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The production function methodology for estimating the value of spectrum

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ABSTRACT

The estimation of production functions for wireless communications markets presents particular challenges including the lumpy nature of spectrum use, and the presence of significant upfront investment. In this paper a systematic study of production functions for wireless markets is undertaken, using data from India. The efficacy of two major functional forms, the Cobb Douglas and the translog functions, are compared by benchmarking the values of spectrum they yield against the values generated by the intuitive but data-intensive cash flow method, and the prices revealed in two auctions. The comparisons allow us to conclude that factoring the lumpy nature of spectrum use by considering 'effective spectrum' data rather than raw spectrum data, and relaxing the assumption of constant elasticity of substitution are useful in obtaining accurate estimates of spectrum value.

1. Introduction

The 'mobile-only' Internet population is expected to grow 56-fold from 14 million subscribers at the end of 2010 to 788 million subscribers by the end of 2015 (Sridhar, Casey, & Hämmäinen, 2013). In emerging economies, including India, wireless access is expected to be the main driver of the uptake of broadband services. The exponentially increasing amounts of wireless data traffic, and increasing varieties of applications have resulted in repeated demands for capacity enhancements of networks.

The rapidly escalating demand for spectrum, an essential input in the provision of mobile services, makes it imperative to evolve appropriate methodologies for its valuation. For instance, an auctioneer requires some idea of the market value to set the reserve price. Bidders would also need to estimate the value of spectrum in order to bid. One of the most common applications of spectrum valuation is in the assignment of spectrum to captive users – those who utilize spectrum for their internal operations not commercial telecommunications services. In many countries the pre-dominant share of spectrum is allocated for such captive use.

Further, governments have, at various points in time, chosen not to auction commercial spectrum but assigned it through an administrative process with administratively determined prices. In India the 2G license bundled with spectrum was assigned based on an auction in 1995, 2001, and 2012–2013. Spectrum in 3G and BWA bands was auctioned in 2010. In 1999, the 2G licensees were migrated to a revenue share, and from 2001 to 2008, licenses and spectrum were assigned on the basis of an administratively determined price (Sridhar, 2011). In all these cases, being able to value spectrum appropriately

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becomes critical. Indeed, the economic valuation of spectrum is important both in a market determined as well as an administrative process of assignment.

Some of the prevailing methods of spectrum valuation consist of benchmarking the current value to some proximate auction, or carrying out a calculation based on the capacity of a given spectrum block to carry signals. For instance, the Indian telecommunications regulator benchmarked the value of spectrum in the 1800 MHz band to the value of the spectrum in the 2100 MHz band discovered in the 2010 auction, after applying a correction based on the different propagation characteristics of the two bands (TRAI, 2012). In the context of spectrum used for operational purposes by government departments (referred to as 'captive spectrum'), the Indian regulator has been carrying out a calculation based on the quantity of bandwidth and the radius over which the spectrum rights are being assigned.

The benchmarking of values to proximate auctions is appropriate when the auctions in question have been held in the recent past, and the spectrum rights being assigned are similar. Of course, the question of how bidders estimated the value of spectrum in the benchmark auction remains unanswered. Moreover, when distant auctions are used for benchmarking, one must factor the change in revenue per MHz of spectrum and the percentage increase in complementary inputs like BTSs. The benchmarking exercise in such cases is not very satisfactory.

The methods used to value captive spectrum often focus on spectrum capabilities to the exclusion of the demand for spectrum. Smith (1776), in his seminal treatise The Wealth of Nations (1776) remarked: 'Nothing is more useful than water; but it will purchase scarce anything. A diamond on the contrary, has scarce any value in use, but a great quantity of other goods may be had in exchange of it'. While the growing scarcity of water threatens to make the comment out of date, the point about incorporating demand into the economic valuation remains irrevocably pertinent. Spectrum has higher value in more densely population, high income regions and this fact needs to be taken into account by administrative methods.

In a liberalized spectrum environment that permits any band of spectrum to be used with any technology, regulators may conclude (for instance, TRAI, 2012) that the relative value of different bands of spectrums is linked only to their relative propagation capability, i.e. their 'intrinsic value', thereby ruling out factors related to the 'extrinsic value' of spectrum (Alden, 2012; Mölleryd & Markendahl, 2012) such as the state of the ecosystem associated with various spectrum bands. As per this reasoning, the 1800 MHz band has 1.2 times the propagation characteristics of the 2100 MHz band and so is 1.2 times more valuable, even though 2100 MHz has a much better developed eco-system for higher generation technologies. This approach also has limited usefulness as it ignores significant aspects of market valuation.

Hence we need an estimation approach that factors the intrinsic value of spectrum, the associated eco-system, and the market demand. Basing our estimate on the production function of telecommunications services allows us to do this. Once a production function for wireless communication has been estimated, marginal productivity theory can be applied to compute the spectrum value relative to other inputs.

The first estimation of a production function for the Indian wireless industry, (and perhaps the earliest such attempt for wireless telephony), was carried out by Prasad and Sridhar (2008) in order to estimate the optimal number of operators in the Indian market. Next, the estimated production function was used to evaluate whether the industry was efficient in an allocative sense (Prasad & Sridhar, 2009), and to estimate the value of spectrum in each circle (Prasad, 2010). In each of these cases, the Cobb–Douglas production function was used.

The use of the Cobb Douglas function in economics originated in the attempt of Cobb and Douglas (1928) to estimate an empirical relationship between the level of inputs and technology on the one hand and output on the other. It was soon applied to study the distribution of income between the different factor inputs in line with the marginal productivity theory of distribution (Biddle, 2012). Vinod (1976) estimated a Cobb Douglas production function for the US fixed line telecommunications sector.

The advantage of the Cobb Douglas specification is its simplicity, and its amenability with a variety of production processes including increasing and decreasing returns to scale (Miller, 2008). Its limitations stem from the inherent assumption of constant elasticity of substitution between the inputs which also implies a constant percentage of income distribution across them.

More general functional forms that retain the assumption of constant elasticity of substitution include the CES production function. Fishelson (1977) estimated a CES production function for the US fixed line telecommunications industry. The translog function relaxes the assumption of constant elasticity of substitution and reduces to the Cobb Douglas function in case there is constant elasticity of substitution. Eldor, Shami, and Sudit (1979) went on to contrast the results of a translog production function with those of a general CES and a Cobb Douglas production function.

The estimation of production functions for wireless communications markets presents particular challenges including the lumpy nature of spectrum use, and the presence of significant upfront investment. In this paper a systematic study of production functions for wireless markets is undertaken, using data from India. The efficacy of two major functional forms, the Cobb Douglas and the translog functions, are compared by benchmarking the values of spectrum they yield against the values generated by the intuitive but data-intensive cash flow method, and the prices revealed in two auctions. The comparisons allow us to conclude that factoring the lumpy nature of spectrum use and relaxing the assumption of constant elasticity of substitution are necessary in order to obtain accurate estimates of spectrum value through the production function method.

The paper is organized as follows: Section 2 lists the relevant features of the Indian telecommunications market, Section 3 presents estimates of spectrum price using the Cobb Douglas and translog functions, Section 4 presents the benchmarks – the cash flow method and the 2014 auction, and presents a statistical comparison of the results; Section 5 discusses finer points of the method proposed; and Section 6 concludes.