Appendix C: Imputing Auction 101 Prices for Weights

1 Introduction

This document outlines a potential statistical regression approach to estimating prices for those markets for which no licenses were available in Auction 101 (28 GHz Band). These imputed prices, along with actual prices from Auction 101 and prices from Auction 102, could then be used to calculate a relative price index to weight MHz-pops across PEAs for purposes of reconfiguring existing 39 GHz licenses consistent with the licenses that will be available in Auction 103.

The *Initial 39 GHz Reconfiguration Procedures Public Notice* sets forth a proposal to calculate the relative price index based on Auction 102 data (as available) and prices from previous auctions of non-millimeter wave spectrum.[1] The proposal declines to use price data from Auction 101 because the auction inventory included less than half the nation, primarily in less densely populated areas, and used a smaller geographic licensing area (counties) than will be used in Auction 103, making it difficult to develop a nationwide PEA-level price index. The *Initial 39 GHz Reconfiguration Procedures Public Notice* seeks comment, however, on an alternative approach that would use statistical regression to impute prices for the markets not included in the Auction 101 inventory to use in creating the relative price index.[2]

2 Regression Approach

For this alternative, we would use a regression methodology to impute the missing prices using the prices of the PEAs that were sold in Auction 101. We would propose to use a constant elasticity regression model that estimates the dollars-per-MHz-pop prices of millimeter wave spectrum as a function of PEA characteristics and past auction price data. Under this approach:

The dependent variable is p_i^{mmW}, the Auction 101 price in PEA *i*

The model estimates coefficients for the following characteristics:

$density_i$	population density for PEA *i*
$hhinc_i$	median household income for PEA *i*
$urban1_i$	percent of PEA *i* that is greater than median urban percentage[3]
$urban2_i$	percent of PEA *i* that is less than median urban percentage
p_i^{AWS}	price of PEA *i* license in AWS-3
p_i^{600}	price of PEA *i* license in 600 MHz
p_i^{700}	price of PEA *i* license in 700 MHz

The regression model is:

[1] *See generally, Notice of Initial 39 GHz Reconfiguration Procedures, et al*., GN Docket No. 14-177, AU Docket No. 19-59, Public Notice, DA 19-196, at Section V.D. (Methodology for Setting Relative Weights for Spectrum Holdings by PEA) (WTB/OEA Mar. 20, 2019) (*Initial 39 GHz Reconfiguration Procedures Public Notice*).

[2] *Id.*

[3] $Urban1_i$ and $urban2_i$ is a linear spline in the percent urban variable with a cut-point at the median percentage urban in our sample, which is 56.8%. We use a linear spline in this variable to allow the effect (slope parameter) of this variable to vary according to how urbanized the PEA is. The spline allows the relationship between prices and percent urban to be linear with one slope below the median percentage urban and then linear with a different slope above the median. If the slopes are different, there is a "kink" where the two lines meet.

$$p_i^{mmW} = exp[\alpha + \beta_1 \, ln(density_i) + \beta_2 ln(hhinc_i) + \beta_3 urban1_i + \beta_4 urban2_i$$
$$+ \beta_5 ln(p_i^{AWS}) + \beta_6 ln(p_i^{600}) + \beta_7 ln(p_i^{700}) + \varepsilon_i]$$

We would estimate the model using a Poisson regression while correcting the standard errors by specifying a robust heteroskedasticity consistent covariance matrix.[4]

3 Data

Auction 101: We would calculate average dollars-per-MHz-pop prices for each PEA in Auction 101 by aggregating the county-level data to a PEA level. We then would calculate the natural logarithm of these prices and use this as the dependent variable in our regressions. If a PEA had one or more counties that were not available in the 28 GHz auction, then this PEA would be dropped from the analysis. This restriction leaves a total of 123 PEAs.

Previous Auctions: We would use PEA prices for Auction 1002 (600 MHz) and calculate PEA prices for Auction 97 (AWS-3) from the prices for the CMA and EA spectrum licenses that were sold in those auctions.

For the CMAs that do not nest entirely within the geographic boundaries of a PEA, we would allocate the CMA revenues to multiple PEAs. We would allocate the total CMA license prices to the individual counties based on the county share of the overall CMA population. We would then aggregate the county-level prices to PEA-level prices. We would allocate EA prices to PEAs based on the PEA's share of the EA population.

Demographic Data: Population data would be based on population estimates for 2017, aggregated to the PEA-level from the county-level by summing the county population totals.[5] Income data would be based on county-level estimates for 2016 or 2017.[6] The percentage of each county that is urban would be based on the 2010 Census Urban and Rural Classification.[7] To calculate the median household income for the PEA and the percentage of the PEA that is urban, we would calculate a population weighted average of the county-level measures of these variables.

[4] A common approach is to take the logarithm of both sides of the constant elasticity model specified above and then estimate the transformed model. This introduces several issues that are avoided by estimating the equation without taking the log transformation. See, for example, Santos Silva, J.M.C., S. Tenreyro 2006. "The Log of Gravity", The Review of Economics and Statistics 88(4):641-658 and Gould B. (2011) "Use poisson rather than regress; tell a friend" https://blog.stata.com/2011/08/22/use-poisson-rather-than-regress-tell-a-friend/.

[5] Population data from Economic Research Service of the United States Department of Agriculture. *See* www.ers.usda.gov/data-products/county-level-data-sets/. As an alternative, we could use the corresponding Census Bureau data for population. *See* www.census.gov/programs-surveys/popest/data/data-sets.html.

[6] Income data from Economic Research Service of the United States Department of Agriculture. *See* www.ers.usda.gov/data-products/county-level-data-sets/. As an alternative, we could use the corresponding Census Bureau data for income. *See* www.census.gov/data/datasets/2017/demo/saipe/2017-state-and-county.html.

[7] *See* www.census.gov/geo/reference/ua/urban-rural-2010.html.