1 Introduction

As in the private marketplace, where firms compete over consumers using prices, jurisdictions compete over tax bases via tax rates. A large theoretical literature has developed around this theme, and a key parameter in these models is the degree of cross-border mobility of taxable economic activity.[1] When agents are highly mobile, the tax bases of jurisdictions are tightly linked, and tax revenues depend crucially upon the policies in other jurisdictions. In these models, equilibrium tax rates tend to be declining in the degree of mobility in the tax base due to the associated competition between jurisdictions.

In the context of commodity taxation, the key mechanism underlying such competition involves cross-border shopping. In this paper, we examine cross-border shopping for lottery tickets in U.S. states. Several features of state lotteries make the market well suited to a cross-border shopping study. First, a lottery ticket is always sold for the same price throughout the state and thus retailers on the border cannot adjust their price in the face of nearby competition. In other contexts, such as the taxation of gasoline, no arbitrage conditions imply that prices must be equal at the border. Second, the fact that jackpots roll over to the next drawing in the event that a winning ticket is not purchased provides a source of high-frequency variation in jackpots, and in turn the incentive to cross borders, across games and over time. In other contexts, such as the sales tax, changes in tax rates are less common. Finally, we study multi-state lottery games in which individual states join a consortium to offer the same lottery game, such as Powerball or Megamillions. This gives us both cross-sectional variation in the competitiveness of borders–a neighboring state may be in the same game, a competing game, or neither game–and longitudinal variation since states enter these consortia at different points in time. Such cooperation between states in the same consortium is not present in other tax systems.

A key issue involves the generality of these results to other products. On the one hand,

[1] See Zodrow and Mieszkowski (1986), Wildasin (1988), Bucovetsky (1991), Wilson (1991), and Hoyt (1993). Kanbur and Keen (1993), Ohsawa (1999), and Nielsen (2001) focus on the spatial aspects of this competition.

government monopoly provision of products, lottery tickets in this case, can be considered equivalent to government taxation of privately provided products (Fisher, 2007). That is, state monopoly pricing of lottery tickets can be interpreted as incorporating an implicit tax on lottery tickets. Given this, our methods and results may apply more broadly to many other forms of commodity tax competition. On the other hand, lottery tickets are a unique product. This is due to the extreme variation in jackpots across drawings, leading to significant variation in effective tax rates across states for a given drawing. Other products tend to have stable tax rates with smaller cross-state differences in tax rates across states.

In order to measure the degree of competition facing state lotteries, we use several insights regarding *where* and *when* cross-border shopping should be most prevalent. Regarding where, anecdotal evidence suggests that cross-border shopping is most common along densely populated borders between states that are not coordinating their lottery games. For example, many New Yorkers, who cannot purchase Powerball tickets within their state boundaries, reportedly cross the Connecticut border, which is just outside of densely populated New York City, in order to purchase Powerball tickets. Regarding when, anecdotal evidence suggests that cross-border shopping is most likely when jackpots are high. That is, the crossing of New Yorkers into Connecticut was particularly salient when the Powerball jackpot reached $250 million in 1998.[2] Put together, this suggests that the relationship between lottery revenues and lottery jackpots may be stronger in densely populated areas that do not share a multi-state game than in sparsely populated areas or along borders cooperating in the same multi-state lottery.

In this paper, we begin by formalizing these ideas in a simple theoretical model of the choices facing lottery players. In the model, players face a trade-off between travel distance and the price of a fair gamble, which is declining in the size of the jackpot and in the odds of winning. Given this trade-off, the model predicts that if cross-border shopping is substantial then the relationship between revenues per resident and prices should be stronger in states

[2] New York Times, July 27, 1998. This event was also mentioned in Brown and Rork (2005).

that have small populations and densely populated border regions, such as Rhode Island and Delaware, than in states that have large populations and more rural border regions, such as California and Texas.

In order to test this hypothesis, our empirical application focuses on the large multi-state games of Powerball and Mega Millions. We combine information from several different datasets. The first dataset consists of weekly lottery revenues between 1995 and 2008 for each state and separately for each game. The second dataset represents game characteristics, most notably odds and jackpots on a drawing-by-drawing basis for Powerball and Mega Millions. The third dataset includes information on the spatial distribution of the population and is used to create measures of the size of the population living near every state border.

The empirical results support the theoretical predictions. Lottery revenues per resident are higher during weeks with large jackpots, which imply low prices. Importantly, this relationship is much stronger in states with small populations and densely populated border regions than in states with large populations and sparsely populated border regions. The results demonstrate that cross-border purchases are an economically significant factor in small, densely populated states. As predicted by the theory, we also show in a placebo test that these relationships are not present along borders in which both states cooperate, or participate in the same interstate lottery game, since there is no incentive to cross state borders in this case.

As noted above, competitive pressure associated with cross-border shopping tends to depress equilibrium tax rates in theoretical models of tax competition. Using our estimates of the degree of cross-border shopping, we attempt to quantify the effects of the associated competition on profit-maximizing prices. Averaged across all states, we find that prices under full collusion (all states in the same consortium), relative to full competition (each state has its own game), would be about 13 percent higher. The magnitude of these effects varies substantially, however, depending upon geography. In California, a large state with sparsely populated borders, there is virtually no difference between prices under collusion versus competition while in Delaware, a small state with densely populated borders, the difference is nearly 50 percent. These findings suggest that cross-border competition may play a substantial role in the pricing of lottery products.

The paper proceeds as follows. We begin by providing background information on state lotteries. We then discuss the relevant literature. This discussion is followed by the presentation of our theoretical model and its key predictions. After describing the data, we present our baseline empirical results and robustness tests. We then use our estimates to compute the effects of competition on optimal pricing. The final section discusses policy implications and concludes.

2 Background on state lotteries

This section provides a brief background on state lotteries with a focus on those issues that are most relevant to cross-border shopping and competition between states. See Clotfelter et al. (1999) and Kearney (2005b) for more complete information on state lotteries.

In 1964, New Hampshire became the first state government in the United States to operate a lottery. Many states followed suit, and, by 2007, 42 state lotteries were in operation.[3] Lottery tickets must be purchased from licensed retailers, which operate only within state boundaries.[4] Thus, individuals wishing to purchase lottery tickets out of state must physically travel to a licensed retailer in that state.

Every state in the continental United States currently either has a lottery or is bordered by at least one state with a lottery. Given this widespread availability, lotteries have become the most common form of gambling. According to a recent Gallup survey, almost one-half of

[3] While state governments have established monopoly rights over the provision of lottery products, they do face competition from related gambling products, such as casinos, even within their borders.

[4] Prior to 1985, six states were offering lottery tickets to out-of-state players via mail, a practice that was declared illegal by the U.S. Postal Service on May 31, 1985 (Washington Post, June 1, 1985). Similar legal issues apply to potential internet sales of lottery tickets to out-of-state players. Relatedly, the reselling of tickets in out-of-state retail outlets is typically illegal. During a large Powerball jackpot in 1993, some Massachusetts retail outlets were selling Powerball tickets originally purchased in Rhode Island, an act that violated Massachusetts law (Boston Globe, July 8, 1993).

respondents reported that they had purchased a state lottery ticket in the preceding year.[5]

Regarding the overall size of the market, lottery revenues in 2007 totaled $76 billion nationwide. In terms of the disposition of these revenues, $56 billion were paid out in prizes, $18 billion were retained by states as profits, and the remaining $2 billion were attributed to administrative expenses.[6] With roughly 230 million U.S. residents over the age of 18, which is a typical minimum age for purchasing lottery tickets, this implies per capita annual purchases of $330. The 24 percent profit margin is consistent with an implicit commodity tax rate of 32 percent, which, while lower than in past years, remains much higher than tax rates on other products (Clotfelter and Cook, 1990).

A variety of games are currently available to lottery players. In the lotto game, which is the focus of this paper, players choose a series of numbers, such as five numbers between 1 and 59 and one number between 1 and 39 in Powerball, and win the jackpot if their numbers match those chosen at the drawing.[7] If there is no winning ticket, the jackpot rolls over to the next drawing, and there are typically two drawings per week. Due to this rollover feature jackpots can grow very large but the odds are also quite long. The odds of winning the jackpot in Powerball, for example, are currently 1 in 195,249,054.

Due in part to demand for games with large jackpots, some states have banded together to form multi-state games (Clotfelter and Cook, 1990). In 1987, the District of Columbia and five relatively small states, Iowa, Kansas, Oregon, Rhode Island, and West Virginia, formed the Multi-State Lottery Association, which offered a lottery game known as LottoAmerica. In 1992, the Association began the Powerball lotto game, which quickly grew in popularity due to its large jackpots. As shown in Table 1, there was significant entry into Powerball

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[5] These data were taken from the website http://www.gallup.com/poll/104086/one-six-americans-gamble-sports.aspx (accessed August 5, 2009).

[6] These data are taken from the Census Bureau 2007 Survey of Governments.

[7] Lottery games can be placed into several broad categories (Clotfelter et al., 1999). In addition to the lotto, there are four other categories of games. Instant scratch tickets allow the player to immediately observe and collect any prizes. In the numbers game, players choose their own three-digit or four-digit numbers and win if their numbers match those chosen during the drawing, which are typically held daily. Keno is a similar game but one in which drawings are held more frequently, often hourly. Video lottery terminals are similar to those found in casinos and offer games such as video poker.

during our sample period 1995-2008. By the end of this period, Powerball tickets were sold in D.C. and in 30 states. As also shown in Table 1, six states came together in 1996 to start a competitor multi-state lottery known as The Big Game. In 2002, the name was changed to Mega Millions, and, by the end of 2008, tickets were sold in 12 of the 13 lottery states not currently selling Powerball tickets. Florida entered Mega Millions in 2009, and every lottery state thus currently participates in either Powerball or Mega Millions. Jackpots in the Mega Millions game have also grown large, with the $390 million top prize on March 6, 2007 marking the largest jackpot in U.S. history.

In order to provide a sense of the spatial distribution of Powerball and Mega Millions states, Figure 1 maps the membership in these two games as of December 31, 2008, the end of our sample period. As shown, two Mega Millions states, Illinois and Washington, are completely surrounded by states participating in the competing Powerball game. At the other extreme, four Powerball states, North Dakota, Minnesota, Kansas, and Maine, are completely surrounded by states cooperating in the Powerball game. Thus, there is significant spatial variation in the degree of competition facing Powerball and Mega Millions states. As can be seen from the map, the Mega Millions states, which include California, New York, and Texas, tend to have larger populations.

A recent agreement between these two multi-state games allows for the simultaneous sale of both sets of tickets in all Powerball and Mega Millions states.[8] This cross-selling of the two lottery tickets began in early 2010 with some states adopting cross-selling immediately and other states deferring its introduction. This agreement may also lay the foundation for the introduction of a new "national lottery" with tickets available in all 42 states currently participating in Powerball or Mega Millions.

[8] Philadelphia Inquirer, October 14, 2009.

3 Existing literature

There are two different strands of the related empirical literature. The first strand looks at spatial interdependence in policies directly, estimating the policy effects of the policies of neighbors, such as in Case et al. (1993), Brueckner and Saavedra (2001), and Besley and Case (1995). In a paper with direct relevance to our subject, Brown and Rork (2005) look at the determinants of US state lottery payout rates and find that states respond to changes in the payout rates of neighbors. See Brueckner (2003) for a more complete review of this literature.

The second strand of empirical work, where we place our paper, looks at the issue of policy interdependence indirectly by estimating the amount of cross-border shopping, which can be considered a measure of the mobility of the tax base. Notable examples include Coats (1995), Lovenheim (2008), Chiou and Muehlegger (2008), Merriman (2010), and DeCicca et. al. (2010) on cigarettes, Beard et al. (1997) and Asplund et al. (2007) on alcohol, Doyle and Samphantharak (2008) on gasoline, and Goolsbee (2000) on goods purchased via the Internet.

The most closely related studies are those that investigate cross-border shopping in the context of lottery tickets. Garrett and Marsh (2002) use lottery sales data for counties in Kansas during 1998 and compare sales in border counties to sales in non-border counties. They find that Kansas counties which border states with lotteries tend to have lower sales, while counties bordering states without lotteries tend to have higher sales.[9] While this study uses only cross-sectional variation across counties, Tosun and Skidmore (2004) use annual lottery sales for counties in West Virginia between 1987 and 2000. Variation across time in the introduction of lottery games in border states allows the authors to control for county fixed effects. The key findings are that sales in border counties decline following the introduction of new lottery games in bordering states. Mikesell (1991) conducts a telephone survey and estimates the determinants of lottery expenditure in Indiana before the Indiana

[9] They control for both county demographic characteristics and spatial autocorrelation.

State Lottery was introduced and thus all expenditures were out of state. His key finding is that Indiana residents living in border counties were more likely to play the lottery. Two studies use national data on cross-border lottery shopping. Stover (1990) uses sales data from 1984 and 1985 for the 17 states with lotteries in these years and finds that sales are influenced by lottery status in neighboring states. While this study is limited to just 34 observations, Walker and Jackson (2008) use a longer panel covering the period 1985 to 2000. They thus use variation across time in the introduction of lotteries in bordering states and show that lottery sales are declining in the fraction of bordering states with a lottery.

Our approach offers several contributions to this literature on cross-border shopping for lottery products. First, our paper develops a theoretical framework for investigating cross-border shopping that incorporates the spatial distribution of the population. This structure yields two insights for measuring cross-border shopping: border shopping is more likely in areas with densely populated border regions, and consumers are more likely to cross borders when price differences are sizeable. Second, while many of the studies discussed above focus on a single state, our study is national. In addition to using nationally-representative data, our study uses cross-state variation in border populations in order to identify cross-border shopping. That is, we test the hypothesis that the revenues should respond more strongly to prices in states with densely populated border regions. Third, we are the first to use high-frequency variation in prices, which results from the rollover feature of lottery jackpots, to estimate the degree of cross-border shopping. Other studies have tended to use annual data and thus rely on the adoption of lotteries by neighboring states. One limitation of this approach in the existing literature involves strategic entry, under which states may choose to adopt lotteries when demand for these products is high. Our study, by contrast, uses variation in jackpots over time for a given configuration of state lotteries and is thus less affected by this issue of strategic entry. On a related note, our approach does not require the adoption of lotteries by states, an event that is becoming increasing rare since, as noted above, nearly every state has already adopted some form of lottery gambling. Finally, our study is the first to quantify the effects of cross-border shopping and the associated competition on optimal pricing.

4 Conceptual framework

In this section, we develop a two-state model in order to illustrate our main approach to identifying cross-border shopping. Given our empirical motivation, we keep the model simple and make specific functional form assumptions in some cases. It should be clear, however, that the results are robust to more general economic environments. Also, while we focus on the market for lottery products, the basic trade-off between travel costs and prices is more general and applies to many other forms of commodity taxation.

4.1 Setup

In the model, player i first chooses one of two possible state lotteries, which are given by West (W) and East (E) and are indexed by s. Conditional on choosing to play the lottery game in state s, individual i must choose how many tickets to purchase (x_{is}) in that game, each of which returns a jackpot j_s with probability p_s.[10] Players are characterized by their geographic locations (l_i), which are assumed to be distributed on the interval $[0, L]$ according to the distribution function F. The border between the states is located at b, and players with $l_i < b$ are thus residents of state W and players with $l_i > b$ are thus residents of state E. The total number of residents is normalized to one, with a fraction N_W living in state W and a fraction $N_E = 1 - N_W$ living in state E. Thus, we have that $F(b) = N_W$.

In order for individual i to play the lottery in the state where he is not a resident, he must travel a distance to the border equal to $d_i = |l_i - b|$, and the marginal cost of such travel is given by c. Thus, total transportation costs associated with playing the lottery in neighboring states is given by cd_i.[11] Players choosing to play the home lottery are assumed

[10] For simplicity we assume that there is only one prize available, the jackpot. In reality, lotto games tend to have multiple prizes with smaller prizes available for matching a subset of the numbers drawn. Our empirical specification will control for both the jackpot as well as the expected payoff from lower tier prizes.

[11] This formulation assumes that individuals travel across borders for the sole purpose of playing lotteries. In reality, individuals may travel across the border to purchase bundles of products when tax rates differ

to have immediate access to a retail store and thus face no transportation costs.

Following Kearney (2002), we also assume that players receive an entertainment value from playing the lottery.[12] We model this entertainment aspect by the function $g(x_{is})$, which is assumed to be homogenous across players and is increasing in the number of tickets purchased but at a decreasing rate.[13] That is, $g'(x_{is}) > 0$ and $g''(x_{is}) < 0$. We normalize this function such that $g(0) = 0$ and also assume that $g'(0) > 1$. The latter assumption guarantees that individuals always prefer to participate in the domestic lottery over not participating in any lottery.[14] Finally, we assume that players are endowed with exogenous income equal to m.

We further assume that players are risk-neutral and that, following Kearney (2002), utility is separable in the financial and entertainment aspects of the lottery. Under these assumptions, player i receives the following utility from purchasing x_{is} lottery tickets in state s:

$$U_{is} = x_{is}p_s(m + j_s - x_{is} - cd_{is}) + (1 - x_{is}p_s)(m - x_{is} - cd_{is}) + g(x_{is})$$

where $d_{is} = 0$ for the home-state lottery. This can be rewritten as follows:

$$U_{is} = m - cd_{is} - \pi_s x_{is} + g(x_{is})$$

where $\pi_s = 1 - p_s j_s$ can be interpreted as the price of purchasing a fair gamble, defined as one that costs \$1 to play and pays an expected value of \$1. Note that $\pi_s \leq 1$ since jackpots cannot be negative.

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substantially across states. In this case, the total travel costs cd_i will be spread across multiple products.

[12] Evidence from Kearney (2005a) suggests that non-financial aspects of games, which can be interpreted as entertainment, are important determinants of sales. For example, games that require players to choose seven digits have higher sales than games that require players to choose four digits, all else equal.

[13] In order to simplify the analysis, we do not allow players to participate in both lotteries, and x_{is} represents the number of tickets purchased in lottery s. One way to justify this restriction is to assume that the entertainment function $g(x_{is})$ depends only upon total tickets purchased. Then, the two lotteries are perfect substitutes, and optimizing players will participate in only one of the two state games even when they have the option to participate in both games.

[14] Below we consider the case in which only one state offers a lottery, and residents of the other state must thus travel in order to purchase lottery tickets. In this case, if the travel costs are sufficiently high, players may choose to not participate even under this assumption.

4.2 Individual choices

Conditional on choosing to play the lottery in state s, the number of tickets purchased by individual i is characterized by the following first-order condition:

$$g'(x_{is}) = \pi_s$$

Thus, players equate the marginal entertainment value to the price of a fair gamble. Note that the marginal entertainment value from a ticket must be significant in order to induce sizable revenues since prices for playing fair games are typically positive. Inverting this first-order condition, we have that $x_{is} = x_s = h(\pi_s)$ where $h = (g')^{-1}$. Since $h' = 1/g'' < 0$, the number of tickets purchased is decreasing in the price of a fair gamble (π_s). An important point for our empirical work is that the price (π_s) is decreasing in the jackpot, so that the higher the advertised jackpot, the greater the number of tickets we expect individuals to purchase.[15] Also, note that the number of tickets is constant across individuals and is independent of the distance traveled.[16] Given these results, the indirect utility for player i choosing lottery s is given by:

$$V_{is} = m - cd_{is} + z(\pi_s)$$

where $z(\pi_s) = g(h(\pi_s)) - \pi_s h(\pi_s)$ represents the non-travel, financial benefits from playing lottery s. Applying the envelope theorem, we have that $z'(\pi_s) = -h(\pi_s)$ and thus the non-travel, financial benefits are decreasing in the price of a fair gamble (π_s).

There exists a cutoff location ($\tilde{l}$) at which residents are indifferent between playing the lotteries in states E and W. This cutoff is given by:

$$\tilde{l} = b + (z(\pi_W) - z(\pi_E))/c$$

[15] Recall that the price equals one minus the expected value ($\pi_s = 1 - p_s j_s$). This specification for expected value is thus a simplification because it does not allow for multiple winners who must split prizes. Incorporating multiple winners would significantly complicate the model as it would introduce strategic interactions between players and would thus require an equilibrium concept. For further information on this issue, see Cook and Clotfelter (1993) and Walker (2008).

[16] Note that optimal spending on lottery tickets is independent of income. While this is driven by the fuctional form assumptions made above, it is consistent with evidence from Kearney (2005a), who shows that average spending levels are similar across different income groups.

Players west of this location ($l_i < \tilde{l}$) thus play lottery W, and those east of this location ($l_i > \tilde{l}$) play lottery E.

4.3 Lottery revenues and cross-border shopping

Lottery revenue for state W, which is the product of revenues per player (x_W) and the number of players $F(\tilde{l})$, can be written as:

$$R_W = h(\pi_W)F\left[b + (z(\pi_W) - z(\pi_E))/c\right]$$

Recalling that $F(b) = N_W$, the log of revenues per resident ($r_W = R_W/N_W$) is then given by:

$$\ln(r_W) = \ln[h(\pi_W)] + \underbrace{\ln F\left[b + (z(\pi_W) - z(\pi_E))/c\right] - \ln\left[F(b)\right]}_{\text{cross-border adjustment factor}}$$

The first term represents log revenues per player, and the second term is the cross-border adjustment factor. If the price of a fair game in E is higher than that in W ($\pi_E > \pi_W$), then this cross-border adjustment factor is positive since residents from state E will cross the border and play lottery W. Similarly, if prices are higher in state W, then this factor is negative since residents from state W will cross the border and play lottery E.[17]

An interesting result from this model is that cross-border shopping increases the combined sum of each state's lottery revenue, compared to a scenario of closed borders.[18] This result is driven by the fact that the number of tickets purchased is decreasing in the price, and players who cross the border in order to buy tickets in the neighboring state thus buy more tickets than they would have in their home state. However, while total revenue is always higher with open borders, revenues of individual states may be lower when the distribution of the population around the border is asymmetric or when one state has systematically

[17] Analogous results can be demonstrated for revenues from state E.

[18] Note that the difference between total revenue with cross-border shopping and without is given by $\left(F\left[b + \frac{z(\pi_W)-z(\pi_E)}{c}\right] - F[b]\right)(h(\pi_W) - h(\pi_E))$. When $\pi_W < \pi_E$ then $\frac{z(\pi_W)-z(\pi_E)}{c} > 0$ and $h(\pi_w) - h(\pi_E) > 0$ and when $\pi_W > \pi_E$ then $\frac{z(\pi_W)-z(\pi_E)}{c} < 0$ and $h(\pi_w) - h(\pi_E) < 0$. Thus, for any pair of prices where $\pi_W \neq \pi_E$, cross-border shopping yields greater total revenue.

higher prices. In the appendix, we provide an example with two prices, a low price π_L and a high price π_H, and two periods where the prices of state W and state E are first (π_L,π_H) and then (π_H,π_L). In this case, we show that, when the population is symmetric around the border, both states have higher revenue, when averaged over the two periods, relative to a scenario in which borders are closed.

4.4 Testable hypotheses

The model yields a number of testable hypotheses related to cross-border shopping. To generate an empirical specification, we first take a first-order linear approximation to the above revenues equation at the point $\pi_W = \pi$ and $\pi_E = \pi$.[19] This yields:

$$\ln(r_W) \approx \alpha + \frac{h'(\pi)}{h(\pi)}\pi_W - \frac{h(\pi)}{c}\lambda(b)\pi_W + \frac{h(\pi)}{c}\lambda(b)\pi_E$$

where $\alpha = \ln[h(\pi)] - \frac{h'(\pi)}{h(\pi)}\pi$ is a constant and $\lambda(b) = f(b)/F(b)$ represents the Mills ratio, the population density function divided by the distribution function, both of which are evaluated at the border.

Using the fact that $f(b) \approx \frac{1}{2\varepsilon}\left[F(b+\varepsilon) - F(b-\varepsilon)\right]$ for small values of ε, the numerator of the Mills ratio can be interpreted as the size of the population near the border, regardless of which side. Since the denominator $F(b)$ represents state population, the model thus predicts that revenues per resident in state W are more responsive to the price of the affiliated lottery (π_W) in states with small populations and densely populated border regions and less responsive in states with large populations and sparsely populated border regions. Finally, note that the magnitude of the effect is decreasing in the cost of travel (c), which makes players less willing to cross borders.

Similarly, the model demonstrates that the relationship between revenues and the price of the rival lottery (π_E) also depends upon the Mills ratio $\lambda(b)$. Thus, revenues per resident

[19] We evaluate this function at the same prices ($\pi_W = \pi_E = \pi$) for two reasons. First, it generates a tractable empirical specification since the terms $z(\pi_W)$ and $z(\pi_E)$ cancel out in the key spatial expressions $f(b)$ and $F(b)$. Second, equal prices will occur on average in our empirical application to follow since, as noted earlier, Powerball and Mega Millions are fairly similar lotteries.

should also be more responsive to the price of the rival lottery in states with small populations and densely populated border regions. Comparing the strength of the affiliated price effect and rival price effect, the former effect is the stronger of the two since it also includes the term $h'(\pi)/h(\pi)$, which reflects the intensive margin, defined as the increased revenues per player induced by lower prices. This intensive margin is not relevant for consumers who choose to play the lottery in the competing state.

The model can also be used to consider the effects of states cooperating in multi-state games, such as Powerball and Mega Millions. In particular, if the two states are part of the same multi-state game, then jackpots, odds, and thus prices are always identical ($\pi_E = \pi_W$), and the cross-border shopping adjustment factor vanishes since there is no incentive to travel to neighboring states when purchasing lottery tickets. In this case, revenues are given by $\ln(r_W) = \ln[h(\pi_W)]$ and thus increases in affiliated prices yield decreases in revenues but only due to the decrease in revenues per player for the domestic population. In particular, the relationship between revenues and both affiliated and rival prices should not depend upon the population density in border regions. We use this prediction to provide a placebo test of our main results in the empirical application to follow.

Finally, we use the model to consider a scenario in which the bordering state E does not have a lottery since this is relevant to our empirical application, in which some states do not have lotteries. In this case, it is possible that some players in state E will prefer to not purchase any lottery tickets if the associated travel costs are sufficiently high. It can then be shown that the linear approximation to revenues is given by:

$$\ln(r_W) \approx \alpha + \frac{h'(\pi)}{h(\pi)}\pi_W - \frac{h(\pi)}{c}\lambda(b + (z(\pi)/c))\pi_W$$

where $\alpha = \ln[h(\pi)] - \frac{h'(\pi)}{h(\pi)}\pi + \ln F\left[b + (z(\pi)/c)\right] - \ln\left[F(b)\right]$.[20] Thus, there are two important differences between the above case with competing lotteries and this case in which the

[20] To generate this, note that there exists a cutoff point located in state E where players are indifferent between playing the lottery in state E and not purchasing any tickets, which yields a utility level of $V = m$. This cutoff is given by:

$$\widetilde{l} = b + z(\pi_W)/c$$

bordering state has no lottery. First, in this case, lottery revenues in state W depend only upon the price of lottery W and thus do not depend upon the price of the rival lottery. Second, the marginal resident is always located in state E, and thus only the population on the foreign side of the border is relevant for cross-border shopping.

In summary, the model yields a number of testable predictions. First, lottery revenues per resident are declining in the price of the affiliated lottery. More importantly, this relationship is stronger in small states, in states with densely populated borders with competing states, and in states with densely populated borders with non-lottery states. Second, the positive relationship between revenues and prices of rival lotteries is stronger in small states and in those states with densely populated borders with competing states. Third, these relationships between revenues and prices should be independent of population density along cooperating borders, defined as those in which both states participate in the same multi-state lottery.

5 Data and Empirical Framework

Since our hypotheses relate lottery revenues to prices and the spatial distribution of the population, we combine data from three different sources. As noted above, we focus on the two multi-state games of Powerball and Mega Millions. Our data on lottery revenues were provided by La Fleur's and include weekly revenues data from 1995 to 2008 separately by game and state.[21] Note that states enter Powerball and Mega Millions at different points in time and thus the panel data are unbalanced in this case.

Given this cutoff, the log of per capita revenues are thus given by:

$$\ln(r_W) = \ln[h(\pi_W)] + \underbrace{\ln F\left[b + (z(\pi_W)/c)\right] - \ln\left[F(b)\right]}_{\text{cross-border adjustment factor}}$$

Thus, the cross-border adjustment factor is always positive in this case.

[21] Note that these LaFleur's data were missing sales information from a number of states. After contacting the missing states on an individual basis, we were able to obtain data for all states except Tennessee. Also, note that there were a few gaps in the data, some of which we were able to fill out by contacting individual states. Finally, we deleted a small number of state-week-game observations that covered only a partial week (i.e. less than seven days).

Data on the size of the jackpot by drawing in Mega Millions between its introduction on September 6, 1996 and the end of 2008 were downloaded from the Massachusetts Lottery website. Drawings in this game are held every Tuesday and Friday. Similar data on the size of the jackpot by drawing in Powerball were provided by the Multi-State Lottery Association and begin in 1992. Drawings for this game are held every Wednesday and Saturday. These measures represent advertised jackpots, defined as the forecast of the jackpot that is communicated to potential players on the days leading up to the drawing.[22] Since we have two observations per week on jackpots but only one observation on revenues, we use the maximum jackpot during the week as our key measure.[23] We then convert the advertised jackpots, which are simply the undiscounted stream of payments into present value terms.[24]

Using these jackpot measures, we then calculate prices as follows:

$$\pi = 1 - (1 - \tau)\left[pJ + EV(LowerTier)\right]$$

where τ is the highest federal marginal tax rate on income and $EV(LowerTier)$ is the expected value of the gamble associated with lower tier prizes.[25] To measure p, we have collected data on the odds of winning the jackpot in both Powerball and Mega Millions. These odds have changed somewhat over our sample period, tending to become longer.[26] We also gathered information on lower-tier prizes, which do not vary with the jackpot, are

[22] The actual jackpot will differ if actual sales during the days leading up to the drawing are not equal to projected sales.

[23] This follows the approach used by Kearney (2005a). We have also experimented with using the average jackpot, and our results are qualitatively similar to those presented here.

[24] Mega Millions jackpots are paid out through 26 equal payments and Powerball jackpots are paid through 30 payments with each payment rising by 4%. Using a 4% interest rate the present value of jackpot J is $0.535J$ for Powerball and $0.615J$ for Mega Millions.

[25] We thus implicitly assume that purchasing a winning ticket will put the taxpayer in the highest marginal tax bracket.

[26] The odds for Mega Millions started at 1 in 52,969,000 in 1995, changed to 1 in 76,275,360 in January 1999, became 1 in 135,145,920 in May 2002, and then 1 in 175,711,536 in June 2005 through the end of our sample period. Powerball odds started at 1 in 54,979,155 in 1995, changed to 1 in 80,089,128 in November 1997, became 1 in 120,526,770 in October 2002, and finally 1 in 146,107,962 in August 2005 through the end of our sample period.

paid out immediately, and range from \$3 to \$200,000 with the odds of winning becoming longer as the value of the prize increases. The expected value from these low tier prizes is relatively stable during our sample period, ranging from 17 to 21 cents for a one dollar ticket.

To measure the size of the population along state borders, we used spatial software and 2000 Census data.[27] We first compute the distance from the center of every census tract to every state border.[28] This then allows us to compute measures of the size of the population near the border for different definitions of proximity. Our baseline proximity definition is 25 kilometers. That is, we measure the number of residents within 25 kilometers of either side of the state border. Assuming that travel occurs on highways at a rate of 65 miles per hour and that retail stores are available directly on the border, this distance represents a one-way travel time of 14 minutes. As a robustness check, we also present results using a 50 kilometer definition and 100 kilometer definition. While these distances do represent significant travel times, we have found accounts of some individuals travelling well in excess of these distances in order to purchase lottery tickets.[29]

As noted above, there are three types of borders. For a state selling Powerball tickets, for example, there are potential borders with states also selling Powerball tickets (cooperating), with states selling Mega Millions tickets (competing), and with states selling neither type of ticket (neither). We expect the responsiveness of revenues in a given state to the price of the affiliated lottery to depend upon the population along both sides of the border with a competing lottery and along the foreign side of the border for states with neither lottery. We

[27] Ideally, we would measure population on an annual basis during our sample period 1995-2008. The Census Bureau releases annual population estimates for each state and county. These estimates, however, are not provided for smaller census areas, such as zip codes, census tracts, block groups, and blocks. Note that our key spatial measures, the inflow and outflow ratios, are based upon the size of the population living near borders divided by the number of state residents. Thus, these measures are unaffected by population growth so long as the growth is similar in both non-border and border regions.

[28] More specifically, we discretize every state border into 2,500 points and then calculate the great circle distance from the census tract centroid to the closest border point.

[29] On the lottery blog http://www.lotterypost.com/topic/196525 (accessed October 28, 2009), an individual reports traveling from Dallas, Texas to Shreveport, Louisiana, a distance of 301 kilometers, in order to purchase Powerball tickets.

refer to this combined population divided by state population as the inflow ratio. We expect the responsiveness of revenues in a given state to the price of the rival lottery to depend upon the population along both sides of the border with a competing lottery. We refer to this population measure divided by state population as the outflow ratio.[30] Thus, as shown in Figure 2, the difference between the inflow and the outflow ratios is due to borders with states that participate in neither Powerball nor Mega Millions. Note that the inflow and the outflow ratios will necessarily change as states enter and exit multi-state games, and we thus calculate these for each of the 21 combinations of multi-state game members, as shown in Table 1, between 1995 and 2008.

Using these measures of revenues, prices, inflow ratios, and outflow ratios, we estimate regressions of the following form:

$$\ln(r_{st}) = \beta_1 \pi_{st}^{AFF} + \beta_2 \pi_{st}^{RIV} + \beta_3 \lambda_{st}^{IN} + \beta_4 \lambda_{st}^{OUT} + \beta_5 \lambda_{st}^{IN} \times \pi_{st}^{AFF} + \beta_6 \lambda_{st}^{OUT} \times \pi_{st}^{RIV} + \alpha_s + \alpha_t + u_{st}$$

where t indexes time, α_s and α_t represent state and time fixed effects, and u_{st} represents unobserved determinants of revenues in state s in time t.[31] The variable π_{st}^{AFF} reflects prices for the affiliated lottery (e.g., Powerball prices for Powerball states) and π_{st}^{RIV} reflects the price of the rival lottery (e.g., Mega Millions prices for Powerball states). Finally, as motivated by the theoretical model, λ_{st}^{IN} is the inflow ratio, as defined above, and λ_{st}^{OUT} is the outflow ratio.

Our identification strategy is thus based upon cross-state differences in the response of revenues to prices. The parameters β_1 and β_2 capture the part of the response of revenues

[30] We calculate these populations as follows. For each census tract in state x we compute the minimum distance to a Powerball or Mega Millions state (which is zero for the affiliated game) and then determine whether or not this is below the cutoff distance. Summing the populations of census tracts within the cutoff distance gives the domestic border population of state x. The foreign border population is calculated analogously. For every tract in states other than x, we first determine whether state x is the closest Powerball or Mega Millions state to that tract, and, if so, whether the distance is below the cutoff (note that border states do not have to be contiguous). Summing the populations of these tracts within the threshold yields the foreign border population of state x. We then use the lottery status (Mega Millions, Powerball, or neither) of state x and all border states to calculate the inflow and outflow ratios, as in figure 2.

[31] Since states often use different definitions of a week in the La Fleur's data, we incorporate monthly, rather than weekly, time fixed effects. Some states may report sales on a Saturday-Friday basis, for example, whereas others may report sales on a Monday-Sunday basis.

to affiliated and rival prices that is common across all states.[32] Similarly, the parameters β_3 and β_4 capture any relationships between revenues and the spatial distribution of the population that are independent of the variation in prices.[33] Finally, the key parameters β_5 and β_6 capture differences in the responsiveness of revenues to prices according to state population and the spatial distribution of the population near state borders. In particular, according to our hypotheses regarding the effect of border density on the relationship between revenues and jackpots, we expect that $\beta_5 = \frac{-h(\pi)}{2\varepsilon c} < 0$ and $\beta_6 = \frac{h(\pi)}{2\varepsilon c} > 0$.

Table 2 provides summary statistics for our key measures. As shown, we have a large sample size, with 22,960 observations, where the unit of observation is the week-state. There is also significant variation in the inflow and outflow ratios, averaging 0.675 and 0.543 respectively and ranging from 0 to 6.235 in the case of Washington, D.C. for the 25-kilometer definition. Washington, D.C. turns out to be a significant outlier in this dimension with no other states having a value in excess of 2. Given this, we exclude Washington, D.C. from the baseline analysis but, as a robustness check, do report results including Washington, D.C. in Table 7.

There is also significant variation in prices over time, averaging 70 cents and ranging from negative to prices of 87 cents. This variation is in turn driven largely by variation in jackpots, which range in our sample from \$2 million to \$390 million. In particular, when we regress the affiliated price on the affiliated jackpot, the R-squared equals 0.85, and this rises to 0.94 when including state and month-by-year fixed effects. Thus, while we interpret our results below as reflecting the response of revenues to variation in prices, they can be equivalently interpreted as reflecting the response of revenues to variation in jackpots.

[32] In addition to the parameter β_1 capturing the intensive margin discussed in the theoretical model above, it also captures the decision to not play the lottery, a margin that was not incorporated into our theoretical model.

[33] For example, if small states with densely populated borders tend to build casinos along borders, then the effect of this factor on sales will be incorporated into these measures λ_{st}^{IN} and λ_{st}^{OUT}.

6 Results

In this section, we first provide graphical evidence supporting our main hypothesis. We then turn to the baseline regression results and present a variety of alternative specifications. Finally, we provide a policy simulation regarding the change in revenues were both Powerball and Mega Millions tickets to be sold in all states.

We first provide a graphical analysis that is designed to highlight our identification strategy. In particular, Figures 3 and 4 depict the relationship between Powerball revenues in Delaware and Rhode Island, respectively, and prices in the affiliated game of Powerball before and after Pennsylvania's entry into Powerball in 2002. Pennsylvania has a large population located near Delaware's border: the northern part of Delaware is included in the definition of the Philadelphia MSA, and the city center of Philadelphia is roughly 25 kilometers from the Delaware border. Thus, in addition to having a small population, Delaware also has densely populated border regions.[34] The state of Rhode Island also has a small number of residents and densely populated areas near the border with Massachusetts, a state that participates in Mega Millions and thus did not enter Powerball during this period. Given that Rhode Island does not border Pennsylvania, we thus expect revenues to be more responsive to prices in Delaware prior to Pennsylvania's entry into Powerball when compared to a similar relationship between revenues and prices in Rhode Island.

As shown in Figure 3, the relationship between revenues and prices was indeed very strong in Delaware prior to the entry of Pennsylvania into Powerball. After Pennsylvania's entry, however, the spikes in revenues when jackpots are high remain visible but these spikes are now much less pronounced. In Rhode Island, by contrast, the relationship between revenues and prices, as depicted in Figure 4, remains fairly stable over this period. Thus, the graphical evidence supports our key hypothesis regarding the relationship between revenues, prices of affiliated lotteries, and the size of the population along state borders.

[34] Consistent with our hypothesis, lottery officials in Delaware were concerned that Pennsylvania's entry into Powerball would severely depress revenues from of Powerball tickets in Delaware (Philadelphia Inquirer, December 19, 2001).

6.1 Baseline Results

Table 3 presents results from our key regressions.[35] As shown in the baseline results in column 1, which are based upon the baseline measure of 25 kilometers, there is a strong response of revenues to the price of the affiliated lottery. In particular, revenues fall almost 230 percent when the price increases from zero to one. As expected, this effect is stronger in areas with high measures of the inflow ratio λ_{st}^{IN}. This supports our main hypothesis regarding the relationship between revenues and affiliated prices.

To provide a sense of the quantitative magnitude of these effects, consider a reduction in the price of the affiliated lottery of one standard deviation, or 16 cents. In cases with no border pressure, such as Powerball revenues in North Dakota, whose neighbors are all currently participating in Powerball, revenues are predicted to rise by 36 percent. In the opposite extreme, consider the case of Rhode Island, which has an inflow ratio of 1.72. In this case, our model predicts that revenues rise by a significantly larger 47 percent. Expressed in terms of elasticities, the affiliated price elasticity is 1.58 in North Dakota and 2.06 in Rhode Island.[36]

Returning to column 1, the coefficient on the interaction between the price of the rival lottery and the outflow ratio is positive and statistically significant at conventional levels. Thus, these results also support the key prediction that the relationship between revenues and the price of the rival lottery is stronger in states with small populations and densely populated border regions. This effect, however, is somewhat weaker in magnitude than the

[35] Note that these results do not account for any possible serial correlation in the unobservable determinants of sales. We have conducted a test and do find significant evidence of autocorrelation. After correcting the standard errors for autocorrelation, our results are very similar to those presented here. A related issue involves serial correlation in the presence of our jackpot measure, which can be interpreted as a lagged dependent variable given the relationship between jackpots and lagged sales. For two reasons, the unique structure of the rollover process complicates the relationship between jackpots and lagged sales. First, high sales in prior periods increase the jackpot conditional on no winning ticket being purchased but also increase the odds of a winning ticket being drawn. Therefore in any two consecutive periods lagged sales may lead to higher or lower future jackpots. Second, in multi-state games, the jackpot depends upon previous sales in all member states, and thus the contribution of each state to the overall jackpot may be relatively small in nature.

[36] These elasticities are evaluated at the mean affiliated price of 70 cents.

relationship between revenues and affiliated prices.

As further evidence regarding the magnitude of these effects, we present results from a counterfactual experiment in Table 4. Using the membership of states in multi-state games between June 2006 and December 2008, the final time period of our sample, we predict the fraction of revenues in each state due to cross-border shopping. In particular, we set both the inflow and the outflow ratios to zero for each state and predict what revenues would have been in the absence of cross-border shopping. We then compare this to the revenues predicted by our baseline model, and the difference between these two measures over time reflects the fraction of revenues due to cross-border shopping. Finally, we average this difference across weeks over the period June 2006-December 2008.

As shown in Table 4, we find that revenues are higher due to cross-border shopping in all states. As discussed earlier, cross-border shopping can benefit all states individually, depending upon the prices and spatial distribution of the population. Thus, allowing players to access games with lower prices in nearby states may have lead to an overall increase in spending on lottery tickets.

While the boost to revenues is positive in all cases, there are significant differences in the magnitude of the effects of cross-border shopping across states. The increase in revenues due to cross-border shopping is close to zero in large states with sparsely populated borders, such as California and Texas, and has a maximal value of 10 percent in Rhode Island. That is, revenues in Rhode Island, a state with densely populated borders and a small number of residents, are 10 percent higher than what they would be in the absence of cross-border shopping.

6.2 Alternative border measures

Returning to Table 3, columns 2 and 3 present robustness checks using the alternative 50 kilometer and 100 kilometer definitions. As shown, the signs on the key coefficients are the same as those in column 1. In terms of the magnitude of the coefficients, recall that the coefficient on the interaction between the inflow ratio and the affiliated price is given by

$\beta_5 = \frac{-h(\pi)}{2\varepsilon c}$ and that ε represents the border proximity definition. Thus, according to this relationship, the coefficient using the 50 kilometer definition should be equal to one-half of the coefficient using the 25 kilometer definition. As shown, this is nearly the case, with the ratio of the coefficient using the 50 kilometer definition to the coefficient using the 25 kilometer definition equal to 0.45. Similarly, the coefficient using the 100 kilometer definition should equal one-quarter of the coefficient using the 25 kilometer definition, and the actual fraction is around 0.33. Also, the coefficients on the interaction between the outflow ratio and the rival price remain positive, with the coefficients again declining in magnitude as the border proximity definition increases. Thus, the results are robust to these broader definitions of borders, and the magnitudes of the various coefficients are in accordance with the predictions of the theoretical model.

Table 5 presents results using additional measures of border populations. One alternative interpretation for our baseline results is that residents of small states with densely populated border regions, relative to residents of other states, are more responsive to prices for reasons unrelated to cross-border shopping. When prices are low, residents of these small states with densely populated borders may be more likely, for example, to play the lottery (as opposed to not purchasing any tickets) or to purchase more tickets. To address this alternative interpretation, we next provide results from a placebo test in which we examine border regions between cooperating states. As noted in our theoretical model, there is no incentive to cross borders between two states participating in the same multi-state lottery game. Thus, in these cases, we would not expect the size of border populations, relative to the number of residents, to affect the price responsiveness of revenues. Under the alternative interpretation outlined above, however, we would expect the size of border populations, relative to the number of residents, to affect the price responsiveness of revenues.

As shown in column 1 of Table 5, these measures indeed have no explanatory power, as the coefficient on the interaction between the cooperating ratio and the price of the affiliated lottery is small when using our baseline proximity measure of 25 kilometers. In addition, after controlling for these measures of the cooperating ratio, the key coefficients on the interactions between affiliated prices and the inflow ratio and between rival prices and the outflow ratio are similar to those in Table 3. Thus, this placebo test also supports our hypotheses related to cross-border shopping.

As an additional check on our baseline measures, we next develop alternative border population measures that account for population differences between the domestic and foreign side of the border. Our baseline measures are based upon an approximation in which prices are equal, the marginal resident is located exactly at the border, and measurement follows by taking small distances around the border. Given this, there is no distinction between the domestic and foreign side of the border. On the other hand, it is clear that, if the affiliated price is lower than the rival price, then cross-border shopping along borders with competing lotteries should flow in only one direction, with residents of foreign states coming in to purchase tickets, and residents of the domestic state not engaging in cross-border shopping. Thus, when the affiliated price is lower, then only the border population on the foreign side of competing borders matters. Conversely, when the affiliated price is higher than the rival price, only the border population on the domestic side of competing borders matters. Figure 2 provides a summary of these price-dependent measures.[37]

Column 3 of Table 5 present results using these price-dependent measures of border populations. As shown, the results are similar to those in the baseline results, with a negative coefficient on the interaction between the affiliated price and the inflow ratio and a positive coefficient on the interaction between the rival price and the outflow ratio. When compared to the baseline results in Table 3, the coefficients are larger, reflecting the fact that the key ratios include the population on only one side of the border and are thus smaller than the baseline measures. In column 4, we present a similar specification where we also control for the "irrelevant" border population. As shown in Figure 2, this is the domestic border population along competing borders when the affiliated price is lower and the foreign border population along competing borders when the affiliated price is higher. As shown, the

[37] Note that we always include the foreign population of bordering states with neither game in the inflow ratio.

results support our key hypothesis, with the irrelevant border populations, when interacted with prices, having no effect on revenues. After controlling for these irrelevant populations, however, the results associated with the relevant border populations are similar to those in the baseline. Taken together, the results are robust to border population measures that account for differences between the domestic and foreign side of the border.

6.3 Commuting

While we interpret our baseline results as reflecting cross-border shopping, where individuals choose to cross the border in search of lower prices, it is possible that these results reflect commuting. That is, for an individual who lives in one state and works in another state, it is possible to purchase the ticket from the state with the lower price and incur no additional transportation costs. To distinguish between commuting and non-commuting border shopping, we next incorporate data from the 2000 Census on state-to-state worker flows. Using these data and, from the perspective of a given state, we distinguish between six types of commuters: commuters to and from competing states, to and from cooperating states, and to and from states with neither game.[38] Analogous to our border measures, we then construct the commuting inflow ratio, which equals the total number of commuters to and from states with competing lotteries and from states with neither game, all divided by state population. Similarly, we construct the commuting outflow ratio, which equals the total number of commuters to and from states with competing lotteries divided by state population.

We first estimate specifications in which we replace our border measures with these commuting measures. As shown in column 1 of Table 6, the results are similar when using commuting measures. That is, revenues are more responsive to prices in states with a large number of commuters, although the results are statistically insignificant for the interaction between the rival price and the commuting outflow ratio. In terms of the magnitude of the

[38] Similarly to our border measures, these commuting numbers are calculated separately for each of the 21 combinations of multi-state games.

effect, the coefficients are larger than those in the baseline results, reflecting the fact that, as shown in Table 2, the commuting measures are substantially smaller in magnitude than the border population measures. In column 2, we attempt to distinguish between commuting and border shopping by controlling for both our baseline border measures and the commuting measures. As shown, the coefficients on the commuting measures have signs that are the reverse of our hypotheses and are no longer statistically significant. After controlling for commuting, however, the coefficients on our baseline measures have signs equal to those in Table 3 and are stronger in magnitude. The standard errors rise as well, likely reflecting the strongly positive correlation between the commuting measures and the border measures, and the coefficient on the interaction between the rival price and the outflow ratio is no longer statistically significant.[39]

6.4 Additional Robustness Checks

Table 7 presents results from three additional robustness checks.[40] In column 1, we present results including Washington, D.C., which as noted above, is a significant outlier. As shown, the coefficients on the key interaction terms are somewhat weaker in magnitude, and the key coefficient on the interaction between the price of the affiliated lottery and the inflow ratio is now statistically insignificant for the 25 kilometer measure at conventional levels. To explore the sensitivity of our results to D.C, we next estimate a specification in which we include D.C. but observations are weighted according to their population. This specification places more weight on large population states, and, as shown in column 2, the weighted results are similar to those in our baseline specification in Table 3.

[39] The correlations between the inflow ratio and the commuting inflow ratio and between the outflow ratio and the commuting outflow ratio are over 0.9.

[40] We also performed two additional robustness that are not reported in the paper. First, we estimated per-capita sales, the key left-hand side variable, in levels, rather than in logs. The results from this specification with respect to the affiliated price are similar to the baseline, although the results with respect to the rival price are statistically insignificant and the overall fit is worse. Second, we relaxed the assumption that non-residents from states with a competing lottery are as responsive to prices as non-residents from states with neither Powerball nor Mega Millions. In this specification, we found that non-residents from states with neither lottery were significantly more responsive to prices than were non-residents from states with the competing game. These results are available upon request from the author.

Finally, we exclude observations in which either the affiliated or rival jackpot is in the top five percent of the jackpot distribution. This allows us to examine whether our baseline results are purely being driven by the largest jackpots. While our model suggests that small differences in jackpots should lead to cross-border shopping, it is possible that the relationship is non-linear, with cross-border shopping occurring only when jackpots are very high. This could result, for example, if the media report on lotteries only when the jackpots exceed a certain threshold. As shown in column 3, however, the results excluding the highest jackpots are quite similar to those in the baseline specification.

6.5 Policy simulation

As noted above, these two key multi-state games, Powerball and Mega Millions, recently began cross-selling their products, and we next use our analysis to predict the level of revenues under this cross-selling arrangement. In our theoretical model, revenue with cross-selling takes a relatively simple form since only consumers in states with neither game would have an incentive to cross borders in order to purchase tickets. For residents of states selling both games, the two become perfect substitutes, and players thus purchase tickets from the game with the lower price. For residents of states selling neither type of game, players will play the game with the lower price in nearby states if the travel cost is sufficiently low. In the context of our empirical specification, revenues are thus predicted to have the following form:

$$\ln(r_{st}) = \beta_1 \min(\pi_{st}^{RIV}, \pi_{st}^{AFF}) + \beta_5 \lambda_{st}^{IN} \min(\pi_{st}^{RIV}, \pi_{st}^{AFF}) + \alpha_s + \alpha_t + u_{st}$$

where λ_{st}^{IN} the numerator reflects the number of foreign residents of states without lotteries near the border with state s. As shown in Table 10, we predict that revenues would rise by a large percentage in all states. The variation in this increase is significant, ranging from 6 percent in Delaware and 7 percent in Rhode Island to 21 percent in Michigan. The lower predicted increases in these small densely populated states reflect the fact that both games were already more easily accessible in these states and their bordering states since travel distances are relatively short. Thus, having both sets of tickets sold in every state represents a less dramatic change in these states.

There are two important caveats associated with this policy simulation. First, our analysis does not account for the fact that multiple winners are more common in this cross-selling scenario since revenues would be significantly boosted. Increased prevalence of multiple winners tends to increase prices and, if players account for multiple winners when making lottery choices, thus dampen these predicted increases in revenues. Second, and perhaps more importantly, our analysis assumes that jackpots would be unchanged over this period. With all players purchasing tickets for the game with the lower price, one jackpot may tend to rise briskly until a winning ticket is purchased. The other jackpot, by contrast, would remain at low levels during this period. Given this, our results can best be interpreted as the short-run effects associated with the cross-selling of Powerball and Mega Millions tickets. An investigation of the long-run effects of this agreement would require a simulation of the dynamics of jackpots in this counterfactual scenario.

7 Competition and Pricing

This analysis can also be used to better understand the role of competitive forces in the development of fiscal policy. In particular, under the assumption that state governments maximize lottery profits, which equal $\pi_{st}^{AFF} r_{st}$ since r_{st} can be interpreted as tickets sold, and using the baseline regression equation, the optimal affiliated prices for a given configuration of state lotteries are:

$$\pi_{st}^{AFF} = \frac{1}{-\beta_1 - \beta_5 \lambda_{st}^{IN}}$$

where λ_{st}^{IN} is the marginal inflow ratio and summarizes the degree of competitive pressures facing state lotteries.[41]

In the context of this optimal pricing rule, we consider three scenarios in which we vary the degree of competition facing states. First, we consider the actual environment facing

[41] Note that there are no explicit strategic interactions between states in this optimal pricing formula. That is, the optimal price in state s does not depend upon the price of competing states. This result is driven by the assumption of revenues being log-linear in prices.

states at the end of the sample. That is, we use the inflow ratio (λ_{st}^{IN}) as measured in 2008. This can be interpreted as a mix of collusion and competition, depending upon the configuration of lottery games in neighboring states. Second, we consider a full competition scenario in which each of the 42 lottery states compete with one another. In this case, the population included in the marginal inflow ratio (λ_{st}^{IN}) is expanded to include borders with states cooperating in the same multi-state game. Third, we consider a scenario of full collusion, under which the 42 states with lotteries all participate in the same multi-state game. In this case, the marginal inflow ratio (λ_{st}^{IN}) includes only foreign residents of border states.

Table 9 compares profit-maximizing prices for each state under these three scenarios. As shown, when using the actual configuration of multi-state games in 2008, the optimal prices are lower in states, such as Delaware and Rhode Island, facing significant competition, and are higher in those states, such as California and Texas, that are largely immune to competition.[42] Under full competition, by contrast, prices, when averaged across states, fall from 41 cents to 39 cents, a 5 percent decline. The degree of this decline again varies across states: large states with sparsely populated borders, such as California, experience no change, whereas small states with densely populated borders, such as Delaware, experience declines of 16 percent. Interestingly, the state with the largest decline in prices (20 percent) is New Jersey, reflecting the densely populated border with the state of New York, which cooperates with New Jersey in Mega Millions. Under full collusion, the national average price increases to 44 cents, representing a 7 percent increase relative to the 2008 configuration and a 13 percent increase relative to full competition. Again, the effects vary significantly across states, with the largest difference being the 47 percent increase in prices under full collusion, relative to full competition, in the state of Delaware.

These findings suggest that competitive pressures associated with cross-border shopping

[42] Averaged across states, the optimal price under the actual environment equals 0.41. Note that this is substantially lower than the actual average price of the affililated lottery, which, as shown in Table 2, is equal to 0.70. The discrepancy between these two prices largely involves federal taxes. After applying the highest federal marginal tax rate of 35 percent, the optimal price under the actual environment rises to 0.62.

and the interdependence of tax bases can have significant effects on pricing. It also suggests that the recent agreement to allow for cross-selling of Mega Millions and Powerball games may provide states with an opportunity to further increase prices and thus reduce payout rates below their already low levels.

8 Conclusion

This paper has investigated competition between state lotteries with a specific focus on competitive forces associated with cross-border shopping. Our theoretical model predicts, and the empirical analysis confirms, that if cross-border shopping is significant, the relationship between revenues and prices should be stronger in states with small populations and densely populated border regions. The magnitude of the estimated effects is large in general, suggesting that states do face significant competitive pressures from neighboring states. The effects also vary significantly across regions, with much stronger effects in small states with densely populated border regions.

The findings have important implications for the recent agreement to sell Powerball and Mega Millions tickets in the 42 states currently selling tickets for one of the two games. First, our policy simulations suggest that, holding prices fixed, revenues in all states will rise significantly following this cross-selling arrangement since consumers have access to a greater variety of products. Second, our findings suggest that this cooperation may reduce the competitive pressures facing states since consumers will no longer have incentives to cross borders in order to purchase tickets. If states respond to these competitive pressures when setting prices, this agreement may lead to significantly higher prices and lower payout rates for consumers, as documented in our analysis of optimal prices under competition and collusion.

These findings also have broader implications for state taxation of lottery tickets and related products. The findings are consistent with the view that consumers have a limited budget for gambling, and the offering of new products may reduce revenues of related products. In particular, the introduction of lotteries in new states may reduce revenues in neighboring states. Under the additional assumption that these results apply to other forms of gambling, the introduction of new casinos, which have been recently proposed in many cash-strapped states, may reduce casino revenues in neighboring states or even reduce lottery revenues within the state borders.

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10 Appendix: Example where cross-border shopping increases revenues

In this section we provide a simple example to demonstrate that states may benefit from cross-border shopping. Consider two prices, a low price π_L and a high price π_H, and two periods where the prices of state W and state E are first (π_L,π_H) and then (π_H,π_L). Under cross-border shopping (C), the combined revenue for state W is given by:

$$R_W^C = R_{W1}^C + R_{W2}^C = h(\pi_L)F\left[b + \frac{z(\pi_L) - z(\pi_H)}{c}\right] + h(\pi_H)F\left[b + \frac{z(\pi_H) - z(\pi_L)}{c}\right]$$

In a regime with no cross-border shopping (N), state W has combined revenue equal to:

$$R_W^N = R_{W1}^N + R_{W2}^N = (h(\pi_L) + h(\pi_H))F[b]$$

For ease of notation, define $\alpha = \frac{z(\pi_L)-z(\pi_H)}{c}$. Then, the difference in revenues with and without border shopping is given by:

$$R_W^C - R_W^N = h(\pi_L)(F[b+\alpha] - F[b]) - h(\pi_H)(F[b] - F[b-\alpha])$$

The first term represents the gains to state W from cross-border shopping (state E residents entering when prices are low) while the second term represents the loss from cross-border shopping (state W residents exiting when prices are high). Assuming a symmetric distribution around the border, $F[b+\alpha] - F[b] = F[b] - F[b-\alpha]$, there are gains to cross-border shopping since more tickets are purchased when prices are low, or $h(\pi_L) > h(\pi_H)$.

Figure 1: Powerball and Mega Millions states as of 12/31/2008

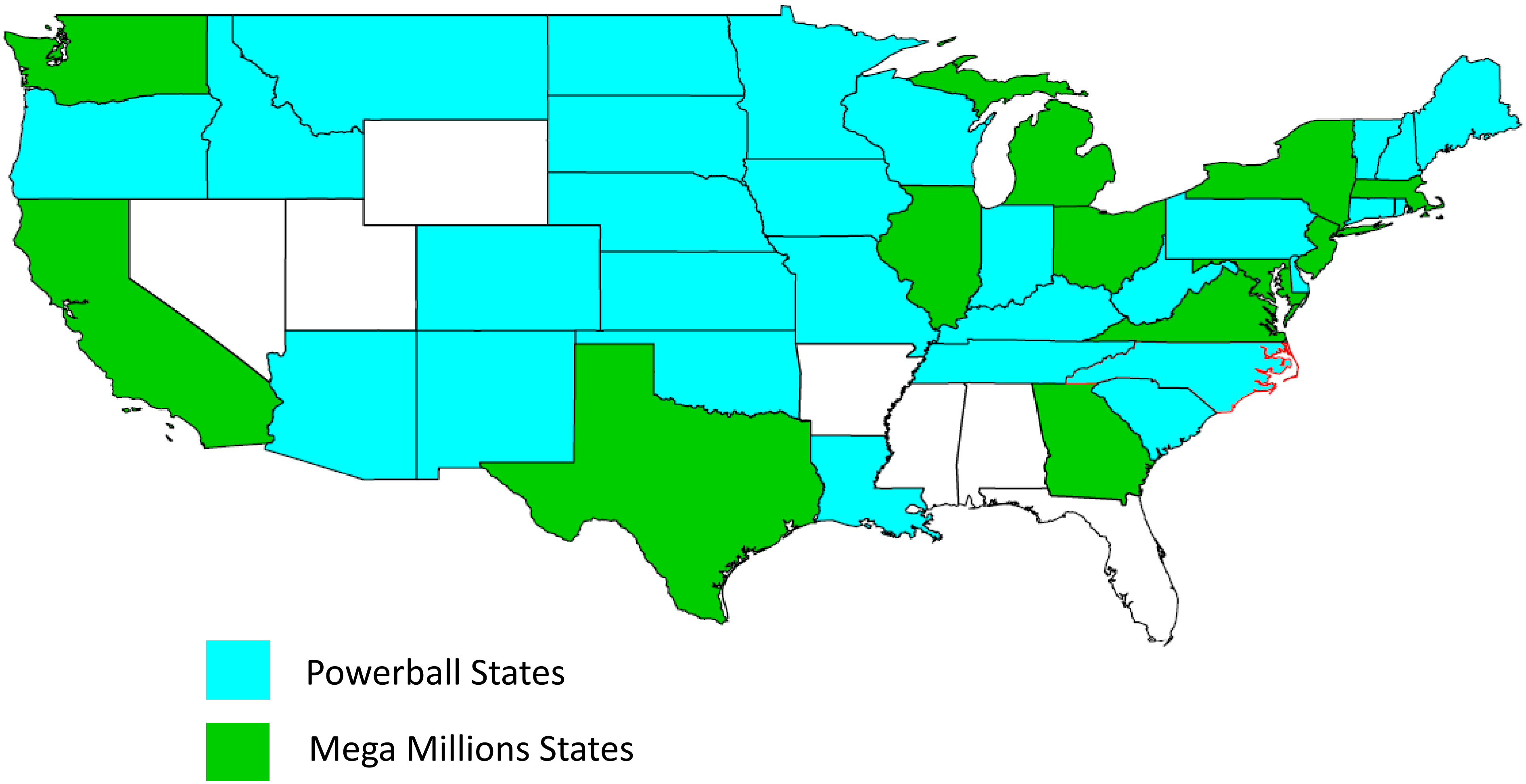


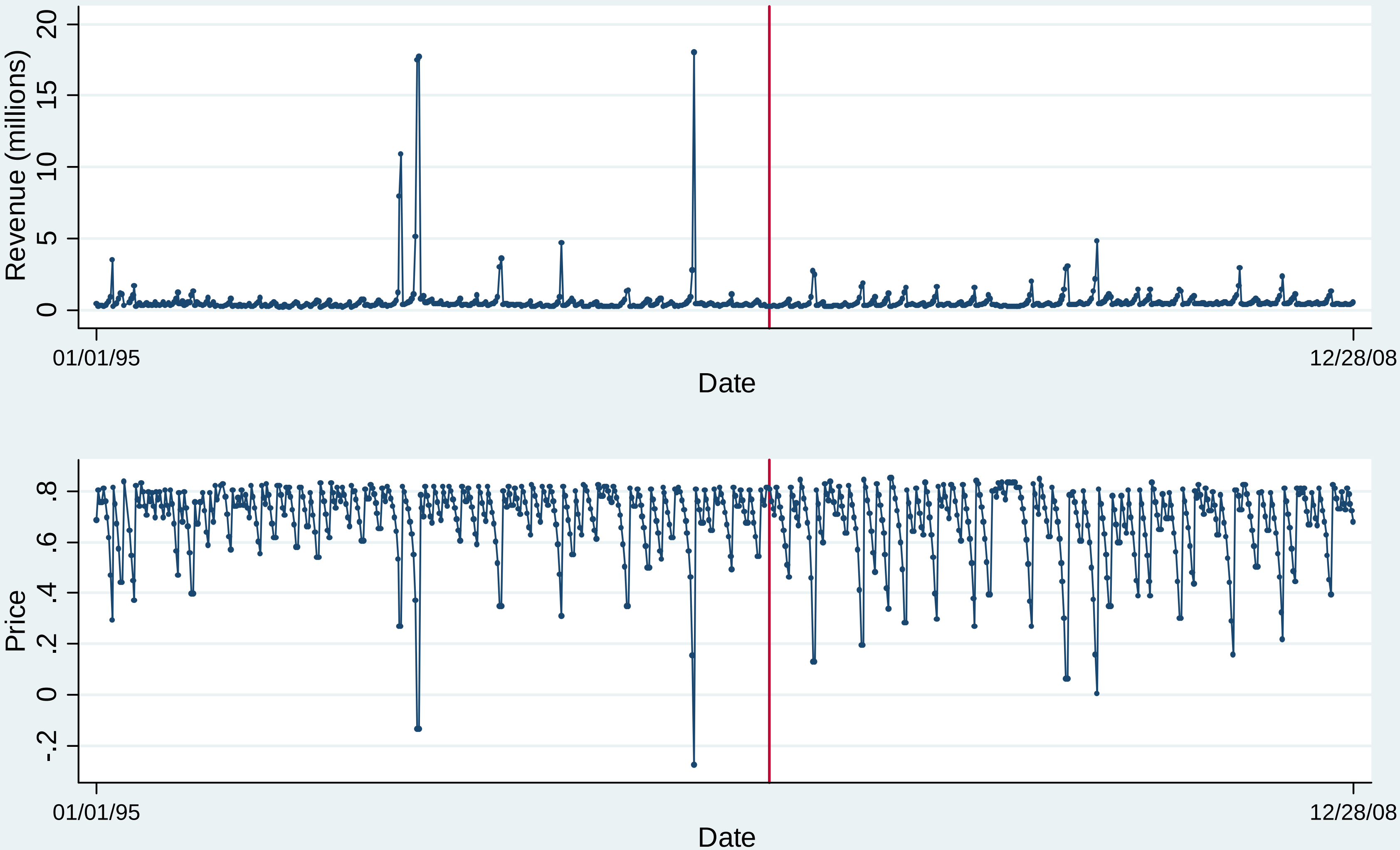
Figure 2: Border Measures Diagram

Baseline Border Measures	Competing		Cooperating		Neither Game	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Marginal Inflow Population						
Marginal Outflow Population						
Placebo Population						

Price Dependent Border Measures	Competing		Cooperating		Neither Game	
	Domestic	Foreign	Domestic	Foreign	Domestic	Foreign
Marginal Inflow Pop. (affiliated price < rival price)						
Marginal Inflow Pop. (affiliated price > rival price)						
Marginal Outflow Pop. (affiliated price < rival price)						
Marginal Outflow Pop. (affiliated price > rival price)						
Irrelevant Pop. (affiliated price < rival price)						
Irrelevant Pop. (affiliated price > rival price)						

Figure 3: DE revenue and Powerball price

Before and after PA Entry into Powerball



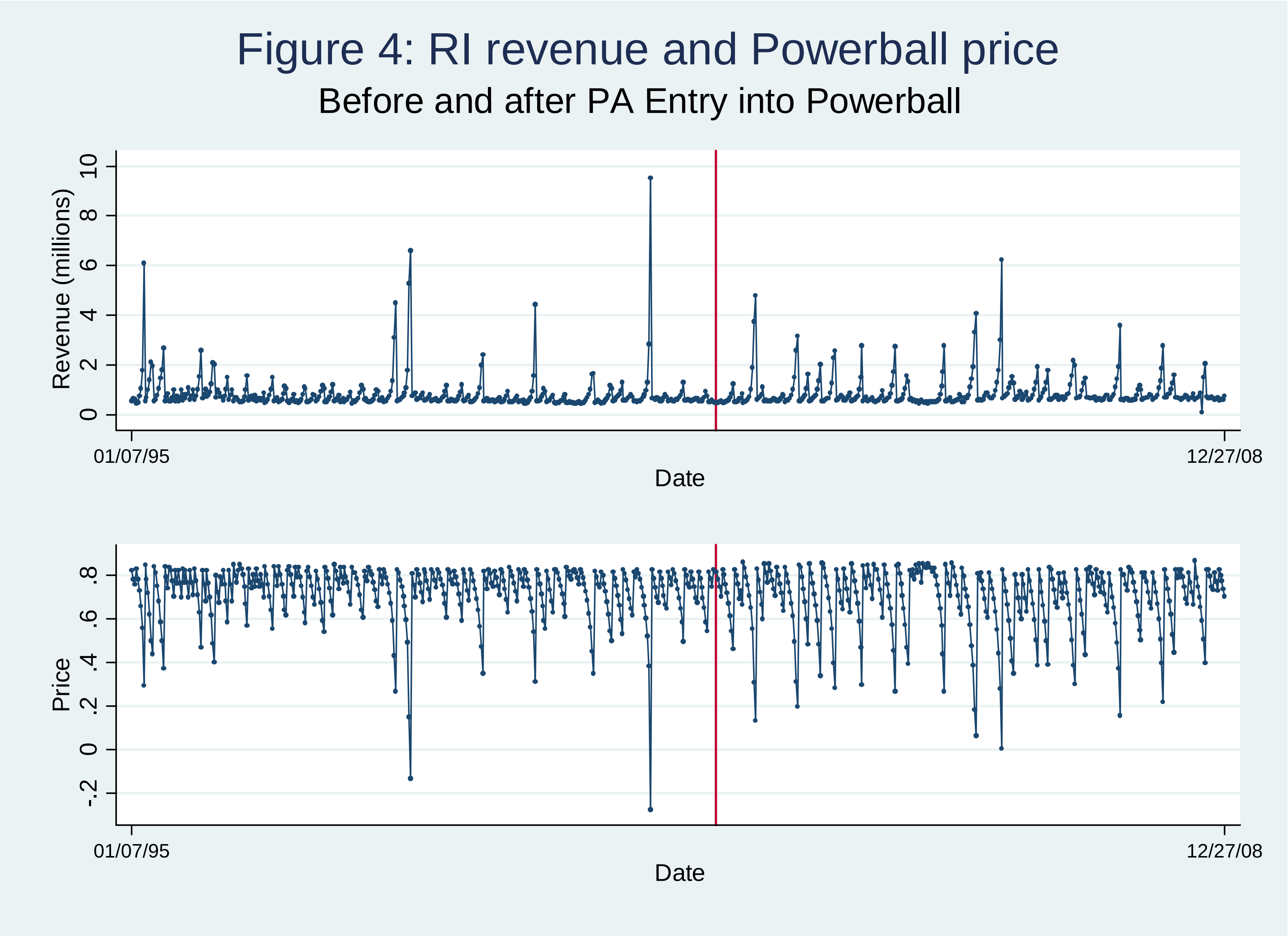


Figure 4: RI revenue and Powerball price
Before and after PA Entry into Powerball
Revenue (millions)
0
2
4
6
8
10
01/07/95
12/27/08
Date
Price
-.2
0
.2
.4
.6
.8
01/07/95
12/27/08
Date

Table 1: Date of Entry into Powerball (P) and Mega Millions (M) by State																					
Date	1/1/1995	3/5/1995	7/1/1995	11/5/1995	11/28/1995	8/31/1996	10/20/1996	5/27/1999	8/2/2001	5/15/2002	6/27/2002	9/1/2002	10/6/2002	6/29/2003	11/30/2003	3/25/2004	4/18/2004	7/31/2004	6/19/2005	1/12/2006	5/28/2006
AZ	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
CA																			M	M	M
CO									P	P	P	P	P	P	P	P	P	P	P	P	P
CT					P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
DE	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
DC	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
GA			P	P	P	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
ID	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
IL						M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
IN	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
IA	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
KS	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
KY	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
LA		P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
ME																		P	P	P	P
MD						M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
MA						M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
MI						M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
MN	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
MO	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
MT	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
NE	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
NH				P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
NJ									M	M	M	M	M	M	M	M	M	M	M	M	M
NM							P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
NY										M	M	M	M	M	M	M	M	M	M	M	M
NC																					P
ND																P	P	P	P	P	P
OH										M	M	M	M	M	M	M	M	M	M	M	M
OK																				P	P
OR	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
PA											P	P	P	P	P	P	P	P	P	P	P
RI	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
SC													P	P	P	P	P	P	P	P	P
SD	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
TN																	P	P	P	P	P
TX															M	M	M	M	M	M	M
VT														P	P	P	P	P	P	P	P
VA						M	M	M	M	M	M	M	M	M	M	M	M	M	M	M	M
WA												M	M	M	M	M	M	M	M	M	M
WV	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P
WI	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P	P

Table 2: Summary Statistics

Variable	*Distance (km)*	Obs	Mean	Std. Dev.	Min	Max
revenue per capita (logs)		22960	-1.042	0.606	-3.970	3.135
affiliated price		22960	0.700	0.157	-0.876	0.867
rival price		22960	0.718	0.191	-0.876	1.000
inflow ratio	25	22960	0.675	1.118	0.000	6.235
inflow ratio	50	22960	1.324	1.959	0.000	9.474
inflow ratio	100	22960	1.872	2.540	0.000	12.383
outflow ratio	25	22960	0.543	1.063	0.000	6.235
outflow ratio	50	22960	0.986	1.717	0.000	9.474
outflow ratio	100	22960	1.277	1.975	0.000	11.507
cooperating ratio	25	22960	0.271	0.314	0.000	1.653
cooperating ratio	50	22960	0.444	0.578	0.000	4.147
cooperating ratio	100	22960	0.789	0.992	0.000	7.216
neither ratio	*25*	22960	0.132	0.419	0.000	5.235
neither ratio	*50*	22960	0.338	1.000	0.000	8.474
neither ratio	*100*	22960	0.595	1.593	0.000	11.383
commuting inflow		22960	0.055	0.163	0.000	0.956
commuting outflow		22960	0.046	0.155	0.000	0.951

Notes: Sample includes DC. Inflow ratio is the size of the population near borders with competing states plus the size of the foreign population near borders with non-lottery states divided by the number of residents. Outflow ratio is the size of the population near borders with competing states divided by the number of residents. Cooperating ratio is the size of the population near borders with cooperating states divided by the number of residents. Neither ratio is the size of the foreign population near borders with non-lottery states divided by the number of residents. Commuting inflow is the size of the domestic and foreign commuting populations in competing states, plus commuters from non-lottery states, divided by the number of domestic residents. Commuting outflow is the size of the domestic and foreign commuting populations in competing states divided by the number of domestic residents.

Table 3: Baseline measures of cross-border shopping

VARIABLES	*(dist=25km)*	*(dist=50km)*	*(dist=100km)*
affiliated price	-2.273***	-2.287***	-2.272***
	[0.067]	[0.058]	[0.056]
rival price	-0.024**	-0.016	-0.017
	[0.011]	[0.011]	[0.011]
inflow ratio	0.396***	0.170***	0.114***
	[0.106]	[0.021]	[0.012]
outflow ratio	-0.103	-0.021	-0.017
	[0.063]	[0.019]	[0.016]
affiliated price*inflow ratio	-0.387***	-0.176***	-0.128***
	[0.089]	[0.028]	[0.015]
rival price*outflow ratio	0.048***	0.016**	0.013**
	[0.012]	[0.007]	[0.006]
state fixed effects	YES	YES	YES
month by year fixed effects	YES	YES	YES
Observations	22231	22231	22231
R-squared	0.88	0.89	0.89

*Notes: Sample excludes DC. Robust standard errors in brackets, clustered by state (40 clusters). *** p<0.01, ** p<0.05, * p<0.1. Inflow ratio is the size of the population near borders with competing states plus the size of the foreign population near borders with non-lottery states divided by the number of residents. Outflow ratio is the size of the population near borders with competing states divided by the number of residents. The dependent variable is per resident revenue in logs.*

Table 4: Percent change in revenue per capita from border shopping

state	Δ revenue pc	state	Δ revenue pc
AZ	0.79%	NC	0.75%
CA	0.23%	ND	0.00%
CO	0.22%	NE	0.11%
CT	6.99%	NH	7.12%
DE	8.91%	NJ	4.02%
GA	2.15%	NM	2.31%
IA	1.33%	NY	1.27%
ID	2.26%	OH	1.97%
IL	3.58%	OK	1.84%
IN	4.88%	OR	3.40%
KS	0.00%	PA	4.48%
KY	2.92%	RI	9.92%
LA	1.62%	SC	1.78%
MA	3.96%	SD	0.10%
MD	4.14%	TX	0.50%
ME	0.00%	VA	2.86%
MI	0.51%	VT	5.45%
MN	0.00%	WA	2.16%
MO	3.40%	WI	1.48%
MT	0.30%	WV	5.72%

Note: Sample excludes DC, calculations for 25km distance.

Table 5: Additional Border Measures			
VARIABLES	*Placebo*	*Price-dependent*	*Price-dependent*
affiliated price	-2.284***	-2.278***	-2.289***
	[0.070]	[0.062]	[0.066]
rival price	-0.024**	-0.023*	-0.024**
	[0.011]	[0.011]	[0.011]
inflow ratio	0.460**	0.545***	0.584***
	[0.179]	[0.139]	[0.176]
outflow ratio	-0.133	-0.153**	-0.142
	[0.099]	[0.074]	[0.101]
affiliated price*inflow ratio	-0.389***	-0.635***	-0.662***
	[0.090]	[0.136]	[0.176]
rival price*outflow ratio	0.048***	0.093***	0.065
	[0.012]	[0.025]	[0.097]
cooperating ratio	0.029		
	[0.274]		
affiliated price*cooperating ratio	0.047		
	[0.152]		
irrelevant border ratio			-0.024
			[0.170]
affiliated price*irrelevant border ratio			0.097
			[0.227]
rival price*irrelevant border ratio			0.033
			[0.095]
state fixed effects	YES	YES	YES
month by year fixed effects	YES	YES	YES
Observations	22231	22231	22231
R-squared	0.89	0.89	0.89

*Notes: Sample excludes DC. Robust standard errors in brackets, clustered by state (40 clusters). *** p<0.01, ** p<0.05, * p<0.1. The price-dependent inflow ratio is the foreign population from a non-lottery state plus either the foreign population along a competitive border when the affiliated price is less than the rival price or the domestic population along a competitive border when the affiliated price is greater than the rival price. The price-dependent outflow ratio is the foreign population along a competitive border when the affiliated price is less than the rival price or the domestic population when the affiliated price is greater than the rival price. The irrelevant border ratio is the domestic population when the affiliated price is less than the rival price and the foreign population when the affiliated price is greater than the rival price. See figure 2 for a diagram. The dependent variable is per resident revenue in logs.*

Table 6: Commuting

VARIABLES	*Commuting Only*	*Commuting and Border Populations*
affiliated price	-2.319***	-2.284***
	[0.073]	[0.066]
rival price	-0.015	-0.017
	[0.013]	[0.011]
commuting inflow ratio	8.593***	2.379
	[2.415]	[4.532]
commuting outflow ratio	-3.535**	-0.368
	[1.447]	[4.638]
affiliated price*commuting inflow ratio	-5.459**	0.420
	[2.112]	[2.019]
rival price*commuting outflow ratio	0.451	-0.936
	[0.345]	[0.981]
inflow ratio		0.518**
		[0.244]
outflow ratio		-0.214
		[0.209]
affiliated price*inflow ratio		-0.650***
		[0.199]
rival price*outflow ratio		0.168
		[0.108]
state fixed effects	YES	YES
month by year fixed effects	YES	YES
Observations	22231	22231
R-squared	0.89	0.89

*Notes: Sample excludes DC. Robust standard errors in brackets, clustered by state (40 clusters). *** p<0.01, ** p<0.05, * p<0.1. Inflow ratio is the size of the population near borders with competing states plus the size of the foreign population near borders with non-lottery states divided by the number of residents. Outflow ratio is the size of the population near borders with competing states divided by the number of residents. Commuting inflow is the size of the domestic and foreign commuting populations in competing states, plus commuters from non-lottery states, divided by the number of domestic residents. Commuting outflow is the size of the domestic and foreign commuting populations in competing states divided by the number of domestic residents. The dependent variable is per resident revenue in logs.*

Table 7: Robustness Checks			
VARIABLES	*Including DC*	*Population weights*	*Largest jackpots excluded*
affiliated price	-2.414***	-2.427***	-2.558***
	[0.058]	[0.058]	[0.071]
rival price	-0.025*	-0.016	0.007
	[0.014]	[0.017]	[0.017]
inflow ratio	0.172**	0.200**	0.568***
	[0.083]	[0.086]	[0.088]
outflow ratio	-0.142**	-0.142*	-0.162**
	[0.057]	[0.071]	[0.073]
affiliated price*inflow ratio	-0.152	-0.247**	-0.663***
	[0.103]	[0.101]	[0.117]
rival price*outflow ratio	0.096*	0.126**	0.102***
	[0.050]	[0.052]	[0.034]
Includes DC	YES	YES	NO
state fixed effects	YES	YES	YES
month by year fixed effects	YES	YES	YES
Observations	22960	22960	19939
R-squared	0.90	0.89	0.88

*Notes: Robust standard errors in brackets, clustered by state (40 clusters). *** p<0.01, ** p<0.05, * p<0.1. Population weights specification has regressions weighted by state populations. Specification with largest jackpots removed excludes observations where the affiliated jackpot is larger than the 5th percentile or the rival jackpot is larger than the 5th percentile. Inflow ratio is the size of the population near borders with competing states plus the size of the foreign population near borders with non-lottery states divided by the number of residents. Outflow ratio is the size of the population near borders with competing states divided by the number of residents. The dependent variable is per resident revenue in logs.*

Table 8: Predicted percent change in revenue from Powerball/Mega Millions cross-selling			
state	Δ revenue pc	state	Δ revenue pc
AZ	15.23%	NC	16.17%
CA	17.76%	ND	17.21%
CO	16.27%	NE	16.60%
CT	9.93%	NH	9.80%
DE	6.06%	NJ	14.63%
GA	14.29%	NM	14.61%
IA	15.59%	NY	17.04%
ID	13.74%	OH	16.35%
IL	17.74%	OK	13.32%
IN	12.04%	OR	13.52%
KS	16.92%	PA	10.50%
KY	14.00%	RI	7.00%
LA	13.47%	SC	13.19%
MA	14.36%	SD	15.17%
MD	17.17%	TX	17.75%
ME	16.92%	VA	15.45%
MI	20.80%	VT	11.47%
MN	14.97%	WA	16.15%
MO	12.12%	WI	15.44%
MT	16.51%	WV	11.20%

Note: Sample excludes DC, calculations for 25km distance.

Table 9: Optimal Pricing Under Competition and Collusion

state	actual environment	full competition	full collusion	state	actual environment	full competition	full collusion
AZ	0.433	0.432	0.437	NC	0.430	0.410	0.440
CA	0.438	0.438	0.439	ND	0.440	0.404	0.440
CO	0.439	0.436	0.439	NE	0.439	0.396	0.439
CT	0.365	0.357	0.440	NH	0.364	0.341	0.440
DE	0.358	0.300	0.440	NJ	0.393	0.314	0.440
GA	0.419	0.419	0.434	NM	0.412	0.406	0.440
IA	0.423	0.391	0.440	NY	0.423	0.382	0.440
ID	0.416	0.408	0.437	OH	0.415	0.410	0.440
IL	0.395	0.395	0.440	OK	0.423	0.418	0.435
IN	0.385	0.369	0.440	OR	0.400	0.398	0.440
KS	0.440	0.387	0.440	PA	0.394	0.389	0.440
KY	0.405	0.368	0.440	RI	0.340	0.326	0.440
LA	0.426	0.426	0.434	SC	0.421	0.390	0.440
MA	0.392	0.390	0.440	SD	0.439	0.401	0.439
MD	0.389	0.366	0.440	TX	0.433	0.433	0.440
ME	0.440	0.418	0.440	VA	0.404	0.384	0.440
MI	0.433	0.428	0.440	VT	0.379	0.354	0.440
MN	0.440	0.416	0.440	WA	0.412	0.412	0.440
MO	0.404	0.381	0.436	WI	0.421	0.406	0.440
MT	0.438	0.430	0.438	WV	0.376	0.357	0.440

Note: Sample excludes DC, calculations for 25km distance.