2016

The Uber Effect

Richard William Kelly
Western University, rkelly59@uwo.ca

The University of Western Ontario

QUANTIFYING UBER'S EFFECT ON TAXI MEDALLION PRICES

ECONOMICS UNDERGRADUATE THESIS

April 4th 2016

Author
Richard William Kelly

Advisor
Professor Terry Sicular

THE UBER EFFECT

ABSTRACT

Taxi industries across the world have been affected by a new trend in transportation; ridesharing services. It is suggested that this effect has been demonstrated through falling taxi medallion prices. This recent decline in taxi medallion prices has been coined the term “The Uber Effect”. This paper analyzes the effect that Uber has had on the taxi industry’s medallion prices since UberX has entered three different markets: New York City, Chicago and Philadelphia. The price of a taxi medallion is modeled against a variable of interest: number of Uber drivers in a city, and control variables: unemployment rate, long term interest rate and labor force population. Through individual city and panel regression analysis, The Uber Effect is tested and quantified.

The key finding from this paper is that the number of Uber drivers in the market is negatively correlated with the price of a taxi medallion, as expected. It is statistically and economically significant; each additional Uber driver reduces the price of a taxi medallion by $22 to $45. Furthermore, the unemployment rate and labor force population variables are statistically significant in all cities used in this study.

INTRODUCTION

Taxi industries across the world have been highly regulated with minimal innovation over the past century. Many American cities still operate under a taxi medallion system. A taxi medallion is a permit for a vehicle to be used as a taxi. Cities that operate under this system limit the number of taxi medallions available. The goal of the medallion system is to control the supply of taxis in the market and to maintain an efficient amount of taxis. However, in many American cities there is an undersupply of taxis (Schaller, 2005). The limited supply of taxi medallions makes them a valuable asset, and from early 2000 until 2013 they have been seen as a great investment as shown by their skyrocketing price (Cumming, 2009). In recent years the price of a taxi medallion has been plummeting from a high of over $1,100,000 in New York City in November 2013 to $600,000 in July 2015 (NYC T&LC, 2016). It is expected that the cause of this drop in medallion price is due to the recent entry of ridesharing companies (Barro, 2014). Ridesharing has disrupted the taxi industries in cities across the world, with the most well-known disruptor being Uber. This study will discover if conventional wisdom is correct; if Uber is causing taxi medallion prices to drop.

The hypothesis is that the dropping price of taxi medallions is due to Uber’s entry to the market; the number of active Uber drivers in the market is statistically significant in determining the price of a taxi medallion with a negative coefficient.

Uber is considered a technology company that simply connects people. Uber connects individuals needing to be driven from point A to point B (riders) with individuals who are available to drive customers (driver partners) through a smartphone application (Nilsen, 2015). There are many different services Uber offers, however the service that stirs up the most controversy is UberX (Elliot, 2014). This service receives the most pushback from the taxi industry because it is a nearly perfect substitute service to a taxi, but it offers the service at a lower price. UberX can charge lower fares because it bypasses taxi industry regulations, such as buying a taxi medallion (Castle, 2015) and insurance requirements (Appel, 2015), which also leaves Uber's operations in a legal gray area. The UberX service essentially allows any person with a clean background check and a vehicle in good condition to act as a taxi driver (Castle, 2015).

LITERATURE REVIEW

This research can be considered an extension of Dan Cumming's Paper "Why has the Price of Taxi Medallions Increased So Dramatically? An Analysis of the Taxi Medallion Market". The research analyzes the price of a New York City taxi medallion from 1976 to 2007. This paper contributes great insight for understanding what causes the fluctuation in taxi medallion prices, however it only analyzes data up to 2007 and misses the entry of Uber., Cumming's research used annual data while this research uses monthly data for the analysis. Additionally, this research paper includes an analysis of Chicago and Philadelphia, not just New York City. This paper utilizes Cumming's research paper and variables found within it as a base reference. The key finding of Cumming's research is that the economic health of a city is a key determinant in the price of a taxi medallion. In his study, this was represented by New York City's unemployment rate. This is expanded on by adding new variables, with Uber driver data being the variable of interest.

The paper "Elasticities for taxicab fares and service availability" by Bruce Schaller examines the change in trip demand with change in taxi fares. This paper concluded that as taxi fares increase, trip demand decreases but overall taxi drivers earned more revenue with a fare increase (Schaller, 1998). This should in turn increase the value of a taxi medallion. However, this study focused on the years of 1990 to 1996, prior to Uber's entry. A taxi fare increase would likely reduce the overall revenue of the taxi industry with Uber in the market. Prior to Uber's entry, individuals did not have an alternative and if they needed a ride, they had to use a taxi. Now they can choose Uber as a less expensive alternative, therefore taxi fares are not included in the study.

The paper "A Regression Model of the Number of Taxicabs in U.S. Cities" by Bruce Schaller models the number of cabs in 118 American cities modeled by a variety of determinants of taxi demand. This paper shows certain demand factors that can affect the value of a taxi medallion. It demonstrates the importance of an efficient amount of taxis to prevent an undersupply or oversupply. Uber does not control the number of Uber driver partners in the market, disrupting the equilibrium.

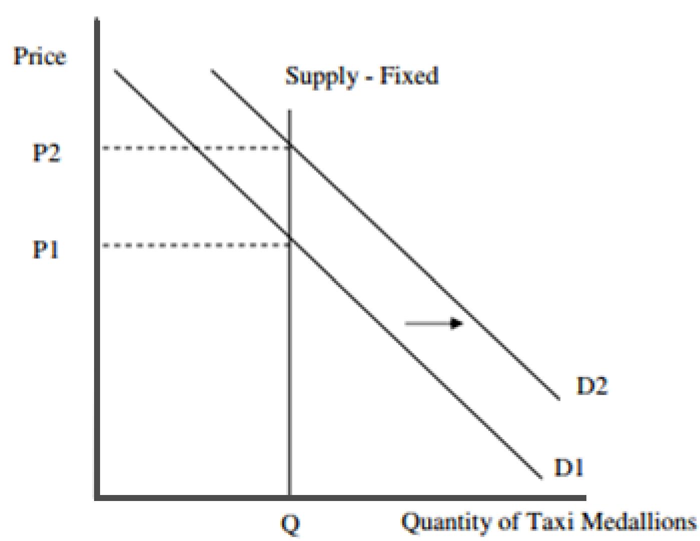
CONTRIBUTION

The research conducted in this study is the first of its kind and quantifies the effect Uber has had economically on the taxi industry. It presents insight into how Uber has affected the price of a taxi medallion since their entry to the market. This paper also provides insight on other independent variables that are significant in determining the price of a taxi medallion. The implications from this paper are that if the taxi industry does not adapt, or if regulations for ridesharing services aren't implemented in a timely manner, the taxi industry will continue to struggle and could eventually collapse. Driver partners are growing exponentially and Uber continues to capture market share from the taxi industry. For cities that have not yet adopted or created new regulations for ridesharing companies, this paper provides insight on the impact of ridesharing on existing taxi services. In addition to the taxi industry, this paper demonstrates the effect that the new "sharing" economy can have on existing industries.

ECONOMICS OF TOPIC

The underlying economics behind changing taxi medallion prices is demonstrated by changes in demand variables. For example, it is expected that an increase in the number of Uber drivers will decrease the demand for a taxi service, thereby decreasing the price of a taxi medallion. This is done by increasing the supply of Uber vehicles available, a (nearly perfect) substitute service to taxis. Figure 1 illustrates how a demand shift works (Cumming, 2009). The shift in demand from D1 to D2 can be explained by a decrease in the number of active Uber drivers. This demonstrates that an increase in demand will increase the price of a taxi medallion, shifting from P1 to P2. The supply does not move in this model because the taxi medallion system fixes the supply of taxis in the market.

FIGURE 1: SUPPLY AND Demand OF TAXI MEDALLIONS



Data

The following section details the data used in this analysis. It reviews each variable used, the data source and retrieval method. Each variable used is in terms of monthly data, spanning a time period of 71 months starting in May 2009.

Dependent Variable

Value of a Taxi Medallion

The value of a taxi medallion is the market value of a taxi medallion in USD being sold in a regulated secondary marketplace. Given that less than 6 years of data is used, adjusting for inflation would not produce a material difference in the results, therefore these values are not adjusted for inflation. The New York City data was sourced from the New York City government website, specifically from the Taxi and Limousine Commission section. The Chicago data was sourced from the Chicago Dispatcher website. Philadelphia's data was sourced from the Philadelphia Parking Authority.

The data was available in monthly figures in PDF documents for New York City and Chicago, and in hard copy paper format for Philadelphia. These documents listed every medallion transfer that occurred in the given month. To obtain the market value of the medallion, monthly average market values were calculated. This was done by taking the total sum of medallion sales divided by the number of medallion sales in a given month. Values below $100,000 were omitted for New York City and Philadelphia, and values below $70,000 were omitted for Chicago, as they were outliers and do not accurately reflect the value of a taxi medallion. The outlier values typically represented a transfer between family members, or in some cases, legal disputes. If there were no taxi medallion sales in a given month, the previous month's average was applied.

Independent Variable of Interest

Number of Uber Drivers

The number of Uber drivers is the number of active UberX and UberBLACK drivers in a given city. An active driver means the driver has provided at least one Uber ride in the given month.

Private technology companies' data is an extremely valuable resource that they want to keep internal. For this reason, finding data on number of Uber drivers was extremely difficult. The data was sourced from a graph in a working paper titled "An Analysis of the Labor Market for Uber's Driver-Partners in the United States" by Jonathan V. Hall and Alan B. Krueger at Princeton University. The data was collected using a software program called Web Plot Digitizer. This software extracted the data by importing a photo of the graph of number of Uber drivers over time from the working paper, calibrating the X and Y axis to create a grid where each pixel is a different data point, and manually selecting data points from the graph. Once all desired data points were selected, the data was exported. This process was repeated 10 times per city to ensure robust data, using the average number of drivers across all 10 data selection trials in analysis. Using this graph and software, the number of Uber Drivers since the launch of UberX were collected totaling 31 months for New York City and Chicago, and 30 months for Philadelphia.

A drawback of this data is that it does not capture any months in 2016 and misses most months in 2015. These months exhibited further dropping taxi medallion values, and for this reason, the magnitude of the effect of the number of active Uber drivers may be underestimated in this study.

INDEPENDENT CONTROL VARIABLES

UNEMPLOYMENT RATE

The unemployment rate numbers used for Chicago are the Chicago-Naperville-Eglin metropolitan area. The numbers used for New York City represent the New York-Jersey City-White Plains metropolitan area. The unemployment rate values used for Philadelphia are for the Philadelphia-Camden-Wilmington metropolitan area. A city's unemployment rate is an indicator of the economic health of the individual city. It is expected that as the unemployment rate increases, the price of a taxi medallion will decrease because of the decrease in local economic health. This data was sourced from the Bureau of Labor Statistics.

LONG TERM INTEREST RATES

The long term interest rate is the rate of government bonds maturing in ten years. These interest rates are the prices government bonds trade for on financial markets, not the interest rates the loans were issued at. These values better indicate the financial health across the entire country, and the values are the same for all cities. It is expected that as the long term interest rate increases, the price of a taxi medallion will decrease because of the decrease in nationwide economic health. This data was sourced from the Organization for Economic Co-operation (OECD).

LABOR FORCE POPULATION

The same metropolitan areas as unemployment rate were used to maintain consistency. This number captures increasing market size and increasing need for the transportation service within a given city. It is expected that an increase in labor force population increases demand for a taxi service, increasing the price of a taxi medallion. This data was sourced from the Bureau of Labor Statistics. Labor force population was selected instead of the total population because individuals who are a part of the labor force are more likely to use a taxi service.

Exhibits 1 through 4 contain further details on the data used including the mean, maxima, minima, standard deviation, number of observations, trends and histograms of the data.

EMPIRICAL MODEL AND STRATEGY

Past literature by Dan Cumming's performed a time series ordinary least squares (OLS) regression analysis to test the significance of independent variables in determining the value of a taxi medallion. To see if this methodology was suitable for this analysis, unit root tests to test for stationarity in all three different cities were conducted. A Dickey Fuller test was conducted for each city on the value of a taxi medallion, with results shown in Exhibit 5. These tests showed mixed results: a p-value of 0.0426, 0.3366 and 0.8267 respectively for New York City, Chicago and Philadelphia. This demonstrates that New York City can reject the null hypothesis that the value of a taxi medallion follows a unit root process at a 95% confidence level, but Chicago and Philadelphia cannot. Since two of the three cities do not reject the null hypothesis, OLS was used for all cities to ensure consistency regarding regression methodology.

INDIVIDUAL CITY TIME SERIES ANALYSIS

The following equation is used for individual city time series analysis:

$$[1]\ valmed_t = \beta_0 + \beta_1 uberdriv_t + \beta_2 unemrate_t + \beta_3 ltintrate_t + \beta_4 laborforce_t + \varepsilon_t$$

The left side of the equation is the dependent variable, value of a taxi medallion, represented by *valmed* by time (t=1, …, T). The right side of the equation includes independent variables used to determine the price of a taxi medallion. All four independent variables affect the demand curve in shifting the equilibrium price. These independent variables are time dependent where *uberdriv, unemrate, ltintrate* and *laborforce* are given by time (t=1, …, T). The error term used in this equation is the standard error term used in Stata's OLS regression.

FIXED EFFECTS PANEL ANALYSIS

For the panel analysis, a fixed effects regression analysis is used. The initial equation with a fixed effect is:

$$[2]\ valmed_{it} = \beta_0 + \alpha_i + \beta_1 uberdriv_{it} + \beta_2 unemrate_{it} + \beta_3 ltintrate_{it} + \beta_4 laborforce_{it} + \varepsilon_{it}$$

The fixed effects equation is formed by subtracting the mean of each variable from its individual values:

$$[3]\ X_{it} - \bar{X}_{it} = \ddot{X}_{it}$$

Through this process, the fixed effect is eliminated:

$$[4]\ \alpha_i - \bar{\alpha}_i = 0$$

This process yields the final equation to be used in the regression analysis:

$$[5]\ \ddot{valmed}_{it} = \beta_0 + \beta_1 \ddot{uberdriv}_{it} + \beta_2 \ddot{unemrate}_{it} + \beta_3 \ddot{ltintrate}_{it} + \beta_4 \ddot{laborforce}_{it} + \ddot{\varepsilon}_{it}$$

The left side of the equation is the dependent variable, value of a taxi medallion, where *valmed* by time (t=1, …, T) and city (i=1,2,3). The right side of the equation includes all independent variables, where *uberdriv, unemrate, ltintrate* and *laborforce* are given by time (t=1, …, T) and city (i=1,2,3). The error term used in this equation is the standard error term used in Stata's fixed effects regression.

Each variable is tested for statistical and economic significance in deciding whether it is a determinant of the value of a taxi medallion. The null hypothesis, H_0, for each variable is: *variable* is not statistically or economically significant in determining the value of a taxi medallion. The alternative hypothesis, H_1, for each variable is: *variable* is statistically and economically significant in determining the value of a taxi medallion. These hypotheses were tested for both individual city multiple regression analyses and the fixed effects regression analysis. A variable could be statistically significant in determining the value of a taxi medallion in one city, but not the other. The variables were tested at a 95% confidence level, accepting values that yield a p-value of less than 0.05 in the results of the multiple regression analysis.

Testing for Non-Linearity

The relationship between taxi medallion prices and the number of Uber drivers could potentially be a non-linear relationship.

Two new variables were created to test for non-linearity. The first, *sqruberdriv*, is equal to the number of active Uber drivers squared ($uberdriv^2$). The second, *sqrtuber*, equals the square root of the number of active Uber drivers ($uberdriv^{1/2}$). Two regression analyses were run, one including *sqruberdriv* and one including *sqrtuber*. These were included in a fixed effects regression using all three cities as a panel of data.

The regression equations are:

$$[6]\ \ddot{valmed}_{it} = \beta_0 + \beta_1 \ddot{uberdriv}_{it} + \beta_2 \ddot{unemrate}_{it} + \beta_3 \ddot{ltintrate}_{it} + \beta_4 \ddot{laborforce}_{it} + \beta_5 sqruberdriv_{it} + \ddot{\varepsilon}_{it}$$

$$[7]\ \ddot{valmed}_{it} = \beta_0 + \beta_1 \ddot{uberdriv}_{it} + \beta_2 \ddot{unemrate}_{it} + \beta_3 \ddot{ltintrate}_{it} + \beta_4 \ddot{laborforce}_{it} + \beta_5 sqrtuber_{it} + \ddot{\varepsilon}_{it}$$

The linearity of the relationship was tested by looking at the statistical significance and sign of *sqruberdriv* and *sqrtuber* in their regressions, and by comparing the AIC values between the models. If either *sqruberdriv* or *sqrtuber* are statistically significant with the proper sign and the models yield a lower AIC value, meaning that the model is more parsimonious, then it is possible that the relationship in non-linear.

Non-linearity could be the case for a few reasons. When Uber first enters a city, it is unlikely to be well known. This implies the impact that Uber drivers have would be very minimal, and there would not be a significant effect on the price of a taxi medallion. As Uber becomes more well known, the taxi industry faces a larger risk. It becomes apparent the taxi industry is losing market share and the number of Uber drivers is increasing quickly. At this stage the number of Uber drivers would have a very high impact on taxi medallion prices, this reflects an increasing elasticity from the number of Uber drivers. This relationship could also be non-linear if Uber has been in the market for a significant amount of time, and regulations have been implemented to allow fair competition between ridesharing and the taxi industry. As the number of drivers continues to increase, the price of a taxi medallion will still decrease but not as rapidly because a relatively stable equilibrium or maximum impact from Uber drivers will have been reached.

RESULTS

NEW YORK

FIGURE 2: NEW YORK CITY REGRESSION TABLE

	NYC			
	b	se	p	t
uberdriv	-30.315***	5.387	0.000	-5.627
unemrate	-104546.190***	23716.770	0.000	-4.408
ltintrate	30511.217	20154.616	0.135	1.514
laborforce	1.568***	0.278	0.000	5.643
_cons	-9253739.708***	2087696.372	0.000	-4.433
r2	0.749			
N	71.000			
aic	1798.333			

* p<0.05, ** p<0.01, *** p<0.001

VARIABLES

The results for New York City show that all variables but long term interest rate are statistically significant at the tested 95% confidence level, and even significant to the 99.9% confidence level. The null hypothesis H_0 is rejected, and the alternative hypothesis H_1 is accepted for all independent variables except long term interest rate, concluding that these variables are statistically significant in determining the value of a taxi medallion.

Additionally, each independent variable has a strong enough magnitude to deem them all economically significant. The price of a taxi medallion in New York City increases by $1.57 for each additional individual that joins the *laborforce*. Each additional 1% increase in unemployment rate decreases the price of a taxi medallion in New York City by $104,546.2. The price of a taxi medallion in New York City decreases by $30.32 for every additional Uber driver that is active in a given month. The magnitude of *ltintrate* intuitively does not make sense. A positive coefficient means that as the interest rate increases, the price of a taxi medallion will increase. However, as interest rates increase, the cost of borrowing increases, which should cause a negative relationship with the price of a taxi medallion. However, since *ltintrate* is not statistically significant, the positive sign on this variable is not concerning. Given that *ltintrate* is not statistically significant could imply that New York City's taxi medallion prices are more determined by local determining factors, not nationwide economic health factors.

Past research for New York City found that only *unemrate* was statistically significant in determining the value of a taxi medallion in New York City (Cumming, 2009). The other variables used in Cumming's regression that were not statistically significant were stock price index, interest rates and population (Cumming, 2009). These results are consistent with Cumming's findings that *unemrate* is statistically significant and *ltintrate* is not.

MODEL

The R^2 for this regression is 0.749, showing that this model is very effective at explaining the variation in taxi medallion prices in New York City. However, this also means that roughly 25% of taxi medallion value variation that is not explained, meaning other independent variables could explain the changes in taxi medallion value. The lower than expected R^2 could also be due to the fact that Uber is still very new in the market, and people are unsure how to react to this new threat. When a disruption like this occurs, there is a probability that it could overtake the older technology, in this case the taxi industry, and also a probability that regulation will prevent the new service, Uber, from operating in the long term. This uncertainty leaves some people debating the impact of Uber's long term presence when making a taxi medallion purchase price decision. This could also be attributed to random variation and the imperfect Uber driver data that was retrieved, given that this data is not widely available.

CHICAGO

FIGURE 3: CHICAGO REGRESSION TABLE

	Chi b	se	p	t
uberdriv	-21.925***	2.655	0.000	-8.258
unemrate	-48615.031***	6231.183	0.000	-7.802
ltintrate	-30158.901***	7249.815	0.000	-4.160
laborforce	1.217***	0.173	0.000	7.057
_cons	-3768151.052***	665328.701	0.000	-5.664
r2	0.830			
N	71.000			
aic	1674.350			

* p<0.05, ** p<0.01, *** p<0.001

VARIABLES

The results for Chicago show that all variables are statistically significant at both the tested 95% confidence level and the 99.9% confidence level. Therefore, the null hypothesis is rejected and the alternative hypothesis is accepted concluding that all variables are statistically significant in determining the value of a taxi medallion.

All independent variables have the expected positive or negative effect on taxi medallion prices, and are economically significant. The price of a taxi medallion in Chicago will decrease by $21.93 for every additional Uber driver. An increase in the unemployment rate of 1% will decrease the price of a taxi medallion in Chicago by

$48,615.0. A 1% increase in the long term interest rate will decrease the price of a taxi medallion in Chicago by $30,158.9. Each additional individual that joins the *laborforce* increases the price of a taxi medallion in Chicago by $1.22.

Past research finds that only *unemrate* was statistically significant in determining the value of a taxi medallion (Cumming, 2009), however these results show all independent variables used are statistically significant in determining the price of a taxi medallion in Chicago. The variables used in Cumming's regression that were not statistically significant were stock price index, interest rates and population (Cumming, 2009). The consistent finding is that *unemrate* is statistically significant, and what is different from Cumming's results is that in this study *laborforce* and *ltintrate* are significant in determining the price of a taxi medallion. These differences could be due to monthly data used instead of annual figures or the time frame that was analyzed.

The difference between Chicago's statistical significance of *ltintrate* and New York City's *ltintrate* could suggest that New York City is not as sensitive to nation-wide economic health conditions as Chicago. New York City could be highly dependent on the local economy, which is possible given the population size is larger than some countries.

MODEL

The R^2 for this regression is 0.830, demonstrating that this model is very effective at explaining the variation in taxi medallion prices in Chicago. However, similarly to New York City, this means there is an unexplained variance in this model of nearly 17%. The lower than expected R^2 could also be due to same reason provided in New York City's case.

PHILADELPHIA

FIGURE 4: PHILADELPHIA REGRESSION TABLE

	Phil b	se	p	t
uberdriv	-44.658**	15.571	0.006	-2.868
unemrate	-79462.112***	6660.829	0.000	-11.930
ltintrate	-34358.528***	9134.368	0.000	-3.761
laborforce	1.563***	0.287	0.000	5.435
_cons	-3650772.851***	887448.969	0.000	-4.114
r2	0.896			
N	71.000			
aic	1680.041			

* p<0.05, ** p<0.01, *** p<0.001

Variables

The results for Philadelphia illustrate that all variables are statistically significant at the tested 95% confidence level, and all but *uberdriv* are significant even to the 99.9% confidence level, with *uberdriv* significant to the 99% confidence level. Therefore, the null hypothesis H_0 is rejected for all independent variables and the alternative hypothesis H_1 is accepted, concluding that all variables are statistically significant in determining the value of a taxi medallion.

All independent variables have the expected positive or negative effect on taxi medallion prices and have a strong enough magnitude to be economically significant. The price of a taxi medallion in Philadelphia will decrease by $44.66 for every additional Uber driver that is active in a given month. The results are surprising given that the magnitude is larger than New York City and Chicago, however there appears to be less of a decline in taxi medallion prices in Philadelphia compared to New York City and Chicago. An increase in the unemployment rate of 1% will decrease the price of a taxi medallion in Philadelphia by $79,462.1. A 1% increase in the long term interest rate will decrease the price of a taxi medallion in Philadelphia by $34,358.5. Each additional individual that joins the *laborforce* in Philadelphia increases the price of a taxi medallion by $1.56.

These relationships are consistent with the relationships discovered in Chicago. The variable *unemrate* is statistically significant, and *ltintrate* and *laborforce* are statistically significant unlike in Cumming's research.

Model

The R^2 for this regression is 0.896, showing that this model is extremely effective at explaining the variation in taxi medallion prices in Philadelphia. However, similarly to the other two cities, there is unexplained variance, but only approximately 10%.

Fixed Effects

Figure 5: Aggregate Fixed Effects Regression Table

	Panel1 b	se	p	t
uberdriv	-24.866***	2.712	0.000	-9.170
unemrate	-65933.222***	6137.112	0.000	-10.743
ltintrate	-13707.727	7656.889	0.075	-1.790
laborforce	1.549***	0.123	0.000	12.596
_cons	-6002137.429***	569745.333	0.000	-10.535
r2	0.703			
N	213.000			
aic	5291.530			

* p<0.05, ** p<0.01, *** p<0.001

Variables

The fixed effects regression analysis using the data as a panel shows similar results as before. All variables except *ltintrate* are statistically significant at the tested 95% confidence level, with significant independent variables significant to the 99.9% confidence level. For these independent variables, the null hypothesis H_0 is rejected and the alternative hypothesis H_1 is accepted concluding that the variable is statistically significant in determining the value of a taxi medallion. The variable *ltintrate* is statistically significant at a 90% confidence level, which still shows this variable is effective at determining the price of a taxi medallion.

In this panel analysis, all independent variables have the expected positive or negative effect on taxi medallion prices. Additionally, each statistically significant independent variable has a strong enough magnitude to be economically significant. For every additional Uber driver that is active in a given month, the price of a taxi medallion will decrease by $24.87. An increase in the unemployment rate of 1% will decrease the price of a taxi medallion by $5,933.2. For each additional individual that joins the *laborforce*, the price of a taxi medallion will increase by $1.55.

Model

The R^2 for this regression is 0.703, showing that this model is very effective at explaining the variation in taxi medallion prices. However, similar to the previous models, this means there is unexplained variance in this model of nearly 30%. The lower than expected R^2 could also be due to same reason that was explained in the individual city models, and also because the scale of these three cities are much different. New York City's labor force population is more than double both Chicago's and Philadelphia's, which can cause difficulties in modeling given the difference in scale.

Testing for Non-Linearity

Figure 6: Non-Linear Regression Results

	Panel1 b/se/p	Panel2 b/se/p	Panel3 b/se/p
uberdriv	-24.87***	-1.11	-40.82***
	(2.71)	(8.90)	(4.53)
	0.00	0.90	0.00
unemrate	-65933.22***	-48143.20***	-27705.35*
	(6137.11)	(8767.46)	(10662.90)
	0.00	0.00	0.01
ltintrate	-13707.73	-23848.51**	-30236.18***
	(7656.89)	(8359.28)	(8294.69)
	0.07	0.00	0.00
laborforce	1.55***	1.36***	1.02***
	(0.12)	(0.14)	(0.17)
	0.00	0.00	0.00
sqruberdriv		-0.00**	
		(0.00)	
		0.01	
sqrtuber			3392.67***
			(788.73)
			0.00
constant	-6002137.43***	-5275597.76***	-3889224.57***
	(569745.33)	(617733.78)	(735171.52)
	0.00	0.00	0.00
r2	0.70	0.71	0.73
N	213.00	213.00	213.00
aic	5291.53	5285.54	5275.12

* p<0.05, ** p<0.01, *** p<0.001

The regression results leave the linearity of this relationship up for debate. Firstly, it is clear that *sqrtuber* is not correct with a positive coefficient, removing Panel 3 as a possibility of non-linearity. The regression including *sqruberdriv* shows this variable to be statistically significant to the 99% confidence level. However, in the linear model, the variable *uberdriv* is statistically significant to the 99.9% confidence level. Both models are nearly equal in explaining the variation, with R^2 values of 0.70 and 0.71. The AIC values are also nearly equal with a difference of only 0.1%. These results are inconclusive in regards to the relationship between the number of Uber drivers and the price of a taxi medallion is linear or non-linear, as both methodologies result in nearly identical statistical significance and R^2 values. For simplicity and consistency, conclusions will be made with regard to a linear relationship.

Comparing Models

Figure 7: Model Comparison Regression Table

	NYC	Chi	Phil	Panel1
	b/se/p	b/se/p	b/se/p	b/se/p
uberdriv	-30.32***	-21.92***	-44.66**	-24.87***
	(5.39)	(2.65)	(15.57)	(2.71)
	0.00	0.00	0.01	0.00
unemrate	-104546.19***	-48615.03***	-79462.11***	-65933.22***
	(23716.77)	(6231.18)	(6660.83)	(6137.11)
	0.00	0.00	0.00	0.00
ltintrate	30511.22	-30158.90***	-34358.53***	-13707.73
	(20154.62)	(7249.81)	(9134.37)	(7656.89)
	0.13	0.00	0.00	0.07
laborforce	1.57***	1.22***	1.56***	1.55***
	(0.28)	(0.17)	(0.29)	(0.12)
	0.00	0.00	0.00	0.00
constant	-9253739.71***	-3768151.05***	-3650772.85***	-6002137.43***
	(2087696.37)	(665328.70)	(887448.97)	(569745.33)
	0.00	0.00	0.00	0.00
r2	0.75	0.83	0.90	0.70
N	71.00	71.00	71.00	213.00
aic	1798.33	1674.35	1680.04	5291.53

* p<0.05, ** p<0.01, *** p<0.001

Across all models the variable of interest, *uberdriv*, remains statistically significant at a minimum confidence level of 99%, and shows a consistent negative coefficient with an economically significant magnitude.

The magnitude of *laborforce* remains fairly constant across models ranging from 1.263 to 1.591. The magnitude of *numdrivers* is also fairly constant ranging from -24.093 to -30.268. The magnitude of *unemrate* has much more variation, ranging from a low magnitude in Chicago of -61,109.811 to a high magnitude in New York City of -116,769.203. This difference is likely attributed to the fact that the scale of New York City is much larger than Chicago. With New York City's labor force population size roughly double Chicago's, it makes sense that the magnitude of a 1% change in unemployment rate would be nearly twice as large in New York City compared to Chicago.

CONCLUSIONS

The number of active Uber drivers in a city is statistically and economically significant in determining the value of a taxi medallion in New York City, Chicago and Philadelphia. The higher the number of active Uber drivers in a city, the lower the value of a taxi medallion. This research shows that "The Uber Effect" is: For each additional active Uber driver, the price of a taxi medallion will decrease by $22 to $45. These results suggest that Uber's recent entry has contributed to the dropping taxi medallion values across multiple cities, and it can be expected that these medallion values will continue to drop as Uber grows in these markets.

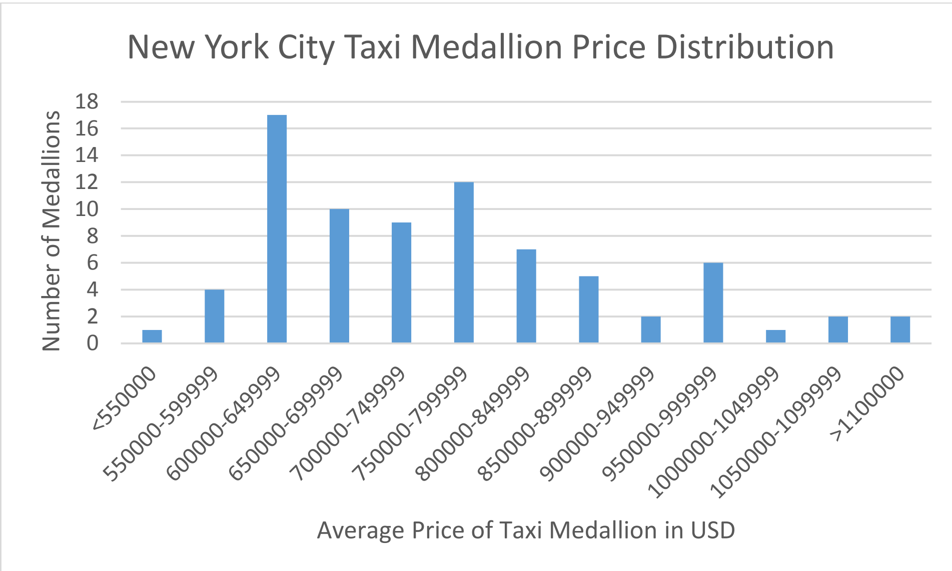
In addition to the number of active Uber drivers, both labor force population and unemployment rate are statistically and economically significant in determining the value of a taxi medallion. Using these three variables is an effective way to predict the price of a taxi medallion. These findings are not entirely consistent with the past literature. Cumming's concluded that only unemployment rate was significant in determining the price of a taxi medallion. These differences could be attributed to either the different time period of the study, or using monthly data instead of annual data.

It is not certain whether the effect of the number of Uber drivers on taxi medallion prices is linear or non-linear. It is likely that this result is dependent on where Uber is in the lifecycle of entering a city. If this study was repeated a decade in the future, it is likely that the relationship would be non-linear, showing that the amount that taxi medallion prices decrease by is decreasing as the number of Uber drivers increases. However, the results in this analysis show that the negative linear effect is highly statistically and economically significant in the given time period.

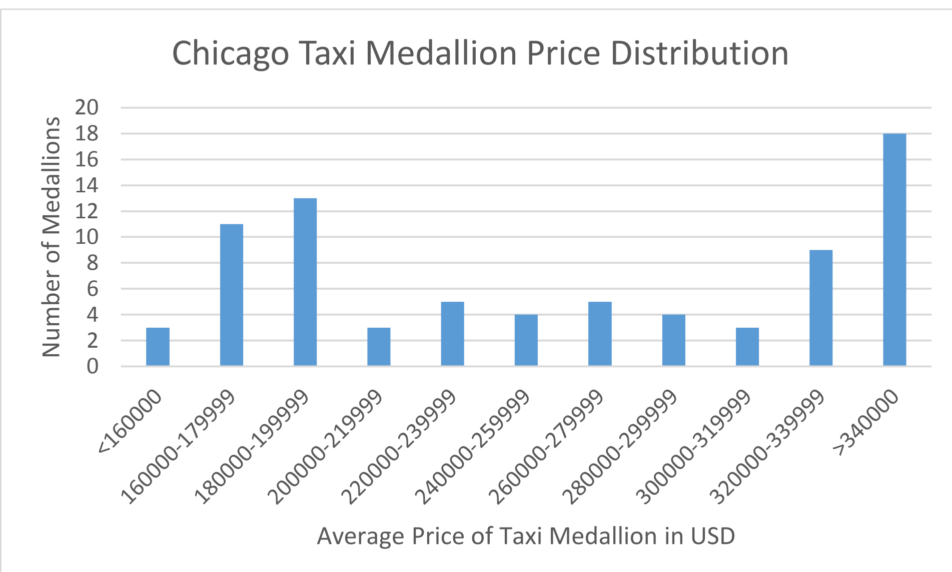
EXHIBITS

EXHIBIT 1: DISTRIBUTION OF MONTHLY AVERAGE TAXI MEDALLION PRICES

NEW YORK CITY



CHICAGO



PHILADELPHIA

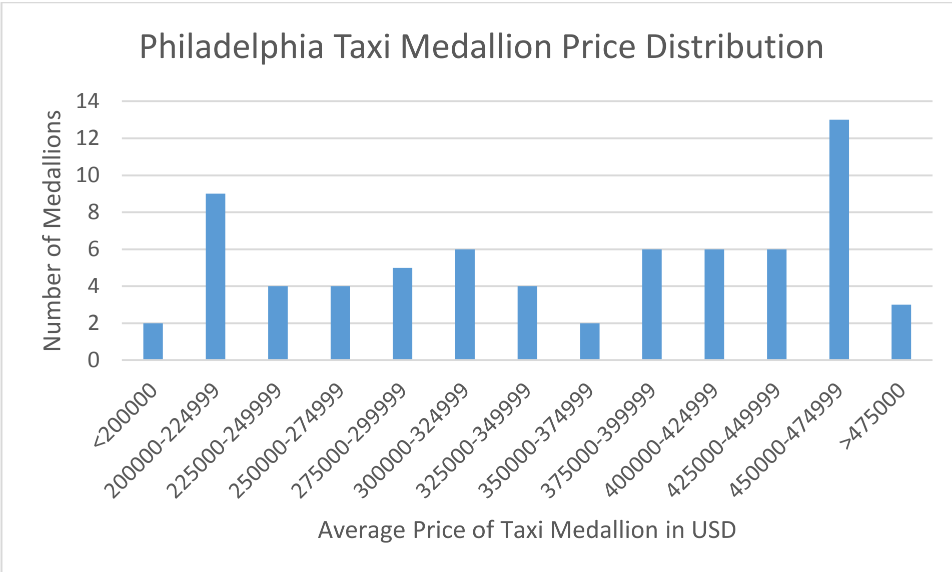
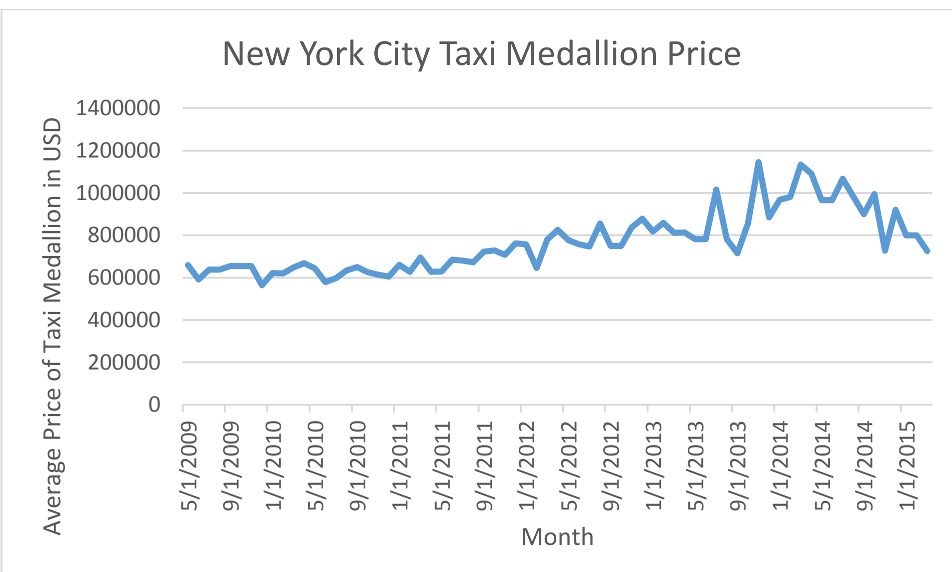
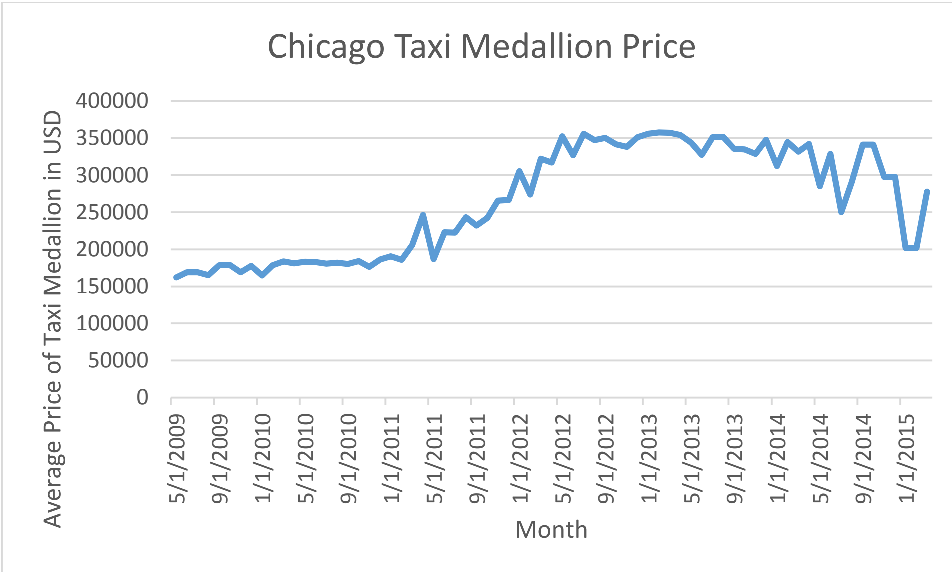


EXHIBIT 2: AVERAGE PRICE OF A TAXI MEDALLION OVER TIME

NEW YORK CITY



CHICAGO



PHILADELPHIA

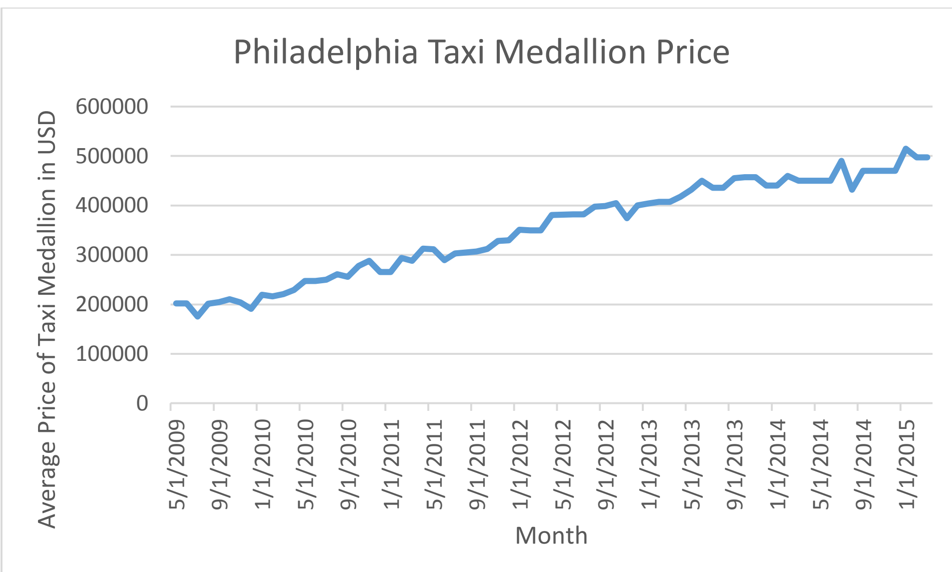


EXHIBIT 3: NUMBER OF ACTIVE UBER DRIVERS OVER TIME

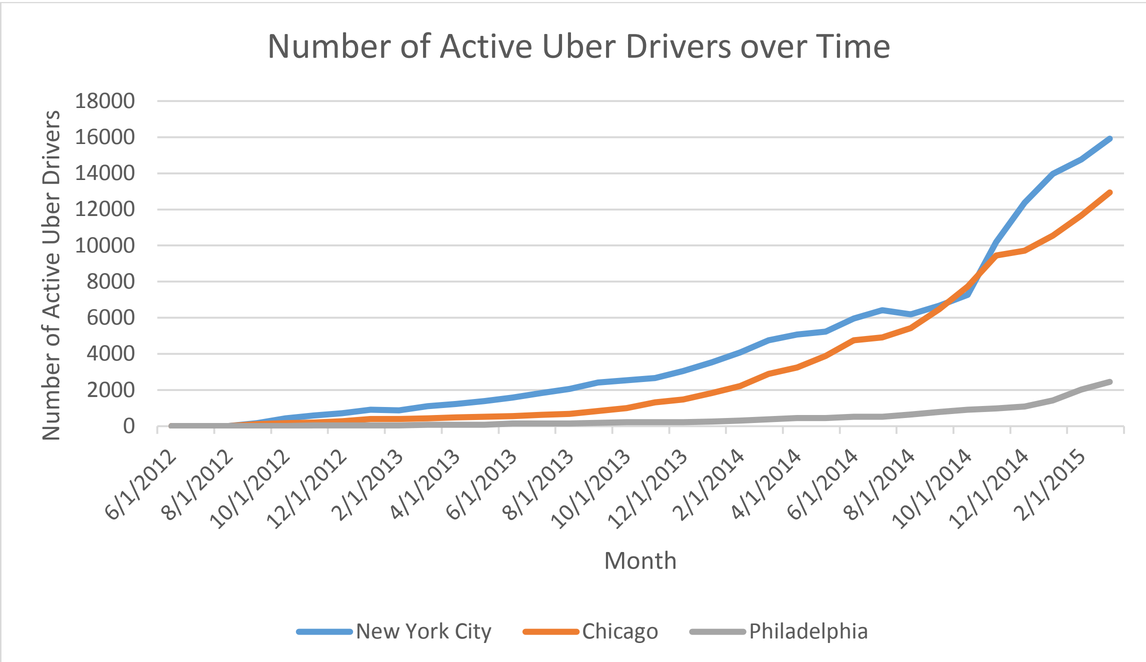


EXHIBIT 4: DESCRIPTIVE STATISTICS

NEW YORK CITY DATA

	valmed	*uberdriv*	*unemrate*	*ltintrate*	*laborforce*
Mean	766,153	2,056	8.43	2.62	6,940,198
Maxima	1,145,455	15,913	9.70	3.85	7,079,321
Minima	564,532	0	6.10	1.53	6,825,891
Std Dev	142317	3728.21	1.04	0.66	76115

CHICAGO DATA

	valmed	*uberdriv*	*unemrate*	*ltintrate*	*laborforce*
Mean	265,052	1,514	9.30	2.62	3,776,527
Maxima	357,600	12,937	11.40	3.85	3,814,046
Minima	161,994	0	6.10	1.53	3,722,701

Std Dev	72223	3059.96	1.44	0.66	25798

PHILADELPHIA DATA

	valmed	*uberdriv*	*unemrate*	*ltintrate*	*laborforce*
Mean	351,774	210	7.90	2.62	3,026,942
Maxima	515,000	2,444	9.10	3.85	3,064,906
Minima	175,313	0	5.50	1.53	2,961,984
Std Dev	96370	452.56	1.06	0.66	20235

AGGREGATE DATA

	valmed	*uberdriv*	*unemrate*	*ltintrate*	*laborforce*
Mean	460,993	1,260	8.58	2.62	4,581,026
Maxima	1,145,455	15,913	11.40	3.85	7,079,321
Minima	161,994	0	5.60	1.53	2,961,984
Std Dev	243,722	2,902.26	1.26	0.66	1,696,741

EXHIBIT 5: DICKEY FULLER UNIT ROOT TESTS

NEW YORK CITY

Dickey-Fuller test for unit root Number of obs = 70

		Interpolated Dickey-Fuller		
	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-2.924	-3.552	-2.914	-2.592

MacKinnon approximate p-value for Z(t) = 0.0426

CHICAGO

Dickey-Fuller test for unit root   Number of obs   =   70

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-1.890	-3.542	-2.908	-2.589

MacKinnon approximate p-value for Z(t) = 0.3366

PHILADELPHIA

Dickey-Fuller test for unit root   Number of obs   =   70

	Test Statistic	Interpolated Dickey-Fuller 1% Critical Value	5% Critical Value	10% Critical Value
Z(t)	-0.774	-3.552	-2.914	-2.592

MacKinnon approximate p-value for Z(t) = 0.8267

BIBLIOGRAPHY

Schaller, Bruce (2005) “A Regression Model of the Number of Taxicabs in U.S. Cities”, Schaller Consulting, Retrieved from: http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1332&context=jpt

Cumming, Dan (2009) "Why has the Price of Taxi Medallions Increased So Dramatically? An Analysis of the Taxi Medallion Market”, The Park Place Economist: Vol. 17, Available at: http://digitalcommons.iwu.edu/parkplace/vol17/iss1/9

Barro, Josh (2014) “Under Pressure from Uber, Taxi Medallion Prices are Plummeting”, The New York Times, Retrieved from: http://www.nytimes.com/2014/11/28/upshot/under-pressure-from-uber-taxi-medallion-prices-are-plummeting.html

Nilsen, Sverre (2015) “I drove Uber for a week, and here’s what it was like”, Business Insider, Retrieved from: http://www.businessinsider.com/i-drove-for-uber-for-a-week-heres-what-its-really-like-2015-2

Elliot, Josh (2014) “Uber Ride Share Taxi or Tech Company”, CTV News retrieved from: http://www.ctvnews.ca/business/uber-ride-share-taxi-or-tech-company-1.2044508

Appel, Jeremy (2015) “UberX Insurance Controversy in Toronto Ontario, Toronto Sun retrieved from: http://www.torontosun.com/2015/06/28/uberx-insurance-controversy-in-to

Castle, Jemma (2015) “UberX vs Taxi – Which is Best?” The Choice Website retrieved from: https://www.choice.com.au/transport/cars/general/articles/uberx-vs-taxi-which-one-is-best

Schaller, Bruce (1998) “Elasticities for Taxicab Fares and Service Availability” Transportation: Volume 26 Issue 3 p283-297, Retrieved from: http://www.schallerconsult.com/taxi/elastic.pdf

Schaller, Bruce (1998) “Issues in Fare Policy: Case of the New York Taxi Industry”, Transportation Research Record, Retrieved from: http://trrjournalonline.trb.org/doi/pdf/10.3141/1618-17

DATA SOURCES

New York City Taxi & Limousine Commission: http://www.nyc.gov/html/tlc/html/about/medallion_transfers.shtml

Chicago Dispatcher: http://chicagodispatcher.com/index117.htm

Organization for Economic Co-operation and Development: https://data.oecd.org/interest/long-term-interest-rates.htm

Philadelphia Parking Authority: http://www.philapark.org/contact/

United States Department of Labor, Bureau of Labor Statistics: http://www.bls.gov/