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PRODUCTIVITY MEASUREMENT IN GAMBLING: PLANT-LEVEL EVIDENCE FROM THE UNITED KINGDOM

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Abstract

Although gambling is one of the fastest growing service industries, there have been no studies of total factor productivity (TFP) in this sector. We attempt to fill this gap using establishment-level data from the U.K. We also discuss key measurement issues in estimating gambling productivity. We also estimate labour and total factor productivity equations based on a stochastic frontier production function framework, focusing in particular on the impact of information technology on productivity. Our preliminary results suggest that the production function models fit well, generating plausible elasticity estimates. We find consistent evidence that productivity increased following major reforms to gambling taxation in 2001. Our findings yield limited evidence of regional variations in efficiency. Another key preliminary result is that Internet operations appear to be associated with higher relative efficiency.

Keywords: efficiency, productivity and measurement, information technology.

JEL Classifications: D24, L83, O33

1. Introduction

As predicted in a seminal paper by William Baumol (Baumol, 1967), the service sector has continued to grow at a more rapid pace than the goods sector in advanced industrial economies. Given that service industries now constitute a large proportion of economic activity, assessment of productivity in such sectors has become an even more important aspect of the public policy agenda. However, as noted in Griliches (1994) and Nordhaus (2002), it is notoriously difficult to measure productivity in service industries (mainly due to problems with output deflators) and in some cases, even in defining the relevant output.

Gambling is one of the fastest growing service industries. While there has been considerable attention paid to the rise in gambling *revenue*, there have been virtually no studies of *total factor productivity* (henceforth, TFP) in this sector. The purpose of this paper is to fill this gap, based on an analysis of U.K. establishment-level data. These data are derived from the Annual Respondents Database (ARD) file, constructed by the U.K. Office for National Statistics, consisting of individual establishment records from the Annual Census of Production. The ARD file contains detailed data on output, capital, materials, employment, and numerous plant and firm characteristics and is quite similar to the U.S.-based Longitudinal Research Database (LRD). This information can be used to construct measures of TFP.

The use of plant-level data offers two key advantages. One advantage is that deflation is not likely to be a serious a problem, since plants in the same industry are likely to face similar factor prices. The ARD also contains data on relatively homogeneous plants. Thus, measurement errors relating to difference in output mixes are not likely to be as severe. A second advantage is that the use of plant-level data allows us to assess and explain (with additional plant and firm characteristic) *relative* productivity. We are especially interested in assessing the relationship between proxies for investment in information technology and TFP. There is limited evidence on the impact of information technology on economic performance in services.

The remainder of the paper is organized as follows. In the next section, we discuss some general productivity measurement issues. Section III presents some background information on the U.K. gambling industry. Section IV describes the rich, longitudinal dataset of gambling establishments. Section V presents the econometric method used to assess and explain the relative productivity of these facilities. The following section contains our empirical results. Section VII presents caveats and preliminary conclusions.

2. Productivity Measurement in Services

2.1 General Issues

To compute real output, data are required on turnover or receipts, as well as a price index to deflate nominal output.[1] Unfortunately, producer or wholesale price indexes are not available for the outputs of many service industries, due to the great difficulty in defining measurable units of output and adjusting for quality changes. We consider the latter issue first. Changes in quality result from heterogeneous inputs and outputs and shifting weights in the use of such inputs and outputs. They also arise from the introduction of new products and services and the disappearance of old ones. An increase in the rate of technological change (e.g., the rise in the rate of investment of investment in computers) can potentially exacerbate difficulties in adjusting prices for changes in quality.

Although it is usually relatively easy to identify the resources used to produce services (i.e., capital, labor, and materials), there is still the problem of deflation of inputs. Academics have been especially frustrated at the difficulty in constructing accurate measures of capital input, which would be used in constructing estimates of capital productivity index as well as a total factor productivity index. Therefore, many researchers have resigned themselves to the analysis of labor productivity, typically measured as real output divided by the number of

[1] As we will discuss later in this report, deflation is not as serious a problem when researchers have access to establishment-level data.

employees or hours worked. The benefit of LP is that is likely to be measured with greater precision than TFP. However, LP measures do not take account of the possibility that companies may substitute capital for labor, as is likely in an industry experiencing rapid technological change. Still, McGuckin and Nguyen (1995), Foster, Haltiwanger, and Krizan (2001), and Disney, Haskel, and Heden (2000) have made inferences regarding overall economic efficiency based on labor productivity indices.

There is a disadvantage associated with using the simpler productivity measure. As noted by Perloff and Wachter (1980: 116), the use of Q/L, or the average product of labor, as a measure of productivity has "numerous serious, if not quite fatal conceptual flaws". Christiansen and Haveman (1980: 3) assert that "although [these] productivity measures … have serious weaknesses, the picture of productivity change which they yield is not greatly different from that of more complete measures."

Three flaws can be enumerated. First, to ensure reliability, output and input measures must be consistent, i.e., they must refer to the same production activity. Since there are many production activities implicitly underlying any aggregate measure of output, a meaningful composite measure must be formulated by denominating the value of each output measure by an appropriate price index. However, when labor is denominated in hours, conceptual problems arise because a labour hours measure corrects for only one of the many heterogeneous aspects of workers, namely and obviously the number of hours each works. Additional adjustments are needed. For example, the age/sex/skill composition of the labour force varies over time as well as from sector to sector. Since average labor productivity indices are primarily used for inter-temporal comparisons, changes in the composition of the work force will affect measured Q, but will not be reflected accurately in a Q/L index unless the changes are perfectly correlated with the way L is measured. This conceptual problem can be overcome by adjusting L for the heterogeneity of the labor force and thereby creating an index with efficiency labor units in the denominator.

Chinloy (1980) describes one method for constructing such an index based on methods used by the U.S. Bureau of Labor Statistics (BLS). This index is calculated on the basis of changes in both the number of hours worked and hourly wages earned by different types of workers, classified by age and education level. Similar indexes of labor productivity or quality have been used by Jorgenson, Gollop, and Fraumeni (1987) and Dean, Kunze, and Rosenblum (1988) in studies of aggregate economic growth. It is important to note that these indexes are also based on the assumption that labour markets are perfectly competitive, as noted in Chinloy (1980).

Chinloy (1980) defines labor quality, *LQ*, changes as:

$$(\partial \ell n\, LQ_t/\partial t) = \Sigma_i\, (v_{it} - b_{it})\, (\partial \ell n\, h_{it}/\partial t) \qquad (1)$$

where h_{it} is hours worked by the ith type of labor in year t, v_{it} is the share of total compensation paid to the ith type of labour, and $\{b_{it} = (h_{it} / m_t)\}$, the share of total hours worked devoted to the ith labour type. The discrete approximation for equation (1) is:

$$QUALIND_t = \Sigma_i\, ½\, (v_{it} + v_{i,t\text{-}1})\, (\ell n\, h_{it} + \ell n\, h_{i,t\text{-}1}) - (\ell n\, m_t - \ell n\, m_{t\text{-}1}) \qquad (2)$$

where $QUALIND_t$ is a quality index that approximates the left-hand-side of equation (1). In constructing these indexes, the key data requirements are a set of employment attributes to identify each of the i different types of labor.

Several ways are used to aggregate over heterogeneous outputs in either partial factor productivity or total factor productivity indices. The base year approach adjusts output values by the price of each product in the base year. The deflated price approach adjusts the value of each product by a current average price index. The choice between the two approaches is important. According to Baumol and Wolff (1984), the base year measure is a defensible index for productivity growth comparisons. However, the authors point out that it is not a useful indicator of inter-industry or inter-sectoral differences in absolute levels of productivity. Similarly, the deflated price index is meaningful for intra-industry comparisons of absolute levels of productivity over time, but it too fails to provide meaningful cross-sectional comparisons. The search for a valid cross-sectional index of absolute production still continues.

A second problem with labor productivity measures is that the average product of labour could be related to the business cycle. Thus, such measures may be capturing effects that are unrelated to technical progress. In this regard, Gordon (1979) contends that firms retain more workers in the last stage of a business cycle than is justified *ex post* by the future level of output. As a result of such biased *ex ante* expectations, Q/L will decline absolutely until firms adjust their hiring patterns to their corrected expectations about future demand.

A third and perhaps the most serious concern regarding labor productivity measures is that neither labor nor capital is the sole source of productivity improvements. Labor-saving improvements resulting from other factors of production are improperly attributed as an improvement in labor productivity when these other factors are not held constant. That is, a major problem with the use of labor productivity as a metric for economic performance is that it measures the efficiency of only one input and does not control for the possibility that the plant, firm, or industry, can substitute capital, materials, or services for labor. Many shun partial factor productivity indices precisely for this reason. A useful and meaningful productivity framework must therefore identity the source of the productivity improvement and their interaction with other factors of production, such as capital, materials, and services in the overall production process. Along similar lines, Craig and Harris (1973) showed that partial factor productivity measures do not quantify the impact of technical substitution. If, for example, a new technology is embodied in capital, Q/L could rise as a result of capital for labor substitution, *ceteris paribus.* But if the cost of the new capital-embodied technology equals the cost savings from fewer workers, then total production costs are unchanged and the initial movement in Q/L is misleading with regard to actual productivity gains. In light of these concerns, we deemed it prudent to present econometric findings based on TFP and LP measures.

The consideration of measurement errors in the service sector is not new. In many service industries, the output price index is a Tornqvist average of input price changes, based on input-output tables.[2] The use of input-based indexes, however, does not take into account changes in the production process. Therefore, the use of the input-output tables may be a source of measurement error. In addition, as noted in previous sections of this report, input indexes are not immune from the problem of properly accounting for the effects of changes in quality.

As a result, it is perhaps not surprising that Baily and Gordon (1988), in their seminal study of productivity in services, identified severe errors of measurement in service sector prices. However, they also concluded that there is no evidence to suggest that such measurement errors are getting worse over time. Siegel (1994, 1995, and 1997) presents similar findings, using multiple indicators of price changes. More specifically, he examined the incidence of measurement errors in output prices caused by incomplete adjustments for quality change. Estimating several variants of a latent variables model, he found that these errors appear to be constant over time. These findings are highly relevant to our work because we will estimate service sector productivity growth using panel data.

In addition to concerns regarding the accuracy of input and output prices, domestic and foreign outsourcing is also a potential source of measurement error (see Siegel-Griliches (1992)). That is, levels and changes in productivity could be driven by systematic underestimation of input growth caused by increases in foreign and domestic outsourcing. Thankfully there does not appear to be a compelling reason to believe that outsourcing exacerbates errors of measurement of service sector productivity. The provision of services (e.g., health care) is mainly a local phenomenon and there does not appear to be substantial outsourcing across industries, as there is in manufacturing.

[2] Gullickson and Harper (1987) report that producer prices are available only for some selected services, such as repair services and real estate and rental.

Indeed, some authors have asserted that outsourcing leads to systematic understatement of input growth, and thus, overstatement of productivity growth. But even in manufacturing, there is considerable evidence (see Siegel-Griliches (1992), Siegel (1995), and ten Raa and Wolff (2001)) suggesting that outsourcing cannot 'explain' the recent acceleration in manufacturing productivity growth. Still, we must be mindful about the potential effects of measurement error on our empirical results.

We have reason to believe that the measurement difficulties cited in this section can be overcome, given the availability of establishment-level data. The primary focus of our analysis will be on assessing levels of relative productivity. The quality change problem is more severe in computing absolute or relative productivity growth. We propose to undertake an analysis of productivity in gambling at two levels of aggregation. The first unit of analysis will be the industry, in which case we will examine changes in productivity over time. The apparent constancy of measurement errors bodes well for the accuracy of such productivity growth measures.

Most importantly, however, the primary unit of observation will be the establishment or plant. The use of establishment level data allows us to measure and 'explain' relative productivity, and thus, conduct analysis of 'best practices'. This is a critical feature of our empirical analysis and one that allows for a much richer and much more accurate assessment and explanation of productivity. For example, it seems highly reasonable to assume that plants in the same industry face the same factor prices and generate similar output mixes. While there may be regional differences in wages, our use of regional dummy variables in the econometric specification controls for such variation.

2.2 Measurement Issues in Gambling

In common with many service industries, gambling presents considerable difficulties in defining and measuring real output (see Griliches (1987) and Siegel and Griliches (1992)). That is, it is not precisely clear what is being sold or the nature of the output.

In the context of banking, Fixler and Zieschang (1992) argue that there are three alternative methods for measuring output: the asset, user cost, and value-added approaches. Under the asset approach, banks are only considered as financial intermediaries between liability holders and those who receive bank funds. In this framework, the outputs of a bank are its loans and other assets. In contrast, the user cost approach assesses whether a financial product is an output or input on the basis of its net contribution to bank revenue. When the financial return on an assert is greater than the opportunity cost of funds, or if the financial costs of a liability are less than the opportunity costs, then the instrument is a financial output. Otherwise, it is an input. The third method is the value-added approach, which allows each asset and liability category to potentially have some output characteristics, rather than distinguishing inputs from outputs in a mutually exclusive way. The researcher uses operating cost allocations (e.g., expenses) to determine which categories have substantial value-added. These are then identified as the key outputs.

Triplett and Bosworth (2004) provide a review of the long-standing debate between proponents of the "gross premium" and "net premium" approaches in the insurance industry. In the gross premium method, insurance claims are treated as business costs. Gross output would therefore equal the total value of premiums. Under the net premium approach, gross output is defined as premiums less the value of claims. This distinction can easily be applied to the gambling industry. The equivalent of the gross premium method is to define gross output as total gambling stakes or turnover. The equivalent of the net premium approach would be to define gross output as total stakes less returns to winning customers (net turnover or gross profits).

The relationship between these two concepts can be formally shown as follows. Firstly we define total stakes as Q, gross profits at GP. Further, we follow the convention and define the amount of a £1 stake that a bettor would expect to lose to the bookmaker as P, the price of gambling. We then have

$$P \cdot Q = GP$$

where Q is the total number of unit stakes placed by gamblers, which can be viewed as the total quantity of bets. Based on this formulation, it seems clear that the counterpart to output in manufacturing is Q – total stakes, suggesting that the gross premium approach is the right one for gambling. On the other hand, Akerlof (cited in Triplett and Bosworth, 2004, p. 14) has argued that margins are a more appropriate measure of output in gambling on the grounds that this measures the entertainment value of the good to the consumer.

There are also practical issues of relevance here, particularly given the shift from the tax on gambling turnover to the tax on gross profits that occurred in the middle of the sample period. For example, consider the case of an operator who pays out the same revenue as he receives. The value of gross profit is zero and, under the net premium approach, this would imply a turnover of zero, despite the fact that gambling activity has taken place. Indeed, if the operator pays out more than he receives, this implies a negative turnover!

The same logic applies to the sector as a whole. Similarly, if margins fall due to increased competition, and more is bet in absolute stakes, employment may rise. However, turnover under this definition has fallen. Therefore, if we use gross profits to measure output, we would conclude that output per unit employment has fallen, i.e. labor productivity has fallen, and this result would still obtain (though to a lesser extent) even if employment was unchanged. At the same time as labor productivity has apparently fallen, bettors have lost a lower proportion of the money they staked, and more money has been gambled. The only way in which productivity has fallen is that output, as measured by turnover, has fallen. If margins remain constant, output is unchanged, and this measure is fine as a measure of productivity. If margins rise, output as measured rises, and productivity appears to rise. This is also unsatisfactory. In conclusion, this measure is potentially flawed at least insofar as there are significant changes in margins over the period of measurement.

On the other hand, if stakes are used to measure output, then a reduction in margins means an increase in stakes, and with a given level of employment, this means more output for the same employment, or higher labor productivity. This is intuitively correct. If margins remain constant, then stakes will not vary substantially, and it is likely that employment will not change much either. Note that this is equivalent to constant productivity. However, there is also a practical problem with using stakes to measure output. In recent years, betting shops have increasingly promoted betting on Fixed- Odds Betting Terminals (FOBTs) over traditional wagering on events such as horse racing. In contrast to horserace betting, FOBT betting tends to be characterised by high volume and low margins. Bettors may spend the same amount of money over the same period of time, but they do so by "repeat" betting. Using the gross premium approach would lead to us observing a large increase in gambling output, whereas it is, in fact, debatable that output has really increased.

In the light of this discussion, we report estimates using both approaches to measure gross output. Note that, as Triplett and Bosworth (2004) demonstrate, this debate is not relevant for the measurement of gross value added which is the same in both cases.

3. Background Information on the U.K. Gambling Industry

We now provide some background information on the salient characteristics of gambling markets and recent industry trends. A fundamental trend in the U.K. has been the rise in gambling activity outside the traditional betting parlour, via telephone or Internet access, including betting exchanges and Interactive TV betting. The remarkable growth in the incidence of virtual gaming machines (Fixed-Odds Betting Terminals, or FOBTs) in betting shops, has served to reinforce this trend.

On the financial side, there was a radical change in tax rates and structure of taxation in October 2001 (see Paton, Siegel, and Vaughan Williams (2002)), moving away from a tax on gross revenue to a tax on gross profits, and effectively halving the incidence of taxation on bookmakers. This has enhanced the competitiveness of U.K. firms and also caused a shift towards low-margin, high-turnover, capital-intensive products, such as FOBTs, which offer 'virtual' betting products, ranging from roulette to horse racing.

A notable shift in the structure of gaming towards video-based technology and machines-based gaming has occurred in the casino industry. The impact of new technology on the gaming machine market has been limited by consumer resistance to video-based reels in the core AWP market and the club/jackpot sector, but it has had a significant impact on the SWP sector. A key growth area for bingo operators in recent years has also been in machine income and high-margin mechanised cash bingo (MCB) income. There has also been rapid growth in off-shore Internet gaming sites, especially Internet casinos, which are reliant on capital-intensive technology.

The U.K. betting market (as distinct from the gaming market) can be divided into five sectors: off-course betting at licensed outlets (the dominant venue for betting), on-course betting, and betting by telephone (through deposit or credit accounts, or via debit cards), Internet betting and Interactive (via TV) betting. Betting can be further sub-divided into fixed-odds betting with bookmakers, pool (parimutuel) betting with the Horserace Totalisator Board (the Tote), 'spread betting' and bet brokerage ('exchange' betting). In Table 1, we provide a breakdown of gambling turnover in the U.K. by betting medium.

The remote betting sector has grown rapidly, particularly since 2000, as the technology for placing bets has become increasingly integral to consumers' everyday lives - notably the Internet, interactive TV (as the digital sector has grown) and then latest developments in hand-held mobile access technology. There has also been a steady growth in the number of multi-telephone line households and broad band connections, enabling easy access to Internet betting opportunities. A significant growth in offshore betting turnover placed by U.K. citizens can also be traced to the independent bookmaker, Victor Chandler, who set up in the late 1990s a tax-free (though not commission-free) operation in Gibraltar.

Another change has been the growth in the number and variety of betting operators who establish operations with no shops, but simply as a remote betting entity (e.g. Betfair, Betdaq, and Sportingbet). Driven by the likely consequences for the competitive base of U.K.-based bookmaking, and associated tax revenue implications, a tax based on the turnover (revenue) of betting operators was replaced in October 2001 by a tax based on their "gross profits" (i.e. the difference between what they receive from bettors and what they return to bettors). The gross profits tax essentially replaced a tax on quantity with a more allocatively efficient tax on price. This was accompanied by the larger U.K. bookmakers repatriating offshore operations and the abolition of deductions levied on bettors' stakes or winnings. Since 2001, betting turnover has grown substantially, although margins have fallen. Betting turnover placed with offshore bookmakers has in significant part been repatriated on-shore.

Internet access has also grown rapidly during the past seven years. Research published by Mintel (2005) found that Internet betting is the most popular method of remote betting with some 9% of bettors having placed a bet with an online bookmaker, while just 5% used a telephone service. 60% of adults are now online, almost double the number in 2001, and further growth can be expected in other methods of remote betting as other digital media platforms become established.

In terms of the off-course market, an attempt by Ladbrokes to take over the betting shops of Coral Racing was blocked by the then Monopolies and Mergers Commission, although the dominating control by the big bookmakers (Ladbrokes, William Hill, Coral and Tote) has essentially continued. The monopoly pricing of the Computerized Straight Forecast offers an important perspective on this structural framework (see Paton and Vaughan Williams, 2001).

In the following section, we describe the rich, longitudinal dataset used to assess and explain the relative productivity of gambling establishments.

4. Assessing Gambling Productivity Using the Annual Respondents Database (ARD)

The Annual Respondents Database (henceforth, ARD) is a plant-level file based on the Annual Business Inquiry, a survey conducted by the Office for National Statistics. Information is collected on a range of variables covering output, employment, investment and expenditure for samples of businesses across the range of industrial sectors. Some variables, such as those relating to the firm's Internet presence, are not collected on an annual basis.

Firms are selected for inclusion in the ABI from the Inter-Departmental Business Register (IDBR) at the ONS. Sampling is based on size by employment on the Register. The probability of being selected for the ABI increases with employment size and the largest firms (currently over 250 employees) are surveyed every year. The ABI is carried out at the level of reporting unit, which is typically at the enterprise level. However, a significant number of enterprises have more than one reporting unit. Selected firms have a statutory duty to provide data to the ABI. In Tables 3a and 3b we report the numbers of selected and non-selected gambling firms included in the ABI for each year from 1997 to 2003 and also a breakdown by number of employees.

A limited amount of data (on employment and turnover) is held for all reported units on the IDBR. There is some evidence (Haskel and Khawaja, 2003) that the employment data in the IDBR are more reliable that the turnover data. For this reason, our productivity analysis is based on the ABI data alone, with the exception that IDBR employment data are used to derive appropriate weights. Data on the service sector (with Standard Industrial Classifications within sections G-P) are available from 1997 through to 2002, albeit with a somewhat more limited set of variables than for the production sector.

Our empirical approach consists of two stages. In the first stage, we calculate a series of labor productivity measures for the gambling sector. These are broadly comparable with the Experimental Productivity Measures currently published for some service industries (but not gambling) by the ONS and reported in Daffid, Reed and Vaze (2002). In the second stage, we estimate stochastic frontier models. These exploratory models allow us to test hypotheses relating to the determinants of levels and changes in productivity.

We report labor productivity estimates for gambling using two measures of production: gross output and value added and two measures of labour. We consider these in turn.

Gross Output (GO)

Direct measures of gross output are not available in the gambling sector, as they would be in a conventional manufacturing industry. Reflecting the discussion above on whether output in gambling should be defined as total stakes or as total stakes less payouts to winning customers, we construct two measures of gross output, GO1 and GO2.[3]

GO1 = turnover + change in work in progress + change in stocks brought for resale + work of a capital nature by own staff.

GO2 = turnover – payouts to winning customers + change in work in progress + change in stocks brought for resale + work of a capital nature by own staff.

Gross Value Added (GVA)

Similarly, direct measures of Gross Value Added (GVA) are not presented in the ARD file for services. We compute it as follows:

GVA = Turnover + Change in Work in Progress at Start and End of Year - Total Purchases.

[3] Further to our discussion above regarding the treatment of payouts to winning customers, a further ground for caution arises from the fact that for some companies, Box 424 (Amounts Paid to Winning Customers) is left blank. We speculate that this is at least partly due to betting exchanges that do not formally pay out winnings to customers. However, there may also be some a small number of firms who (incorrectly) report net stakes (gross profits) as turnover.

Labor Input Measures

We measure labor input using the employment measures reported in the ARD. The first measure is total employment (question q50). This includes part-time work. With the second measure, we adjust for part-time employment, assuming that one part-time employee is equivalent to 0.5 full-time employees. Part-time employment is given in questions q52 and q54, so the second measure is calculated as q50 - 0.5 q52 - 0.5 q54).

In calculating these measures, we deal with three methodological measures to consider: deflation, reporting period and weighting for non-selected firms.

There are several possible deflators, including the GDP deflator, Producer Price Index (PPI), and the Retail Price Index (RPI), and others. Here we choose to deflate all variables by the Consumer Price Index for Recreation & Culture published by the ONS (series CHVS) with the base year of 1996. Given that we are focusing on a single industry, the choice of deflation measure is less important than with cross-industry studies. Reassuringly, however, our gambling results are relatively robust to different inflation indicators.

For some firms, the reporting period for the data does not cover the standard annual month period. To control for this, we multiply each variable by the number of days in the reporting period divided by 365. We base our productivity estimates on data from the firms selected for the ABI. It is important to control for the fact that larger firms have a greater chance of being selected. We control for this by weighting the observations, using as a basis, the employment data from the IDBR following the methodology of Haskel and Khawaja (2003).

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5. Econometric Model

To assess relative productivity, we use stochastic frontier analysis (henceforth, SFA) method developed independently by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977). SFA generates a production (or cost) frontier with a stochastic error term that consists of two components: a conventional random error ("white noise") and a term that represents deviations from the frontier, or relative inefficiency.

SFA can be contrasted with data envelopment analysis (DEA), a non-parametric estimation technique that has been used extensively to compute relative productivity in service industries.[4] DEA and SFA each have key strengths and weaknesses. DEA is a mathematical programming approach that does not require the specification of a functional form for the production function. It can also cope more readily with multiple inputs and outputs than parametric methods. However, DEA models are deterministic and highly sensitive to outliers. SFA allows for statistical inference, but requires somewhat restrictive functional form and distributional assumptions.

In SFA, a production function of the following form is estimated:

$$y_i = \mathbf{X}_i \beta + \epsilon_i \qquad (3)$$

where the subscript i denotes the i^th^ university, y represents output, $\mathbf{X}$ is a vector of inputs, β is the unknown parameter vector, and ϵ is an error term with two components, $\epsilon_i = V_i - U_i$, where U_i represents a non-negative error term to account for technical inefficiency, or failure to produce maximal output, given the set of inputs used. V_i is a symmetric error term that accounts for random effects. The standard assumption (see Aigner, Lovell, and Schmidt (1977)) is that the U_i and V_i have the following distributions:

$$U_i \sim \text{ i.i.d. } N^+(0, \sigma^2_u), U_i \geq 0$$

$$V_i \sim \text{ i.i.d. } N(0, \sigma^2_v)$$

That is, the inefficiency term (U_i) is assumed to have a half-normal distribution; i.e., establishments are either "on the frontier" or below it. An important parameter in this model is $\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$, the ratio of the standard error of technical inefficiency to the standard error of statistical noise, which is bounded between 0 and 1. Note that $\gamma = 0$ under the null hypothesis of an absence of inefficiency, signifying that all of the variance can be attributed to statistical noise.

In recent years, SFA models have been developed that allow the technical inefficiency term to be expressed as a function of a vector of environmental or organizational variables. This is consistent with our argument in the previous that deviations from the frontier (which measure relative inefficiency) are related to environmental and organizational factors. Following Reifschneider and Stevenson (1991), we assume that the U_i are independently distributed as truncations at zero of the $N(m_i, \sigma^2_u)$ distribution with

$$m_i = \mathbf{Z}_i \delta \qquad (4)$$

where **Z** is a vector of environmental, institutional, and organizational variables that are hypothesized to influence efficiency and δ is a parameter vector.[5]

To implement this model, we estimate the following Cobb-Douglas production function:

$$\log(Q_{it}) = \beta_0 + \beta_1 \log(K_{it}) + \beta_2 \log(L_{it}) + \beta_3 \log(M_{it}) + \upsilon_{it} - \mathbf{U}_{it} \qquad (5)$$

where

Q = output of firm i in year t.
K = capital stock
L = labour
M = materials
υ_{it} = a standard, "white-noise" error term
$\mathbf{U}_{it}$ = inefficiency of firm i at time t, assumed to follow the truncated normal distribution.

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[4] See Charnes et al. (1994).
[5] Battese and Coelli (1995) have recently extended this model to incorporate panel data.

As explained above, the SFA technique allows us to simultaneously estimate the production frontier and the determinants of relative efficiency of establishment. We conjecture that the technical inefficiency ($\mathbf{U}_{it}$) term in equation (13) can be expressed as:

$$\mathbf{U}_{it} = \delta_0 + \Sigma_k \delta_k \mathbf{TECH_i} + \delta_S \log(S_{it}) + \mu_i \qquad (6)$$

where **TECH** refers to a vector of technology indicators and S is market share.

There is a long-standing theoretical and empirical literature (see Griliches (1979, 1994) and Lichtenberg and Siegel (1991)) linking proxies for investment in technology (TECH) and productivity. Market share (S) is included in the regression to avoid bias in factor estimates from heterogeneous pricing across firms, due, for example to market power (see Carstensen, 2004). The relative efficiency equation we actually estimate is:

$$\mathbf{U}_i = \delta_0 + \delta_1 \text{COMP}_i + \delta_2 \text{TELEPHONE}_i + \delta_3 \text{INTERNET}_i + \delta_S \log(S_{it}) + \mu_i \qquad (7)$$

where COMP and TELEPHONE are the ratios of expenditures on computers and telephony, respectively, as a proportion of total turnover, INTERNET is a dummy variable that is equal to 1 if the firm operates via the Internet; 0 otherwise, and time subscripts have been suppressed for simplicity. Note that information on Internet operations is only available since 2000. Thus, we estimate the model separately with and without that variable. Regional and year dummies are also included as potential determinants of inefficiency.

We estimate two panel-data based variants of the production function model. The first variant is a time-varying decay production function, which allows us to formally test whether there are efficiency changes over time. The second variant involves simultaneous estimation of the production function and the determinants of relative efficiency, using a one-stage maximum likelihood procedure.

6. Empirical Results

6.1 Descriptive data and trends from the ABI

In Table 4, we present data on the number of enterprises, turnover, employment, gross value added and net capital expenditure from the Annual Business Inquiry, as published by the ONS, for the years 1996 to 2003. For comparative purposes, we also report data for all firms in Section O ("Other community, social and personal service activities") of the Standard Industrial Classification, for all firms in Division 92 (Recreational Cultural and Sporting Activities) and for firms within class 92.71 ("Gambling and betting activities"). Several stylized facts emerge from this table. Firstly, the number of gambling enterprises has decreased by 21% since 1996, whilst employment (from 1998), turnover and value added have all increased significantly.

The pattern of data before and after the change to betting taxation in 2001 is also of interest. Comparing the years immediately before and after the change (2000 and 2002), turnover increased by 38.3% and GVA by 74.8%. In the following year, turnover increased even more, whilst GVA reduced slightly.[6] There are two reasons why turnover responded to the betting tax change. Firstly, the effective tax rate was lowered significantly and this might be expected to lead to an increase in the demand for betting. Although some of the demand may have come from other gambling sectors, there is clear evidence (Paton, Siegel and Vaughan Williams, 2002) that the tax decrease led to an expansion in total gambling. Secondly, many businesses decided to repatriate phone and Internet business to the UK from off-shore locations in response to the tax decrease. There are, however, two particularly striking features of the increase in gambling activity.

The first is that between 2000 and 2003, GVA increased less than turnover. This is consistent with a view that the shift to GPT enhanced competition in betting and reduced margins (Paton, Siegel and Vaughan Williams, 2002).[7]

[6] The reason for focussing on these two years is the tax changes took place during the course of 2001. Specifically, the changes were announced in the April 2001 and were introduced in October of that year.
[7] A complicating factor in understanding this trend is the growing impact of two segments of the market: betting exchanges and fixed-odds betting terminals (FOBTs). It is very difficult to draw meaningful comparisons between betting exchanges or FOBTs and conventional betting using turnover measures. Indeed, even across different

The second striking feature of the increase in turnover and GVA is that employment increased by just 2.3% between 2000 and 2002. Thus, the substantial expansion of gambling investment and activity appears to have been undertaken without any increase in employment. Obviously there are employment considerations that may of interest, but, for the purposes of this report, this is *prima facie* evidence of a large increase in gambling productivity between 2000 and 2003.

Note also that capital expenditure declined from 236 mil £ to 185 mil £ between 1999 and 2000, before rising to 383 mil £ in 2002 (an increase of 84% on the 1996 figure) and 315 mil £ in 2003. Thus, there is some evidence that uncertainty regarding the regulatory and tax environment prior to 2001 severely limited investment in the gambling sector. However, after the more-favourable tax regime was announced in early 2001, investment began to accelerate.

We now report findings from our analysis of the establishment level data relating to estimates of productivity and the determinants of relative productivity.

6.2 Labour Productivity Estimates 1997-2003

In this section, we present the labour productivity estimates for 1997 to 2003 using the different productivity measures as described in chapter 4, weighted for non-selected firms.

The estimates using both gross output measures (GO1 and GO2) and gross value added (GVA) are summarised in Table 5. The top panel contains results for total employment, whilst the bottom panel presents findings based on full-time equivalent employment. The general pattern is similar for most measures. Labour productivity increases up to 1999, then decreases sharply thru 2001, followed by a recovery in 2002 and 2003. The post-2001 increase is most

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betting exchanges there are differences in how firms measure turnover - sometimes it is the amount matched (adding up the back and lay sides of the bet), sometimes it is the amount at risk on the lay side. A consequence of this is that the turnover series reported by the ONS must be viewed in a different light to that of bookmakers' turnover in estimating the actual growth of gambling activity. Like betting exchanges, FOBTs are another example of the trend towards low-margin, high-turnover betting facilities. These machines, which offer the opportunity to play virtual casino-type games, notably roulette, generate profit on the basis of rapid turnover compared to traditional bookmaker-based betting, but lower margins.

dramatic for GO1 for which the 2002 and 2003 figures are significantly higher than for any previous year. The estimates using GO2 and GVA show similar trends, but in each case labour productivity in 2002 is estimated to be below the 1997 value. There are no significant differences between the trends for total and FTE employment.

Of course, these results relate only to labor productivity. We have argued above that investment in technology has been of particular importance in this industry. It may be that ignoring changes in capital inputs will lead to incorrect inferences regarding productivity trends in gambling. Thus, in the next section we present the more formal SFA analysis of productivity and determinants.

6.3 Stochastic Frontier Analysis of Productivity

6.3.1 Productivity Changes over Time

As a first cut, we estimate Cobb-Douglas production functions for Gross Output (GO) and Gross Value Added (GVA). The basic models are reported in the first three columns of Table 6. There are some notable differences between the results based on GO1, GO2 and GVA. For example, the Coelli (1995) test provides strong evidence of the presence of an inefficiency term for GO2 and GVA, but not for GO. Note also that for GO, the coefficient on labor (an estimate of the output elasticity of labor, given our log-linear specification) is 0.293 (standard error 0.023), the coefficient on capital is 0.669 (0.019), while that for materials is 0.056 (0.017). For these values, we cannot reject the null hypothesis of constant returns to scale. For GO2, the, the coefficient on labor is higher at 0.370 (0.028) whilst that for capital is much smaller at 0.360 (0.023). For GVA, the coefficient on labor is even higher and that for capital even lower. In the case of G02, there is evidence of decreasing returns to scale. Thus, it is clear that, as expected, the choice of output measure is important in this context.

We retrieve the efficiency scores and summarise these year-by-year in Table 7 and by employment group in Table 8. There is no discernable trend in the scores using GO2 and

GVA. However, for GO1 efficiency appears to have increased considerably both between 1998 and 2003 and between 2000 (immediately prior to the tax change) and 2003. The results in Table 8 suggest some evidence that the very small firms (below 20) are less efficient than the largest firms when using GO1 to measure output. There does not appear to be a monotonic relationship between size and efficiency. Further, even this relationship is not observed when using GO2 or GVA.

We provide several formal tests of the hypothesis of changing productivity following the 2001 tax change. First, we estimate the time-varying decay model. These results are reported in the last three columns of Table 6. Note that the coefficient on the decay parameter is positive for all three output measures, although significant only for GVA. The interpretation of a positive coefficient is that the inefficiency component is decreasing over time. In other words, we find some evidence that efficiency has increased over time, but only significantly so when measured by GVA.

Secondly, we conduct Chow tests for each model, splitting the sample into pre- and post-tax change periods. The results of the Chow tests indicate that a structural break occurred after 2001. For example, for GO1, the chi-square test statistic with four degrees of freedom is 59.46. For GO2, the chi-square statistic is 36.75 and for GVA, it is 23.31. In each case, the p-values are zero.

Another aspect of interest is to compare how gambling firms have performed relative to all firms within SIC 92, “Recreational, Cultural and Sporting Activities”. Consequently, we re-estimate our model for the whole of this category. We retrieve the efficiency scores from this model for all firms and for gambling firms. The scores using GO2 and GVA are reported in Table 9 and, in both cases, gambling productivity appears to increase faster than in the rest of the recreation sector. Note that for non-gambling firms, GO2 and G01 are equivalent.

6.3.2 Explanations of Varying Productivity

We have observed that there was a significant increase in the productivity of gambling after 2001. Productivity differentials across firms are also of interest. In this regard, we consider the results of including three factors on expected efficiency levels: regional effects, intensity of expenditure on computer equipment and intensity of expenditure on telecommunications. Our expectations are that there will be significant regional differences in efficiency and the computers and telecommunications expenditure will be positively associated with efficiency. The results are reported in Table 10. Note that a significantly positive coefficient in the inefficiency equation means that variable is associated with greater inefficiency (lower efficiency).

The first point of interest is that the dummy variable for the post-tax years is always negative and sometimes significant. This provides additional evidence of an increase in efficiency after the 2001 tax changes.

We find only modest variation in regional efficiency, whilst the results on technology are mixed. The ratio of spending on computing is associated with higher relative efficiency, although this result is not statistically significant. The ratio of spending on telecommunications is found to be to be associated with significantly greater inefficiency for GO1 and greater efficiency for GO2 and GVA. In the second half of Table 10, we report the results using the indicator variable for whether or not the firm receives orders on the Internet. This may be particularly important in this industry where virtually all activity of some firms is carried out online. Note that information on this variable is only available from 1999 and so the sample size is considerably reduced. We find that Internet operations are associated with lower inefficiency (more efficiency) for al three output measures, significantly so for GO2 and GVA.

To summarise, our evidence suggests that productivity in gambling increased following the 2001 tax change. We find little evidence of significant regional productivity differences among firms, whilst we find consistent evidence that gambling establishments operating online are closer to the frontier (i.e., more efficient) than comparable establishments.

We conducted several robustness checks of our key results, including using different error specifications for the SFA results, using a translog functional form and using fixed and random effects panel data estimators. To conserve space, we do not report the results of these experiments here. In general, they indicate that our main findings are quite robust. Full details are available from the authors on request.

7. Preliminary Conclusions and Caveats

Our empirical analysis is based on plant-level data on the number of enterprises, turnover, employment, gross value added and net capital expenditure from the Annual Business Inquiry for the years 1996 to 2003. We find that the number of enterprises decreased by 21.0% since 1996, while employment (from 1998), turnover and value added all increased significantly. Comparing the years immediately before and after the tax change (2000 and 2002), turnover increased by 38.3% and GVA by 74.8%.

Significantly also, despite the increase in turnover and GVA, employment increased by just 2.26% between 2000 and 2003. Thus, the huge expansion of gambling investment and activity appears to have been undertaken without any increase in employment. Moreover, the 'Total Net Capital Expenditure' series declines from 236 to 185 between 1999 and 2000, before rising to 383 in 2002, an increase of 84% on the 1996 figure, and 315 in 2003. Thus, there is some evidence that uncertainty over the regulatory and tax situation prior to 2001 severely limited investment in the gambling sector. However, after the more-favorable tax regime was announced in early 2001, investment started to accelerate.

Next we estimated Cobb-Douglas production functions using two measures of Gross Output (GO1 and G02) and Gross Value Added (GVA). We provide formal tests of the hypothesis of changing productivity after the 2001 tax change by estimating the time-varying decay model and by conducting and by conducting Chow tests of structural stability. We find consistent evidence that gambling productivity increased following the 2001 tax change.

We then assessed the effects of three factors on expected efficiency levels: regional effects, intensity of expenditure on computer equipment and intensity of expenditure on telecommunications. We find only limited evidence regional variations in efficiency. However, we find consistent evidence that Internet operations are associated with lower inefficiency (greater efficiency). These findings are consistent with a large body of empirical evidence in manufacturing industries indicating that computers enhance productivity[8].

A key caveat must be noted. In the current version of the paper, we have eschewed consideration of the possible endogeneity of factor inputs. It is now common in production function literature for authors to employ some form of instrumental variables (e.g., GMM) or the Olley-Pakes (1996) and Levinsohn and Petrin (2003) semi-parametric methods, due to the well-known concern regarding simultaneity. Olley and Pakes (1996) noted that unobserved productivity shocks could result in correlation between factor inputs and the error term, which could be controlled for by using investment as a proxy for these shocks. Levinsohn and Petrin (2003) proposed an alternative estimator based on intermediate inputs as the proxy, which they assert does a superior job of addressing this simultaneity problem.

Thus, the simple approach used in this version of the paper could have generated inconsistent estimates of the production function parameters. In the next version of the paper, we will implement the Olley and Pakes (1996) and Levinsohn and Petrin (2003) estimators and include additional robustness checks suggested by Van Biesesbroeck (2003, 2004).

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[8] See Indjikian and Siegel (2005) for a comprehensive review of these empirical studies.

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Table 1
U.K. Gambling Stakes by Segment, 1998-2002

	1998 £m	%	2002 £m	%	% change 1998-2002
Betting	7,109	29	17,502	49	+146.2
Gaming Machines	8,489	34	8,585	24	+1.1
National Lottery	5,207	21	4,640	13	-10.9
Casinos	2,669	11	3,850	11	+44.2
Bingo	1,041	4	1,200	3	+15.3
Football Pools	264	1	130	0	-50.8
Total	**24,779**	**100**	**35,907**	**100**	**+44.9**

Source: HM Customs & Excise/Gaming Board for Great Britain/Mintel (2003)

Table 2
U.K. Pay-TV households, by platform, 1998-2003

	1998	**1999**	**2000**	**2001**	**2002**	**2003***
	m	**m**	**m**	**m**	**m**	**m**
Analogue satellite	3.8	1.7	0.4	0.1	-	-
Digital satellite	0.3	2.5	4.7	5.3	6.3	6.4
Analogue cable	2.9	3.2	2.6	2.1	1.3	1.2
Digital cable	-	0.1	0.8	1.5	2.1	2.1
Terrestrial digital	0.1	0.5	1.0	1.1	1.7	1.6**
Other free-to-air	-	-	-	-	-	0.7***
Total	**7.1**	**8.0**	**9.5**	**10.1**	**11.4**	**12.0**
% penetration	29	33	38	40	44	48

* as at March 2003
** Freeview subscribers
*** the estimated number of Sky digital viewers that watch freeview channels only and do not pay for packages

Source: Mintel (2003)

Table 3a: IBRD Data for Non-selected Gambling Firms

	1997	1998	1999	2000	2001	2002	2003
Enterprises	1861	1860	1818	1681	1592	1542	1500
Mean Employment	24.98	20.46	23.13	16.29	13.22	11.56	13.4
250+ **100-249**	48	31	35	30	31	16	36
50-99	69	46	60	61	51	52	38
20-49	186	173	162	142	138	126	128
10-19	320	292	284	263	232	231	197
<10	1,238	1,318	1,277	1,185	1,137	1,117	1,101

Source: *ONS*

Table 3b: IBRD Data for Selected Gambling Firms

	1997	1998	1999	2000	2001	2002	2003
Enterprises	96	113	94	105	123	120	112
Mean Employment	318.85	346.96	384.27	479.12	531.4	546.9	582.7
250+	20	20	18	23	24	25	21
100-249	15	22	20	17	20	20	13
50-99	<10	19	12	14	21	16	18
20-49	15	18	15	16	24	26	23
10-19	<10	17	12	14	11	13	15
<10	29	17	17	21	23	20	22

Source: *ONS*

Table 4: Summary Data from ABI for Other Services, Recreation and Gambling

SIC	Description	Year	Number of enterprises	Total turnover	GVA Basic Prices	Total emp.	Total emp. costs	Total net capital spend
			Number	£ million	£ m	'000	£ m	£ million
O	Other community, social and personal service activities	1996	148,924	52,511	21,721	..	7,874	4,089
		1997	145,797	58,751	24,270	..	9,381	5,767
		1998	168,046	65,284	25,991	1,132	13,085	5,774
		1999	170,495	72,057	30,238	1,212	15,042	6,642
		2000	170,562	77,891	31,947	1,271	16,580	6,163
		2001	172,761	84,078	34,751	1,323	17,393	6,218
		2002	173,589	91,240	36,336	1,351	19,763	6,158
		2003	172,158	102,131	36,955	1,347	20,711	6,217
92	Recreational, cultural and sporting activities	1996	62,450	35,313	12,184	..	4,866	1,650
		1997	63,674	40,542	13,656	..	6,198	2,555
		1998	65,261	41,353	13,494	524	6,714	2,253
		1999	68,009	45,383	16,031	581	7,925	2,621
		2000	69,378	50,930	18,331	638	9,098	2,688
		2001	70,736	54,306	19,382	638	9,543	2,763
		2002	71,549	61,619	20,866	672	11,087	2,696
		2003	71,383	71,408	21,133	682	11,673	2,520
92.71	Gambling and betting activities	1996	2,240	11,849	1,462	..	708	208
		1997	2,061	13,229	1,907	..	708	262
		1998	2,076	13,938	1,834	76	760	202
		1999	2,009	14,831	2,329	77	751	236
		2000	1,878	16,503	2,620	88	1,111	185
		2001	1,814	16,805	2,385	90	1,069	318
		2002	1,719	21,572	3,081	90	1,178	383
		2003	1,770	28,290	2,787	90	1,257	315

Source: *ONS*

Table 5: Weighted Mean Labor Productivity in Gambling 1997-2003

Total Employment	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
GO1	216.09	227.60	256.75	206.59	196.56	262.18	315.21
GO2	95.61	101.87	113.32	83.96	75.12	99.86	89.29
GVA	75.09	83.46	94.94	69.00	61.23	67.69	60.42
FTE Employment							
GO1	255.93	254.95	296.49	245.37	228.24	318.61	391.34
GO2	111.21	114.79	129.29	96.77	85.22	116.79	106.62
GVA	85.81	93.11	108.58	78.61	69.57	79.06	70.66

Source: *derived by the authors from ONS data.*

Table 6: SFA Gambling Production Functions, 1998-2003

	Dependent Variable					
Coefficient on:	**GO1**	**GO2**	**GVA**	**GO1**	**GO2**	**GVA**
Labor	0.293***	0.370***	0.604***	0.291***	0.354***	0.560***
	(0.023)	(0.028)	(0.030)	(0.027)	(0.032)	(0.035)
Capital	0.669***	0.360***	0.378***	0.638***	0.362***	0.382***
	(0.019)	(0.023)	(0.023)	(0.022)	(0.025)	(0.027)
Materials	0.056***	0.218***	-	0.098***	0.223***	-
	(0.017)	(0.021)		(0.016)	(0.018)	
Constant	1.583***	2.291***	1.702***	42.07	8.516	6.719***
	(0.091)	(0.229)	(0.299)	(27.29)	(19.26)	(0.909)
Time Decay	-	-	-	0.0022	0.0137	0.015***
				(0.0014)	(0.040)	(0.004)
N	587	580	677	587	580	677
Log Likelihood	-533.87	-623.65	-873.96	-492.86	-558.96	-716.86
Wald χ^2	11126.9***	5506.62***	4393.6***	5672.3***	2990.8***	1799.5***
Inefficiency	-0.701	4.129***	3.752***	-	-	-
CRS test	2.25	12.31***	1.18	2.85*	9.61***	6.04**

Notes

(i) All production function variables are specified in logs.
(ii) *** indicates significance at the 1% level; ** at the 5% level; * at the 10% level.
(iii) The inefficiency term is assumed to follow a truncated normal distribution.
(iv) "Inefficiency" indicates test statistics for the presence of an inefficiency term using the Coelli (1995) one sided test.
(v) "CRS test" indicates a two-sided test of the null of constant returns to scale.
(vi) "Time Decay" is an estimate of how the degree of inefficiency is changing over time. When Time Decay > 0, this indicates that inefficiency is decreasing over time.

Table 7: Mean SFA Efficiency Scores, 1997-2002

	GO1	GO2	GVA
1998	0.364	0.335	0.578
1999	0.350	0.335	0.577
2000	0.316	0.335	0.577
2001	0.299	0.335	0.576
2002	0.289	0.334	0.576
2003	0.267	0.334	0.576

Note:
(i) The figures are minus the natural log of technical efficiency. i.e. larger scores indicate greater inefficiency.
(ii) Figures for GO2 and GVA have been multiplied by 1000 for ease of presentation.

Table 8: Mean SFA Efficiency Scores by employment group

Employees	GO1	GO2	GVA
250+	0.282	0.334	0.576
100-249	0.328	0.335	0.577
50-99	0.303	0.335	0.577
20-49	0.317	0.335	0.577
10-19	0.356	0.335	0.577
<10	0.303	0.334	0.577

Notes:
(i) The figures are minus the natural log of technical efficiency. That is, larger scores indicate greater inefficiency.

Table 9: Mean SFA Efficiency Scores: All Recreation and Gambling, 1997-2002

	GO2		GVA	
	All Rec	**Gambling**	**All Rec**	**Gambling**
1998	0.728	0.912	0.725	0.718
1999	0.708	0.807	0.706	0.612
2000	0.693	0.791	0.699	0.580
2001	0.677	0.756	0.653	0.567
2002	0.640	0.662	0.625	0.552
2003	0.603	0.653	0.582	0.494

Note:
(i) The figures are minus the natural log of technical efficiency. i.e. larger scores indicate greater inefficiency.
(ii) "All Rec" refers to all firms within SIC 92, "Recreational, Cultural & Sporting Activities"

Table 10: SFA Conditional Mean Production Functions: 1998-2002

	Dependent Variable					
Coefficient on:	**GO1**	**GO2**	**GVA**	**GO1**	**GO2**	**GVA**
Labor	0.288***	0.377***	0.596***	0.332***	0.386***	0.619***
	(0.024)	(0.028)	(0.030)	(0.029)	(0.032)	(0.038)
Capital	0.651***	0.389***	0.412***	0.619***	0.349***	0.341***
	(0.020)	(0.024)	(0.023)	(09.024)	(0.026)	(0.028)
Materials	0.070***	0.197***	-	0.073***	0.206***	-
	(0.017)	(0.021)		(0.021)	(0.023)	
Constant	2.260	2.330***	1.663***	2.049	2.668***	2.355***
	(44.40)	(0.113)	(0.133)	(61.05)	(0.166)	(0.225)
Inefficiency Equation						
Computer ratio	-0.0019	-0.031	-0.039	-	-	-
	(0.007)	(0.030)	(0.038)			
Telephone ratio	0.047***	-0.093***	-0.057*	-	-	-
	90.013)	(0.036)	(0.030)			
Internet sales	-	-	-	-0.027	-0.147*	-0.279***
				(0.073)	(0.089)	(0.100)
North	0.109	0.144*	0.154	0.182**	0.009	0.168
	(0.070)	(0.088)	(0.098)	(0.091)	(0.101)	(0.127)
West	0.093	0.019	0.068	0.188*	-0.171	0.261*
	(0.089)	(0.122)	(0.128)	(0.112)	(0.163)	(0.154)
East	-0.055	-0.182	-0.222*	-0.021	-0.499*	-0.173
	(0.085)	(0.111)	(0.128)	(0.108)	(0.264)	(0.172)
Scotland/Wales	0.104	0.041	0.008	0.200**	0.020	0.275**
	(0.078)	(0.100)	(0.118)	(0.097)	(0.107)	(0.134)
Post-tax change	-0.368***	-0.125	-0.148	-0.149**	-0.327***	-0.186**
	(0.059)	(0.080)	(0.103)	(0.062)	(0.083)	(0.087)
Constant	0.862	0.455***	0.443***	0.473	0.533***	0.493**
	(44.40)	(0.108)	(0.122)	(61.05)	(0.159)	(0.220)
N	587	580	673	413	408	412
Log Likelihood	-517.75	-596.31	-831.53	-378.32	-412.11	-506.9
Wald χ^2	8643.8***	4744.2***	3939.2***	6187.8***	3785.0***	2466.6***

Notes
(i) See Table 5, notes (i) to (iii).
(ii) Regional dummies are specified using London as the reference area. Year dummies are specified using 1997 as the reference year. When Internet is included as an explanatory variable, 2002 is the reference year.
(iii) In these specifications, the inefficiency term is modelled as a linear function of variables. A significantly negative coefficient implies that variable is associated with an increase in inefficiency.

APPENDIX

Table A1: Variable Description and Summary Statistics

VARIABLE	DESCRIPTION	Mean (£000)	SD
Gross Output (GO1)	log(Turnover + change in work in progress + change in stocks brought for resale + work of a capital nature by own staff.)	8.529	2.525
Gross Output (GO2)	log(Turnover – payouts to winning customers + change in work in progress + change in stocks brought for resale + work of a capital nature by own staff.)	-	-
Gross Value Added (GVA)	log(Turnover + Change in Work in Progress at Start and End of Year – Purchases)	7.513	2.325
Capital	Log(capital stock	8.658	2.742
Labor	Log(total number of employees)	4.221	2.099
Labor1	Log(total number of employees - half number of part-time employees)	3.969	2.110
Share	log(firm IBRD employment/total industry IBRD employment)	-2.406	1.974
Computer ratio	Ratio of computer & related service costs to other costs	0.255	0.558
Telephone ratio	Ratio of computer & related service costs to other costs	0.821	1.865
Internet sales	= 1 if goods and orders are received via the Internet.	0.766	0.424
North	Dummy variable = 1 if firm is located in Yorkshire, North East, Lancashire or Cumbria	0.316	0.465
West	Dummy variable = 1 if firm is located in West Midlands or South West	0.149	0.356
East	Dummy variable = 1 if firm is located in East Midlands or East Anglia	0.153	0.360
Scotland/Wales	Dummy variable = 1 if firm is located in Wales or Scotland	0.174	0.380
London	Dummy variable = 1 if firm is located in London or South East	0.209	0.407

Source: *ONS*

Notes
(i) Summary statistics are calculated using the GVA sample, N = 478.
(ii) All variables are deflated to 1996 constant prices using the CPI for Recreation & Culture, series - CHVS, with the exception of capital stock which is calculated by ONS and deflated to 1995 prices.