed, while, for Windsor citizens, only the winnings from Detroit casinos are withheld as taxable income.

To quantify the effect of the winning tax, we need to calculate the probability of a gambler's win, and accordingly, the winning tax withholding rate of the U.S. By following Kilby et al. (2005), we assume a simple game: a gambler bets $1 in the game in which this gambler receives $1 when he wins and loses $1 when the house wins. Thus, the gambler's expected value (EV) is

$$EV = \Phi \cdot 1 + (1-\Phi)\cdot(-1) = -(1-\pi) < 0,$$

where Φ is the probability of the gambler's win and $(1-\pi)$ is the casino's house advantage for a $1 bet. For example, in American Roulette, there are two zeroes and 36 non-zero numbers (18 red and 18 black). If a player bets $1 on red, his chance of winning $1 is therefore 18/38 and his chance of losing $1 is 20/38. Thus, the player's expected value $EV = 18/38 \times 1 + 20/38 \times (-1) = -5.26\%$. Therefore, for this $1 bet the house edge is 5.26%. In our model, the wager is x, and we then have:

$$EV = \Phi \cdot x + (1-\Phi)\cdot(-x) = -(1-\pi)\cdot x < 0.$$

or equivalently,

$$x[1 + \Phi - (1-\Phi)] = \pi x. \tag{32}$$

Given that the RTP $\pi = 0.9$, we can thus calculate the probability of the gambler's win as $\Phi = 0.45$.

In the model, $EV = -(1-\pi) < 0$ implies that gamblers on average will lose in the model. Thus, by focusing on an income tax withholding rate of $\tau^{\omega} = 25\%$ for gambling winnings, we assume that there exists a *pseudo* withholding rate ω and rewrite (32) as:

$$x[1 + \Phi(1-\tau^{\omega}) - (1-\Phi)] = (1-\omega)\pi x.$$

Given $\tau^{\omega} = 25\%$, we can calculate the pseudo withholding rate as $\omega = 12.5\%$. Maremony and Berzon (2013) estimate that of the top 10% of bettors – those placing the largest number of total wagers over a two-year period – about $90\% - 95\%$ ended up losing money. As for regular gamblers, just 11% of players ended up in the black over the full period, and most of those pocketed less than $150. Moreover, gambling winnings are subject to withholding tax only when the winnings exceed a certain amount. For example, regular gambling withholding requires the payer to withhold 25% of the gambling winnings for income tax only if the net prize value (the amount of winnings minus the amount wagered) is greater than $5000.[22] Obviously, the "effective winning withholding tax" should not be as high as $\omega = 12.5\%$. In line with Maremony and Berzon (2013), we assume that only 5% of gamblers win and are subject to the winning withholding, and thus compute *the effective winning withholding rate* as $\omega' = 0.125 \times 5\% = 0.625\%$. For simplicity, we further assume that the winnings of Windsor's gamblers from the Detroit casino are also subject to the same withholding tax rate.

Table A3 in the Online Appendix shows the effects of the winning tax. Similar to a rise in Detroit's GST surcharge on gambling s_1, imposing a winning tax ω' increases the price elasticity of demand for Detroit's casino, but decreases the demand elasticity for Windsor's casino. Thus, the equilibrium price in Detroit p_1^* falls and the equilibrium price in Windsor p_2^* rises, resulting in a higher relative price of Windsor p^*. A higher relative price of Windsor p^*, together with the winning taxation in the U.S., decreases all individual gambling demand ($x_{11,m}^*, x_{12,m}^*, x_{21,m}^*$, and $x_{22,m}^*$) in both casinos. As for Detroit's citizens, the winnings from either the Detroit or Windsor casino have to be reported as taxable income. Thus, the higher relative price of

[22] The winning withholding tax rate is complicated and differs across casino games. For instance, the threshold is $1200 for slot machine winnings before the casino is required to withhold the tax for the IRS. See Charitable Gaming (website: http://www.michigan.gov/cg/0,4547,7-111-34357-287539–,00.html) and Greenlees (2008) for more details.

Windsor p^* discourages Detroit's citizens from cross-border gambling (a lower μ_1^{CB}). As for Windsor's citizens, since gambling winnings are tax exempt in Canada, Detroit's withholding tax on winnings sharply reduces the cross-border gambling of Windsor μ_2^{CB}. Both lead to lower export-based tax revenues EBT_1^* and EBT_2^*. Nonetheless, because the cross-border gambling of Windsor is more pronounced than that of Detroit, the aggregate demand for Detroit's casino X_1^* decreases, while the aggregate demand for Windsor's casino X_2^* increases. As a result, casino revenue AGR_1^* and tax revenue TR_1^* in Detroit fall, but in Windsor they rise. These outcomes are accompanied by lower disorder costs in Detroit but higher disorder costs in Windsor.

In practice, some gamblers underreport their winnings and hence the proportion of gamblers subject to the winning withholding becomes lower. This implies that the effective winning withholding rate is lower than 0.625%. It is straightforward to see that the quantitative changes in the extended model with winning taxation will turn out to be smaller, while the importance of the winning tax will be dampened with tax evasion.

5.4. Exchange rate

According to the OLG records, between the years 2009 and 2014, revenues for the Windsor casino struggled. In 2015, revenues, however, started to climb and the average number of customers per day has also been going up. This turnaround seems to coincide with the CAD's depreciation (Potvin, 2015). Jhoan Baluyot, spokeswoman for Caesars Windsor confirmed that currency exchange is in their favor; the depreciation of the CAD encourages U.S. tourists to travel across the border for their holidays. This subsection examines the effects of the exchange rate swings.

We define ζ as the change in the exchange rate: a positive (negative) ζ implies a depreciation (appreciation) in the CAD. A change in the CAD affects casino consumption only when people cross the border to gamble. Thus, we re-derive the cross-border casino consumption per gambler as follows:

$$x_{12,P} = \frac{\gamma_H(1+t)}{(1-\zeta)\{p_2(1+(1+s_2)t)-\pi\}} + \eta_P,$$

$$x_{12,R} = \frac{\gamma_H(1+t)}{(1-\zeta)p_2\{(1+(1+s_2)t)-\pi\}} - \eta_R,$$

$$x_{21,P} = \frac{\gamma_L(1+t)}{(1+\zeta)\{p_1(1+(1+s_1)t)-\pi\}} + \eta_P,$$

$$x_{21,R} = \frac{\gamma_L(1+t)}{(1+\zeta)\{p_1(1+(1+s_1)t)-\pi\}} - \eta_R.$$

The effects of the exchange rate are shown in Table A4 in the Online Appendix. Intuitively, a depreciation in the CAD (a positive ζ) increases the price elasticity of demand for Detroit's casinos, but decreases the demand elasticity for Windsor's casino. Thus, the equilibrium price in Detroit p_1^* decreases and the equilibrium price in Windsor p_2^* increases, resulting in a higher relative price of Windsor p^*. A lower p_1^* increases the casino consumption per gambler when Detroit's gamblers visit their own casinos (a higher $x_{11,m}^*$), while a higher p_2^* decreases the casino consumption per gambler when Windsor's gamblers visit their own casino (a lower $x_{22,m}^*$) where $m = P$ (problem gamblers) or $m = R$ (recreational gamblers). Moreover, the depreciation in the CAD attracts more of Detroit's people to cross the border to gamble (a larger μ_1^{CB}) with more consumption per gambler (an increase in $x_{12,m}^*$), but discourages Windsor's people from crossing the border to gamble (a smaller μ_2^{CB}) with less consumption per gambler (a decrease in $x_{21,m}^*$). Of particular note, in response to a 5% depreciation in the CAD, the problem gamblers in Detroit start to cross the border to gamble in the Windsor casino. As a result, the aggregate demand for Detroit's casino (X_1^*) falls whereas the aggregate demand for Windsor's casino (X_2^*) rises. While the higher purchasing power of the USD favors Windsor, increasing Windsor's casino revenues (AGR_2^*), and tax revenues (EBT_2^* and TR_2^*), it harms Detroit, lowering its casino revenues (AGR_1^*) and tax revenues (EBT_1^* and TR_1^*). *The increase in the casino and tax revenues explains the latest turnaround of Windsor's casinos.* The social disorder costs, however, become lower in Detroit but higher in Windsor.

6. Concluding remarks

We have developed a framework of cross-border casino competition and conducted welfare analyses for various scenarios. We have verified that the presence of cross-border casino gambling provides an outside option to gamblers, leading to an elastic aggregate demand for casino services despite the addictive nature of gambling. We have shown in a calibrated economy that 1) cross-border competition in Detroit-Windsor induces both cities to lower casino taxes and 2) that the optimal tax mix features a shift away from casino revenue to a good and service tax surcharge on gambling in Detroit but a reversed shift in Windsor. We have also found a casino buy-out deal for Windsor to pay Detroit to ban its casinos to not be credible.

Along the lines of our analysis, a natural extension is to apply our framework to studying cross-border casino competition in other international or interstate cases. Moreover, it is interesting to investigate whether the market structure ranging from monopolistic competition to monopoly may affect casino tax designs. Furthermore, it is also intriguing to conduct welfare analysis on quantity rather than price competition in the domain of the number of tables/slot machines or hotel rooms. Finally, one may examine whether online casino gaming with a broader customer base geographically may influence physical cross-border casino competition and the policy design.

To conclude, we highlight, as a generalization for policy design, that jurisdictions with stronger preferences for gambling and higher social disorder costs should set relatively high casino taxes to control the social cost of gambling by preventing problem gamblers. For jurisdictions with weaker preferences for gambling and lower social disorder costs, it is optimal to aggressively set lower taxes to revenues and income creation by pulling in cross-border visitor.

Author statement

The authors, Juin-Jen Chang, Ingo Fiedler, Ching-Chong Lai and Ping Wang, of the submitted paper, "Cross-Border Casino Competition, Externalities and Optimal Tax Policy: A Unified Theory with Quantitative Analysis," to the *Regional Science and Urban Economics*, declare that the paper has not been published previously and that we bear no financial or personal relationships with other people or organizations that could inappropriately influence our work.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.regsciurbeco.2021.103653.

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