How should gambling machines be taxed?

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Abstract

Gambling taxation is a highly controversial area of policy debate involving tensions between industry profitability, economic growth (especially tourism), and government revenue. Here we examine the taxation of electronic gambling ('slot') machines, one of the most popular forms of gambling around the globe. We introduce a simple theoretical framework which shows that under reasonable assumptions, shifting from a per-machine license fee to a gross profits tax (GPT) on machine revenue can help to resolve some of the policy tensions. We test our model using data on recent changes to gambling taxation in the UK. Our theoretical and empirical results reveal that a shift to a GPT led to an increase in industry capacity without compromising government tax 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.

Keywords: gambling; taxation; slot machines; gross profits tax

JEL codes: H21, H25

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1. Introduction

The gambling sector is of huge importance to the economies of many jurisdictions, both in its own terms as well as in its contribution to public revenues. In the USA, for example, the commercial casino gambling sector has annual revenues in excess of $40bn, supports (directly and indirectly) about 800,000 jobs and generates nearly $10bn per annum in direct gaming tax revenue (AGA, 2018).

Although there is a well-established literature on the economic approaches to 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 is much more limited. This is surprising for at least two reasons. First, this part of the gambling industry has been responsible for much of the growth in gambling revenues in recent years (AGA, 2018). Second, the choice regarding the optimal approach to taxing gambling machines has been the subject of intense lobbying and political debate. Although one important aspect of the debate relates to the use of taxation to control the extent and costs of problem gambling, much of the argument reflects the more general tension between governments' desire to maximize public revenue and industry concerns about the effect of high taxation rates on profits and growth.

In this paper, we demonstrate how a closer economic analysis of the choices over the type of taxation rather than its absolute level may be helpful in resolving some of this tension between government and industry. Specifically, we introduce a model which compares the two most commonly used options for taxing gambling machines: per-machine license fees and gross revenue taxation (sometimes termed a gross profits tax, or GPT). We then examine empirical evidence in support of our model based on the recent debates over gambling taxation in the United Kingdom that resulted in a switch from per-machine license fees to a GPT.

In the next section of the paper, we discuss in more detail the political and economic debates over the taxation of gambling machines along with providing institutional context. In section 3, we describe our theoretical model. In section 4 we introduce our data and empirical approach. Our empirical results are reported in section 5. In the final section we discuss these results and their relation to the theoretical predictions and draw some implications for policy.

2. Debates over the taxation of gambling machines

Machine taxation policy in the US

Gambling taxation policy has developed within a public choice context featuring high-profile conflicts of policy preferences by key stakeholders and the revenue-raising authorities. Debates have been especially controversial in the UK and US.

A major focus in the US has been an examination 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. Rose also highlights such social costs as increased gambling addiction and congestion. Eadington (1998) includes tourism development, economic revitalization, tax revenue, jobs, and new investment and employment opportunities for minorities as benefits from casinos, whilst Eadington (1999) argues that destination casinos play a strong role in job creation, capturing significant tax revenue for the local jurisdiction.

Additional research has found potentially significant economic costs of casino gambling.[1] Thompson et al (2000) assert that costs such as fraud, forgeries, bad debts, and treatment costs outweigh the benefits of casino gambling. Other authors (e.g. Grinols and Mustard, 2001, 2006; Simmons, 2000) also emphasize the social costs of gambling. Simmons (2000) finds that while casinos do create employment in related industries, they also tend to divert consumer expenditures from other businesses and casinos tend to create lower-paying jobs. More mixed evidence on the employment impacts of casino generation are found by Garrett (2003). Lastly, the displacement effects between casino revenue and state lottery revenue have been studied. Siegel and Anders (2001) report evidence of substitution between casinos and state lotteries, while Popp and Stehwien (2002) find evidence of a negative correlation between Indian casino gambling and state revenues.

A key public choice issue arising from these debates is the economic benefits and social costs of different types of gambling and the displacement effects between them, and the issue of revenue generation for state government through tax and the protection and growth of revenue by gambling operators (e.g. Walker and Jackson, 2011).

Garrett (2001) uses state lottery agencies as a unique object of study as they, unlike other governmental units, openly acknowledge that their primary objective is revenue maximization. In so doing, he is able to test whether the existing tax structure of lottery games was the revenue maximizing structure. He finds strong empirical evidence for the Leviathan model first proposed by Brennan and Buchanan (1977, 1980), in which only constitutional constraints on both the sources of revenue and levels of expenditure can curb government's desire for continued growth.

Martin and Yandle (1990) examine the determinants of decisions to operate state lotteries, providing an overview of the way that state sponsorship of gambling has been important historically. A public choice issue addressed specifically is that between the use of state lotteries and the taxation of private gambling as a means of revenue generation. Following

[1] A thorough review of the literature on the socioeconomic impacts of gambling is provided in Walker and Sobel (2016).

on from this, Calcagno (2010) examines the determinants of casino adoption decision by state governments. Their results suggest a public choice framework in which casino legalization is determined by state fiscal stress, in particular efforts to keep gambling revenues (and the concomitant gambling taxes) within the state, and to attract tourism or "export taxes."

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

Furthermore, the regulatory, economic, and legal environment surrounding gambling machines in the US is changing rapidly, as a number of states have liberalized or are considering liberalizing gambling laws with the intention of capturing economic benefits from the industry along with public revenue from associated taxation. For example, 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 recently ruled that Federal prohibition on sports betting is unconstitutional, so states are now free to pass statutes that would legalize sports gambling within their borders. Given that the bulk of states' tax revenue from gambling comes from gambling machines, it is unclear the degree to which sports betting may cannibalize gambling machine activity. Finally, the spread of casino 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]

Machine taxation policy in the UK

In contrast to the US, the UK gambling sector has historically been dominated by sports betting in shops known as bookmakers. In contrast, the casino sector has been relatively less important. There has long been a significant gambling-machine industry based not only in casinos but in bookmakers, in bingo halls, in pubs and specialized arcades often located in

[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/

seaside tourist centers. As of 2017, the UK Gambling Commission estimates that there were over 180,000 electronic gambling machines in the main sectors.[4]

Until recently, UK gambling taxation was sector-specific. Sports betting was taxed based on the gross stakes placed by punters, whilst machines were subject to an annual license fee (Amusement Machines License 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 (higher for higher prize machines, ranging in 2012-13 from £3,150 p.a. for B1 machines to £935 p.a. for C machines – D machines were charged no AMLD). Bingo halls were over this period permitted a maximum of eight B3/B4 machines (with a maximum stake of £2 and jackpot of £500), or 20% of the total number of gaming machines. Adult Gaming Centers (AGCs) were permitted a maximum of four such machines.

In July, 2011, the number of B3/B4 machines was increased to 20% of all machines. Licensed betting offices (LBOs) are allowed only four machines per betting shop (usually B2 machines – Fixed Odds Betting Terminals), with a current maximum stake of £100 and a maximum jackpot of £500. Machine numbers in casinos (almost universally B1 machines with a maximum stake of £2 and jackpot of £4,000 – increased in 2014 to £5 and £10,000) are capped at 20.

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 the HM Customs and Excise department 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 key 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, including Singapore (2005), Spain and Greece (2011), Denmark (2012), Italy (2013), Bulgaria (2014) and Kenya (2017). Gambling machines largely remained outside the remit of the GPT system until the introduction of the Machines Games Duty into the UK in 2013.

In 2013, the UK Government decided to bring the tax system for electronic gambling machines into line with these other sectors. From the 1 February of that year, the system of

[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.

license fees and sales tax for machine gambling was replaced with an exclusive gross profits tax known as Machine Games Duty (MGD).

This followed a consultation exercise on the introduction of a machine games duty, published by HM Treasury on 24 May, 2011. 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. Exempting the takings from machine games will also increase the stability of the tax regime as the playing of machine games will then receive the same VAT treatment as other gambling activities. 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. Under the current AMLD system, for machines of a given category, AMLD liability is the same regardless of profit. By improving fairness within the industry, this measure will particularly help support businesses with less profitable machines and low VAT recovery rates." (Justine Greening, Economic Secretary to the Treasury, Foreword to HM Treasury/HM Revenue & Customs, 2011).

There were 32 substantive written responses to the consultation exercise and the government responded in December, 2011 (HM Treasury/HM Revenue & 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 centers. Suggestions were also put forward for changes aimed at limiting the impact of the VAT exemption, notably by including a *de minimis* limit for MGD to mirror the VAT threshold and allowing input VAT to be offset against MGD payable. A few business and trade organizations also suggested that instead of introducing MGD, all gambling activities should be made subject to VAT. 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. During what is already a period of precarious economic trading, this could see further closures of businesses, a reduction in investment, loss of jobs and loss of tax revenue for the Treasury. In particular, the proposal … is likely to damage seaside towns and businesses." (BACTA, 2011).

In response, the Government agreed to limit the scope of MGD to machine games offering cash prizes greater than stakes. Machines such as crane grabs and redemption machines only offering non-cash prizes would remain subject to the VAT. This would, it was argued, help support many small family entertainment centers that are commonly found at British seaside resorts." The suggestions put forward aimed at limiting the impact of the VAT exemption were not adopted because they were either not permissible under EU law, would be highly complex to introduce, or would lead to significant avoidance risks.

The rates of MGD vary by type of machine, from 5% for low stakes (maximum of 20 pence), low jackpot (maximum of £10) machines, to 20% for other machines. A 25% duty was introduced on machines where the maximum stake can exceed £5, effective for accounting

periods starting on or after 1 April, 2014, which took effect on 1 March, 2015. In practice, this applied only to B2 machines. The introduction of MGD was intended to be revenue neutral, defined in terms of the overall impact on the Exchequer (HM Revenue & Customs, 2012, p.3).

There has been a parallel controversy over the problem gambling effects of B2 machines, and the maximum stake size on these machines, with the bookmakers in conflict with major lobbying and media pressure, as well as from the opposition parties in Parliament. However, it was the rate at which the tax was set that proved immediately controversial, as the gross profits tax to that date had been applied almost across the board to the rest of the gambling sector at 15 per cent (a notable exception was sports spread betting at 10 per cent and financial spread betting at 3 per cent). The machine duty rate was in fact at least partly based on price-elasticity estimates used by HM Revenue and Customs (formerly HM Customs and Excise) in assessing the effect of the tax change on gambling machine revenue (HM Revenue and Customs, 2012).

The shift in the approach to gambling machine taxation in the UK provides a natural experiment as to the effect of gross profits taxation. 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 licenses to gross profits. We anticipate that the results will be helpful in informing gambling policy in many different jurisdictions. First though, we provide a more formal framework for our analysis by way of a theoretical model of machine gambling taxation.

3. Theoretical Framework

This section presents the model for a representative profit-maximizing casino with price-setting power. The profit maximization model serves as the basis for the subsequent theoretical analysis of how a switch from a per-machine license fee (L) to a revenue-neutral ad valorem Gross-Profits Tax (GPT) will increase allocative efficiency by increasing the number of gaming machines.[5] The analysis is similar to the classic work of Suits and Musgrave (1953) that examines the effects of per-unit and ad valorem taxes on monopoly, but it differs in the sense that here we examine monopoly profit-maximization from the input side rather than the output side because the license fee is a per-unit tax on input (gaming machines) rather than a per-unit tax on gaming output.

To begin the analysis, it is first useful to consider profit for a representative monopoly casino absent any taxation. Assume the casino uses one input, gaming machines (M), to generate a profit-maximizing level of gaming output (Q). Gambling output is defined as the total

[5] The market structure for casino gaming may more closely resemble monopolistic competition rather than monopoly. However, the profit-maximizing model and profit-maximizing conditions are nearly identical for these two models of market structure; the only difference between the two is that monopolistic competition allows movement in the firm's demand curve due to competitor behaviour.

amount wagered in the casino, which is commonly referred to as 'handle' (see Anderson, 2005, 2013).[6] 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).[7] 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.[8] The firm's problem is to choose the M that maximizes profits. The profit-maximizing M also determines the optimal level of gaming output, Q, since $Q = Q(M)$.

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

$$max_M \pi = P(Q) \cdot Q - (c + L) \cdot M,$$

The first-order condition is

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

which simply says that the optimal (profit-maximizing) number of machines occurs when the marginal revenue product of an additional machine is equal to the marginal input cost of an additional machine. Because this is the profit-maximizing condition, equation (1) can be expressed as a function of output price under the license fee (P_L) and rearranged as

$$MRP_L(P_L) - L = c(P_L). \tag{2}$$

Assume now that the government decides to replace the license fee with a revenue-neutral GPT with rate t. The firm's problem is now

$$\max_M \pi = P(Q) \cdot Q \cdot (1 - t) - c \cdot M.$$

With a revenue-neutral GPT, the revenue-neutral GPT tax rate is $t = L \cdot M_L/(P_L \cdot Q_L)$, where $M_L, P_L,$ and Q_L are the profit-maximizing quantities under the license fee.[9] Note that under the GPT, the choices $M_L, P_L,$ and Q_L do not necessarily remain as the profit-maximizing quantities. This implies the following first-order condition under the GPT,

$$MRP_L(P_L) \cdot (1 - t) = c(P_L) + Z, \tag{3}$$

where Z is the differences between the net marginal revenue product and the marginal input cost under the GPT at the price level under the license fee.

The question is whether Z in equation (3) is positive or negative. If $Z > 0$, then net marginal revenue product is greater than marginal input costs, which implies that the casino

[6] 'Handle' includes both the out-of-pocket wagers by casino patrons and any winnings that are wagered again.
[7] The assumptions of zero fixed costs and constant variable costs are made for notational simplicity. Relaxing these two assumptions, i.e. allowing for positive fixed costs and non-constant costs, does not change our final result and conclusions.
[8] Gaming revenue to the casino after paying winnings is referred to gross gaming revenue in the United States and gross gaming profit in the UK.
[9] Tax revenue under the license fee is $L \cdot M_L$. Equal tax revenue under the GPT at P_L, and Q_L is $t \cdot P_L \cdot Q_L$.

will increase the number of machines until net marginal revenue product is equal to marginal input costs. On the other hand, $Z < 0$ implies that the casino will decrease the number of machines. Substituting the above expression for t into equation (3) and subtracting equation (2) from equation (3) yields

$$L \cdot [1 - MRP_L(P_L) \cdot M_L/(P_L \cdot Q_L)] = Z. \quad (4)$$

Recognizing that $M_L/(P_L \cdot Q_L)$ is simply the inverse of average revenue product (ARP) under the license fee, equation (4) can be written as

$$L \cdot [1 - MRP_L(P_L)/ARP_L(P_L)] = Z. \quad (5)$$

Since $ARP > MRP$ under monopoly, we have $Z > 0$.[10] This implies, from equation (3), that the net marginal revenue product at P_L under the GPT will exceed marginal input cost at P_L. Thus, under the GPT the casino will increase input (machine) usage. Furthermore, since $Q'(M) > 0$ and $P'(Q) < 0$, an increase in the number of machines should increase gaming output (wagers), decrease the price of casino gaming, and increase consumer surplus all relative to the license fee. Thus, the switch from the license fee to a revenue-neutral GPT is predicted to have increased allocative efficiency in the UK casino gaming market.

As shown 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 gambling sector, a license fee system corresponds to AMLD whilst GPT corresponds to MGD introduced in 2013. The next section of the paper empirically examines whether, as predicted by the above theory, the switch from licenses to a revenue-neutral GPT did indeed increase the number of machines. Confirmation of this finding will then provide empirical evidence that allocative efficiency in the UK gaming market has increased under the revenue-neutral GPT relative to the license fee.

4. Data and empirical approach

We explore our hypothesis using data on the UK experience since the introduction of MGD (equivalent to a GPT) for gambling machines in 2013. 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 revenue is available at an aggregate level, machine numbers data are broken down by five different gambling sectors: adult gaming centers (AGC), bingo venues, casinos, family entertainment center (FEC) and licensed betting offices (LBOs) and by the various machine categories. These data are available for 20 years, from 2008-9 until 2017-18. We provide a summary of the machine numbers in each sector-category combination in Table 1.

[10] Note that this result holds for any firm having some degree of price-setting power, not necessarily only a monopoly firm.

A casual inspection of data (Figure 1) on the number of machines before and after the switch to a GPT provides preliminary support for our hypothesis that the number of machines increased after the switch. Figure 1 presents the trend in machine numbers (excluding category D machines that were not subject to the license fee) and tax revenue before and after the introduction of MGD in early 2013. As seen in Figure 1, AMLD revenue was relatively stable prior to the taxation change in 2013.[11] 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 successful in their aim of broad revenue neutrality when switching to MGD.[12] In the subsequent three years, tax revenue increased steadily. Total 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, numbers increased significantly year-on-year up until 2017-18.

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 160 observations in total. The model can be summarized as:

$$N_{i,t} = \alpha + \beta_1 MGD_t * NonCatD_t + \beta_2 MGD_t * CatD_t + \boldsymbol{\gamma X}_{i,t} + \varphi_i + u_{i,t} \quad (6)$$

In this specification, N is the number of machines in sector-category i and year t, *MGD* is the proportion of months in that year in which MGD was in place, *NonCatD* and *CatD* are dummy variables indicating whether a machine is in category D or not, $\boldsymbol{X}$ is a vector of other variables 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 interaction terms between *MGD* and Category D dummies are motivated by the fact that 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 AMDL 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.

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

[12] 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.

In the vector ***X***, we include the annual unemployment rate (*UN*) to control for economic conditions and 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 (*D_MGD_B2*).
- A relaxation of a cap in the permitted number of Category B3 and B4 machines from July 2011 on (D_B3_B4).
- A relaxation of a cap in the permitted number of Category C and D machines in Bingo halls from July 2011 on. (D_C_D).

We expect unemployment and the increase in the MGD rate to be negatively associated with the number of machines whilst the relaxation of the cap should be associated with an increase in the number of machines in the affected categories.

Several technical points are worth noting. First, we are unable to include year fixed effects as our key intervention variable is time-specific. However, we do estimate models with sector-specific and also sector-category-specific time trends. Although including so many separate trends is demanding of the data, this approach should help to control for time-variant unobservable factors and which might otherwise confound our main effect. Second, some of the category-sector combinations have only a small number of machines and so we weight our results by the number of machines in each combination[13]. We report panel corrected standard errors which allow for heteroscedasticity, contemporaneous correlation across categories and first order autocorrelation. Finally, we consider some alternative specifications to explore the dynamics of any effect.

5. Results

We report the estimates of our econometric model in Tables 2 and 3. In the first column of Table 2, we report a simple model with the MGD variables and fixed effects but without the other covariates. In the second column, we add the control variables. The final two models reported in Table 2 include sector-specific and category-sector specific time trends respectively.

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 models without the time trends.

Using the specification with sector-category trends, the switch from licenses to MGD is associated with an average increase in non-Category D machines of around 4,000 in each sector-category combination per year, implying a percentage increase of over 40%. The absolute

[13] In fact our key results are robust to using unweighted regressions.

decrease in Category D machines is estimated to be about 3,600, implying a much lower percentage change of around 20%. In practical terms, Category D machines tend to be small stakes and with very low profitability per machine, meaning the decrease is of limited economic and political significance.

The signs of the coefficients on of the co-variates are generally consistent with expectations, though statistical significance varies depending on the specification. Most noteworthy is that a decrease in the unemployment rate is associated with a significant increase in the number of machines, even when allowing for sector-category specific trends.

In Table 3, we explore the dynamics of the MGD effect. We start by including a single period lag for both the MGD interaction terms (column 1). The coefficients on both lagged variables are significant suggesting evidence of a differential short and long run effect. This is confirmed by the results in column 2 in which both the MGD effects are estimated by means of an interaction with linear time trends. In the latter case, the significance of the effect on non-Category D machines is reduced but the direction of both effects is the same as in the previous models.

In the final two columns of Table 3, we report two further experiments.[14] The first is to specify the dependent variable in terms of natural logarithms instead of levels. In this case, the coefficients on the MGD effects can be interpreted directly as elasticities. The estimated impact of the switch from licenses to MGD on non-Category D machines remains positive and significant, but the implied percentage increase is reduced to 17%. The estimated effect of introducing MGD to Category D machines is negative but no longer statistically significant.

The second experiment (reported in column 4) is to include the number of premises in each sector as an additional co-variate (*PREMISES*). The motivation for this is the possibility that any increase in machines may be due not to the change 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 inclusion or omission of this variable has very little effect on the estimated MGD effects which is reassuring.[15]

To summarize, both the simple trends and the more formal econometric estimates suggest that the switch from AMLD to MGD led to a very significant increase in the number of machines in affected categories. These results are consistent with the theoretical analysis in which the change to MGD induced companies to introduce more machines.

[14] Our main results are robust to a number of further experiments which we conducted but do not report here for reasons of space. These include different combinations of co-variates and alternative ways of specifying the standard errors.

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

6. Conclusions

While there is a well-established literature on the economic impact of the growth of gambling facilities on local and regional economies, and on the taxation of gambling generally, there has to date been relatively little focus on the taxation of gambling machines. The key public choice debate in the context of gambling policy has turned around the economic benefits and social costs of different types of gambling and the displacement effects between them. The issue of revenue generation for state government through tax and the protection and growth of revenue by gambling operators has, however, gained increasing attention. A key change to the taxation of gambling in the UK since the introduction of betting taxation in 1966 was the switch in 2001 from a system of taxation based on the turnover of betting operators to a system based on their gross profits. The theoretical benefits of the GPT regime, notably in terms of allocative efficiency, were soon confirmed by the evidence of a massive expansion in gambling turnover and operator profits, as well as lower prices for consumers. This culminated in the introduction in 2013 of a Machines Games Duty, based on the gross profits generated by such machines. In so doing, this brought the taxation of gambling machines in line with other gambling sectors, essentially unifying the structure of UK gambling taxation.

The decision to introduce Machine Games Duty was not without its critics and opponents. While the Treasury argued that MGD would improve the predictability and sustainability of the tax regime by making it more resilient to technological progress and regulatory changes, as well as improving fairness within the industry, key lobbyists raised concerns about the impact of MGD on family entertainment venues. BACTA, which represents the British amusement and gaming machine industry in the UK, was particularly critical of MGD, arguing that it would introduce additional complexity, compliance burden and cost and would inevitably create some economic losers across and within sectors of the industry, predicting further closures of businesses, a reduction in investment, loss of jobs and loss of tax revenue for the Treasury. In response, the Government agreed to limit the scope of MGD to machine games offering cash prizes greater than stakes, but otherwise it proceeded with the introduction of the Machines Games Duty.

In summary, 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 maximizing government revenue to a taxation system based on licenses payable for each machine, and should generate additional tax revenue. Early empirical evidence suggests that the recent shift to a gross profits tax has indeed realized additional tax revenue without compromising industry viability. Based on the evidence here other jurisdictions, such as Nevada, which continue to use a licensing taxation system for slot machines should consider following this example by also switching to a gross profits tax.

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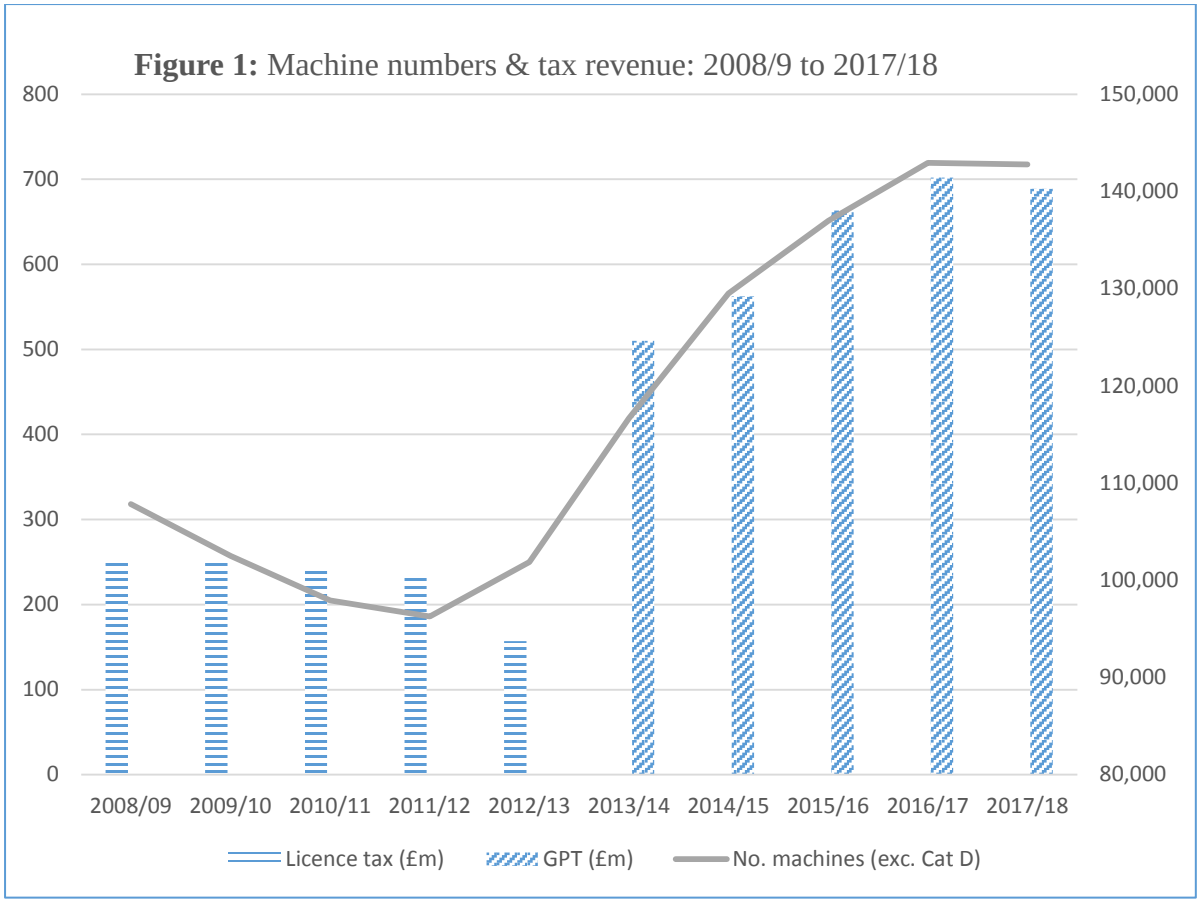

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Notes:
(i) Tax revenue figures are adjusted for inflation using the Consumer Price Index (2015 = 100)

Table 1: Descriptive summary of machine numbers by sector-category

Variable	Mean	Standard Deviation
All machines categories	167,808.3	13,655.8
All Non-Category D machines	117,534.0	18,878.5
All Category D machines	50285.3	8,845.6
AGC (Adult Gaming Centers), B3	9,885.3	1000.2
AGC (Adult Gaming Centers), B4	115.5	56.35
AGC (Adult Gaming Centers), C	31,191.2	4,873.4
AGC (Adult Gaming Centers), D	16,778.7	2,073.5
Bingo B3	7,389.7	3,950.2
Bingo B4	216.0	82.22
Bingo C	29,528.0	15,143.4
Bingo D	8,362.0	6,072.3
Casino B1	2714.4	185.6
Casino B2	118.5	68.33
Casino B3	5.45	4.73
FEC (Family Entertainment Centers), C	2,557.2	622.5
FEC (Family Entertainment Centers), D	25,144.6	3,369.3
LBO (Licensed Betting Office), B2	33,529.0	952.0
LBO (Licensed Betting Office), B3	147.5	143.1
LBO (Licensed Betting Office), C	125.3	127.1

Notes
(i) Means and standard deviation relate to the 10 years in the sample from 2008/9 to 2017/18

Table 2: Determinants of machine numbers 2008-9 to 2017-18

	(1)	(2)	(3)	(4)
*MGD*NonCatD*	5,392***	3,785***	3,960***	3,992***
	(1,358)	(1,193)	(1,020)	(1,335)
*MGD*CatD*	-3,642**	-5,139***	-3,472*	-3,547
	(1,566)	(1,900)	(1,923)	(2,847)
UN		-822.1***	-792.8***	-805.6***
		(196.6)	(114.9)	(117.3)
D_MGD_B2		-2,121	-1,421	-2,252
		(1,675)	(1,916)	(1,957)
D_B3_B4		-771.3	2,318*	644.0
		(1,111)	(1,390)	(1,083)
D_C_D		12,218***	5,160**	3,048
		(4,002)	(2,481)	(2,446)
Sector-category effects	Yes	Yes	Yes	Yes
Sector trends	No	No	Yes	No
Sector-category trends	No	No	No	yes
Observations	160	160	160	160
R-squared	0.885	0.916	0.952	0.977
Number of sector-categories	16	16	16	16

Notes

(i) In each case the dependent variable is the number of machines 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, first order autocorrelation and cross-sectional contemporaneous correlation.

(iv) Regressions are weighted by the number of machines in each sector-category combination.

Table 3: Determinants of machine numbers 2008-9 to 2017-18

	(1)	(2)	(3)	(4)
*MGD*NonCatD*	3,231***		0.169**	3,598***
	(918.6)		(0.0662)	(1,193)
*MGD*NonCatD* [t-1[	2,730***			
	(952.1)			
*MGD*CatD*	-1,316		-0.241	-2,418
	(2,129)		(0.173)	(2,648)
*MGD*CatD* [t-1]	-6,477***			
	(2,276)			
*MGD*NonCatD*trend*		1,499***		
		(387.9)		
*MGD*CatD*trend*		-900.3*		
		(535.2)		
UN	-960.8***	-477.6**	-0.0122*	-639.6**
	(325.1)	(213.4)	(0.00682)	(253.8)
D_MGD_B2	-1,373	-2,494	-0.0386	-1,209
	(1,511)	(1,982)	(0.0624)	(1,327)
D_B3_B4	1,352	2,165*	-0.0630	99.70
	(1,202)	(1,215)	(0.0559)	(1,026)
D_C_D	3,678	5,734**	0.506***	2,478
	(2,329)	(2,792)	(0.124)	(2,686)
PREMISES				3.504**
				(1.718)
Sector-category effects	Yes	Yes	Yes	Yes
Sector trends	No	No	No	No
Sector-category trends	No	No	No	No
Observations	144	160	160	148
R-squared	0.985	0.947	0.999	0.980
Number of sector-categories	16	16	16	16

Notes

(i) In (1), (2) and (4) the dependent variable is the number of machines in each sector-category in that reporting year. In (3) it is the natural log of the number of machines.

(ii) *** indicates significance at the 1% level; ** at the 5% and * at the 10%.

(iii) Figures in brackets are standard errors corrected for heteroscedasticity, first order autocorrelation and cross-sectional contemporaneous correlation.

(iv) Regressions are weighted by the number of machines in each sector-category combination.