

The Supply and Demand for Audiologists: Preliminary Modeling and Analyses

Kelli Marquardt, BS¹; Holly Hosford-Dunn, PhD²; Price Fishback, PhD³
April 28, 2017

Abstract

As the average age of the country is rising, so too is the demand for health care services geared to an aging population. Recent data analysis has predicted that the supply of audiologists will not be enough to cover the rising demand in the next 30 years. This paper analyzes the market for audiologists to establish determinants of supply and demand. An instrumental variable and 2 stage least squares regression technique are employed to consistently estimate both supply and demand.

There are three main findings in the analysis.

1. Demand for audiologists is price elastic while supply is relatively price inelastic.
2. Costco Hearing Centers have become a substitute for hearing aid testing and fitting services and their entrants into the market are decreasing the demand for audiologists.
3. The most significant determinant of supply are academic variables, specifically the number of audiology programs available to students. This is in agreement with work done by Windmill and Freeman (2013, 2017) and suggests a need for a change in the structure of audiology programs in order to ensure the stability of the audiology profession.

I. Introduction

An audiologist is a healthcare based professional who provides patient care for disorders and conditions related to hearing. Often, as people get older, they experience hearing loss and require attention from an audiologist (Goman & Lin, 2016).⁴ Therefore, as the average age of the country is rising, so too is the demand for hearing health services. However, paired with this increase in demand is a static or even decreasing audiology work force. Windmill and Freeman (2013) use a Physician Supply Model to determine that the future supply for audiologists will not be large enough to cover the increasing demand. Windmill and Freeman (2013; 2017), along with Hosford-Dunn (2017a,b,c) analyze audiology data and make predictions as to the reasons underlying this inadequate supply.

¹ Department of Economics, Eller School, University of Arizona, Tucson AZ

² Hearing Health & Technology Matters, LLC, Tucson AZ

³ Department of Economics, Eller School, University of Arizona, Tucson AZ

⁴ Goman and Lin (2016) report that approximately 81% of people who are 80 years or over experience hearing loss, 55% of individuals 70-79 years of age experience hearing loss, and 27% of individuals 60-69 years of age experience hearing loss

One thing not mentioned in the analyses of prior articles, which we assume in this paper, is that observed data is reflective of market equilibrium. Demand and supply represent relationships between wage and employment. As the wage increases, more people are willing to work, and thus we expect to see an increase in quantity supplied. On the other hand, employers must pay their workers more, and thus we expect to see a decrease in quantity demanded. In equilibrium, the equilibrium wage equates quantity demanded and quantity supplied. Therefore, without a complete analysis of real world data, we cannot distinguish the different determinants of quantity supplied and quantity demanded. So, while Windmill and Freeman (2013) predict future demand and supply, they do so with past observations and do not explicitly estimate the supply and demand equations themselves. That is what this paper aims to do: use instrumental variables and a two stage least squares regression to estimate both the demand and the supply equations for the Audiology labor market.

According to the results, while supply for audiologists is relatively price inelastic, the demand is price elastic, which is in support of the conclusions offered by Hosford-Dunn (2017b,c) that there are substitutes in demand, namely hearing aid specialists. The results also suggest that while interest in the profession is growing, the accredited audiology programs play a significant role in determining supply.⁵ And in addition, the quantity demanded is falling due to the increasing number of Costcos in each state, which now provide hearing test and hearing aids using licensed hearing healthcare professionals that may not be audiologists.⁶ Section V explores these results further.

II. Model

To estimate the quantity demanded and quantity supplied, we first develop the general model and present the identification strategy. We assume that the quantity demanded is a linear function of wage and other exogenous variables and that quantity supplied is also a linear function of wage and exogenous variables.

$$q_{dit} = \beta_1 w_{it} + x'_{it} \beta_2 + \varepsilon_{dit} \quad (1)$$

$$q_{sit} = \alpha_1 w_{it} + x'_{it} \alpha_2 + \varepsilon_{sit} \quad (2)$$

Where q_{dit} is the quantity demanded in state i and time t , q_{sit} is the quantity supplied in state i and time t , w_{it} is the wage in state i and time t , and x_{it} is a vector of exogenous control variables.

Ideally, we would want to consistently estimate β_1 , β_2 , α_1 and α_2 , however we cannot do so through simple Ordinary Least Squares estimation. To estimate consistently, we apply a 2 stage least squares regression with instrumental variables.

⁵ See Windmill and Freeman (2013) for a more detailed data analysis on audiology programs.

⁶ Costco Hearing Centers do not bill insurance for hearing tests, which are administered at no charge to potential hearing aid candidates. For these reasons, over and beyond wage gap between audiologists and dispensers, Costco does not need to demand audiologists to perform initial testing, supervise, or perform other hearing aid-related services.

First, we make the assumption that the observed data are market equilibrium prices and quantity for each state and time. Assuming equilibrium leads to equating quantity supplied and quantity demanded and thus, what we observe is

$$q_{it} = q_{dit} = q_{sit} \quad (3)$$

Equations 1 and 2 now become:

$$q_{it} = \beta_1 w_{it} + x_{it}' \beta_2 + \varepsilon_{dit} \quad (4)$$

$$q_{it} = \alpha_1 w_{it} + x_{it}' \alpha_2 + \varepsilon_{sit} \quad (5)$$

Solving for wage and quantity, we can rewrite the two equations above with the endogenous variables on one side and exogenous variables on the other.

$$w_{it} = x_{it}' \gamma_1 + u_{itw} \quad (6)$$

$$q_{it} = x_{it}' \delta_1 + u_{itq} \quad (7)$$

Wage is a function of the exogenous variables, x_{it} , and an error term u_{itw} and quantity is a function of the exogenous variables, x_{it} , and an error term u_{itq} .

The next issue that arises stems from the economic assumption that wage is determined endogenously in the supply and demand model. We expect that $\beta_1 \leq 0$ and $\alpha_1 \geq 0$. This comes from the basic economic theory that says wage and quantity demanded are inversely related while wage and quantity supplied are directly related. OLS estimation of equation 4 or 5 will lead to biased and inconsistent estimates for both β_1 and α_1 . Instrumental variables are often used in economic analyses to account for different biases, and this paper follows the methods in Angrist et al. (2000) and Lin (2011) using instrumental variables and two stage least squares to estimate simultaneous equations.

To apply the Instrumental Variable technique, we make the following assumptions:

1. $q_{it} = q_{dit} = q_{sit}$ at a market clearing wage.
2. $x_{it} = (x_{it}^d, x_{it}^s, x_{it}^c)$
where x_{it}^d are variables that shift demand but not supply, x_{it}^s are variables that shift supply but not demand, and x_{it}^c are variables that may affect both supply and demand.

The supply and demand equations can now be written as follows:

$$q_{dit} = \beta_1 w_{it} + x_{it}^d' \beta_2^d + x_{it}^s' \beta_2^s + x_{it}^c' \beta_2^c + \varepsilon_{dit} \quad (8)$$

$$q_{sit} = \alpha_1 w_{it} + x_{it}^d' \alpha_2^d + x_{it}^s' \alpha_2^s + x_{it}^c' \alpha_2^c + \varepsilon_{sit} \quad (9)$$

3. $\beta_2^s = 0$ and $\alpha_2^d = 0$.

This assumption follows from the claim that x_{it}^d shifts demand but not supply and x_{it}^s shifts supply but not demand.

The supply and demand equations can now be written as:

$$q_{dit} = \beta_1 w_{it} + x_{it}^d \beta_2^d + x_{it}^c \beta_2^c + \varepsilon_{dit} \quad (10)$$

$$q_{sit} = \alpha_1 w_{it} + x_{it}^s \alpha_2^s + x_{it}^c \alpha_2^c + \varepsilon_{sit} \quad (11)$$

Since we have assumption 1, in order to estimate β_1 , β_2^d , β_2^c , α_1 , α_2^s , and α_2^c consistently, we use instrumental variables. The variables x^s can be used as an instrument for wage in equation (10) as it is correlated with wage through equation (6), but is uncorrelated with the error term through assumption 3. Similarly, x^d can be used as an instrument for wage in equation (11) as it is correlated with wage through equation (6) but uncorrelated with the error term through assumption 3.

Given valid instruments x^s and x^d , and employing 2 Stage Least Squares Regression, the estimates for β_1 , β_2 , α_1 and α_2 will be consistent and unbiased (Angrist et al. 2000). Therefore, we can appropriately estimate equations for quantity supplied and quantity demanded and determine effects of wage, other endogenous variables, and exogenous variables.

III. Identification

The purpose of this paper is to estimate the supply and demand equations in the market for audiologists. To do so, the model described above is applied, with the exogenous variables defined as follows:

x^c : a vector that includes unemployment rate, per capita income, population, year and state fixed effects.

x^s : the number of audiology programs

x^d : the number of Costco Shopping Centers, percent of population 85 years and older

The vector of exogenous control variables, x^c , includes unemployment rate, per capita income, population, and fixed effects. These variables are exogenous to the model and affect both the supply and the demand for audiologists.

The instrument variable, x^s , is the number of audiology programs. We argue that x^s is a supply shifter but not a demand shifter: i.e. x^s belongs in equation (11) but not in equation (10). The only way to practice as an audiologist is to obtain a degree from an accredited audiology program. Clearly if the number of audiology programs increases, at any given wage, more students have the opportunity to attend a program and thus to become a certified audiologist. Therefore, the supply will increase along with the number of audiology programs and so x^s appropriately belongs in equation (11). We now claim that x^s does not belong in equation (10).

While it is intuitive that as demand for labor rises, so too will the demand for educational programs, it is also the case that schools are slow to respond to these changes in demand due to long lags of opening a new 4 year AuD program. Thus, the effect of demand on the number of audiology programs would not be realized until several years later, and thus, we claim that in a given state and given year, the number of programs available is not correlated with the demand for audiologists. Therefore, we claim that x^s is uncorrelated with the error term in (10) and is thus a valid instrument to use in estimating the demand equation.

The instrumental variables, x^d , are the number of Costco warehouses and the percent of population 85 years and older. We first argue that x^d belongs in equation (10) but not in equation (11). Over half of the population over 85 years of age experience significant hearing loss and thus demand hearing health services. So clearly, this variable is a determinant of demand and belongs in equation (10). Next, we discuss the Costco instrument with these assumptions⁷:

- As time progresses, hearing aid technology advances.
- Demand for hearing aids increases with a rising aging population.
- Seeing this, Costco decides to add Hearing Centers to existing and future stores; now, almost all US Costco stores provide hearing aid tests and sell hearing aids to adults (Costco Annual Report to Shareholders, 2016; Hosford-Dunn, 2017d; Swearingen, 2017).
- Although Costco may seek to hire audiologists to work in their Hearing Centers, it also exercises the option in its business model to hire state-licensed hearing aid dispensers and/or train existing employees in-house (Yang et al., undated). to be licensed hearing aid dispensers, both of which offer employer cost savings. (Hosford-Dunn, 2017c).

Therefore, many people who traditionally sought out audiologists to obtain hearing aids can now choose to see a hearing aid specialist at Costco, a close substitute in demand for audiologists. With this emerging substitute for hearing aids and associated services, we expect to see a decrease in demand for audiologists, and thus we believe that this variable appropriately belongs in equation (10).

What is left to show is that x^d is uncorrelated with the error term in supply equation (11). The quantity of audiologists supplied is essentially the number of licensed audiologists who want to work as audiologists. This is an individual choice that entails extensive schooling and high cost to obtain the required degree and licensure. Therefore, it is unlikely that the percentage of people 85 years and older or the number Costco shopping centers in a state will influence an individual's complex academic/professional decision to work as an audiologist. If we can believe that this is true, i.e. that the decision to work as an audiologist is independent of the percentage of older individuals and the number of Costco's per state, then we see that x^d is uncorrelated with the error term in (11) and is thus a valid instrument for estimating the supply equation.

⁷ "Costco" may serve in the near future as a proxy for other large retailers (e.g., CVS, Walgreens) that are likely to enter the market and emulate the Costco model.

Given the arguments above and the model described in section II, the following 2SLS analysis for supply and demand is employed:

Stage 1: Regress wage on x^d , x^s , and x^c to obtain an estimate for wage, \hat{w}

Stage 2: Regress quantity on \hat{w} , x^c , and x^d to get estimates for equation (10) and regress quantity on \hat{w} , x^c , and x^s to get estimates for equation (11)

IV. Data

The analysis was done using a panel data set with observations for each US state and District of Columbia for the years 2009 to 2014.⁸ The analysis starts in 2009 as that is the last year in which programs transitioned from a master to a doctoral program.⁹

The total number of audiologists for each state and each year was collected from the Bureau of Labor Statistics. In addition, the average salaried wage was also obtained from the BLS. To adjust for inflation, the average salaried wage was divided by the CPI with the base year of 1982.

The number of programs was obtained from The American Speech and Hearing Association (ASHA) yearly academic reports (CDS education survey data). These data are available from 2009/2010 school year to the 2014/2015 school year. The observations are recorded as the year of the respective fall semester.

The Costco data were obtained from financial records in the public domain. Specifically, Costco Annual Reports to shareholders and Costco 10-K Annual reports submitted to the Securities and Exchange Commission were accessible through Internet searches for most years included in the present study.

Additional variables used in the model are:

- the unemployment rate
- per capita income
- total population
- percentage of the population 85 years and older.

⁸ This results in 306 potential observations. However due to missing observations, we are left with 254 total observations for the final analysis. For example, Alaska did not report the number of audiologists to BLS and thus is removed from the analysis.

⁹ Some states require a 4 year AuD degree to practice audiology while some other states still only require a Masters. Unfortunately, we do not have a variable that represents this requirement. In addition, for states with the doctoral requirement, audiologists already in the workforce were grandfathered in under licensure laws.

The unemployment rate was obtained from the BLS website and represents annual averages. The total population and the percentage of the population 85 years and older was obtained from the United States Census. Per capita income was obtained from the Bureau of Economic Analysis and is adjusted to real values given the CPI with base year 1982.

Table 1 shows the national summary statistics for the variables of interest and Table 2 shows the state summary statistics from years 2009 to 2014.

Table 1: National Summary Statistics

	Total Audiologists	Average Salaried Wage	Percent of Population 85up	Population (100,000)	Per Capita Income	Unemployment Rate	Number of Programs	Number of Costcos
Mean	12300.00	71955.00	1.75	3139.56	51485.00	8.32	74.33	442.33
SD	459.65	3506.62	0.07	36.32	2815.43	1.33	0.52	22.94
Min	11550.00	66850.00	1.70	3093.48	48050.00	6.20	74.00	413.00
Max	12860.00	76790.00	1.80	3185.63	55320.00	9.70	75.00	474.00
Missing	0	0	4	1	0	0	0	0

Table 2: State Summary Statistics

	Total Audiologists	Average Salaried Wage	Percent of Population 85up	Population (100,000)	Per Capita Income	Unemployment Rate	Number of Programs	Number of Costcos
Mean	281.26	70660.52	1.80	61.35	42675.13	7.59	1.44	8.59
SD	246.28	10143.67	0.39	68.90	7747.81	2.05	1.37	16.95
Min	30	48690	0.6	5.6	30569	2.7	0	0
Max	1560.00	102360.0	2.70	387.92	70379.00	14.40	5.00	120.00
Missing	52	37	0	0	0	0	0	0

Since we are analyzing panel data, a better way to understand the data is to visualize the progression of variables over time. Plots are on the national level, but are representative of the trends within states. Figure 1 shows the quantity of audiologists across time. Figure 2 shows the real annual wage trend across time. Figure 3 shows both the number of programs over time along with the number of applications and entering students.

Figure 1: Number of Audiologists Trend

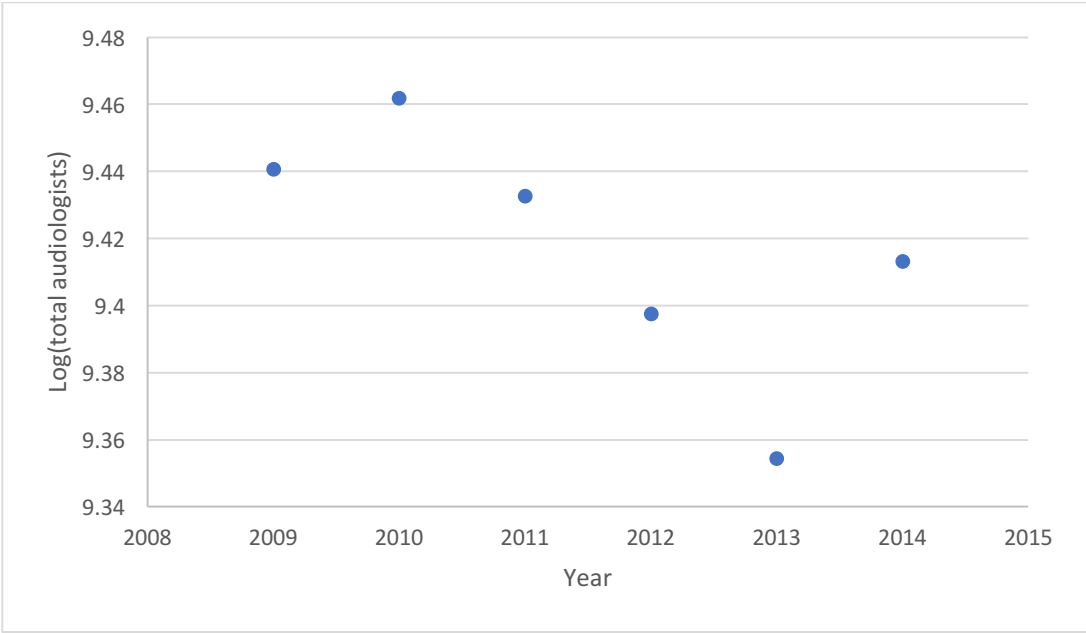


Figure 2: Real Annual Earnings Trend

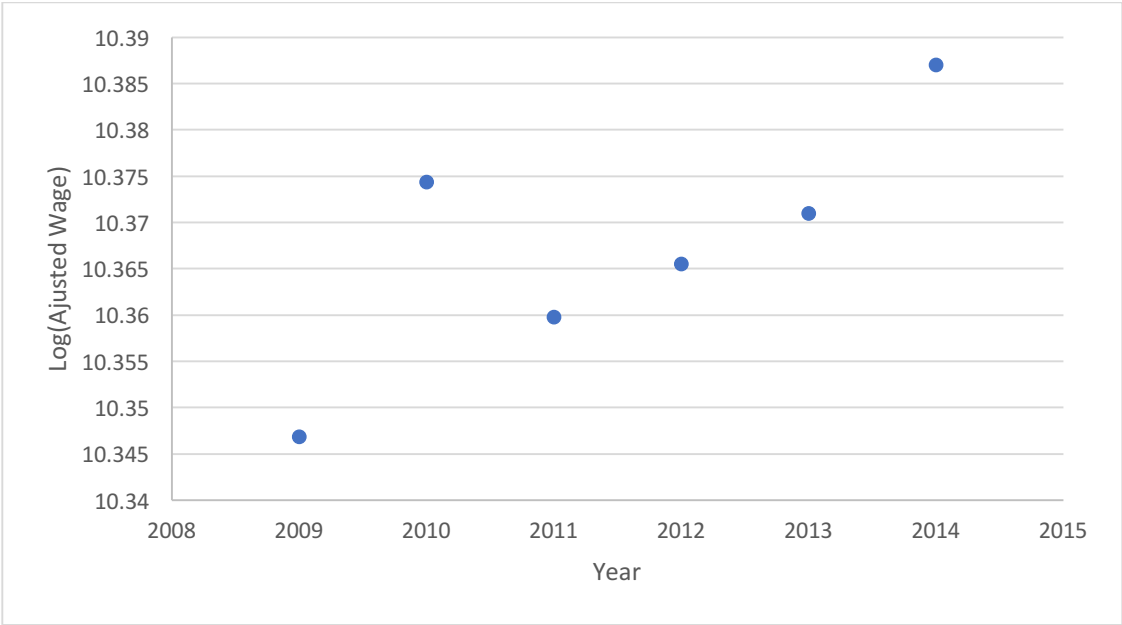


Figure 3: Academic Variable Trends

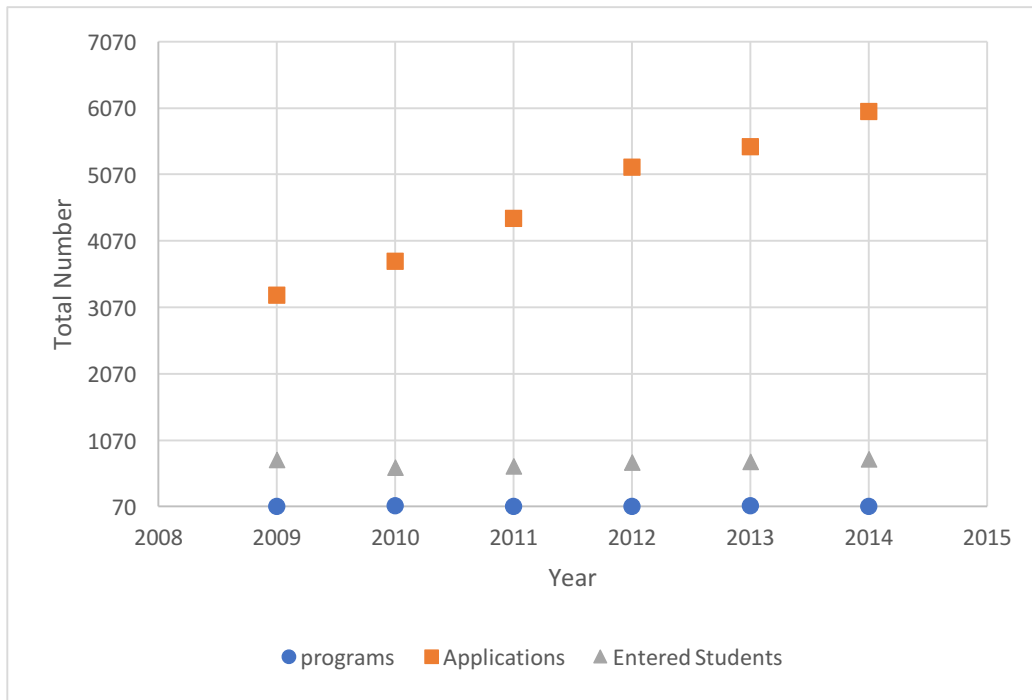


Figure 2 shows that the real annual earnings are generally increasing over time. This can be indicative of a rise in demand, a fall in supply, or both. Along with Figure 1, we see a scatter of equilibrium quantities which is indicative that over time the market experiences both a shift in supply and a shift in demand. The analysis of this paper attempts to predict the indicators of these shifts.

Figure 3 shows that while the number of programs and number of entering students stays relatively constant over time, the number of applications increases.¹⁰ This suggests that the supply for audiologists would be increasing had there not been a static program and acceptance rate.

V. Results

Given the model, the identification strategy, and the data, we can now summarize the results. Three different regressions were run for each equation estimation and shown in columns in Tables 3-6:

- Column (1): without fixed effects

¹⁰ The increase in applications may reflect growth of total number of perspective students or a growing trend for applicants to apply to multiple programs. Efforts to obtain data in this regard are under way.

- Column (2): with year fixed effects
- Column (3): with year and state fixed effects

Due to the lack in variation across time in the number of school programs available per state, we lose explanatory power by including state fixed effects, but all three regressions are included for comparison. The remaining discussion of the results focuses on the regression with year fixed effects only, which is represented in column two of each table. Tables 3 and 4 present the results from the reduced form estimation, equations (6) and (7) respectively.

Table 3: Reduced Form Equation for Wage

Dependent Variable: Log(Real Annual Earnings)			
	(1)	(2)	(3)
Log(Adjusted Per Capita Income)	0.340*** (0.046)	0.344*** (0.046)	1.049*** (0.300)
Population (100,000)	0.001*** (0.0002)	0.001*** (0.0002)	0.0001 (0.004)
Unemployment Rate	0.009** (0.004)	0.012** (0.005)	-0.003 (0.009)
% Population 85 yrs+	-1.031 (2.215)	-0.985 (2.222)	5.073 (10.722)
Programs	-0.046*** (0.008)	-0.046*** (0.008)	-0.012 (0.024)
Costcos	-0.002** (0.001)	-0.002** (0.001)	-0.009 (0.008)
Year Fixed Effects	N	Y	Y
State Fixed Effects	N	N	Y
N	269	269	269
R2	0.299	1.000	1.000
Adjusted R2	0.283	1.000	1.000

Notes:

***Significant at the 1 percent level.
 **Significant at the 5 percent level.
 *Significant at the 10 percent level.

Table 4: Reduced Form Equation for Employment

Dependent Variable: Log(Quantity of Audiologists)

	(1)	(2)	(3)
Log(Adjusted Per Capita Income)	0.352* (0.197)	0.353* (0.199)	-1.055 (0.976)
Population (100,000)	0.008*** (0.001)	0.008*** (0.001)	0.011 (0.012)
Unemployment Rate	0.049*** (0.017)	0.054** (0.022)	0.051* (0.029)
% Population 85 yrs+	0.947 (9.847)	0.725 (9.935)	-27.568 (36.806)
Programs	0.192*** (0.032)	0.191*** (0.032)	0.056 (0.077)
Costcos	-0.003 (0.004)	-0.003 (0.004)	0.023 (0.026)
Year Fixed Effects	N	Y	Y
State Fixed Effects	N	N	Y
N	254	254	254
R2	0.696	0.992	0.998
Adjusted R2	0.688	0.992	0.998

Notes:

***Significant at the 1 percent level.
 **Significant at the 5 percent level.
 *Significant at the 10 percent level.

As stated in Section II of this paper, the estimates shown in Table 3 and Table 4 will be biased, so these tables are only provided to show the sign and significance of the covariates on wage and quantity of labor. The dependent variable for equation (6) is the log of the real annual earnings, and the dependent variable for equation (7) is the log of the total number of audiologists.

As shown in the tables, the supply shifter, number of audiology programs, has a negative effect on wage but a positive effect on quantity. Economic theory suggests that an equilibrium wage decrease and quantity increase is associated with an increase in supply, which supports the claim that the number of audiology programs is a supply shifter.

The demand shifter, percent of population 85 years and older, has no significant effect on wage or quantity and the sign changes depending on the specification. So, the results from the table do not tell us much about the effect of this variable on demand or supply, but we rely on the intuition explored in Section III of this paper and keep this as a demand shifter in the analysis.

The other demand shifter, number of Costco warehouses, has a negative and significant effect on wage but no significant effect on quantity. Economic theory would suggest that this variable is either associated with a decrease in demand or an increase in supply. Relying on the intuition discussed in Section III of this paper, we claim it is the former.

We identify the strength of the instruments by looking at the first stage regression which is represented in Table 3. The F-statistic for the number of programs in the first two specifications are 36.6 and 37.3 respectively.¹¹ The strength of the instrument decreases significantly when including state fixed effects, however we will put the focus on the second regression in which this is a strong instrument for wage.¹² The F statistic for Costco in the first two specifications is 5.06 and 5.48 respectively. Again, in the third regression, the strength decreases significantly and we note that the strength of the other demand instrument, percent of population over 85 years, is also weak. Ideally, a stronger instrument would be preferred, but given the limitations in the data, we claim that these are valid instruments for our preliminary analysis.

Because both x^d and x^s hold some explanatory power in these first stage regressions, we can now run the second stage regressions, presented in Tables 5 and 6. Table 5 presents the results for estimating supply and Table 6 presents the results for estimating demand.

Table 5: Second Stage Estimation of Supply Equation

Dependent Variable: Log(Quantity of Audiologists)			
	(1)	(2)	(3)
Log(Real Annual Wages)	1.113 (1.597)	1.082 (1.510)	-1.687 (2.422)
Log(Adjusted Per Capita Income)	-0.009 (0.539)	-0.006 (0.520)	0.845 (2.655)
Population (100,000)	0.006*** (0.001)	0.006*** (0.001)	0.011 (0.013)
Unemployment Rate	0.037 (0.023)	0.038 (0.029)	0.045 (0.034)
Programs	0.247*** (0.063)	0.246*** (0.060)	0.037 (0.090)
Year Fixed Effects	N	Y	Y
State Fixed Effects	N	N	Y
N	254	254	254
R2	0.695	0.992	0.998
Adjusted R2	0.689	0.992	0.998

Notes:

***significant at the 1 percent level.
 **significant at the 5 percent level.
 *significant at the 10 percent level.

¹¹ The values in the tables represent rounded numbers while the F-statistic was calculated using non-rounded estimates and standard errors.

¹² As a rule of thumb, a strong instrument should have an F-statistic of at least 10.

Referring to Table 5, we can estimate the supply equation using the percentage of population of 85 years or older and the number of Costcos as instruments for wage, we find in the second stage results that a 1% increase in real annual earnings leads to a 1.1% increase in quantity supplied. The positive effect is consistent with economic theory that an increase in the wage is associated with an increase in the number of individuals willing to work for the wage. However, this effect is not significant or large, and in the regression in the third column, the effect even has the opposite sign, which contradicts basic economic theory. We explain this odd result in two ways:

- 1) The data is limited and the demand shifter instruments are weak; thus we are not picking up the full effect of wage on supply.
- 2) Even with a more complete dataset, it is not unreasonable to believe that the price elasticity of supply might still be small. Choosing audiology over other healthcare occupations with higher average wages and/or lower academic training time implies a passion for serving the health needs of others notwithstanding the high cost of schooling and relatively low wage base. Perhaps this passion for the career overpowers the economic force of wage and thus we would be willing to believe that the supply of audiologists is price inelastic.

What is interesting in this analysis is that the strongest determinant of supply is the academic variable, the number of programs available. Besides population, the other regressors have either no or weak explanatory power. This could be due to the fact that supply is largely determined by the availability of academic programs required to become an audiologist. As shown in the data section of this paper and visualized in Figure 2, the real annual earnings are increasing with time. Thus, it is likely that audiologists already in the market will continue to work and that this wage increase attracts new audiologists to the market. However, potential new audiologists may be blocked from entering the market due to the limited number of audiology academic programs. This analysis is consistent with the findings of Windmill and Freeman (2013) that supply of audiologists is largely dependent on the academic programs and admittance and graduation rates.¹³

¹³ See Windmill and Freeman (2013) for a discussion on how to combat this potential issue.

Table 6: Second Stage Estimation of Demand Equation

Dependent Variable: Log(Quantity of Audiologists)			
	(1)	(2)	(3)
Log(Real Annual Wages)	-4.159*** (1.028)	-4.075*** (1.006)	-4.102 (8.806)
Log(Adjusted Per Capita Income)	1.796*** (0.459)	1.796*** (0.458)	3.219 (9.394)
Population (100,000)	0.012*** (0.001)	0.012*** (0.001)	0.011 (0.018)
Unemployment Rate	0.090*** (0.027)	0.110*** (0.034)	0.032 (0.059)
% of Population 85+	-11.588 (14.848)	-12.318 (14.827)	-25.209 (57.561)
Costcos	-0.011*** (0.004)	-0.012*** (0.004)	-0.026 (0.112)
Year Fixed Effects	N	Y	Y
State Fixed Effects	N	N	Y
N	254	254	254
R2	0.334	0.983	0.996
Adjusted R2	0.318	0.982	0.995

Notes:

***Significant at the 1 percent level.

**Significant at the 5 percent level.

*Significant at the 10 percent level.

The results for the demand estimates are shown in Table 6. Using the number of programs as an instrument for wage, in the second stage results we see that a 1% increase in real annual earnings leads to a -4.1% decrease in quantity demanded. The negative effect is consistent with economic theory that an increase in wage is associated with employers offering fewer audiology jobs in the market. This effect is large, which suggests the demand for audiologists is price elastic. This could be explained by the substitutes in labor demand, namely hearing aid specialists (Hosford-Dunn, 2017c). Hearing aid specialists are licensed to dispense hearing aids as their primary professional activity. Hearing aid dispensing is a primary duty of many audiologists, along with other duties they may perform under their scope of practice. Hearing aid dispensers earn on average \$11,000 less per year in real wages than audiologists mainly because state licensing distinguishes between differences in training requirements and scopes of practice between the two careers. Therefore, if the wage for audiologists increases, employers may shift employment to hearing aid specialists in situations where the main duty is testing and fitting hearing aids.¹⁴

¹⁴ Since the profession of Hearing Aid Specialists is fairly new, BLS does not have enough data on wages and quantity to include this in our analysis.

The results in Table 6 also support that claim that the number of Costcos in a state decreases the quantity of audiologists demanded. We can infer the demand for hearing aids in particular has increased with the aging population, the advances in technology, and the decrease in the social stigma around hearing aids. Costco takes on this demand by opening up hearing centers in their stores to provide basic hearing tests and sell hearing aids. Whereas when people formerly would need to see an audiologist for these services and products, they can now obtain them at Costco. In addition, Costco may not prefer to (or be able to, see Swearingner, 2017) hire licensed audiologists when instead they may train and hire from within or hire hearing aid specialists. Therefore, as more Costcos open in a state, we might expect more people to prefer Costco for their basic hearing aid needs (Hosford-Dunn, 2017e,f) and thus experience a decrease in the demand for audiologists.

From table 6, we also see that a 1% increase in income results in a 1% increase in quantity of audiologists demanded, suggesting that this is a normal good. In addition, we unexpectedly see a significant and positive effect of overall unemployment rate on quantity demanded. Though this paper does not explore this result, some recent research has found that demand for healthcare workers is countercyclical.¹⁵

VI. Conclusion

Recent research on the audiology profession done by Windmill and Freeman (2013) and Hosford-Dunn (2017a,b,c) finds that future demand for audiologists will outnumber the supply. The analysis in this paper, on the other hand, uses a similar data set but assumes that markets clear- i.e. observations reflect market equilibrium. We extend on this assumption by estimating the equations for supply and demand using instrumental variables and two stage least squares regression technique.

We find that since Costco stores have introduced hearing centers, they offer some of the services that audiologists provide, namely hearing tests and selling hearing aids. With this, we made an argument that the number of Costco centers in a state, along with the percentage of people 85 years and older, are exogenous determinants of demand and are used as an instrument for wage. This leads to a consistent estimation for the supply equation in which we determine that supply is relatively price inelastic.

We also argue that while the number of audiology programs affects quantity supplied, it is not correlated with quantity demanded due to the extreme lagged response of starting these 4 year AuD programs. Using this as our instrument, we see that a 1% increase in wage leads to a 4% decrease in quantity demanded and suggests that demand for audiologists is price elastic.

This paper is the first to estimate the supply and demand equations for audiologists. We are able to use instruments to consistently estimate price elasticities for supply and demand as well as determine effects by other exogenous regressors. One important contribution comes from the analysis done on the Costco variable and quantity demanded. We analytically found that more

¹⁵ See Staiger et al. (2012)

Costcos in each state leads to a decrease in quantity demanded. We argue that this negative effect is due to the fact that Costco Hearing Centers have become a substitute in the market for hearing aids. And, while audiologists provide more advanced services than simple hearing tests and providing hearing aids, they nonetheless do not set themselves apart enough from Costco to distinguish a better service in that particular category and that is why there is a decrease in the quantity demanded.

Another important contribution comes from the analysis done on the education variables and quantity supplied. Windmill and Freeman (2013, 2017) and Hosford-Dunn (2017b) both discuss that supply is stifled by the lack of growth in the audiology programs. The analysis in this paper showed that the number of programs indeed has a much higher significant effect on quantity supplied than any of the other variables and supports the idea that for the profession to grow, we would need growth in academic programs. Thus, the results in this paper do agree with those made by Windmill and Freeman (2013) regarding the lack of growth in supply, however we also note that while demand for hearing based services is growing, the demand for audiologists as provider of choice may not be growing at the same rate, due to Costco's entrance into the hearing aid market.

The data collected for this analysis includes many more variables that could be included in the analysis on quantity supplied. For example, in future work we hope to add wages for substitute careers in the analysis along with other academic variables such as number of applications and percentage of students to receive funding. In addition, we plan to amass more data regarding the employment structure- i.e. highest education, distribution of workplace, retirement rates, and audiology unemployment rates. With this data, we can relax assumption 1, that markets clear, by including the unemployment rate for audiologists into the above analysis. The richer dataset will also allow more accurate estimates for price elasticities and estimates of other determinants of supply and demand for the audiology labor market.

References

- Angrist, J.D., Graddy, K. and Imbens, G.W., 2000. "The interpretation of instrumental variables estimators in simultaneous equations models with an application to the demand for fish." *The Review of Economic Studies*, 67(3), pp.499-527.
- Angrist, J and Krueger, AB, 2001. "Instrumental variables and the search for identification: From supply and demand to natural experiments" (No. w8456). National Bureau of Economic Research.
- Chen, MK and Chevalier, JA, 2012. "Are women overinvesting in education? Evidence from the medical profession." *Journal of Human Capital*, 6(2), pp.124-149.
- Goman, AM and Lin, FR, 2016. "Prevalence of Hearing Loss by Severity in the United States." *American journal of public health*, 106(10), pp.1820-1822.
- Hosford-Dunn, H, 2017a. [New Year's Resolution: Demand an Audiologist](#). Jan 3, Hearing Economics, HearingHealthMatters.org.
- Hosford-Dunn, H, 2017b. [How much and how low, Audiology workforce part 2](#). Jan 10, Hearing Economics, HearingHealthMatters.org.

- Hosford-Dunn, H, 2017c. [Supply and demand in the audiology labor market, part 4](#). Feb 21, Hearing Economics, HearingHealthMatters.org.
- Hosford-Dunn, H, 2017d. [Costco growth – get your hot dogs and hearing aids here!](#) Apr 4, Hearing Economics, HearingHealthMatters.org.
- Hosford-Dunn, H, 2017e. [Costco’s business model: Build it and they will come](#). Apr 12, Hearing Economics, HearingHealthMatters.org.
- Hosford-Dunn, H, 2017f. [The Costco way: Ya gotta eat and ya oughta hear](#). May 17, Hearing Economics, HearingHealthMatters.org.
- Kalist, DE and Spurr, SJ, 2004. “The effect of state laws on the supply of advanced practice nurses.” *International journal of health care finance and economics*, 4(4), pp.271-281.
- Lin, CYC, 2011. “Estimating supply and demand in the world oil market.” *Journal of Energy and Development*, 34(1), pp.1-32.
- Qin, X, Li, L and Hsieh, CR, 2013. “Too few doctors or too low wages? Labor supply of health care professionals in China.” *China Economic Review*, 24, pp.150-164.
- Sekscenski, ES, Sansom, S, Bazell, C, Salmon, ME and Mullan, F, 1994. “State practice environments and the supply of physician assistants, nurse practitioners, and certified nurse- midwives.” *New England Journal of Medicine*, 331(19), pp.1266-1271.
- Showalter, MH and Thurston, NK, 1997. “Taxes and labor supply of high-income physicians.” *Journal of Public Economics*, 66(1), pp.73-97.
- Staiger, DO, Auerbach, DI and Buerhaus, PI, 2012. “Registered nurse labor supply and the recession—are we in a bubble?.” *New England Journal of Medicine*, 366(16), pp.1463- 1465.
- Sundstrom, W. Guide to R for SCU Economics Students: Instrumental Variables Regression. [https://rstudio-pubs-static.s3.amazonaws.com/109978_7bfc270924c1474e924ddd42e998d42.html].
- Swearinger, G. April 18, 2017. FTC Workshop Transcript Now Hear This: Competition, Innovation, and Consumer Protection Issues in Hearing Health Care. Federal Trade Commission.
- Windmill, IM and Freeman, BA, 2013. “Demand for audiology services: 30-yr projections and impact on academic programs.” *Journal of the American Academy of Audiology*, 24(5), pp.407-416.
- Windmill, IM and Freeman, BA. 2017. [Demand an audiologist, but will there be one available?](#) Hearing Economics, HearingHealthMatters.org.
- Yang, J, Whitfield, M, McKee, C. et al. (undated). Competition with both quality and quantity – a case study. <http://www.aabri.com/SC2015Manuscripts/SC15032.pdf>

Data Sources

- Bureau of Labor Statistics, U.S. Department of Labor, *Occupational Employment Statistics*, [Jan. 26, 2017] [www.bls.gov/oes/].
- Communication Sciences and Disorders (CSD) Education Survey Data Reports. [Feb 17, 2017] [http://www.asha.org/Academic/HES/CSD-Education-Survey-Data-Reports/].
- Costco Annual Reports to shareholders [http://phx.corporateir.net/phoenix.zhtml?c=83830&p=irol-reportsannual]
- Costco Annual 10-K financial reports to SEC.
- U.S. Bureau of Economic Analysis, [Feb. 17, 2017] [https://www.bea.gov/].

United States Census, State Population Totals Tables: 2010:2016, [Jan 18, 2017]
[<https://www2.census.gov/programs-surveys/popest/datasets/>]

Collaborators

The authors wish to thank Neil diSarno and Sarah Slater from the American Speech-Language-Hearing Association; Ian Windmill and Barry Freeman from the American Audiology Association; and Carole Rogin from the Hearing Industries of America. They, and the groups they represent, contributed extensive data and perspectives to the project. We also wish to thank Harvey Abrams for his encouragement and assistance at each step of the study from its inception.