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A Global Analysis of Third Generation Mobile Telecommunications Market Entry*†

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Abstract

National regulatory authorities (NRAs) attempt to encourage participation in spectrum assignments by enhancing entrants' likelihood of success. The question this study addresses is: Can NRA policy tools really affect the probability an entrant wins a 3G spectrum licence? In particular, the econometric analysis allows consideration of whether licence concession or mode of assignment encourages entry. The study finds that auction assignment processes only slightly increase the probability of entry, whilst price and quantity concessions have no impact.

JEL Classification: D82, L51, L96

Keywords: Market entry; global mobile telephone markets; 3G spectrum assignment

1. Introduction

Electromagnetic spectrum is the conduit for the provision of wireless communication services. Granting rights to spectrum is a two-stage process. First, spectrum bands are allocated by international institutions such as the International Telecommunication Union (ITU). Second, national regulatory authorities (NRAs) assign spectrum within countries to mobile network operators (MNOs) (Gruber, 2005).

Gruber (2007) argues that benefits arising from new MNO entry (firms that do not operate 2G networks in the country assigning spectrum) include lower retail prices and improved service quality. Hoppe et al. (2006) study the relationship between the number of 3G spectrum licences offered and ex post competition (or market structure proxied by the number of active firms). They find incumbents more willing to deter entry the greater the loss of potential profit. Interestingly, the probability of entry increases with incumbent numbers.[1]

Importantly, NRAs sometimes employ policy instruments in an attempt to influence ex post market structure.[2] For instance, licences are set aside for entrants or they receive bidding credits, while incumbents' purchasing capacity is limited. The above free-rider problem provides a rationale for reserving licences beyond just attracting more entrants (viz., it reduces the incumbent's private incentive to prevent entry).[3] Also, bidding credits are intended to enhance potential entrants' willingness to pay for licences. However, to assure entry the bidding credit must raise the entrant's willingness to pay above the incumbent's pre-emptive willingness to pay (Hoppe et al., 2006; Gruber, 2007; Azacis and Burguet, 2008; Ansari and Munir, 2008).[4]

Other policy tools available to NRAs to encourage entry include: (a) the mode of licence assignment (whether by auction or beauty contest); and (b) the number of licences to be awarded (in excess of incumbent operator numbers) (Jehiel and Moldovanu, 2003).[5]

Whilst the above arguments are compelling (and generally accepted), somewhat surprisingly, there is an absence of empirical research establishing whether in fact NRA policy tools (including the mode of assignment) influence the probability that new entrants win 3G spectrum licences. The resolution of this question is fundamentally important given industry convergence, growth in demand for data services and the spectrum dividend made available from the 'switch off' of analogue networks. Most likely, this paucity of empirical analysis results from data limitations. Namely, available data sets typically do not include information on whether potential entrants decide to bid or not.

That is, cogent econometric analysis requires that the potential new entrant's decision making process on participation is incorporated into the estimating equations, i.e., that self-selection in the participation decision is addressed. Potential new entrants initially must assess their willingness to apply (and pay) for spectrum and then, whether to submit bids. If potential new entrants perceive a disadvantage relative to incumbent operators, they might not bother to bid at all, or they might try to form consortia with incumbents. Both types of behaviour are observed in spectrum assignments (Jehiel and Moldovanu, 2003: 286).

The econometric analysis employed obtains consistent parameter estimates by treating the selection issue as an omitted variable problem. The approach is an application of two-stage residual inclusion procedures, where the first-stage estimation number of bidders equation is specified as negative binomial. The residuals from this regression are included as arguments in the second-stage binomial probit entry equation. Importantly the approach is applicable to a wide range of selection problems where data availability is limited.

For estimation, 3G spectrum assignments information are sourced from the DotEcon Spectrum Awards Database (2008). These data consist of descriptive statistics for 49 national award processes covering 141 licences for the period 1999–2008. Only licences for which both incumbents and entrants may bid are considered. The estimation results show that auction assignment processes enhance the probability of entry, while price and quantity concessions are ineffective.

The paper is structured as follows. Section 2 discusses policy tools developed by NRAs to encourage market entry. Section 3 outlines the econometric procedures. In Section 4, variables used in the empirical analysis are defined, and the expected signs of the policy-relevant coefficients are indicated. Section 5 describes the market and licence conditions that entrants typically encounter. Section 6 presents estimation results, while Section 7 concludes.

2. Policy Tools and Market Entry, 1999–2008

Licence assignments are mostly made by auction or administrative tender (beauty contest). In auctions operators ‘simply’ price-bid for spectrum. Conversely, beauty contests require operators to bid for spectrum via multi-dimensional plans that include intended spectrum use, network coverage and pricing. Table 1 shows that 29 national assignments are by beauty contest, while 20 are by auction. These data also indicate that, after controlling for the number of licences offered by mode, entry is more common in auctions (30% via auction versus 25% via beauty contest).

Table 1. Entry by Assignment Mode

Assignment Mode	Number	Entrant-Licence Ratio	
		Mean	Std. Dev.
Auction	20	0.30	0.36
Beauty Contest	29	0.25	0.35
Sample	49	0.27	0.35

Note: The mean Entrant-Licence ratios by assignment mode are not significantly different from zero.

Notably, the environment in which licences are offered is affected by NRA positions on encouraging entry. In particular, NRAs intend to encourage entry by: (a) making available more licences than incumbent operators; (b) withholding licences for entrants; and (c) offering entrant-only concessions. More precisely, entry concessions include targeted spectrum and spectrum price discounts.

Table 2 lists the number of excess licences and national market entry for 1999–2008. Of 49 national assignment processes, in 25 cases excess licences equal the number of entrants. In the remaining 24 assignments either the number of excess licences is greater than entrant number (9 cases); or the number of entrants exceeds excess licences (15 cases). Table 3 indicates that entrants receive concessions to encourage entry in only 6 (of 52) processes. However, in these assignments only Greece did not award an entrant a licence.[6] Additionally, Table 4, lists the number (and percentage) of withheld licences by World Bank national income classification for 1999–2008. Withholding licences is uncommon (8 of 116 licence assignments), and only applied in High Income countries.

Table 2. Excess Licences and New Entrants by Assignment, 1999–2008

Country	Year	Excess Licences [a]	Market Entrants [b]
Finland	1999	0	0
Austria	2000	2	2
Germany	2000	2	2
Italy	2000	0	0
Japan	2000	0	0
Korea Republic	2000	0	0
Netherlands	2000	0	0
Norway	2000	1	1
Poland	2000	2	0
Portugal	2000	1	1
Spain	2000	1	1
Sweden	2000	1	2
Switzerland	2000	1	1
UK	2000	0	0
Belgium	2001	0	0
Czech Republic	2001	1	0
Denmark	2001	0	1
France	2001	1	0
Greece	2001	0	0
Israel	2001	1	0
Liechtenstein	2002	2	0
New Zealand	2001	1	2
Singapore	2001	0	0
Slovenia	2001	1	0
France	2002	1	0
Ireland	2002	0	1
Latvia	2002	0	0
Luxembourg	2002	1	1
Malaysia	2002	0	0
Slovak Republic	2002	0	0
Taiwan	2002	1	2
Estonia	2003	1	0
Luxembourg	2003	0	1
Croatia	2004	0	1
Hungary	2004	1	0
Romania	2004	0	0
Bulgaria	2005	0	0
Denmark	2005	0	1
Latvia	2005	0	1
Poland	2005	1	1
Egypt	2006	0	1
Georgia	2006	0	2
Indonesia	2006	0	1
Malaysia	2006	1	1
Philippines	2006	1	1
Slovenia	2006	0	1
Ireland	2007	0	1
Russia	2007	0	0
Slovenia	2008	0	1
Total		**26**	**31**

Note: (a) Calculated as number of licences offered for which both entrants and incumbents can apply in excess of incumbent operators; (b) Does not include entrants which won a withheld licence.

Table 3. Entrant Concessions, 1999–2008

Country	Year	Assignment Mode	Concession
Italy	2000	Auction	s
UK	2000	Auction	s, p
Greece	2001	Auction	s
Israel	2001	Auction	p
Ireland	2002	Beauty Contest	s, p [b]
Slovak Republic	2002	Beauty Contest	s

Note: (a) s indicates additional spectrum is made available only to entrants while p indicates the spectrum price is discounted to entrants; (b) The Irish entrant price advantage is via awarding additional points to entrants. Source: Börgers and Dustmann (2003), Analysys (2007), DotEcon Spectrum Awards Database (2008).

Table 4. Withheld Licences by National Income, 1999–2008

Income Classification	Awarded Licences	Withheld Licences		Entrants	
		Number	%	Number	%
High	116	8 [b]	7	30	26
Upper-Middle	22	0	0	4	18
Lower-Middle	11	0	0	5	45
Sample	**149**	**8**	**5**	**39**	**25**

Note: (a) World Bank income classification; (b) Belgium withheld a licence but eventually awarded it to an incumbent due to a lack of interest.

The relationship between entry and excess licences is explored via the joint probabilities reported in Table 5. The table shows that entrants win licences when no excess licences are available in 9% of cases, compared to 13% when excess licences are offered. Table 6 reports the conditional probability of entry with excess licences at 0.25. Further, the probability that there is entry when there are no excess licences is 0.18. These probabilities indicate that market entry occurs when incumbent numbers are greater than or equal to available licences, and that the presence of excess licences is not a guarantee for entry. For mode of assignment, Table 7 shows the entry probability is marginally higher for auction processes.

Table 5. Joint Probability

Event	Probability
Prob(ENTRANT $\cap$ EXCESS)	0.13
Prob(ENTRANT $\cap$ ~EXCESS)	0.09
Prob(INCUMBENT $\cap$ EXCESS)	0.40
Prob(INCUMBENT $\cap$ ~EXCESS)	0.38
Total	**1.00**

Note: Data is in binary form. When entrants exceed one, ENTRANT = 1, and 0 otherwise. When excess licences exceed zero, EXCESS = 1; 0 otherwise.

Table 6. Entry Probability Conditional on Excess Licences

Event	Probability
Prob(ENTRANT$\mid$ EXCESS)	0.25
Prob(ENTRANT$\mid$ ~ EXCESS)	0.18

Note: Data is in binary form. When entrants exceeds one, ENTRANT = 1; 0 otherwise. When excess licences exceed zero, EXCESS = 1; otherwise.

Table 7. Entry Probability Conditional on Auction Process

Event	Probability
Prob(ENTRANT$\mid$ AUCTION)	0.23
Prob(ENTRANT$\mid$ ~ AUCTION)	0.21

Note: Data is in binary form. When entrants exceeds one, ENTRANT = 1; 0 otherwise. When spectrum is assigned by auction, AUCTION = 1; 0 otherwise.

To summarise, making excess licences available is an often used tool, whilst withholding licences (and awarding other concessions) is reasonably uncommon. Further, market entry mostly occurs in the absence of policy. Moreover, when these policies are in effect often entry does not occur, and other factors affect the entry probability.

3. Econometric Method

Following Greene (2008: 884), the most simple sample selection (or incidental truncation) equation is:

$$z_i^* = \mathbf{w_i'}\boldsymbol{\delta} + u_i, \tag{1}$$

with the equation of primary interest given by:

$$y_i = \mathbf{x_i'}\boldsymbol{\beta} + \varepsilon_i, \tag{2}$$

where y_i is observed only if $z_i^* > 0$. The standard result is that with u_i and ε_i distributed bivariate normal with zero means and correlation ρ, then:

$$\begin{aligned} E(y_i \mid z_i^* > 0) &= E(y_i \mid u_i > -\mathbf{w_i'}\boldsymbol{\delta}) \\ &= \mathbf{x_i'}\boldsymbol{\beta} + \beta_k \lambda_i(\alpha_{ii}) \end{aligned} \tag{3}$$

where $\alpha_{ii} = -\mathbf{w_i'}\boldsymbol{\delta}$ and $\lambda_i(\alpha_{ii}) = \phi(-\mathbf{w_i'}\boldsymbol{\delta}/\sigma_u)/\Phi(-\mathbf{w_i'}\boldsymbol{\delta}/\sigma_u)$. Clearly, least squares regression of the licensee being an entrant or not produces inconsistent estimates of $\boldsymbol{\beta}$ when the estimation omits the independent variable λ.

That is, consistent parameter estimates of the sample selection model require estimation by maximum likelihood or Heckman (1979) two-step estimation procedure (see Greene: 888).[7] However, the approach is not feasible as the current sample does not contain data on the selection mechanism variable, i.e., whether a potential entrant decides to bid or not. With the sample containing data only on bidders an alternative approach must be sought.

Accordingly, the approach adopted is to replace the independent variable λ with a proxy. The proxy variable is sourced from a count model (negative binomial regression) explaining the number of bidders. The count model is suggested by De Silva et al. (2009) who explicitly recognise the sequential decision process of the bidders in their modelling, viz., that the decision whether or not to bid is made prior to deciding on a particular bid value. They report that as the number of bidders increases the probability of submitting a bid declines under both private and common value uncertainty.[8] Furthermore, Doyle (2009) argues that spectrum assignments involve a mix of private and common values.[9]

The method employed to estimate the model follows from Terza et al. (2008). Terza et al. compare the performance of alternative methods to address endogeneity in empirical research: two-stage predictor substitution (2SPS) and two-stage residual inclusion (2SRI). 2SPS is the extension to non-linear models of linear two-stage least squares estimation. By contrast, in 2SRI in the second stage of estimation the first-stage residuals are included as additional regressors. Within a generic nonlinear framework, Terza et al. demonstrate that 2SRI is consistent, while 2SPS is not.[10] Furthermore, they simulate several special cases to determine the magnitude and behaviour of bias resulting from the application of the alternative procedures. Of particular interest is the estimation of an (ordered) logit model with count-valued endogenous treatment. For this model, the 2SRI approach clearly outperforms the 2SPS estimation-based simulations in terms of the magnitude of the average treatment bias, and its diminution with increases in sample size.

Next, the number of bidders equation is specified negative binomial. The negative binomial regression model is an extension of the Poisson regression model which allows the variance of the process to differ from the mean. The model arises from the specification of the mean μ_i as:

$$\log \mu_i = \log \gamma_i + v_i, \tag{4}$$

where $\exp(v_i)$ is distributed gamma with unit mean and variance α. The corresponding conditional probability is,

$$\text{Prob}(Z = z_i | \mathbf{w}_i) = \frac{\Gamma(\theta + z_i)}{\Gamma(\theta)\Gamma(z_i + 1)} \psi_i^{\theta} (1 - u_i)^{z_i}, \quad z_i = 0,1,2,.... \tag{5}$$

where $\psi_i = \theta / (\theta + \gamma_i)$ and $\theta = 1/\alpha$. The model has an overdispersion parameter α such that

$$\text{Var}(z_i) = E[z_i \{1 + \alpha E[z_i]\}]. \tag{6}$$

Estimation is conducted via LIMDEP version 9.0 by maximum likelihood.

The second-stage of the 2SRI estimator applies to the binomial probit model, viz. either the winning bidder is an entrant $(Y = 1)$ or an incumbent operator $(Y = 0)$ in the period is which the sample is obtained, so that

$$\begin{aligned} &\text{Prob}(Y = 1 | \mathbf{x}) = F(\mathbf{x}, \boldsymbol{\beta}) \\ &\text{Prob}(Y = 0 | \mathbf{x}) = 1 - F(\mathbf{x}, \boldsymbol{\beta}). \end{aligned} \tag{7}$$

With the distribution function specified as normal this gives rise to the probit model

$$\text{Prob}(y_i = 1 | \mathbf{x}) = \int_{-\infty}^{\mathbf{x'\beta}} \phi(t) dt = \Phi(\mathbf{x'\beta}) \tag{8}$$

where Φ denotes the standard normal distribution. In addition to the observed values of the exogenous variables $\mathbf{x}$ also contains the residuals from the count data model. The simulated maximum likelihood estimator is asymptotically consistent as the number of observations and draws tend to infinity.[11] Within this framework the variances of the disturbances are normalised to unity. Additionally, standard errors are corrected for clustering in the sample.[12] That is, the data set is partitioned into 49 (national spectrum assignments by year) mutually exclusive and exhaustive clusters. The corrected asymptotic covariance matrix is:

$$\text{Est. Asy. Var}\left[\hat{\beta}\right] = \mathbf{V}\left(\frac{G}{G-1}\right)\left[\sum_{i=1}^{G}\left(\sum_{j=1}^{n_i}\mathbf{g}_{ij}\right)\left(\sum_{i=1}^{n_i}\mathbf{g}_{ij}\right)'\right]\mathbf{V} \tag{9}$$

where $\mathbf{V}$ is the estimated asymptotic covariance matrix ignoring the clustering and $\mathbf{g}_{ij}$ is the matrix of first derivatives of the log likelihood function for all model parameters for assignment i in cluster j.

Greene (2008) constructs the marginal effects for the model as the coefficient vector multiplied by the density function:

$$\frac{\partial E[y_i | \mathbf{x}]}{\partial \mathbf{x}} = \frac{dF(\mathbf{x'\beta})}{d(\mathbf{x'\beta})}\boldsymbol{\beta} = \phi(\mathbf{x'\beta})\boldsymbol{\beta}. \tag{10}$$

4. Data and Variables

National 3G spectrum assignment data are sourced from the DotEcon Spectrum Awards Database (2008). DotEcon data records the name of the winning bidder, and characteristics of the licence and assignment process. These data are augmented with information obtained from operator, NRA and media Web sites. Particular information sought from this search concern whether the winning bid is by carriers that operate a network in the nation prior to the 3G spectrum assignment. To analyse market entry only processes in which both incumbents and entrants are able to bid are included. This treatment provides a sample of 141 national licence awards from 49 assignment processes for the period 1999–2008.

Table 8 and Table 9, respectively, present the definition, mean and standard deviation for the dependent and independent variables employed in the empirical analysis. The dependent variables for first-stage and second-stage estimation are respectively the numbers of bidders that contest for the licence (BIDDERS) and the discrete variable whether the licence is assigned to an entrant or not (ENTRANT).

Table 8. Dependent Variable Summary Statistics, 1999–2008

Variable	Definition	Mean	Std. Dev.
BIDDERS	= Number of bidders contesting the spectrum licence	4.83	2.49
ENTRANT	= 1, if licence is assigned to an entrant; = 0, otherwise	0.22	0.42

Many variables potentially impact on the bidding probability and the entry probability. Variables contained in Table 9 measure entry incentives (entrant price concessions, entrant spectrum quantity concessions); assignment mode (auction or beauty contest); licence availability (excess licences, withheld licences); spectrum package attributes (population coverage obligation, licence duration, annual licence fees, upfront spectrum price, reserve price, time to achieve coverage obligation); and national economic and mobile market conditions (population density, national income, existing market structure).

Table 9. Independent Variable Summary Statistics, 1999–2008

Variable	Definition	Mean	Std. Dev.
Entry incentives			
PCONC	= 1, if entrant price concession; = 0, otherwise	0.04	0.20
SCONC	= 1, if entrant spectrum quantity concession; = 0, otherwise	0.08	0.27
Assignment mode			
AUCTION	= 1, if licence assignment is via an auction; = 0, otherwise	0.49	0.50
Licence availability			
EXCESS	= Licences available minus incumbent operators	0.59	0.90
WITHHOLD	= Licences withheld for entrants in an assignment process	0.10	0.31
Spectrum package attributes			
COVER	= Population to be covered by the network (%)	0.46	0.36
DURATION	= Licence term (years)	16.91	4.08
FEE	= Annual fee ($US per 100 MHz per million population)	0.60	2.53
INITIAL	= Upfront payment $US million per MHz per million population	0.56	1.04
RESERVE	= Minimum allowable spectrum bid price (US$ millions)	183	580
SERVICE	COVERAGE / TIME (% per annum)	1.20	1.26
TIME	= Years to achieve network population coverage	3.45	2.68
National economic and mobile market conditions			
DENSITY	= National population per square kilometre	303	966
INCOME	= GDP per capita ($US)	1841	1270
MCOMP	= Inverse one plus number of facilities-based mobile operators	0.23	0.05

The willingness of potential entrants to contest for licences (probability of bidding) is conditioned by macroeconomic variables, and generally applicable (to both entrants and incumbents) spectrum package attributes. Whether there are licences available beyond those likely to be contested by incumbents, and entry incentives (entrant spectrum price and quantity concessions), are included as explanatory variables.

The primary equation of interest is the probability of entry. Of the macroeconomic and mobile market variables, higher population density lowers network deployment costs, and higher income translates into more potential expenditure for mobile services. Additionally, less competitive domestic mobile markets imply greater price-cost margins. NRAs determine the mode of assignment; the number and form in which licences are made available; financial and network coverage obligations of licence holders; and any incentives for potential entrants to bid. Of the generally applicable control variables, more 'attractive' licences typically have longer duration, less stringent network deployment obligations and more favourable financial commitments. As a consequence attractive licences are likely more contested and, certeris paribus, because of inherent bidding advantages (i.e., market knowledge and financial resources) incumbents disproportionally win these licences. Therefore, entry is likely associated with 'unattractive' licences.

Furthermore, in response to the bidding dominance by incumbents, NRAs develop policy tools in an attempt to enhance the probability of entry. For instance, any excess or withheld licences are intended to create an incentive for potential entrants to bid. Additionally, spectrum price and quantity concessions are intended to create more level playing fields in the absence of set-aside licences. Finally, NRAs control the mode of assignment. Importantly, it is widely argued that auction assignment processes encourage entry.

Table 10. Expected Impact on Entry of NRA Policy Tools

Variable	Rationale	Expected Sign
Assignment mode		
AUCTION	Entry is more common via auction processes	Positive
Licence availability		
EXCESS	More licences better enable potential entrants to win licences	Positive
WITHHOLD	Withheld licences reduce competition for remaining spectrum	Negative
Entry incentives		
PCONC	Price concessions encourage entry	Positive
SCONC	Quantity concessions encourage entry	Positive

5. Entrant Market and Licence Conditions

With spectrum assignments embedded in administrative processes clearly not all assignments are equally attractive to bidders. An interesting question then is whether incumbents, driven by expected profit considerations (Klemperer, 2002: 177; Hope et al., 2006), mostly win licences in more attractive assignments. Such an outcome is equivalent to entrants mostly winning licences in relatively unattractive markets. Inspection of the sample data contained in Table 11 confirms that while entrants, on average, win licences in markets with higher national income (INCOME), population density (DENSITY) is lower. Furthermore, entrants generally win licences with more onerous conditions, viz., shorter licence duration (DURATION); higher annual fees (FEE); and less time to achieve coverage obligations (TIME).

Table 11. Market and Licence Conditions by Entry

Variable	Entrant	Incumbent	Desired Value
National economic and mobile market conditions			
DENSITY	142	348	High
INCOME	21,554	17,520	High
MCOMP	0.24	0.23	Low
Spectrum package attributes			
COVER	0.48	0.46	Low
DURATION	15.8	17.2	High
FEE	0.22	0.14	Low
INITIAL	0.42	0.60	Low
TIME	3.06	3.56	High

6. Estimation Results

In the first stage of the empirical analysis a count model (negative binomial regression) explaining the number of bidders is estimated. In the second stage of estimation the first-stage residuals are included as an additional argument in the binomial probit entry model, thus addressing the omitted variable bias problem. Both models include a set of controls for entry incentives, licence availability, spectrum package attributes, and national economic and mobile market conditions. However, the two specifications differ. The bidding stage incorporates information important in deciding whether to bid, i.e., the annual licence fee (FEE) and minimum spectrum bid price (RESERVE). In the entry equation, variables included concern the assignment mode (AUCTION), whether licences are set aside for entrants (withheld from incumbents, WITHHOLD) and the upfront payment required for the licence (INITIAL). Finally, the first-stage residual (RESIDUAL) is added to the entry equation. A significant RESIDUAL coefficient supports the model specification.

Table 12 reports the estimated bidding model from negative binomial regression. Estimation is by maximum likelihood procedures as outlined by Greene (2008: 911–915). Further, the likelihood test rejects the null hypothesis that explanatory variables do not impact on bidding. Additionally, the McFadden pseudo R^2 statistic is reported.[13] While the measure is not a direct counterpart to R^2 in linear models, it does provide a useful summary measure (McFadden, 1973: 123). These data suggest that licence availability (EXCESS), spectrum package attributes (RESERVE and SERVICE) and national economic and market conditions (DENSITY and MCOMP) are particularly important for explaining the willingness to bid for spectrum. Table 12 contains parameter estimates, standard errors and *t* statistics for the negative binomial model. Of particular interest is that the availability of excess licences (EXCESS) appears to encourage bidding (presumably by potential entrants), while entry incentives (PCONS and SCONC) have no effect.

Table 12. Negative Binomial Regression Maximum Likelihood Estimates

Category	Variable	Coefficient	Standard Error	*t* statistic	Marginal Effect
	Constant	1.65188***	0.45062	3.666	
Entry incentives					
	PCONC	–0.29899	0.38507	–0.776	–0.53649
	SCONC	–0.11484	0.39381	–0.292	–0.30712
Licence availability					
	EXCESS	0.38109***	0.08357	4.560	0.63418
Spectrum package attributes					
	DURATION	–0.00852	0.01648	–0.517	–0.00201
	FEE	–0.04456	0.17992	–0.248	–0.09776
	RESERVE	–0.00034**	0.00018	–1.862	–0.00063
	SERVICE	–0.13682**	0.05754	–2.378	–0.30918
National economic conditions					
	DENSITY	–0.00073*	0.00040	–1.855	–0.00140
	INCOME	0.00001	0.00000	1.099	0.00001
	MCOMP	–3.86450**	1.57784	–2.449	–8.35749
	Number of observations	141			
	McFadden pseudo R^2	0.120			
	Log likelihood	–265.531			
	Restricted log likelihood	–301.658			

Note: * significant at 10%; ** significant at 5%; *** significant at 1%.

The equation of primary interest is the second-stage probit entry model. Estimation is by maximum likelihood procedures as outlined by Greene (2008: 777–793), with the results reported in Table 13. Importantly, the specification of the model structure is supported with a statistically significant RESIDUAL coefficient. Additionally, the likelihood test rejects the null hypothesis that explanatory variables do not impact on bidding. Furthermore, the errors are homoscedastic. Finally, the model tracks the data well with 79% of the observations correctly predicted, and similarly the Ben Akiva-Lerman R^2 is 72%.

Table 13. Binomial Probit Regression Maximum Likelihood Estimates

Category	Variable	Coefficient	Standard Error	*t* statistic	Marginal Effect
	Constant	0.72912	1.01353	0.719	
Entry incentives					
	PCONC	–0.63299	0.74283	–0.852	–0.02624
	SCONC	0.05186	0.70581	0.073	0.00378
Assignment mode					
	AUCTION	0.69401**	0.27958	2.482	0.05162
Licence availability					
	EXCESS	–0.14448	0.12632	–1.144	–0.01011
	WITHHOLD	–7.72095***	0.66233	–11.657	–0.54022
Spectrum package attributes					
	COVER	0.83905*	0.50706	1.655	0.05871
	DURATION	–0.05481*	0.02913	–1.881	–0.00383
	FEE	0.33577	0.21786	1.541	0.02349
	INITIAL	0.03261	0.12133	0.269	0.00228
	TIME	–0.20170***	0.07272	–2.774	–0.01411
National economic conditions					
	DENSITY	–0.00116	0.00082	–1.402	–0.00001
	INCOME	0.00002***	0.00001	2.702	0.00001
	MCOMP	–3.35471	3.66784	–0.915	–0.23472
Residual inclusion					
	RESIDUAL	0.13903**	0.07060	1.969	0.00973

Number of observations	141
% observations correctly predicted	79.43
Ben Akiva-Lerman R^2	0.716
Log likelihood	–60.691
Restricted log likelihood	–74.269

Note: * significant at 10%; ** significant at 5%; *** significant at 1%.

Several distinct patterns emerge from the results contained in Table 13. First, the only national economic and mobile market condition variable that is individually significant in explaining whether there is market entry is INCOME (with partial effect 0.00001), which is positive. Second, for variables describing generally applicable (to both incumbents and entrants) spectrum package attributes, licence required geographical network coverage (COVER = 0.05871) is positive, whilst duration (DURATION = –0.00383) and the time to complete the required geographical network coverage (TIME = –0.01411) are both negative. Whilst these signs initially appear counterintuitive, this is not the case, and they reflect the finding of Section 5 that entrants generally win licences with more onerous conditions, e.g., shorter licence duration (DURATION) and less time to achieve coverage obligations (TIME). In this circumstance the reported signs are expected.

The main interest is in the estimated coefficients of policy relevant tools that are intended to enhance the probability of entry, viz., entry incentives (PSCONC and SCONC), assignment mode (AUCTION) and licence availability (EXCESS and WITHHOLD). Interestingly, incentives offered on entry by NRAs are not statistically important. This outcome may be because either an entrant considers the measures insufficient in their magnitudes or ineffective because of the mode of implementation. Further analysis is required to determine whether this approach should be modified or abandoned.

An alternative mechanism considered by NRAs to encourage entry is to control the availability of licences by either allotting more licences than the number of incumbent 2G operators (EXCESS) or by setting aside licences exclusively for entrant operators (WITHHOLD). The former policy stance is prima facie more market oriented (as potential entrants still have to bid in an 'open' process for spectrum assignment), whereas the latter approach is more administratively orientated (in that only potential entrants can bid for the restricted pool of licences). Withholding licences has the anticipated negative impact (WITHHOLD = –0.54022) on the entry probability. Namely, as only processes in which both potential entrants and incumbents can bid are modelled, setting aside licences diminishes the pool of potential entrants bidding for the remaining licences. This diminution of potential entrant bidders, in turn, reduces the probability of an entrant winning licences. Finally, using an AUCTION mode to assign 3G spectrum increases the entry probability (AUCTION = 0.05162).

Table 14 contains elasticity estimates for NRA policy tools. The reported elasticity values (evaluated at the sample means) are inelastic. The elasticity value for WITHHOLD (whether another licence is withheld for an entrant in the particular assignment) suggests that when an entrant is removed from the pool of potential entrants, the probability that another licence is won by an entrant falls by 2.46%. Further, using an AUCTION to assign 3G spectrum increases the entry probability by 1.15%, albeit only slightly.

Table 14. NRA Policy Variable Elasticity Estimates

Category	Variable	Elasticity
Entry incentives	PCONC	–0.005
	SCONC	0.001
Assignment mode	AUCTION	**0.115**
Licence availability	EXCESS	–0.387
	WITHHOLD	**–0.246**

Note: Bold indicates coefficient is statistically significant.

7. Conclusions

Recently, empirical research on the assignment of spectrum licences is concerned with whether particular designs result in assignments. However, surprisingly, whether market entry occurs has not received attention. The reason for this paucity of research is probably the nature of the available data. Namely, these data typically do not contain information on whether potential entrants decide to bid or not, blocking the use of standard selection approaches. With the sample containing data only on bidders an alternative approach is developed that replaces the omitted independent variable with a proxy sourced from a count model explaining the number of bidders.

The modelling approach is based on the premise that the impact of NRA policy tools designed to encourage entry have not been empirically tested to assess their effectiveness. Accordingly, the fundamental question this study addresses is: What policy tools determine the probability that an entrant wins a 3G spectrum licence? The short answer is that auction assignment processes enhance the probability of entry, while price and quantity concessions are ineffective.

At first glance, these findings suggest that NRAs are not able to design spectrum packages to increase the likelihood of new entry, and that trust in auction modes of assignment is appropriate, but weak. However, the reason for the ineffectiveness of price and quantity concessions regarding entry is not resolved by this analysis. It may be either that entrants consider the measures insufficient in their magnitudes or ineffective because of the mode of implementation. Further analysis is required to determine whether this concessions approach should be modified or abandoned.

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[1] This free-riding effect occurs where incumbents as a group have an incentive to purchase licences, but not the individual incentive to ‘go it alone’.

[2] Western European NRAs were first to assign spectrum to MNOs during 1999–2001. The environment in which these assignments are made is shaped by the European Commission’ Directive 97/13/EC that states new operators should be encouraged to enter markets to ensure the development of European telecommunications service markets. In particular, the UMTS Forum argues that market entry is required to stimulate competition and that optimum subscriber benefit is achieved only when competing infrastructures provide advanced and innovative services, viz., “...assessment of (3G licence) applications should take into account the benefits of allowing current operators into the UMTS market in terms of synergies and existing commercial experience, balanced against those of letting in new entrants whereby introducing new competition” (UMTS Forum, 1998: 11).

[3] However, if NRAs are to use reserved licences to influence market structure, they need perfect information about how much any potential licensee values a licence. That is, the inefficiency of allocating a licence to a low-value (inefficient) firm may outweigh any positive effect on social welfare due to market entry (Hoppe et al., 2006).

[4] Once again, if the NRA has only limited information about the potential licensees’ valuations, bidding credits may result in an inefficient allocation of licences which may outweigh any potential social gains.

[5] Beauty contests require MNOs to submit plans or bids including spectrum use plans. After hearing proposals, NRAs award spectrum to operators that present the most attractive proposals. Importantly, spectrum price is only one aspect of NRAs’ decision making. Conversely, auctions require operators to make price bids for spectrum lots. Thus, an auction is a competitive, price-based mechanism which should result in allocations to operators with

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highest spectrum valuations (Cramton, 2002: 608). Implicit value calculations are based on operators' projected future revenue and cost streams.

[6] Greece was the only country not to have made available an excess number of licences over incumbents.

[7] Further, the model is generalised for the case when the selection variable is not observed. In this case the selection mechanism is specified as a probability model to account for the latent selection variable. Another generalization is to allow nonlinear specification of the primary equation (see Greene 1992, 2006; and Terza 1995, 1998 for examples of the approach).

[8] De Silva et al. (2009: 14) argue that in pure private value settings, an increase in the number of bidders increases the winning bid value (competitive effect). However, as a results of lower profit margins for the winner, this depresses the number of bids submitted (entry effect). In the common value setting, due to the winner's curse considerations, the entry effect is itself theoretically ambiguous.

[9] Private value is determined largely by firm-specific assets such as the value of the brand, whereas common value is determined by market circumstances such as market demand and technology.

[10] De Silva et al. (2009: 534) assert that the 2SRI method is first proposed by Hausman (1978) in a linear model context. Consistent 2SRI methods for specific nonlinear models are developed by Blundell and Smith (1989, 1993), Newey (1987), Rivers and Vuong (1998), and Smith and Blundell (1986).

[11] Cappellari and Jenkins (2003) argue that if the number of draws is greater than the square root of the sample size the parameter estimates are robust to different initial seed values.

[12] The cluster estimator corrects estimated standard errors for panel data type effects that are present, but omitted from the model. An LM test is initially used to test for heteroskedasticity (as recommended by Greene, (2007)). The null hypothesis of homoskedasticity is rejected for all model specifications. Yatchew and Griliches (1984) find that maximum likelihood estimators for binary choice models are inconsistent and the covariance matrix inappropriate under conditions of heteroskedasticity. Greene (2008) notes this test will likely detect other forms of misspecification if they are present e.g., unmeasured heterogeneity, omitted variables, nonlinearity or an error in the distributional assumption (Greene, 2008: 780). Given this, a safe estimation strategy is to use robust correction methods.

[13] McFadden's Pseudo R^2 is calculated as $1-[\log L(\text{model}) / \log L(\text{constants only})]$ (Greene, 2007: E18-21).