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The revenue impacts of cross-border lottery shopping in the presence of spatial autocorrelation

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Abstract

In this paper we perform the first-ever analysis of cross-border lottery shopping. We directly estimate the lottery revenue gains and losses between a state and its neighbors using models that account for spatial dependence between cross-sectional units. This methodology has been rarely used in studies exploring regional public finance issues and is shown to improve upon standard OLS estimation of cross-sectional data. We find that cross-border lottery shopping can lead to significant reductions in lottery revenue. Given that 37 states rely on lotteries to fund certain state programs, our results have significant policy implications for state officials and lottery operators. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

State lotteries have become big business. Currently, 37 states and the District of Columbia offer lotteries, generating nearly \$36 billion in sales during 1999. After

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prize payouts, commissions, and operating expenses lottery states received \$11 billion in net lottery revenues.¹ Although lotteries provide a source of entertainment for millions of lottery players nationwide, the primary goal of any state lottery is to maximize revenues. Clotfelter and Cook (1989, p. 11) note that "Lottery agencies are not merely acting out of a liberal respect for consumer sovereignty. They are engaged in a well-focused quest for increased revenues." This pursuit of additional revenue results from each lottery's responsibility to fund various social programs within a state. As states are facing increased demands for public services, state officials will undoubtedly become more dependent on lottery revenues to help ease mounting fiscal pressures.

Given the importance of lottery revenue for state finance, researchers have explored several issues surrounding lottery finance. Studies by Vrooman (1976), Clotfelter and Cook (1987, 1989), Scott and Garen (1994) and Hansen (1995) examined the significant demographic characteristics of lottery players and the equity implications of the lottery tax. Research by Thiel (1991), Quiggin (1991), Scoggins (1995), and Garrett and Sobel (1999) focused on the 'optimal' prize and odds structure of a lottery game, optimal in terms of revenue maximization. These studies found that states which offer lottery games having large jackpots with remote odds of winning, such as Lotto, will be rewarded with higher sales. Finally, studies by Gulley and Scott (1989), Vasche (1990), and Ovedovitz (1992) explored the revenue impacts of competition between state lotteries and other forms of gambling within a state, such as parimutuel racing and casino gambling.

Although past works have provided insights into state lottery finance, the issue of cross-border lottery shopping has received little attention in the literature. Most research done on cross-border shopping has focused on the revenue impacts of cross-border shopping for alcohol and cigarettes.² These studies have shown that states do indeed face revenue competition due to differences in tax rates, prices, and geographical convenience (minimal transportation costs) across states. Revenues in one state are dependent upon economic conditions and policies in a neighboring state. Whereas past studies of cross-border shopping did not consider lottery products, there is no reason to believe that cross-border shopping for lottery tickets does not occur. Each state offers lottery games that are unique to the state — most games across states differ in terms of prize payouts and odds of winning, except in the case of multi-state lottery games.³ Certainly players living in border areas will respond to changes in lottery jackpots, both in their state and in neighboring states. In May of 1998 the jackpot for PowerBall, a multi-state lottery

¹From the US Bureau of the Census' Statistical Abstract of the United States 2000.

²See Smith (1976), Thursby et al. (1991), Saba et al. (1995), and Beard et al. (1997).

³Multi-state lottery games have numerous states participating in the same game. Due to economies of scale, low population states cannot individually offer large jackpots relative to higher population states. By pooling their ticket sales with other states, small population states can offer large jackpot lottery games. See Deboer (1985).

game, reached \$175 million. In West Virginia, a PowerBall state, a local newspaper reported that thousands of Pennsylvanians traveled across the state line into West Virginia in order to buy tickets for the big drawing. According to one PowerBall player "...this is the closest store that sells PowerBall tickets. And somebody's gonna win it all".⁴

It seems that non-lottery states are aware of the potential revenue loss as residents cross state lines to purchase lottery tickets. Alm et al. (1993) find that while states initially adopted lotteries in order to alleviate the increasing demand for state government services, competition for lottery dollars lost to cross-border shopping is becoming a more significant reason for lottery adoption.⁵ Although 37 states currently offer state lotteries, and one of the primary reasons for lottery adoption has been revenue competition, there has been no study to date that measures the revenue gains and losses arising from cross-border lottery shopping.

In this paper we attempt to quantify the revenue impacts of cross-border lottery shopping. With the state of Kansas as the cornerstone of our analysis, we estimate lottery revenue net gains and net losses between Kansas and each of five distinct border regions — Nebraska, Oklahoma, Colorado, Missouri, and Kansas City, Missouri. Kansas provides a unique setting to test for cross-border lottery shopping for several reasons. First, with the rectangular shape of Kansas, except for the northeast corner, each of its four border regions (north, south, east, and west) are bordered by a single state. Second, as discussed later, several neighboring states have lotteries while another does not, thus providing the opportunity to measure cross-border lottery shopping between lottery states and between a lottery and non-lottery state. Using a cross-section of all 105 Kansas counties for 1998, we use models of spatial dependence to accurately assess cross-border shopping between Kansas and each of the five border regions. Models of spatial dependence, sometimes termed 'spatial autocorrelation', have yet to be widely applied to regional public finance issues.⁶

Pioneered by Cliff and Ord (1981) and Anselin (1988a), models of spatial dependence account for direct influence from spatial neighbors, as well as externalities and spillover effects between cross-sectional units of observation. Although somewhat analogous to autocorrelation in time series models, spatial autocorrelation is multi-dimensional in that it depends upon all contiguous units of observation (in this case counties). Just as one corrects for autocorrelation in time series analysis, accurate cross-sectional analyses requires testing and correcting for spatial autocorrelation. Performing OLS in the presence of spatial autocorrelation may result in biased, inefficient, or even inconsistent coefficient estimates.

⁴From 'Got \$40, gonna buy 40 tickets,' *The Dominion Post*, Morgantown, West Virginia, Wednesday, May 20, 1998, p. A1.

⁵Several other studies have explored issues surrounding state lottery adoption. See Davis et al. (1992), Hersch and McDougall (1989), and Garrett (1999).

⁶See Case (1991, 1992), Case et al. (1993), and Ohsawa (1999).

The paper is structured as follows: the next section sets the stage for the analysis by providing a background on the Kansas Lottery and the lotteries present in the regions bordering Kansas. We also discuss our a priori expectations regarding cross-border lottery shopping between Kansas and each region based on past works on the determinants of cross-border shopping and the optimal prize and odds structure for lottery games. The following section presents our spatial autocorrelation model and the data used in the analysis. We then present empirical evidence on the magnitude of cross-border lottery shopping between Kansas and each of the five border regions. The final section is reserved for policy implications and concluding comments.

2. Cross-border lottery shopping: background and expectations

2.1. Kansas and its neighbors

The Kansas Lottery began operations in November of 1987. The lottery currently offers roughly 10 instant games and five on-line games, with every game available in each Kansas county. In terms of the number of games available, the lottery portfolio of Kansas is not very different than that of the average state. Ticket sales have increased nearly every year since the lottery was introduced, with sales topping \$192 million in 1998. Of its three neighboring states with lotteries, Kansas was third to adopt a lottery. Colorado, to the west of Kansas, started its lottery in January of 1983. To the east, the Missouri lottery started 3 years later in January of 1986. Nebraska, to the north, followed Kansas in lottery adoption with ticket sales beginning in September of 1993. Only Oklahoma, to the south of Kansas, does not offer a state lottery.

Different patterns of cross-border shopping are expected to occur between each border region. Western Kansas counties are influenced by the Colorado Lottery, northern Kansas counties by the Nebraska lottery, and eastern Kansas counties by the Missouri Lottery. There is no reason to assume that patterns of cross-border shopping are the same for these three regions.

Unlike the other three regions, the southern counties in Kansas border a non-lottery state. Lottery availability in neighboring states thus provides an interesting opportunity to examine differences in cross-border shopping between lottery states and cross-border shopping between a lottery state and non-lottery state.

⁷Instant games, also called 'scratch-offs,' require the player to scratch the play area to reveal a winning combination of symbols. To play on-line games, a player must obtain a play slip from a lottery retailer and select a combination of numbers. The player then submits the slip for processing. Drawing for on-line games are aired on TV. Relative to instant games, on-line games offer much higher jackpots at much more remote odds of winning.

2.2. Why cross-border lottery shopping may occur

Previous literature on cross-border shopping cites differences in prices, taxes and geographical convenience as three predominant reasons why cross-border shopping may occur.8 As most lottery tickets cost one-dollar, the price of a lottery ticket is equal to the lottery game's takeout rate, with the takeout rate set by the state lottery. In a simple framework, the takeout rate is defined as 1 - EV, where EV is the expected value or return to the player for every dollar wagered (ignoring jackpot rollovers and sales variability). Thus, on average, the portion of every dollar bet that the player can expect not to be returned to him is equal to the price of the lottery ticket. Except for multi-state games like PowerBall, the takeout rate of each state's lottery games are slightly different than that of other states. This simple expression for the price of a lottery ticket thus suggests that a state which offers lottery games having lower takeout rates relative to its neighbors' lottery games should experience an inflow of lottery shoppers from out-of-state. However, it is unlikely that slight differences in the takeout rates across lottery states alone would induce large amounts of cross-border shopping unless the expected benefit of a slightly lower takeout rate out-of-state exceeds the transportation costs of making the trip.

What is more likely to induce cross-border shopping is the presence of large jackpots that occur from rollovers. Rollovers occur when there is no jackpot winner — monies allocated to the top prize are rolled-over into the prize pool for the next drawing. This process continues until there is a winner, resulting in massive jackpots. Studies by Thiel (1991), Quiggin (1991), Scoggins (1995), and Garrett and Sobel (1999) have shown that lottery players favor lottery games offering huge jackpots at remote odds of winnings over smaller prize, better odds games. Thus, as a lottery jackpot continues to grow in the absence of any winners, more players are attracted to the game. As suggested by the PowerBall jackpot in 1998, the large jackpots can induce players to cross state lines for a chance of winning. Of course, jackpots do not have to reach several hundred millions of dollar to induce cross-border shopping. The above studies suggest that players substitute between lottery games by weighing the relative perceived benefits from each game.

Retail trade, population centers, and geographic convenience are other explanations for the existence of cross-border shopping. Regions having a large retail trade area (higher product availability) are expected to draw consumers from neighboring areas that have less retail trade (lower product availability). Thus for two neighboring counties, one predominately rural and the other urban, one would

⁸See Footnote 2.

⁹Huge jackpots also impact the expected value of a lottery ticket. As a jackpot continues to grow, large marginal changes in the expected value of the ticket occur (since the odds of winning are constant), thus decreasing the price of the ticket.

Table 1					
A priori	expectations	for	cross-border	lottery	shopping

Kansas border region	Hypothesized net flow of lottery sales based on:			
	Lottery game characteristics	Retail trade and population	Lottery games, retail trade, and population	
Kansas City,	(0)	(-)	(- or 0)	
Missouri (not	(0)	(-)	(- or 0)	
Kansas City) Nebraska	(0)	(-)	(- or 0)	
Colorado	(+)	(0)	(+ or 0)	
Oklahoma	(+)	(+)	(+)	

⁽⁺⁾ refers to a net inflow of lottery dollars into the Kansas border region, (-) is a net outflow from the Kansas border region, and (0) is a net effect of zero for the Kansas border region.

expect rural consumers to travel to urban areas as there is a greater availability of retail goods in the urban area relative to the rural area. As population is highly correlated with retail trade areas, one would also expect consumers to travel from low population areas to higher population areas. Similarly, commuting patterns also lend to cross-border shopping. Again, for the urban and rural areas, higher employment opportunities in the urban region will draw workers from the rural area. As workers travel between regions, consumption expenditures will follow commuting patterns.

2.3. Cross-border lottery shopping: a priori expectations

Our expectations regarding cross-border lottery shopping in Kansas are based on differences in lottery games, retail and population centers, and commuting patterns between Kansas and neighboring states. The empirical model, which is discussed later, captures the net impact of cross-border shopping for each border region (border counties); that is, the sum of lottery expenditures into Kansas and lottery expenditures out of Kansas. The net impact of cross-border lottery shopping between Kansas and each border is region is discussed below, with a summary of our expectations shown in Table 1.

Oklahoma is located along the southern border of Kansas. As of 1999, Oklahoma was one of 13 states that has not yet adopted a lottery. Given that Kansas has a lottery and Oklahoma does not, we expect people from border

¹⁰Cross-border lottery shopping may also occur due to differences in retail sales tax rates across states if retail sales and lottery sales are positively correlated. Kansas currently has a state sales tax rate of 4.9% with a local sales tax option. A comparison of Kansas state and local sales tax rates with those of neighboring states reveals only minimal rate differentials.

regions in Oklahoma to travel to Kansas to purchase lottery tickets. Obviously, lottery expenditures will not flow from Kansas to Oklahoma. Furthermore, the southern border of Kansas is more populated than the northern border of Oklahoma. Based on the availability of lottery products and the presence of several large communities along the southern border, we expect to find a positive flow of lottery dollars from Oklahoma to Kansas.

The Colorado Lottery offers several on-line lottery games that are very similar to games offered in the Kansas Lottery. However, unlike Kansas, Colorado does not offer PowerBall. As discussed before, PowerBall is a multi-state lottery game that can offer jackpots totaling several hundred million dollars. Although both lotteries are similar except for PowerBall, the large jackpots available in PowerBall relative to those offered in the Colorado Lottery could cause cross-border lottery shopping from Colorado to Kansas. This flow of lottery expenditures is doubtful, however, given the characteristics of the regions. Both eastern Colorado and western Kansas counties, although sharing a common border over 200 miles long, have a combined population of less than 95 000. The region is characterized by prairie land and large agricultural and livestock farms, with no significant retail trade areas. So although we would expect a positive flow of lottery dollars from Colorado into Kansas because of PowerBall, the lack of a significant population and retail trade centers suggests this flow would be minimal at best.

Nebraska lies to the north of Kansas. Nebraska, like Kansas, is one of the 20 states that offers PowerBall. The other lottery games available in Nebraska are very similar to those available in Kansas. Both states offer instant games and on-line games having similar odds of winning and prize payouts. Given the similarity of both states' lotteries, one would expect little cross-border shopping to occur between Kansas and Nebraska. However, the border regions for each state are different. The southern border of Nebraska, while having a population only about 15 000 greater than the northern border of Kansas, has several large retail trade areas very close to the Kansas border. Kansas has no significant trade areas near the Nebraska border. Based on lottery game and border characteristic comparisons between both states, it is unlikely that Kansas would experience a net inflow of lottery dollars from Nebraska. Rather, depending on the draw of Nebraska's border retail areas, one could expect the net flow of lottery dollars to be zero or slightly negative for Kansas counties bordering Nebraska.

The final border state examined is Missouri. Like Nebraska, Missouri also offers PowerBall in addition to other on-line lottery games that are similar to those offered in the Kansas Lottery. Therefore, one would expect very little cross-border lottery shopping between the two states based on differences in lottery games. There are significant population and retail trade differences, however, between

¹¹The southern border counties in Nebraska have a population of about 91 000. Northern border counties in Kansas have a combined population of roughly 76 000.

Kansas and Missouri. We consider two distinct Missouri border regions — Kansas counties bordering Kansas City, Missouri and the remaining Kansas counties that border Missouri. The 'Kansas City' area actually contains two different cities — Kansas City, Kansas and Kansas City, Missouri — separated by the Missouri River. Kansas City, Kansas is a moderately populated residential area, whereas Kansas City, Missouri is a typical city, characterized by skyscrapers and much larger suburban areas. As a result, the Missouri side of the border is a much more populated area due to the presence of Kansas City, Missouri. Missouri border counties have a combined population of over 1.3 million, with almost 1 million of the 1.3 million coming from the Kansas City, Missouri area. Besides Kansas City, Missouri, the Missouri side of the border also has the relatively large cities of St. Joseph and Joplin. Kansas border counties have a total population of about 750 000, with 630 000 of this total living in Kansas City, Kansas. Kansas City, Kansas is by far the largest city on the Kansas side of the border. Based on population differences, retail trade locations, and commuting patterns, one would expect a large net outflow of lottery dollars from Kansas into Missouri, with this outflow being greatest in those Kansas counties that border Kansas City, Missouri.

3. Data and empirical methodology

We obtained 1998 data from all 105 Kansas counties for our analysis. Our general methodology involves a regression of per capita lottery sales in county *i* on a vector of county demographic characteristics and several border binary dummy variables. By controlling for all other factors that influence lottery sales we can assure that the border dummy variables are only capturing the effects of cross-border shopping. The dummy variables capture differences in lottery sales due to differences in retail sales taxes, population differences, commuting patterns, and the strength of retail trade areas between border areas.¹² The demographic variables we include are based on previous authors' works on the demand for lottery tickets. Income, education, religious affiliation, and ethnicity have been shown to be significant determinants of lottery expenditures. We also include other factors which are hypothesized to impact lottery sales, such as tourism, the number of road miles in the county, and the number of lottery retail outlets available in the

¹²If lottery sales in Kansas and its bordering states are jointly dependent, a simultaneous system of equations would be required and the results presented here will suffer from bias. A simultaneous system of lottery sales would require a data set identical to that used here for each bordering state. Besides the time costs of this data gathering, the issue of almost infinite borders applies. If we consider sales and demographics in those states bordering Kansas, then ideally states that border the Kansas border states should also be included (i.e., Utah for Colorado, South Dakota for Nebraska, Texas for Oklahoma, etc.), and so on. As there is no established procedure to accommodate edge effects (See Anselin, 1988a) in the spatial econometrics literature, we have chosen the empirical methodology presented.

county. Also included are dummy variables for whether a county has a casino or a parimutuel racetrack. Definitions and summary statistics for the demographic variables are shown in Table 2.

There are a total of 40 border counties in Kansas. We have five border dummy variables, one for each border region in Kansas. Each border dummy variable has

Table 2 Variable description and summary statistics

Variable	Description	Mean	S.E.
Per capita	1998 county lottery sales per	75.6	168.7
lottery sales	capita		
Per capita	1998 county per capita income	20 313.6	35 297
income			
Percent high	Percent of the county population	77.7	93.0
school grad	with a high school diploma		
Tourism	The number of hotels, RV	6.06	74.0
	parks, and campsites in county		
Religion	Percent of county population	26.8	51.1
	classified as 'Conservative		
	Christian'		
Road miles	The total number of road miles in	1269.9	3733.0
	the county		
Per capita	The number of lottery retail outlets	0.95	2.6
lottery outlets	in the county per 1000 population		
Percent urban	Percent of county population living	32.1	98.9
	in an urban area		
Percent	Percent of county population	4.84	32.9
nonwhite	classified as nonwhite		
Track	'1' if county has a parimutuel	0.019	0.14
	racetrack, '0' otherwise		
Casino	'1' if county has a casino, '0'	0.029	0.17
	otherwise		
Kansas City,	'1' if county borders Kansas City,	0.029	0.17
Missouri	MO, '0' otherwise		
Missouri	'1' if county borders Missouri (not	0.057	0.23
	Kansas City), '0' otherwise		
Nebraska	'1' if county borders Nebraska, '0'	0.114	0.32
	otherwise		
Colorado	'1' if county borders Colorado, '0'	0.057	0.23
	otherwise		
Oklahoma	'1' if county borders Oklahoma, '0'	0.123	0.33
	otherwise		

Per capita income, education, and ethnicity data are from the US Bureau of the Census. Tourism figures are from US Bureau of the Census' County Business Patterns. Religion data is from The National Council of Churches' Churches and Church Membership in the United States 1980. 'Conservative Christian' is defined as Baptist, Methodist, Mennonite, and Brethren. The number of road miles is from the Kansas Department of Transportation. Lottery sales and the number of lottery retail outlets per county were obtained from the Kansas State Lottery. Number of observations is 105.

a value of '1' if county *i* borders the corresponding state, '0' otherwise. Although most border counties in Kansas only border one state, there are three counties, located in the northwest, southwest, and southeast corners of the state that border two states. We assigned each corner county to the border state sharing a majority of the county border.¹³ For our analysis, there are 12 counties that border Nebraska, three counties that border Kansas City, Missouri, 13 counties that border Oklahoma, six counties that border Colorado, and six counties that border Missouri.

We wish to estimate the impact of cross-border lottery shopping between Kansas border counties and neighboring states. The majority of cross-border shopping is presumed to occur in border counties. Any possible cross-border shopping between internal Kansas counties and neighboring states will be captured in the constant term (reflecting the average level of sales in the internal counties) and the explanatory variables accounting for tourism, road miles, and the presence of a racetrack and casino. The coefficient estimates on the border dummy variables will thus measure the net impact (sum of inflows and outflows) of cross-border shopping between each border region in Kansas and the corresponding border state relative to the internal counties. So, for example, a positive and significant coefficient on the Oklahoma dummy variable would reveal that Kansas counties that border Oklahoma have, on average, higher lottery sales than internal Kansas counties. As we have controlled for other factors that impact lottery sales, the positive coefficient would thus suggest a net inflow of lottery dollars from Oklahoma to Kansas.

Although OLS would be the common estimation technique for our analysis, the cross-sectional nature of our data presents the potential problem of spatial dependence. Spatial dependence results from a lack of independence among cross-sectional units caused by (1) spill-over effects between units of observation and (2) the presence of direct influence of neighboring units of observation. Ordinary least squares can produce inefficient coefficient estimates and biased variance estimates when error terms are spatially correlated (see Anselin, 1988a), as the error terms from OLS violate the classical assumptions of independence and identical distribution (IID). In the presence of spatial correlation due to direct influence of spatial neighbors, which is characterized by a spatially lagged dependent variable, estimates from ordinary least squares will be biased and inconsistent (Anselin, 1988a). In our model of lottery sales, it is not unreasonable to believe that lottery sales in one county impact lottery sales in neighboring counties. Changes in the number of retail outlets, advertising, etc. in a county is likely to impact sales in neighboring counties. Also, if one county has a large town that is located near the border of a neighboring county, lottery sales in the neighboring county are certainly a function of lottery sales in the large town. To

¹³Changing the assignment of each corner border county did not alter the empirical results.

account for these possible spillover effects between Kansas counties, diagnostic tests for spatial autocorrelation must be performed.

To ensure consistent and efficient coefficient estimates, we test and correct for spatial autocorrelation in our model of cross-border lottery shopping. The following section discusses the methodology used to estimate models of spatial autocorrelation.

3.1. Models of spatial autocorrelation

The basic model of spatial autocorrelation innovated by Cliff and Ord (1981) and Anselin (1988a) allows for spatial dependence in the dependent variable (termed a 'spatial lag') or in the error component (termed 'spatial error lag'). The first-order spatial autoregressive model, or spatial lag model, can be expressed as:

$$y = \rho \cdot W \cdot y + X \cdot \beta + \epsilon \tag{1}$$

where y is the $(N\times 1)$ dependent variable, ρ , a scalar, is the spatial autoregressive coefficient, W is a $(N\times N)$ spatial weights or contiguity matrix, X is a $(N\times K)$ matrix of exogenous variables, and ϵ is the $(N\times 1)$ IID error term. The spatial autoregressive coefficient, ρ , reflects positive spatial correlation if $\rho > 0$, negative spatial correlation if $\rho < 0$, and no spatial correlation if $\rho = 0$.

Our spatial weights matrix W is specified to capture exponential distance decay (see Bodson and Peters, 1975; Cliff and Ord, 1981; Dubin, 1988). The elements of our contiguity matrix $W = \{w_{ij*}\}$ are defined as $w_{ij}^* = \mathrm{e}^{-d_{ij}/\gamma}$ where d_{ij} the absolute difference between county i's distance to the nearest border state and county j's distance to the nearest border state. As the distance difference d_{ij} increases (decreases), w_{ij}^* exponentially decreases (increases), thus giving less (more) spatial weight to that county pair when $i \neq j$. For i = j, $w_{ij}^* = 0$ by standard

¹⁴Unlike the standard first-order autoregressive model in time series analysis, ρ does not necessarily have to lie between -1 and 1 in the first-order spatial autoregressive model. Generally, values for ρ are between the inverse of both the smallest and largest eigenvalues of the weights matrix. See Anselin (1995).

¹⁵We tested an exhaustive set of alternative weight matrices. These included the binary joins matrix (Cliff and Ord, 1981; Anselin, 1988a), where $w_{ij}=1$ if observations i and j ($i \neq j$) have common borders and $w_{ij}=0$ otherwise. Also, variations of the inverse distance weight matrix were tested. Finally, we examined an alternative binary contiguity matrix used by Case (1992) and Marsh et al. (2000). The elements of this contiguity matrix, $W=\{w_{ij}, \}$ were defined as $w_{ij}^*=w_{ij}/\Sigma_j w_{ij}$, where $w_{ij}=1$ if observations i and j ($i \neq j$) were from the same spatial region and $w_{ij}=0$ otherwise. One limitation of these structures, unlike the negative exponential structure presented here, is that they assume equal spatial weights across all spatial neighbors. The binary weights matrix also does not allow one to effectively capture spatial distances or distance decay. Diagnostic tests were performed on all specifications of the weights matrix, and the exponential distance decay weights matrix performed better than the binary weights matrix. Results using the alternative weights matrices will gladly be provided upon request.

convention. The positive parameter γ , which moderates the exponential decay, is estimated as a parameter in the regression model. Although W is a function of γ , for convenience it is suppressed in the notation $W = W(\gamma)$.

The spatial lag model presented above assumes spatial correlation in the dependent variable only, which may arise because of simultaneous interaction over space. For example, the contiguity matrix W defined above posits that per capita lottery sales are correlated for counties with like geographic proximity to a border state. However, spatial correlation may also occur in the error term, ϵ . Spatially correlated errors may occur due to spatial correlation among the explanatory variables, omitted variables, or spatial correlation in the dependent variable, especially when a spatially lagged dependent variable is not included in the model (Anselin, 1988a, Chapter 8). Diagnostic tests presented later will determine whether spatial correlation exists in the dependent variable or in the error term. To model spatial error dependence, we assume a first-order spatial autoregressive structure where the error term is given as:

$$\epsilon = \lambda \cdot W \cdot \epsilon + v = (I - \lambda W)^{-1} v \tag{2}$$

 ϵ is the $(N \times 1)$ vector of error terms, v is a $(N \times 1)$ component of the error terms made up of IID random variables, W is the $(N \times N)$ contiguity matrix described above, and λ is a scalar interpreted as the unobserved spatial error correlation coefficient. The error terms are positively correlated if $\lambda > 0$, negatively correlated if $\lambda < 0$, and not correlated if $\lambda = 0$.

The model of joint spatial lag dependence and spatial error dependence is represented by Eqs. (1) and (2). Combining the components, the mixed first-order spatial autoregressive model is given by:

$$y = \rho \cdot W \cdot y + X \cdot \beta + (I - \lambda W)^{-1} v \tag{3}$$

In the presence of a spatial lag, as shown in Anselin (1988a, p. 58), ordinary least-squares estimation of (3) will yield biased and inconsistent coefficient estimates. We perform maximum likelihood (ML) estimation on various forms of (3) to arrive at unbiased and consistent coefficient estimates. We set $\lambda = 0$ for the spatial lag model and $\rho = 0$ for the spatial error model.¹⁷ Under the assumption of

¹⁶Unlike the standard first-order autoregressive model in time series analysis, λ does not necessarily have to lie between -1 and 1 in the first-order spatial autoregressive model. Generally, values for λ are between the inverse of both the smallest and largest eigenvalues of the weights matrix. See Anselin (1995).

¹⁷As noted in Anselin (1988a), estimating (3) can lead to possible identification problems. To avoid this problem, we follow the standard approach and estimate the spatial lag and spatial error models individually.

normally distributed error terms, v, and homoscedasticity, the log-likelihood function for (3) is:¹⁸

$$\ln L(\beta, \sigma^{2}, \rho, \lambda, \gamma) = \ln[1 - \rho W(\gamma)] + \ln[1 - \lambda W(\gamma)] - \ln(2\pi\sigma^{2}) - 0.5(y^{*} - X^{*}\beta)'(y^{*} - X^{*}\beta)/\sigma^{2}$$
(4)

where $y^* = (I - \lambda W)(I - \rho W)y$, and $X^* = (I - \lambda W)X$. Note that restricting $\rho = \lambda = 0$ yields the standard likelihood function for the general linear model. Introducing the spatial components into the regression model in (3) does not alter the physical interpretation of the coefficient vector β , but the values of the β vector do adjust to reflect the influence of spatial correlation.

We can test for spatial dependence in the dependent variable, the error term, or both in several ways. Because the ordinary least squares, spatial lag, and spatial error models are all nested in the mixed spatial autoregressive model, it is straight forward to apply Lagrange multiplier (LM), Likelihood ratio, or Wald tests for spatial autocorrelation. Empirical evidence suggests that LM tests for spatial autocorrelation may be superior relative to Wald and Likelihood ratio tests (Anselin, 1988a, 1988b, 1995). In the empirical analysis, we report values of LM test statistics that are distributed χ^2 with q degrees of freedom (where q are the number of restricted coefficients).

Correcting for spatial dependence is critical. As we are providing direct evidence on the magnitude of cross-border shopping between Kansas and each of its five border regions, we want to ensure that our estimates are free of any biases. Only then can one confidently use the empirical results as a basis evaluating cross-border shopping and conducting appropriate policy.

4. Cross-border lottery shopping: empirical evidence

In this section we present empirical evidence of cross-border lottery shopping. We first conduct OLS by regressing per capita lottery sales on all demographic and

¹⁸The following likelihood function assumes homoscedasticity, as diagnostic testing for heteroscedasticity resulted in a failure to reject the null hypothesis of homoscedasticity at conventional levels. However, the likelihood function can be easily modified to correct for heteroscedasticity. See Anselin (1988a, 1995).

¹⁹Anselin (1988a) also suggests two other tests for evaluating the presence of spatial correlation in the dependent variable or in the error terms. One test in the Moran I statistic (Moran, 1950). The other test is the Likelihood Ratio test. However, of the three test statistics, the Lagrange Multiplier test is the most robust under Monte Carlo simulations. See Anselin (1990) and Anselin et al. (1996) for additional discussions on testing and estimating models of spatial autocorrelation.

border dummy variables shown in Table 2.20 The results from this regression are shown in the first column of Table 3. All demographic coefficient estimates, except religion, have the expected sign, although some variables are not statistically significant. It also appears that parimutual racetracks and casinos do not have a significant impact on lottery sales. Given the cross-sectional nature of our data, diagnostic tests for heteroscedasticity were also performed for all models. The Breusch–Pagan test for heteroscedasticity reveals the null hypothesis of homoscedasticity cannot be rejected.

The coefficient estimates on the border dummy variables reveal the presence of cross-border lottery shopping for each border regions. As expected, the estimates for Kansas City and Nebraska are negative and significant, suggesting a net outflow of dollars from Kansas counties bordering these regions. The OLS results suggest that the net impact of cross-border shopping between Kansas border counties and Missouri and Colorado is not statistically different from zero. Although cross-border shopping undoubtedly occurs in both directions across state lines, the net revenue impact is zero. Finally, the large positive and significant coefficient for Kansas counties that border Oklahoma corresponds with prior expectations. Kansas is experiencing a positive net flow of lottery dollars from Oklahoma.

Although a majority of the coefficient estimates from our OLS regression are in line with prior expectations, the possibility of spatial dependence in cross-sectional data calls into question the reliability of the OLS estimates. We estimate two ML model specifications to assess and correct for spatial correlation. We estimate a model that includes a spatially lagged dependent variable and a model that includes a spatially lagged error term. The results from each ML model are shown in columns 2 and 3 in Table 3. The spatial lag and error models were estimated using the MAXIMUM LIKELIHOOD 4 applications module of the GAUSS computer package (Aptech Systems, Inc., 1995) and verified using SpaceStat (Anselin, 1995). LM tests are used to assess the presence of spatial dependence in both the dependent variable and in the error term.

Considering the spatially lagged dependent variable model (Table 3, column 2), the estimate for ρ is negative and significant at a 5% level (based on an asymptotic

²⁰We ran the above models using several different specifications, including the addition of squared variables to overcome the potential problem of multicollinearity between the demographic variables. Little improvement was had by including these variables, and there were no significant differences in the results between these specifications and the final specification used.

²¹Using the MAXIMUM LIKELIHOOD 4 applications module of the GAUSS computer package, a grid search was performed to optimize the likelihood function conditioned on γ . Further, the optimized value of γ , along with β , ρ , and λ , from the grid search were used as the starting values to estimate the unconditioned likelihood function in (4). The value of γ that optimized the unconditioned likelihood function in (4) for the spatial lag model was 9.7. The spatial error coefficient was not statistically significant for any value of γ , which is consistent with the LM tests presented in Table 3. To confirm these results, the spatial lag and spatial error models were re-estimated using SpaceStat (Anselin, 1995).

Table 3 Evidence of cross-border lottery shopping: OLS and ML estimation results

Variable	(1) OLS: no	(2) MLE:	(3) MLE:	
	spatial lag	spatial lag	spatial error	
			lag	
Constant	37.601	56.793	15.314	
	(0.96)	(1.56)	(0.44)	
Per capita	-0.491	-0.220	-0.592	
income	(0.81)	(0.39)	(1.08)	
Percent high	-0.341	-0.421	-0.087	
school graduate	(0.73)	(1.00)	(0.21)	
Tourism	-0.170	-0.125	-0.295	
	(0.68)	(0.55)	(1.29)	
Religion	0.052	-0.031	0.105	
•	(0.25)	(0.15)	(0.54)	
Road miles	0.010**	0.010**	0.011**	
	(1.99)	(1.98)	(2.48)	
Per capita	51.054***	49.304***	53.043***	
lottery outlets	(9.41)	(9.94)	(10.64)	
Percent urban	0.273***	0.272***	0.287***	
	(3.55)	(3.91)	(4.06)	
Percent non-	1.182***	1.048***	1.192***	
white	(2.79)	(2.07)	(3.13)	
Track	-16.227	-16.283	-13.769	
	(0.97)	(1.07)	(0.89)	
Casino	-3.896	-2.45	-4.884	
Cusino	(0.39)	(0.27)	(0.52)	
Kansas City	-23.159*	-22.834**	-21.109**	
ransus city	(1.97)	(2.16)	(2.02)	
Missouri	-4.581	-0.717	-3.416	
Missouri	(0.59)	(0.10)	(0.52)	
Nebraska	-28.522***	-20.782***	-29.734***	
- reorasia	(5.07)	(3.30)	(6.77)	
Colorado	-2.723	5.027	-4.087	
Colorado	(0.32)	(0.60)	(0.57)	
Oklahoma	20.691***	28.162***	19.841***	
Oktanoma	(3.95)	(4.756)	(4.96)	
ρ	(3.73)	-0.0090**	(4.50)	
Ρ		(2.12)		
λ	_	(2.12)	-0.064*	
			(1.67)	
Log-likelihood	-433.56	-431.37	-432.56	
$LM-H_0: \rho = \lambda = 0$	3.91	-31.37		
$LM-H_0: \rho = 0$ $LM-H_0: \rho = 0$	3.79*	_	6.31**	
$LM-H_0: \ \ \lambda = 0$ $LM-H_0: \ \lambda = 0$	0.57	1.36	0.51	
$L_{IVI}-H_0$. $\Lambda=0$	0.57	1.30	_	

Absolute *t*-statistics in parentheses. Significance at ***1%, **5% and *10%. Dependent variable is per capita lottery sales. For simplicity in presentation, the coefficient on per capita income has been multiplied by 1000. Number of observations = 105.

t-test), revealing negative spatial correlation in the lagged dependent variable. The result of the LM test on spatial error dependence, which involves testing the null hypothesis $H_0:\lambda=0$ against the alternative hypothesis $H_1:\lambda\neq0$, reveals that considering spatial correlation in the error term would not significantly improve the model. This is confirmed by the spatial error model results shown in column 3 of Table 3. While λ is significant at the 10% level based on the asymptotic t-statistic, the likelihood function is lower than that of the spatial dependent variable model. Also, the result of the LM test on $H_0: \rho=0$ reveals that including a spatially lagged dependent variable would significantly improve the model. Together these hypothesis tests suggest that the inclusion of a spatially lagged dependent variable captured all spatial correlation. Based on the maximum likelihood principle and the LM tests, our spatially lagged dependent variable model is thus selected as the model of choice to assess the impacts of cross-border lottery shopping.

The results of the spatial dependent variable lag model suggest that Kansas is experiencing a lottery revenue net loss to Kansas City and Nebraska due to cross-border lottery shopping. However, a net inflow of lottery dollars into Kansas from Oklahoma is found. Finally, there appears to be no significant gain or loss in lottery dollars between Kansas and Colorado and Missouri. The exact dollar gains and losses are presented in the following section. Although the coefficient signs and significance from the spatial lag model are the same as under OLS, the OLS estimates are inconsistent from the omission of the spatial dependent variable lag.

5. Cross-border lottery shopping: revenue impacts

We compute the net revenues gains and losses from cross-border shopping for each border region and the state as a whole using the coefficient estimates on the five border dummy variables and the constant presented in the spatially lagged dependent variable specification. Our goal is not to predict per capita sales for each region, which would require using the means of all independent variables as well, but rather capture the relative difference in average per capita sales due to cross-border shopping only.

Internal counties have per capita sales of \$56.79. Relative to these internal counties, Oklahoma border counties have per capita sales of \$84.96 (\$28.16 higher than internal counties), Nebraska border counties have per capita sales of \$36.01 (\$20.78 lower than internal counties), and Kansas City, Missouri border counties have per capita sales of \$33.96 (\$22.83 lower than internal counties). Per capita sales in Colorado and Missouri border counties are not significantly different than per capita sales in the internal counties, thus suggesting a zero-sum gain in lottery revenues from these border areas. To compute the revenue gains and losses for

each region we simply multiply the dummy coefficient by population for the corresponding region. Total revenues from each region are found by adding the net gain or loss to the sales amount present if no cross-border shopping occurred. These computations are shown in the top portion of Table 4.

The bottom portion of Table 4 consists of the revenues gains and losses to the state of Kansas. These values are found by summing the gains from each region and the losses from each region presented at the top of Table 4. We find that Kansas has a net gain of \$5.55 million from Oklahoma, but has a net loss of almost \$16 million from Nebraska and Kansas City, Missouri. We also compute the net impact of cross-border lottery shopping, which is simply the sum of the regional gains and losses. This computation reveals that Kansas lost almost \$10.5 million in 1998 to cross-border lottery shopping.

Table 4
Predicted revenue impacts of cross-border lottery shopping

Region	Cross-border shopping Impact	Per capita lottery revenues	Total lottery revenues (per capita×pop) ^a	
Internal counties	No border impact	\$56.79	\$91 335 799	
Kansas City,	With no border impact	\$56.79	\$35 812 763	
Missouri	Net loss from border impact	(\$22.83)	(\$14 398 795)	
	Total revenues	\$33.96	\$21 413 968	
Missouri	No border impact	\$56.79	\$6 252 864	
Nebraska	With no border impact	\$56.79	\$4 326 896	
	Net loss from border impact	(\$20.78)	(\$1 583 341)	
	Total revenues	\$36.01	\$2 743 555	
Colorado	No border impact	\$56.79	\$1 031 590	
Oklahoma	With no border impact	\$56.79	\$11 187 843	
	Net gain from border impact	\$28.16	\$5 547 796	
	Total revenues	\$84.96	\$16 735 639	
Kansas total:				
Gains from cross-border shopping:			\$5 547 796	
Losses from cross-border shopping:			\$15 982 136	
Net revenue impact of cross-border shopping:			(\$10 434 341)	

^a The population for each of the six regions is: Internal counties, 1 608 220; Kansas City, 630 583; Missouri (not including Kansas City), 110 099; Nebraska, 76 187; Colorado, 18 164; Oklahoma, 196 993. Total population for Kansas in 1998 was 2 640 246. The unrounded coefficients from column 2, Table 3 were used to compute total lottery revenues rather than the rounded per capita values shown above.

6. Concluding comments

Thirty-seven states and the District of Columbia currently rely on lottery revenues to fund various social programs. Previous studies have shown that state lotteries face varying degrees of competition from parimutuel racing and casino gambling. Our study, however, is the first to consider that a state lottery may also be subject to competition from neighboring state lotteries and geographic locations of population and retail trade areas. Using Kansas as the basis for our analysis, we estimate the lottery revenue impacts of cross-border lottery shopping between Kansas and five border regions. Our results suggest that states are vulnerable to a revenue loss due to neighboring states with lotteries. Given this potential vulnerability, states may not wish to rely on lottery revenues as a stable source of long run revenues.

Although this study focused on Kansas, cross-border lottery shopping is an issue all lottery states should consider. By understanding the patterns of cross-border lottery shopping in other states and regions, more effective policies to reduce the negative revenue effects could be had. As increasing fiscal pressures force state officials to rely on alternative revenue sources such as lotteries, the problem of lost revenues due to cross-border lottery shopping will be a growing concern for state policy makers.

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