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Taxing Gambling Machines To Enhance Public and Private Revenue

Thomas A. Garrett, David Paton and Leighton Vaughan Williams*

1. INTRODUCTION

The commercial gambling industry is an important source of tax revenue in many locations across the world. In the U.S., casino gambling has annual revenues in excess of $40bn, supports (directly and indirectly) about 800,000 jobs and generates nearly $10bn per annum in direct gambling taxes (Long 1995; American Gaming Association 2018). For example, Las Vegas and Atlantic City, the largest casino gambling markets in the U.S., attract around 40 and 24 million visitors per year, respectively. Casinos provide direct support for the general tourism industry in many locales across the country as local and state governments use the lure of casino gambling as a means of increasing local economic growth and development. On a smaller scale, hundreds of small communities rely on casino gambling as a means to increase tourism and economic development in their communities.

In recent years, a number of jurisdictions have relaxed gambling laws with the explicit purpose of boosting economic activity and development. In particular, gambling is the dominant source of tourism for the Chinese territory of Macau, now the largest casino market in the world, whilst a number of other countries such as Australia and the UK have sought to exploit the growth of gambling tourism by relaxing laws relating to the casino industry. This is reflected in the breadth and depth of the economic literature on gambling, as well as its extensive

* Thomas A. Garrett, Professor of Economics Department of Economics The University of Mississippi P. O. Box 1848 University, MS 38677-1848. Tel: + 1 662 915 5829; E-mail: tgarrett@olemiss.edu. David Paton (corresponding author) Professor of Industrial Economics Nottingham University Business School Wollaton Road Nottingham NG8 1BB United Kingdom. Tel: + 44 115 846 6601; E-mail: david.paton@nottingham.ac.uk. Leighton Vaughan Williams Professor of Economics and Finance Nottingham Business School Nottingham Trent University 50 Shakespeare Street Nottingham NG1 4FQ United Kingdom. Tel: + 44 115 848 6150; E-mail: leighton.vaughan-williams@ntu.ac.uk. We would like to thank the Editor, Professor David Stadelmann, and two anonymous referees for their helpful comments and suggestions.

international span (e.g. Smith and Wynne 2000; Pryor 2008; Vaughan Williams and Siegel 2013; Rodriguez et al. 2017).

In addition to casino gambling serving as a driver for tourism and economic growth, governments around the world depend on the gambling industry as an important source of tax revenue. While previous work has examined the taxation of gambling in general (for surveys see Walker and Hodges 2018; Anderson 2013), the literature examining the taxation of electronic gambling ('slot') machines, a sector which has driven recent growth in the industry, is much more limited. This is surprising given the rapid growth in gambling machine revenues in recent years. Further, the choice regarding the optimal approach to taxing gambling has been the subject of intense lobbying and political debate. As such, it can reasonably be argued that outcomes have not always been driven by evidence-based economics but instead by intense lobbying by well-funded industry and pressure groups.

Electronic gambling ('slot') machines are in fact a key component of the global gambling and casino industry, and the taxation of these machines is a highly controversial area of policy debate involving tensions between industry profitability, economic growth and government revenue.

Key tensions were highlighted in a consultation exercise on the switch from a licence fee model of gambling machine taxation (Amusement Machine Licence Duty, or AMLD) to one based on gross profits (Machine Games Duty, or MGD), published in the UK by HM Treasury. In its document outlining the proposed changes to the taxation of gambling machines, HM Treasury argued that:

> *"MGD will improve the future predictability and sustainability of the tax regime by making it more resilient to technological progress, regulatory changes and to inflation … MGD also supports the Government's objective of a fairer tax system by ensuring the taxation of machine games will be more closely linked to machine profits."* (HM Treasury/HM Revenue and Customs 2011).

Key representations to the consultation pointed out that MGD would extend beyond the current scope of AMLD and raised concerns that this would adversely impact venues such as family entertainment centres. BACTA, which represents the British amusement and gaming machine industry in the UK, was particularly critical of MGD:

> *"A structural tax change will introduce additional complexity, compliance burden and cost and will inevitably create some 'losers' across and within sectors of the industry."* (BACTA 2011 - See also HM Revenue & Customs, 2011).

Although one important aspect of the debate relates to the use of taxation to control the extent and costs of problem gambling ("gambling that disrupts or damages personal, family or recreational pursuits" – Royal College of Psychiatrists 2014), much of the argument reflects the more general tension between governments' desires to maximise tax revenue and industry concerns about the effect of high tax rates on profits and growth.

In this paper, we compare the two most commonly used options for taxing gambling machines (licence fees and taxation of machine profits) both from a theoretical perspective and empirically. We are fortunate in undertaking our empirical analysis that there has been a relatively recent switch in the way that gambling machines are taxed in the UK, from a levy based on a licence fee per machine to a tax based on the profit generated per machine (a Machine Games Duty, or MGD).

We examine the impact of the switch from a licence fee system of taxation to a revenue-neutral gross profits tax on machines, testing whether it had any significant effect on the number of machines and on machine revenue. Our results provide useful guidance for all parties involved in the gambling taxation debate, especially those jurisdictions that are considering a change to their gambling tax system. In particular, we seek to confirm whether other jurisdictions which continue to use a licensing taxation system for slot machines should, on the basis of the evidence we find, consider switching to a gross profits tax on gambling machines.

In the next sections of the paper, we discuss in more detail the literature on gambling machine taxation followed by a discussion of the institutional context for our case study in the UK. In section 4, we describe our theoretical model. In section 5 we introduce our data and empirical approach. Our empirical results are reported in section 6. In the final section we discuss these results, their relation to the theoretical predictions, and their implications for policy. In particular, we indicate how a shift in the system of taxation of gambling machines can resolve one of the key policy tensions between industry and government over the sustainability and growth of tax revenues versus industry profitability; namely, the enhancement of both public and private revenue.

2. THE TAXATION AND REGULATION OF GAMBLING: SOME BACKGROUND AND EVIDENCE

The development of gambling taxation policy has been characterised by tensions between the interests of key stakeholders and the revenue-raising authorities. The taxation of gambling machines has been a notably controversial part of policy debates, involving a specific tension between industry profitability and government revenue.

A major focus of the wider debate in the U.S. has been an assessment of the economic benefits and costs of gambling. Rose (2001) draws on a survey of more than a hundred published studies to conclude that, as a general rule, a new casino provides economic benefits to its host economy – see also Barrow et al. 2016. Rose also highlights such social costs as increased gambling addiction and congestion. Eadington (1998, 1999a) includes tourism development, economic revitalisation, tax revenue, jobs, and new investment and employment opportunities for minorities as benefits from casinos, whilst Eadington (1999b) argues that destination casinos (which are designed to attract national and international visitors who can enjoy a range of types of recreation and entertainment) play a strong role in job creation and provide significant tax revenue for the local jurisdiction. Large casinos (centred in large part around gaming machines) are considered “tourist draw cards” (Delfabbro and King 2017, p. 319). Wardle et al. (2014) observe that in the UK, gambling venues are typically concentrated in areas with heavier tourist traffic**,** including seaside suburbs. Notably also, Macau has over recent years come to play a dominant role in terms of world gaming revenue. The development of Macau as a pre-eminent destination gambling capital is well explored in Sheng and Gu (2018).

A key issue of debate is the economic benefits and social costs of different types of gambling and the displacement effects between them (e.g. Walker and Sobel 2016; Cummings et al. 2017). In the U.S., state governments tend to be particularly concerned with revenue generation through taxation, a goal which can be in conflict with the desire by gambling operators to protect and grow their revenues (Walker and Jackson 2011).

This tension often crops up in discussions of the balance between state lotteries and private gambling. For example, Calcagno et al. (2010) examine the determinants of casino adoption decisions by state governments (see also Calcagno and Walker 2016). Their results suggest that casino legalisation is determined by state fiscal stress, notably efforts to keep gambling revenues (and the concomitant gambling taxes) within the state, and the desire to attract tourism or “export taxes”.[1]

The market for electronic gambling machines in the U.S. varies widely from state to state, as does the taxation of gambling machine revenue. Of the 900,000 machines estimated to be in operation, some 90% are located in commercial or tribal casinos and nearly 20% of all machines are located in just one state – Nevada. State tax rates on casino gambling revenue are quite different, ranging from a maximum rate of 6.75% in Nevada to a maximum rate of 67% in Maryland. Some states such as Delaware and Pennsylvania implement a tax as a percentage of machine revenue (‘gross profits’) whilst others charge a licence fee (or excise tax) per machine or a mix of licences and a revenue tax. For example, Nevada levies an excise tax of $250 per machine per year whilst operators in ‘restricted locations’ such as casinos pay an additional revenue-based tax (AGA, 2018).

Furthermore, the regulatory, economic, and legal environment surrounding gambling machines in the U.S. is changing rapidly, as a number of states have liberalised or are considering liberalising gambling laws with the intention of

[1] Although it is not the focus of this paper, a case can also be made for considering the implications of any expansion in the prevalence of machine gambling within the wider health perspective related to casinos (Philander 2019).

capturing economic benefits from the industry along with public revenue from associated taxation. Several states that require their casinos to pay a tax on each patron's admission to the casino (about $2 to $3) are considering abolishing this tax and altering the tax rate on casino gaming revenue, the bulk of which comes from gambling machines.[2] Also, the U.S. Supreme Court ruled in May, 2018 that Federal prohibition on sports betting is unconstitutional, so states are now free to pass statutes that would legalise sports gambling within their borders. Given that the bulk of states' tax revenue from gambling comes from gambling machines, it is unclear to what degree sports betting may cannibalise gambling machine activity. Finally, the general spread of gambling machines across the country is a continuing concern for states as this increased competition for gambling has resulted in slowing or declining tax revenue from casino gambling machines.[3]

In contrast to the U.S., the UK gambling sector has historically been dominated by sports betting in shops known as bookmakers. The casino sector has also been relatively less important, although there was intense competition by 27 cities for one of the regional or destination casinos allowed by the Gambling Act of 2005 (2005 c19), reflecting the aspirations of these cities to emulate in some respects the destination tourism of Las Vegas (Casino Advisory Panel 2007). There has also long been a significant gambling-machine industry based not only in casinos but in bookmakers, in bingo halls, in pubs and specialised arcades often located in seaside tourist centres. As of 2017, the UK Gambling Commission estimates that there were over 180,000 electronic gambling machines in the main sectors.[4]

The Australian and Canada gambling industries are also well explored and key resources are available from the Australian Government Productivity Commission (2010) and the Canadian Partnership for Responsible Gambling (2013) respectively. Other recent international studies include Arvidsson et al. (2017), of Sweden, Friehe and Mechtel (2017), of Germany, and PwC (2017), of South Africa.

A major international collaboration, providing a conceptual framework of harmful gambling, is presented by Abbott et al. (2018), while Wardle et al. (2018), for the UK Gambling Commission, shine a focus on estimation of the wider costs to society of gambling-related harms – see also Thorley et al. (2016).

3. DIFFERENT APPROACHES TO MACHINE TAXATION: THE CASE OF THE UK

Until recently, UK gambling taxation was sector-specific. Sports betting was taxed based on the gross stakes placed by punters, whilst machines were subject

[2] See https://www.casino.org/news/indiana-casinos-3-admission-tax-might-be-headed-for-exit-soon

[3] See https://lasvegassun.com/news/2011/oct/07/nevadas-tax-income-gaming-well-below-other-markets/

[4] Machines in pubs are not covered by the Gambling Commission data so the total number of electronic gambling machines in the UK is higher than this.

to an annual licence fee (Amusement Machines Licence Duty, or AMLD) as well as a sales tax (known as VAT) levied on gross revenue. The level of AMLD was linked to the type of machine, and caps were introduced on the number of machines and types of machine permitted in different types of gambling venue, such as bingo halls, Licensed Betting Offices (LBOs) and casinos.

During the late 1990s, the growth of online gambling and the decision by many companies to move their operations to low-tax offshore locations stimulated the UK Government to undertake a fundamental review of betting tax policy. Although industry and consumer interests were involved in the review, the Government drew heavily on economic analysis of the alternative taxation options. In a report for HM Customs and Excise titled ‘An economic analysis of the options for taxing betting’ (Paton et al. 2000), it was argued that a tax on gross profits (i.e. stakes placed minus winnings paid out) tends to result in lower prices for consumers and higher turnover for bookmakers compared to the existing tax levied on bettors’ stakes. As a result, and in the face of opposition from some industry stakeholders, in 2001 the UK introduced a taxation system based on gross profits for bookmakers and subsequently extended this to other sectors such as bingo halls and football pools (2002) and betting exchanges (2003). Other countries followed suit in implementing a gross profits tax on betting, including Singapore (2005), Spain and Greece (2011), Denmark (2012), Italy (2013), Bulgaria (2014), Kenya (2017) and, more recently, several US states. Gambling machines largely remained outside the remit of the GPT system in the UK until 2013.

In that year, the UK Government decided to bring the tax system for electronic gambling machines into line with these other sectors. From 1 February, 2013, the system of licence fees and sales tax for machine gambling was replaced with an exclusive gross profits tax known as Machine Games Duty (MGD). In contrast to most machines, those classified as being Category D (at the bottom end of the stake and payout ladder) had not been subject to AMLD but did become subject to MGD from February 2013, a feature which is useful for the identification strategy in our empirical work below.[5]

In the empirical section of this paper, we use data from the UK before and after the policy change to evaluate the effects of shifting from a per-machine licence fee to a gross profits tax. We anticipate that the results will be helpful in informing gambling policy in many different jurisdictions. First though, we provide a formal framework for our analysis by way of a theoretical model of machine gambling taxation.

[5] A full description of the different machine categories in the UK is given in the Supplementary Appendix A2.

4. THEORETICAL FRAMEWORK

This section presents the partial-equilibrium model for a representative profit-maximising casino having some degree of price-setting power. The assumption of price-setting power captures the reality that 1) casinos operate in product-differentiated markets, i.e. while offering similar gaming products, casinos differ in their portfolio of gaming machines, customer service, gaming environment, and complimentary items (free casino play, free drinks, show tickets, etc.) to encourage players to gamble; and 2) the UK government restricts entry into gaming markets by requiring operators to apply for a licence as well as restricting, to some degree, the availability of various casino licences.[6] The profit maximisation model serves as the basis for the subsequent theoretical analysis of how a switch from a per-machine licence fee (L) to a revenue-neutral ad valorem Gross Profits Tax (GPT) will increase allocative efficiency by increasing the number of gaming machines. [7]

To begin the analysis, it is first useful to consider profit for a representative casino (or other gaming machine operator) absent any taxation. Assume the casino uses one input, gaming machines (M), to generate gaming output (Q). Gaming output is defined as the total amount wagered in the casino, which is commonly referred to as 'handle' (see Anderson 2005, 2013).[8] The casino has the implicit production technology $Q = Q(M)$, where $Q'(M) > 0$ and $Q''(M) < 0$ to capture diminishing marginal product. The price (P) of casino gaming is the percentage of each dollar wagered that is not returned to players, often called the "takeout rate" or "win percentage." The casino faces consumer (inverse) demand, $P(Q)$, where $P'(Q) < 0$. Fixed cost for machines is assumed to be zero, and variable cost per machine (c) is constant (average variable cost is equal to marginal cost).[9] Casino profit (π) absent taxation can be expressed as $\pi = P(Q) \cdot Q - c \cdot M$, where $P(Q) \cdot Q$ is gross gaming revenue and $c \cdot M$ is total cost.[10] The casino's problem is to choose the M that maximises profits. The profit-maximising M also determines the optimal level of gaming output, Q, since $Q = Q(M)$.

Under the initial condition of a per-machine (M) licence fee (L), the casino's problem is:

6 The literature generally agrees that the casino industry exhibits some degree of market power. See Gazel (1998), Eadington (1999b), and Anderson (2005) for further evidence and discussion.

7 The economic effect of per-unit taxation versus ad valorem taxation (like the GPT) is one of the most widely studied topics in public finance. A review and discussion of the earlier literature is found in Keen (1998).

8 'Handle' includes both the out-of-pocket wagers by casino patrons and any winnings that are wagered again.

9 The assumptions of zero fixed costs and constant variable costs are made for notational simplicity. Relaxing these two assumptions does not change our final result and conclusions.

$$\max_{M} \pi = P(Q) \cdot Q - (c + L) \cdot M.$$

Differentiating this objective function with respect to *M* yields the first-order condition

$$MRP_L = c + L, \tag{1}$$

which simply says that the optimal (profit-maximising) number of machines occurs when the marginal revenue product of an additional machine is equal to the marginal input cost of an additional machine.[11]

Assume now that the government decides to replace the licence fee with a GPT having rate *t*.[12] The casino's problem is:

$$\max_{M} \pi = [P(Q) \cdot Q] \cdot (1 - t) - c \cdot M.$$

Differentiating this objective function with respect to *M* yields the first-order condition

$$MRP_t \cdot (1 - t) = c. \tag{2}$$

Equation (2) reveals that the profit maximising number of machines occurs when the post-GPT marginal revenue product of an additional machine is equal to the marginal cost of an additional machine.

Economic theory indeed tells us that a switch from a per-machine licence fee to a revenue-neutral GPT will increase the number of machines in the UK gaming market under the assumption that casinos have some degree of pricing power. While we do provide a simple proof in the Supplementary Appendix (A4) to formally demonstrate this increase in the number of machines, the economic intuition of this result is straightforward as follows:

10 Gaming revenue to the casino after paying winnings is referred to as gross gaming revenue in the U.S. and gross gaming yield (GGY) in the UK.

11 This result should be intuitive: if the additional revenue to the casino from using an additional machine is less (greater) than the additional cost from the additional machine, then the casino will use fewer (more) machines.

12 Our model compares a pure licence fee system with a pure GPT system. In fact, the key results are easily generalizable to a case where a mix of taxation is used (as happens in some U.S. states) but policy makers switch the balance of taxation either wholly or partially in favour of GPT.

- Profit maximising casinos choose to operate additional machines until the additional (marginal) revenue from more machines equals the additional (marginal) costs of more machines.
- A licence fee increases the marginal costs, as seen in equation (1). Removing the licence fee thus decreases the marginal costs of machines meaning that, other things equal, more machines will be used.
- A GPT effectively reduces the marginal revenue product received by the firm, as seen in equation (2). However, because the GPT is levied on the price of the product, a firm with some degree of price setting power will respond to the GPT by setting a lower price and higher output. As a result of this behavioural response, a (tax-revenue neutral) switch to GPT will mean that the reduction in machines from GPT is less than the increase in machines from no licence fee. Thus, the number of machines under the GPT will be higher than under the per-machine licence fee.

The above result also implies that allocative efficiency will be greater under the GPT than the licence fee. Since the switch from a per-machine licence fee to the GPT increases the number of machines, it follows that an increase in the number of machines will increase gaming output (wagers) and decrease the price of casino gaming since $Q'(M) > 0$ and $P'(Q) < 0$. The increase in output and the decrease in price will increase gross (pre-tax) gaming revenue to the casino and will increase consumer surplus (welfare) relative to the licence fee because any firm with price-setting power only operates along the elastic portion of consumer demand (which implies that marginal revenue to the casino is positive in this range).[13] Thus, the switch from the licence fee to a revenue-neutral GPT is predicted to have increased allocative efficiency with respect to consumers in the UK casino gaming market.[14]

As discussed above, the primary factor leading to an increase in allocative efficiency under the revenue-neutral GPT is an increase in the number of gaming machines. In the context of the UK machine gaming sector, a licence fee system corresponds to AMLD whilst GPT corresponds to MGD introduced in 2013. Note that if the government sets taxes optimally, it should set the rate of GPT

[13] In other words, any percentage increase in output resulting from an increase in the number of machines is greater than the percentage reduction in price. Since gross gaming revenue is simply price multiplied by quantity, it is clear that gross gaming revenue will increase as the number of machines increases as long as marginal revenue is positive. Of course, the impact on price, output, and consumer welfare resulting from an increase in the number of machines depends upon a casino's specific price elasticity of demand.

[14] These results and conclusion do not hold if the casino industry is perfectly competitive. A broader evaluation of allocative efficiency from switching from a licence fee to a GPT would involve a model such as that found in the optimal tax literature (Diamond and Mirrlees 1971a,b) that considers not only consumer surplus, but also producer surplus and sufficient revenue to the government to meet its spending objectives. This broader analysis is worthy of future research, but it is beyond the scope and objectives of our paper.

anticipating the sort of behavioural change predicted by the model. Otherwise, the rate of taxation might be set at too high a level, which could contribute to some unnecessary resistance to the policy change by the industry.

The next section of the paper examines empirically whether, as predicted by the above theory, the switch from a licence fee to a revenue-neutral GPT did indeed increase the number of machines. Confirmation of this finding would provide empirical evidence that allocative efficiency in the UK gaming market has increased under the revenue-neutral GPT relative to the licence fee.

5. DATA AND EMPIRICAL APPROACH

We test the hypotheses generated by our theoretical model using data on the UK experience since the introduction of MGD (equivalent to a GPT) for gambling machines in 2013. Tax revenue from AMLD and MGD are available from Her Majesty's Revenue and Customs (HMRC) department whilst the UK Gambling Commission provides annual data on the number of machines. However, whilst tax revenue is only available at an aggregate level, machine numbers data are broken down by five different gambling sectors: adult gaming centres (AGC), bingo venues, casinos, family entertainment centres (FEC) and licensed betting

Table 1

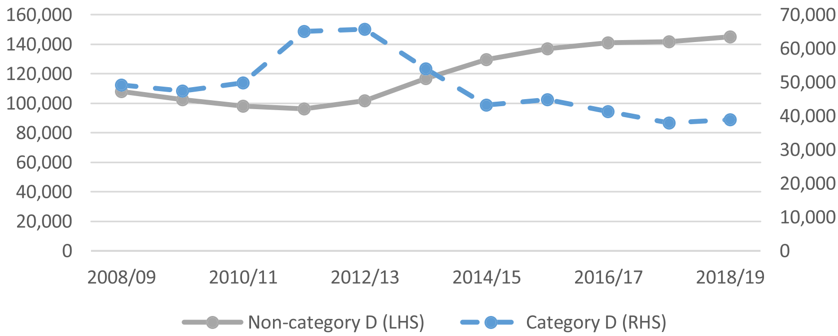
Descriptive summary of machine numbers by sector-category

	Machine numbers		Machine revenue (GGY)	
	Mean	SD	Mean (£m)	SD (£m)
All machine categories	168,583.3	13,066.8	2,365.9	321.9
All Non-Category D machines	119,726.1	19,364.3	2,264.6	324.0
All Category D machines	48,857.2	9,486.5	101.3	8.3
AGC (Adult Gaming Centres), B3	9804.0	771.9	151.6	38.2
AGC (Adult Gaming Centres), B4	106.5	59.0	0.5	0.2
AGC (Adult Gaming Centres), C	31008.4	4621.3	111.8	13.0
AGC (Adult Gaming Centres), D	16393.6	2283.4	28.1	6.7
Bingo B3	7827.1	4020.0	134.0	59.3
Bingo B4	209.1	81.2	2.0	1.4
Bingo C	31660.8	16004.3	98.9	20.6
Bingo D	8656.4	5756.1	12.7	7.2
Casino B1	2756.5	222.9	156.0	27.5
Casino B2	121.8	65.4	7.9	5.6
Casino B3	4.9	4.8	0.1	0.2
FEC (Family Entertainment Centres), C	2432.4	705.1	4.7	1.7
FEC (Family Entertainment Centres), D	23807.3	5037.0	60.5	7.2
LBO (Licensed Betting Office), B2	33548.7	920.5	1,559.8	176.6
LBO (Licensed Betting Office), B3	132.3	142.9	36.7	91.9
LBO (Licensed Betting Office), C	113.7	126.4	0.6	0.6

Notes
(i) Means and standard deviation relate to the 11 years in the sample from 2008-9 to 2018-19
(ii) Machine revenue is in millions at constant (2015) prices.

FIGURE 1

Machine numbers by category: 2008-9 to 2018-19



Source: Gambling Commission *(2019)* [Colour figure can be viewed at wileyonlinelibrary.com]

offices (LBOs) and by the various machine categories (see Supplementary Appendix A2). These data are available for 10 years, from 2008-9 until 2018-19. Reporting to the Gambling Commission by machine operators is mandatory and so the machine data is comprehensive. We provide a summary of the machine numbers in each sector-category combination in Table 1.

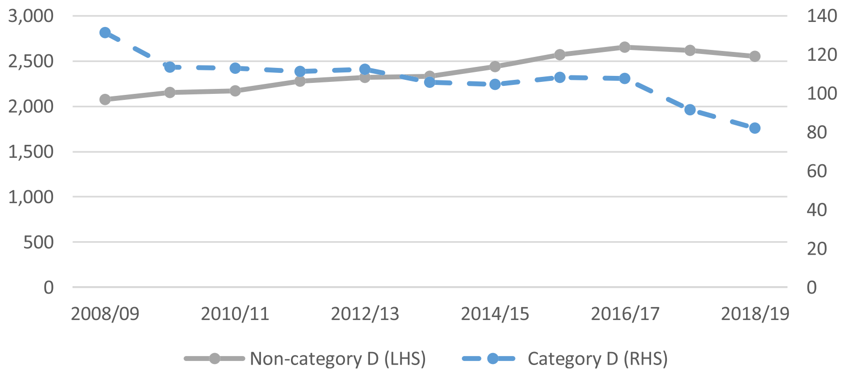
A casual inspection of data before and after the switch to a GPT provides preliminary support for our hypothesis that industry capacity increased after the switch. Figure 1 presents the trend in machine numbers for machines previously subject to a licence fee (non-category D) and those for which the GPT tax was entirely new. Non-category D machine numbers had been decreasing year-on-year from 2008-9. In the run-up to the introduction of MGD, this trend was reversed and from the start of the MGD period in early 2013, numbers increased significantly year-on-year up until 2018-19. In contrast, category D machines decreased significantly after the introduction of MGD. A similar pattern is found with trends in Gross Gambling Yield (GGY) (Figure 2) increasing after GPT for non-category D machines but decreasing for category D. Notably, both the number of machines and revenue from all categories (including category D) increased after the introduction of GPT.

In terms of tax take, AMLD revenue was relatively stable prior to the taxation change in 2013.[15] Taking into account revenue from VAT which was payable in addition to AMLD prior to 2013, revenue from MGD in 2013-14 was similar to that in previously comparable years, suggesting that the Government was

[15] The sharp decrease in revenue from AMLD in 2012-13 was due to technical reasons relating to the timing of the licence renewal in anticipation of the switch to MGD.

FIGURE 2

Machine revenue (GGY) by category: 2008-9 to 2018-19



Source: Gambling Commission *(2019)*
Notes: (i) Machine revenue is Gross Gambling Yield (GGY) in £million adjusted for inflation using the Consumer Price Index (2015 = 100). Revenue in unallocated categories is assigned to categories in proportion to allocated revenue. [Colour figure can be viewed at wileyonlinelibrary.com]

successful in their aim of broad revenue neutrality when switching to MGD.[16] In the subsequent three years, tax revenue increased by over 40% from £500 m in 2013-14 to £720 m in 2018-19 (HM Revenue and Customs, 2019). In other words, it seems that the increase in industry capacity induced by the switch to GPT was achieved without compromising Government tax revenue.

To more rigorously test our hypothesis, we exploit the breakdown of machine numbers by category and sector to estimate a fixed effects regression model of the determinants of the number of machines in each year. Our cross-sectional unit is the sector-category combination. So, for example, Category B3 in casinos is treated as a different group to Category B3 in LBOs. We have data on 16 different sector-category pairs, giving us 174 observations in total.[17] The model can be summarised as:

16 VAT revenue from machines was not reported on any consistent basis. HM Revenue and Customs (2012) provide an estimate of VAT revenue in the period prior to the change to MGD and these figures indicate that total revenue (i.e. AMLD + VAT) in 2011-12 (the most comparable pre-MGD year) was similar to revenue from MGD in 2013-14.

17 We lose one observation due to a single zero observation which drops out due to estimating the model in natural logarithms.

$$N_{i,t}\left[or\ GGY_{i,t}\right] = \alpha + \beta_1 MGD\ for\ non\ category\ D\ machines_{i,t} + \beta_2 MGD\ for\ category\ D\ machines_{i,t} + \gamma \boldsymbol{X}_t + \boldsymbol{\delta} \boldsymbol{Y}_{\boldsymbol{it}} + \varphi_i + u_{i,t} \quad (6)$$

In this specification, N is the number of machines in sector-category i and year t. GGY is an alternative dependent variable measuring machine revenue or gross gambling yield (GGY).[18] *MGD for non-category D machines* is equal to the proportion of months in that year in which MGD was in place for non-category D machines and equal to zero for category-D sectors.[19] *MGD for category D machines* is the proportion of months in which MGD was in place for category D machines and equal to zero for other non-D category-sectors. $\boldsymbol{X}_t$ and $\boldsymbol{Y}_{\boldsymbol{it}}$ are vectors of variables controlling for a variety of other factors which might affect machine numbers, and φ is a set of fixed effects for each sector-category. The fixed effects help to control for unobservable factors affecting both the different sectors and the different machine types.

The inclusion of two *MGD* terms is motivated by the fact that only non-Category D machines faced a switch from AMLD to MGD. Based on our theoretical model, we expect that the switch to MGD should increase the numbers of these machines. In contrast, Category D machines were not subject to AMLD and so faced a significant increase in the burden of taxation when MGD was introduced. As a result, we expect the introduction of MGD to result in a reduction in numbers of these machines. Note that both variables have time and cross-sectional variation and so can be estimated independently of the sector-category fixed effects.

The coefficients on *MGD for non-category D machines* and *MGD for category D machines* give the average change in machine numbers for each sector-category after the introduction of MGD for each category. We measure our dependent variables in natural logs which means that the coefficients on the MGD variables can be interpreted as the percentage change resulting from the introduction of MGD.

In the vector $\boldsymbol{X}_t$ we include the annual unemployment rate (*Unemployment*) to control for economic conditions, the annual number of tourism visits to the UK (*UK visitor numbers*) to control for variation in tourism-based demand, and gambling yield from National Lottery sales (*National Lottery*) to control for potential

[18] In some cases, part of GGY is reported in aggregate rather than allocated to individual machine types. For this reason, the results using GGY are probably less reliable than those using machine numbers.

[19] We use the proportion of months in preference to a straight 1-0 dummy variable to take account of the fact that the MGD change came in part-way through a year and, hence, we would expect a smaller effect in that year relative to when the change was in place for the full calendar year. Results are not sensitive to re-specifying these variables as 1-0 dummies.

effects from a key non-machine gambling sector. All three variables are measured in natural logs. In the vector $\boldsymbol{Y}_{it}$ we include three dummy variables to capture policy changes affecting particular machine types as follows:

- Increase in the MGD rate affecting Category B2 machines only from 2015 on (*MGD increase for B2 machines*).
- A relaxation of a cap on the permitted number of Category B3 and B4 machines from July 2011 on (*Cap on B3/B4 machines relaxed*).
- A relaxation of a cap in the permitted number of Category C and D machines in Bingo halls from July 2011 on. (*Cap on C/D bingo machines relaxed*).

We report specific variable descriptions and sources in Supplementary Appendix 3.

Although our main focus is on machine numbers, we also estimate a version of equation (6) using machine revenue as the dependent variable.

The economic significance of each category-sector combination varies considerably and in a few cases, they include only a small number of machines. As a result, regression estimates are weighted by the average number of machines or, for the revenue models, average gambling yield in each sector-category combination.

An important consideration is whether our models can successfully identify the effect of MGD. For example, a positive coefficient on *MGD for non-category D machines* may be spurious if there are unobserved factors affecting machine numbers (or revenue) but which change in line with the introduction of MGD. To the extent that any unobserved factors affect all machine categories, our estimation of separate effects for non-category D and category D machines will be helpful in establishing causality. However, we further explore this issue in several ways. First, given that non-stationarity is a common cause of spurious regression results, we run the Levin et al. (2002) test for panel stationarity on our dependent variables. For both machine numbers and revenue, the tests indicate stationarity.[20] Conscious that panel stationarity tests may be of low power when (as in our case) the panel has a relatively short time series element, we test whether our results are robust to the inclusion of sector-specific time trends. We also report panel corrected standard errors which allow for panel-specific first order autocorrelation as well as for heteroscedasticity and contemporaneous correlation across categories.

We do not include year fixed effects in our baseline model. Because the change from AMLD to MGD is time-specific and applied to all machine

[20] For machine numbers, the adjusted t-statistic is -4.797 (p-value = 0.00) and for machine revenue it is 3.079 (p-value = 0.00) meaning that in both cases we reject the null that panels contain unit roots in favour of the alternative that the panels are stationary.

categories except D, time effects might leave insufficient variation to identify any MGD effect. On the other hand, omitting year effects involves the risk that any estimated effect of MGD is due to unobservable factors which are also time specific. For this reason, we also report models including year fixed effects. With these models any MGD effect is identified by the fact that the introduction of MGD affected Category D machines in a different way to other categories. Due to multicollinearity, we can no longer include a separate dummy variable for the MGD effect on category D machines in these models. Similarly, the time-specific control variables in the vector $\boldsymbol{X}_t$ also drop out of the model in these specifications.

Our final approach to identifying a causal effect of MGD is to estimate 'difference-in-difference' (D-D) versions of our revenue model including a gambling sector in which machines are not relevant as a control. We have two such candidates, namely the UK National Lottery and on-course betting.[21] Any spurious association of the MGD change on revenue should be observed in the lottery or on-course betting sectors, whilst a true causal effect of MGD will not. Hence, in these specifications we estimate the effect of MGD on machine revenue *relative to* its effect on the relevant control sector.[22]

6. RESULTS

We report the estimates of our econometric model in Tables 2 to 4. In the first panel of Table 2, we report the estimates using machine numbers. In the second panel, we report estimates using machine revenue (gross gambling yield). In each case we report first a simple model including only the MGD variables and sector-category fixed effects. We then add the control variables and, in the final column of each panel, we add year fixed effects.

In all the models, the estimated effect of the change to MGD on non-Category D machines is positive (as expected) and strongly statistically significant. The estimated effect on Category D machines is consistently negative but only significantly so at the 5% level or better in the count model with covariates.

In the models including covariates but not year fixed effects (our preferred specification), the switch from a licence fee to MGD is associated with an average increase in non-Category D machines of just over 16% which is equivalent to

21 Much off-course betting takes place in licensed betting offices (LBOs) all of which also offer machine gambling.

22 This is implemented by running our revenue model on pooled data including all the machine category-sectors and National Lottery or on course betting as an additional sector. This increases our sample size to 185. We then include three MGD-related variables: one equalling the proportion of months in which MGD was in place in that year for all sector-categories, another for non-category D machines only and the third for category D machines only. The coefficients on the latter two variables give the estimated effects of MGD *relative to* any spurious effect on the National Lottery or off-course betting sectors.

Table 2

Impact of Machine Gambling Duty (MGD) on machine numbers and revenue 2008-9 to 2018-19

Dependent variable: natural log of the number of machines or machine revenue	(1)	(2)	(3)	(4)	(5)	(6)
	Number of machines			Machine revenue		
MGD for non-category D machines	0.180***(0.0391)	0.165***(0.0520)	0.377**(0.169)	0.153**(0.0604)	0.167***(0.0565)	0.273***(0.0847)
MGD for category D machines	-0.0624(0.157)	-0.226**(0.114)		-0.0398(0.0549)	-0.0725(0.0765)	
MGD increase for B2 machines		-0.162**(0.0661)	-0.165***(0.0595)		-0.0486(0.0688)	-0.198**(0.0785)
Cap on B3/B4 machines relaxed		-0.0887*(0.0497)	-0.0547(0.0396)		0.137*(0.0786)	0.0781(0.0504)
Cap on C/D Bingo machines relaxed		0.871***(0.146)	0.909***(0.156)		0.356**(0.158)	0.298*(0.175)
Unemployment		-0.259**(0.121)			0.266(0.254)	
UK visitor numbers		-0.429(0.364)			1.232(0.751)	
National Lottery		-0.0193(0.180)			0.861**(0.375)	
Sector-category effects@	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	No	No	Yes	No	No	Yes
Sector-specific trend	No	No	No	No	No	No
Observations	174	174	174	174	174	174
Number of sector-categories	16	16	16	16	16	16

Notes
(i) The dependent variable in (1)-(3) is the natural log of the number in each sector-category in that reporting year. In (3)-(6) it is the natural log of the gross gambling yield.
(ii) *** indicates significance at the 1% level; ** at the 5% and * at the 10%.
(iii) Figures in brackets are standard errors corrected for heteroscedasticity, panel-specific first order autocorrelation and cross-sectional contemporaneous correlation.
(iv) Regressions are weighted by the mean number of machines or revenue in each sector-category combination.
(v) The continuous independent variables are measured in natural logs.

Table 3

Impact of Machine Gambling Duty (MGD) on machine numbers 2008-9 to 2018-19: robustness checks

Dependent variable: natural log/level of the number of machines/machine revenue	(1)	(2)	(3)	(4)	(5)	(6)
		Number of machines			Machine revenue	
MGD for non-category D machines	0.148***(0.0512)	0.238***(0.0704)	3,880***(886.2)	0.0528(0.0491)	0.176***(0.0578)	182.0***(63.34)
MGD for category D machines	-0.119(0.144)	-0.236**(0.118)	-5,656***(1,913)	-0.0504(0.0743)	-0.00296(0.0864)	104.4(68.89)
MGD increase for B2 machines	-0.0407(0.0637)	-0.220***(0.0819)	-4,554***(1,440)	-0.00913(0.0889)	-0.0913(0.0730)	268.0***(96.95)
Cap on B3/B4 machines relaxed	0.0214(0.0541)	-0.0441(0.0740)	-1,278(1,175)	0.0703(0.0860)	0.0905(0.102)	-22.15(70.13)
Cap on C/D Bingo machines relaxed	0.336***(0.104)	0.722***(0.0969)	12,119***(4,508)	0.0930(0.193)	0.360**(0.179)	-32.17(74.12)
Unemployment	-0.209**(0.0923)	0.280(0.236)	-1,025***(335.8)	0.115(0.166)	0.411(0.284)	22.53(37.43)
UK visitor numbers	-0.440(0.310)	1.659**(0.715)	-0.158(0.192)	0.0517(0.560)	1.965**(0.876)	-0.0211(0.0209)
National Lottery	0.212(0.140)	0.379(0.238)	-0.592(1.208)	0.536**(0.260)	1.017***(0.385)	0.184(0.125)
Premises		0.794***(0.154)			0.322(0.197)	
Sector-category effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	No	No	No	No	No	No
Sector-specific trend	Yes	No	No	Yes	No	No
Observations	174	174	174	174	174	174
Number of sector-categories	16	16	16	16	16	16

Notes
(i) The dependent variable in (1)-(2) is the natural log of the number of machines in each sector-category in that reporting year. In (4)-(5) it is natural log of machine revenue. In (3) and (6) the dependent variables are measured in levels.
(ii) *** indicates significance at the 1% level; ** at the 5% and * at the 10%.
(iii) Figures in brackets are standard errors corrected for heteroscedasticity, panel-specific first order autocorrelation and cross-sectional contemporaneous correlation.
(iv) Regressions are weighted by the mean number of machines or revenue in each sector-category combination.
(v) The continuous independent variables are measured in natural logs except for (3) and (6) in which they are in levels.

Table 4

Impact of Machine Gambling Duty (MGD) on machine revenue 2008-9 to 2018-19: difference-in-difference estimates

Dependent variable: natural log of machine revenue	(1)	(2)	(3)	(4)	(5)	(6)
	Relative to the National Lottery			Relative to on-course betting		
MGD for non-category D machines	0.206***(0.0565)	0.125**(0.0529)	0.183***(0.0635)	0.311***(0.0842)	0.275***(0.0874)	0.321***(0.0858)
MGD for category D machines	0.0128(0.0716)	-0.0304(0.0629)		0.118(0.0731)	0.0965(0.0687)	
MGD increase for B2 machines		0.0265(0.0429)	-0.00376(0.0227)		-0.126*(0.0662)	
Cap on C/D Bingo machines relaxed		0.104(0.0827)	0.0355(0.0757)		0.136*(0.0807)	0.0838(0.0518)
Unemployment		0.430***(0.113)			0.422***(0.144)	
UK visitor numbers		0.194(0.216)			0.321(0.256)	
Sector-category effects	Yes	Yes	Yes	Yes	Yes	Yes
Year effects	No	No	Yes	No	No	Yes
Sector-specific trend	No	No	No	No	No	No
Observations	185	185	185	185	185	185
Number of sector-categories	17	17	17	17	17	17

Notes
(i) The dependent variable is the natural log of machine revenue in each sector-category in that reporting year.
(ii) *** indicates significance at the 1% level; ** at the 5% and * at the 10%.
(iii) Figures in brackets are standard errors corrected for heteroscedasticity, panel-specific first order autocorrelation and cross-sectional contemporaneous correlation.
(iv) Regressions are weighted by the mean revenue in each sector-category combination.
(v) The continuous independent variables are measured in natural logs.
(vi) Regression (1)-(3) include the National Lottery as the non-intervention category. Regressions (3)-(5) include on-course betting as the non-intervention category. The coefficients on *MGD for on-category D machines* and *MGD for Category D machines* are measured relative to the effect of MGD on the respective non-intervention category.

about 20,000 additional machines. Machine revenue is estimated to increase by 17%, implying about £380 m additional revenue per year. The decrease in Category D machines is even larger – about 23%, but this represents a smaller drop in absolute terms of about 11,000 machines. In practical terms, Category D machines tend to involve small stakes and have relatively low profitability per machine, meaning the decrease is of limited economic and political significance.

It is noteworthy that, even when year fixed effects are included, the switch to MGD is still estimated to have a positive and significant impact on non-category D machine numbers and revenue.

As expected, the unemployment rate is associated with a decrease in the number of machines, whilst the reduction in the cap on C- and D-category machines in Bingo halls is associated with a significant increase in machines. The signs and statistical significance of the other control variables vary with the specification.[23]

In Table 3, we present some robustness checks of our estimates. We report three experiments for both the machine numbers and revenue models. The first is to include sector-specific time trends. For machine numbers, the estimated impact of MGD on non-category D machines is slightly smaller than in our baseline models but it remains statistically significant. The estimated effect on revenue is still positive but is no longer statistically significant.

The second experiment is to include the number of premises in each sector as an additional independent variable (*Premises*). The motivation for this is the possibility that any increase in machines may be due not to the switch to MGD but to other changes in industry structure which made it worthwhile to open up new outlets. A counter-argument is that including this variable might hide some of the effect of MGD if the switch in taxation made it profitable for operators to open up more premises. In fact, the estimated effects of MGD are larger in this specification compared to our baseline. [24]

The final experiment reported in Table 3 is to estimate the model in levels rather than natural logarithms. We continue to find a positive and significant effect of MGD on machine numbers and revenue.

We report the estimates from our "difference-in-difference" (D-D) revenue models in Table 4. The first panel reports the estimates using the National Lottery as our 'control' sector, whilst the second panel reports estimates using off-course betting. The coefficients on our MGD variables now indicate the effect on machine revenue relative to the effect on revenue in the control sector. In each case,

[23] Our measures of unemployment, tourist visits and National Lottery are time-specific and do not vary between categories. This means that there is only limited variation with which to identify the effects. As a result, we are cautious about inferring too much from those estimates. It is reassuring, though, that the signs and significance estimates of our key policy variables are robust to the inclusion or exclusion of these variables.

[24] Due to some missing data, the sample size is reduced when including the number of premises.

we report the simple model, the model with control variables and, finally, the model including year fixed effects. The net effects of the switch to MGD on non-category D machines and revenue are estimated to be smaller (relative to the baseline models) when comparing to the National Lottery and bigger when comparing to off-course betting. Specifically, for our preferred models (reported in columns (2) and (4)), we estimate that the move to MGD is associated with a 13% increase in machine revenue (just under £300 m) relative to the National Lottery but 28% (over £600 m) when estimated relative to on-course betting. In every case, the estimated effect is statistically significant.

To summarise, both the simple trends and the more formal econometric estimates suggest that the switch from AMLD to MGD led to a significant increase in both the number of machines and in machine revenue in affected categories. These results hold up to nearly all the robustness and identification checks we have performed and are consistent with the theoretical analysis in which the change to MGD induced casinos to introduce more machines.

7. CONCLUSIONS

Electronic gambling (‘slot’) machines are a key component of the global gambling industry, yet the taxation of these machines is a highly controversial area of policy debate. The key policy debates have focused on the economic benefits and social costs of different types of gambling and the displacement effects between them, and also involve tensions between industry profitability, economic growth and government revenue. The issue of revenue generation through taxation and the protection and growth of revenue by gambling operators has also begun to gain increasing attention.

We introduced a theoretical framework employing a model for a representative profit-maximising casino having price-setting power due to operating in a differentiated market. The assumption of price-setting power captures the reality that, while offering similar gaming products, casinos differ in their portfolio of gaming machines, customer service, gaming environment, and complimentary items to encourage players to gamble. The profit maximisation model serves as the basis for a theoretical analysis of how a switch from a per-machine licence fee to a revenue-neutral ad valorem Gross Profits Tax (GPT) will increase allocative efficiency by increasing the number of gaming machines, suggesting that a move from a licence fee to a tax on machine profits can help to resolve the policy tensions.

We tested our model using data on recent changes to gambling taxation in the UK, in particular the move to a GPT which was implemented through the introduction in 2013 of a Machines Games Duty (MGD), based on the gross profits generated by such machines. This move brought the taxation of gambling machines in line with other gambling sectors, essentially unifying the structure of UK gambling taxation. Notably, we examined empirically whether, as predicted by the theory, the switch from a licence fee to a revenue-neutral MGD did in fact increase the number of machines, and we are able to confirm this. As such, allocative efficiency in the UK gaming market increased under the revenue-neutral MGD relative to the licence fee. Our results provide useful guidance for jurisdictions in which gambling taxes are a significant source of public revenue.

These findings have wider international implications, which can vary between jurisdictions. As noted above, some states such as Delaware and Pennsylvania implement a tax as a percentage of machine revenue ('gross profits') whilst others charge a licence fee (or excise tax) per machine or a mix of licences and a revenue tax. For example, Nevada levies an annual excise tax of $250 per machine whilst operators in 'restricted locations' such as casinos pay an additional revenue-based tax (AGA, 2018). Depending on the jurisdiction, the relative importance of the findings presented here to the policy debate will therefore vary.

Even so, as the number of states and other jurisdictions considering the liberalisation of gambling laws grows with the intention of capturing economic benefits from the industry along with public revenue from associated taxation, the importance of these findings for their respective policy debates has never been greater.

The theory, evidence and implications of the switch from a tax on turnover to a tax on gross profits is part of the more general debate on the relative merits of a commodity tax and an 'ad valorem' tax, and can be applied equally to other forms of gambling, such as sports betting. This has particularly topical relevance to the policy debate in the U.S. on the taxation of betting since the ruling of the U.S. Supreme Court in May, 2018 that federal prohibition on sports betting is unconstitutional.

In summary, we find that the switch from a licence fee system for gambling machines to one based on gross profits led to a significant increase both in the number of machines and in machine revenue in affected categories. These results are consistent with theoretical analysis in which the change to MGD induced companies to introduce more machines. Put another way, the simple theoretical model developed here suggests that taxing slot machines on the basis of gross profits or 'cash-in-box' is preferable from the point of view of consumer welfare and maximising government revenue to a taxation system based on licences payable for each machine, and which should generate additional tax revenue. Our empirical evidence suggests that the recent shift to a gross profits tax has indeed resulted in additional tax revenue without compromising industry viability. To the extent that this holds, it resolves one of the key policy tensions between industry and government over the sustainability and growth of tax revenues versus industry profitability. In particular, the results show that both public and private revenue can be enhanced by a straightforward change to the general system of taxation of gambling machines.

Based on the evidence presented here, other jurisdictions which continue to use a licence fee system for taxing slot machines should consider following this example by also switching from a system of taxation based on licence fees to a system of taxation based on gross profits. This can increase revenue and benefit all stakeholders. Future work might be similarly framed around the idea of formulating policy which enhances the interests of all stakeholders.

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Data S1 Supporting information

SUMMARY

Electronic gambling ('slot') machines are a key component of the global gambling industry. We introduce a theoretical framework which shows that under reasonable assumptions, shifting from a per-machine licence fee to a gross profits tax (GPT) on machine revenue can help to resolve policy tensions between industry profitability, economic growth and government revenue. We test the theory using data on recent changes to gambling taxation in the UK, in particular the move to a gross profits-based Machine Games Duty (MGD). Our results reveal that the shift from licence fees to a revenue-neutral MGD led to a significant increase in the number of machines, as predicted by the theory, and in machine revenue. These results provide useful guidance for all parties involved in the gambling taxation debate, especially those jurisdictions that are considering or are open to a change to their gambling tax system.

