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A TALE OF TWO CITIES:
CROSS-BORDER CASINO COMPETITION BETWEEN DETROIT AND WINDSOR

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ABSTRACT

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Keywords: Cross-Border Casino Competition, Social-Disorder and Income-Creation Externalities, Optimal Tax Policy.

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1 Introduction

Over the past two decades, casino gaming in North America has grown sharply. While casino gaming revenues in the U.S. increased by 233% from \$11.2 billion in 1993 to \$37.3 billion in 2012, such revenues in Canada increased by 135% from \$6.4 billion in 1995 to \$15.1 billion in 2010-2011.[1] Today in the U.S., there are 508 commercial casinos in 15 states, while in Canada, there are 71 casinos in 8 of the 10 provinces. An interesting observation is that many casinos were built along various borders across states (most noticeably along the California-Nevada border; also, the Atlantic City-Philadelphia casino market along the New Jersey-Pennsylvania border and the riverboat gambling in Quad Cities along the Illinois-Iowa border) as well as across countries (such as in Detroit, the U.S. and Windsor, Canada; Bellingham, the U.S. and British Columbia, Canada; and Eilat, Israel and Taba, Egypt). Despite this new development, a systematic study of such *cross-border casino competition* and its welfare implications for casino regulatory policies remains completely unexplored.

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 – for example, casinos in Windsor, Canada, are directed at the Detroit market (Deloitte-Touche, 1995).[2] However, the monopoly situation can turn into a highly competitive one, when casinos are positioned for new competition from the other side of the border (Felsenstein and Freeman, 2002). For example, since May 1994 when Windsor won a bid to operate a casino, Casino Windsor has attracted approximately 80% of its visitors to the casino from the U.S. and has dramatically increased the revenues of stores, restaurants and hotels in Windsor. In the 1996 referendum, Michigan approved plans to build three casinos in downtown Detroit, which finally emerged in 2000 and have since then raised the stakes in the city's cross-border competition with Windsor's casinos. Once 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.[3] While bordering casinos generate demand

[1] The booming casino industry generated \$8.6 billion in tax revenues for U.S. states/local governments in 2012 and around \$13.5 billion in revenues for Canada where casinos are government-run.

[2] There are many other cases: while the Nevada casinos (outside of Las Vegas) target the large population concentrations of Northern California (Eadington, 1995), the riverboats of Northest Indiana feed off the Chicago market (Przybylski and Littlepage, 1997). Similarly, the Macau casinos service the China and Hong Kong markets (Hobson, 1995).

[3] 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 Goodman, 1995). Grinols and Mustard (2001) find that about 0.77% of the U.S. sample could be classified as compulsive gamblers. The comparable figure in Canada is about 0.4%. Goodman (1995) estimates that each problem gambler costs the government and the private economy \$13,200 a year. Similarly, Thompson, Gazel, and Rickman (1995) impute the associated social costs

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 (hereafter referred to as 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.

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 pricing and 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 tax surcharge on gamblers? How would the fiscal competition outcome in turn affect cross-border casino competition?

To address these questions, 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 aggregate 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 tax surcharge on gamblers) to achieve the highest local welfare. In other words, we analyze cross-border casino competition for both 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 income creation and the "export" of external disorder costs. Finally, we provide the first attempt to conduct positive and normative analyses quantitatively by calibrating the theoretical model to fit the Detroit-Windsor data. It is an interesting case not only because of the relentless competition over one of the busiest commercial borders between the U.S. and Canada with cross-border gambling, but also because of some drastic *counterfactuals* of interest to test.[4] These counterfactuals could have not been examined empirically under limited data that lacked a good measure of casino pricing and a panel to account for unobserved individual heterogeneities. Moreover, we are able to pin down *city-specific optimal*

as ranging between $12,000 and $50,000 per problem gambler.

[4]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.

casino taxation that is valuable to policymakers.

More specifically, 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. Upon characterizing the theoretical model, we calibrate the model to fit the border casino competition between Detroit and Windsor. We perform two interesting counterfactual analyses, quantifying how increased commuting costs due to 911 and decreased population size in Detroit affect cross-border casino competition. We further assess quantitatively 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 tax surcharge. 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 tax surcharge on gamblers), 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. Second, a higher wagering tax is more effective in reducing the casino disorder cost than a casino tax surcharge. That is, it exhibits *nonequivalence* in the tax burden between the casino revenue tax and the casino tax surcharge. 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 would decrease, but each gambler would consume 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 and income creation. 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, income creation, 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 casino tax surcharge, the government's tax competition tends to make the cross-border casino competition *more intense* regardless of the instruments of the casino tax.

Moreover, our quantitative welfare analysis 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. When the disorder costs in both cities rise by 50% from the benchmark values, both cities should impose higher tax rates compared to the benchmark case. However, in Detroit with stronger gambling preferences and higher disorder costs, each tax is raised *above* the pre-existing level, whereas in Windsor it is still better to lower the respective taxes below the pre-existing rates. 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 both cities have favorable tax mixes *toward the casino revenue tax*, which may serve to explain why the casino wagering tax is most commonly observed. However, such an optimal shift from the tax surcharge to the casino revenue tax is more pronounced in Windsor with weaker preferences toward gambling and lower social disorder costs. Third, we perform 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 to *lower* casino revenue tax rates and tax surcharges compared to those where the rival's tax policy is given (i.e., the optimal policy of a single casino tax obtained above). When the disorder costs of gambling are less severe, it is optimal for Detroit to aggressively set lower casino taxes in order to pull in the cross-border visitors via attracting some problem gamblers from Windsor. When the disorder costs of gambling become sufficiently severe, Detroit has to raise its casino taxes by preventing Windsor's problem gamblers from crossing the border.

Furthermore, our model-based quantitative exercises allow us to conduct counterfactual analysis, in particular, two drastic changes in the commuting cost and the Detroit potential gambling population. First, we find that had the commuting cost been restored to the pre-911 level, it need not have favored Windsor: while Windsor's producer's surplus and tax revenues would have increased, its consumer's surplus and welfare would have fallen as a result of more intense cross-border gambling. Second, had Detroit maintained its population at the higher level as in 2000, Windsor would have enjoyed a larger producer's surplus and tax revenues, but its consumer's surplus would have fallen due to more intense cross-border gambling, thus leading to only a modest welfare gain.

Generally speaking, 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. The theoretical approach developed in this paper can be readily applied to other broader issues inclusive of (i) tourism competition with negative congestion externalities accompanied by positive income creation, (ii) spatial competition by sellers to attract customers from different locations with traffic and queuing externalities, and (iii) fiscal competition for attracting manufacturing firms in the presence of negative pollution externalities and positive job creation, to name but a few. Quantitatively, our welfare and counterfactual analyses provide policy implications to the casino policymakers of the bordering cities and offer new insights into the sparse economic literature on casino gambling. To date, efforts to consider optimal gaming 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 as advocated by Anderson (2013). Regarding the counterfactual analysis, Walker (2013) has stressed that when evaluating the social costs and benefits associated with gambling behavior, it is important to consider a counterfactual scenario, although measuring such social costs and benefits in the counterfactual is empirically difficult. Our model-based quantitative approach offers such assessment in a systematic manner, which is valuable as well for other broader studies with limited data.

Related Literature

In the economics literature, there is a lack of a comprehensive theoretical analysis of casinos in both positive and normative aspects. There are only rare exceptions. In Sauer (2001), a political competition model is constructed to study how gambling restrictions lower the level of gambling. By highlighting three external effects of casino-style gambling (the casino income creation, social disorder costs, and cross-border gambling), Chang, Lai and Wang (2010) study the entry and tax regulation of oligopolistically competitive privately-run casinos and government-run casinos in a jurisdiction.

Their attention is exclusively directed at the optimal casino regulation and its welfare effect. The study of Felsenstein and Freeman (2002) is most closely related to the present study. By applying the concept of the prisoner's dilemma, they conduct an *empirical* analysis on the outcomes of casino competition between two casinos (Taba and Eilat) located along the Egyptian-Israeli border. A similar hypothesis is discussed in Thompson and Gazel (1997) and involves the case of casinos along the border of greater Chicago and Northern Indiana. Nonetheless, none of these previous papers theoretically examine cross-border casino competition, which is the primary focus of our paper.

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), Bellingham (U.S.) vs. British Columbia (Canada), 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 $\{p_1, p_2\}$ of the two bordering casinos, 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.

2.1 Gamblers' Optimization

We focus on the behavior of the gambling population. 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.

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 will discuss the welfare effects of the negative externalities in the next section.

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. We can thus define:

$$\begin{aligned} x_{i,m}(\theta_i) &= \theta_i x_{ii,m} + (1-\theta_i) x_{ij,m}, \\ q_{i,m}(\theta_i) &= \theta_i q_{ii,m} + (1-\theta_i) q_{ij,m}, \\ \varrho_{i,m}(\theta_i) &= \theta_i \, \varrho_{ii,m} + (1-\theta_i) \varrho_{ij,m}. \end{aligned}$$

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

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

where t is the consumption tax rate imposed on the composite good and s_j is a tax surcharge imposed on the consumption of the casino service. Concerning casino pricing, p_j is the price per dollar gambled (including the gambling-related products and services) and π is the return to player (RTP) percentage.

We note that, in most forms of gambling, the price of the gamble is not easily observed by consumers. Yet, casinos usually reveal the RTP percentage 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 gaming (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 or payout ratio 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. Moreover, to focus on gambling-related taxes, we assume that the consumption tax rate t on the composite good is also identical in both cities.

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 now are 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:

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

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

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

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

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

$$\varpi_{i\tau,m}(\theta_i,\varepsilon_{i,m}) = \gamma_\tau \ln\left(x_{i,m}(\theta_i) - \eta_m\right) + \frac{\left[I_i + \pi x_{i,m}(\theta_i) - \varrho_i(\theta_i) - \left[1+(1+s_j)\,t\right]p_j x_{i,m}(\theta_i)\right]}{1+t} - DC_i + IC_i - \theta_i\varepsilon_{i,m}.$$

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 1 residents' demands for the casino and composite goods, respectively, as follows:

$$\begin{aligned} x_{11,P} &= \frac{\gamma_H(1+t)}{p_1[1+(1+s_1)t]-\pi}+\eta_P,\ x_{12,P}=\frac{\gamma_H(1+t)}{p_2[1+(1+s_2)t]-\pi}+\eta_P, \\ x_{11,R} &= \frac{\gamma_H(1+t)}{p_1[1+(1+s_1)t]-\pi}-\eta_R,\ x_{12,R}=\frac{\gamma_H(1+t)}{p_2[1+(1+s_2)t]-\pi}-\eta_R, \end{aligned} \tag{5}$$

$$\begin{aligned} q_{11,P} &= \frac{I_1\text{-}\gamma_H(1+t)\text{-}\eta_P\{p_1[1+(1+s_1)t]\text{-}\pi\}}{1+t},\ q_{12,P}=\frac{I_1\text{-}\gamma_H(1+t)\text{-}\eta_P\{p_2[1+(1+s_2)t]\text{-}\pi\}\text{-}T}{1+t}, \\ q_{11,R} &= \frac{I_1\text{-}\gamma_H(1+t)+\eta_R\{p_1[1+(1+s_1)t]\text{-}\pi\}}{1+t},\ q_{12,R}=\frac{I_1\text{-}\gamma_H(1+t)+\eta_R\{p_2[1+(1+s_2)t]\text{-}\pi\}\text{-}T}{1+t}. \end{aligned} \tag{6}$$

By analogy, City 2 residents' demands for the casino and composite goods are:

$$\begin{aligned} x_{22,P} &= \frac{\gamma_L(1+t)}{p_2[1+(1+s_2)t]-\pi}+\eta_P,\ x_{21,P}=\frac{\gamma_L(1+t)}{p_1[1+(1+s_1)t]-\pi}+\eta_P, \\ x_{22,R} &= \frac{\gamma_L(1+t)}{p_2[1+(1+s_2)t]-\pi}-\eta_R,\ x_{21,R}=\frac{\gamma_L(1+t)}{p_1[1+(1+s_1)t]-\pi}-\eta_R, \end{aligned} \tag{7}$$

$$\begin{aligned} q_{22,P} &= \frac{I_2\text{-}\gamma_L(1+t)\text{-}\eta_P\{p_2[1+(1+s_2)t]\text{-}\pi\}}{1+t},\ q_{21,P}=\frac{I_2\text{-}\gamma_L(1+t)\text{-}\eta_P\{p_1[1+(1+s_1)t]\text{-}\pi\}\text{-}T}{1+t}, \\ q_{21,R} &= \frac{I_2\text{-}\gamma_L(1+t)+\eta_R\{p_1[1+(1+s_1)t]\text{-}\pi\}\text{-}T}{1+t},\ q_{22,R}=\frac{I_2\text{-}\gamma_L(1+t)+\eta_R\{p_2[1+(1+s_2)t]\text{-}\pi\}}{1+t}. \end{aligned} \tag{8}$$

From (5) and (7), we can derive the demand elasticity of problem and recreational gamblers, respectively. Specifically, we obtain the demand elasticity for own ($e_{ii,m}$) and cross-border casino gambling ($e_{ij,m}$)

$$e_{ii,P}=-\frac{p_i\partial x_{ii,P}}{x_{ii,P}\partial p_i}=\frac{p_i[1+(1+s_i)t]}{p_i[1+(1+s_i)t]\text{-}\pi}(1\text{-}\frac{\eta_P}{x_{ii,P}}),\ e_{ij,P}=-\frac{p_j\partial x_{ij,P}}{x_{ij,P}\partial p_j}=\frac{p_j[1+(1+s_j)t]}{p_j[1+(1+s_j)t]\text{-}\pi}(1\text{-}\frac{\eta_P}{x_{ij,P}}) \tag{9}$$

for problem gamblers ($m=P$) and

$$e_{ii,R}=-\frac{p_i\partial x_{ii,R}}{x_{ii,R}\partial p_i}=\frac{p_i[1+(1+s_i)t]}{p_i[1+(1+s_i)t]\text{-}\pi}(1+\frac{\eta_R}{x_{ii,R}}),\ e_{ij,R}=-\frac{p_j\partial x_{ij,R}}{x_{ij,R}\partial p_j}=\frac{p_j[1+(1+s_j)t]}{p_j[1+(1+s_j)t]\text{-}\pi}(1+\frac{\eta_R}{x_{ij,R}}) \tag{10}$$

for recreational gamblers ($m = R$).

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 constant payout ratio* π. *It is greater than one for recreational gamblers and less than one for problem gamblers, if* η_P *is sufficiently large such that* $\eta_P > \max\left\{\frac{\pi x_{ii,P}}{p_i[1+(1+s_i)t]}, \frac{\pi x_{ij,P}}{p_j[1+(1+s_j)t]}\right\}$.

Proof: All proofs are relegated to the Appendix.

Anderson (2013) and Philander (2014) argued that the overall demand for casino gambling comprises two quite different groups of gamblers, each with distinct demand characteristics. 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 their argument.

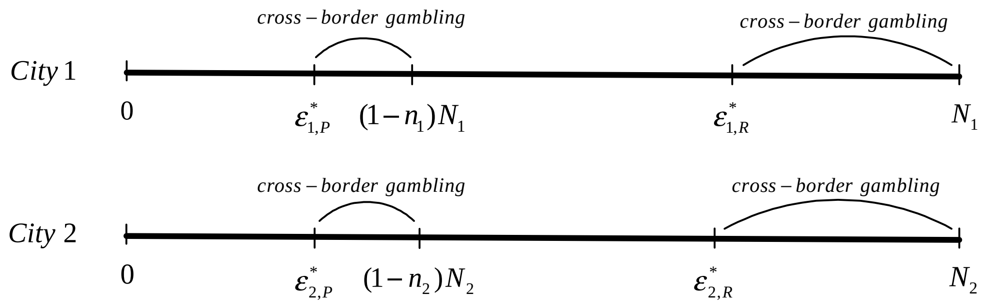
We now solve the second stage problem which determines the gambling location. By focusing on City 1, substituting (5)-(8) into the resident's utility function (1) yields the respective values associated with gambling locations, $v_{11,m}(\varepsilon_{i,m})$ and $v_{12,m}(\varepsilon_{i,m})$ where $m = P$ or $m = R$. Thus, $\varepsilon^*_{1,m}$ solves $v_{11,m}(\varepsilon^*_{1,m}) = v_{12,m}(\varepsilon^*_{1,m})$, implying:

$$\begin{aligned}
\varepsilon^*_{1,P} &= \gamma_H \ln(\frac{x_{11,P} - \eta_P}{x_{12,P} - \eta_P}) + q_{11,P} - q_{12,P} \\
&= \gamma_H \ln(\frac{p_2\,[1 + (1 + s_2)\,t] - \pi}{p_1\,[1 + (1 + s_1)\,t] - \pi}) + \frac{\{p_2\,[1 + (1 + s_2)\,t] - p_1\,[1 + (1 + s_1)\,t]\}\,\eta_P + T}{1 + t}, \quad (11) \\
\varepsilon^*_{1,R} &= \gamma_H \ln(\frac{x_{11,R} + \eta_R}{x_{12,R} + \eta_R}) + q_{11,R} - q_{12,R} \\
&= \gamma_H \ln(\frac{p_2\,[1 + (1 + s_2)\,t] - \pi}{p_1\,[1 + (1 + s_1)\,t] - \pi}) + \frac{\{p_1\,[1 + (1 + s_1)\,t] - p_2\,[1 + (1 + s_2)\,t]\}\,\eta_R + T}{1 + t}. \quad (12)
\end{aligned}$$

Similarly, the cutoff in City 2 ($\varepsilon^*_{2,m}$) is:

$$\begin{aligned}
\varepsilon^*_{2,P} &= \gamma_L \ln(\frac{x_{22,P} - \eta_P}{x_{21,P} - \eta_P}) + q_{22,P} - q_{21,P} \\
&= \gamma_L \ln(\frac{p_1\,[1 + (1 + s_1)\,t] - \pi}{p_2\,[1 + (1 + s_2)\,t] - \pi}) + \frac{\{p_1\,[1 + (1 + s_1)\,t] - p_2\,[1 + (1 + s_2)\,t]\}\,\eta_P + T}{1 + t}, \quad (13) \\
\varepsilon^*_{2,R} &= \gamma_L \ln(\frac{x_{22,R} + \eta_R}{x_{21,R} + \eta_R}) + q_{22,R} - q_{21,R} \\
&= \gamma_L \ln(\frac{p_1\,[1 + (1 + s_1)\,t] - \pi}{p_2\,[1 + (1 + s_2)\,t] - \pi}) + \frac{\{p_2\,[1 + (1 + s_2)\,t] - p_1\,[1 + (1 + s_1)\,t]\}\,\eta_R + T}{1 + t}. \quad (14)
\end{aligned}$$

These gambling locations are shown as follows.



From (11)-(14), we can characterize the schedules of the *cross-border gambling intensities*. To do so, we define the proportion of the overall cross-border patrons ($\mu_i^{CB} = \frac{[(1-n_i)N_i - \varepsilon^*_{i,P}] + [N_i - \varepsilon^*_{i,R}]}{N_i}$) as well as the proportion of the cross-border problem patrons ($\mu_{i,P}^{CB} = \frac{(1-n_i)N_i - \varepsilon^*_{i,P}}{(1-n_i)N_i}$) and the proportion of the cross-border recreational patrons ($\mu_{i,R}^{CB} = \frac{N_i - \varepsilon^*_{i,R}}{n_i N_i}$) 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), the overall cross-border gambling intensity schedule (μ_i^{CB}) is upward-sloping in its own price (p_i) and shifts outward in response to a higher casino tax surcharge imposed in its own city (s_i), a lower casino tax surcharge in its rival city (s_j), or a lower commuting cost (T). The cross-border gambling intensities for both problem ($\mu_{i,P}^{CB}$) and recreational patrons ($\mu_{i,R}^{CB}$) are decreasing in the commuting cost (T). While the cross-border gambling intensity for problem gamblers always increases with its own casino price, that for recreational patrons may not.*

Under a reasonable condition $\eta_P > \eta_R$, the cross-border gambling intensities are positively related to their own casino prices. Overall, a higher casino price p_i or tax surcharge s_i encourages city i's own gamblers to engage in cross-border gambling, μ_i^{CB}. 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

To match the reality, the two bordering casinos are assumed to engage in Bertrand price-competition against each other for cross-border gambling. 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), (7), and (11)-(14):

$$\begin{aligned} X_1(p_1) &= \varepsilon_{1,P}^* x_{11,P} + \left(\varepsilon_{1,R}^* - (1-n_1)N_1\right) x_{11,R} + \left((1-n_2)N_2 - \varepsilon_{2,P}^*\right) x_{21,P} + (N_2 - \varepsilon_{2,R}^*) x_{21,R} \\ &= \frac{(1+t)\gamma_L}{p_1\left[1+(1+s_1)t\right]-\pi}\left\{\gamma[\varepsilon_{1,P}^* + \varepsilon_{1,R}^* - (1-n_1)N_1] + (2-n_2)N_2 - (\varepsilon_{2,P}^* + \varepsilon_{2,R}^*)\right\} \\ &\quad + \left[\varepsilon_{1,P}^* + (1-n_2)N_2 - \varepsilon_{2,P}^*\right]\eta_P - \left[\varepsilon_{1,R}^* + N_2 - (1-n_1)N_1 - \varepsilon_{2,R}^*\right]\eta_R, \end{aligned} \tag{15}$$

$$\begin{aligned} X_2(p_2) &= \varepsilon_{2,P}^* x_{22,P} + \left(\varepsilon_{2,R}^* - (1-n_2)N_2\right) x_{22,R} + \left((1-n_1)N_1 - \varepsilon_{1,P}^*\right) x_{12,P} + (N_1 - \varepsilon_{1,R}^*) x_{12,R} \\ &= \frac{(1+t)\gamma_L}{p_2\left[1+(1+s_2)t\right]-\pi}\left\{\varepsilon_{2,P}^* + \varepsilon_{2,R}^* - (1-n_2)N_2 + \gamma[(2-n_1)N_1 - (\varepsilon_{1,P}^* + \varepsilon_{1,R}^*)]\right\} \\ &\quad + \left[\varepsilon_{2,P}^* + (1-n_1)N_1 - \varepsilon_{1,P}^*\right]\eta_P - \left[\varepsilon_{2,R}^* + N_1 - (1-n_2)N_2 - \varepsilon_{1,R}^*\right]\eta_R. \end{aligned} \tag{16}$$

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 $\varepsilon_{2,m}^*$). 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 in Tel Aviv, Jerusalem and Beer Sheva (Felsenstein and Freeman, 2002).

Assume that the casinos in either city have an identical constant marginal cost c, which allows us to focus on casino taxation. In each City i, there is a casino revenue (variable) tax σ_i and a fixed licensing fee f_i (or operating permit). In practice, the revenue tax (i.e., wagering tax) is the most common form of taxation (see Suits, 1979). Faced with the casino taxation, the rival city's casino price p_j $(j \neq i)$ and its own demand schedule X_i given above ((15) and (16), respectively), each casino firm sets its own price p_i to maximize its profit:

$$\max_{p_i} \Pi_i(p_i) = (1-\sigma_i)(p_i - \pi)X_i(p_i) - c_i X_i(p_i) - f_i. \tag{17}$$

The first-order conditions can be derived below:

$$\frac{\partial \Pi_1}{\partial p_1} = (1-\sigma_1)X_1\left[1 - \frac{(1-\sigma_1)(p_1-\pi) - c_1}{(1-\sigma_1)(p_1-\pi)}\cdot E_1\right] = 0, \tag{18}$$

$$\frac{\partial \Pi_2}{\partial p_2} = (1-\sigma_2)X_2\left[1 - \frac{(1-\sigma_2)(p_2-\pi) - c_2}{(1-\sigma_2)(p_2-\pi)}\cdot E_2\right] = 0, \tag{19}$$

where

$$\begin{aligned} E_1 &= -\left(\frac{\partial X_1}{\partial p_1}\frac{p_1}{X_1}\right) = \left[1+(1+s_1)t\right]\cdot\Big\{\frac{2\gamma_L(1+\gamma)(\eta_p - \eta_r)}{p_1\left[1+(1+s_1)t\right]-\pi} + \frac{2(\eta_p^2+\eta_r^2)}{1+t} \\ &\quad + \frac{\gamma_L(1+t)\left\{\gamma[\varepsilon_{1,P}^* + \varepsilon_{1,R}^* - (1-n_1)N_1] + (2-n_2)N_2 - (\varepsilon_{2,P}^* + \varepsilon_{2,R}^*) + \frac{2(\gamma_H^2+\gamma_L^2)}{\gamma_L}\right\}}{\left[p_1\left[1+(1+s_1)t\right]-\pi\right]^2}\Big\}\frac{p_1}{X_1}, \end{aligned}$$

$$E_2 = -(\frac{\partial X_2}{\partial p_2}\frac{p_2}{X_2}) = [1+(1+s_2)\,t]\cdot\{\frac{2\gamma_L(1+\gamma)(\eta_p-\eta_r)}{p_2\,[1+(1+s_2)\,t]-\pi}+\frac{2(\eta_p^2+\eta_r^2)}{1+t}$$
$$+\frac{\gamma_L(1+t)\left\{\varepsilon^*_{2,P}+\varepsilon^*_{2,R}-(1-n_2)N_2+\gamma[(2-n_1)N_1-(\varepsilon^*_{1,P}+\varepsilon^*_{1,R})]+\frac{2(\gamma_H^2+\gamma_L^2)}{\gamma_L}\right\}}{[p_2\,[1+(1+s_2)\,t]-\pi]^2}\}\frac{p_2}{X_2},$$

are the respective price elasticities of aggregate casino demand in the two cities (in absolute value). We can rewrite the first-order condition as $p_i - \pi = \frac{c_i E_i}{(1-\sigma_i)(E_i-1)}$, indicating that $E_i > 1$ must hold true. That is, the presence of cross-border casino gambling provides an outside option to gamblers, thus leading to an *elastic* aggregate demand for casino services.

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 casino-competition outcomes. It is thereby useful to characterize these elasticity schedules which are rewritten as:

$$\begin{aligned} E_1 &= A_1\cdot E_{1,R}+(1-A_1)\cdot E_{1,P} \quad (20)\\ &= A_1\,[B_{1R}e_{11,R}+(1-B_{1R})e_{21,R}+C_{1R}]+(1-A_1)\,[B_{1P}e_{11,P}+(1-B_{1P})e_{21,P}+C_{1P}] \end{aligned}$$

$$\begin{aligned} E_2 &= A_2\cdot E_{2,R}+(1-A_2)\cdot E_{2,P} \quad (21)\\ &= A_2\,[B_{2R}e_{22,R}+(1-B_{2R})e_{12,R}+C_{2R}]+(1-A_2)\,[B_{2P}e_{22,P}+(1-B_{2P})e_{12,P}+C_{2P}] \end{aligned}$$

where $A_1 = \frac{X_{1,R}}{X_1} = \frac{[\varepsilon^*_{1,R}-(1-n_1)N_1]x_{11,R}+(N_2-\varepsilon^*_{2,R})x_{21,R}}{X_1}$, $B_{1R} = \frac{[\varepsilon^*_{1,R}-(1-n_1)N_1]x_{11,R}}{X_{1,R}}$, $B_{1P} = \frac{\varepsilon^*_{1,P}x_{11,P}}{X_{1,P}}$, $C_{1R}=\left[\frac{\gamma_L(\gamma x_{11,R}+x_{21,R})}{p_1[1+(1+s_1)t]-\pi}-\frac{\eta_r(x_{11,R}+x_{21,R})}{(1+t)}\right]\frac{p_1[1+(1+s_1)t]}{X_{1,R}}$, $C_{1P}=\left[\frac{\gamma_L(\gamma x_{11,R}+x_{21,R})}{p_1[1+(1+s_1)t]-\pi}+\frac{\eta_P(x_{11,R}+x_{21,R})}{(1+t)}\right]\frac{p_1[1+(1+s_1)t]}{X_{1,P}}$, $A_2 = \frac{X_{2,R}}{X_2} = \frac{[\varepsilon^*_{2,R}-(1-n_2)N_2]x_{22,R}+(N_1-\varepsilon^*_{1,R})x_{12,R}}{X_2}$, $B_{2R} = \frac{[\varepsilon^*_{2,R}-(1-n_2)N_2]x_{22,R}}{X_{2,R}}$, $B_{2P} = \frac{\varepsilon^*_{2,P}x_{22,P}}{X_{2,P}}$, $C_{2R} = \left[\frac{\gamma_L(x_{22,R}+\gamma x_{12,R})}{p_2[1+(1+s_2)t]-\pi}-\frac{\eta_r(x_{22,R}+x_{12,R})}{(1+t)}\right]\frac{p_2[1+(1+s_2)t]}{X_{2,R}}$, $C_{2P} = \left[\frac{\gamma_L(x_{22,R}+\gamma x_{12,R})}{p_2[1+(1+s_2)t]-\pi}+\frac{\eta_P(x_{22,R}+x_{12,R})}{(1+t)}\right]\frac{p_2[1+(1+s_2)t]}{X_{2,P}}$. 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_{1R}, C_{1P}, C_{2R}, and C_{2P} (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: (Price Elasticity of Overall Casino Demand) *In the presence of casino competition, travel to use gambling services results in a higher price elasticity of demand for casino gambling in each city (in absolute value). Moreover, the price elasticity of aggregate casino demand (E_i)*

(i) *is increasing in the own city's casino price (p_i) or tax surcharge (s_i) and decreasing in the rival city's casino price and tax surcharge, but is independent of the fixed licensing fee (f_i);*

(ii) *decreases with the population of the rival city (N_j, $j \neq i$), while ambiguously responding to the own city's population (N_i);*

Furthermore, a lower commuting cost T raises the price elasticity of aggregate casino demand in the city with a stronger taste for gambling (City 1), but reduces that in the rival city (City 2).

The aggregate demand schedule in each city, given by (15) and (16), depends on both the intensive and extensive margins. Both margins depend negatively on the own casino price and tax surcharge 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 tax surcharge 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 differential 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. 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]

3 Equilibrium

We are now prepared to 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* 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., (18) and (19). 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 Figure 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 ($R2$).

[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.

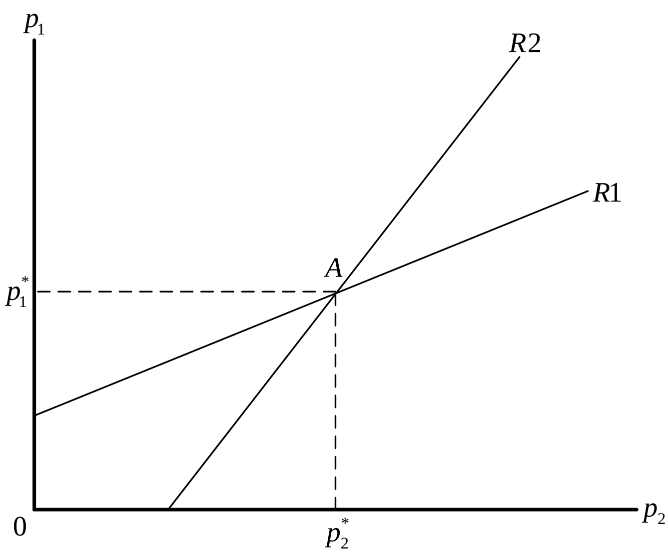


Figure 1. Equilibrium Casino Prices

With a unique equilibrium established, we can now examine the responses of the equilibrium casino prices to changes in the tax policy (σ_i and s_i), the commuting cost (T), and the population size (N_i). These comparative statics results are summarized in the following proposition:

Proposition 4: (Equilibrium Casino Prices) *In the presence of casino competition, increasing the revenue tax rate in either city (σ_1 or σ_2) increases the equilibrium casino prices p_1^* and p_2^*. These equilibrium casino prices, however, have an ambiguous response to the casino tax surcharge s_i, the population size N_i, and the commuting cost T.*

It is clear from (18) and (19) that the revenue tax (i.e., the wagering tax which is the most common form of tax applied to casino games) has a more direct effect on the equilibrium casino prices and, therefore, increasing either σ_1 or σ_2 unambiguously raises both city's casino prices p_1^* and p_2^*. Intuitively, when Detroit raises the 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 Windsor's casino to become less elastic, allowing the Windsor casino to raise its price p_2^*, too. Since a city's casino firm is more responsive to its own price change, the relative price of the Windsor casino p^* ($= p_2^*/p_1^*$) decreases in response. In a way differing from the wagering tax, the casino tax surcharge 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 5 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:

$$\begin{aligned} CS_1 \;=\; & [\gamma_H \ln(x_{11,P}\text{-}\eta_P)\text{-}p_1(1\text{+}(1\text{+}s_1)t)x_{11,P}\text{-}1]\varepsilon_{1,P}^*\text{+}[\gamma_H(\ln x_{12,P}\text{-}\eta_P)\text{-}p_2(1\text{+}(1\text{+}s_2)t)x_{12,P}\text{-}T][(1\text{-}n_1)N_1\text{-}\varepsilon_{1,P}^*] \\ & +[\gamma_H \ln(x_{11,R} + \eta_R) - p_1(1 + (1 + s_1)t)x_{11,R} - 1][\varepsilon_{1,R}^* - (1 - n_1)N_1] \\ & +[\gamma_H(\ln x_{12,R} + \eta_R) - p_2(1 + (1 + s_2)t)x_{12,R} - T](N_1 - \varepsilon_{1,R}^*) - DC_1 + IC_1, \end{aligned} \tag{22}$$

$$\begin{aligned} CS_2 \;=\; & [\gamma_L \ln(x_{22,P}\text{-}\eta_P)\text{-}p_2(1\text{+}(1\text{+}s_2)t)x_{22,P}\text{-}1]\varepsilon_{2,P}^*\text{+}[\gamma_H(\ln x_{21,P}\text{-}\eta_P)\text{-}p_1(1\text{+}(1\text{+}s_1)t)x_{21,P}\text{-}T][(1\text{-}n_2)N_2\text{-}\varepsilon_{2,P}^*] \\ & +[\gamma_L \ln(x_{22,R} + \eta_R) - p_2(1 + (1 + s_2)t)x_{22,R} - 1][\varepsilon_{2,R}^* - (1 - n_2)N_2] \\ & +[\gamma_L(\ln x_{21,R} + \eta_R) - p_1(1 + (1 + s_1)t)x_{21,R} - T](N_2 - \varepsilon_{2,R}^*) - DC_2 + IC_2. \end{aligned} \tag{23}$$

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/pathological gambling behavior, such people cause significant social costs (Walker, 2013, chapter 6). 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:

$$DC_i = d_i(DC_{i,P} + z \cdot DC_{i,R}), \tag{24}$$

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:

$$\begin{aligned} DC_{1,P}&=DC^1_{1,P}+DC^2_{1,P}+DC^3_{1,P}=\{\varepsilon^*_{1,P}x_{11,P}+\phi_c[(1\text{-}n_2)N_2\text{-}\varepsilon^*_{2,P}]x_{21,P}+\phi_a[(1\text{-}n_1)N_1\text{-}\varepsilon^*_{1,P}]x_{12,P}\},\\ DC_{2,P}&=DC^1_{2,P}+DC^2_{2,P}+DC^3_{2,P}=\{\varepsilon^*_{2,P}x_{22,P}+\phi_c[(1\text{-}n_1)N_1\text{-}\varepsilon^*_{1,P}]x_{12,P}+\phi_a[(1\text{-}n_2)N_2\text{-}\varepsilon^*_{2,P}]x_{21,P}\}, \end{aligned} \tag{25}$$

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

$$\begin{aligned} DC_{1,R}&=DC^1_{1,R}+DC^2_{1,R}+DC^3_{1,R}=\{[\varepsilon^*_{1,R}\text{-}(1\text{-}n_1)N_1]x_{11,R}+\phi_c(N_2\text{-}\varepsilon^*_{2,R})x_{21,R}+\phi_a(N_1\text{-}\varepsilon^*_{1,R})x_{12,R}\},\\ DC_{2,R}&=DC^1_{2,R}+DC^2_{2,R}+DC^3_{2,R}=\{[\varepsilon^*_{2,R}\text{-}(1\text{-}n_2)N_2]x_{22,R}+\phi_c(N_1\text{-}\varepsilon^*_{1,R})x_{12,R}+\phi_a(N_2\text{-}\varepsilon^*_{2,R})x_{21,R}\}, \end{aligned} \tag{26}$$

where ϕ_c and ϕ_a are positive but less than one. To measure the social disorder costs caused by both types of gamblers, 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 (2007) and Chang, Lai and Wang (2010), the disorder costs associated with local gamblers should be viewed as much more severe. These disorder costs are captured by $DC^1_{1,m}$ for City 1 and $DC^1_{2,m}$ 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 $DC^2_{1,m}$ for City 1 and $DC^2_{2,m}$ for City 2 with $\phi_c < 1$. 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 $DC^3_{1,m}$ for City 1 and $DC^3_{2,m}$ for City 2 with again $\phi_a < 1$.

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

$$IC_i = a_i \cdot [(p_i - \pi)X_i\,(p_i)], \tag{27}$$

which includes the job creation in the casino industry and in other casino-related industries. Walker and Jackson (2008) and Walker (2013) find that U.S. gambling industries (lotteries and horse and dog racing) cannibalize each other. Thus, the multiplier of income creation is assumed to be less than one, i.e., $0 \leq a_i \leq 1$.

The producer's surplus is simply measured by the casino firm's profits, reported in (17). In addition, the tax revenues of City i stem from the casino tax surcharge, revenue tax, and fixed fees:

$$TR_i = [(1 + s_i)tp_i + \sigma_i(p_i - \pi)]X_i + f_i. \tag{28}$$

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

$$\begin{aligned} EBT_1 &= (1+s_1)tp_1\{[(1-n_2)N_2-\varepsilon_{2,P}]x_{21,P}+(N_2-\varepsilon_{2,R})x_{21,R}\}, \\ EBT_2 &= (1+s_2)tp_2\{[(1-n_1)N_1-\varepsilon_{1,P}]x_{12,P}+(N_1-\varepsilon_{1,R})x_{12,R}\}. \end{aligned} \tag{29}$$

We can then write City i's welfare as:

$$W_i = CS_i + PS_i + TR_i. \tag{30}$$

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 may attempt to export casino services and to capture external sources of tax revenues, as well as to "roll over" negative net externalities (casino disorder costs minus income creation). 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, conduct welfare exercises and perform counterfactual analyses, based on calibrated parametrization. Specifically, we will calibrate the model to fit the cross-border casino competition between Detroit and Windsor – one of the most relentless forms of casino competition whereby some interesting counterfactual analyses may be conducted.

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 $POP_2 = 239.82$ (in thousands). 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

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

Observed		Computed	
N_1	446.652	p_1^*	1.284
N_2	158.283	p_2^*	1.260
$1-n_1$	2.1%	$\varepsilon_{1,P}^*$	9.379
$1-n_2$	2%	$\varepsilon_{2,P}^*$	3.166
POP_1	629.087	$\varepsilon_{1,R}^*$	225.015
POP_2	239.820	$\varepsilon_{2,R}^*$	139.192
I_1	29526	$x_{11,P}^*$	7776.537
I_2	38047	$x_{12,P}^*$	7687.955
σ_1	19%	$x_{22,P}^*$	7616.901
σ_2	20%	$x_{21,P}^*$	7703.748
t	5.5%	$x_{11,R}^*$	3703.537
s_1	0.8	$x_{12,R}^*$	3614.955
s_2	1.361	$x_{22,R}^*$	3543.901
$\tilde{s}_1$	0.0417	$x_{21,R}^*$	3630.748
$\tilde{s}_2$	0.071	X_1^*	940869.704
π	0.9	X_2^*	1307384.101
f_1 / AGR_1	1.25%	$e_{11,P}^*$	0.831
f_2 / AGR_2	1.3%	$e_{12,P}^*$	0.815
CE_1	2.657	$e_{22,P}^*$	0.807
CE_2	2.833	$e_{21,P}^*$	0.822
RR	1.338	$e_{11,R}^*$	1.745
$FCWD$	0.613	$e_{12,R}^*$	1.734
z	1/3	$e_{22,R}^*$	1.734
		$e_{21,R}^*$	1.745
Calibrated			
γ_L	1766.6	c_1	0.307
γ_H	1801.9	c_2	0.282
T	191.67	$d_1 = d_2$	1
η_P	4061	$\phi_c = \phi_a$	0.5
η_R	12	a_1	0.267
p^*	0.981	a_2	0.281

Table 1. Benchmark Parameter Values

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. There are two types of gamblers: problem and recreational gamblers. Williams, Volberg and Stevens (2012) estimate the population of problem gamblers showing that 2.1% of Michigan adults are estimated to manifest a gambling disorder (based on the 2012 U.S. Census Bureau investigation for 7,234,755 persons age 18 and over as well as four Michigan problem gambling prevalence studies in 1997, 1999, 2001, and 2006). This implies that in Detroit the population size of problem gamblers is about $(1-n_1)N_1 = 2.1\% \times 446.652 = 9.379$ (in thousands). Moreover, Cox et al. (2005) estimate that problem gamblers constitute around 2% of the population in Ontario, referring the population of problem gamblers to $(1-n_2)N_2 = 2\% \times 158.283 = 3.166$ in Windsor. 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 tax surcharge rates. The wagering tax is levied based on the casino revenues, i.e., the Adjusted Gross Receipts (AGR, or casino win) of the game. The AGR represent a 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, $AGR_i = (p_i - \pi)X_i$.[7] 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 19% tax on their gross gaming revenues (AGR) and a fixed fee, which is about $\frac{f_1}{AGR_1} = 1.25\%$ of the gross gaming revenues (see the 2013 American Gaming Association (AGA) Survey of Casino Entertainment). In Windsor, casinos are required to pay the government of Ontario a "win contribution" (i.e., gaming tax) of $\sigma_2 = 20\%$ of the gaming revenue, along with a municipal hosting fee which is around $\frac{f_2}{AGR_2} = 1.3\%$ of the gross gaming 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 casino tax surcharge $s_j t$ could result in a 4.4% gaming excise tax, so the effective tax surcharge is $\tilde{s}_1 = \frac{1+(1+s_1)t}{(1+t)} - 1 = \frac{s_1 \cdot t}{1+t} = 0.0417$. In Canada there is a 7.5% harmonized good and service tax imposed on gambling activities and the effective tax surcharge of Windsor is $\tilde{s}_2 = \frac{0.075}{1+5.5\%} = 0.071$. These imply that $s_1 = 0.8$ and $s_2 = 1.361$.

We turn to the commuting cost computation, containing time costs, gasoline costs and tolls and

[7] See Suits (1979) and Combs, Landers and Spry (2013).

[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% to 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.

depending crucially on the average number of trips for cross-border gambling. According to the 2006 AGA 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 given by: $\frac{[(1-n_1)N_1-\varepsilon^*_{1,P}]+(N_1-\varepsilon^*_{1,R})+[(1-n_2)N_2-\varepsilon^*_{2,P}]+(N_2-\varepsilon^*_{2,R})}{N_1+N_2}$. With the average number of casino trips per gambler being 6.1 per year, the average cross-border trips are $ACBT = 6.1 \times \frac{[(1-n_1)N_1-\varepsilon^*_{1,P}]+(N_1-\varepsilon^*_{1,R})+[(1-n_2)N_2-\varepsilon^*_{2,P}]+(N_2-\varepsilon^*_{2,R})}{N_1+N_2}$. 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 hours, the time costs per trip become $\$23.5 \times 3$. Using an average gasoline cost of \$2.43 per hour of driving, we obtain the gasoline cost per trip of $\$2.43 \times 3$.[12] Thus, on average the cross-border commuting cost is given by:

$$T = [3(23.5 + 2.43) + 9.25] \cdot ACBT. \tag{31}$$

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. border controls. 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.[13] As a result, between 60% and 70% of the business of the Windsor casino currently comes from across the border (Duggan, 2009 and Hall, 2009), while U.S. customers still represent a crucial portion of business for Caesars (Battagello, 2014).[14] To capture the downward trend, we set the fraction of the casino consumption of Windsor coming from Detroit ($FCWD$) as:

$$FCWD = \frac{[(1-n_1)N_1-\varepsilon^*_{1,P}]x^*_{12,P}+(N_1-\varepsilon^*_{1,R})x^*_{12,R}}{\varepsilon^*_{2,P}x^*_{22,P}+[\varepsilon^*_{2,R}-(1-n_2)N_2]x^*_{22,R}+[(1-n_1)N_1-\varepsilon^*_{1,P}]x^*_{12,P}+(N_1-\varepsilon^*_{1,R})x^*_{12,R}} = 0.613. \tag{32}$$

[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.

[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.

[14] Caesars Windsor is not exactly certain how much of the local casino's business may have recently come from across the border.

In addition, further insight is needed in order to compute the relative gambling revenue. Notably, there are three casinos (MotorCity Casino, MGM Grand Detroit, and Greektown Casino) in Detroit city, while there is only one casino (Caesars Windsor) 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.[15] 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 1.338. By using (15) and (16), we can thus express the relative AGR of the Windsor casino to the Detroit casino (RR) as follows:

$$\begin{aligned} RR &= \frac{AGR_2^*}{AGR_1^*} = \frac{(p_2^* - \pi)X_2^*}{(p_1^* - \pi)X_1^*} \qquad (33) \\ &= \frac{(p_2^*\text{-}\pi)\{\varepsilon_{2,P}^* x_{22,P}^* + [\varepsilon_{2,R}^*\text{-}(1\text{-}n_2)N_2]x_{22,R}^* + [(1\text{-}n_1)N_1\text{-}\varepsilon_{1,P}^*]x_{12,P}^* + (N_1\text{-}\varepsilon_{1,R}^*)x_{12,R}^*\}}{(p_1^*\text{-}\pi)\{\varepsilon_{1,P}^* x_{11,P}^* + [\varepsilon_{1,R}^*\text{-}(1\text{-}n_1)N_1]x_{11,R}^* + [(1\text{-}n_2)N_2\text{-}\varepsilon_{2,P}^*]x_{21,P}^* + (N_2\text{-}\varepsilon_{2,R}^*)x_{21,R}^*\}} = 1.338. \end{aligned}$$

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

$$1 = \frac{(1-\sigma_1)(p_1^* - \pi) - c_1}{(1-\sigma_1)p_1^*} \cdot E_1^*, \tag{34}$$

$$1 = \frac{(1-\sigma_2)(p_2^* - \pi) - c_2}{(1-\sigma_2)p_2^*} \cdot E_2^*, \tag{35}$$

and accordingly obtain the equilibrium relative price ratio as follows:

$$p^* = \frac{p_2^*}{p_1^*} = \frac{(1 - \frac{1}{E_1^*})(1-\sigma_1)[(1-\sigma_2)\pi + c_2]}{(1 - \frac{1}{E_2^*})(1-\sigma_2)[(1-\sigma_1)\pi + c_1]}, \tag{36}$$

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 $p_1^* = 1.284$ and the *overall* house advantage is $(p_1^* - \pi) = 0.384$.

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 (Anderson, 2013). 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

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

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

$$e^*_{11,P} = -\frac{\partial x^*_{11,P}}{\partial p_1}\frac{p^*_1}{x^*_{11,P}} = 0.83, \tag{37}$$

and the demand elasticity of regular gamblers as

$$e^*_{11,R} = -\frac{\partial x^*_{11,R}}{\partial p_1}\frac{p^*_1}{x^*_{11,R}} = 1.75. \tag{38}$$

These demand elasticities are within a reasonable range of the elasticity estimates on the wagering handle from 0.75 to 1.9 (see Nichols and Tosun, 2013 and Frontier Economics, 2014 for comprehensive surveys) and are also 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 $\varepsilon^*_{2,R}$, (31)-(38) allow us to calibrate $\gamma_H = 1802$, $\gamma_L = 1766.6$, $\eta_p = 4061$, $\eta_r = 12$, $T = 191.67$, $c_1 = 0.307$, $c_2 = 0.282$, and $p^* = 0.981$ (implying $p^*_2 = 1.26$). As a consequence, $\gamma \equiv \frac{\gamma_H}{\gamma_L} = 1.02$ and 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., $T/\{\frac{[((1-n_1)N_1-\varepsilon^*_{1,P})+(N_1-\varepsilon^*_{1,R})]I_1+[((1-n_2)N_2-\varepsilon^*_{2,P})+(N_2-\varepsilon^*_{2,R})]I_2}{[((1-n_1)N_1-\varepsilon^*_{1,P})+(N_1-\varepsilon^*_{1,R})]+[((1-n_2)N_2-\varepsilon^*_{2,P})+(N_2-\varepsilon^*_{2,R})]}\}$) is around 0.63%, which seems very reasonable. Moreover, the equilibrium proportion of the cross-border gamblers for Detroit ($\mu_1^{CB} = \frac{[(1-n_1)N_1-\varepsilon^*_{1,P}]+[N_1-\varepsilon^*_{1,R}]}{N_1} = 49.6\%$) is larger than that for Windsor ($\mu_2^{CB} = \frac{[(1-n_2)N_2-\varepsilon^*_{2,P}]+[N_2-\varepsilon^*_{2,R}]}{N_2} = 12.1\%$), which is consistent with common 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 $(p^*_1 - \pi) = 0.384$ for the Detroit casino and $(p^*_2 - \pi) = 0.36$ for the Windsor casino. Accordingly, the gross rate of profit is around 19.03% for the Detroit casino and 20.56% for the Windsor casino, which are empirically reasonable.[17]

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

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

Furthermore, we calculate the multiplier of casino income creation a_i from (27). Tannenwald (1995) shows a multiplier of 1.23 per casino job. With the median household income I_i, the multiplier of casino income creation a_i can be calculated by:

$$a_i = \frac{1.23(CE_i \cdot I_i)}{(p_i - \pi)X_i\,(p_i)}, \tag{39}$$

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 can obtain $a_1 = 0.267$ for Detroit and $a_1 = 0.281$ for Windsor. The calculation of the disorder costs is more complicated. The National Opinion Research Center has investigated the relationship between problem and pathological gambling and general measures of social well-being. In addition to high rates of mental health problems and poor general health, high rates of job loss, divorce, bankruptcy, arrest, and incarceration were found to be associated with problem and pathological gambling (see Casino and Gaming: Research Brief (2014, Sustainability Accounting Standards Board, for the details). It has been shown that (i) 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; (ii) 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); and (iii) 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. Given these findings, we set the relative damage of the problem to regular gamblers as $z = 1/3$. Moreover, we set the cross-border intensity parameters as being half of those facing local gamblers, i.e., $\phi_c = \phi_a = 0.5$. In the absence of empirical observations, we set the scaling parameters of the distortion costs from casino gambling in both cities as being identical and normalize them at $d_1 = d_2 = 1$. Accordingly, the disorder costs in Detroit (484233.090) are larger than in Windsor (330392.895), whereas the casino income creation in Detroit (96494.216) is lower than in Windsor (132578.196).

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 static results is relegated to Appendix Table A1). We shall focus on the effects of the casino revenue tax (σ_i), the casino tax surcharge (s_i), the commuting cost (T), the total population size (N_1) and the fraction of problem gamblers ($1 - n_1$) of Detroit on each city's casino prices, cross-border gambling, casino demand and revenue, total and export-based casino tax revenue, casino income creation, and the social disorder costs.

We begin by studying the responses to the two tax instruments.

Benchmark		(+1%) $\sigma_1 = 0.1919$		(+1%) $\sigma_2 = 0.202$		(+1%) $s_1 = 0.808$		(+1%) $s_2 = 1.3736$	
p_1^*	1.284	1.285	0.060%	1.285	0.009%	1.284	-0.005%	1.285	0.009%
p_2^*	1.260	1.260	0.009%	1.261	0.061%	1.260	0.005%	1.260	-0.009%
p	0.981	0.981	-0.051%	0.982	0.052%	0.981	0.011%	0.981	-0.017%
$x_{11,P}^*$	7776.537	7770.371	-0.079%	7775.601	-0.012%	7772.988	-0.046%	7775.654	-0.011%
$x_{12,P}^*$	7687.955	7687.064	-0.012%	7681.937	-0.078%	7687.442	-0.007%	7682.283	-0.074%
$x_{22,P}^*$	7616.901	7616.028	-0.011%	7611.001	-0.077%	7616.399	-0.007%	7611.341	-0.073%
$x_{21,P}^*$	7703.748	7697.703	-0.078%	7702.830	-0.012%	7700.268	-0.045%	7702.883	-0.011%
$x_{11,R}^*$	3703.537	3697.371	-0.166%	3702.601	-0.025%	3699.988	-0.096%	3702.654	-0.024%
$x_{12,R}^*$	3614.955	3614.064	-0.025%	3608.937	-0.166%	3614.442	-0.014%	3609.283	-0.157%
$x_{22,R}^*$	3543.901	3543.028	-0.025%	3538.001	-0.166%	3543.399	-0.014%	3538.341	-0.157%
$x_{21,R}^*$	3630.748	3624.703	-0.166%	3629.830	-0.025%	3627.268	-0.096%	3629.883	-0.024%
$e_{11,P}^*$	0.831	0.830	-0.131%	0.831	-0.020%	0.830	-0.076%	0.831	-0.019%
$e_{12,P}^*$	0.815	0.815	-0.020%	0.814	-0.132%	0.815	-0.011%	0.814	-0.125%
$e_{22,P}^*$	0.807	0.807	-0.020%	0.806	-0.133%	0.807	-0.011%	0.806	-0.125%
$e_{21,P}^*$	0.822	0.821	-0.132%	0.822	-0.020%	0.822	-0.076%	0.822	-0.019%
$e_{11,R}^*$	1.745	1.744	-0.044%	1.745	-0.007%	1.744	-0.025%	1.745	-0.006%
$e_{12,R}^*$	1.734	1.734	-0.006%	1.733	-0.044%	1.734	-0.004%	1.733	-0.041%
$e_{22,R}^*$	1.734	1.734	-0.006%	1.733	-0.044%	1.734	-0.004%	1.733	-0.041%
$e_{21,R}^*$	1.745	1.744	-0.044%	1.745	-0.007%	1.745	-0.025%	1.745	-0.006%
μ_1^{CB}	0.496	0.502	1.147%	0.491	-1.141%	0.499	0.660%	0.491	-1.076%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.502	1.147%	0.491	-1.141%	0.499	0.660%	0.491	-1.076%
μ_2^{CB}	0.121	0.105	-13.053%	0.136	12.989%	0.112	-7.512%	0.135	12.242%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{2,R}^{CB}$	0.121	0.105	-13.053%	0.136	12.989%	0.112	-7.512%	0.135	12.242%
X_1^*	940869.704	920935.705	-2.119%	959008.099	1.928%	929390.384	-1.220%	957964.361	1.817%
X_2^*	1307384.101	1325081.057	1.354%	1287326.959	-1.534%	1317569.282	0.779%	1288479.660	-1.446%
AGR_1^*	361739.573	354788.139	-1.922%	368825.900	1.959%	357261.904	-1.238%	368418.015	1.846%
AGR_2^*	471013.644	477540.320	1.386%	464779.994	-1.323%	474769.468	0.797%	464061.016	-1.476%
TR_1^*	192895.972	189784.986	-1.613%	196560.051	1.900%	191104.352	-0.929%	196349.176	1.790%
EBT_1^*	8814.202	7655.513	-13.146%	9957.487	12.971%	8180.040	-7.195%	9891.693	12.224%
TR_2^*	314554.573	318779.369	1.343%	311079.857	-1.105%	316985.919	0.773%	311266.001	-1.045%
EBT_2^*	131286.262	132771.260	1.131%	129651.124	-1.245%	132140.894	0.651%	130407.184	-0.670%
DC_1^*	484233.090	480572.774	-0.756%	487032.352	0.578%	482124.762	-0.435%	486871.149	0.545%
DC_2^*	330392.895	333250.377	0.865%	326951.453	-1.042%	332036.940	0.498%	327149.126	-0.982%
IC_1^*	96494.216	94639.917	-1.922%	98384.497	1.959%	95299.795	-1.238%	98275.693	1.846%
IC_2^*	132578.196	134415.287	1.386%	130823.584	-1.323%	133635.363	0.797%	130621.210	-1.476%

Table 2-a. Effects of Casino Revenue Tax and Casino Tax Surcharge

Benchmark		(+1%) $T = 193.5867$		(-1%) $N_1 = 422.1855$		(-1%) $n_1 = 0.9692$	
p_1^*	1.284	1.284	0.00005%	1.284	-0.00122%	1.285	0.00780%
p_2^*	1.260	1.260	-0.00005%	1.260	-0.00709%	1.260	0.00117%
p	0.981	0.981	-0.00010%	0.981	-0.00586%	0.981	-0.00663%
$x_{11,P}^*$	7776.537	7776.532	-0.00006%	7776.663	0.00161%	7775.738	-0.01028%
$x_{12,P}^*$	7687.955	7687.960	0.00006%	7688.654	0.00909%	7687.840	-0.00150%
$x_{22,P}^*$	7616.901	7616.906	0.00006%	7617.586	0.00899%	7616.788	-0.00149%
$x_{21,P}^*$	7703.748	7703.743	-0.00006%	7703.871	0.00160%	7702.964	-0.01018%
$x_{11,R}^*$	3703.537	3703.532	-0.00013%	3703.663	0.00339%	3702.738	-0.02159%
$x_{12,R}^*$	3614.955	3614.960	0.00013%	3615.654	0.01933%	3614.840	-0.00319%
$x_{22,R}^*$	3543.901	3543.906	0.00013%	3544.586	0.01933%	3543.788	-0.00319%
$x_{21,R}^*$	3630.748	3630.743	-0.00013%	3630.871	0.00339%	3629.964	-0.02159%
$e_{11,P}^*$	0.831	0.831	-0.00011%	0.831	0.00267%	0.831	-0.01701%
$e_{12,P}^*$	0.815	0.815	0.00010%	0.815	0.01534%	0.815	-0.00253%
$e_{22,P}^*$	0.807	0.807	0.00010%	0.807	0.01543%	0.807	-0.00255%
$e_{21,P}^*$	0.822	0.822	-0.00011%	0.822	0.00268%	0.822	-0.01711%
$e_{11,R}^*$	1.745	1.745	-0.00004%	1.745	0.00089%	1.745	-0.00570%
$e_{12,R}^*$	1.734	1.734	0.00003%	1.734	0.00510%	1.734	-0.00084%
$e_{22,R}^*$	1.734	1.734	0.00003%	1.734	0.00510%	1.734	-0.00084%
$e_{21,R}^*$	1.745	1.745	-0.00004%	1.745	0.00089%	1.745	-0.00570%
μ_1^{CB}	0.496	0.492	-0.81757%	0.492	-0.89548%	0.497	0.14862%
$\mu_{1,P}^{CB}$	0.000	0.000	0.00000%	0.000	0.00000%	0.000	0.00000%
$\mu_{1,R}^{CB}$	0.496	0.492	-0.81757%	0.492	-0.89548%	0.497	0.14862%
μ_2^{CB}	0.121	0.109	-9.54083%	0.119	-1.46487%	0.119	-1.69150%
$\mu_{2,P}^{CB}$	0.000	0.000	0.00000%	0.000	0.00000%	0.000	0.00000%
$\mu_{2,R}^{CB}$	0.121	0.109	-9.54083%	0.119	-1.46487%	0.119	-1.69150%
X_1^*	940869.704	940966.248	0.01026%	938446.322	-0.25757%	956111.236	1.61994%
X_2^*	1307384.101	1307290.359	-0.00717%	1293507.655	-1.06139%	1309677.844	0.17545%
AGR_1^*	361739.573	361777.280	0.01042%	360793.096	-0.26165%	367695.352	1.64643%
AGR_2^*	471013.644	470979.083	-0.00734%	465898.808	-1.08592%	471859.354	0.17955%
TR_1^*	192895.972	192915.4713	0.01011%	192406.517	-0.25374%	195975.213	1.59632%
EBT_1^*	8814.202	7973.2468	-9.54091%	8685.273	-1.46274%	8663.915	-1.70506%
TR_2^*	314554.573	314532.1975	-0.00711%	311242.781	-1.05285%	315102.083	0.17406%
EBT_2^*	131286.262	130213.0163	-0.81748%	128825.276	-1.87452%	131478.721	0.14659%
DC_1^*	484233.0897	484275.8858	0.00884%	480614.797	-0.74722%	512391.235	5.81500%
DC_2^*	330392.8946	330350.9807	-0.01269%	328092.088	-0.69639%	330763.015	0.11202%
IC_1^*	96494.21569	96504.2740	0.01042%	96241.742	-0.26165%	98082.923	1.64643%
IC_2^*	132578.1958	132568.4676	-0.00734%	131138.501	-1.08592%	132816.241	0.17955%

Table 2-b. Effects of Commuting Costs, Detroit’s Total and Problem Gambling Populations

Result 1: (Effects of Casino Revenue Tax and Casino Tax Surcharge)

(i) *An increase in the revenue tax rate (σ_i) in either city raises the equilibrium prices of both casinos (p_1^* and p_2^*), while an increase in the casino tax surcharge (s_i) in City i lowers the equilibrium price in its own casino (p_i) but raises the equilibrium price in the neighboring casino (p_j).*

(ii) *In response to an increase in the revenue tax rate (σ_i) or the casino tax surcharge (s_i),*

- **a.** *all individual casino demands ($x_{ij,m}^*$) fall,*
- **b.** *the proportion of City i's cross-border gamblers commuting to the other city (μ_i^{CB}) rises,*
- **c.** *the total casino demand (X_i^*), casino revenue (AGR_i^*), total tax revenue (TR_i^*), export-based tax revenue (EBT_i^*), casino income creation (IC_i^*), and social disorder costs (DC_i^*) in City i all decrease.*

(iii) *The responses to the other city's tax changes are exactly the opposite.*

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 costs, 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. At the same time, the positive externality of casino income creation in Detroit (IC_1^*) also decreases because the Detroit casino market shrinks. 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 gaming 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. 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 2.119%) and revenue (AGR_1^* by 1.914%), while it decreases Windsor's casino demand (X_2^* by 1.35%) and revenue (AGR_2^* by 1.381%). This implies that a 1% increase in the AGR of Detroit's casino leads to a 0.72% decline in that of Windsor's casino. Compared 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 ($AGR_1^* + AGR_2^*$).[18]

Next, we examine the effects of the casino tax surcharge. As indicated in Proposition 3(i), raising Detroit's tax surcharge (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 casino tax surcharge s_1, and, accordingly, the casino tax surcharge 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 casino tax

[18] 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. Due to the inability to control for other changes, this counterfactual estimate may be potentially biased. It may thus be valuable to apply our approach to revisit the case.

surcharge (-13.146% and -1.613% vs. -7.195% and -0.929% 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 suggests that *for Detroit, a higher wagering tax can reduce the casino disorder cost more significantly than a casino tax surcharge*. The tax incidence of the wagering tax is also different from that of the casino tax surcharge. 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 casino tax surcharge, 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 wagering 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 casino tax surcharge 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 casino tax surcharge* 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 (Result 6), this will lead to rich optimal tax outcomes.

When do problem gamblers cross the border to gamble? In the 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 casino tax surcharge s_2) by 16% (18%) or when Detroit lowers the wagering tax rate σ_1 (the casino tax surcharge 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 270.55%, because problem patrons gamble more intensively (a higher $x_{21,P}^*$). Similarly, if Windsor raises the casino tax surcharge s_2 by 18%, Detroit's export-based tax revenue will increase by 232.26%. 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 12166 and $DC_{1,R}^2$ increases by 234.79%, resulting in an increase of about 13.17% in the total disorder costs. As for the effects of the casino tax surcharge, $DC_{1,P}^2$ increases from 0 to 6122 and $DC_{1,R}^2$ increases by 214.1%, resulting in a 10.93% increase in total disorder costs.

We next turn to quantifying the effects of an increase in the commuting cost. As noted previously, 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. Based on our parametrization, the effects of an increase in the commuting cost T are summarized in the following result:

Result 2: (Effects of Commuting Costs) *In response to a rise in the commuting cost T of crossing the border between Detroit and Windsor,*

(i) *the equilibrium casino price increases in Detroit (p_1^*) but decreases in Windsor (p_2^*);*

(ii) *the proportion of both cities' cross-border gamblers to the other city (μ_i^{CB}) and the export-based tax revenue (EBT_i^*) decline;*

(iii) *in Detroit individual demand for casinos ($x_{11,m}^*$ and $x_{21,m}^*$) falls, while total demand (X_1^*), casino revenue (AGR_1^*), tax revenue (TR_1^*), casino income creation (IC_1^*), and social disorder costs (DC_1^*) rise.*

(iv) *in Windsor individual demand for casinos ($x_{12,m}^*$ and $x_{22,m}^*$) rises, while total demand (X_2^*), casino revenue (AGR_2^*), tax revenue (TR_2^*), casino income creation (IC_2^*), and social disorder costs (DC_2^*) fall.*

Intuitively, due to a higher commuting cost, the proportions of the cross-border gamblers for both cities fall. 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 contrast to the responses to tax shifts, *a higher commuting cost causes the cross-border casino consumption of Detroit to exhibit an intensive margin response in the sense that the proportion of the cross-border gamblers decreases, but the cross-border casino consumption per gambler increases.* 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. In short, 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 and income creation.

The tighter restrictions on the U.S. side of the border have led Windsor's gambling revenues to fall significantly. To counter this drop-off, Caesars Casino Windsor has offered passport photo sessions, information on what documents are needed to cross the border and even keeps passport applications in its customer relations offices (Hall, 2009 and McArthur, 2009). The new Caesars Windsor has also offered $3,500 in tunnel fares to U.S. visitors on a first-come, first-served basis.[19] 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.

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. It is therefore also interesting to examine the effects of a reduction in Detroit's population.

Result 3: (Effects of Detroit's Population) *In response to a reduction in Detroit's potential gambling population (N_1),*

(i) *the equilibrium casino prices in both Detroit (p_1^*) and Windsor (p_2^*) decrease;*

(ii) *all individual casino demands ($x_{ij,m}^*$) increase;*

(iii) *cross-border gambling (μ_i^{CB}), total casino demand (X_i^*), casino revenue (AGR_i^*), total (TR_i^*) and export-based casino (EBT_i^*) tax revenues, income creation (IC_i^*), and social disorder costs (DC_i^*) in both cities all decline.*

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, income creation, and social disorder costs in both cities are all lower. There is an intensive margin response whereby the gambling market size decreases while the casino consumption per gambler increases. Of particular interest, *the drop in Detroit's population hurts its neighboring casino, Windsor, more severely.* 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 (9.377%), total tax revenues (5.265%), and AGR (5.428%).

In a meta-analysis of gambling disorders among adults in the U.S. and Canada, Shaffer, Hall, and Vander Bilt (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

[19] In 2008, the Windsor Casino was rebranded and rebuilt as "Caesars Windsor," with an investment of over CAD $400 million.

immense social acceptance of gambling. Although the percentage of problem gamblers is small, such people give rise to significant social costs. Thus, we examine the impacts of an increase in the proportion of Detroit's problem gamblers $(1 - n_1)$ which are summarized as follows:

Result 4: (Effects of Detroit's Problem Gambling Population) *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 gambling population* (N_1)*. Quantitatively,*

(i) *the percentage increases in Detroit's total casino demand* (X_1^*)*, casino revenue* (AGR_1^*)*, tax revenue* (TR_1^*)*, casino income creation* (IC_1^*)*, and social disorder costs* (DC_1^*) *are much larger in response to a rising proportion of Detroit's problem gamblers compared to a rising population of Detroit's gamblers;*

(ii) *the percentage increases in Windsor's total casino demand* (X_2^*)*, casino revenue* (AGR_2^*)*, tax revenue* (TR_2^*)*, casino income creation* (IC_2^*)*, and social disorder costs* (DC_2^*) *are much smaller in response to a rising proportion of Detroit's problem gamblers compared to a rising population of Detroit's gamblers.*

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^*)*, tax revenues* (TR_i^*) *and income creation* (IC_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 5% increase in Detroit's problem gamblers increases the disorder costs sharply by about 30%. By contrast, *such percentage gains and costs in Windsor are much larger in response to an increase in the population of Detroit's gamblers.*

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 (Nichols and Tosun, 2013). 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.

Result 5: (Demand Elasticity and Casino Tax) *For both cities,*

(i) *the demand for gambling is more responsive to the wagering tax* (σ_i) *than the casino tax surcharge* (s_i)*;*

(ii) *fiscal competition in either the wagering tax (lowering σ_i) or casino tax surcharge (lowering s_i) raises the price elasticities of demand for gambling for both problem and recreational gamblers ($e^*_{ij,m}$).*

By focusing on the tax elasticity of the demand for gambling, we can see from Table 2-a that the *individual demand for gambling ($x^*_{ij,m}$) is more responsive to the wagering tax (σ_i) than the casino tax surcharge (s_i)*, because casinos can pass more of their tax burden onto consumers in response to a higher wagering tax rate. 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 tax surcharge. In addition, Table 2-a shows that a decrease in either the wagering tax (σ_i) or casino tax surcharge (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.*

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 tax surcharge rate 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. To shed light on the importance of the social disorder costs, in addition to the benchmark $d_1 = d_2 = 1$, this welfare analysis also considers a parallel case with a higher disorder cost parameter, $d_1 = d_2 = 1.5$. The results are summarized below.

Consider the first exercise. Figure 2 shows that, given the rival's tax policy and the alternative tax instrument, if $d_1 = d_2 = 1$, the optimal casino revenue/wagering tax rate in Detroit involves a decrease from its pre-existing value of 0.19 to $\sigma^*_1 = 0.158$ (Figure 2-a), whereas that in Windsor involves in a decrease from 0.20 to $\sigma^*_2 = 0.184$ (Figure 2-b).[20] While the optimal casino tax surcharge in Detroit declines from its pre-existing value of 0.8 to $s^*_1 = 0.343$ (Figure 2-c), that in Windsor decreases from 1.361 to $s^*_2 = 0.926$ (Figure 2-d). If we consider a higher disorder cost parameter, $d_1 = d_2 = 1.5$ (see Figures A1-a – A1-d in the Appendix), the optimal casino revenue/wagering tax rate increases sharply to $\sigma^*_1 = 0.229$ in Detroit (compared with $\sigma^*_1 = 0.158$ in the $d_1 = d_2 = 1$ case), while it only slightly increases to $\sigma^*_2 = 0.185$ in Windsor. As for the casino tax surcharge, in Detroit the optimal level dramatically increases to $s^*_1 = 1.062$ (compared with $s^*_1 = 0.343$ in the $d_1 = d_2 = 1$

[20] We have ruled out the possibility of the negative demand for casinos in the welfare analysis.

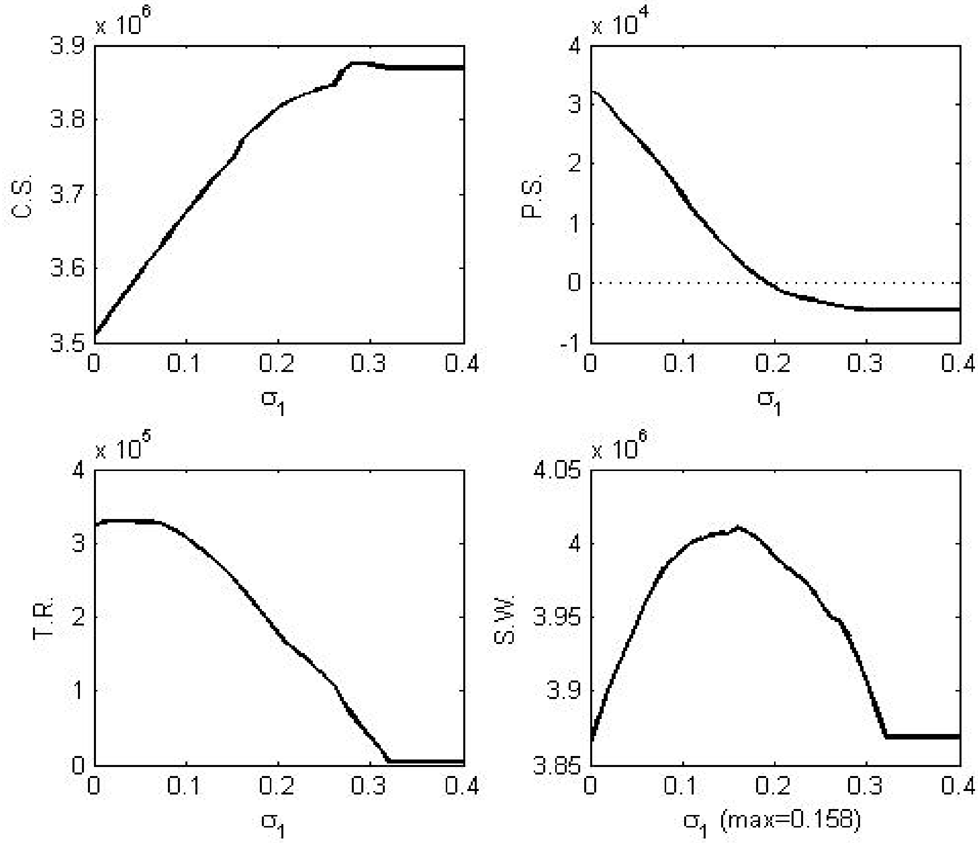


Figure 2-a. Optimal Casino Revenue Tax: Detroit (d1=d2=1)

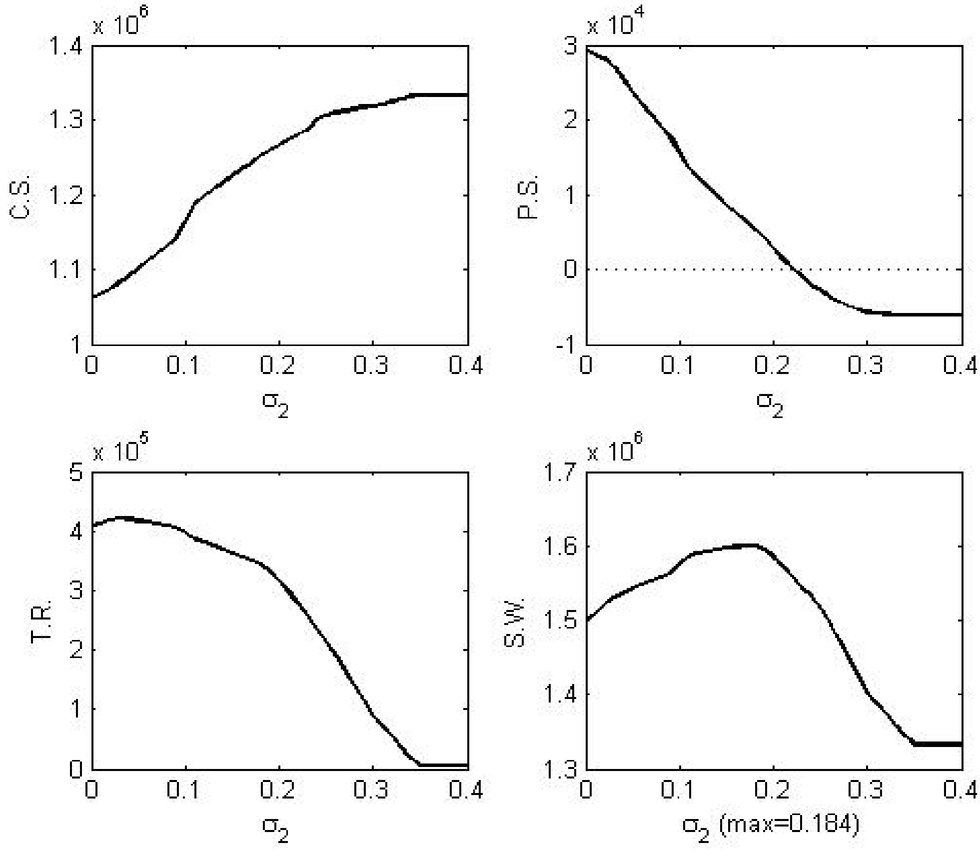


Figure 2-b. Optimal Casino Revenue Tax: Windsor (d1=d2=1)

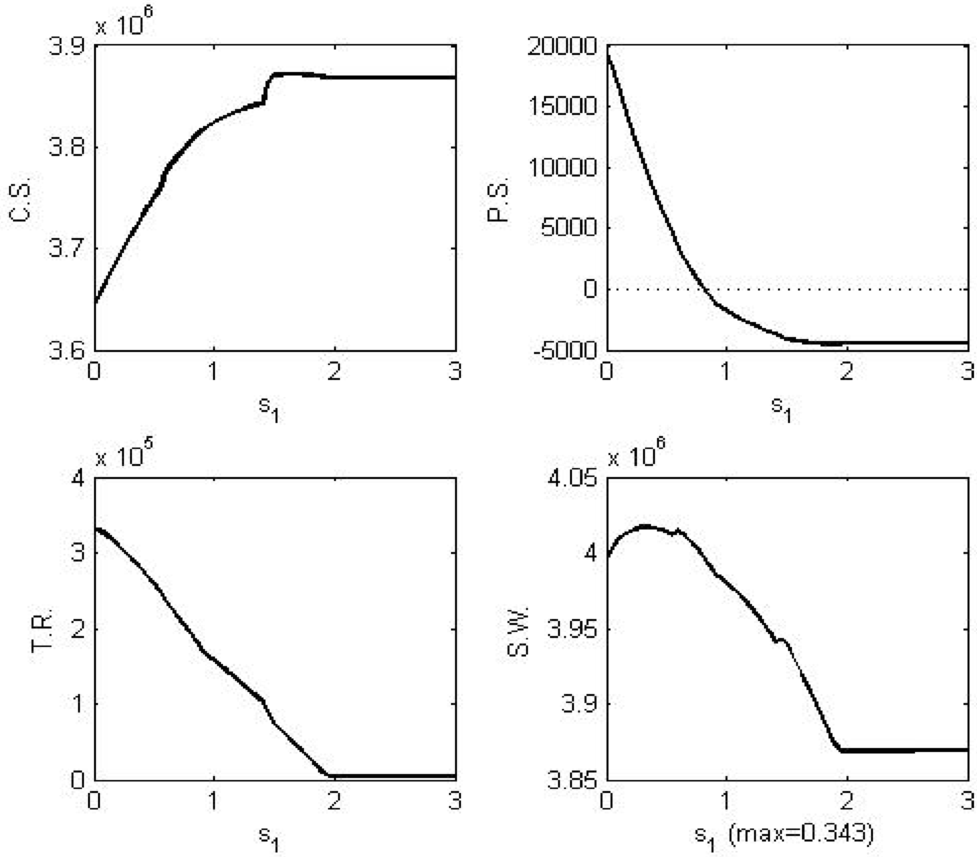


Figure 2-c. Optimal Casino Tax Surcharge: Detroit (d1=d2=1)

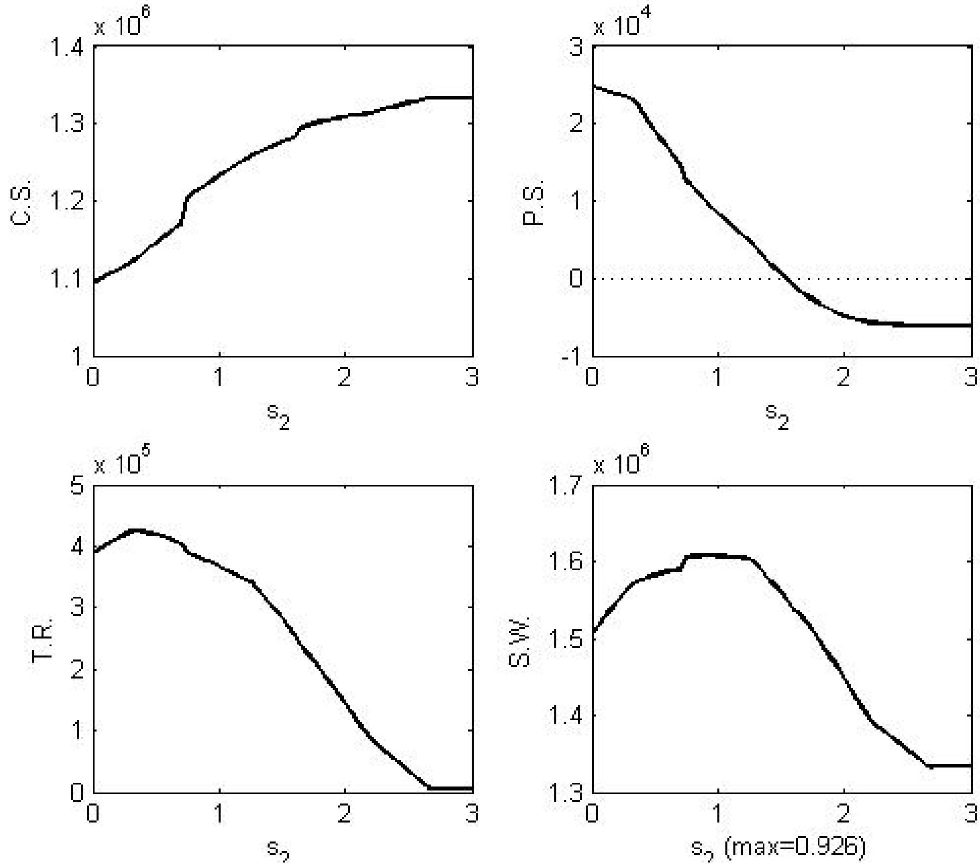


Figure 2-d. Optimal Casino Tax Surcharge: Windsor (d1=d2=1)

case) and in Windsor it slightly increases to $s_2^* = 1.253$ (compared with $s_2^* = 0.926$ in the $d_1 = d_2 = 1$ case).

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 net casino externality (disorder costs net of income creation), but suppresses the producer's surplus as a result of a weakening competitive advantage. Given that total tax revenue is hump-shaped (i.e., a Laffer curve), the optimal tax rate is determined by balancing these components.[21] When the disorder costs of gambling are not that serious ($d_1 = d_2 = 1$), each city should lower its casino taxation in order to attract more cross-border gamblers, thereby establishing a competitive advantage over its rival. This may explain 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. By contrast, if the social disorder costs of gambling are considered to be a more serious issue ($d_1 = d_2 = 1.5$), both cities should levy higher casino taxes to control the social cost. In this case, both cities should raise taxes compared to the benchmark case ($d_1 = d_2 = 1$). However, with stronger gambling preferences and higher disorder costs, *Detroit should raise both the wagering tax σ_1^* and casino tax surcharge s_1^** above the pre-existing levels (the disorder costs of Detroit are almost twice as large as those of Windsor in the benchmark). By contrast, *Windsor remains better off by lowering the wagering tax rate σ_2^* and casino tax surcharge s_2^* compared to the pre-existing rates.* This is because Windsor's casinos are more dependent on cross-border visitors from Detroit and the income creation is more important for Windsor than for Detroit (the casino income creation of Windsor is about 40% larger than that of Detroit in the benchmark).

Next turn to the second exercise with the optimal tax mixes depicted by Figure 3. Given Windsor's existing tax policy $(\sigma_2, s_2) = (0.2, 1.36)$, Detroit's optimal tax mix is $(\sigma_1^{**}, s_1^{**}) = (0.264, 0)$ for $d_1 = d_2 = 1$ (Figure 3-a) and is $(\sigma_1^{**}, s_1^{**}) = (0.355, 0.007)$ for $d_1 = d_2 = 1.5$ (Figure A2-a in the Appendix). As is evident, Detroit's optimal tax mix favors a shift from the tax surcharge to the casino revenue/wagering tax. *When the social distortion cost is severe* (e.g., $d_1 = d_2 = 1.5$) *the optimal tax mixes may feature an interior solution* under which all problem gamblers cross the border to gamble ($\mu_{1,P}^{CB} = 1$). By contrast, given Detroit's existing tax policy $(\sigma_1, s_1) = (0.19, 0.8)$, Windsor's optimal tax mix is $(\sigma_2^{**}, s_2^{**}) = (0.331, 0)$ for $d_1 = d_2 = 1$ (Figure 3-b) and is $(\sigma_2^{**}, s_2^{**}) = (0.351, 0)$ for $d_1 = d_2 = 1.5$ (Figure A2-b in the Appendix). Windsor's optimal tax mix is in favor of taxing only the casino revenue/wagering tax by fully exempting the consumers from a tax surcharge (i.e., a corner solution), which is sufficient for preventing Detroit's problem gamblers from crossing the

[21] Total tax revenues, as shown in (28), are collected from not only the tax surcharge imposed on gamblers but also the revenue tax imposed on casinos. In the case of the optimal tax surcharge in Detroit reported in Figure 2-c, the total tax revenue-maximizing s_1 is zero, although the tax surcharge-maximizing s_1 is 0.122 which is in line with the prototypical Laffer curve property.

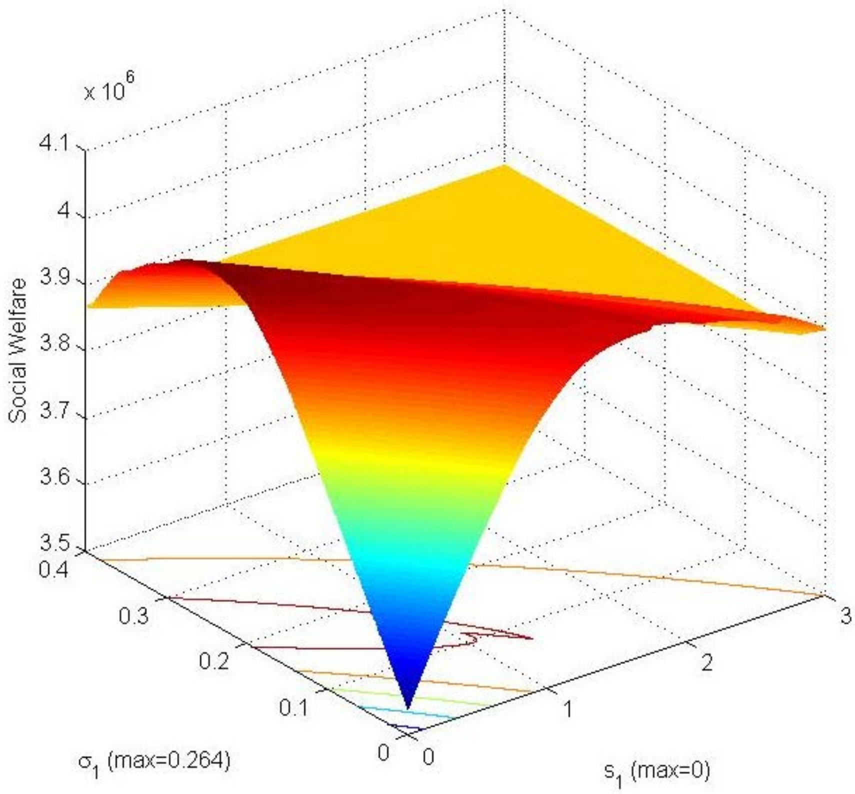


Figure 3-a. Optimal Casino Tax Mix: Detroit (d1=d2=1)

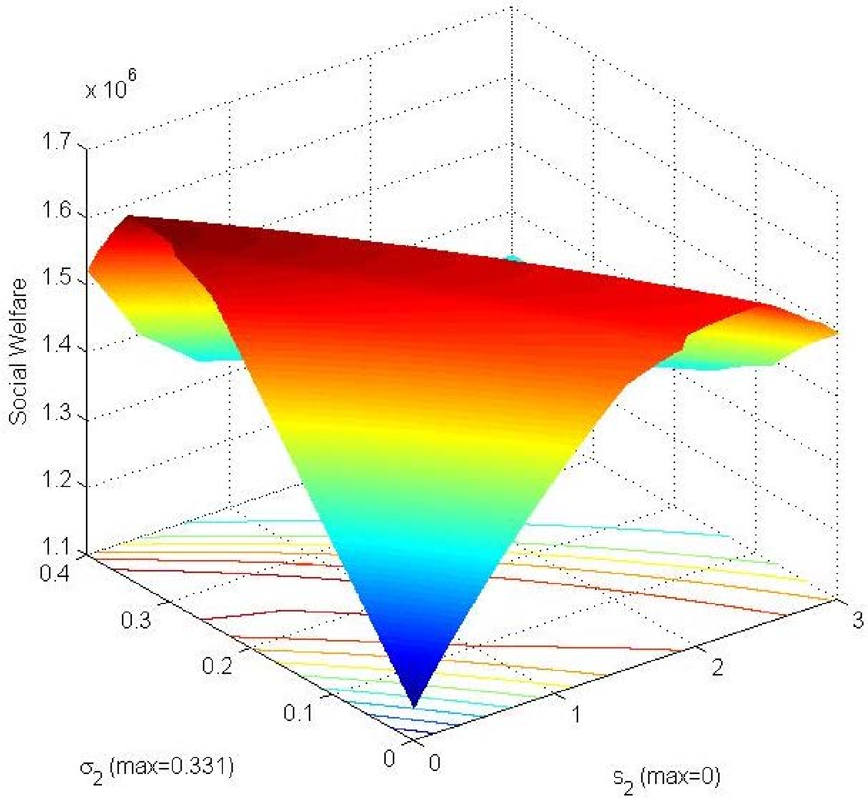


Figure 3-b. Optimal Casino Tax Mix: Windsor (d1=d2=1)

border ($\mu_{1,P}^{CB} = 0$) under the $d_1 = d_2 = 1.5$ case. In both cities, *the favorable tax mix toward casino revenue/wagering tax may serve to explain why the casino wagering tax is the most common form of taxation.* Nonetheless, such an optimal tax shift is more pronounced in Windsor with weaker preferences toward gambling and lower social disorder costs.

It is interesting to note that if the population of Detroit's problem gamblers $(1 - n_1)$ increases, it is optimal for both cities to raise the wagering tax for controlling the potential social cost caused by Detroit's problem gamblers. One may also inquire into what happens to the optimal tax mix in both cities if Detroit's population N_1 falls. In response to a population drop in Detroit, 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.

We finally perform the third exercise concerning welfare-based pairwise casino competition. In the $d_1 = d_2 = 1$ case, given the alternative tax instrument, the welfare-based casino competition in terms of the casino revenue tax is $(\sigma_1^{***}, \sigma_2^{***}) = (0.02, 0.05)$, whereas the welfare-based casino competition in terms of the tax surcharge is $(s_1^{***}, s_2^{***}) = (0.05, 0.31)$. In the $d_1 = d_2 = 1.5$ case, the welfare-based casino competition in terms of the casino revenue tax is $(\sigma_1^{***}, \sigma_2^{***}) = (0.043, 0.033)$, whereas the welfare-based casino competition in terms of the tax surcharge 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 $(s_1, s_2) = (0.8, 1.36)$, the optimal taxes (wagering taxes and casino tax surcharges) are lower due to an intense cross-border casino competition. Interestingly, *in order to better compete with the neighboring casino, the welfare-based casino competition always features lower casino revenue tax rates and tax surcharges than those where the rival's tax policy is given* (i.e., $\sigma_i^{***} < \sigma_i^*$ and $s_i^{***} < s_i^*$).

Our numerical analysis reveals that if the disorder cost parameter is relatively low ($d_1 = d_2 = 1$), we have $\sigma_1^{***} < \sigma_2^{***}$ and $s_1^{***} < s_2^{***}$, but if the disorder cost parameter is relatively high ($d_1 = d_2 = 1.5$), the opposite result is true, i.e., $\sigma_1^{***} > \sigma_2^{***}$ and $s_1^{***} > s_2^{***}$. In the model, 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 and lead to more income creation. *When the disorder costs of gambling are less severe (*$d_1 = d_2 = 1$*), it is optimal for Detroit to aggressively set lower casino taxes in order to pull into the cross-border visitors via attracting some problem gamblers from Windsor* ($\mu_{2,P}^{CB} > 0$). When the disorder costs of gambling become more severe ($d_1 = d_2 = 1.5$), *Detroit has to raise its casino taxes in order to control the social cost of gambling by pushing the problem gamblers in Windsor back to their own casinos.* In this case, Windsor will take advantage of this to set relatively low casino taxes for enhancing casino and tax revenues and income creation. Should the population of Detroit's problem gamblers increase, the welfare-based pairwise casino competition unambiguously features higher casino revenue tax and tax surcharge rates for Detroit that has relatively large casino external distortions (disorder costs net of income creation).

We are now ready to conclude with the following:

Result 6: (Optimal Casino Tax Policy)

(i) (Optimal Policy of a Single Casino Tax) *Given the rival city's tax policy and the alternative tax instrument, it is optimal for both cities to lower each of the tax rates from the pre-existing level when the social disorder costs are less severe. If the social disorder costs are sufficiently high, Detroit should raise both the wagering tax and casino tax surcharge from the pre-existing levels, while Windsor remains better off by reducing both the wagering tax and casino tax surcharge from their pre-existing levels.*

(ii) (Optimal Tax Mix) *Given the rival city's tax policy, the optimal tax mix favors a shift from the tax surcharge to the casino revenue tax in both cities, which is more pronounced for Windsor.*

(iii) (Welfare-Based Pairwise Casino Competition) *Given the alternative tax instrument, welfare-based casino competition features lower casino revenue tax rates and tax surcharges than those in the absence of casino competition. When the disorder costs of gambling are less severe, it is optimal for Detroit to aggressively set lower casino taxes to attract some problem gamblers from Windsor; when the disorder costs of gambling are more severe, it is optimal for Detroit to raise casino taxes by preventing Windsor's problem gamblers from crossing the border.*

Remark: As is conventional, our welfare analysis is conducted under a benevolent government. One may inquire what would happen if the government is a Leviathan revenue-maximizer. We find that, in all optimal casino tax policy exercises, the optimal tax rates on both casino revenue and gambler tax surcharge are lower than those of their benevolent government counterparts. This is because a Leviathan government fails to account for the Pigouvian tax correction of negative casino externalities that would affect the consumer's surplus. For example, in the benchmark case with $d_1 = d_2 = 1$, $(\sigma_1^{**}, s_1^{**}) = (0.161, 0)$ and $(\sigma_2^{**}, s_2^{**}) = (0.245, 0)$, which are both lower than the comparable figures of $(0.264, 0)$ and $(0.331, 0)$ under the benevolent government setting.

4.4 Counterfactual Analysis

We now perform two counterfactual exercises to assess how the welfare analysis conducted above may change in response to changes in the underlying economies. The first counterfactual is to inquire into what would have happened if there had been no 911 incident with the commuting cost being restored to the pre-911 level. The second is to inquire into what would have happened if Detroit had maintained its population at the 2000 level. In what follows, we focus on the benchmark case where $d_1 = d_2 = 1$.

Concerning the first counterfactual, we note that in the pre-911 era, the commuting time per trip was about half (i.e., 1.5 hours). Accordingly, the commuting cost is lowered by about 45%.

Result 7: (Counterfactual with Respect to Commuting Costs) *Restoring the commuting cost to the pre-911 level reduces Detroit's producer's surplus (by* 38.58%*) and tax revenues (by* 0.46%*), but raises its consumer's surplus (by* 0.40%*) and welfare (by* 0.36%*). By contrast, Windsor's producer's surplus (by* 2.14%*) and tax revenues (by* 0.32%*) rise, while its consumer's surplus (by* 0.89%*) and welfare (by* 0.65%*) fall.*

If there had been no 911 incident, Detroit residents would have more easily crossed the border to Windsor at a lower commuting cost. Since the proportion of cross-border gamblers is higher and the proportion of local gamblers is lower, the social disorder costs are considered to be less pronounced in Detroit. As a result, Detroit's consumer's surplus and welfare increase, while its producer's surplus and tax revenues decrease. An interesting finding is that *due to more intense cross-border gambling, such a circumstance is not necessarily favorable to Windsor*: while Windsor's producer's surplus and tax revenues would have increased, its consumer's surplus and welfare would have fallen.

With regard to the second counterfactual, we are particularly interested in the consequence of restoring Detroit's population to the level in 2000 (amounting to an 8.5% increase).

Result 8: (Counterfactual with Respect to Detroit's Population) *Restoring Detroit's population to the level in 2000 raises Detroit's producer's surplus (by* 135.14%*), tax revenues (by* 2.15%*), consumer's surplus (by* 8.57%*), and welfare (by* 8.26%*), while it increases Windsor's producer's surplus (by* 62.27%*), tax revenues (by* 8.95%*), and welfare (by* 1.41%*), but reduces its consumer's surplus (by* 0.59%*).*

If Detroit had maintained its size in 2000, its consumer's surplus, producer's surplus, tax revenues, and welfare would have all been higher. While Windsor would have enjoyed a greater producer's surplus and tax revenues, *its consumer's surplus would have fallen due to more intense cross-border gambling*. Since its producer's surplus would have increased drastically (by more than 60%), this outweighs the detrimental effect on its consumer's surplus, resulting in higher welfare. By examining the data, compared with the 2000 level, the average gross casino revenues of Windsor (during 2000-2012) have declined by nearly 50%. It follows from Results 6 and 7 that compared with the rise in the cross-border commuting cost, the large reduction in Detroit's population seems to affect the Detroit-Windsor casino market more markedly.

5 Further Discussions

In this section, we consider three extensions by investigating the role played by the winning tax, a positive casino externality, and the exchange rate in the cross-border casino competition.

5.1 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 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, Fox, and Lucas (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,

$$x[1 + \Phi - (1 - \Phi)] = \pi x. \tag{40}$$

Given that the return to player (RTP) percentage $\pi = 0.9$, 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 (40) 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 \$5,000.[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.

In the Appendix, Table A3 shows the effects of the winning tax. Similar to a rise in Detroit's tax surcharge 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 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 and income creation in Detroit and higher casino externalities in Windsor.

With regard to welfare analysis, we only focus on the case where $d_1 = d_2 = 1$ in the extension, which is shown in Figure A3 (in the Appendix). Intuitively, given the disadvantage of American income tax law (the presence of the winning withholding tax), Detroit has to lower its optimal wagering tax σ_1^* (from 0.158 to 0.143) and casino tax surcharge s_1^* (from 0.343 to 0.268) in order to better compete with the neighboring casino. By contrast, Windsor can take advantage of the winning tax exemption by raising its optimal wagering tax σ_2^* (from 0.184 to 0.191) and casino tax surcharge s_2^* (from 0.296 to 0.983).

[22] The winning withholding tax rate is complicated and differs across casino games. See Charitable Gaming (website: http://www.michigan.gov/cg/0,4547,7-111-34357-287539–,00.html) and Greenlees (2008) for more details.

5.2 Positive Net Casino Externality

In the benchmark, we have performed welfare analysis in the cases where $d_1 = d_2 = 1$ and $d_1 = d_2 = 1.5$. For both cases, the disorder costs of gambling are larger than the income creation, giving rise to negative net casino externalities. Some cost-benefit analyses, however, identify potentially positive net casino externalities – particularly when casinos are established in deprived areas where they create more jobs and incomes (see Anders, 2013). It is thereby worthwhile performing a robustness check for the case of positive net casino externalities.

Because the multiplier of casino income creation a_i is calibrated to fit the data, we accomplish the task by lowering the disorder-cost parameter to $d_1 = d_2 = 0.2$ under which the casino income creation is larger than its gambling disorder cost in both cities ($IC_i > DC_i$). The comparative statics results in Table 2 (and Tables A1 and A2 in the Appendix) remain the same due to the social externalities of gambling being taken as given by all gamblers and casinos, while the welfare analysis provides some interesting results. By solving the optimal tax policy (σ_i^*, s_i^*) one by one, given the rival's tax policy at the benchmark values, we find that the presence of a positive net casino externality makes the casino competition between Detroit and Windsor more intense. As shown in the Appendix (Figure A4), both cities dramatically lower their casino taxes in order to compete with neighboring cities. Lower wagering taxes or casino tax surcharges allow the city government to enhance social welfare by increasing gambling revenues and expanding its income creation. This is particularly true for a city that originally had a serious gambling problem, i.e., Detroit. Figure A4-c shows that the optimal casino tax surcharge in Detroit is to be fully eliminated, as compared to the benchmark of $s_1^* = 0.343$ (under $d_1 = d_2 = 1$).

The intensity of casino competition is also reflected in the optimal tax mixes. Figure A5 indicates that in the presence of a positive net casino externality ($IC_i > DC_i$), the optimal tax mixes for both cities refer to a zero casino tax surcharge associated with a relatively low wagering tax rate: $(\sigma_1^{**}, s_1^{**}) = (0.193, 0)$ and $(\sigma_2^{**}, s_2^{**}) = (0.246, 0)$. Moreover, the welfare-based casino competition yields optimal casino revenue taxes at $(\sigma_1^{***}, \sigma_2^{***}) = (0.01, 0.049)$ and optimal tax surcharges at $(s_1^{***}, s_2^{***}) = (0.01, 0.31)$ – both are lower than the comparable figures in the benchmark case ($d_1 = d_2 = 1$).

To sum up, while our main findings remain robust, a new insight is that the presence of a positive net casino externality tends to lower optimal casino taxes due to more intense casino competition.

5.3 Exchange Rate

To examine 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. Most notably, a change in 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 Appendix. Intuitively, a depreciation in the CAD (a positive ζ) 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^* 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 casino (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^*), tax revenues (EBT_2^* and TR_2^*), and income creation (IC_2^*), it harms Detroit, lowering its casino revenues (AGR_1^*), tax revenues (EBT_1^* and TR_1^*), and income creation (IC_1^*). The disorder costs, however, become lower in Detroit but higher in Windsor.

The increase in the casino and tax revenues explains the latest turnaround of Windsor's casinos. According to the OLG record, between the years 2009 and 2014, revenues for the Windsor casino struggled. In 2015, revenues, however, have 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 while competition is still strong, currency exchange is in their favor; the depreciation of the CAD encourages U.S. tourists to travel across the border for their holidays.

6 Concluding Remarks

This paper has developed a theoretical model of cross-border casino competition in which (i) problem and recreational gamblers endogenously choose both the location and the amount of casino gambling, (ii) two bordering casinos compete with each other for the aggregate source of demand from both sides of the border (cross-border casino competition), and (iii) both governments exercise cross-border casino tax competition to optimize their casino tax policy by accounting for the import of tax revenues and the export of external disorder costs. Analytically, we have shown 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. 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 further established that a lower commuting cost favors cross-border casino business in a city with a weaker taste for gambling. Moreover, the positive scale effect of a rising local population may be offset by a negative effect on cross-border gambling, leading to ambiguous outcomes.

In our calibrated two-city economy fitting the case of Detroit and Windsor, we have conducted various quantitative analyses which provide valuable policy implications to the casino policymakers of the bordering cities. By solving the optimal policy of a single casino tax instrument of a city, we have obtained that cross-border competition induces both city governments to lower each tax to below the pre-existing rate, although in Detroit with its stronger gambling preferences and higher disorder costs, it is possible to raise each tax above the pre-existing rate when the disorder costs are sufficiently high. By conducting a tax incidence exercise, we have established that the optimal tax mix features a shift from the tax surcharge to the casino revenue tax. By performing welfare-based pairwise casino competition, we have concluded that in order to better compete with the neighboring casino, it is optimal to impose a lower casino tax rate than that obtained in the absence of casino competition. Finally, by means of counterfactual analysis, we have shown that had the commuting cost been restored to the pre-911 level, it need not have favored Windsor; moreover, had Detroit maintained its population at the higher level as in 2000, Windsor would have enjoyed only a modest welfare gain due to a loss in consumer's surplus.

Turning next to policy design, what would be the best casino tax instruments for each city to choose? Given the rival city's tax policy, the optimal tax mix favors a shift from the tax surcharge to the casino revenue tax. Such an optimal tax shift is more pronounced in a city with weaker preferences toward gambling and lower social disorder costs. As for tax competition, it is optimal for both cities to lower their tax rates to secure the attractiveness for cross-border gambling. When the disorder costs of gambling are less severe, it is optimal for the city with stronger preferences for gambling and higher social disorder costs to aggressively set lower casino taxes to attract some cross-border problem gamblers; when the disorder costs of gambling are more severe, it is then optimal to raise casino taxes by preventing the neighboring city's problem gamblers from crossing the border.

Appendix

(Not Intended for Publication)

Proof of Proposition 1.

It follows immediately from (9) and (10). ■

Proof of Proposition 2.

From (11)-(14), we derive

$$\begin{aligned}
\frac{\partial \mu_i^{CB}}{\partial p_i} &= \frac{1}{N_i}\{\frac{2\gamma_\tau\left[1+(1+s_i)\,t\right]}{p_j\left[1+(1+s_j)\,t\right]-\pi}+\frac{\left[1+(1+s_i)\,t\right]}{(1+t)}(\eta_P-\eta_R)\}>0,\\
\frac{\partial \mu_i^{CB}}{\partial p_j} &= -\frac{1}{N_i}\{\frac{2\gamma_\tau\left[1+(1+s_j)\,t\right]}{p_j\left[1+(1+s_j)\,t\right]-\pi}+\frac{\left[1+(1+s_j)\,t\right]}{(1+t)}(\eta_P-\eta_R)\}<0,\\
\frac{\partial \mu_i^{CB}}{\partial s_i} &= \frac{1}{N_i}\{\frac{2\gamma_\tau t p_i}{p_j\left[1+(1+s_j)\,t\right]-\pi}+\frac{tp_i}{(1+t)}(\eta_P-\eta_R)\}>0,\\
\frac{\partial \mu_i^{CB}}{\partial s_j} &= -\frac{1}{N_i}\{\frac{2\gamma_\tau t p_j}{p_j\left[1+(1+s_j)\,t\right]-\pi}+\frac{tp_j}{(1+t)}(\eta_P-\eta_R)\}<0,\\
\frac{\partial \mu_{i,P}^{CB}}{\partial p_i} &= \frac{1}{(1-n_i)N_i}\{\frac{\gamma_\tau\left[1+(1+s_i)\,t\right]}{p_j\left[1+(1+s_j)\,t\right]-\pi}+\frac{\left[1+(1+s_i)\,t\right]\eta_P}{(1+t)}\}>0,\\
\frac{\partial \mu_{i,P}^{CB}}{\partial p_j} &= -\frac{1}{(1-n_i)N_i}\{\frac{\gamma_\tau\left[1+(1+s_j)\,t\right]}{p_j\left[1+(1+s_j)\,t\right]-\pi}+\frac{\left[1+(1+s_j)\,t\right]\eta_P}{(1+t)}\}<0,\\
\frac{\partial \mu_{i,P}^{CB}}{\partial s_i} &= \frac{1}{(1-n_i)N_i}\{\frac{\gamma_\tau t p_i}{p_j\left[1+(1+s_j)\,t\right]-\pi}+\frac{tp_i\eta_P}{(1+t)}\}>0,\\
\frac{\partial \mu_{i,P}^{CB}}{\partial s_j} &= -\frac{1}{(1-n_i)N_i}\{\frac{\gamma_\tau t p_j}{p_j\left[1+(1+s_j)\,t\right]-\pi}+\frac{tp_j\eta_P}{(1+t)}\}<0,\\
\frac{\partial \mu_{i,R}^{CB}}{\partial p_i} &= \frac{\left[1+(1+s_i)\,t\right]}{n_iN_i}\{\frac{\gamma_\tau}{p_j\left[1+(1+s_j)\,t\right]-\pi}-\frac{\eta_R}{(1+t)}\}\gtreqless 0 \text{ if } \eta_R \lesseqgtr \frac{\gamma_\tau(1+t)}{p_j\left[1+(1+s_j)\,t\right]-\pi},\\
\frac{\partial \mu_{i,R}^{CB}}{\partial p_j} &= \frac{-\left[1+(1+s_j)\,t\right]}{n_iN_i}\{\frac{\gamma_\tau}{p_j\left[1+(1+s_j)\,t\right]-\pi}-\frac{\eta_R}{(1+t)}\}\gtreqless 0 \text{ if } \eta_R \gtreqless \frac{\gamma_\tau(1+t)}{p_j\left[1+(1+s_j)\,t\right]-\pi},\\
\frac{\partial \mu_{i,R}^{CB}}{\partial s_i} &= \frac{p_it}{n_iN_i}\{\frac{\gamma_\tau}{p_j\left[1+(1+s_j)\,t\right]-\pi}-\frac{\eta_R}{(1+t)}\}\gtreqless 0 \text{ if } \eta_R \lesseqgtr \frac{\gamma_\tau(1+t)}{p_j\left[1+(1+s_j)\,t\right]-\pi},\\
\frac{\partial \mu_{i,R}^{CB}}{\partial s_j} &= \frac{p_jt}{n_iN_i}\{\frac{\gamma_\tau}{p_j\left[1+(1+s_j)\,t\right]-\pi}-\frac{\eta_R}{(1+t)}\}\gtreqless 0 \text{ if } \eta_R \gtreqless \frac{\gamma_\tau(1+t)}{p_j\left[1+(1+s_j)\,t\right]-\pi},\\
\frac{\partial \mu_i^{CB}}{\partial T} &= \frac{-2T}{N_i(1+t)}<0,\ \frac{\partial \mu_{i,P}^{CB}}{\partial T}=\frac{-T}{(1-n_i)N_i(1+t)}<0,\ \frac{\partial \mu_{i,R}^{CB}}{\partial T}=\frac{-T}{n_iN_i(1+t)}<0.
\end{aligned}$$

where $\tau = H$ if $i = 1$ and $\tau = L$ if $i = 2$. ■

Proof of Proposition 3.

Let $P_i = p_i[1 + (1 + s_i)t] - \pi$ where $i = 1, 2$. From (20) and (21), we can then obtain:

$$
\begin{aligned}
\frac{\partial E_1}{\partial p_1} &= \frac{1}{X_1}\left\{\frac{p_1}{X_1}\left[(\frac{\partial X_1}{\partial p_1})^2 - X_1\frac{\partial^2 X_1}{(\partial p_1)^2}\right] - \frac{\partial X_1}{\partial p_1}\right\} > 0, \frac{\partial E_1}{\partial s_1} = \frac{p_1}{(X_1)^2}\left[\frac{\partial X_1}{\partial p_1}\frac{\partial X_1}{\partial s_1} - \frac{\partial^2 X_1}{\partial p_1 \partial s_1}\right] > 0,\\
\frac{\partial E_1}{\partial p_2} &= \frac{p_1}{(X_1)^2}\left[\frac{\partial X_1}{\partial p_1}\frac{\partial X_1}{\partial p_2} - X_1\frac{\partial^2 X_1}{\partial p_1 \partial p_2}\right] < 0, \frac{\partial E_1}{\partial s_2} = \frac{p_1}{(X_1)^2}\left[\frac{\partial X_1}{\partial p_1}\frac{\partial X_1}{\partial s_2} - X_1\frac{\partial^2 X_1}{\partial p_1 \partial s_2}\right] < 0,\\
\frac{\partial E_1}{\partial N_1} &= \frac{p_1}{(X_1)^2}\left[\frac{\partial X_1}{\partial p_1}\frac{\partial X_1}{\partial N_1} - X_1\frac{\partial^2 X_1}{\partial p_1 \partial N_1}\right] \gtrless 0, \frac{\partial E_1}{\partial N_2} = \frac{p_1}{(X_1)^2}\left[\frac{\partial X_1}{\partial p_1}\frac{\partial X_1}{\partial N_2} - X_1\frac{\partial^2 X_1}{\partial p_1 \partial N_2}\right] < 0,\\
\frac{\partial E_1}{\partial T} &= -\frac{2(\gamma_H - \gamma_L)}{P_1 X_1}\left(\frac{p_1\left[1 + (1+s_1)\,t\right]}{P_1} + E_1\right) < 0, \frac{\partial E_2}{\partial p_2} = \frac{1}{X_2}\left\{\frac{p_2}{X_2}\left[(\frac{\partial X_2}{\partial p_2})^2 - X_2\frac{\partial^2 X_2}{(\partial p_2)^2}\right] - \frac{\partial X_2}{\partial p_2}\right\} > 0,\\
\frac{\partial E_2}{\partial s_2} &= \frac{p_2}{(X_2)^2}\left[\frac{\partial X_2}{\partial p_2}\frac{\partial X_2}{\partial s_2} - X_2\frac{\partial^2 X_2}{\partial p_2 \partial s_2}\right] > 0, \frac{\partial E_2}{\partial p_1} = \frac{p_2}{(X_2)^2}\left[\frac{\partial X_2}{\partial p_1}\frac{\partial X_2}{\partial p_2} - X_2\frac{\partial^2 X_2}{\partial p_1 \partial p_2}\right] < 0,\\
\frac{\partial E_2}{\partial s_1} &= \frac{p_2}{(X_2)^2}\left[\frac{\partial X_2}{\partial p_2}\frac{\partial X_2}{\partial s_1} - X_2\frac{\partial^2 X_2}{\partial p_2 \partial s_1}\right] < 0, \frac{\partial E_2}{\partial N_2} = \frac{p_2}{(X_2)^2}\left[\frac{\partial X_2}{\partial p_2}\frac{\partial X_2}{\partial N_2} - X_2\frac{\partial^2 X_2}{\partial p_2 \partial N_2}\right] \gtrless 0,\\
\frac{\partial E_2}{\partial N_1} &= \frac{p_2}{(X_2)^2}\left[\frac{\partial X_2}{\partial p_2}\frac{\partial X_2}{\partial N_1} - X_2\frac{\partial^2 X_2}{\partial p_2 \partial N_1}\right] < 0, \frac{\partial E_2}{\partial T} = \frac{2(\gamma_H - \gamma_L)}{P_2 (X_2)^2}\left(\frac{p_2\left[1 + (1+s_2)\,t\right]}{P_2} + E_2\right) > 0.
\end{aligned}
$$

where

$$
\begin{aligned}
\left(\tfrac{\partial X_1}{\partial p_1}\right)^2 - X_1\tfrac{\partial^2 X_1}{\partial p_1 \partial p_1} &= \tfrac{4[1+(1+s_1)t]^2}{P_1^2}\{\Phi_1 + 2(\gamma_H+\gamma_L)^2(\eta_P^2+\eta_R^2)\left[1+\tfrac{P_1(\eta_P-\eta_R)}{(1+t)}\right] + \tfrac{P_1^2(\eta_P^2+\eta_R^2)^2}{(1+t)^2}\\
&\quad + \left[\tfrac{\gamma_L(1+t)}{P_1}(\tfrac{\Psi_1}{4} + \tfrac{(\gamma_H^2+\gamma_L^2)}{\gamma_L}) + (\gamma_H+\gamma_L)(\eta_P-\eta_R)\right]\Psi_3(\eta_P+\eta_R)\} > 0,\\
\tfrac{\partial X_1}{\partial p_1}\tfrac{\partial X_1}{\partial s_1} - X_1\tfrac{\partial^2 X_1}{\partial p_1 \partial s_1} &= \tfrac{4p_1[1+(1+s_1)t]t}{P_1^2}\{\Phi_1 + 2(\gamma_H+\gamma_L)^2(\eta_P^2+\eta_R^2)\left[1+\tfrac{P_1(\eta_P-\eta_R)}{(1+t)}\right] + \tfrac{P_1^2(\eta_P^2+\eta_R^2)^2}{(1+t)^2}\\
&\quad + \left[\tfrac{\gamma_L(1+t)}{P_1}(\tfrac{\Psi_1}{4} + \tfrac{(\gamma_H^2+\gamma_L^2)}{\gamma_L}) + (\gamma_H+\gamma_L)(\eta_P-\eta_R)\right]\Psi_3(\eta_P+\eta_R)\} > 0,\\
\tfrac{\partial X_1}{\partial p_1}\tfrac{\partial X_1}{\partial p_2} - X_1\tfrac{\partial^2 X_1}{\partial p_1 \partial p_2} &= -[1+(1+s_1)\,t][1+(1+s_2)\,t]\left\{2\Gamma_1\Upsilon + \tfrac{(\gamma_H+\gamma_L)(\gamma-1)\Psi_5\eta_p}{P_1^2}\right\} - \tfrac{\Psi_3(\eta_P+\eta_R)}{P_1^2} < 0,\\
\tfrac{\partial X_1}{\partial p_1}\tfrac{\partial X_1}{\partial s_2} - X_1\tfrac{\partial^2 X_1}{\partial p_1 \partial s_2} &= -p_2[1+(1+s_1)\,t]t\left\{\Gamma_1\Upsilon + \tfrac{(\gamma_H+\gamma_L)(\gamma-1)\Psi_5\eta_P}{P_1^2}\right\} - \tfrac{\Psi_3(\eta_P+\eta_R)}{P_1^2} < 0,\\
\tfrac{\partial X_1}{\partial p_1}\tfrac{\partial X_1}{\partial N_1} - X_1\tfrac{\partial^2 X_1}{\partial p_1 \partial N_1} &= (1-n_1)[1+(1+s_1)t]\{2\Gamma_1\left[\eta_R - \tfrac{(1+t)\gamma_H}{P_1}\right] + \tfrac{(1+t)\gamma_L}{P_1^2}\left[(\Psi_1-\gamma\Psi_3)\eta_R + \gamma\Psi_7\eta_P\right]\} \gtrless 0,\\
\tfrac{\partial X_1}{\partial p_1}\tfrac{\partial X_1}{\partial N_2} - X_1\tfrac{\partial^2 X_1}{\partial p_1 \partial N_2} &= -2[1+(1+s_1)\,t]\Gamma_1\left[\tfrac{(2-n_2)\gamma_H(1+t)}{P_1} + (1-n_2)\eta_P - \eta_R\right] - \tfrac{(1-n_1)\eta_p+\Psi_3(\eta_P+\eta_R)}{P_1}\\
&\quad - \tfrac{(2-n_2)[1+(1+s_1)t](\gamma-1)\Psi_5\eta_P}{P_1^2} < 0,\\
\left(\tfrac{\partial X_2}{\partial p_2}\right)^2 - X_2\tfrac{\partial^2 X_2}{\partial p_2 \partial p_2} &= \tfrac{4[1+(1+s_2)t]^2}{P_2^2}\{\Phi_2 + 2(\gamma_H+\gamma_L)^2(\eta_P^2+\eta_R^2)\left[1+\tfrac{P_2(\eta_P-\eta_R)}{(1+t)}\right] + \tfrac{P_2^2(\eta_P^2+\eta_R^2)^2}{(1+t)^2}\\
&\quad + \left[\tfrac{\gamma_L(1+t)}{P_2}(\tfrac{\Psi_2}{4} + \tfrac{(\gamma_H^2+\gamma_L^2)}{\gamma_L}) + (\gamma_H+\gamma_L)(\eta_P-\eta_R)\right]\Psi_4(\eta_P+\eta_R)\} > 0,\\
\tfrac{\partial X_2}{\partial p_2}\tfrac{\partial X_2}{\partial s_2} - X_2\tfrac{\partial^2 X_2}{\partial p_2 \partial s_2} &= \tfrac{4p_2[1+(1+s_2)t]t}{P_2^2}\{\Phi_2 + 2(\gamma_H+\gamma_L)^2(\eta_P^2+\eta_R^2)\left[1+\tfrac{P_2(\eta_P-\eta_R)}{(1+t)}\right] + \tfrac{P_2^2(\eta_P^2+\eta_R^2)^2}{(1+t)^2}\\
&\quad + \left[\tfrac{\gamma_L(1+t)}{P_2}(\tfrac{\Psi_2}{4} + \tfrac{(\gamma_H^2+\gamma_L^2)}{\gamma_L}) + (\gamma_H+\gamma_L)(\eta_P-\eta_R)\right]\Psi_4(\eta_p+\eta_r)\} > 0,\\
\tfrac{\partial X_2}{\partial p_1}\tfrac{\partial X_2}{\partial p_2} - X_2\tfrac{\partial^2 X_2}{\partial p_1 \partial p_2} &= -[1+(1+s_2)\,t][1+(1+s_1)\,t]\left\{2\Gamma_2\Upsilon + \tfrac{(\gamma_H+\gamma_L)(\gamma-1)\Psi_6\eta_P}{P_2^2}\right\} - \tfrac{\Psi_4(\eta_P+\eta_R)}{P_2^2} < 0,\\
\tfrac{\partial X_2}{\partial p_2}\tfrac{\partial X_2}{\partial s_1} - X_2\tfrac{\partial^2 X_2}{\partial p_2 \partial s_1} &= -p_2[1+(1+s_2)\,t]t\left\{\Gamma_2\Upsilon + \tfrac{(\gamma_H+\gamma_L)(\gamma-1)\Psi_6\eta_P}{P_2^2}\right\} - \tfrac{\Psi_4(\eta_P+\eta_R)}{P_2^2} < 0,\\
\tfrac{\partial X_2}{\partial p_2}\tfrac{\partial X_2}{\partial N_2} - X_2\tfrac{\partial^2 X_2}{\partial p_2 \partial N_2} &= (1-n_2)[1+(1+s_2)t]\{2\Gamma_2\left[\eta_R - \tfrac{(1+t)\gamma_L}{P_2}\right] + \tfrac{(1+t)\gamma_L}{P_2^2}\left[(\Psi_2-\Psi_4)\eta_R + \Psi_8\eta_P\right]\} \gtrless 0,\\
\tfrac{\partial X_2}{\partial p_2}\tfrac{\partial X_2}{\partial N_1} - X_2\tfrac{\partial^2 X_2}{\partial p_2 \partial N_1} &= -2[1+(1+s_2)\,t]\Gamma_2\left[\tfrac{(2-n_1)\gamma_H(1+t)}{P_2} + (1-n_1)\eta_P - \eta_R\right] - \tfrac{(1-n_2)\eta_P+\Psi_4(\eta_P+\eta_R)}{P_2}\\
&\quad - \tfrac{(2-n_1)[1+(1+s_2)t](\gamma-1)\Psi_6\eta_P}{P_2^2} < 0,
\end{aligned}
$$

$$\Phi_1 = \frac{(1+t)^2}{P_1^2} + \frac{2(1+t)(\eta_P-\eta_R)(\gamma_H+\gamma_L)(\gamma_H^2+\gamma_L^2)}{P_1} + (\gamma_H^2+\gamma_L^2) + (\eta_P-\eta_R)^2 > 0,$$
$$\Phi_2 = \frac{(1+t)^2}{P_2^2} + \frac{2(1+t)(\eta_P-\eta_R)(\gamma_H+\gamma_L)(\gamma_H^2+\gamma_L^2)}{P_2} + (\gamma_H^2+\gamma_L^2) + (\eta_P-\eta_R)^2 > 0,$$
$$\Gamma_1 = \frac{(1+t)(\gamma_H^2+\gamma_L^2)}{P_1^2} + \frac{(\gamma_H+\gamma_L)(\eta_P-\eta_R)}{P_1} + \frac{(\eta_P^2+\eta_R^2)}{(1+t)} > 0,\ \Gamma_2 = \frac{(1+t)(\gamma_H^2+\gamma_L^2)}{P_2^2} + \frac{(\gamma_H+\gamma_L)(\eta_P-\eta_R)}{P_2} + \frac{(\eta_P^2+\eta_R^2)}{(1+t)} > 0,$$
$$\Psi_1 = \gamma\Psi_5 + (2-n_2)N_2 - (\varepsilon_{2,P}^* + \varepsilon_{2,r}^*) > 0,\ \Psi_2 = \varepsilon_{2,P}^* + \varepsilon_{2,R}^* - (1-n_2)N_2 + \gamma\Psi_6 > 0,$$
$$\Psi_3 = \varepsilon_{1,R}^* - (1-n_1)N_1 + N_2 - \varepsilon_{2,R}^* > 0,\ \Psi_4 = \varepsilon_{2,R}^* - (1-n_2)N_2 + N_1 - \varepsilon_{1,R}^* > 0,$$
$$\Psi_5 = \varepsilon_{1,P}^* + \varepsilon_{1,R}^* - (1-n_1)N_1 > 0,\ \Psi_6 = (2-n_1)N_1 - (\varepsilon_{1,P}^* + \varepsilon_{1,R}^*) > 0,$$
$$\Psi_7 = \varepsilon_{1,P}^* + [(1-n_2)N_2 - \varepsilon_{2,P}^*] > 0,\ \Psi_8 = \varepsilon_{2,P}^* + [(1-n_1)N_1 - \varepsilon_{1,P}^*] > 0,$$
$$\Upsilon = \frac{2(1+t)(\gamma_H^2+\gamma_L^2)+(\gamma_H+\gamma_L)(\eta_P-\eta_R)(P_1+P_2)}{P_1P_2} + \frac{2(\eta_P^2+\eta_R^2)}{(1+t)} > 0. \blacksquare$$

Proof of Theorem 1. Let $\Omega_1 = (1-\sigma_1)(p_1-\pi) - c_1 > 0$ and $\Omega_2 = (1-\sigma_2)(p_2-\pi) - c_2 > 0$. From (18) and (19), we obtain the slope of locus $R1$ and locus $R2$, respectively:

$$\left.\frac{\partial p_1}{\partial p_2}\right|_{R1} = \frac{\Omega_1 \frac{\partial E_1}{\partial p_2}}{\frac{[c_1+(1-\sigma_1)\pi]E_1}{p_1} + \Omega_1\frac{\partial E_1}{\partial p_1}} > 0 \text{ and } \left.\frac{\partial p_1}{\partial p_2}\right|_{R2} = \frac{\frac{[c_2+(1-\sigma_2)\pi]E_2}{p_2} + \Omega_2\frac{\partial E_2}{\partial p_2}}{\Omega_2\frac{\partial E_2}{\partial p_1}} > 0,$$

indicating that both loci $R1$ and $R2$ are upward sloping. We can further obtain that locus $R1$ intersects the p_1-coordinate at $\pi + \frac{c_1 \cdot \lim_{p_2\to 0} E_1}{(1-\sigma_1)(\lim_{p_2\to 0} E_1 - 1)} > 0$, and locus $R2$ intersects the p_2-coordinate at $\pi + \frac{c_2 \cdot \lim_{p_1\to 0} E_2}{(1-\sigma_2)(\lim_{p_1\to 0} E_2 - 1)} > 0$, as shown in Figure 1.

To ensure the existence and uniqueness of the equilibrium casino prices (p_1^*, p_2^*), we can prove from (18) and (19) that the determinant of the Jacobian is:

$$\begin{aligned}\Delta &\equiv \frac{\partial^2\Pi_1}{\partial(p_1)^2}\frac{\partial^2\Pi_2}{\partial(p_2)^2} - \frac{\partial^2\Pi_1}{\partial p_1\partial p_2}\frac{\partial^2\Pi_2}{\partial p_1\partial p_2}\\ &= \frac{\Omega_1\Omega_2(p_1-\pi)(p_2-\pi)\left[\frac{\partial E_1}{\partial p_1}\frac{\partial E_2}{\partial p_2} - \frac{\partial E_1}{\partial p_2}\frac{\partial E_2}{\partial p_1}\right] + c_1E_1\Omega_2\frac{\partial E_2}{\partial p_2} + c_2E_2(\Omega_1\frac{\partial E_1}{\partial p_1} + c_1E_1)}{(1-\sigma_1)(p_1-\pi)^2(1-\sigma_2)(p_2-\pi)^2} > 0,\end{aligned}$$

provided that $\frac{\partial E_1}{\partial p_1}\frac{\partial E_2}{\partial p_2} > \frac{\partial E_1}{\partial p_2}\frac{\partial E_2}{\partial p_1}$, implying that each city's casino firm is more responsive to its own price changes. This also implies that Casino 1's reaction function ($R1$) should be flatter than that of Casino 2 ($R2$) in the (p_1, p_2) space, as shown in Figure 1. $\blacksquare$

Proof of Proposition 4. From (18) and (19), , we have:

$$\begin{aligned}\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}\begin{bmatrix} dp_1 \\ dp_2 \end{bmatrix} &= \begin{bmatrix} a_{13} \\ a_{23} \end{bmatrix} d\sigma_1 + \begin{bmatrix} a_{14} \\ a_{24} \end{bmatrix} d\sigma_2 + \begin{bmatrix} a_{15} \\ a_{25} \end{bmatrix} ds_1 + \begin{bmatrix} a_{16} \\ a_{26} \end{bmatrix} ds_2 \\ &\quad + \begin{bmatrix} a_{17} \\ a_{27} \end{bmatrix} dN_1 + \begin{bmatrix} a_{18} \\ a_{28} \end{bmatrix} dN_2 + \begin{bmatrix} a_{19} \\ a_{29} \end{bmatrix} dT.\end{aligned}$$

Accordingly, we can derive:

$$\begin{aligned}
\frac{\partial p_1^*}{\partial \sigma_1} &= \frac{(a_{13}a_{22}-a_{12}a_{23})}{\Delta} > 0, \; \frac{\partial p_2^*}{\partial \sigma_1} = \frac{(a_{11}a_{23}-a_{13}a_{21})}{\Delta} > 0,\\
\frac{\partial p_1^*}{\partial \sigma_2} &= \frac{(a_{14}a_{22}-a_{12}a_{24})}{\Delta} > 0, \; \frac{\partial p_2^*}{\partial \sigma_2} = \frac{(a_{11}a_{24}-a_{14}a_{21})}{\Delta} > 0,\\
\frac{\partial p_1^*}{\partial s_1} &= \frac{(a_{15}a_{22}-a_{12}a_{25})}{\Delta} \gtreqless 0, \; \frac{\partial p_2^*}{\partial s_1} = \frac{(a_{11}a_{25}-a_{15}a_{21})}{\Delta} \gtreqless 0,
\end{aligned}$$

$$\begin{aligned}
\frac{\partial p_1^*}{\partial s_2} &= \frac{(a_{16}a_{22}-a_{12}a_{26})}{\Delta} \gtreqless 0, \; \frac{\partial p_2^*}{\partial s_2} = \frac{(a_{11}a_{26}-a_{16}a_{21})}{\Delta} \gtreqless 0,\\
\frac{\partial p_1^*}{\partial N_1} &= \frac{(a_{17}a_{22}-a_{12}a_{27})}{\Delta} \gtreqless 0, \; \frac{\partial p_2^*}{\partial N_1} = \frac{(a_{11}a_{27}-a_{17}a_{21})}{\Delta} \gtreqless 0,\\
\frac{\partial p_1^*}{\partial N_2} &= \frac{(a_{18}a_{22}-a_{12}a_{28})}{\Delta} \gtreqless 0, \; \frac{\partial p_2^*}{\partial N_2} = \frac{(a_{11}a_{28}-a_{18}a_{21})}{\Delta} \gtreqless 0,\\
\frac{\partial p_1^*}{\partial T} &= \frac{(a_{19}a_{22}-a_{12}a_{29})}{\Delta} \gtreqless 0, \; \frac{\partial p_2^*}{\partial T} = \frac{(a_{11}a_{29}-a_{19}a_{21})}{\Delta} \gtreqless 0,
\end{aligned}$$

where
$a_{11} = -\frac{[(1-\sigma_1)(p_1-\pi)-c_1](p_1-\pi)\frac{\partial E_1}{\partial p_1}+c_1E_1}{(1-\sigma_1)(p_1-\pi)^2} < 0$, $a_{12} = -\frac{[(1-\sigma_1)(p_1-\pi)-c_1]\frac{\partial E_1}{\partial p_2}}{(1-\sigma_1)(p_1-\pi)} > 0$,
$a_{21} = -\frac{[(1-\sigma_2)(p_2-\pi)-c_2](p_2-\pi)\frac{\partial E_2}{\partial p_1}}{(1-\sigma_2)(p_2-\pi)} > 0$, $a_{22} = -\frac{[(1-\sigma_2)(p_2-\pi)-c_2](p_2-\pi)\frac{\partial E_2}{\partial p_2}+c_2E_2}{(1-\sigma_2)(p_2-\pi)^2} < 0$,
$a_{13} = -\frac{c_1E_1}{(1-\sigma_1)^2(p_1-\pi)} < 0$, $a_{23} = 0$, $a_{14} = 0$, $a_{24} = -\frac{c_2E_2}{(1-\sigma_2)^2(p_2-\pi)} < 0$,
$a_{15} = \frac{[(1-\sigma_1)(p_1-\pi)-c_1]\frac{\partial E_1}{\partial s_1}}{(1-\sigma_1)(p_1-\pi)} > 0$, $a_{25} = \frac{[(1-\sigma_2)(p_2-\pi)-c_2]\frac{\partial E_2}{\partial s_1}}{(1-\sigma_2)(p_2-\pi)} < 0$,
$a_{16} = \frac{[(1-\sigma_1)(p_1-\pi)-c_1]\frac{\partial E_1}{\partial s_2}}{(1-\sigma_1)(p_1-\pi)} < 0$, $a_{26} = \frac{[(1-\sigma_2)(p_2-\pi)-c_2]\frac{\partial E_2}{\partial s_2}}{(1-\sigma_2)(p_2-\pi)} > 0$,
$a_{17} = \frac{[(1-\sigma_1)(p_1-\pi)-c_1]\frac{\partial E_1}{\partial N_1}}{(1-\sigma_1)(p_1-\pi)} \gtreqless 0$, $a_{27} = \frac{[(1-\sigma_2)(p_2-\pi)-c_2]\frac{\partial E_2}{\partial N_1}}{(1-\sigma_2)(p_2-\pi)} < 0$,
$a_{18} = \frac{[(1-\sigma_1)(p_1-\pi)-c_1]\frac{\partial E_1}{\partial N_2}}{(1-\sigma_1)(p_1-\pi)} < 0$, $a_{28} = \frac{[(1-\sigma_2)(p_2-\pi)-c_2]\frac{\partial E_2}{\partial N_2}}{(1-\sigma_2)(p_2-\pi)} \gtreqless 0$,
$a_{19} = \frac{[(1-\sigma_1)(p_1-\pi)-c_1]\frac{\partial E_1}{\partial T}}{(1-\sigma_1)(p_1-\pi)} < 0$, $a_{29} = \frac{[(1-\sigma_2)(p_2-\pi)-c_2]\frac{\partial E_2}{\partial T}}{(1-\sigma_2)(p_2-\pi)} > 0$. ■

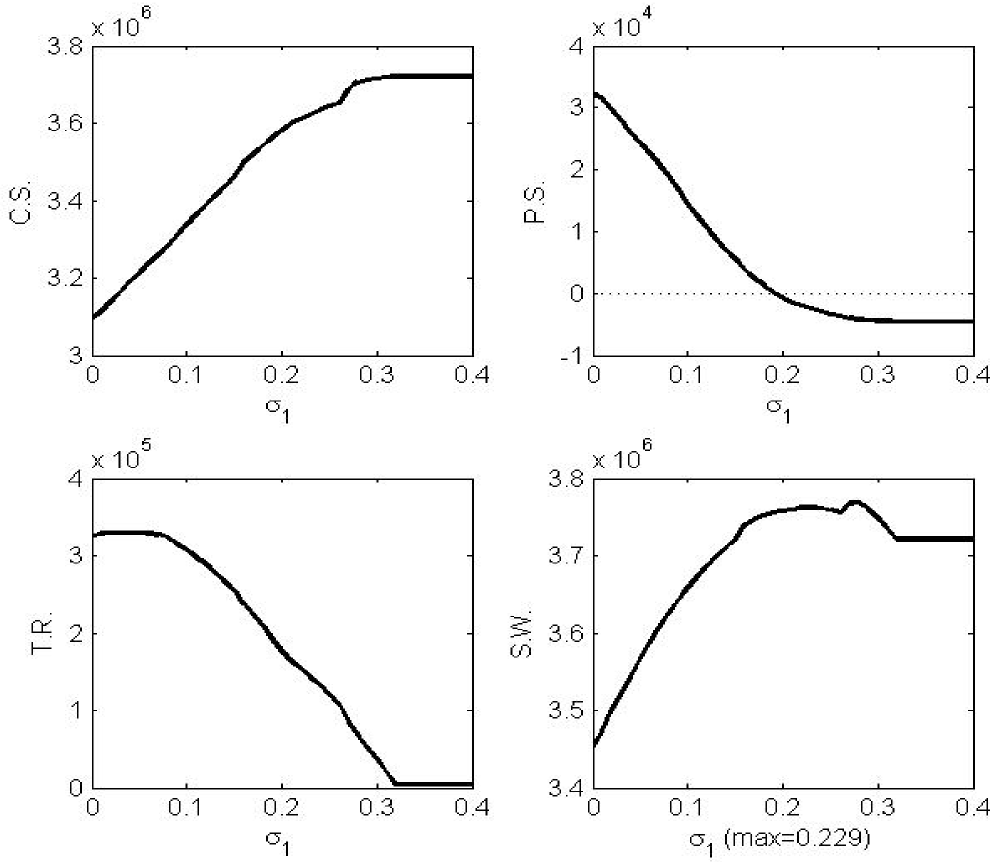


Figure A1-a. Optimal Casino Revenue Tax: Detroit (d1=d2=1.5)

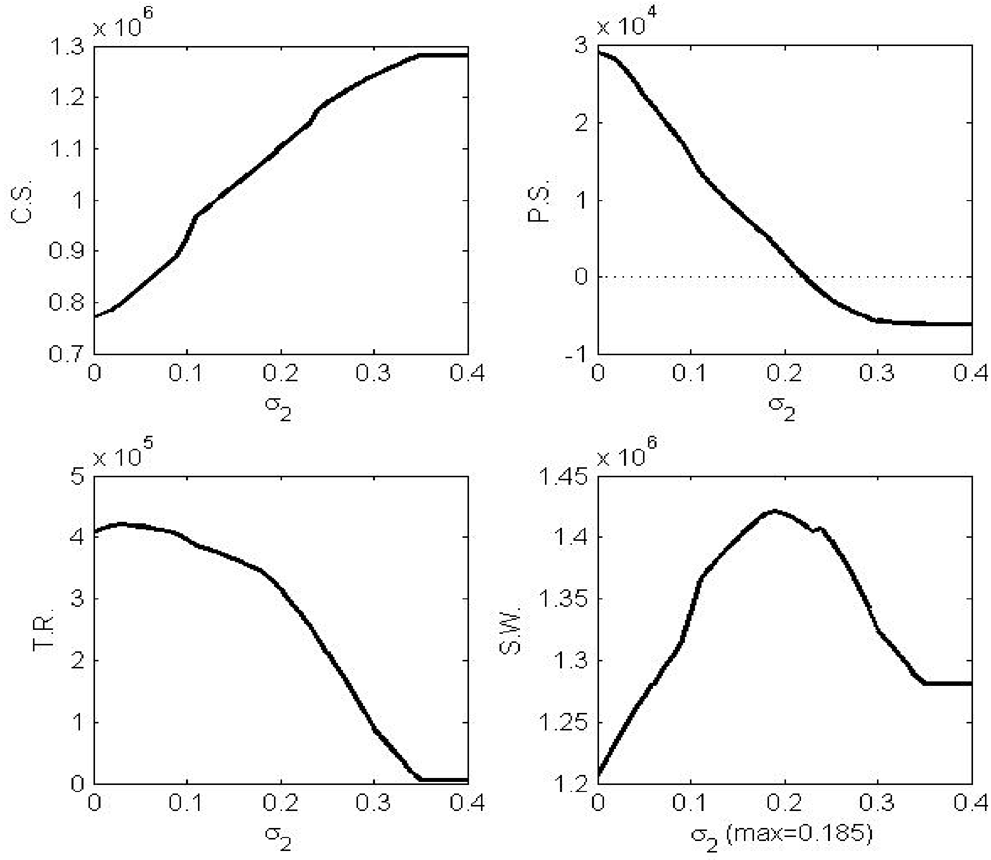


Figure A1-b. Optimal Casino Revenue Tax: Windsor (d1=d2=1.5)

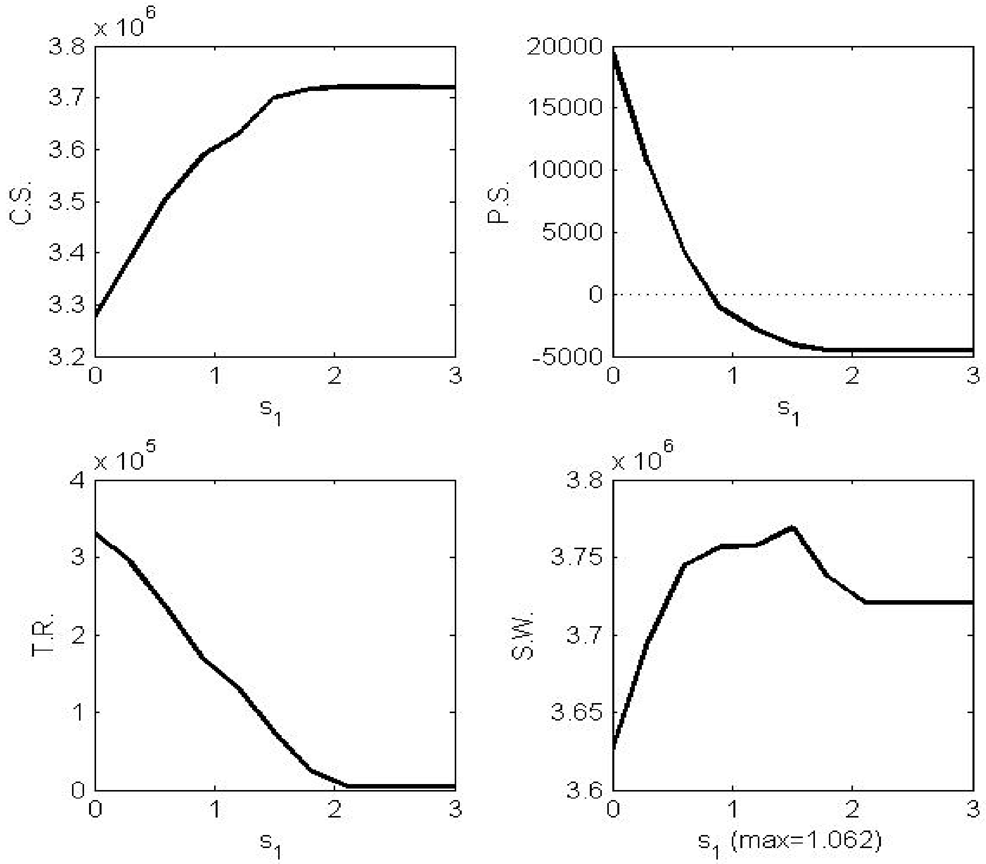


Figure A1-c. Optimal Casino Tax Surcharge: Detroit (d1=d2=1.5)

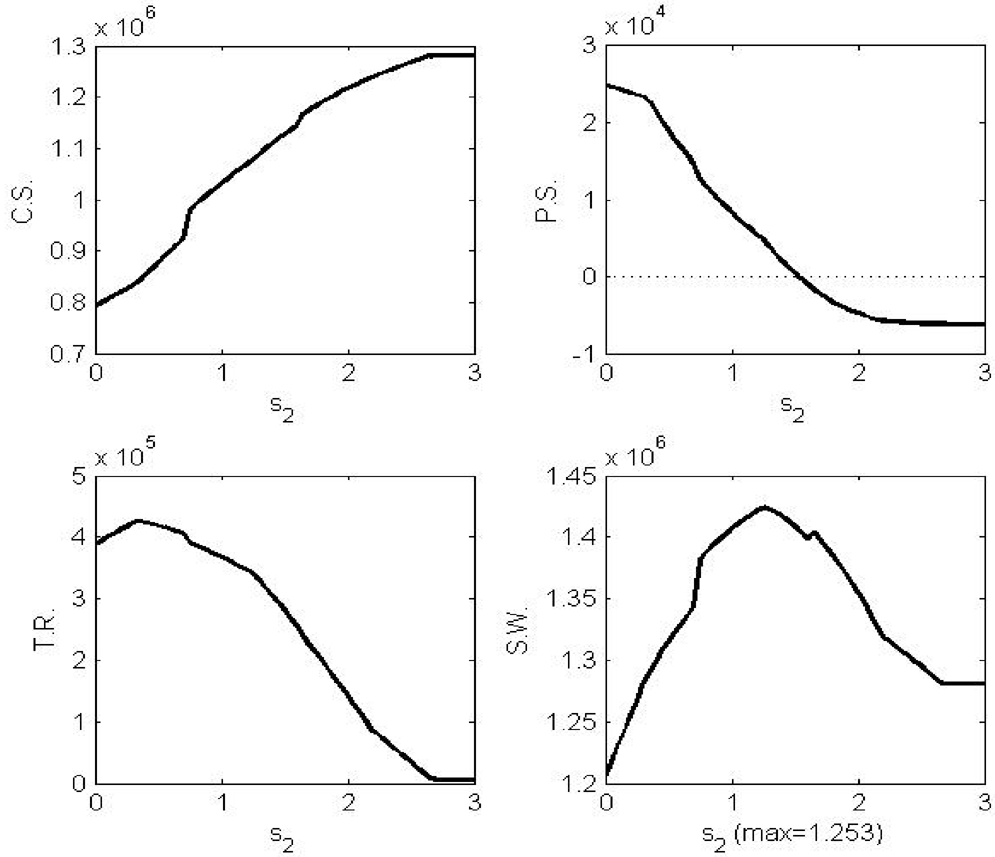


Figure A1-d. Optimal Casino Tax Surcharge: Windsor (d1=d2=1.5)

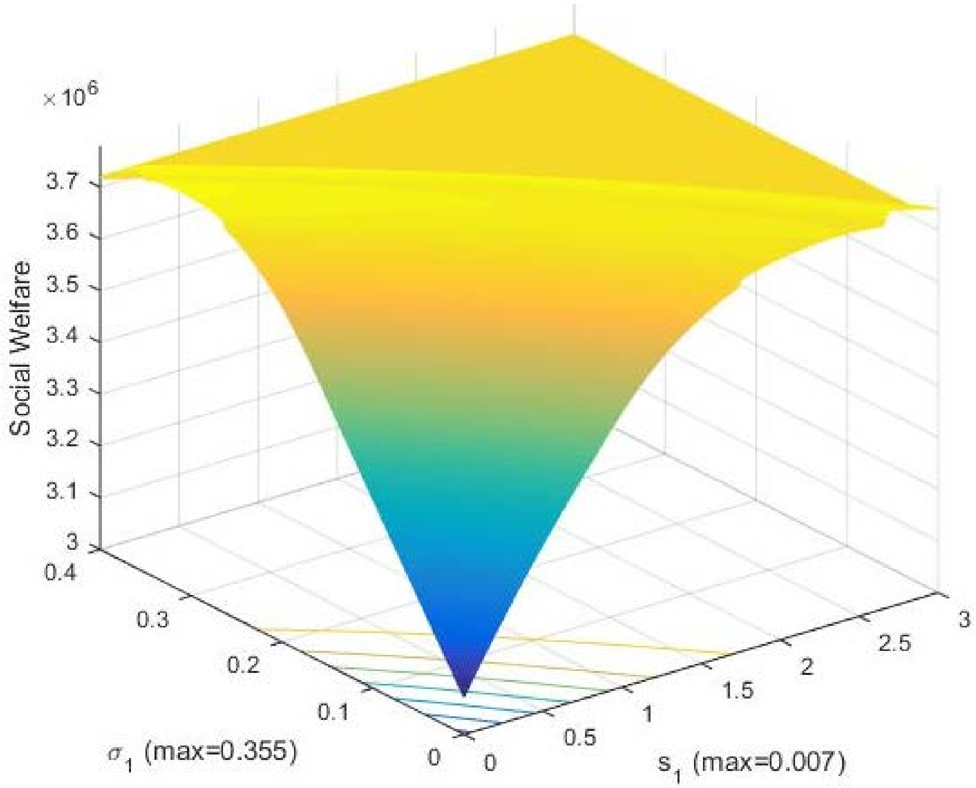


Figure A2-a. Optimal Casino Tax Mix: Detroit (d1=d2=1.5)

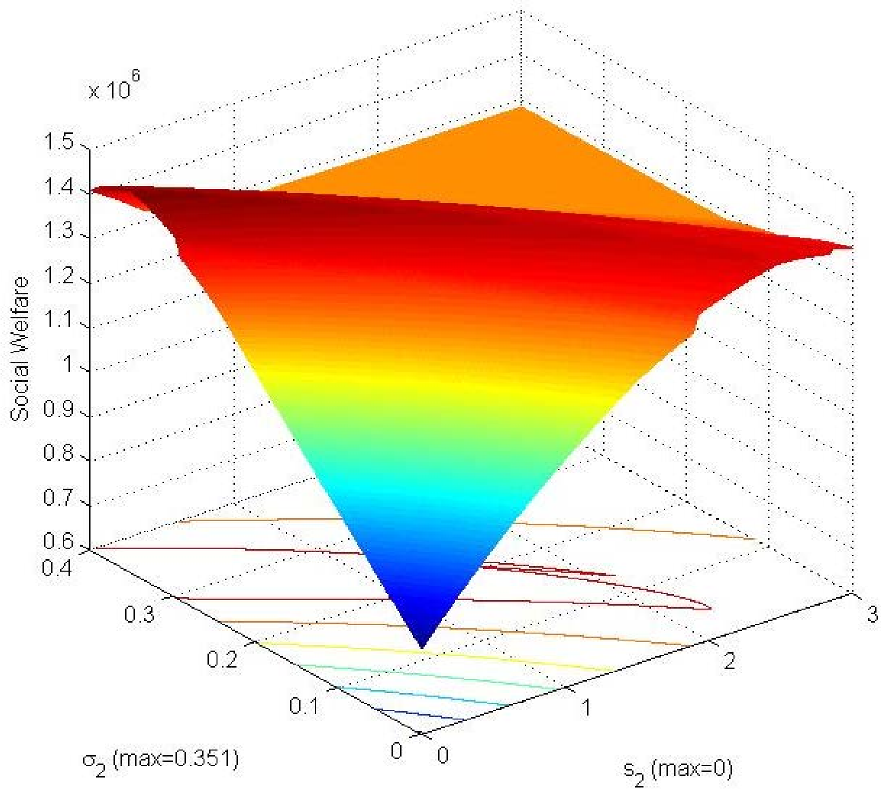


Figure A2-b. Optimal Casino Tax Mix: Windsor (d1=d2=1.5)

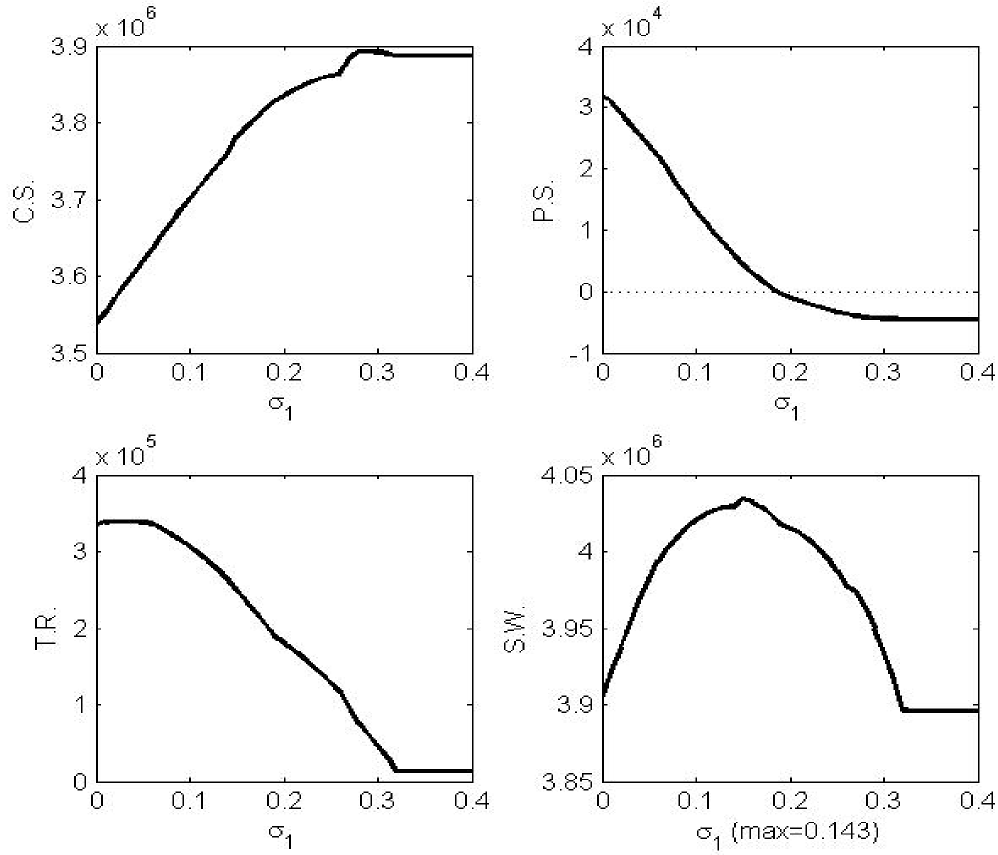


Figure A3-a. Optimal Casino Revenue Tax: Detroit (including winning withholdings)

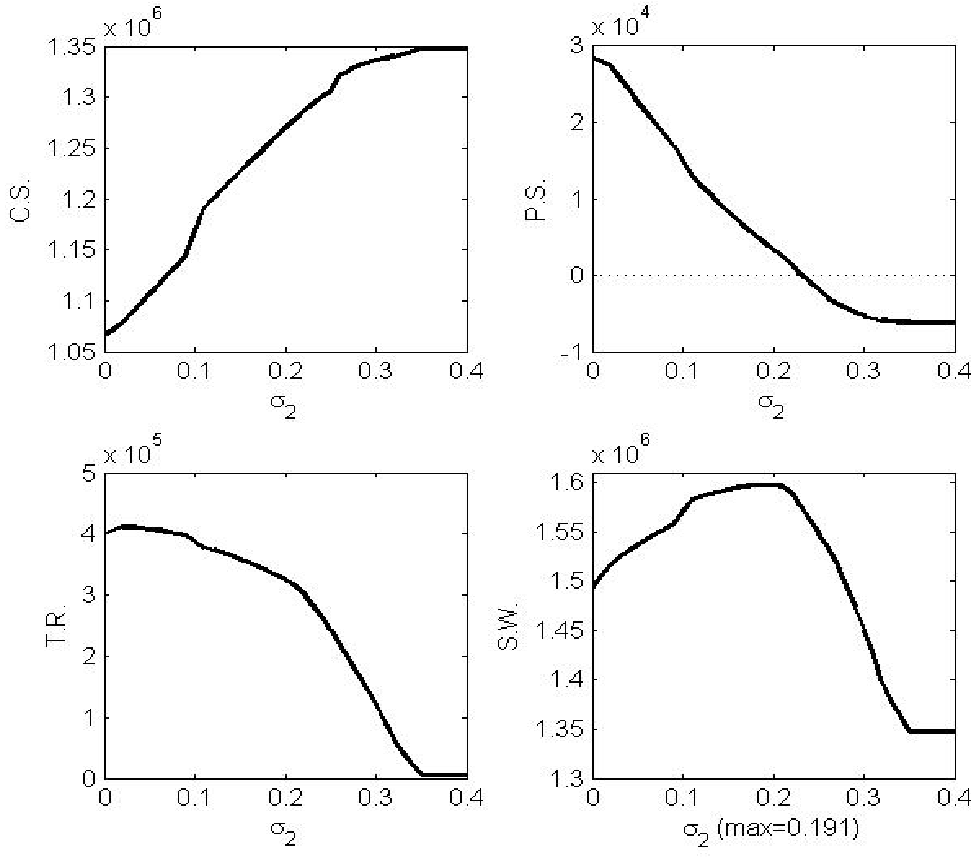


Figure A3-b. Optimal Casino Revenue Tax: Windsor (including winning withholdings)

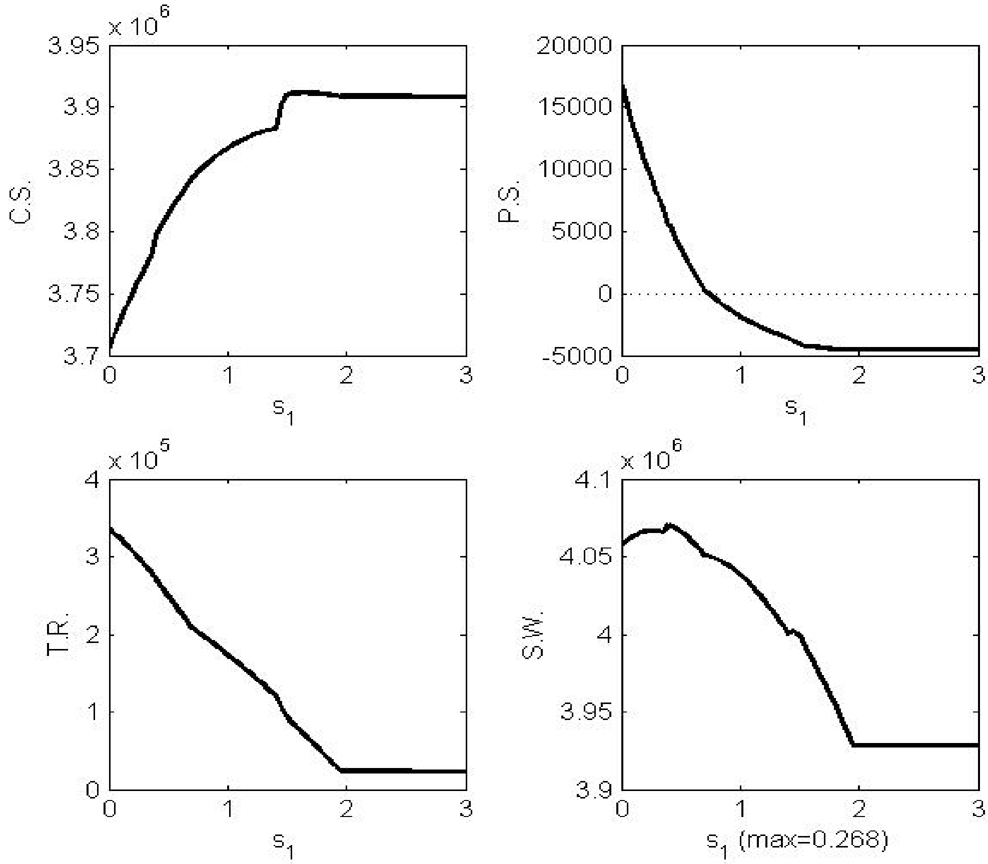


Figure A3-c. Optimal Casino Tax Surcharge: Detroit (including winning withholdings)

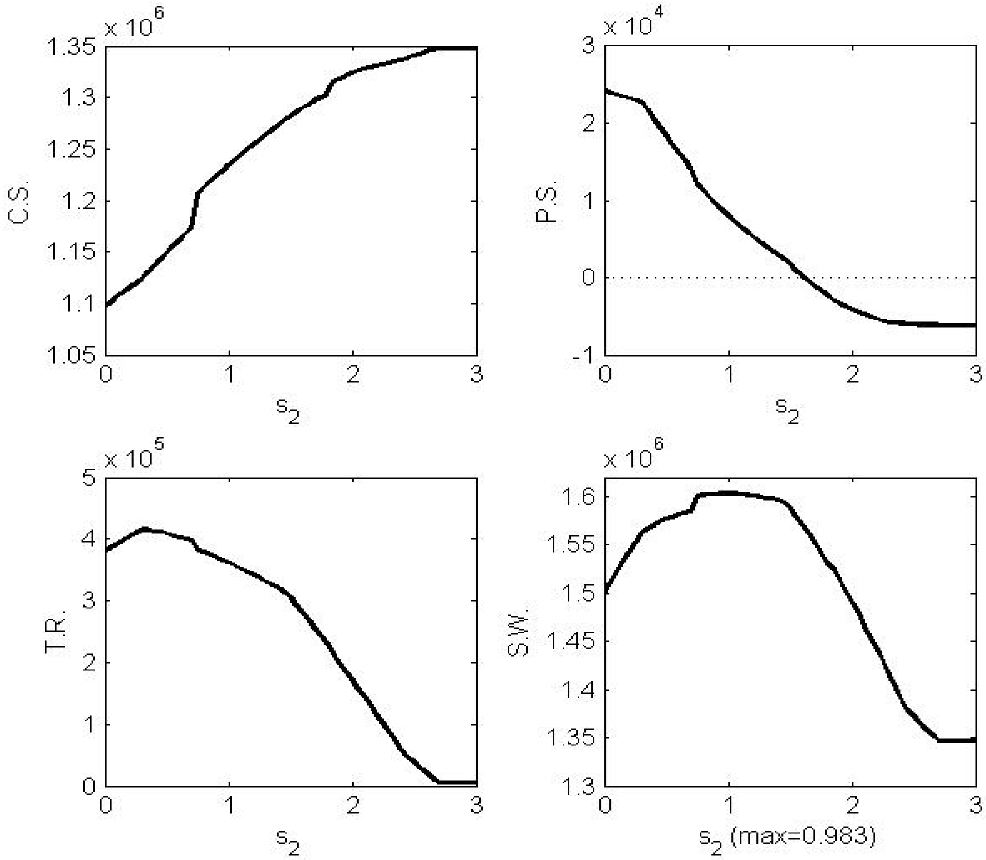


Figure A3-d. Optimal Casino Tax Surcharge: Windsor (including winning withholdings)

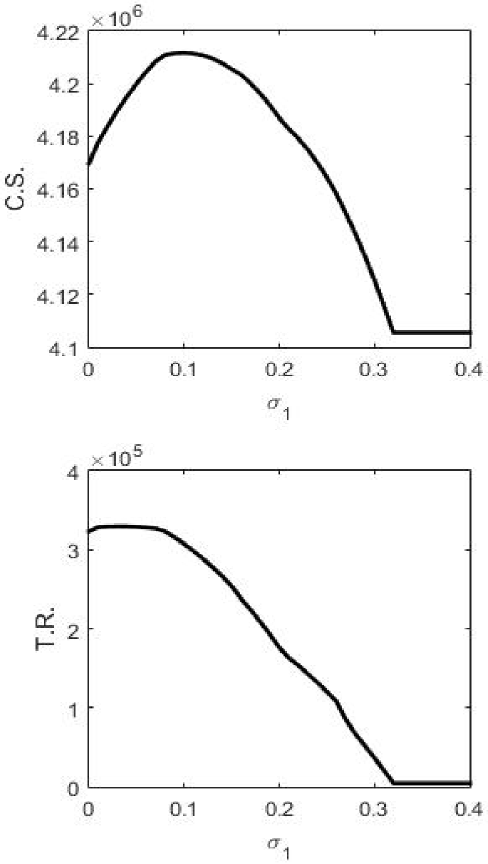


Figure A4-a. Optimal Casino Revenue Tax: Detroit (d1=d2=0.2)

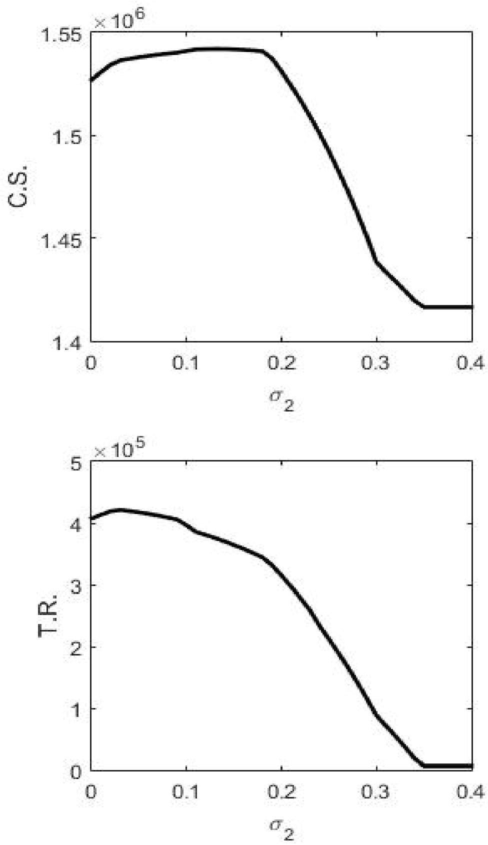


Figure A4-b. Optimal Casino Revenue Tax: Windsor (d1=d2=0.2)

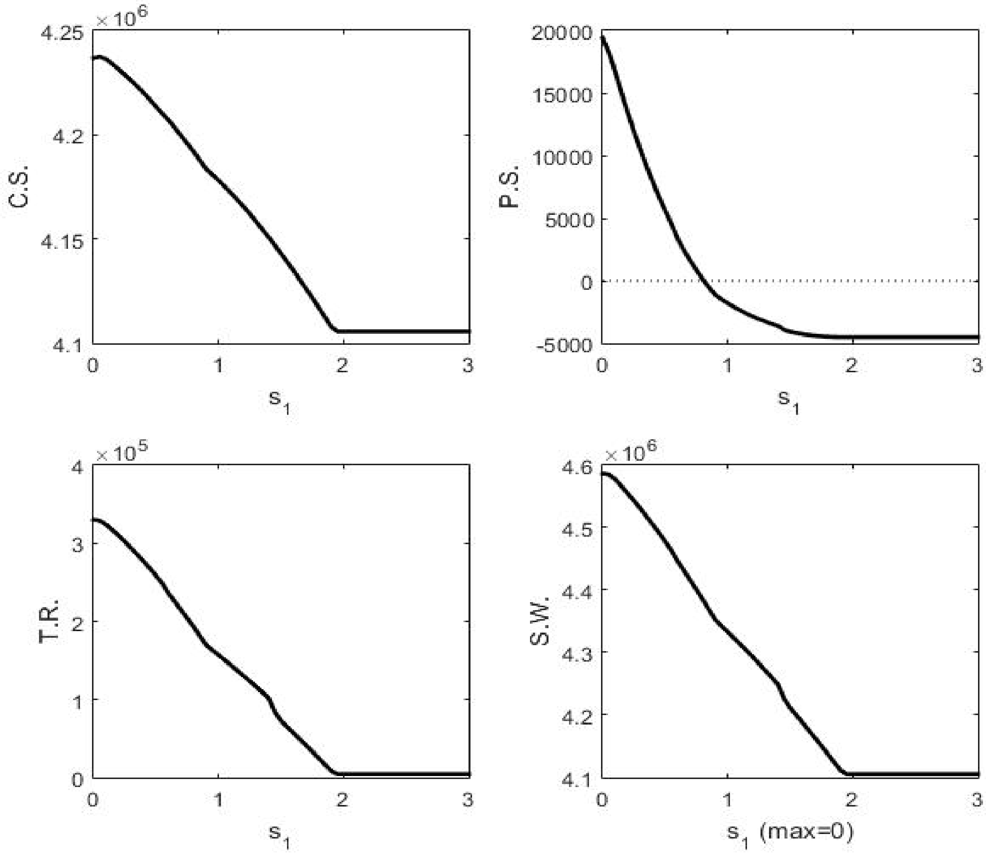


Figure A4-c. Optimal Casino Tax Surcharge: Detroit (d1=d2=0.2)

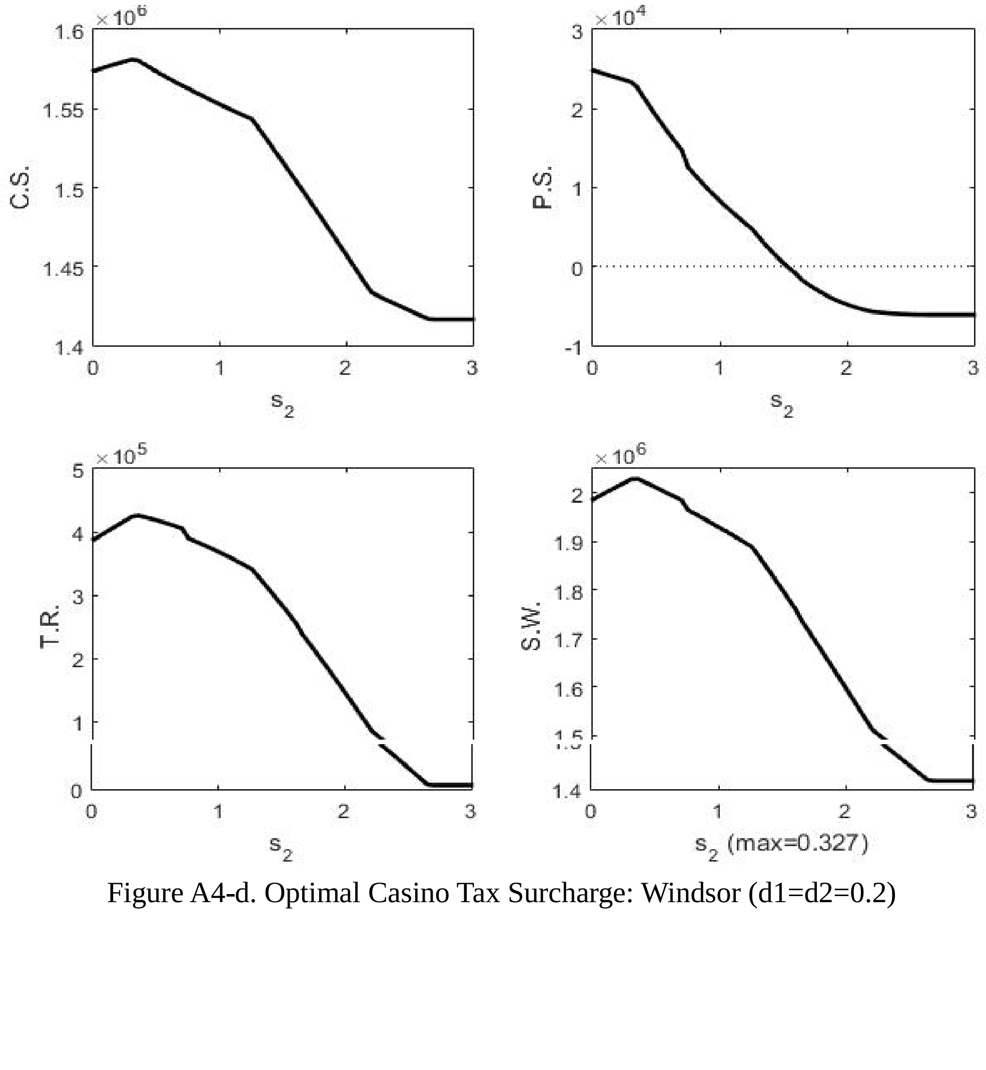


Figure A4-d. Optimal Casino Tax Surcharge: Windsor (d1=d2=0.2)

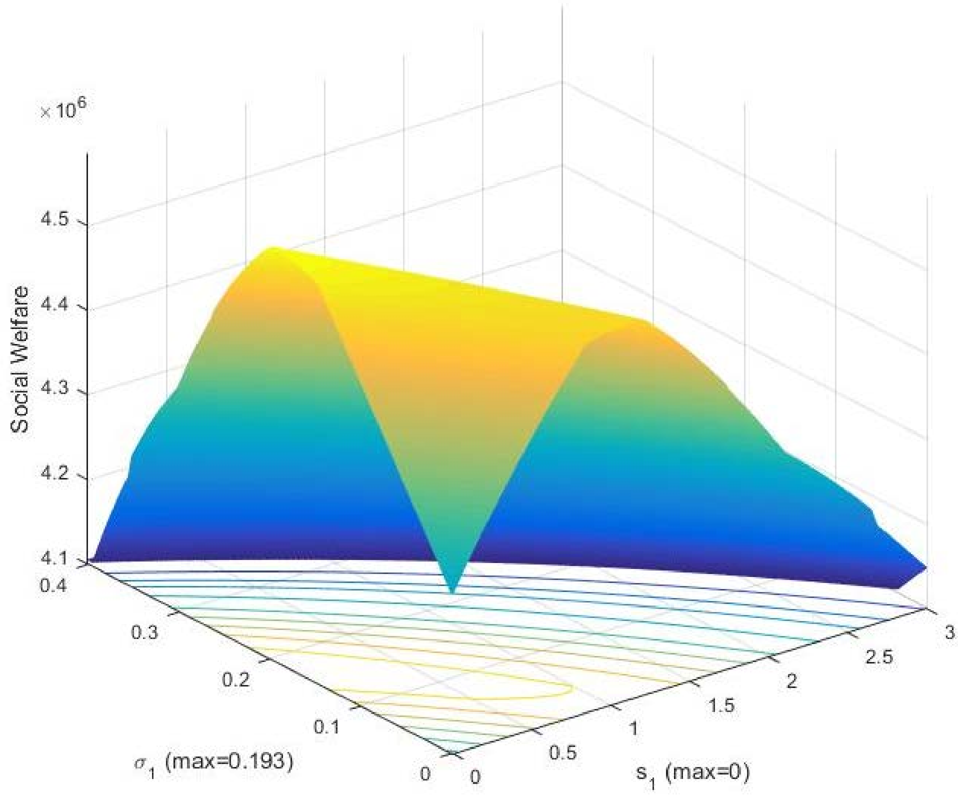


Figure A5-a. Optimal Casino Tax Mix: Detroit (d1=d2=0.2)

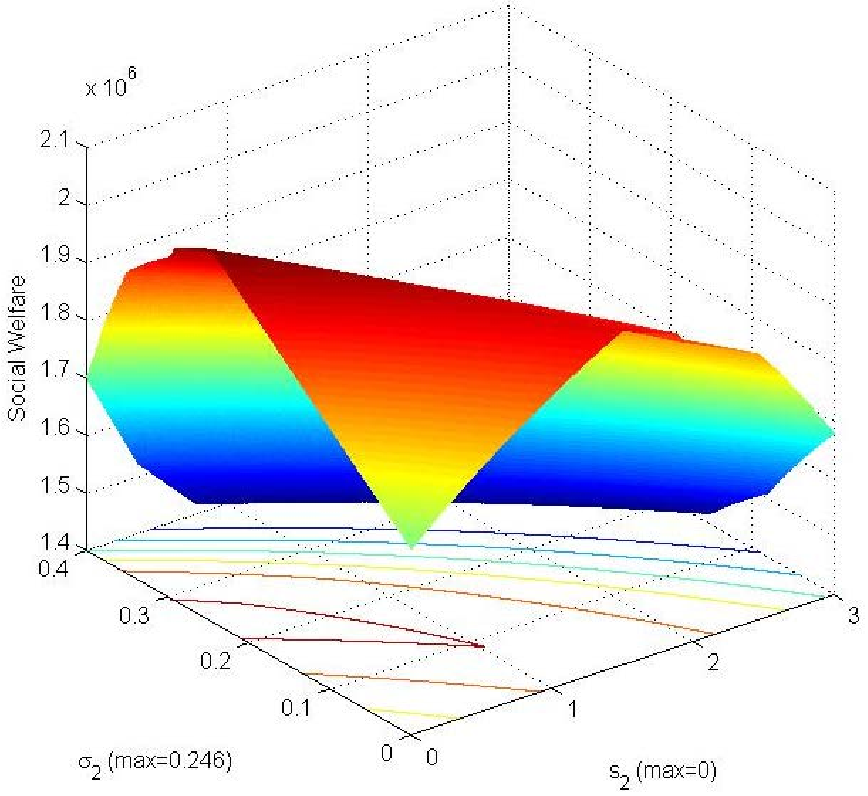


Figure A5-b. Optimal Casino Tax Mix: Windsor (d1=d2=0.2)

(Benchmark) $\sigma_1 = 0.19$		(+1%) $\sigma_1 = 0.1919$		(+5%) $\sigma_1 = 0.1995$		(-1%) $\sigma_1 = 0.1881$		(-5%) $\sigma_1 = 0.1805$	
p_1^*	1.284	1.285	0.060%	1.288	0.304%	1.284	-0.060%	1.281	-0.297%
p_2^*	1.260	1.260	0.009%	1.261	0.045%	1.260	-0.009%	1.260	-0.045%
p	0.981	0.981	-0.051%	0.979	-0.258%	0.982	0.051%	0.984	0.253%
$x_{11,P}^*$	7776.537	7770.371	-0.079%	7745.620	-0.398%	7782.694	0.079%	7807.258	0.395%
$x_{12,P}^*$	7687.955	7687.064	-0.012%	7683.482	-0.058%	7688.844	0.012%	7692.353	0.057%
$x_{22,P}^*$	7616.901	7616.028	-0.011%	7612.516	-0.058%	7617.773	0.011%	7621.214	0.057%
$x_{21,P}^*$	7703.748	7697.703	-0.078%	7673.436	-0.393%	7709.785	0.078%	7733.867	0.391%
$x_{11,R}^*$	3703.537	3697.371	-0.166%	3672.620	-0.835%	3709.694	0.166%	3734.258	0.829%
$x_{12,R}^*$	3614.955	3614.064	-0.025%	3610.482	-0.124%	3615.844	0.025%	3619.353	0.122%
$x_{22,R}^*$	3543.901	3543.028	-0.025%	3539.516	-0.124%	3544.773	0.025%	3548.214	0.122%
$x_{21,R}^*$	3630.748	3624.703	-0.166%	3600.436	-0.835%	3636.785	0.166%	3660.867	0.830%
$e_{11,P}^*$	0.831	0.830	-0.131%	0.826	-0.659%	0.832	0.131%	0.836	0.652%
$e_{12,P}^*$	0.815	0.815	-0.020%	0.814	-0.098%	0.815	0.020%	0.816	0.097%
$e_{22,P}^*$	0.807	0.807	-0.020%	0.806	-0.099%	0.807	0.020%	0.808	0.097%
$e_{21,P}^*$	0.822	0.821	-0.132%	0.817	-0.663%	0.823	0.132%	0.828	0.656%
$e_{11,R}^*$	1.745	1.744	-0.044%	1.741	-0.221%	1.746	0.044%	1.749	0.218%
$e_{12,R}^*$	1.734	1.734	-0.006%	1.733	-0.033%	1.734	0.006%	1.734	0.032%
$e_{22,R}^*$	1.734	1.734	-0.006%	1.733	-0.033%	1.734	0.006%	1.734	0.032%
$e_{21,R}^*$	1.745	1.744	-0.044%	1.741	-0.221%	1.746	0.044%	1.749	0.218%
μ_1^{CB}	0.496	0.502	1.147%	0.525	5.771%	0.491	-1.143%	0.468	-5.691%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.502	1.147%	0.525	5.771%	0.491	-1.143%	0.468	-5.691%
μ_2^{CB}	0.121	0.105	-13.053%	0.041	-65.685%	0.136	13.012%	0.199	64.768%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{2,R}^{CB}$	0.121	0.105	-13.053%	0.041	-65.685%	0.136	13.012%	0.199	64.768%
X_1^*	940869.704	920935.705	-2.119%	841207.112	-10.593%	960804.241	2.119%	1040721.927	10.613%
X_2^*	1307384.101	1325081.057	1.354%	1396350.309	6.805%	1289734.812	-1.350%	1219436.663	-6.727%
AGR_1^*	361739.573	354788.139	-1.922%	326708.037	-9.684%	368663.883	1.914%	396157.042	9.514%
AGR_2^*	471013.644	477540.320	1.386%	503865.486	6.975%	464508.573	-1.381%	438643.583	-6.872%
TR_1^*	192895.972	189784.986	-1.613%	176995.647	-8.243%	195972.803	1.595%	207975.962	7.818%
EBT_1^*	8814.202	7655.513	-13.146%	3008.428	-65.868%	9971.665	13.132%	14599.926	65.641%
TR_2^*	314554.573	318779.369	1.343%	335806.986	6.756%	310342.485	-1.339%	293580.372	-6.668%
EBT_2^*	131286.262	132771.260	1.131%	138754.382	5.688%	129805.531	-1.128%	123910.563	-5.618%
DC_1^*	484233.090	480572.774	-0.756%	465972.113	-3.771%	487897.376	0.757%	502623.331	3.798%
DC_2^*	330392.895	333250.377	0.865%	344801.831	4.361%	327547.430	-0.861%	316255.713	-4.279%
IC_1^*	96494.216	94639.917	-1.922%	87149.535	-9.684%	98341.279	1.914%	105675.093	9.514%
IC_2^*	132578.196	134415.287	1.386%	141825.142	6.975%	130747.186	-1.381%	123466.858	-6.872%

Table A1-a. Effects of Detroit's Revenue Tax

(Benchmark) $\sigma_2 = 0.20$		(+1%) $\sigma_2 = 0.202$		(+5%) $\sigma_2 = 0.21$		(-1%) $\sigma_2 = 0.198$		(-5%) $\sigma_2 = 0.19$	
p_1^*	1.284	1.285	0.009%	1.285	0.046%	1.284	-0.009%	1.284	-0.045%
p_2^*	1.260	1.261	0.061%	1.264	0.309%	1.260	-0.061%	1.256	-0.301%
p	0.981	0.982	0.052%	0.984	0.263%	0.981	-0.052%	0.979	-0.256%
$x_{11,P}^*$	7776.537	7775.601	-0.012%	7771.829	-0.061%	7777.472	0.012%	7781.186	0.060%
$x_{12,P}^*$	7687.955	7681.937	-0.078%	7657.760	-0.393%	7693.963	0.078%	7717.889	0.389%
$x_{22,P}^*$	7616.901	7611.001	-0.077%	7587.298	-0.389%	7622.791	0.077%	7646.249	0.385%
$x_{21,P}^*$	7703.748	7702.830	-0.012%	7699.133	-0.060%	7704.664	0.012%	7708.305	0.059%
$x_{11,R}^*$	3703.537	3702.601	-0.025%	3698.829	-0.127%	3704.472	0.025%	3708.186	0.126%
$x_{12,R}^*$	3614.955	3608.937	-0.166%	3584.760	-0.835%	3620.963	0.166%	3644.889	0.828%
$x_{22,R}^*$	3543.901	3538.001	-0.166%	3514.298	-0.835%	3549.791	0.166%	3573.249	0.828%
$x_{21,R}^*$	3630.748	3629.830	-0.025%	3626.133	-0.127%	3631.664	0.025%	3635.305	0.126%
$e_{11,P}^*$	0.831	0.831	-0.020%	0.830	-0.100%	0.831	0.020%	0.832	0.099%
$e_{12,P}^*$	0.815	0.814	-0.132%	0.810	-0.664%	0.816	0.132%	0.821	0.656%
$e_{22,P}^*$	0.807	0.806	-0.133%	0.801	-0.668%	0.808	0.133%	0.812	0.660%
$e_{21,P}^*$	0.822	0.822	-0.020%	0.822	-0.101%	0.823	0.020%	0.823	0.099%
$e_{11,R}^*$	1.745	1.745	-0.007%	1.744	-0.034%	1.745	0.007%	1.745	0.033%
$e_{12,R}^*$	1.734	1.733	-0.044%	1.730	-0.221%	1.735	0.044%	1.738	0.218%
$e_{22,R}^*$	1.734	1.733	-0.044%	1.730	-0.221%	1.735	0.044%	1.738	0.218%
$e_{21,R}^*$	1.745	1.745	-0.007%	1.744	-0.034%	1.745	0.007%	1.746	0.033%
μ_1^{CB}	0.496	0.491	-1.141%	0.468	-5.747%	0.502	1.137%	0.524	5.647%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.491	-1.141%	0.468	-5.747%	0.502	1.137%	0.524	5.647%
μ_2^{CB}	0.121	0.136	12.989%	0.199	65.404%	0.105	-12.944%	0.043	-64.272%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{2,R}^{CB}$	0.121	0.136	12.989%	0.199	65.404%	0.105	-12.944%	0.043	-64.272%
X_1^*	940869.704	959008.099	1.928%	1032109.215	9.697%	922785.483	-1.922%	850984.669	-9.553%
X_2^*	1307384.101	1287326.959	-1.534%	1207033.468	-7.676%	1327434.565	1.534%	1407567.861	7.663%
AGR_1^*	361739.573	368825.900	1.959%	397428.371	9.866%	354678.659	-1.952%	326686.149	-9.690%
AGR_2^*	471013.644	464779.994	-1.323%	439560.128	-6.678%	477219.127	1.317%	501762.874	6.528%
TR_1^*	192895.972	196560.051	1.900%	211339.475	9.561%	189244.064	-1.893%	174756.776	-9.404%
EBT_1^*	8814.202	9957.487	12.971%	14567.201	65.270%	7674.535	-12.930%	3151.645	-64.244%
TR_2^*	314554.573	311079.857	-1.105%	296827.055	-5.636%	317994.333	1.094%	331408.108	5.358%
EBT_2^*	131286.262	129651.124	-1.245%	123087.321	-6.245%	132919.088	1.244%	139427.401	6.201%
DC_1^*	484233.090	487032.352	0.578%	498360.430	2.917%	481446.770	-0.575%	470429.349	-2.851%
DC_2^*	330392.895	326951.453	-1.042%	313215.408	-5.199%	333837.214	1.042%	347642.356	5.221%
IC_1^*	96494.216	98384.497	1.959%	106014.221	9.866%	94610.713	-1.952%	87143.697	-9.690%
IC_2^*	132578.196	130823.584	-1.323%	123724.842	-6.678%	134324.879	1.317%	141233.311	6.528%

Table A1-b. Effects of Windsor's Revenue Tax

(Benchmark) $s_1 = 0.8$		(+1%) $s_1 = 0.808$		(+5%) $s_1 = 0.84$		(-1%) $s_1 = 0.792$		(-5%) $s_1 = 0.76$	
p_1^*	1.284	1.284	-0.005%	1.284	-0.027%	1.285	0.005%	1.285	0.027%
p_2^*	1.260	1.260	0.005%	1.261	0.026%	1.260	-0.005%	1.260	-0.026%
p	0.981	0.981	0.011%	0.982	0.053%	0.981	-0.011%	0.981	-0.053%
$x_{11,P}^*$	7776.537	7772.988	-0.046%	7758.856	-0.227%	7780.094	0.046%	7794.386	0.230%
$x_{12,P}^*$	7687.955	7687.442	-0.007%	7685.399	-0.033%	7688.468	0.007%	7690.529	0.033%
$x_{22,P}^*$	7616.901	7616.399	-0.007%	7614.395	-0.033%	7617.405	0.007%	7619.425	0.033%
$x_{21,P}^*$	7703.748	7700.268	-0.045%	7686.413	-0.225%	7707.235	0.045%	7721.247	0.227%
$x_{11,R}^*$	3703.537	3699.988	-0.096%	3685.856	-0.477%	3707.094	0.096%	3721.386	0.482%
$x_{12,R}^*$	3614.955	3614.442	-0.014%	3612.399	-0.071%	3615.468	0.014%	3617.529	0.071%
$x_{22,R}^*$	3543.901	3543.399	-0.014%	3541.395	-0.071%	3544.405	0.014%	3546.425	0.071%
$x_{21,R}^*$	3630.748	3627.268	-0.096%	3613.413	-0.477%	3634.235	0.096%	3648.247	0.482%
$e_{11,P}^*$	0.831	0.830	-0.076%	0.828	-0.376%	0.832	0.076%	0.834	0.379%
$e_{12,P}^*$	0.815	0.815	-0.011%	0.815	-0.056%	0.815	0.011%	0.816	0.056%
$e_{22,P}^*$	0.807	0.807	-0.011%	0.806	-0.056%	0.807	0.011%	0.807	0.057%
$e_{21,P}^*$	0.822	0.822	-0.076%	0.819	-0.379%	0.823	0.076%	0.826	0.381%
$e_{11,R}^*$	1.745	1.744	-0.025%	1.743	-0.126%	1.745	0.025%	1.747	0.127%
$e_{12,R}^*$	1.734	1.734	-0.004%	1.733	-0.019%	1.734	0.004%	1.734	0.019%
$e_{22,R}^*$	1.734	1.734	-0.004%	1.734	-0.019%	1.734	0.004%	1.734	0.019%
$e_{21,R}^*$	1.745	1.745	-0.025%	1.743	-0.126%	1.745	0.025%	1.747	0.127%
μ_1^{CB}	0.496	0.499	0.660%	0.513	3.294%	0.493	-0.661%	0.480	-3.309%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.499	0.660%	0.513	3.294%	0.493	-0.661%	0.480	-3.309%
μ_2^{CB}	0.121	0.112	-7.512%	0.075	-37.494%	0.130	7.518%	0.166	37.657%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{2,R}^{CB}$	0.121	0.112	-7.512%	0.075	-37.494%	0.130	7.518%	0.166	37.657%
X_1^*	940869.704	929390.384	-1.220%	883783.703	-6.067%	952380.299	1.223%	998737.617	6.150%
X_2^*	1307384.101	1317569.282	0.779%	1358193.384	3.886%	1297187.200	-0.780%	1256281.838	-3.909%
AGR_1^*	361739.573	357261.904	-1.238%	339487.001	-6.152%	366230.921	1.242%	384334.110	6.246%
AGR_2^*	471013.644	474769.468	0.797%	489763.072	3.981%	467254.841	-0.798%	452189.701	-3.996%
TR_1^*	192895.972	191104.352	-0.929%	183875.379	-4.676%	194681.281	0.926%	201758.789	4.595%
EBT_1^*	8814.202	8180.040	-7.195%	5603.458	-36.427%	9444.333	7.149%	11924.163	35.284%
TR_2^*	314554.573	316985.919	0.773%	326687.860	3.857%	312120.872	-0.774%	302362.411	-3.876%
EBT_2^*	131286.262	132140.894	0.651%	135550.528	3.248%	130430.735	-0.652%	126999.648	-3.265%
DC_1^*	484233.090	482124.762	-0.435%	473761.281	-2.163%	486348.450	0.437%	494880.735	2.199%
DC_2^*	330392.895	332036.940	0.498%	338608.570	2.487%	328748.397	-0.498%	322165.915	-2.490%
IC_1^*	96494.216	95299.795	-1.238%	90558.331	-6.152%	97692.285	1.242%	102521.320	6.246%
IC_2^*	132578.196	133635.363	0.797%	137855.676	3.981%	131520.189	-0.798%	127279.741	-3.996%

Table A1-c. Effects of Detroit’s Casino Tax Surcharge

(Benchmark) $s_2 = 1.36$		(+1%) $s_2 = 1.3736$		(+5%) $s_2 = 1.428$		(-1%) $s_2 = 1.3464$		(-5%) $s_2 = 1.292$	
p_1^*	1.284	1.285	0.009%	1.285	0.043%	1.284	-0.009%	1.284	-0.043%
p_2^*	1.260	1.260	-0.009%	1.260	-0.044%	1.260	0.009%	1.261	0.044%
p	0.981	0.981	-0.017%	0.980	-0.086%	0.981	0.017%	0.982	0.087%
$x_{11,P}^*$	7776.537	7775.654	-0.011%	7772.143	-0.057%	7777.422	0.011%	7780.982	0.057%
$x_{12,P}^*$	7687.955	7682.283	-0.074%	7659.769	-0.367%	7693.644	0.074%	7716.579	0.372%
$x_{22,P}^*$	7616.901	7611.341	-0.073%	7589.268	-0.363%	7622.479	0.073%	7644.965	0.368%
$x_{21,P}^*$	7703.748	7702.883	-0.011%	7699.440	-0.056%	7704.616	0.011%	7708.106	0.057%
$x_{11,R}^*$	3703.537	3702.654	-0.024%	3699.143	-0.119%	3704.422	0.024%	3707.982	0.120%
$x_{12,R}^*$	3614.955	3609.283	-0.157%	3586.769	-0.780%	3620.644	0.157%	3643.579	0.792%
$x_{22,R}^*$	3543.901	3538.341	-0.157%	3516.268	-0.780%	3549.479	0.157%	3571.965	0.792%
$x_{21,R}^*$	3630.748	3629.883	-0.024%	3626.440	-0.119%	3631.616	0.024%	3635.106	0.120%
$e_{11,P}^*$	0.831	0.831	-0.019%	0.830	-0.093%	0.831	0.019%	0.832	0.095%
$e_{12,P}^*$	0.815	0.814	-0.125%	0.810	-0.620%	0.816	0.125%	0.820	0.627%
$e_{22,P}^*$	0.807	0.806	-0.125%	0.802	-0.624%	0.808	0.126%	0.812	0.631%
$e_{21,P}^*$	0.822	0.822	-0.019%	0.822	-0.094%	0.823	0.019%	0.823	0.095%
$e_{11,R}^*$	1.745	1.745	-0.006%	1.744	-0.031%	1.745	0.006%	1.745	0.032%
$e_{12,R}^*$	1.734	1.733	-0.041%	1.730	-0.206%	1.734	0.041%	1.737	0.208%
$e_{22,R}^*$	1.734	1.733	-0.041%	1.730	-0.206%	1.735	0.041%	1.737	0.208%
$e_{21,R}^*$	1.745	1.745	-0.006%	1.744	-0.031%	1.745	0.006%	1.746	0.032%
μ_1^{CB}	0.496	0.491	-1.076%	0.470	-5.363%	0.502	1.077%	0.523	5.401%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.491	-1.076%	0.470	-5.363%	0.502	1.077%	0.523	5.401%
μ_2^{CB}	0.121	0.135	12.242%	0.194	61.034%	0.106	-12.259%	0.046	-61.471%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{2,R}^{CB}$	0.121	0.135	12.242%	0.194	61.034%	0.106	-12.259%	0.046470677	-61.471%
X_1^*	940869.704	957964.361	1.817%	1026020.814	9.050%	923742.573	-1.820%	854906.71	-9.137%
X_2^*	1307384.101	1288479.660	-1.446%	1213687.907	-7.167%	1326372.080	1.452%	1403168.933	7.326%
AGR_1^*	361739.573	368418.015	1.846%	395043.499	9.207%	355052.245	-1.849%	328213.4838	-9.268%
AGR_2^*	471013.644	464061.016	-1.476%	436591.476	-7.308%	478000.782	1.483%	506298.6273	7.491%
TR_1^*	192895.972	196349.176	1.790%	210107.771	8.923%	189437.307	-1.793%	175547.6293	-8.994%
EBT_1^*	8814.202	9891.693	12.224%	14183.144	60.912%	7734.846	-12.246%	3398.620347	-61.442%
TR_2^*	314554.573	311266.001	-1.045%	297965.371	-5.274%	317828.267	1.041%	330771.7884	5.156%
EBT_2^*	131286.262	130407.184	-0.670%	126778.302	-3.434%	132153.914	0.661%	135508.5381	3.216%
DC_1^*	484233.090	486871.149	0.545%	497414.104	2.722%	481594.119	-0.545%	471029.2927	-2.727%
DC_2^*	330392.895	327149.126	-0.982%	314351.292	-4.855%	333654.597	0.987%	346882.8928	4.991%
IC_1^*	96494.216	98275.693	1.846%	105378.055	9.207%	94710.368	-1.849%	87551.1142	-9.268%
IC_2^*	132578.196	130621.210	-1.476%	122889.243	-7.308%	134544.895	1.483%	142510.0087	7.491%

Table A1-d. Effects of Windsor's Casino Tax Surcharge

(Benchmark) $T = 191.67$		(+1%) $T = 193.5867$		(+5%) $T = 201.2535$		(-1%) $T = 189.7533$		(-5%) $T = 182.0865$	
p_1^*	1.284	1.284	0.00005%	1.284	0.00024%	1.284	-0.00005%	1.2845	-0.00024%
p_2^*	1.260	1.260	-0.00005%	1.260	-0.00024%	1.260	0.00005%	1.2603	0.00024%
p	0.981	0.981	-0.00010%	0.981	-0.00048%	0.981	0.00010%	0.9812	0.00048%
$x_{11,P}^*$	7776.537	7776.532	-0.00006%	7776.512	-0.00032%	7776.542	0.00006%	7776.5622	0.00032%
$x_{12,P}^*$	7687.955	7687.960	0.00006%	7687.979	0.00031%	7687.950	-0.00006%	7687.9315	-0.00031%
$x_{22,P}^*$	7616.901	7616.906	0.00006%	7616.925	0.00030%	7616.897	-0.00006%	7616.8783	-0.00030%
$x_{21,P}^*$	7703.748	7703.743	-0.00006%	7703.724	-0.00032%	7703.753	0.00006%	7703.7728	0.00032%
$x_{11,R}^*$	3703.537	3703.532	-0.00013%	3703.512	-0.00067%	3703.542	0.00013%	3703.5622	0.00067%
$x_{12,R}^*$	3614.955	3614.960	0.00013%	3614.979	0.00065%	3614.950	-0.00013%	3614.9315	-0.00065%
$x_{22,R}^*$	3543.901	3543.906	0.00013%	3543.925	0.00065%	3543.897	-0.00013%	3543.8783	-0.00065%
$x_{21,R}^*$	3630.748	3630.743	-0.00013%	3630.724	-0.00067%	3630.753	0.00013%	3630.7728	0.00067%
$e_{11,P}^*$	0.831	0.831	-0.00011%	0.831	-0.00053%	0.831	0.00011%	0.8310	0.00053%
$e_{12,P}^*$	0.815	0.815	0.00010%	0.815	0.00052%	0.815	-0.00010%	0.8152	-0.00052%
$e_{22,P}^*$	0.807	0.807	0.00010%	0.807	0.00052%	0.807	-0.00010%	0.8067	-0.00052%
$e_{21,P}^*$	0.822	0.822	-0.00011%	0.822	-0.00053%	0.822	0.00011%	0.8224	0.00053%
$e_{11,R}^*$	1.745	1.745	-0.00004%	1.745	-0.00018%	1.745	0.00004%	1.7449	0.00018%
$e_{12,R}^*$	1.734	1.734	0.00003%	1.734	0.00017%	1.734	-0.00003%	1.7338	-0.00017%
$e_{22,R}^*$	1.734	1.734	0.00003%	1.734	0.00017%	1.734	-0.00003%	1.7339	-0.00017%
$e_{21,R}^*$	1.745	1.745	-0.00004%	1.745	-0.00018%	1.745	0.00004%	1.7450	0.00018%
μ_1^{CB}	0.496	0.492	-0.81757%	0.476	-4.08783%	0.500	0.81757%	0.5165	4.08783%
$\mu_{1,P}^{CB}$	0.000	0.000	0.00000%	0.000	0.00000%	0.000	0.00000%	0.0000	0.00000%
$\mu_{1,R}^{CB}$	0.496	0.492	-0.81757%	0.476	-4.08783%	0.500	0.81757%	0.5165	4.08783%
μ_2^{CB}	0.121	0.109	-9.54083%	0.063	-47.70417%	0.132	9.54083%	0.1781	47.70417%
$\mu_{2,P}^{CB}$	0.000	0.000	0.00000%	0.000	0.00000%	0.000	0.00000%	0.0000	0.00000%
$\mu_{2,R}^{CB}$	0.121	0.109	-9.54083%	0.063	-47.70417%	0.132	9.54083%	0.1781	47.70417%
X_1^*	940869.704	940966.248	0.01026%	941352.421	0.05131%	940773.159	-0.01026%	940386.9794	-0.05131%
X_2^*	1307384.101	1307290.359	-0.00717%	1306915.388	-0.03585%	1307477.843	0.00717%	1307852.807	0.03585%
AGR_1^*	361739.573	361777.280	0.01042%	361928.107	0.05212%	361701.867	-0.01042%	361551.0404	-0.05212%
AGR_2^*	471013.644	470979.083	-0.00734%	470840.837	-0.03669%	471048.206	0.00734%	471186.4524	0.03669%
TR_1^*	192895.972	192915.4713	0.01011%	192993.468	0.05054%	192876.473	-0.01011%	192798.4752	-0.05054%
EBT_1^*	8814.202	7973.2468	-9.54091%	4609.440	-47.70440%	9655.159	9.54093%	13019.0005	47.70481%
TR_2^*	314554.573	314532.1975	-0.00711%	314442.695	-0.03557%	314576.948	0.00711%	314666.4502	0.03557%
EBT_2^*	131286.262	130213.0163	-0.81748%	125920.017	-4.08744%	132359.505	0.81748%	136652.4620	4.08740%
DC_1^*	484233.0897	484275.8858	0.00884%	484447.011	0.04418%	484190.288	-0.00884%	484019.0205	-0.04421%
DC_2^*	330392.8946	330350.9807	-0.01269%	330183.382	-0.06341%	330434.814	0.01269%	330602.5504	0.06346%
IC_1^*	96494.21569	96504.2740	0.01042%	96544.507	0.05212%	96484.157	-0.01042%	96443.9244	-0.05212%
IC_2^*	132578.1958	132568.4676	-0.00734%	132529.555	-0.03669%	132587.924	0.00734%	132626.8368	0.03669%

Table A1-e. Effects of Commuting Costs

(Benchmark) $N_1 = 446.652$		(+1%) $N_1 = 451.1158$		(+5%) $N_1 = 468.9846$		(-1%) $N_1 = 422.1855$		(-5%) $N_1 = 424.3194$	
p_1^*	1.284	1.284	0.00122%	1.285	0.00611%	1.284	-0.00122%	1.284	-0.00612%
p_2^*	1.260	1.260	0.00709%	1.261	0.03541%	1.260	-0.00709%	1.260	-0.03546%
p	0.981	0.981	0.00586%	0.981	0.02930%	0.981	-0.00586%	0.981	-0.02934%
$x_{11,P}^*$	7776.537	7776.412	-0.00161%	7775.911	-0.00805%	7776.663	0.00161%	7777.165	0.00807%
$x_{12,P}^*$	7687.955	7687.257	-0.00908%	7684.469	-0.04535%	7688.654	0.00909%	7691.453	0.04550%
$x_{22,P}^*$	7616.901	7616.217	-0.00899%	7613.483	-0.04487%	7617.586	0.00899%	7620.331	0.04502%
$x_{21,P}^*$	7703.748	7703.625	-0.00160%	7703.134	-0.00797%	7703.871	0.00160%	7704.364	0.00799%
$x_{11,R}^*$	3703.537	3703.412	-0.00339%	3702.911	-0.01691%	3703.663	0.00339%	3704.165	0.01695%
$x_{12,R}^*$	3614.955	3614.257	-0.01931%	3611.469	-0.09644%	3615.654	0.01933%	3618.453	0.09676%
$x_{22,R}^*$	3543.901	3543.217	-0.01931%	3540.483	-0.09645%	3544.586	0.01933%	3547.331	0.09676%
$x_{21,R}^*$	3630.748	3630.625	-0.00339%	3630.134	-0.01691%	3630.871	0.00339%	3631.364	0.01695%
$e_{11,P}^*$	0.831	0.831	-0.00267%	0.831	-0.01332%	0.831	0.00267%	0.831	0.01335%
$e_{12,P}^*$	0.815	0.815	-0.01533%	0.815	-0.07655%	0.815	0.01534%	0.816	0.07676%
$e_{22,P}^*$	0.807	0.807	-0.01542%	0.806	-0.07702%	0.807	0.01543%	0.807	0.07724%
$e_{21,P}^*$	0.822	0.822	-0.00268%	0.822	-0.01340%	0.822	0.00268%	0.823	0.01344%
$e_{11,R}^*$	1.745	1.745	-0.00089%	1.745	-0.00446%	1.745	0.00089%	1.745	0.00447%
$e_{12,R}^*$	1.734	1.734	-0.00509%	1.733	-0.02545%	1.734	0.00510%	1.734	0.02551%
$e_{22,R}^*$	1.734	1.734	-0.00509%	1.733	-0.02544%	1.734	0.00510%	1.734	0.02550%
$e_{21,R}^*$	1.745	1.745	-0.00089%	1.745	-0.00446%	1.745	0.00089%	1.745	0.00447%
μ_1^{CB}	0.496	0.501	0.87781%	0.517	4.22244%	0.492	-0.89548%	0.473	-4.66534%
$\mu_{1,P}^{CB}$	0.000	0.000	0.00000%	0.000	0.00000%	0.000	0.00000%	0.000	0.00000%
$\mu_{1,R}^{CB}$	0.496	0.501	0.87781%	0.517	4.22244%	0.492	-0.89548%	0.473	-4.66534%
μ_2^{CB}	0.121	0.122	1.46420%	0.129	7.31427%	0.119	-1.46487%	0.112	-7.33117%
$\mu_{2,P}^{CB}$	0.000	0.000	0.00000%	0.000	0.00000%	0.000	0.00000%	0.000	0.00000%
$\mu_{2,R}^{CB}$	0.121	0.122	1.46420%	0.129	7.31427%	0.119	-1.46487%	0.112	-7.33117%
X_1^*	940869.704	943292.005	0.25745%	952970.470	1.28613%	938446.322	-0.25757%	928741.908	-1.28900%
X_2^*	1307384.101	1321256.185	1.06106%	1376701.299	5.30198%	1293507.655	-1.06139%	1237957.871	-5.31032%
AGR_1^*	361739.573	362685.705	0.26155%	366466.798	1.30680%	360793.096	-0.26165%	357003.704	-1.30919%
AGR_2^*	471013.644	476129.357	1.08611%	496601.064	5.43242%	465898.808	-1.08592%	445448.121	-5.42777%
TR_1^*	192895.972	193385.231	0.25364%	195340.318	1.26718%	192406.517	-0.25374%	190446.719	-1.26973%
EBT_1^*	8814.202	8943.066	1.46200%	9457.875	7.30268%	8685.273	-1.46274%	8168.903	-7.32113%
TR_2^*	314554.573	317866.144	1.05278%	331110.293	5.26323%	311242.781	-1.05285%	297993.320	-5.26499%
EBT_2^*	131286.262	133746.730	1.87412%	143583.493	9.36673%	128825.276	-1.87452%	118976.091	-9.37659%
DC_1^*	484233.090	487850.219	0.74698%	502307.201	3.73252%	480614.797	-0.74722%	466129.888	-3.73853%
DC_2^*	330392.895	332693.036	0.69618%	341887.001	3.47892%	328092.088	-0.69639%	318882.136	-3.48396%
IC_1^*	96494.216	96746.597	0.26155%	97755.205	1.30680%	96241.742	-0.26165%	95230.920	-1.30919%
IC_2^*	132578.196	134018.137	1.08611%	139780.395	5.43242%	131138.501	-1.08592%	125382.160	-5.42777%

Table A1-f. Effects of Population in Detroit

(Benchmark) $n_1 = 0.979$		(-1%) $n_1 = 0.9692$		(-5%) $n_1 = 0.9301$	
p_1^*	1.284	1.285	0.00780%	1.285	0.03897%
p_2^*	1.260	1.260	0.00117%	1.260	0.00585%
p	0.981	0.981	-0.00663%	0.981	-0.03311%
$x_{11,P}^*$	7776.537	7775.738	-0.01028%	7772.546	-0.05132%
$x_{12,P}^*$	7687.955	7687.840	-0.00150%	7687.379	-0.00750%
$x_{22,P}^*$	7616.901	7616.788	-0.00149%	7616.336	-0.00742%
$x_{21,P}^*$	7703.748	7702.964	-0.01018%	7699.836	-0.05079%
$x_{11,R}^*$	3703.537	3702.738	-0.02159%	3699.546	-0.10776%
$x_{12,R}^*$	3614.955	3614.840	-0.00319%	3614.379	-0.01595%
$x_{22,R}^*$	3543.901	3543.788	-0.00319%	3543.336	-0.01595%
$x_{21,R}^*$	3630.748	3629.964	-0.02159%	3626.836	-0.10777%
$e_{11,P}^*$	0.831	0.831	-0.01701%	0.830	-0.08490%
$e_{12,P}^*$	0.815	0.815	-0.00253%	0.815	-0.01265%
$e_{22,P}^*$	0.807	0.807	-0.00255%	0.807	-0.01273%
$e_{21,P}^*$	0.822	0.822	-0.01711%	0.822	-0.08543%
$e_{11,R}^*$	1.745	1.745	-0.00570%	1.744	-0.02844%
$e_{12,R}^*$	1.734	1.734	-0.00084%	1.734	-0.00421%
$e_{22,R}^*$	1.734	1.734	-0.00084%	1.734	-0.00420%
$e_{21,R}^*$	1.745	1.745	-0.00570%	1.744	-0.02844%
μ_1^{CB}	0.496	0.497	0.14862%	0.500	0.74213%
$\mu_{1,P}^{CB}$	0.000	0.000	0.00000%	0.000	0.00000%
$\mu_{1,R}^{CB}$	0.496	0.497	0.14862%	0.500	0.74213%
μ_2^{CB}	0.121	0.119	-1.69150%	0.110	-8.44646%
$\mu_{2,P}^{CB}$	0.000	0.000	0.00000%	0.000	0.00000%
$\mu_{2,R}^{CB}$	0.121	0.119	-1.69150%	0.110	-8.44646%
X_1^*	940869.704	956111.236	1.61994%	1016923.095	8.08331%
X_2^*	1307384.101	1309677.844	0.17545%	1318836.379	0.87597%
AGR_1^*	361739.573	367695.352	1.64643%	391489.167	8.22404%
AGR_2^*	471013.644	471859.354	0.17955%	475236.808	0.89661%
TR_1^*	192895.972	195975.213	1.59632%	208269.962	7.97009%
EBT_1^*	8814.202	8663.915	-1.70506%	8064.160	-8.50948%
TR_2^*	314554.573	315102.083	0.17406%	317288.424	0.86912%
EBT_2^*	131286.262	131478.721	0.14659%	132247.222	0.73196%
DC_1^*	484233.090	512391.235	5.81500%	624690.898	29.00624%
DC_2^*	330392.895	330763.015	0.11202%	332241.570	0.55954%
IC_1^*	96494.216	98082.923	1.64643%	104429.935	8.22404%
IC_2^*	132578.196	132816.241	0.17955%	133766.907	0.89661%

Table A1-g. Effects of Problem Gambling Population in Detroit

(Benchmark) $\sigma_1 = 0.19$		(-15%) $\sigma_1 = 0.1615$		(-16%) $\sigma_1 = 0.1596$		(-18%) $\sigma_1 = 0.1558$		(-20%) $\sigma_1 = 0.152$	
μ_1^{CB}	0.496	0.413	-16.782%	0.408	-17.876%	0.398	-19.752%	0.388	-21.797%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.413	-16.782%	0.408	-17.876%	0.398	-19.752%	0.388	-21.797%
μ_2^{CB}	0.121	0.351	191.003%	0.366	203.451%	0.406	236.673%	0.440	264.657%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.014	--	0.020	--
$\mu_{2,R}^{CB}$	0.121	0.351	191.003%	0.366	203.451%	0.392	224.809%	0.420	248.075%
EBT_1^*	8814.202	26054.137	195.593%	27196.465	208.553%	31393.011	256.164%	34430.814	290.629%
EBT_2^*	131286.262	109504.686	-16.591%	108081.599	-17.675%	105655.660	-19.523%	102999.522	-21.546%
$DC_{1,P}^2$	0.000	0.000	0.000%	0.000	0.000%	8845.018	--	12380.791	--
$DC_{1,R}^2$	11552.378	34447.916	198.189%	35978.582	211.439%	38625.833	234.354%	41519.881	259.406%
$DC_{1,P}^3$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{1,R}^3$	133534.550	111527.798	-16.480%	110087.886	-17.558%	107642.697	-19.390%	104957.350	-21.401%
$DC_{2,P}^2$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{2,R}^2$	133534.550	111527.798	-16.480%	110087.886	-17.558%	107642.697	-19.390%	104957.350	-21.401%
$DC_{2,P}^3$	0.000	0.000	0.000%	0.000	0.000%	8845.018	--	12380.791	--
$DC_{2,R}^3$	11552.378	34447.916	198.189%	35978.582	211.439%	38625.833	234.354%	41519.881	259.406%

Table A2-a. Effects of Detroit's Revenue Tax

(Benchmark) $\sigma_2 = 0.20$		(+15%) $\sigma_2 = 0.23$		(+16%) $\sigma_2 = 0.232$		(+18%) $\sigma_2 = 0.236$		(+20%) $\sigma_2 = 0.24$	
μ_1^{CB}	0.496	0.409	-17.550%	0.403	-18.691%	0.393	-20.775%	0.381	-23.213%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.409	-17.550%	0.403	-18.691%	0.393	-20.775%	0.381	-23.213%
μ_2^{CB}	0.121	0.362	199.743%	0.380	215.054%	0.426	253.025%	0.459	280.780%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.003	--	0.020	--	0.020	--
$\mu_{2,R}^{CB}$	0.121	0.362	199.743%	0.377	212.724%	0.406	236.443%	0.439	264.198%
EBT_1^*	8814.202	26354.779	199.004%	27926.256	216.832%	32661.447	270.555%	35089.093	298.097%
EBT_2^*	131286.262	106512.736	-18.870%	104926.220	-20.078%	102024.569	-22.288%	98664.530	-24.848%
$DC_{1,P}^2$	0.000	0.000	0.000%	1710.035	--	12165.553	--	12162.503	--
$DC_{1,R}^2$	11552.378	34493.689	198.585%	35976.400	211.420%	38676.659	234.794%	41844.955	262.219%
$DC_{1,P}^3$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{1,R}^3$	133534.550	107315.922	-19.634%	105649.691	-20.882%	102600.831	-23.165%	99089.920	-25.795%
$DC_{2,P}^2$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{2,R}^2$	133534.550	107315.922	-19.634%	105649.691	-20.882%	102600.831	-23.165%	99089.920	-25.795%
$DC_{2,P}^3$	0.000	0.000	0.000%	1710.035	--	12165.553	--	12162.503	--
$DC_{2,R}^3$	11552.378	34493.689	198.585%	35976.400	211.420%	38676.659	234.794%	41844.955	262.219%

Table A2-b. Effects of Windsor's Revenue Tax

(Benchmark) $s_1 = 0.8$		(-15%) $s_1 = 0.68$		(-16%) $s_1 = 0.672$		(-18%) $s_1 = 0.656$		(-20%) $s_1 = 0.64$	
μ_1^{CB}	0.496	0.447	-9.970%	0.443	-10.639%	0.437	-11.980%	0.430	-13.322%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.447	-9.970%	0.443	-10.639%	0.437	-11.980%	0.430	-13.322%
μ_2^{CB}	0.121	0.257	113.470%	0.267	121.088%	0.285	136.345%	0.303	151.628%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{2,R}^{CB}$	0.121	0.257	113.470%	0.267	121.088%	0.285	136.345%	0.303	151.628%
EBT_1^*	8814.202	17832.110	102.311%	18399.447	108.748%	19521.065	121.473%	20625.135	133.999%
EBT_2^*	131286.262	118358.325	-9.847%	117489.136	-10.509%	115747.972	-11.835%	114003.078	-13.165%
$DC_{1,P}^2$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{1,R}^2$	11552.378	25020.816	116.586%	25938.975	124.534%	27783.056	140.496%	29637.546	156.549%
$DC_{1,P}^3$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{1,R}^3$	133534.550	120480.092	-9.776%	119601.662	-10.434%	117841.708	-11.752%	116077.609	-13.073%
$DC_{2,P}^2$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{2,R}^2$	133534.550	120480.092	-9.776%	119601.662	-10.434%	117841.708	-11.752%	116077.609	-13.073%
$DC_{2,P}^3$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{2,R}^3$	11552.378	25020.816	116.586%	25938.975	124.534%	27783.056	140.496%	29637.546	156.549%

Table A2-c. Effects of Detroit's Casino Tax Surcharge

(Benchmark) $s_2 = 1.36$		(+15%) $s_2 = 1.564$		(+16%) $s_2 = 1.5776$		(+18%) $s_2 = 1.6048$		(+20%) $s_2 = 1.632$	
μ_1^{CB}	0.496	0.417	-15.976%	0.412	-17.029%	0.402	-18.929%	0.393	-20.827%
$\mu_{1,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$\mu_{1,R}^{CB}$	0.496	0.417	-15.976%	0.412	-17.029%	0.402	-18.929%	0.393	-20.827%
μ_2^{CB}	0.121	0.340	181.823%	0.354	193.809%	0.391	223.784%	0.427	253.619%
$\mu_{2,P}^{CB}$	0.000	0.000	0.000%	0.000	0.000%	0.010	--	0.020	--
$\mu_{2,R}^{CB}$	0.121	0.340	181.823%	0.354	193.809%	0.380	215.442%	0.407	237.037%
EBT_1^*	8814.202	24784.589	181.189%	25834.926	193.106%	29286.145	232.261%	32713.434	271.145%
EBT_2^*	131286.262	116946.807	-10.922%	115906.185	-11.715%	114086.775	-13.101%	112227.443	-14.517%
$DC_{1,P}^2$	0.000	0.000	0.000%	0.000	0.000%	6122.022	--	12165.487	--
$DC_{1,R}^2$	11552.378	32442.651	180.831%	33814.695	192.708%	36283.100	214.075%	38744.521	235.381%
$DC_{1,P}^3$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{1,R}^3$	133534.550	109616.704	-17.911%	108076.659	-19.065%	105290.860	-21.151%	102525.421	-23.222%
$DC_{2,P}^2$	0.000	0.000	0.000%	0.000	0.000%	0.000	0.000%	0.000	0.000%
$DC_{2,R}^2$	133534.550	109616.704	-17.911%	108076.659	-19.065%	105290.860	-21.151%	102525.421	-23.222%
$DC_{2,P}^3$	0.000	0.000	0.000%	0.000	0.000%	6122.022	--	12165.487	--
$DC_{2,R}^3$	11552.378	32442.651	180.831%	33814.695	192.708%	36283.100	214.075%	38744.521	235.381%

Table A2-d. Effects of Windsor's Casino Tax Surcharge

(Benchmark) $\omega' = 0$		$\omega' = 0.625\%$	
p_1^*	1.2845	1.28414	-0.0256%
p_2^*	1.2603	1.26060	0.0261%
p	0.9812	0.98167	0.0517%
$x_{11,P}^*$	7776.5373	7738.70283	-0.4865%
$x_{12,P}^*$	7687.9550	7646.9297	-0.5336%
$x_{22,P}^*$	7616.9014	7614.3834	-0.0331%
$x_{21,P}^*$	7703.7483	7666.6550	-0.4815%
$x_{11,R}^*$	3703.5373	3665.7028	-1.0216%
$x_{12,R}^*$	3614.9550	3573.9297	-1.1349%
$x_{22,R}^*$	3543.9014	3541.3834	-0.0711%
$x_{21,R}^*$	3630.7483	3593.6550	-1.0216%
$e_{11,P}^*$	0.8310	0.8229	-0.9733%
$e_{12,P}^*$	0.8152	0.8065	-1.0695%
$e_{22,P}^*$	0.8067	0.8063	-0.0567%
$e_{21,P}^*$	0.8224	0.8144	-0.9783%
$e_{11,R}^*$	1.7449	1.7372	-0.4379%
$e_{12,R}^*$	1.7338	1.7257	-0.4679%
$e_{22,R}^*$	1.7339	1.7336	-0.0187%
$e_{21,R}^*$	1.7450	1.7374	-0.4379%
μ_1^{CB}	0.4962	0.4916	-0.9236%
$\mu_{1,P}^{CB}$	0.0000	0.0000	0.0000%
$\mu_{1,R}^{CB}$	0.4962	0.4916	-0.9236%
μ_2^{CB}	0.1206	0.0146	-87.8641%
$\mu_{2,P}^{CB}$	0.0000	0.0000	0.0000%
$\mu_{2,R}^{CB}$	0.1206	0.0146	-87.8641%
X_1^*	940869.7097	878872.2174	-6.5894%
X_2^*	1307384.0879	1350027.9667	3.2618%
AGR_1^*	361739.5770	337614.0639	-6.6693%
AGR_2^*	471013.6419	486820.7487	3.3560%
TR_1^*	192895.9735	189757.8703	-1.6268%
EBT_1^*	8814.2027	1058.4813	-87.9912%
TR_2^*	314554.5707	324761.3335	3.2448%
EBT_2^*	131286.2607	128631.0104	-2.0225%
DC_1^*	484233.0898	470760.5608	-2.7822%
DC_2^*	330392.8921	337060.5189	2.0181%
IC_1^*	96494.2166	90058.7237	-6.6693%
IC_2^*	132578.1951	137027.4881	3.3560%

Table A3. Effects of Winning Withholdings

(Benchmark) $\varsigma = 0$		(+1%) $\varsigma = 0.01$		(+5%) $\varsigma = 0.05$		(-1%) $\varsigma = -0.01$		(-5%) $\varsigma = -0.05$	
p_1^*	1.2845	1.2831	-0.1031%	1.2785	-0.0047	1.2861	0.0013	1.2916	0.5525%
p_2^*	1.2603	1.2616	0.1093%	1.2666	0.0050	1.2586	-0.0013	1.2529	-0.5860%
p	0.9812	0.9832	0.2126%	0.9907	0.0097	0.9786	-0.0026	0.9700	-1.1322%
$x_{11,P}^*$	7776.5373	7787.1368	0.1363%	7825.0205	0.0062	7763.5291	-0.0017	7720.7494	-0.7174%
$x_{12,P}^*$	7687.9550	7778.0201	1.1715%	8196.4564	0.0661	7604.6345	-0.0108	7301.8447	-5.0223%
$x_{22,P}^*$	7616.9014	7606.3700	-0.1383%	7569.2818	-0.0063	7629.8287	0.0017	7674.4321	0.7553%
$x_{21,P}^*$	7703.7483	7615.8805	-1.1406%	7300.6447	-0.0523	7793.7540	0.0117	8216.8817	6.6608%
$x_{11,R}^*$	3703.5373	3714.1368	0.2862%	3752.0205	0.0131	3690.5291	-0.0035	3647.7494	-1.5063%
$x_{12,R}^*$	3614.9550	3705.0201	2.4915%	4123.4564	0.1407	3531.6345	-0.0230	3228.8447	-10.6809%
$x_{22,R}^*$	3543.9014	3533.3700	-0.2972%	3496.2818	-0.0134	3556.8287	0.0036	3601.4321	1.6234%
$x_{21,R}^*$	3630.7483	3542.8805	-2.4201%	3227.6447	-0.1110	3720.7540	0.0248	4143.8817	14.1330%
$e_{11,P}^*$	0.8310	0.8329	0.2252%	0.8395	0.0103	0.8287	-0.0028	0.8211	-1.1911%
$e_{12,P}^*$	0.8152	0.8252	1.2160%	0.8687	0.0656	0.8060	-0.0113	0.7703	-5.5152%
$e_{22,P}^*$	0.8067	0.8048	-0.2374%	0.7980	-0.0108	0.8091	0.0029	0.8171	1.2908%
$e_{21,P}^*$	0.8224	0.8125	-1.2108%	0.7745	-0.0583	0.8322	0.0119	0.8761	6.5292%
$e_{11,R}^*$	1.7449	1.7462	0.0754%	1.7509	0.0034	1.7433	-0.0009	1.7379	-0.3996%
$e_{12,R}^*$	1.7338	1.7323	-0.0875%	1.7268	-0.0040	1.7356	0.0011	1.7419	0.4707%
$e_{22,R}^*$	1.7339	1.7325	-0.0784%	1.7277	-0.0036	1.7356	0.0010	1.7413	0.4256%
$e_{21,R}^*$	1.7450	1.7465	0.0845%	1.7518	0.0039	1.7432	-0.0010	1.7372	-0.4452%
μ_1^{CB}	0.4962	0.5834	17.5682%	0.9928	1.0006	0.4169	-0.1599	0.1046	-78.9305%
$\mu_{1,P}^{CB}$	0.0000	0.0000	0.0000%	0.0210	--	0.0000	0.0000	0.0000	0.0000%
$\mu_{1,R}^{CB}$	0.4962	0.5834	17.5682%	0.9718	0.9583	0.4169	-0.1599	0.1046	-78.9305%
μ_2^{CB}	0.1206	0.0000	--	0.0000	--	0.3518	1.9166	1.0000	729.1016%
$\mu_{2,P}^{CB}$	0.0000	0.0000	0.0000%	0.0000	0.0000	0.0000	0.0000	0.0200	0.0000%
$\mu_{2,R}^{CB}$	0.1206	0.0000	--	0.0000	--	0.3518	1.9166	0.9800	712.5196%
X_1^*	940869.7097	729321.1135	-22.4844%	12145.8077	-0.9871	1206586.1075	0.2824	2165935.8062	130.2057%
X_2^*	1307384.0879	1537599.5733	17.6089%	2432901.0700	0.8609	1035420.2311	-0.2080	150780.0539	-88.4670%
AGR_1^*	361739.5770	279438.8699	-22.7514%	4596.9093	-0.9873	465874.0407	0.2879	848116.0277	134.4549%
AGR_2^*	471013.6419	556072.2757	18.0586%	891822.5710	0.8934	371293.1196	-0.2117	53208.3353	-88.7034%
TR_1^*	192895.9735	150262.0893	-22.1020%	6932.4429	-0.9641	246666.1646	0.2788	442612.1570	129.4564%
EBT_1^*	8814.2027	0.0000	--	0.0000	--	26378.2822	1.9927	85516.3855	870.2112%
TR_2^*	314554.5707	369564.9767	17.4884%	585135.6797	0.8602	249820.1373	-0.2058	41326.9725	-86.8617%
EBT_2^*	131286.2607	158369.3943	20.6291%	307390.9130	1.3414	107608.8652	-0.1803	24562.1281	-81.2912%
DC_1^*	484233.0898	452706.5750	-6.5106%	340776.2412	-0.2963	525810.6359	0.0859	692591.4364	43.0285%
DC_2^*	330392.8921	368252.6513	11.4590%	542276.9730	0.6413	286596.6970	-0.1326	145267.2535	-56.0320%
IC_1^*	96494.2166	74540.4611	-22.7514%	1226.2279	-0.9873	124272.1380	0.2879	226235.3829	134.4549%
IC_2^*	132578.1951	156520.0073	18.0586%	251025.0581	0.8934	104509.4394	-0.2117	14976.7744	-88.7034%

Table A4. Effects of Exchange Rates

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