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RESEARCH ARTICLE

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Socioeconomic correlates of the lottery rollover effect in Toronto, Canada

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ABSTRACT

Background: In a lottery with a progressive jackpot, the rollover effect refers to an increase in revenue or engagement with an accumulating jackpot size. Using an ecological dataset of lottery ticket sales aggregated by postcode, we test two corollaries of the rollover effect. First, how does the rollover effect change in neighborhoods with higher or lower socioeconomic status? Second, how do fluctuations on a progressive-prize lottery affect the consumption of fixed-prize lottery tickets in the same neighborhoods, in line with economic notions of 'substitution' versus 'complementarity'?
Methods: We used time-series data on ticket sales from 2012-2015 from 3 progressive-prize lotteries (Lotto 649, Lotto Max, and Lottario) in Toronto, Canada, aggregated for 95 forward-sortation area (FSA) postcodes. Regression models controlled for other cyclical fluctuations including day of week, month of year, and common paydays.
Results: Jackpot size positively predicted lottery ticket sales in all models, with a large effect size. There was a significant interaction between jackpot size and neighborhood SES, such that lottery sales in higher SES neighborhoods were more sensitive to jackpot size, although the effect sizes were negligible. Sales of fixed-prize lotteries were positively related to sales of progressive-prize lotteries, supporting complementarity. We observed a significant interaction between SES and progressive-prize sales, in which fixed-prize sales were more affected by progressive-prize sales in higher SES neighborhoods.
Conclusion: Both the effect of larger jackpots on ticket sales, and the effects of progressive-prize sales on a second lottery type, are attenuated within more disadvantaged (i.e. lower SES) neighborhoods.

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1. Introduction

Gambling is a widely enjoyed recreational activity for many participants, but a subset of consumers may experience significant harms, such as financial distress and hardship. Many jurisdictions worldwide are moving toward a public health approach to reducing gambling harm, which integrates clinical provision and preventative programming with scrutiny of the risks posed by specific gambling products and environments (Korn and Shaffer 1999; Langham et al. 2016; Wardle et al. 2019). Lottery products are the most popular form of gambling in many parts of the world. In a Canadian prevalence study, 57.4% of adult men and 50.0% of adult women had purchased lottery or raffle tickets in 2018 (Williams et al. 2021), in the context of an overall past-year gambling rate of 70.5% for men and 62.2% for women. In 2019, lottery sales generated approximately $3.7 billion in revenue in Ontario, Canada (Ontario Lottery and Gaming Corporation 2019). Lottery revenue is often used by governments to fund public-facing projects such as charity grants or the arts (Grote and Matheson 2006).

Lottery products come in several distinct forms. Although prior research has tended to group these sub-forms as one, recent studies suggest that they should be differentiated and examined separately (Short et al. 2015; Costes et al. 2018; Fu et al. 2021a). On prize-draw lotteries, winning numbers are typically revealed on a weekly or bi-weekly basis, and these can be further subdivided into 'progressive–prize' or 'fixed-prize' jackpots. The current paper focuses primarily on the rollover effect, as a defining characteristic of progressive-prize lotteries, which are themselves a popular and ubiquitous category of gambling product. For example, in Canada, 'Lotto 649' has a biweekly draw, and the jackpot accumulates as a function of ticket sales. On draws when there are no (claimed) winning tickets, the jackpot 'rolls over' to the subsequent draw, and only resets when the jackpot is won. In this way, the progressive prize can accumulate to a multi-million-dollar jackpot, which frequently garners significant publicity. By contrast, 'fixed prize' lotteries are structurally similar in terms of their draw frequency, but offer finite and smaller jackpots typically in the order of $2000 - $5000,

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with a somewhat higher probability of winning (e.g. 1 in 10,000 for 'Pick 4'). Lastly, instant-win (or 'scratch-card') lottery products are typically available from the same establishments (e.g. grocery stores, gas stations) as prize-draw lotteries, but these tickets can be revealed immediately upon purchase, and thus constitute a continuous form of gambling. When looking at lottery products separately, survey-based research has found that the frequency of purchasing instant-win lottery products correlated significantly with the level of gambling problems, whereas the frequency of engaging in prize-draw lotteries did not (Short et al. 2015). This finding is congruent with other literature. Although prize-draw lotteries present a range of issues, including their associations with social inequalities (Clotfelter 1979; Clotfelter and Cook 1987; Oster 2004; Sulkunen et al. 2018), and effects on youth exposure (Newall et al. 2020) and normalization of gambling (Pugh and Webley 2000; Ariyabuddhiphongs 2011), they are generally considered to be less (directly) risky in terms of gambling problems (Binde 2011; Costes et al. 2018; Monson et al. 2019).

Progressive-prize lotteries typically combine a low ticket price with a potentially life-changing jackpot amount, albeit with a very low probability of winning (Ariyabuddhiphongs 2011). In the case of Lotto 649, there are odds of 1:14 million to win a jackpot that varied from $3 million to $64 million in the timeframe of our study. This extreme skewness of the gamble is likely a key factor in the popularity of progressive-prize lotteries because the expected return ('house edge') of lottery products is relatively unfavorable. Across many jurisdictions, a consistent finding is that lower socioeconomic status (SES) individuals spend a greater proportion of their income on gambling (MacDonald et al. 2004; Beckert and Lutter 2009; Bol et al. 2014; Castrén et al. 2018), and on lottery products as a specific form (Oster 2004; Ariyabuddhiphongs 2011; Barnes et al. 2011; Beckert and Lutter 2013; Fu et al. 2021a). Lower SES is also a reliable predictor of gambling problems (Van der Maas 2016).

Ecological analyses of geographical areas have been particularly insightful. Combining spatial data on gambling outlets and socioeconomic variables, several ecological studies (Pérez et al. 2022 in Madrid, Spain; Adeniyi et al. 2023 in Leeds, Nottingham, and Bristol in the United Kingdom) have reported higher concentrations of gambling outlets in disadvantaged neighborhoods. Considering ecological data for lottery outlets more specifically, Wiggins et al. (2010) examined census tracts in Middlesex County, New Jersey, reporting a higher density of lottery outlets in neighborhoods with a greater percentage of households identifying as Hispanic ethnicity, and percent in poverty. Several other studies (Rintoul et al. 2013 in Melbourne, Australia; Raisamo et al. 2019 in Finland; Grumstrup and Nichols 2021 in Illinois, the United States) have found higher concentrations of electronic gambling machines (EGMs) in disadvantaged neighborhoods, along with higher spending on EGMs in those neighborhoods (Rintoul et al. 2013; Grumstrup and Nichols 2021). In our own past work, we obtained lottery sales data for Forward Sortation Areas (FSAs; the first 3 digits of the postal code) in Toronto, Canada. Lower SES neighborhoods, defined using a composite of household income, education, and white-collar employment, record higher lottery ticket sales per capita (Fu et al. 2021a). This relationship with SES further varied by lottery product type, with the strongest effect for fixed-prize lottery sales. These ecological studies support an emerging argument that lower SES is not only a risk factor for gambling harm, but that engagement in gambling further amplifies this harm by exacerbating social inequalities (Sulkunen et al. 2018).

In the classic lottery 'rollover' effect, ticket sales rise as the jackpot accumulates (DeBoer 1990; Shapira and Venezia 1992; Forrest et al. 2002). A previous ecological study investigated how this increase in sales varied by neighborhood SES across zip codes in Connecticut, USA (Oster 2004). Lottery sales were positively related to jackpot size (supporting the rollover effect), and negatively related to the average household income by neighborhood (supporting the association with lower SES). A significant interaction effect was observed between SES and jackpot size, such that the impact of lower SES on lottery sales was attenuated at higher jackpot sizes. In other words, the proportion of lottery spending was greater in higher-income neighborhoods on large rollovers, suggesting that affluent households are more flexible to the opportunities presented by the accumulating jackpot. To our knowledge, the effect tested by Oster has not been tested or replicated in other ecological datasets; those data are from ∼2000 and were specific to one jurisdiction. Given the implications of this finding for social inequalities in gambling, the first objective of the present study was to replicate and extend the study by Oster (2004) using more recent data from another jurisdiction (Toronto, Canada), and further disambiguate the roles of income and education as contributors to SES.

The rollover effect can also provide further insight into a distinct question in gambling economics of how sales of *other* gambling products are affected as the jackpot size on a progressive-prize lottery increases. These analyses examine whether different gambling products serve as *substitutes* for one another (i.e. increasing sales of one product is associated with a corresponding reduction in sales of a competing product), or, could perhaps be *complementary* to one another (e.g. increasing sales around a high jackpot might also drive up sales of related products). Grote & Matheson have examined the rollover effect in this context. Although substitution was observed in US state lottery sales when a large multi-state lottery (PowerBall) was introduced, there was also evidence for complementarity within 11 of the 12 states during the draws when the PowerBall jackpot was higher. Other studies have found that rollovers do not affect sales of fixed-prized lottery products (Cook and Clotfelter 1993; Forrest et al. 2004), that substitution effects occur between instant win and fixed-prize lotteries (Forrest et al. 2004), and also that progressive-prize lotteries can have a complementary effect on other progressive-prize lotteries (Grote and Matheson 2006). Thus, the current literature has mixed findings on whether lottery products are complements or substitutes of

Figure 1. Figure showing monthly sales of Lotto 649 from the years 2012–2015.

each other (Grote and Matheson 2011). Our second objective was to examine substitution vs complementarity on fixed prize sales as a function of the progressive prize jackpot, and to test whether this effect is moderated by neighborhood SES. If interactions with SES are supported, this could help reconcile contradictory findings in other jurisdictions. Moreover, if we see evidence of greater complementarity in lower SES neighborhoods, this would point to another mechanism by which lottery products could exacerbate social inequalities and inequities.

The present study used a well-characterized and diverse neighborhood-level data set of lottery gambling from a large Canadian city (Toronto, population ~ 3 million), previously reported by Fu et al. (2021a, 2021b). In the present paper, we focus on sales of the progressive prize lottery products as a function of area code SES. As a first step, forming the basis of subsequent questions, we test the classic rollover effect, that lottery sales should increase with jackpot size. We then focus on three questions: 1) Does neighborhood SES moderate the rollover effect of jackpot size on progressive-prize lottery sales, in line with Oster (2004)? 2) Can we disambiguate income and education as two neighborhood demographics in predicting lottery sales? 3) Do larger jackpot sizes on progressive prize lotteries affect fixed-prize lottery sales in line with either substitution or complementarity; if so, is this effect further moderated by neighborhood SES?

2. Methods

2.1. Ontario lottery and gambling corporation (OLG) data

We acquired lottery product sales by postal code from the Ontario Lottery and Gaming Corporation (OLG) *via* an Access to Information Act request (Fu et al. 2021a, 2021b). These data are publicly available (https://osf.io/qwrxy/). The datasheets contain lottery sales for three lottery product types - progressive-prize, fixed prize, and instant win prizes - organized by postal code for the years 2012-2015 in Greater Toronto. Postal code was specified by FSA, a geographical region defined by the first three digits of a postal code (e.g. M1C), with an average population size of 18,701 in our dataset. In our study, these FSAs roughly encompass the eight boroughs of Central Toronto, Downtown Toronto, East York, Etobicoke, North York, Scarborough, West Toronto, and York.

Table 1. Descriptive statistics for the 3 progressive prize lotteries.

	Sales (CAD $)		Jackpot Size (CAD $)	
	M	SD	Min	Max
Lottomax	32,887,750	15,486,180	10,000,000	60,000,000
Lotto649	10,976,730	8,872,854	3,000,000	64,000,000
Lottario	453,785.8	294,889.3	250,000	1,510,000

As our research question concerns the effect of accumulating jackpots, we focus on the sales data for the three progressive-prize lottery products: Lottario, Lotto Max, and Lotto 649 (see Figure 1 and Table 1). In our analyses of complementarity vs substitution, we examine how the fluctuating progressive jackpots influence fixed-prize lottery sales as an adjacent product type, on nine specific products (Daily Keno, Pick2, Pick3, Pick4, Wheel of Fortune, Mega Dice, Living the Life Lottery, Poker Lotto, and NHL lotto). For the instant lottery (scratchcard) data, these ticket sales were aggregated as 'pack activations' per day (not all tickets in a pack are sold on the same day), which is an important difference from the temporal resolution of the progressive- and fixed- prize data that limits their suitability for analyzing day-to-day fluctuations.

2.2. Demographic data

Demographic data for each FSA was collected from Statistics Canada 2011 Census Profile (Statistics Canada, n.d.) comprising: the number of adult residents, personal income levels, highest completed level of education for the population aged 25 years or older (Grosset 1991; Molla et al. 2004), and the proportion of residents with white-collar employment (Otto et al. 2016; Fu et al. 2021b, 2021a). White collar employment was defined as the proportion of residents aged 15 or older employed in management, business finance and administration, health, education, law, social community and government services, art, culture, recreation and sport, natural and applied sciences and related occupations, according to the National Occupational Classification (Government of Statistics Canada 2012). We calculated a composite SES variable for each FSA by taking the sum of the Z-scores for (1) per-capita income, (2) years of education, and (3) the proportion of white-collar workers (Roberts 1997).

2.3. Nuisance variables

Our analysis plan controlled for year, day-of-week, and month-of-year, using a series of dummy-coded regressors (e.g. twelve regressors to handle month-of-year effects) (Otto et al. 2016; Otto and Eichstaedt 2018; Fu et al. 2021b). Following the work of (Evans and Moore, 2011), we added a further dummy-coded regressor for statutory holidays (New Year's Day, Family Day, Good Friday, Victoria Day, Canada Day, Labor Day, Thanksgiving, Christmas Eve, Christmas Day, and Boxing Day). Following Dahan (2021) showing fluctuations in lottery sales around paydays, we coded two further regressors for common paycheck receipt days, the 1^{st} and the 15^{th} of each month; if these dates fell on a weekend in any given month, the immediate preceding weekday was used.

2.4. Statistical methodologies

We excluded a small number of FSAs comprising industrial/commercial neighborhoods, by filtering the FSAs with less than 1000 adult residents according to the Statistics Canada 2011 Census Profile (Statistics Canada, n.d.). This left us with 95 FSAs for our analysis. Of the five excluded FSAs, four of them had a population of 0, which creates two analytical issues: the dependent variable (sales/population) would require dividing by 0, and second, SES is meaningless in an area (e.g. a business district) with no residential population. For each FSA, the time series data over the 4-year timeframe (including a leap year) sum to 1,461 data-points per FSA, and 138,701 data-points in total. We excluded 'add-on gambles', i.e. optional gambles that customers can add to a purchase (e.g. 'Poker Lotto All in', 'Spiel Lotto Max', and 'Spiel Daily Keno') because they introduce conditional dependencies.

We used the lme4 package in R programming language (Bates et al. 2015) to build a mixed-effects linear regression model to study the lottery gambling behavior in different neighborhoods. Our analysis plan proceeded in five steps, investigating the effects of different predictor variables on lottery sales. The dependent variable for Models 1-3 was the log of the aggregated sales (in Canadian dollars) for each progressive-prize lottery divided by the adult population in that FSA (i.e. ticket sales per resident). This takes into account the variability in population size across FSAs, and the log transformation accounts for substantial skew in sales (see also Oster 2004; Rintoul et al. 2013; Grumstrup and Nichols 2021). Model 1 investigates the classic rollover effect, as the effect of jackpot size regressed on ticket sales. Model 2a tests the interaction between jackpot size and neighborhood SES (on ticket sales), as the replication of Oster (2004). In Model 2b, we investigated whether the effects of jackpot size could be better explained by simply representing streak length (the number of draws since the last jackpot was won) instead of the pecuniary jackpot value. Model 3 explores whether the composite effect of SES on lottery sales could be better explained by education levels (model 3a) or income (model 3b) as separate predictors. For Model 4, to study the complementarity/substitution effect, we used the log of the aggregated sales of the fixed-prize lotteries divided by the adult population of that FSA as the dependent variable. Effect sizes were calculated [b/standard deviation of the residuals] and interpreted using standard thresholds for Cohen's d ($d < 0.2$, negligible; $d = 0.2 - 0.5$, small; $d = 0.5 - 0.8$, medium; $d > 0.8$, large)(Cohen 2013).

The regression equation for model 2a is:

$$\begin{aligned} \log\_lotto649\_sales\_per\_capita \sim\ & \log\_lotto649\_jackpotsize + ses \\ & + \ (nuisance\ variables^{*}) \\ & + ((nuisance\ variables)\ |FSA) \end{aligned}$$

*see supplementals for a full list of nuisance variables. The regression equations for the other models are also specified in the Supplemental Materials.

To test for multicollinearity, we have included a table with the $\mathrm{GVIF}^{(1/(2*\mathrm{df})}$ of our independent variables (see Table S1) (Fox and Monette 1992).

For model comparisons, we could not model the variables of interest simultaneously due to collinearity between streak length and jackpot size (model 2), and between education and income (model 3). Instead, we compare model fits using the Akaike information criterion (AIC) and Bayesian information criterion (BIC), which are widely used for model selection and designed to strike a balance between the goodness of fit of a model and its complexity. They consider how well a model fits the data while penalizing excessive complexity in the model (see Table S1). In both AIC and BIC, a lower score indicates a better model. It is important to note that the models for which we compare AIC/BICs are similar in complexity, which helps us interpret which variables contribute to better model fit. We also compared models 4a and 4b to examine whether progressive-prize sales or the progressive-prize jackpot size generated better-fitting models for the complementarity/substitution effects.

3. Results

The first set of models investigates the simple relationship between progressive-prize lottery sales and jackpot size, controlling for the nuisance regressors. We found that relationships between jackpot size and sales were positive and significant across all three progressive-prize lottery types (e.g. $b = 0.27$, $p < 0.001$ for Lotto649; see Table 2). The effect sizes for the jackpot size predictor in each model were large (e.g. Lotto649, $d = 1.35$), as shown in Table S1.

The second set of models adds SES, and the SES $\times$ jackpot-size interaction term as predictors (see Table 3). In addition to the effect of jackpot-size on each progressive game, SES had a significant negative effect on sales across all three progressive-prize games (e.g. Lotto649, $b = -0.28$, $p < 0.001$; see Table 4): sales per capita tended to be higher in postal codes with lower SES, consistent with ecological effects reported previously. Figure 2 shows a map of Toronto illustrating the relationship between SES and the sales per capita, for Lotto649. The effect sizes for the SES predictor in each model were large (e.g. Lotto649, $d = -1.38$). The SES × jackpot-size interaction terms were significant for each progressive game (e.g. for Lotto649, $b = 0.01$, $p < 0.001$). In each case, the positive beta indicates that at higher levels of SES, the relationship between jackpot size and ticket sales is stronger, confirming the effect reported by Oster (2004). While statistically significant, the effect sizes of the SES x Jackpot size interaction terms were negligible (e.g. Lotto649, $d = 0.05$). Figure 3 shows an interaction plot between the relationship of Lotto649

Table 2. Mixed-effects regression coefficients for model estimating effects of lotto649 jackpot size upon lotto649 sales.

Coefficient	Estimate	Std. Error	P-value
(Intercept)	−6.997	0.066	<0.0001
Log(lotto649 Jackpot)	0.270	0.001	<0.0001
2012	0.010	0.011	0.3228
2013	0.063	0.009	<0.0001
2014	−0.004	0.006	0.4675
Jan	−0.077	0.005	<0.0001
Feb	−0.091	0.005	<0.0001
Mar	−0.035	0.005	<0.0001
Apr	−0.011	0.005	0.0168
May	−0.074	0.005	<0.0001
Jun	−0.096	0.005	<0.0001
Jul	−0.121	0.005	<0.0001
Aug	−0.161	0.005	<0.0001
Sep	−0.060	0.005	<0.0001
Oct	−0.020	0.005	<0.0001
Nov	−0.057	0.004	<0.0001
Mon	0.508	0.037	<0.0001
Tue	0.856	0.036	<0.0001
Wed	1.863	0.035	<0.0001
Thu	0.659	0.040	<0.0001
Fri	1.168	0.039	<0.0001
Sat	1.743	0.021	<0.0001
First of month	−0.001	0.005	0.7766
Fifteenth of month	0.023	0.004	<0.0001
Victoria Day	−0.943	0.045	<0.0001
Labor Day	−0.903	0.048	<0.0001
Family Day	−0.134	0.015	<0.0001
Good Friday	−0.763	0.045	<0.0001
New Years	−0.817	0.043	<0.0001
Thanksgiving	−0.871	0.048	<0.0001
Canada Day	−0.609	0.034	<0.0001
Christmas Eve	0.563	0.015	<0.0001
Christmas Day	−1.205	0.055	<0.0001
Boxing Day	−0.480	0.029	<0.0001

Table 4. Mixed-effects regression coefficients for model estimating effects of lotto649 jackpot size and SES upon lotto649 sales.

Coefficient	Estimate	Std. Error	p-value
(Intercept)	−7.011	0.064	<0.0001*
SES	**−0.275**	**0.015**	**<0.0001**
Log(lotto649 Jackpot)	**0.270**	**0.001**	**<0.0001**
2012	0.010	0.010	0.3194
2013	0.063	0.009	<0.0001
2014	−0.004	0.006	0.4731
Jan	−0.077	0.005	<0.0001
Feb	−0.091	0.005	<0.0001
Mar	−0.035	0.005	<0.0001
Apr	−0.011	0.005	0.0157
May	−0.074	0.005	<0.0001
Jun	−0.096	0.005	<0.0001
Jul	−0.121	0.005	<0.0001
Aug	−0.161	0.005	<0.0001
Sep	−0.060	0.005	<0.0001
Oct	−0.020	0.005	<0.0001
Nov	−0.057	0.004	<0.0001
Mon	0.508	0.036	<0.0001
Tue	0.856	0.035	<0.0001
Wed	1.863	0.035	<0.0001
Thu	0.659	0.038	<0.0001
Fri	1.168	0.038	<0.0001
Sat	1.743	0.022	<0.0001
First of month	−0.001	0.005	0.7773
Fifteenth of month	0.023	0.004	<0.0001
Victoria Day	−0.944	0.044	<0.0001
Labor Day	−0.903	0.047	<0.0001
Family Day	−0.134	0.015	<0.0001
Good Friday	−0.763	0.045	<0.0001
New Years Day	−0.817	0.041	<0.0001
Thanksgiving	−0.873	0.049	<0.0001
Canada Day	−0.608	0.034	<0.0001
Christmas Eve	0.562	0.015	<0.0001
Christmas Day	−1.204	0.054	<0.0001
Boxing Day	−0.480	0.029	<0.0001
SES*log(lotto649 jackpot)	**0.010**	**0.000**	**<0.0001**

Table 3. Table of model *b* and p-values.

Model	Lottery	Jackpot Size / Lottery Sales Predictor	SES predictor	Interaction Effect
Progressive Sales ~ Jackpot Size (Model 1)	Lotto 649	$b = 0.27$, $p < 0.001$	NA	NA
	Lottario	$b = 0.40$, $p < 0.001$	NA	NA
	Lotto Max	$b = 0.46$, $p < 0.001$	NA	NA
Progressive Sales ~ SES and Jackpot Size (Model 2a)	Lotto649	$b = 0.27$, $p < 0.001$	$b = -0.28$, $p < 0.001$	$b = 0.01$, $p < 0.001$
	Lottario	$b = 0.41$, $p < 0.001$	$b = -0.33$, $p < 0.001$	$b = 0.01$, $p < 0.001$
	Lotto Max	$b = 0.46$, $p < 0.001$	$b = -0.31$, $p < 0.001$	$b = 0.01$, $p < 0.001$
Progressive Sales ~ SES and Streak (Model 2b)	Lotto 649	$b = 0.09$, $p < 0.001$	$b = -0.14$, $p < 0.001$	$b = 0.003$, $p < 0.001$
	Lottario	$b = 0.08$, $p < 0.001$	$b = -0.10$, $p < 0.001$	$b = 0.002$, $p < 0.001$
	Lotto Max	$b = 0.14$, $p < 0.001$	$b = -0.12$, $p < 0.001$	$b = 0.003$, $p < 0.001$
Progressive Sales ~ Education and Jackpot Size (Model 3a)	Lotto 649	$b = 0.27$, $p < 0.001$	$b = -0.85$, $p < 0.001$	$b = 0.03$, $p < 0.001$
	Lottario	$b = 0.40$, $p < 0.001$	$b = -1.00$, $p < 0.001$	$b = 0.04$, $p < 0.001$
	Lotto Max	$b = 0.46$, $p < 0.001$	$b = -1.00$, $p < 0.001$	$b = 0.04$, $p < 0.001$
Progressive Sales ~ Income and Jackpot Size (Model 3b)	Lotto 649	$b = 0.27$, $p < 0.001$	$b = -0.61$, $p < 0.001$	$b = 0.02$, $p < 0.001$
	Lottario	$b = 0.40$, $p < 0.001$	$b = -0.64$, $p < 0.001$	$b = 0.02$, $p < 0.001$
	Lotto Max	$b = 0.46$, $p < 0.001$	$b = -0.63$, $p < 0.001$	$b = 0.03$, $p < 0.001$
Fixed Sales ~ SES and Progressive Sales (Model 4a)	Lotto 649	$b = 0.07$, $p < 0.001$	$b = -0.13$, $p < 0.001$	$b = 0.004$, $p < 0.001$
	Lottario	$b = 0.01$, $p < 0.001$	$b = -0.11$, $p < 0.001$	$b = 0.004$, $p < 0.001$
	Lotto Max	$b = 0.10$, $p < 0.001$	$b = -0.10$, $p < 0.001$	$b = 0.002$, $p < 0.001$
Fixed Sales ~ SES and Progressive Jackpot (Model 4b)	Lotto 649	$b = 0.00074$, $p = 0.41$	$b = -0.12$, $p < 0.001$	$b = -0.001$, $p < 0.005$
	Lottario	$b = -0.03$, $p < 0.001$	$b = -0.13$, $p < 0.001$	$b = -0.0004$, $p = 0.316$
	Lotto Max	$b = 0.03$, $p < 0.001$	$b = -0.12$, $p < 0.001$	$b = -0.0003$, $p = 0.51$

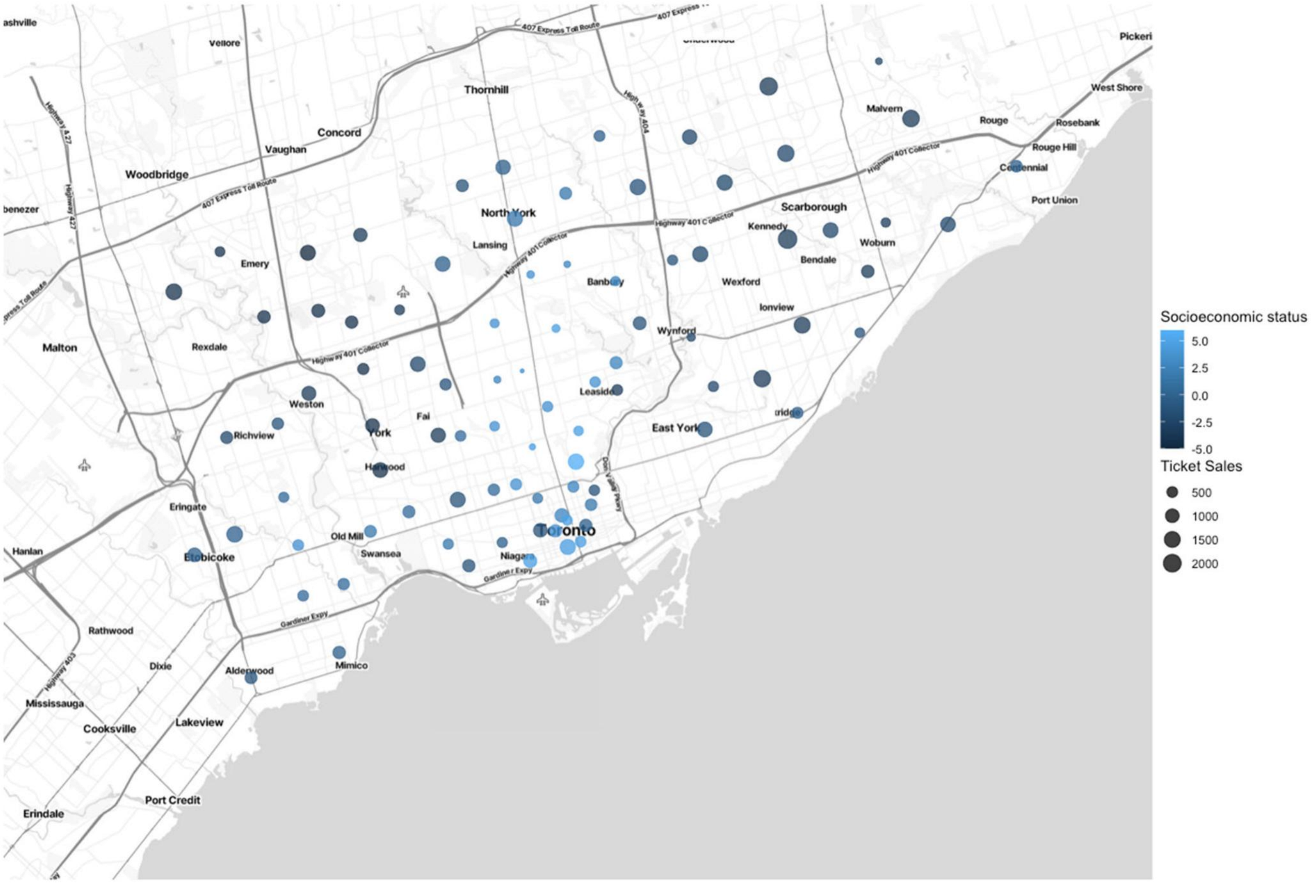

Figure 2. Map of Toronto showing socio-economic status and total per capita sales from 2012–2015.

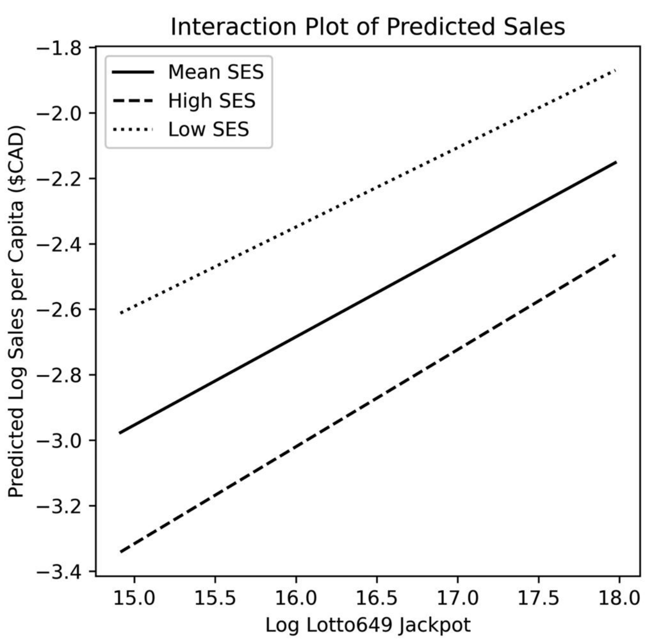

Figure 3. Interaction plot showing the relationship between jackpot size and sales per capita (for Lotto649) as a function of SES, and ± 1 standard deviation from the mean.

Jackpot and predicted sales at mean and ± 1 standard deviation levels of SES (see Table 5 for descriptives for two FSAs representative of ±1SD for SES).

Model 2b replaced the jackpot size (in $) with a streak variable that indicates how many successive lottery draws had 'rolled over'. For each progressive game, the streak length (i.e. the number of rollovers) had a significant positive effect on sales, in line with the jackpot size effect in model 1. The significant negative relationship between SES and sales was confirmed from the original model. The interaction effect between SES × Streak Length interaction terms were positive and significant (e.g. for Lotto649, $b = 0.003$, $p < 0.001$; see Table 3). The effect sizes for the SES × Streak Length interaction terms were negligible (e.g. Lotto649, $d = 0.02$) (see Table S1). Comparing model fit between models 2a and 2b (jackpot size vs streak length), the models using jackpot size as a predictor had lower AIC/BIC, indicating better model fit.

Table 5. Education, income, and white collar workforce (%) of two representative FSAs selected at approximately +1 and -1 SD from the mean for SES.

SD	FSA	Years of Education	Median Income	White collar workers (% of workforce)
+1	M2L	12.12	$38,683	78.20
−1	M9W	6.43	$24,869	44.27

Model 3 decomposed the SES composite variable to investigate whether the moderating effects on lottery sales were predominantly driven by education (model 3a) or income (model 3b). In model 3a, education exerted a significant negative effect on sales, and the Education × Jackpot-size interaction term was significant for each progressive lottery game. Likewise, in model 3b, income exerted a significant negative effect on sales, and the Income × Jackpot-size interaction term was significant for each game. In model comparisons, model 3a (education) achieved lower AIC and BIC values, indicating better fit, compared to model 3b (income) for each of the 3 progressive games (see Table S1).

Model 4 investigated how fluctuations in the progressive-prize lottery games influenced summed fixed-prize lottery sales as the dependent variable. Model 4a used the progressive-prize sales for each game as the predictor variable. Across each game, progressive-prize sales exerted a significant positive effect on fixed-prize sales, indicating complementarity (e.g. for Lotto649, $b = 0.07$, $p < 0.001$; see Table 3). The SES × Progressive Sales interaction terms were significant and positive for each progressive game, such that at higher levels of SES, the relationship between progressive sales and fixed prize sales was stronger (see Figure 4). Effect sizes for the progressive-prize sales on fixed-prize sales were small for Lotto649 ($d = 0.32$) and LottoMax ($d = 0.48$), and negligible for Lottario ($d = 0.\ 04$) (see Table S1).

Model 4b used the jackpot size from the progressive lottery games as the predictor. These results differed between the three progressive games. On Lottomax, jackpot size exerted a significant positive effect as in model 4a; for Lottario, jackpot size had a significant *negative* effect on fixed-prize sales; and lastly for Lotto649, the effect of jackpot size on fixed-prize sales was non-significant. Across the 3 progressive lotteries, the effect of SES on fixed-prize sales was negative and significant. There was a significant SES × Jackpot Size interaction for Lotto649, such that at higher levels of SES, the relationship between progressive jackpot size and fixed-prize sales was reduced; these corresponding interaction terms were non-significant for Lottario and Lottomax (see Table 3). In model comparisons between model 4a and 4b (see Table S1), model 4a achieved lower AIC and BICs on two of the three progressive games, Lottomax and Lotto649, and hence we emphasize the more consistent effects of model 4a using progressive-prize sales.

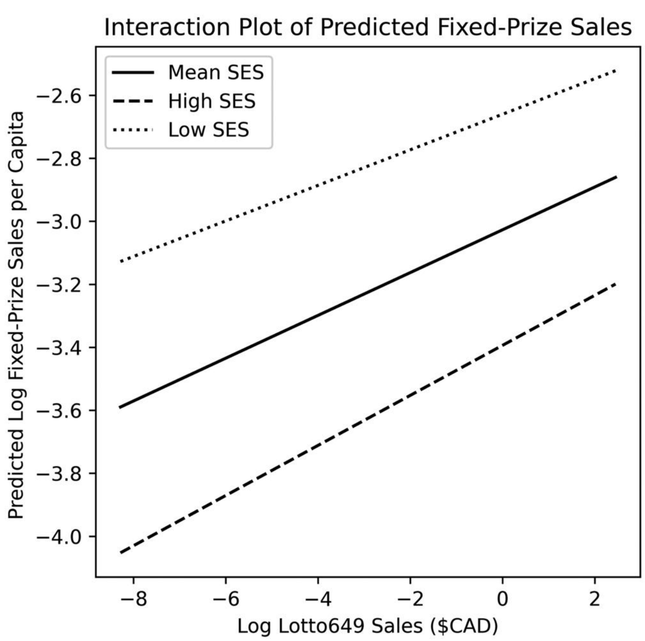

Figure 4. Interaction plot showing the relationship between progressive-prize sales and predicted fixed-prize lottery sales as a function of SES, at ± 1 standard deviation from the mean.

4. Discussion

In a dataset from large metropolitan Canadian city, daily fluctuations in lottery ticket sales were closely related to the accumulating jackpot size, in line with the well-established rollover effect (DeBoer 1990; Shapira and Venezia 1992; Forrest et al. 2002). Confirming our previous analyses on the same dataset, lower SES neighborhoods in Toronto contributed to greater ticket sales per capita (Fu et al. 2021a). Here, we observed a significant interaction between jackpot size and neighborhood SES, such that ticket sales in higher SES neighborhoods were more sensitive to the rollover effect. This replicates an older observation from Connecticut, USA by Oster (2004), although the effect sizes for these interactions were negligible. Our second set of questions examined how fluctuations in progressive-prize lottery sales influenced sales of a second type of lottery product, fixed-prize lotteries, which are typically available from the same outlets (e.g. gas stations, grocery stores). At time points with higher progressive-prize sales, sales of fixed-prize lottery tickets reliably increased, supporting complementarity rather than substitution in this dataset. This effect also displayed a significant interaction with neighborhood SES, such that the complementarity on fixed-prize sales was stronger in higher SES neighborhoods.

Focusing first on the progressive-prize (i.e. within-product) analysis, the ecological interaction between jackpot size and SES was observed across all three progressive-prize products (Lottomax, Lotto649, Lottario), whereby lottery sales in higher SES neighborhoods reacted more strongly to fluctuations in jackpot size compared to sales in lower SES neighborhoods. Thus, while low SES neighborhoods spent more on lottery tickets overall, this over-representation of lottery sales in lower SES neighborhoods was attenuated at larger (rollover) jackpots. Prior studies indicate complex relationships between socioeconomic variables, gambling involvement, and gambling harms, in which more affluent groups tend to spend more on gambling overall, but less affluent groups commit a greater *proportion* of their income to gambling (Beckert and Lutter 2013; Castrén et al. 2018; Roukka and Salonen 2020). In ecological analyses using geographical units, point-of-sale locations for different forms of gambling (including lottery outlets) tend to be concentrated in less affluent neighborhoods (Pearce et al. 2008; Wardle et al. 2014; Grumstrup and Nichols 2021). In our dataset, we infer that greater ticket sales equate to greater financial losses for residents in those zip codes, given the house edge that is built into lottery products. At the same time, the interaction between jackpot size and SES observed in the present data points to an attenuation of these effects at larger jackpots. Oster (2004) extrapolated from her regression data on the US Powerball lottery to argue that the ‘regressivity’ of that lottery would reverse above a jackpot of $805 million (USD), such that the lottery would draw more revenue from more affluent sectors of society. Our equivalent value, extrapolated from Model 2a, is over CAD $2 trillion

(Lotto649), which underscores the negligible effect size for these interactions. (In the data window used here from 2012-2015, the maximum rollover jackpot was just $64 million). Lottery operators may consider creating larger jackpot sizes to reduce social inequalities, for example by amalgamating products – although under such conditions, individuals with lower SES individuals may still spend more as a proportion of their income, and thus it is questionable whether social inequities are really mitigated through this approach.

Secondary analyses sought to test some further influences in the interaction between jackpot size and SES. In model 2b, we confirmed the significant interaction effect when jackpot size was replaced with a 'streak' predictor that represented the number of consecutive draws that had rolled over. The jackpot size and streak predictors were highly correlated, which prohibited a direct inferential comparison of the models, but the AIC/BIC values indicated a better fit for the model predicting ticket sales from the pecuniary value of the jackpot. Model 3 decomposed the SES measure into income and education. The model using education as a predictor achieved better fit and slightly stronger effect sizes. Given that gambling harms operate primarily through financial losses (Langham et al. 2016), one might anticipate low income to be the stronger component of SES, but other work has also described effects of education on problem gambling and gambling expenditure (Wong and So 2003; Welte et al. 2017; Grönroos et al. 2021). For example, in a US survey study, after controlling for other sociodemographic variables including job prestige and income, only lower education significantly predicted problem gambling symptoms (Welte et al. 2017). In the earlier ecological analysis of lottery outlets in New Jersey, Wiggins et al. (2010) also saw no relationship between household income and lottery outlet density. In our data, moderate-to-high collinearity of income and education precluded inferential comparisons by modeling these predictors simultaneously, but we recommend future studies aim to disambiguate education and income as predictors of SES.

In the tests of complementarity on fixed-prize lottery sales (Model 4), the analyses using progressive-prize *sales* as a predictor (Model 4a) showed clearer and more consistent effects than the models entering the progressive jackpot size *per se*. For progressive-prize sales, the overall complementarity effect and the interaction effect with SES were significant (and consistent in their direction) across all three progressive lotteries, whereas using jackpot size as the predictor, even the single jackpot size predictor did not exert a stable effect across the three lotteries. Presumably, any effect that a fluctuating jackpot size might have on fixed-prize sales is mediated by progressive-prize *sales*. It is also possible that further complementarity may exist between the three progressive-prize lotteries (e.g. Lotto649 fluctuating influencing the sales of Lottomax). Although we controlled for several time-course nuisance variables in our analyses, the three progressives were modeled separately such that we could not test such effects. Previous economic analyses of lotteries paint a complex picture for complementarity vs substitution, with a range of boundary conditions (Forrest et al. 2004, Grote and Matheson 2006); for example, different effects may be observed when correlating two existing gambling products, versus the impact of a new offering on an existing product, or correlating state-restricted versus national products (Grote and Matheson 2006) In showing an ecological moderation of these effects by SES, we highlight a neglected variable that may help reconcile these competing findings in the literature.

Several limitations should be noted. A defining aspect of our dataset is that it pertains to ticket sales in downtown Toronto. Our SES measure used an aggregate of z-scores for each FSA, combining 1) per-capita income, 2) years of education, and 3) proportion of white-collar workers, but these must be treated as relative measures within Toronto. Toronto has a relatively high median income (CAD $85,000 CAD) compared to other cities, even within Canada (e.g. $65,500 CAD in Montréal, and $79,500 CAD in Vancouver) (Government of Statistics Canada 2022). Interactions with SES may change in more rural and/or remote areas. Furthermore, the education and white-collar employment indices in the Canadian Census adopt specific age thresholds (ages 25 and 15, respectively), which do not map perfectly to the legal gambling age of 19. Here, we use this measure as a proxy for neighborhood education level, as using 19 years old as the cut off could be misleading as some may not have completed their post-secondary education. Second, in relation to the analyses of complementarity vs substitution, an important question is how fluctuations in progressive-prize lotteries impact instant lottery sales, as a higher-risk product type. This could not be examined here due to differences in the sales data for the instant lotteries that precluded analysis of day-by-day fluctuations (see Methods). Third, the available SES data in the Canadian Census does not represent variability *within* an FSA, and average values will neglect individuals living under severe disadvantage, including poverty and homelessness, which are relevant variables in the context of gambling harms (Hahmann et al. 2021). FSAs also vary in population size, which will further affect diversity within FSAs. Future research testing alternative measures of disadvantage, as well as other spatial units such as enumeration areas (which are designed to represent a relatively uniform population size) may be fruitful. Lastly, in correlating lottery sales in an area against SES, we assume those sales are attributable to residents of that area. This is unlikely to be entirely correct and future studies could consider spatial autocorrelation between neighborhoods; for example, in relation to tourism or commuter districts (Pérez et al. 2022).

Our Ontario dataset captured a 4 year timeframe from 2012 to 2015. In the intervening years, online gambling has become a dominant mode of access, and in most jurisdictions (including Ontario), lottery products can now be purchased online as well as from land-based stores. Our dataset, relying on land-based sales, would not capture online engagement. Nevertheless, online gambling participation also scales with socioeconomic variables and is therefore likely to have ecological correlates. These effects could be investigated in FSA data linked to online gambling accounts, as a direction for future research.

5. Conclusion

Gambling harms arise through processes operating at the level of the person, the product, and the environment (Korn and Shaffer 1999). The lottery rollover effect is afforded by the progressive-prize structure, as a 'structural characteristic' (Griffiths 1993) that provides a naturalistic insight into the wider question of how very large jackpots affect gambling engagement. These analyses have considered how this product-level effect varies with SES, conceptualized at an ecological level. The moderating effects that we observe for SES on jackpot size (Model 2a) and complementarity (Model 4a) indicate stronger effects in more affluent (less disadvantaged) neighborhoods. Conversely, we do *not* see evidence that large progressive jackpots disproportionately appeal to lower SES groups, a possibility with more profound implications for the links between gambling and social inequality. Nevertheless, our findings resonate with other data showing that groups who experience marginalization in various forms (e.g. poverty, migrants, or gender minorities) are at elevated risk for gambling harms, and that their involvement in gambling may further amplify these social inequalities (Sulkunen et al. 2018; Wardle et al. 2019; Hahmann et al. 2021; Lee and Grubbs 2023).

Ethical statement

This study using a publicly available secondary dataset that does not require ethics board approval.

Disclosure statement

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