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Working Papers in Economics

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Number 0413

June 2004

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June 2004

Paper presented at the SSHRC International Conference on "Index Number Theory and the Measurement of Prices and Productivity," Vancouver, BC, June 30, 2004

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Abstract

Gambling is one of the fastest growing service industries. Unfortunately, there have been no studies of total factor productivity (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, materials, energy, 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. We also construct estimates of labour productivity, since TFP is may be measured with error.

We use these data to estimate labour and total factor productivity equations based on a stochastic frontier production function framework. The latter approach enables us to assess whether investment in information technology enhances relative productivity. Our preliminary results suggest that the production function models fit well, generating plausible elasticity estimates and indicating constant returns to scale. While investment in computers per se does not appear to have a productivity enhancing effect, gambling establishments that use Internet-based technology appear to be closer to the frontier.

I. Introduction

As predicted in a seminal paper by William Baumol (Baumol, 1967), the service sector has continued to grow much more rapidly than the goods sector in advanced industrial economies. Given that service industries now constitute a large proportion of economic activity, the assessment of productivity in such sectors has become 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 information 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 general issues in productivity measurement. Section III presents some background information on the U.K. gambling industry. Section IV describes the rich, longitudinal dataset that we use to assess and explain the relative productivity of gambling establishments. Section V presents the econometric method used to assess and explain relative productivity. The following section contains our empirical results. Section VII presents preliminary conclusions.

II. General Issues in Productivity Measurement in Services

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 because of the great difficulty in defining measurable units of output and adjusting for quality changes. We will 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 computer investment) 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, labour, 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

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

productivity index. Therefore, many researchers have resigned themselves to the analysis of labour productivity, typically measured as real output divided by the number of 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 labour, 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 labour 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 labour, 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 labour 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 labour 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 labour force and thereby creating an index with efficiency labour 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 labour 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 labour 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 labour 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 and m denotes total hours. 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 (9). In constructing these indexes, the key data requirements are a set of employment attributes to identify each of the i different types of labour.

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 labour 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 labour productivity measures is that neither labour nor capital is the sole source of productivity improvements. Labour-saving improvements resulting from other factors of production are improperly attributed as an improvement in labour productivity when these other factors are not held constant. That is, a major problem with the use of labour 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 labour. 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 labour 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

[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.

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 not appear to be substantial outsourcing across industries, as there is in manufacturing.

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.

III. 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. One 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 has occurred towards video-based technology and machines-based gaming 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, in particular Internet casinos, reliant on capital-intensive technology. Section 3.4 concludes.

U.K. betting markets (as distinct from gaming markets) 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).

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 set up operations with no shops, but simply as a remote betting force, e.g. Betfair, Betdaq, Sportingoptions, Sportingbet, Blue Square. 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 paid out to bettors), essentially replacing 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 carried out by MORI on behalf of Mintel (2003) found that 48% of consumers had access to the Internet, which represented an increase from 15% in March 1998. Table 2 provides a more detailed demographic breakdown of home/work/place of study Internet users.

In terms of access to digital TV, Mintel (2003) estimated that around 42% of households have digital TV, delivered either via satellite or cable. Continental Research found in March 2001 that 46% of households with digital TV had used the interactive services, with the most popular being pay-per-view movies, radio, computer games and pay-per-view sports.

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, Williams Hill, Coral, Tote, Stanley) 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).

A key distinction must be made between the U.K. betting and gaming sectors. The major sectors of the gaming industry are gaming machines, bingo and casinos. The National Lottery can also be considered to be part of the industry.

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

IV. 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 (over 100 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.

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 labour 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 labour 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. Instead, we construct a measure of gross output as follows:

GO = turnover + 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 contained in the ARD file for service industries. We compute it as follows:

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

There is no compelling argument to favour either measure, particularly in the light of the shift to a Gross Profits Tax for several gambling sectors over recent years.

To clarify, the definition of 'gross profits' of the operator in the gambling context is the difference between revenue received from customers by the operator and payouts to customers. This is essentially 'net revenue', and excludes operating costs. In the case of an operator who pays out the same as he receives, however, this implies a turnover of zero. 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. If we use gross profits, therefore, to measure output, we would conclude that output per unit employment has fallen, i.e. labour productivity has fallen, and this result would still obtain (though to a lesser extent) even if employment was unchanged. At the same time as labour 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 fall in margins means an increase in stakes, and with a given level of employment, this means more output for the same employment, or higher labour productivity. This is intuitively correct. If margins stay constant, then stakes will not change much, and probably neither will employment. This is the same thing as unchanged productivity. However, the problem with using stakes to measure output is that more can be staked for reasons for example of marketing or because of substitution or complementary effects, without there being any real change in output.

A further ground for caution arises from the fact that for some companies, Box 424 (Amounts Paid to Winning Customers) is left blank. This could at least partly due to betting exchanges, which 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.

In light of this discussion, we perform our analysis based both on turnover (as measured by Gross Output) and stakes (as measured by Gross Value Added.

Labour Measures

We measure labour using the employment measures reported in the ARD. The first measure is total employment (question wq50). 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 wq52 and wq54, so the second measure is calculated as wq50 - 0.5 wq52 - 0.5 wq54).

In calculating these measures, we confront three methodological issues: 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 study, the choice of deflation measure is less important than with cross-industry studies. In any comparisons with other service industries, we use the RPI for consistency. Reassuringly, however, our empirical results are relatively robust to using different measures such as the RPI.

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).

V. 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.[3] 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} plant or firm, 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:

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

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

[3] See Charnes et al. (1994).

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.[4]

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.

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 technology (TECH) and productivity. Market

[4] Battese and Coelli (1995) have recently extended this model to incorporate panel data.

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, μ is a white noise term, 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. We also include regional and year dummies as possible 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.

VI. Empirical Results

Table 3 summarises the scope of the ARD data for SIC code 92.71: Gambling and Betting Activities for the selected and non-selected firms for the years 1997 to 2002. Not surprisingly, these results indicate that the selected firms tend to be larger. This is a common problem with plant-level studies (see Lichtenberg and Siegel, 1991) based on an annual survey, rather than a quinennial census of establishments. **More to follow when we have the 2002 numbers in the table)**

It is important to note two limitations regarding our empirical analysis. One concern is the relatively small number of gambling establishments in the ARD. In particular, many such establishments have few employees, which implies that they have a very low probability of being sampled every year. As a result, we are unable to construct a large panel data set of firms. As discussed above, many recent parametric studies of productivity have employed panel data econometric techniques, such as dynamic GMM estimation that are unavailable to us.

A second limitation is that there is only a single SIC code for the entire gambling sector. Thus, we cannot conduct a disaggregated analysis within the gambling industry. Thus, we are likely to have bookmakers, bingo operators and casinos in our sample. As discussed in Section III of this paper, the factors affecting productivity (e.g. tax and technology changes) are often specific to one segment of the industry, but our empirical analysis is largely unable to distinguish among them. We do, however, consider one ad hoc mechanism for distinguishing betting from other sectors: measures of retail sales. Retail sales (e.g. of food and alcoholic beverages) are much more important for bingo halls and casinos. For this reason, we distinguish between reporting units with a reported retail turnover above a basic minimum level, on the assumption that firms with retail sales below this level are more likely to be bookmakers. Even if this approach is successful, a further complication is that some firms in our sample operate in more than one sector of the gambling industry (e.g. bookmakers and casino's). Given that data on the ARD is provided by reporting units our view is that it is unlikely that operations in different sectors will be provided under the same reporting unit. However, the level of the reporting units is determined by the enterprise, so it is impossible to be sure of this. For these reasons, we believe it is important that our econometric results be accompanied by detailed qualitative analysis of changes to different sectors.

Table 4 presents statistics on the number of enterprises, turnover, employment, gross value added, and net capital expenditure from the Annual Business Inquiry for the years 1996 to 2002. For comparative purposes, we also report in the same table the data for all firms in Section O ("Other community, social and personal service activities") of the SIC, 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. First, note that the number of enterprises has decreased by 20.9% since 1996, while 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 tax change (2000 and 2002), turnover has increased by 38.3% and GVA by 74.8%.[5] We conjecture that there are two reasons for this positive response. First, the effective tax rate was lowered significantly, which should 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. Second, we conjecture that 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 GVA appears to have increased much more than turnover. This is somewhat of a surprise. There is evidence that the shift to GPT stiffened competition in betting and reduced margins (Paton, Vaughan Williams and Siegel, 2002). As a consequence, one would expect that turnover would increase faster than gross margins. Indeed the likelihood of this

[5] 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.

happening was highlighted in the discussion on different output measures in gambling. We believe that the most likely explanations for the dramatic increase in value added lie in the growth of importance of two segments of the market: betting exchanges and fixed odds betting terminals (FOBT). It is very difficult to compare turnover measures between betting exchanges and conventional betting. Even across different betting exchanges there are differences in how they 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.

The second striking feature of the increase in turnover and GVA is that employment increased by just 2.26% between 2000 and 2002 and employment costs were virtually unchanged. Thus, the huge 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 massive increase in gambling productivity between 2000 and 2002.

The final variable worth noting is Total Net Capital Expenditure. This series dips by from 236 to 185 between 1999 and 2000, before rising to 446 in 2002 (an increase of 114% on the 1996 figure). 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-favourable tax regime was announced in early 2001, investment started to accelerate.

We now use the establishment level data that are available to us to look closer at productivity changes and determinants in gambling. We present labour productivity estimates for 1997 to 2002 using the different productivity measures as described in the previous section, weighted for non-selected firms. Estimates using Gross Output and Gross Value Added specifications of the production function are summarised in Table 5. For each measure we report the values using total numbers in employment and full time equivalent employment as described above. **(We can't discuss this until clearance is received from IBRD)**

Of course these results relate only to labour productivity. We have argued above that investment in technology has been of particular importance in this industry, so it is potentially misleading to make inferences regarding economic performance based on partial productivity measures. Thus, in the next section we present the more formal SFA analysis of productivity and determinants.

Table 6 presents estimates of SFA Cobb-Douglas production functions, using Gross Output (GO) and Gross Value Added (GVA) and the dependent variables. There are some notable differences between the results based on GO and those based on GVA. Firstly, the Coelli (1995) test provides strong evidence of the presence of an inefficiency term for GVA but not for GO. Secondly, for GO, the coefficient on labour (an estimate of the output elasticity of labour, given our log-linear specification) is 0.284 (standard error 0.027), the coefficient on capital is 0.704 (0.022), whilst that for materials is 0.021 (0.207). Note the latter coefficient is not statistically significant, which could be due to measurement error. For these values, we cannot reject the null hypothesis of constant returns to scale. For GVA, the coefficient on labour is higher at 0.586 (0.036) whilst that for capital is much smaller at 0.368 (0.028). In this case, there is evidence of increasing returns to scale. This pattern of results is repeated through most of our experiments reported below. Thus, it is clear that, as expected, the choice of output measure is very important in this context. One possibility is that the differences between results may be driven by the divergence between GO and GVA in 2002 reported above. However, when the model is estimated without the 2002 data (not reported here), the estimates are changed very little.

In the next phase of our analysis, we retrieve the efficiency scores and summarise these year-by-year in Table 7. [**Results not yet released by IBRD]**

We provide a formal test of the hypothesis of changing productivity over time by estimating the time-varying decay model. These results are reported in the second half of Table 6. The coefficient on the decay parameter is positive for both output measures, but 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, at least when measured by GVA. Note also that the elasticity estimates associated with the time-varying decay model (columns 3 and 4) appear to be more plausible.

We have already seen how there has been a significant increase in the productivity of gambling after 2001. Productivity differentials across firms are also of interest. Here 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 8. Note that a significantly positive coefficient in the inefficiency equation means that variable is associated with greater inefficiency (lower efficiency).

As expected, there appears to be significant variations in regional efficiency. Relative to London and the South East (the reference region) and the East of England, Scotland/Wales, the North and the West are found to be less efficient. The coefficients on the time dummies shed more light on the timing of productivity improvements over time. The coefficient on the 2002 dummy is negative and strongly significant in both models and no other coefficient is significant at the 5% level. This suggests a clear jump in efficiency in 2002, as opposed to a gradual improvement over the whole period.

The results on technology are mixed. The proportion of spending on computing is associated with significantly greater inefficiency for GO, but less inefficiency for GVA. Spending on telecommunications appears to be associated with greater inefficiency. In the second half of Table 8, 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 significantly associated with lower inefficiency (more efficiency) in both the GO and GVA models, significantly so in the case of the former.

To summarise, we find that productivity improved significantly in 2002, following the 2001 tax change. Productivity appears to be relatively high in London and the South East and the Eastern parts of England. Lastly, our results on technology are somewhat conflicting. We find evidence suggesting that firms investing heavily in new technology are actually less efficient than other firms, but that gambling firms operating online are more efficient than traditional operators.

We now report the results from several robustness checks. These findings are reported in Tables 9 and 10. The first robustness check is undertaken in the light of the concern express above that some firms do not record winnings paid to customers. We re-estimate the conditional mean production functions excluding these firms and the results are reported in the first two columns of Table 9.

There are some quite striking differences in the results compared to those reported in Table 8. Taking the production functions first, the coefficients on employment in both GO and GVA models are estimated to be much lower than before, and those on capital, higher. The coefficient on market share is now positive and strongly significant in both models. Looking at the inefficiency equation, the proportion of spend on computers is now associated with significantly higher productivity in the GVA model and is insignificant in the GO model. There is also less evidence of regional differences in efficiency for both models. Lastly, for the GO model, there is evidence of a more gradual increase in efficiency over time rather than a 'jump' just in 2002, whilst in the GVA model, we find no evidence of increasing productivity over time.

The second robustness check involves the use of full time equivalent employment instead of total number of employees. These results are reported in the second half of Table 9. The results are closer to those reported in the first half of Table 8, suggesting that the choice of employment measure is not so critical. A major difference is that the coefficient on the 2002 dummy is still negative, but insignificantly so in the GVA model.

Our final robustness check is to estimate output as a function of all the independent variables using standard panel data techniques. As we have only a small number of firms with more than two continuous observations, we do not report fixed effects estimates. Rather, in Table 10, we report random effects estimates for GO and GVA. The production equation parameters and their significance are very close in value to those estimated by the frontier analysis. Further, we see the same pattern of regional and time differences to that reported in Table 8. This provides some reassurance for our central results.

VII. Preliminary Conclusions

In this paper, we have conducted an exploratory analysis of productivity in a service industry, using plant-level data from gambling establishments on turnover, employment, gross value added and net capital expenditure from the U.K. Annual Business Inquiry. A key stylized fact is that the number of enterprises decreased by 20.9% from 1996 to 2002, while employment, turnover, and value added have all increased significantly over the same period. Significantly, GVA appears to have increased much more than turnover. We believe that the most likely explanation for the dramatic increase in value added lies in the growing impact of two segments of the market: betting exchanges and fixed-odds betting terminals (FOBTs). Significantly also, despite the increase in turnover and GVA, employment increased by just 2.26% between 2000 and 2002 and employment costs were virtually unchanged. Thus, the huge expansion of gambling investment and activity appears to have been undertaken without any increase in employment.

Next, we estimated Cobb-Douglas stochastic production functions for Gross Output (GO) and Gross Value Added (GVA). These results appear to be plausible and demonstrate that production frontiers can be estimated in service industries, as well as in manufacturing sectors. We note some key differences between the results based on GO and those based on GVA. In particular, we find strong evidence of the presence of an inefficiency term for GVA but not for GO. This confirms our expectation that the choice of output measure is very important in this context. One possibility is that the differences between results may be driven by the divergence between GO and GVA in 2002 reported above. However, when the model is estimated without the 2002 data (not reported here), the estimates are changed very little.

We also provide a formal test of the hypothesis of a shift in productivity over time, by estimating the time-varying decay model. The coefficient on the decay parameter is positive for both output measures, but 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, at least when measured by GVA.

Next 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. As expected, we find evidence of significant variations in regional efficiency. Relative to London and the South East (the reference region), Scotland/Wales, the North and the West are all found to be less efficient in at least some specifications.

The results on technology are mixed. The proportion of spending on computing is associated with significantly greater inefficiency for GO, but less inefficiency for GVA. Spending on telecommunications appears to be associated with greater inefficiency. We find that Internet operations are associated with lower inefficiency (more efficiency) in both the GO and GVA models, significantly so in the case of the former.

To summarize, we find productivity to be high in London and the South East and the Eastern parts of England, relative to other areas. We find conflicting evidence on the relationship between expenditure on information technology and relative productivity. However, it appears as though gambling firms that operate online are more efficient than traditional operators. These results appear to be sensitive to several robustness checks.

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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 3

IBRD Data for Non-selected Gambling Firms

	1997	1998	1999	2000	2001	2002
Enterprises	1861	1860	1818	1681	1592	
Mean Employment	24.98	20.46	23.13	16.29	13.22	
250+	8	7	8	3	4	
100-249	40	24	27	27	28	
50-99	69	46	60	61	52	
20-49	186	173	162	142	138	
10-19	310	292	284	263	232	
<10	1,238	1,318	1,277	1,185	1,138	

IBRD Data for Selected Gambling Firms

	1997	1998	1999	2000	2001	2002
Enterprises	96	113	94	105	120	
Total Employment	318.85	346.96	384.27	479.12	543.3	
250+	20	20	18	23	24	
100-249	15	22	20	17	19	
50-99	8	19	12	14	20	
20-49	15	18	15	16	24	
10-19	9	17	12	14	11	
<10	29	17	17	21	22	

<u>Table 4</u>

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	86,241	35,661	1,337	18,311	6,701
		2002	173,589	94,187	38,327	1,352	20,017	6,582
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	56,411	20,540	655	10,022	3,453
		2002	71,549	64,157	22,778	672	11,257	2,997
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	2,387	90	1,069	318
		2002	1,770	22,825	4,172	90	1,199	446

Table 5

Weighted Mean Labour Productivity in Gambling Based on Gross Output

[Still awaiting clearance from IBRD]

	1997	1998	1999	2000	2001	2002
Overall Mean (employees)	207.3	215.7	235.2	198.4	369.9	
250+						
100-249						
50-99						
20-49						
10-19						
<10						
Overall Mean (FTE)	245.0	248.7	296.8	240.7	502.3	
250+						
100-249						
50-99						
20-49						
10-19						
<10						

Weighted Mean Labour Productivity in Gambling Based on GVA

	1997	1998	1999	2000	2001	2002
Overall Mean (employees)	75.2	82.3	86.1	65.4	84.7	
250+						
100-249						
50-99						
20-49						
10-19						
<10						
Overall Mean (FTE)	86.0	93.2	108.9	76.2	107.9	
250+						
100-249						
50-99						
20-49						
10-19						
<10						

Table 6
SFA Gambling Production Functions, 1997-2002
Dependent Variable

Coefficient on:	GO	GVA	GO	GVA
Labour	0.284*** (0.027)	0.586*** (0.036)	0.290*** (0.032)	0.529*** (0.041)
Capital	0.704*** (0.022)	0.368*** (0.028)	0.671*** (0.026)	0.376*** (0.033)
Materials	0.021 (0.207)	-	0.067*** (0.021)	-
Constant	1.410*** (0.113)	1.856*** (0.300)	28.92 (42.23)	7.027*** (1.415)
Time Decay	-	-	0.004 (0.0054)	0.0072** (0.0036)
N	396	478	396	478
Log Likelihood	-340.50	-610.81	-322.40	-479.14
Wald χ^2	7871.2***	2939.8	4444.5***	1330.9***
Inefficiency	-0.629	8.297***	-	-
CRS test	0.56	5.71**	2.47	13.3***

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: SFA Efficiency Scores, 1997-2002

[Still awaiting clearance from BDL]

Table 8
SFA Conditional Mean Production Functions: 1997-2002

	Dependent Variable			
Coefficient on:	**GO**	**GVA**	**GO**	**GVA**
Labour	0.257*** (0.028)	0.575*** (0.037)	0.318*** (0.038)	0.603*** (0.051)
Capital	0.686*** (0.022)	0.367*** (0.028)	0.633*** (0.030)	0.320*** (0.039)
Materials	0.059*** (0.021)	-	0.065** (0.029)	-
Constant	1.581*** (0.134)	2.032*** (0.162)	1.570*** (0.156)	2.611*** (0.228)
Inefficiency Equation				
Computer intensity	0.226*** (0.077)	-0.877*** (0.330)	-0.531 (1.044)	-0.344 (0.343)
Telephone intensity	0.094*** (0.034)	0.308*** (0.091)	0.253 (0.245)	0.303*** (0.098)
Internet sales	-	-	-0.471** (0.212)	-0.203 (0.142)
North	0.131* (0.072)	0.517 (0.321)	0.103 (0.211)	0.150 (0.184)
West	0.234** (0.097)	0.556 (0.346)	0.199 (0.224)	0.376* (0.215)
East	-0.027 (0.087)	0.140 (0.324)	-0.252 (0.241)	-0.479* (0.248)
Scotland/Wales	0.153* (0.089)	0.755** (0.343)	0.047 (0.219)	0.318 (0.197)
1998	0.263*** (0.090)	0.093 (0.174)	-	-
1999	0.174* (0.090)	-0.168 (0.238)	-	-
2000	dropped	-0.089 (0.180)	0.128 (0.330)	0.292* (0.161)
2001	0.006 (0.086)	-0.071 (0.189)	0.596** (0.253)	0.304* (0.163)
2002	-0.264*** (0.096)	-0.229 (0.169)	reference year	reference year
Constant	0.126 (0.107)	-0.325 (0.380)	-0.127 (0.265)	0.036 (0.254)
N	396	478	244	252
Log Likelihood	-319.21	-596.35	-207.62	-317.10
Wald χ^2	7441.7***	2797.0***	4434.1***	1436.0***

Notes
(i) See Table 6, 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.

Table 9
SFA Production Functions-Robustness Checks
Dependent Variable

	Non-retail & FTE employment (Labour1)		Market share in inefficiency equation	
Coefficient on:	**GO**	**GVA**	**GO**	**GVA**
Labour	0.304*** (0.030)	0.589*** (0.040)	0.166*** (0.051)	0.240*** (0.067)
Capital	0.694*** (0.023)	0.354*** (0.030)	0.683*** (0.022)	0.347*** (0.028)
Materials	0.028 (0.021)	-	0.052** (0.021)	-
Constant	1.358*** (0.124)	2.321*** (0.181)	3.123*** (0.878)	5.636*** (0.723)
Inefficiency Equation				
Share	-	-	-0.109** (0.053)	-0.393*** (0.069)
Computer intensity	0.287*** (0.096)	-1.124*** (0.351)	0.223*** (0.077)	-0.052 (0.124)
Telephone intensity	0.148** (0.064)	0.347*** (0.093)	0.079** (0.036)	0.0709* (0.039)
North	0.040 (0.101)	0.099 (0.126)	0.131* (0.078)	0.271** (0.115)
West	0.213* (0.110)	0.124 (0.152)	0.246** (0.099)	0.404** (0.137)
East	-0.156 (0.144)	-0.418** (0.180)	0.013 (0.097)	0.054 (0.136)
Scotland/Wales	0.194* (0.108)	0.242* (0.146)	0.157* (0.099)	0.397*** (0.131)
1998	0.210** (0.102)	0.030 (0.178)	0.285*** (0.090)	0.198 (0.142)
1999	0.052 (0.103)	-0.073 (0.171)	0.196** (0.090)	0.032 (0.142)
2000	-0.062 (0.110)	-0.044 (0.173)	-	-0.083 (0.144)
2001	dropped	-0.144 (0.201)	0.006 (0.086)	-0.083 (0.140)
2002	-1.054*** (0.368)	-0.246 (0.164)	-0.242*** (0.094)	-0.293** (0.137)
Constant	0.039 (0.108)	0.225 (0.177)	0.963 (0.763)	0.965** (0.454)
N	332	400	396	478
Log Likelihood	-261.91	-493.19***	-317.34	-580.68
Wald χ^2	6890.7***	2397.6***	1472.0***	228.88***

Notes
(i) See Table 6, notes (i) to (iii).

Table 10
Random Effects Production Functions, 1997-2002
Dependent Variable

Coefficient on:	**GO**	**GVA**
Labour	0.160*** (0.051)	0.308*** (0.053)
Capital	0.660*** (0.026)	0.327*** 90.032)
Materials	0.084*** (0.020)	-
Share	0.100* (0.052)	0.296*** (0.056)
Computer intensity	-0.266*** (0.074)	-0.060 (0.074)
Telephone intensity	-0.104*** (0.034)	-0.057** (0.026)
North	-0.092 (0.092)	-0.185 (0.118)
West	-0.170 (0.112)	-0.318** (0.136)
East	-0.016 (0.111)	-0.123 (0.145)
Scotland/Wales	-0.138 (0.111)	-0.370** (0.155)
1998	-0.109 (0.073)	-0.084 (0.073)
1999	dropped	0.101 (0.074)
2000	0.173 (0.074)	0.140* (0.072)
2001	0.190*** (0.073)	0.159** (0.071)
2002	0.472*** (0.081)	0.267*** (0.073)
Constant	2.038*** (0.370)	4.192*** (0.420)
N	396	478
Wald χ^2	4814.0***	1543.4***

Notes
(i) Parameters are the GLS random effects estimates.
(ii) See Table 6, notes (i) and (ii) and Table 8, note 2.

APPENDIX

Variable Descriptions and Summary Statistics

VARIABLE	DESCRIPTION	Mean (£000)	SD
Gross Output (GO)	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 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
Labour	Log(total number of employees)	4.221	2.099
Labour1	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
Materials	Log (Purchases)		
Computer intensity	Purchases of computer & related services as a proportion of turnover	0.255	0.558
Telephone intensity	Purchases of telephony services as a proportion of turnover	0.821	1.866
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

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.