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Pushing the Limits of Increased Casino Advantage on Slots: An Examination of Performance Effects and Customer Reactions

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Abstract

This field study examined performance data from reel slot games located in two casinos. The paired design incorporated games that appeared identical to the players but featured substantially different, yet concealed, pars (i.e., prices). The results revealed significantly elevated revenues for the high-par games, despite egregious price hikes, while also failing to provide compelling evidence of rational play migration to the low-par games. The latter result suggested that frequently visiting players were not able to detect differences in the pars of games, even over lengthy sample periods. These outcomes were produced by the greatest par gaps of any paired-design study. These expanded gaps also generated the greatest revenue gains within this research stream. Increasing pars may represent a rare opportunity for operators to increase revenues, without concern for eventual brand damage or loss of market share. Limitations regarding the current uses of reel pars are also revealed.

Keywords

casino management; casino operations; casino marketing; pricing; marketing and sales; marketing research; operations analysis; slot machines

Introduction

Slot revenues are critical to the success of most casino resorts. This is especially true for smaller properties that comprise the majority of the world's casinos. Several markets featuring these smaller venues support this position, with more than 85% of the total casino revenue coming from slots (Colorado Department of Revenue, 2017; Iowa Racing and Gaming Commission, 2017; South Dakota Commission on Gaming, 2017). The Australian club sector relies exclusively on electronic gaming devices (EGDs) for casino revenues, as live table games are prohibited (KPMG, 2016). Most of these smaller casinos cater to a local clientele characterized by frequent slot players. This is the case for nearly all of Mexico's small casinos. Apart from the Las Vegas Strip, the vast majority of U.S. casinos also serve a frequently visiting clientele. While the world's glitzy megaresorts garner most of the media attention, they are far less common.

Given the importance of slot revenues to most casinos, this study sought to gain a better understanding of how differences in the house advantages (i.e., pars) affect game-level revenues and (b) whether pars are detectable over time, by a frequently visiting clientele. In short, par represents the casino's advantage expressed as a percentage of each wager (e.g., 5%). Unlike video poker and most electronic table games, par is concealed from reel slot players, inhibiting our understanding of its short- and long-term effects on revenue. For instance, previous findings have questioned the existing paradigm of player sensitivity to reel pars (Lucas, 2019; Lucas & Brandmeir, 2005; Lucas & Spilde, 2019a, 2019b). Contrary to the inveterate wisdom of the industry, these studies found high-par games to produce greater revenue, while failing to provide evidence of play migration, that is, price sensitivity. Our study extended this work by expanding the difference in the obfuscated pars of otherwise identical games. Valuable results were added to this growing research stream, helping establish the limits of performance gains and player sensitivity to differences in pars.

In addition, operators are armed with results that aid them in difficult tasks such as machine purchase decisions,

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positioning strategies, and most importantly, optimizing slot revenues. For manufacturers, these results provide critical insight for par recommendations on participation games (i.e., games for which revenue is shared with the operators). On these games, greater win benefits both the operators and the game makers. As the development costs of participation games are born by the manufacturers, greater revenues improve returns on the significant capital investment required to bring these games to market. For all these reasons, understanding the impact of par on game performance has clear and relevant implications for both game makers and operators.

Literature Review

Industry Perspectives

Casino operators are interested in the perceptions and sensitivity of players to changes or differences in pars, to the extent that it affects the performance of the games. Ultimately, property-level management is charged with optimizing casino operating profits, to which slot revenues are critical. It is the fear of losing players (i.e., revenue) due to the perception of a tight slot floor that attenuates operators to par and its use in "price" positioning strategies (Frank, 2017; Gruetze, 2014; Legato, 2015). Although few methodological details are provided, there is a strong cautionary voice within the trade literature regarding player sensitivity to pars (Frank, 2017; Higgins, 2010; Klebanow, 2006, 2014; Meczka, 2017). Furthermore, there are those who contend that the ability to detect such differences improves with time (Frank, 2017; Gallaway, 2014; Legato, 2015) and/or a player's level of gaming involvement (Meczka, 2017). But what if differences in pars were not readily detected by reel slot players? Would it still be wise to use par as the primary positioning tool, with respect to gaming value? What if slot revenues were optimized via alternative strategies? These remain important questions for operators.

In terms of performance, management's primary concern should be optimizing theoretical win (T-win). T-win represents the expected value for slot win, given the dollar amount wagered. It is the most meaningful performance metric, as T-win embodies both wagering volume and the casino advantage levied on the wagers. However, operators may be wary of short-term gains in T-win at the expense of lost play in the longer term (Frank, 2017; Lucas & Spilde, 2019b). Alternatively stated, many would pass on short-term increases in T-win if they believed that players could eventually perceive the increased pars that produced them. In support, others have noted the widespread concern of operators related to consequences stemming from player perceptions of a tight slot floor (Frank, 2017; Legato, 2015; Meczka, 2017).

Game Performance and Par

There are those who have argued that decreasing payback percentages in U.S. gaming jurisdictions have led to decreased slot revenues in the period following the global financial crisis (Applied Analysis, 2015). At the center of their argument is the contention of price sensitivity among slot players, where par serves as a proxy for price. Specifically, they contend U.S. gamblers are not playing as much because the casinos have increased the pars. They note several exceptions to their general conclusion, but the study also suffered from omitted variable bias. For example, it failed to account for the effects of newly legalized jurisdictions. That is, the emergence of new markets was very likely to have negatively affected revenues produced in the existing adjacent markets, during their designated postrecession periods. In addition, their historical data demonstrated extended periods that failed to support their general price sensitivity conclusion.

A study comparing the performance of US$5.00 reels in an Atlantic City casino found the games with the 7.5% pars to outperform the 5.0% games, in terms of daily T-win per unit (Lucas & Brandmeir, 2005). But the increased performance was not statistically significant. During the Year-1 sample period, the games featured 5.0% pars. In the corresponding Year-2 sample period, the pars were increased to 7.5%. The game titles, minimum and maximum wagers, cabinet styles, and floor locations of the games remained constant, but the 5- to 8-month year-over-year sample periods varied by game. In addition, the year-over-year design opened the door to potential temporal confounds, stemming from differences such as changes in the competitive landscape, economy, promotional offers, or the property itself.

Other studies that have featured paired designs have found increases in the pars of low-denomination games to be associated with significant increases in T-win (Lucas, 2019; Lucas & Spilde, 2019a, 2019b). These increases were also economically significant, ranging from 48.66% to 236.45% above the T-win levels produced by the low-par games. All three of these studies featured paired reel slots with identical game titles, reward schedules, wagering constraints, bonus features, and cabinet styles. All paired games were located on opposite ends of the same small bank of slots. All performance data were collected over the same sample periods, eliminating temporal confounds. Together, these three studies found significant gains in T-win on the high par games across 13 different two-game pairings, in five different casinos, in three different countries, and with par differences ranging from 2.5 to 8.9 percentage points.

Ability to Detect Pars

Harrigan and Dixon (2010) simulated play on two versions of a reel slot machine, with a difference in pars of 13 percentage points (i.e., 2% vs. 15%). Analyzing outcomes produced by 2,000 virtual players, they found the means of key performance metrics such as total number of spins to be greater on the 2% games. The authors were careful to note that these findings did not hold when the median was the measure of central tendency. This indicated that the means were heavily influenced by a few big winners on the games, a likely artifact of requiring these players to wager until reaching a zero-credit balance.

Using the same two games, researchers conducted a laboratory study that addressed the ability of players to detect differences in pars (Dixon et al., 2013). Individuals played each of the two games for 500 spins over 30 play sessions. The recorded outcomes of session-level play indicated significant differences in the payback percentages, for six of the seven individuals. After completing all 30 play sessions on both games, all seven of the individuals were able to correctly identify the low-par game. This result was achieved at a par gap of 13 percentage points (i.e., a 650% increase from the 2% game).

Staying within the problem gambling literature, other researchers have produced results that generally do not support the ability of players to detect differences in the outcomes of games with different pars (Haw, 2008; Weatherly & Brandt, 2004; Weatherly et al., 2009). In short, these laboratory studies failed to indicate an attenuation to differences in actual payback percentages (Haw, 2008), differences in the number of trials (Weatherly & Brandt, 2004), and sensitivity to differences in pars (Weatherly et al., 2009). In both Weatherly and Brandt (2004) and Weatherly et al. (2009), the short duration of play likely influenced the results. Specifically, the limited numbers of trials on the games may have considerably affected the ability of the individuals to detect differences in the results.

A simulation study found that virtual players would not be able to detect differences in the pars of reel slots solely from playing the games (Lucas & Singh, 2011). This result held across four different par comparisons and three levels of pay table variance. The maximum difference in the pars of the two-game pairings was 9 percentage points (i.e., 12% vs. 3%). The fixed number of trials on each of the paired games ranged from 250 to 2,000. Their results also indicated that an individual playing each of the two paired games would not be likely to detect the difference in the pars from her outcomes alone, even after equal play on 10,000 consecutive days. That equates to more than 27 years of daily play. Although virtual players have no memory, it is difficult to believe that the human capacity for storing such a great number of daily outcomes would be sufficient to reverse such a result.

Three studies have examined play migration within paired reel slot machines (Lucas, 2019; Lucas & Spilde, 2019a, 2019b). Their findings failed to support the detection of par differences up to 8.9 percentage points. The results of time series regression analyses failed to indicate a significant shift in daily coin-in from the high-par game. While the low-par games generally produced greater daily coin-in, the differences from the paired high-par games failed to change over time, indicating an inability of frequent players to detect differences in the pars of the games. Alternatively stated, there was no evidence of play migration away from the high-par games, despite the identical reward schedules. Analysis of daily T-win observations fully supported this conclusion. These studies were conducted in five different casinos, all of which catered to a frequently visiting local clientele. Such players were thought to have an increased capacity for the detection of pars.

Cognitive Bias

Field studies have produced evidence of the gambler's fallacy, hot outcome bias, hot hand bias, and stock-of-luck bias in live gaming environments (Keren & Wagenaar, 1985; Sundali & Croson, 2006). In addition, the results of laboratory studies have supported the manifestation of these cognitive biases in various wagering scenarios (Ayton & Fischer, 2004; Edwards, 1961; Gilovich et al., 1985). Within the extant literature, some of the failure to detect differences in the concealed pars of reel slots may have been due in part to the presence of these and other forms of cognitive bias.

Cognitive bias affects the decision-making process of gamblers by establishing (a) a belief in positive autocorrelation within a series of nonautocorrelated, random outcomes or (b) a belief in negative autocorrelation within the same form of outcomes (Sundali & Croson, 2006). Hot hand and hot outcome are examples of the former, and the gambler's fallacy and stock-of-luck bias are examples of the latter. In lay terms, hot hand and hot outcome are anchored in the belief that a streak will continue, while the gambler's fallacy and stock-of-luck biases are based in a belief that a streak will end.

Analysis of observed wagering activity by roulette players in live gaming environments has revealed the presence of the gambler's fallacy and hot hand bias, both at the market and individual levels (Croson & Sundali, 2005; Sundali & Croson, 2006). Keren and Wagenaar (1985) observed both hot hand and stock-of-luck bias in live blackjack play. Within live gaming environments, this work has demonstrated a belief among gamblers in both positive and negative autocorrelation within a randomly generated series of nonautocorrelated outcomes, that is, the presence of cognitive bias in decision-making under risk. The presence of these phenomena serves only to impair the ability of gamblers to rationally assess the outcomes associated with wagering activity. While the current study does not directly examine this ability at the level of the individual gambler, it does invoke a game-level performance proxy that assesses behavior at the level of the clientele.

Given the remarkable variance in the outcome distribution of modern slot machines, it is exceedingly difficult for individual players to produce a sufficient number of trials (i.e., sample) to identify a population parameter such as par (Singh et al., 2013). This challenge becomes more difficult when attempting to detect a difference in the pars of two games. An inordinate amount of time and money would be required to succeed in this task. Instead, players may succumb to what Tversky and Kahneman (1971) referred to as the law of small numbers. This is a representativeness heuristic that embodies an overreliance on small samples as estimates of a population parameter. Given the sample sizes produced by individual slot players, the presence of this phenomenon could affect the ability of these gamblers to make accurate assessments of pars. This overreliance on small samples could also affect rational play migration.

The linkage to the law of small numbers may be clarified by way of example. Let us consider two versions of an actual reel slot title offered in casinos. Version 1 features a return-to-player (RTP) percentage of 94% (i.e., a 6% par), while the RTP of Version 2 is 92% (i.e., an 8% par). This equates to a 25% increase in par, from the low-par base. Next, let us assume that a player produces 100,000 spins on each version, ceteris paribus. From the par sheets, we know that the 95% prediction interval for the RTP of Version 1 has a lower bound of 86.36% and an upper bound of 101.81%. But the lower and upper bounds for the Version 2 game are 84.35% and 99.62%, respectively. Given the considerable overlap in these prediction intervals, what is the chance that this player would produce outcomes that would fall within this common space? Of course, the likelihood is great, and this is after 100,000 spins on each game.

Assuming 500 spins per hour of play, the following activity would produce 100,000 spins on a game: (a) four visits per week, (b) 1 hour of play on each visit, and (c) 50 weeks of the patronage described in (a) and (b). This activity would equate to 100,000 spins on one version of the game (i.e., $4 \times 500 \times 50 = 100{,}000$). Of course, an additional hour of play on each visit would be required to hit this mark on the other version. Such behavior would represent a valuable reel slot player to nearly any casino.

Without prior knowledge of the respective prediction intervals, most would agree that this would be a sufficient sample size to identify a difference in the pars of the two versions. But for a slot machine, these are small numbers. As demonstrated in Tversky and Kahneman (1971), even academics are willing to conclude that much smaller, randomly derived, sample sizes are sufficient to identify population parameters such as a mean (e.g., par). That is, our belief in the law of small numbers has been repeatedly demonstrated under far less extensive sampling conditions, so it is not surprising that reel players would overly rely on the results of 100,000-spin samples in drawing conclusions about pars. The current study provides insight regarding the extent to which empirical field data are consistent with the manifestation of the law of small numbers.

Law of Demand

One of the most robust ideas in economics is the law of demand, holding that increases in price will likely result in decreases in the quantity demanded, ceteris paribus. Of course, exceptions are possible, but in this case, the visible pay tables of the paired games were identical. Therefore, if players could detect differences in the obfuscated pars, they would surely avoid the high-par games. This would result in a declining difference in the daily T-win of the paired games, over time. All else held equal, the steepness of the decline should be affected by the magnitude of the price (par) shock, with the paired games in this study featuring the greatest par gaps in this research stream (i.e., 187%–267% price increases).

Without naming it expressly, many have argued that the law of demand can be applied to reel slot play, holding that gamblers eventually detect the par (price) and subsequently decrease play on the high-par games (Frank, 2017; Gallaway, 2014; Legato, 2015, 2019; Meczka, 2017). To the contrary, the price shocks in previous research of a similar design have not produced support for the law of demand (Lucas, 2019; Lucas & Brandmeir, 2005; Lucas & Spilde, 2019a, 2019b). Furthermore, at the level of the clientele, the responses to these previous price shocks would not be considered rational, within the context of the generalized axiom of revealed preference (i.e., GARP). With identical pay tables on the paired units, gamblers should have migrated to the low-par games, provided they were able to detect the par (i.e., price). This observed behavior supports one of the two things: an irrational response, or an inability to detect a difference in the pars.

Extension of Literature

The current field study extends the literature by examining the effects of par gaps greater than 9 percentage points, but less than 13 percentage points. This middle ground lies between the studies that suggest increased pars lead to increased performance, without signs of detection (Lucas, 2019; Lucas & Spilde, 2019a, 2019b), and those that suggest that players may begin to notice the par gaps (Dixon et al., 2013; Harrigan & Dixon, 2010). The results will elucidate both performance and detection effects at this gap level. In addition, our results include outcomes produced by four new game pairings, four new game titles, two new casino venues, and two new gaming markets, all of which add to the body of extant results. This work features the greatest increases in the pars of the paired games, within the field studies research stream. Together with the existing findings, the results produced by the par gaps examined

Table 1.
Par Comparisons Within Two-Game Pairings.

Two-Game Pairing	Game Theme/Title	Par 1 (%)	Par 2 (%)	Par Diff. (% Pts.)	Par Inc. (%)
TRI-1	Precious Jade	4.02	14.77	10.75	267.41
TRI-2	Lucky Tree	3.80	14.54	10.74	282.63
MEX-1	Choy Coin Doa—Dragon Ingot	4.81	14.81	10.00	207.90
MEX-2	Wild Fiesta Coins	5.11	14.71	9.60	187.87

Note. The Choy Coin Doa version featured the Extra Extra Bonus Wilds.

here will further define the relationship between game performance and par.

The results will also indirectly examine Tversky and Kahneman's (1971) law of small numbers. More specifically, individual players must make decisions/judgments about the pars of reel slot games, which feature remarkable amounts of variance in their outcome distributions. And they must do so based on small samples produced by a series of individual play sessions, interspersed across time. For example, a failure to find play migration toward the low-par games would be consistent with the manifestation of the law of small numbers, in that players would appear to be drawing incorrect conclusions about the population parameters (i.e., pars). To the contrary, evidence of such play migration would suggest that the law of small numbers would not apply in this context, in that players would show signs of correctly identifying pars. Furthermore, given that par is a concealed, price-based, population parameter, the results provide an interesting take on the law of demand, that is, with respect to its bearing on responses to price shocks, when price is not expressly marked.

Study 1 Methodology

Data Sources

The purpose of Study 1 was to assess the difference in game-level revenues within each pairing. TRI was a tribal hotel-casino resort featuring a wide range of dining outlets, multiple entertainment venues, a full-service spa, and a variety of retail shopping outlets. This property was located in the Western United States with close proximity to a major metropolitan area, and TRI relied heavily on its local customer base, competing for market share against multiple nearby hotel-casino resorts. The casino offered an extensive array of popular table games, slots, bingo, and off-track race betting. TRI offered fewer than 500 hotel rooms. MEX was located near a major metropolitan area of Northeastern Mexico. Executives from MEX considered this to be a mature repeater market comprising approximately 25 direct competitors. MEX's amenities included two casual restaurants and a lounge that featured live entertainment. The casino offered approximately 1,000 EGDs and 20 live table games. The EGDs primarily comprised reel slots, but also included a few electronic table games (i.e., those without a live dealer). No video lottery terminals (VLTs) were included in the EGDs. With no hotel rooms, MEX relied almost exclusively on a local clientele. Both MEX and TRI were selected for their reliance on the repeat slot player, as these patrons have been deemed most likely to detect a difference in the pars of otherwise identical games (Legato, 2019; Meczka, 2017). Further description of TRI and MEX was not permitted, as access to the gaming floors was granted with the understanding that both resorts would remain anonymous.

Experimental Games

Other than the difference in the pars, the two games that formed each pairing were identical in terms of the following characteristics: the number of wagering lines, base credit values, maximum bets, minimum bets (i.e., cost to cover), visible pay tables, and cabinet style. All games occupied end units within the same small bank of games, and no games featured any form of progressive award. At TRI, the sample dates for the daily, game-level outcomes ranged from February 8, 2018, through August 7, 2018. The MEX sample began on September 1, 2018, and ended on February 28, 2019. Both samples produced 181 daily T-win observations for each experimental game. The sample durations/sizes were consistent with those from Lucas and Spilde (2019a, 2019b), which were based on recommendations from the data donors and game manufacturers, all of whom held that 6 months was more than sufficient time for a repeat clientele to detect a par setting. Table 1 lists the pairings by game title, along with the high- and low-par values for each pairing.

The location of the first game in each bank was randomly assigned. From there, the remaining three games were assigned their locations such that the high- and low-par games appeared on opposite ends of the bank, to mitigate end bias (see Figure 1). Furthermore, the experimental game titles did not appear anywhere else on the casino floors, effectively steering interested players to the experimental games.

Given this study's extreme par gaps, it is worth noting that the low-par games represented remarkably low house

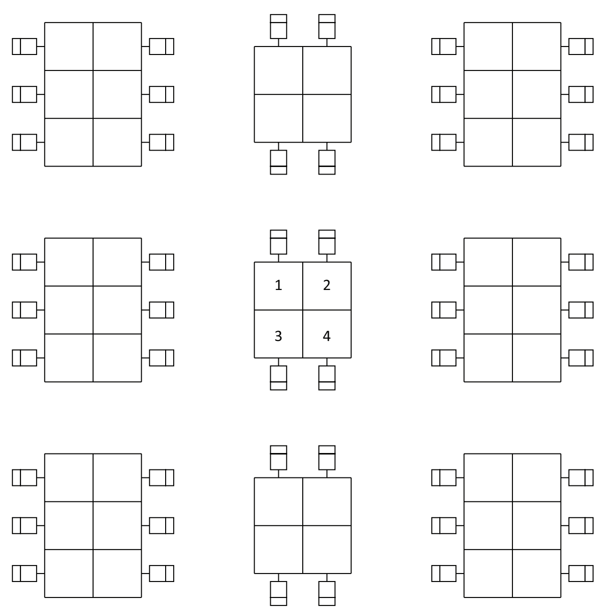

Figure 1.
Illustration of Experimental Bank Configuration at MEX.
Note. Pairings MEX-1 and MEX-2. Unit 1: Choy Coin Doa, 4.81% par; Unit 2: Choy Coin Doa, 14.81% par; Unit 3: Wild Fiesta Coins, 14.71% par; and Unit 4: Wild Fiesta Coins, 5.11% par.

advantages, within the category of penny reels. For example, nearly all penny reels on the TRI floor featured pars between 10% and 15%, making the 3.80% and 4.02% games the best gaming values on the floor. While the same could be said for low-par games on the MEX floor, the high-par games were also a bit unusual, in that nearly all the like-kind games were set at or very near to 8%. This 8% par in the MEX market is the predominant house edge for reel slots. This background information may be helpful in framing the results of the current study.

Hypothesis

Consistent with previous research, dependent-measures *t* tests were employed to test for differences in the daily mean T-win for each two-game pairing (Lucas, 2019; Lucas & Spilde, 2019a, 2019b). The following null hypothesis reflects this design.

$$H_01: \mu_{(TW,\ High)} - \mu_{(TW,\ Low)} = 0.$$

Per H_01, $\mu_{(TW,\ High)}$ represented the mean daily T-win for the high-par game and $\mu_{(TW,\ Low)}$ represented the same for the paired low-par game. This hypothesis was tested for each of the four, two-game pairings. The alpha for this two-tailed test was .05. Because the H_01 test was repeated four times, a Bonferroni adjustment was necessary, reducing the critical value from 0.05 to 0.0125.

T-win was selected as the measure of performance, as coin-in only reflects wagering activity, without concern for the casino's advantage (i.e., par) on the wagers. For example, if coin-in were used as a performance measure, video poker games would likely appear as the best performers in many venues. This would occur despite their substantially lower T-win levels, as compared with reel slots. The comparatively low house advantage serves to diminish the casino win on video poker games.

Daily actual win was not selected due to excessive variance at the individual game level. This was supported by scatter plots of daily differences in the actual win data for each of the four pairings. Furthermore, Cardno et al. (2015) noted the considerable limitations of using actual win as a slot performance measure within this context.

Study 1 Results

Prior to the repeated tests of H_01, a review of the descriptive statistics was conducted. From Table 2, it was evident that the mean daily T-win for the high-par game exceeded that produced by the low-par game, in each of the four pairings. This condition held across the full data sets and those with the outliers omitted. While all outlier cases appeared to be valid, the presence of a premium player on either of the paired games could produce a daily T-win well beyond the other observed values. In the interest of understanding the typical case, histograms of the daily T-win differences for each pairing were reviewed to identify outliers. A maximum of three daily T-win differences were removed, as reported for MEX-1 (i.e., $n = 178$).

Although not shown in Table 2, a review of Pearson correlation coefficients indicated a statistically significant correlation between the T-win values produced by the high- and low-par games in each pairing, with all four p values $< .01$. This was likely due to the sequential order of the observations, with respect to time. For example, the paired games both experienced increased T-win on the weekends and decreased T-win during the midweek periods. Because of this significant correlation, two independent-samples *t* tests could not be performed, as the correlated observations violated the assumption of independence. As a result, paired-samples *t* tests were employed to test H_01, with the results displayed in Table 3.

From Table 3, the mean daily difference in T-win was significantly different from zero, in all four pairings. In each case, this difference was positive, indicating that the mean daily T-win for the high-par game was significantly greater, within each pairing. For example, in TRI-2, the high-par game outperformed its low-par counterpart by an average of US$208.55 per day, in the outliers-omitted condition. In the case of MEX-1 and MEX-2, the mean difference was expressed in terms of Mexican pesos. If converted to U.S. dollars, the mean daily T-win of the high-par game for MEX-2 was US$111.06 greater than that of its paired

Table 2.
Descriptive Statistics: Daily T-Win Differences by Two-Game Pairing.

Two-Game Pairing (High–Low)	*M*	Median	*SD*	Minimum	Maximum
TRI-1: Precious Jade (n = 181)					
All cases: (14.77%–4.02%)	206.15	158.85	170.66	−47.35	1,584.76
TRI-1: Precious Jade (n = 180)					
Outliers omitted: (14.77%–4.02%)	198.43	158.75	136.42	−47.35	623.46
TRI-2: Lucky Tree (n = 181)					
All cases: (14.54%–3.80%)	213.54	180.17	132.45	−13.43	752.66
TRI-2: Lucky Tree (n = 179)					
Outliers omitted: (14.54%–3.80%)	208.55	178.18	123.99	−13.43	530.63
MEX-1: Choy Coin Doa (n = 181)					
All cases: (14.77%–4.02%)	1,876.22	1,757.54	1,445.51	−1,219.41	7,195.99
MEX-1: Choy Coin Doa (n = 178)					
Outliers omitted: (14.77%–4.02%)	1,790.45	1,741.98	1,295.04	−1,219.41	5,892.89
MEX-2: Wild Fiesta (n = 181)					
All cases: (14.54%–3.80%)	2,226.48	1,929.10	1,592.52	−1,223.44	10,813.13
MEX-2: Wild Fiesta (n = 179)					
Outliers omitted: (14.54%–3.80%)	2,135.78	1,917.70	1,346.64	−1,223.44	7,332.28

Note. All descriptive statistics associated with the performance of the MEX-1 and MEX-2 pairings were in terms of Mexican pesos, whereas all values associated with TRI-1 and TRI-2 were expressed in terms of U.S. dollars. All statistics represented daily values.

Table 3.
Results of Paired-Samples *T* Tests on Daily T-Win for Each Game Pairing.

Two-game Pairing (High–Low)	Mean Diff.	*SE* Diff.	*t*	*p*	*df*
All cases					
TRI-1 (14.77%–4.02%)	US$206.15	US$12.68	16.252	<.0005	180
TRI-2 (14.54%–3.80%)	US$213.54	US$9.84	21.691	<.0005	180
MEX-1 (14.81%–4.81%)	MX$1,876.22	MX$107.44	17.462	<.0005	180
MEX-2 (14.71%–5.11%)	MX$2,226.48	MX$118.37	18.809	<.0005	180
Outliers omitted					
TRI-1 (14.77%–4.02%)	US$198.49	US$10.17	19.522	<.0005	179
TRI-2 (14.54%–3.80%)	US$208.55	US$9.27	22.503	<.0005	178
MEX-1 (14.81%–4.81%)	MX$1,790.45	MX$97.07	18.445	<.0005	177
MEX-2 (14.71%–5.11%)	MX$2,135.78	MX$100.65	21.219	<.0005	178

Note. All positive mean differences indicated a greater mean for the game with the *greater* casino advantage.

low-par game. This assumed a conversion rate of $1.00 US for every $19.23 of Mexican pesos, which was reflective of the average currency exchange rates over the course of the sample dates. Using the same exchange rate, the high-par game in MEX-1 exceeded the low-par game by an average of US$93.10 per day, over the 178-day sample period.

Study 2 Methodology

The aim of Study 2 was assessing the ability of players to detect the difference in the pars of the paired games, over time. This focus addressed the long-term concerns of operators regarding negative player reactions to price hikes. Study 2 analyzed the same data gathered from the same games as Study 1. While Study 1 demonstrated significant increases in T-win on the high-par games, it then became important to understand whether the mean difference in T-win changed over time. If evidence of play migration from the high-par games were present, then operator concerns of *eventual* price sensitivity would be supported.

Again, operators need only be concerned with T-win, given the context of this performance analysis. After all, the primary concern for operators is the potential decline of revenue over time, as opposed to coin-in. Moreover, any drop in the coin-in difference over time would produce a corresponding decline in the T-win difference. This occurs because the T-win observations are produced by multiplying the daily coin-in for each of the paired games by a constant (i.e., their respective pars). This was further verified by way of time series plots of daily differences in both coin-in and T-win, for each of the four pairings.

Initially, time series plots were examined to assess the stationarity of each difference series. Based on these plots, the appropriate trend variables were created. These variables were designed to measure the change in the mean, daily, T-win difference over time. For example, a linear trend variable with a slope coefficient of zero (i.e., a horizontal line) would indicate no change in the mean value of the daily T-win difference over the 181-day sample period.

Next, the effects of the trend variables were tested within time series regression analyses designed to explain the percentage change in the daily T-win difference for each pairing. These ARMA models included autoregressive (AR) terms to address any correlation among lagged values of the dependent variable, as well as moving average (MA) terms to remedy problematic correlation among the error terms. In addition, binary variables were employed to represent any outlier differences. With the exception of the trend variables, all other variables were added on an as-needed basis. This approach was consistent with that employed by Lucas and Spilde (2019a, 2019b) and Lucas (2019).

Hypothesis

Evidence of play migration was formally assessed via the following hypothesis

$$H_0 2:\ B_{TREND} = 0,$$

where B_{TREND} represented the regression coefficient associated with the trend variable. This hypothesis was tested for each of the four pairings. The results were evaluated against a .05 alpha, but due to repeated tests, the critical value was reduced to 0.0125 by way the Bonferroni adjustment (i.e., $0.05 \div 4 = 0.0125$).

One difference from Lucas and Spilde (2019a, 2019b) and Lucas (2019) was the expression of the dependent variable. In this study, it represented the percentage change in the daily T-win difference, as opposed to the daily dollar change. That is, the daily observations for each pairing were computed as follows: (T-win from the high-par game − T-win from the low-par game) ÷ T-win from the low-par game. The reason for this alternate expression was to limit the effects of seasonality. The following example explains the rationale behind this approach.

Let us assume that players enter the casino on Day 1 with a combined bankroll of $1,000 and produce $20,000 in coin-in (i.e., wagers) before losing it all. Game 1 of Pairing A received $12,000 of the coin-in, and Game 2 of Pairing A received the remaining $8,000. Using the method employed by Lucas and Spilde (2019a, 2019b), the Day 1 coin-in difference for Pairing A would be 4,000, assuming the coin-in from Game 2 is subtracted from that of Game 1. On Day 2, the players only brought a combined bankroll of $500 to the casino, generating $10,000 in coin-in before losing it all. Given the same percentage share of the coin-in, Game 1 would have received $6,000 and Game 2 would have received the remaining $4,000. In this case, Lucas and Spilde would have recorded a coin-in difference for Day 2 of $2,000 for Pairing A, presenting the illusion of play migration. That is, the Day 1 difference was $4,000 and the Day 2 difference was $2,000. With the percentage method described in the preceding paragraph, the difference in the daily player bankroll (i.e., business volume) is considered, producing an identical decline of 33% from the level of Game 1 coin-in, for both Day 1 and Day 2. As gaming volumes can vary considerably across lengthy longitudinal samples, the percentage approach prevents seasonality from masquerading as play migration, or concealing it.

This measurement bias is easier to explain via coin-in, but the same effect occurs in daily T-win differences. Use of the daily dollar difference is a reasonable approach, and it is less of a factor when seasonality is mild or absent from the data. Still, the percentage method does a better job of muting seasonality effects, allowing for a more precise measurement of potential play migration.

Study 2 Results

A review of the time series plots indicated that a linear trend variable was appropriate for each pairing. Consistent with the extant literature (Lucas, 2019), this variable was set to a value of 1 on the first day of the sample and increased by a value of 1 on each successive day. Per Figure 2, three of the plots failed to indicate the presence of a decline in the daily T-win differences, expressed as a percentage change from the level of the low-par game. This suggested that problematic play migration was not present for TRI-2, MEX-1, and MEX-2. If it were, the linear trend lines would have been in obvious decline. Instead, the nearly horizontal trend lines suggested an absence of play migration to the low-par game. Only TRI-1 showed signs of a mild decline.

Despite the graphic evidence presented in the time series plots, $H_0 2$ was tested to identify any statistically significant change in the mean difference over time, for all four pairings. Gaining additional perspective on TRI-1 was the primary concern here. Table 4 displays the results of the linear trend variable for each of the four pairings.

Per Table 4, none of the linear trend variables produced a statistically significant effect, as all *p* values were greater than the Bonferroni-adjusted critical value of 0.0125. TRI-1 was close, with a *p* value of .033. While not statistically significant, this result suggested that a one-unit change in the linear trend variable resulted in a decrease in the daily T-win difference of 67/100 of 1%. For perspective, the high-par game in TRI-1 generated a mean daily T-win that

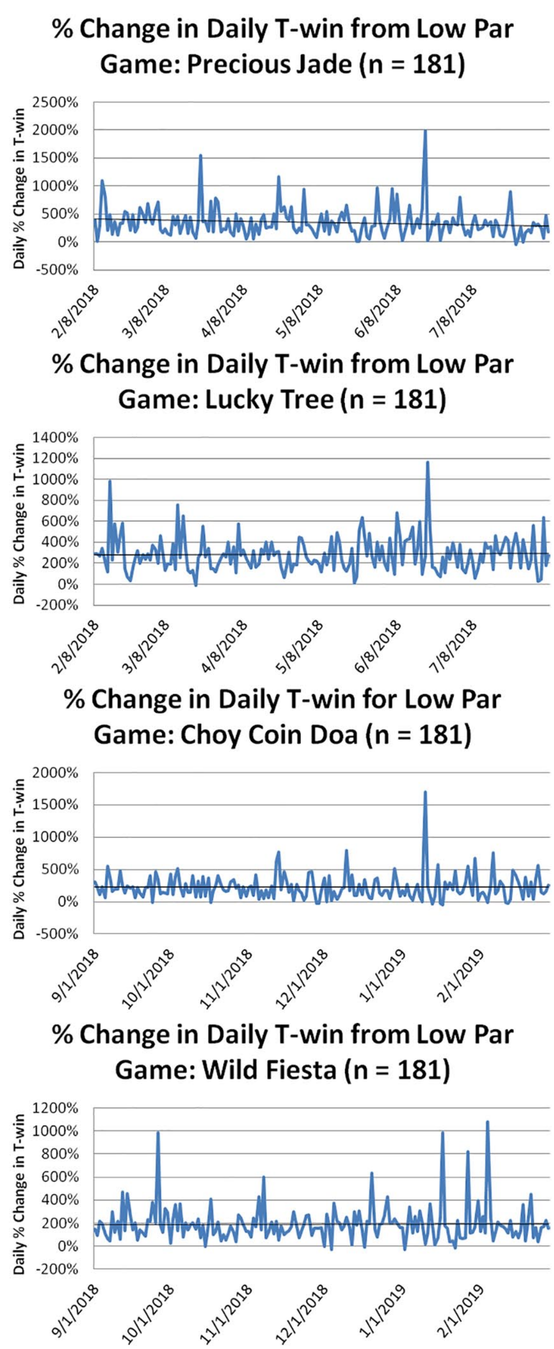

Figure 2.
Time Series Plots of Daily Percentage Differences in T-Win for Each Pairing, With Trend Lines.

was 268.1% greater than its low-par counterpart, over the course of the sample period. This was the greatest percentage increase of any pairing. Although not shown here, TRI-1 was the only pairing in which the coin-in was actually greater for the high-par game, by US$106 per day.

Table 4.
Summary of Results for Linear Trend Variables Dependent Variable: Percentage Change in Daily T-win (n = 181).

Difference Series	Trend Coefficient	*SE B*	*t*	*p*
TRI-1	−0.0067	0.0031	−2.1541	.0326
TRI-2	0.0014	0.0017	0.8542	.3942
MEX-1	−0.0012	0.0019	−0.6338	.5270
MEX-2	−0.0014	0.0016	−0.8599	.3910

Note. "Difference Series" referred to the percentage change in daily coin-in within each game pairing (i.e., [high par T-win − low par T-win] ÷ low par T-win).

Given this result, the slight but gradual decline may have been partially due to regression to the mean.

Discussion

$H_0 1$ was rejected in all four pairings, as the high-par games significantly outperformed their low-par counterparts. This result occurred despite the expanded par gaps within the paired games (i.e., 9.60–10.75 percentage points). While this finding was consistent with the previous field studies (Lucas, 2019; Lucas & Spilde, 2019a, 2019b), the increased par gaps produced even greater increases in performance. Specifically, the high-par games in this study produced the greatest percentage gains, from the level of their paired low-par counterparts. Our findings also supported those from Lucas and Brandmeir (2005), with respect to the superior performance of the high-par games.

The results failed to reject $H_0 2$ in all four pairings. There was no significant change in the mean, percentage difference in daily T-win across time, suggesting an absence of play migration to the low par games. Supported by the results of $H_0 2$, the times series plots illustrated the general stability of the difference in performance across the sample periods. These findings were in line with those produced by Lucas and Singh (2011), in that their simulations indicated that players would not have the wherewithal to detect differences in pars, based solely on outcomes from play. Our findings were also consistent with those from problem gambling researchers, supporting the inability of players to detect differences in the pars via actual outcomes (Haw, 2008; Weatherly & Brandt, 2004; Weatherly et al., 2009). Most notably, the results of the $H_0 2$ tests and the time series plots fully supported the outcomes produced by prior field research aimed at the measurement of play migration (Lucas, 2019; Lucas & Spilde, 2019a, 2019b). This support was produced despite substantial increases in the price shocks of the paired games featured in the current study.

The lack of play migration to the low-par games was inconsistent with the findings of Harrigan and Dixon (2010) as well as those from (Dixon et al., 2013). Again, this difference in results could be due to a difference in the par gaps. Specifically, they examined games with a par gap of 13 percentage points, exceeding the maximum par gap analyzed in the current study (i.e., 10.75 percentage points). Also, their studies were not conducted in the field, nor did they feature own-money wagering with the potential for real loss.

The results from both Study 1 and Study 2 would be consistent with the manifestation of cognitive biases such as the gambler's fallacy, hot outcome, hot hand, and stock of luck, all of which are at least partially related to Tversky and Kahneman's (1971) law of small numbers. These phenomena are all capable of countering objective and appropriate judgments of the cumulative results, potentially impeding play migration to the low-par games. Given the similarity of the single-visit results produced by Lucas and Singh (2011), the presence of cognitive biases only makes detection more difficult.

Consistent with the extant findings from this research stream, our results failed to support the law of demand (Lucas, 2019; Lucas & Brandmeir, 2005; Lucas & Spilde, 2019a, 2019b). Contrary to the narrative expressed in Frank (2017) and Meczka (2017), there was no significant decline in the daily T-win difference, on any of the paired games. At the level of the clientele, it appeared that the price shock was undetected. Notably, all results in this research stream were produced by a clientele characterized by frequent visitation, as it could argued that these players would be most likely to detect any such differences.

Given the well documented replication crisis in the research world (Lynn, 2017), the four consecutive field studies featuring the paired design have consistently produced results in favor of the high-par games, despite stepped increases in the par gaps. Furthermore, none of these studies have produced evidence of significant play migration from these high-par games. These results have held across three countries, seven casinos, five markets, nine game titles, 17 pairings, and 11 different par gaps.

Managerial Implications

While these results may buck conventional wisdom on par sensitivity, the performance gains and lack of problematic play migration may spur new thinking on this issue. The pressure on operators to optimize slot revenues is often great, adding value to any insight on this formidable challenge. Furthermore, the proliferation of casino gaming across the globe has only made markets more competitive, adding to the difficulty of increasing slot win at the property level. Therefore, the results of this work may be of interest to operators.

This study produced profound gains in T-win for the high-par games, in terms of both dollars and percentages. The low-par Precious Jade game averaged US$74.04 in daily T-win, while its high-par counterpart generated US$272.54 in average daily T-win, for a 268.1% increase. For Lucky Tree, the low-par game posted US$81.15 in average daily T-win, with its high-par counterpart earning US$289.70 of the same, resulting in a 257.0% increase. To standardize interpretation, the same results for Choy Coin Doa and Wild Fiesta Coins were stated in terms of U.S. dollars (i.e., 1 U.S. dollar for every 19.23 Mexican pesos). The low-par Choy Coin Doa game recorded US$53.93 in average daily T-win, with the high-par game coming in at US $147.03, for a gain of 172.6%. The low-par Wild Fiesta Coins game generated an average daily T-win of US$71.15, while the high-par game registered US$182.21 of the same, producing a 156.1% gain. All these results were computed within the outliers-omitted condition. With such substantial unit-level gains in T-win, these outcomes may indicate a promising opportunity to grow revenues.

Looking across the four studies with the paired design, the relationship between the percentage increase in par and the percentage increase in average daily T-win was not perfectly monotonic. Still, in general, there was a positive relationship between these two variables. At the group level, as the par gap increased so too did the gain in performance. Specifically, the studies in this research stream were grouped and ordered with respect to the percentage increase in the par gap, beginning with Lucas and Spilde (2019b) who analyzed par differences averaging 59.16% (Group 1, $n = 5$ pairs). Next, Lucas and Spilde (2019a) and Lucas (2019) examined par differences averaging 112.71% (Group 2, $n = 8$ pairs). Finally, the current study featured an average par gap of 236.45% (Group 3, $n = 4$ pairs). The corresponding average daily T-win gains for Groups 1, 2, and 3 were 48.66%, 99.88%, and 213.46%, respectively. At the group level, increases in par have produced increases in T-win. Furthermore, the percentage increases in pars have led to similar percentage gains in T-win (i.e., Group 1, 59.16% and 48.66%; Group 2, 112.71% and 99.88%; Group 3, 236.45% and 213.46%). All these percentage changes were computed from the level of the low-par games.

These results suggest that greater increases in pars are producing greater increases in T-win, which runs counter to the idea that reel slot players are hypersensitive to price (i.e., par). This condition likely stems from the obfuscation of par on reel slots, and the inability of players to detect differences in the pars of otherwise identical games from play alone. The time series plots and the results of H_02 support this conclusion.

The extant results could also be the product of a possible reality in which gambling budgets do not represent earmarked funds. That is, bankroll that is not lost to the casino on a given gambling trip becomes available to cover life's expenses, such as unforeseen medical bills, home repairs, car repairs, and many others. Contrary to popular belief, operators in repeater markets may not eventually win the player's gaming budget on subsequent visits, as it could be diminished by these other personal expenses. In this possible reality, gaming budgets would represent a fluid remainder of personal funds, after covering life's more pressing needs. Therefore, from the operator's perspective, it may be beneficial to win the gaming budget when afforded the chance. Alternatively, some players are time constrained. This would also limit the opportunity for operators to win player bankrolls. To wit, higher pars may optimize revenues from time-constrained players, over the long term. As the number of these players is not known, increased pars may be more valuable than some might expect. Of course, if there were compelling evidence of par sensitivity/play migration over time, all of this conjecture would be called into question. But no such evidence has been found in this study, or any of the three preceding studies that have measured play migration (Lucas, 2019; Lucas & Spilde, 2019a, 2019b).

Given that this research stream is new, convincing operators to consider the results will likely be challenging. This is understandable as most corporate entities are risk averse, especially the profitable ones. In addition, Plato's general notion that storytellers rule the world (or society) is also likely applicable to the adoption process. Specifically, many have long held the belief that players can detect differences in pars, based largely on frequently cited yet anecdotal evidence. Subscription to this consistent and popular narrative can evolve into deeply anchored beliefs. Still, both of the data donors in this study are considering a second phase of this experiment, in which a greater number of pairings will be examined.

For game makers, our results suggest increasing the pars under trial-purchase conditions. This will likely increase the game's revenue while in the trial phase, increasing the likelihood that the operator will decide to purchase the game. Of course, the operators will make the final decision on the par setting for the game's trial period, but it would appear to be in the best interest of all parties to select a greater par.

Regarding participation games, game makers may want to consider increasing the pars by limiting the choice set of licensed options. As these games operate under a revenue-sharing agreement, the manufacturers may have more negotiating leverage. Participation games are owned by the manufacturers, and often feature licensed themes (e.g., Batman), enhanced graphics and game features, and upgraded cabinet designs. These and other traits usually make participation games more desirable than the standard slot product, potentially increasing the negotiating leverage of the manufacturers, with respect to par settings. In any case, greater revenues will either improve game sales or the revenue share, both of which improve the return on investment for game makers.

Limitations and Future Research

There is no reason to believe that players would detect differences in pars if more games were included in the experiment, but it remains a possibility. The same could be said for differences in the daily T-win produced by the games. As previously noted, there is interest in a stepped approach that includes a greater number of pairings. This is recommended, as operators would have to assume some amount of risk if all pars were increased at once. It is possible that a tipping point could exist. Assuming an understandable degree of risk aversion/trepidation, most gaming operators would likely prefer an incremental approach. Moreover, if the results were to support those from extant studies, additional games could be adjusted within 6 to 12 months. This approach would guard against surpassing a potential tipping point, should one exist.

In terms of the quasi-experimental design, overall occupancy levels could have limited play migration. For example, high occupancy levels on the slot floor could have restricted the ability of players to abandon the high-par games for their low-par counterparts. While overall occupancy was not expressly monitored during the experiment, historical records within the slot systems indicated overall occupancy rates of 26% at TRI and 29% at MEX, with occupancy levels exceeding 50% on less than 5 days during the sample periods. Therefore, high occupancy rates were not likely to have meaningfully restricted play migration or affected the overall game performance.

One could not expect to reproduce our results on paired video poker units, as the casino advantage on these games must be manipulated via the visible pay table, assuming a normal 52-card deck is used. This is because the probabilities of making the winning hands do not change. Therefore, video poker players would have the ability to infer price from changes to the visible pay tables. In this case, we would expect to find support for the law of demand.

Some contend that the premium players (a.k.a. high rollers) represent a subset of players who are hypersensitive to pars (Meczka, 2017). As such players were not isolated in any existing research, replication of this experiment within high-limit slot sections would empirically examine this contention. To the contrary, nearly all the peak daily differences in the time series plots in Figure 2 illustrated greater T-win on the high-par games. If one were to assume these results were produced by premium players, it would seem reasonable to expect some great negative differences on subsequent dates. At a minimum, there should have been at least some deep dips in the daily T-win differences, over the course of the samples. The absence of such declines suggests that these impactful players have either not played the low-par games, or they did, but were not able to detect the lower pars. Furthermore, these players seem to have been unable to detect and exploit differences in the paired games, across all 17 pairings to date. It seems unlikely that no premium, or at least relatively premium, players have encountered any of the experimental pairings, over the course of all these lengthy sample periods.

We do not know the extent to which individual players engaged the experimental titles, despite the exclusive representation of these titles on the slot floors. Management believed that 6 months was more than ample time for such conspicuous differences in the pars to be discovered. Still, a laboratory study could provide additional perspective on par detection, by requiring individuals to play both paired games. But the field study results are more representative of how actual players interact with the games on a slot floor that features many title choices, and with their own money at risk. This setting is especially relevant to decisions regarding the performance of individual games (e.g., T-win production).

Due to the field study approach, it was assumed that the portfolio of gamblers that patronized each of the paired games was not importantly different. The duration of the sample was helpful in this regard, providing an opportunity for a variety of players to engage each game. The omission of outliers also helped improve the homogeneity of the player portfolios, at the game level. Again, a laboratory study would address this concern, adding additional perspective to the research stream. Still, the challenge would be to incorporate own-money wagering and to replicate the real-world conditions of engagement. Ultimately, the combination of laboratory and field work is likely the best way to fully understand the dynamics of game performance and the ability of players to detect differences in obfuscated pars. Given the magnitude and importance of slot win to the viability of most of the world's casinos, this work takes on exaggerated importance for both operators and game makers.

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