Typology	Quantity	Price	Observation
Blue Zone	33′000 ↘	Visitor: first hour free of charge. Residents: Fr. 300/year	Only control charge possible
White Zone	9′000 →	Control fee Fr. -.50/h, control plus usage fee Fr. 3.-/h, Fr. 7.50/2h	
Private property I (private)	200′000 ↗	CHF 100.00/Mt to CHF 500.00/Mt	Usage-related (residential, service, etc.), approved with municipal parking ordinance
Private property II (public accessible)	25′000 ↗	Prices city centre : Fr. 4.-/h, Fr. 9.-/2h	E.g. Parking garages, open parking facilities

Table 2: Parking space categories in the city of Zürich (Willi, 2018).

3 Case Study: Zürich Street Parking Fee Increase

On April 1, 2017, a wide-reaching parking fee increase in the city of Zürich came into effect.[4] This concerned street parking on spots in the entire downtown area and the district of Oerlikon, an area referred to as "Hochtarifzone" (high fee area). The affected spots can be seen as temporally-spatially priced: The spots in this area are free at night, but a payment is required during the daytime (see Table 3).

Zone	Operational times
Downtown + Oerlikon	Mon - Sat, 09:00 - 20:00
Zürich-West	Mon - Wed, 09:00 - 20:00 and Thur - Sun, 09:00 - 09:00

Table 3: Parking operational times in Zürich.

Study goal

Politicians hoped that the parking fee increase would lead to a decrease in traffic. My goal is to investigate whether the pricing change actually resulted in the desired

[4] "Erste Gebührenerhöhung seit 23 Jahren bei den Parkplätzen - Stadt ..." 29 March 2017, `https://www.stadt-zuerich.ch/pd/de/index/das_departement/medien/medienmitteilung/2017/170329a.html`. Accessed 19 Dec. 2018.

decrease in car traffic volume. We aim to find a relation between traffic volume before and after the price increase, inside and outside of the "Hochtarifzone", during the operational times of the parking meters and outside of these times.

Data

The traffic department of the city of Zürich publishes an exhaustive data set of traffic volume at approximately 90 different measurement locations within the city[5]. Data is available starting from 2012, however we are only considering the measurements starting from July 16, 2015 up to December 17, 2018, which gives the same amount of data before and after the price increase. Data at certain locations and moments in time is missing in the data set, e.g. due to construction sites or technical failures. To minimize distortion from these lacking data points, we also create a "restricted data set", in which only the 39 measurement locations where measurements are available at 99.5% of time are considered.

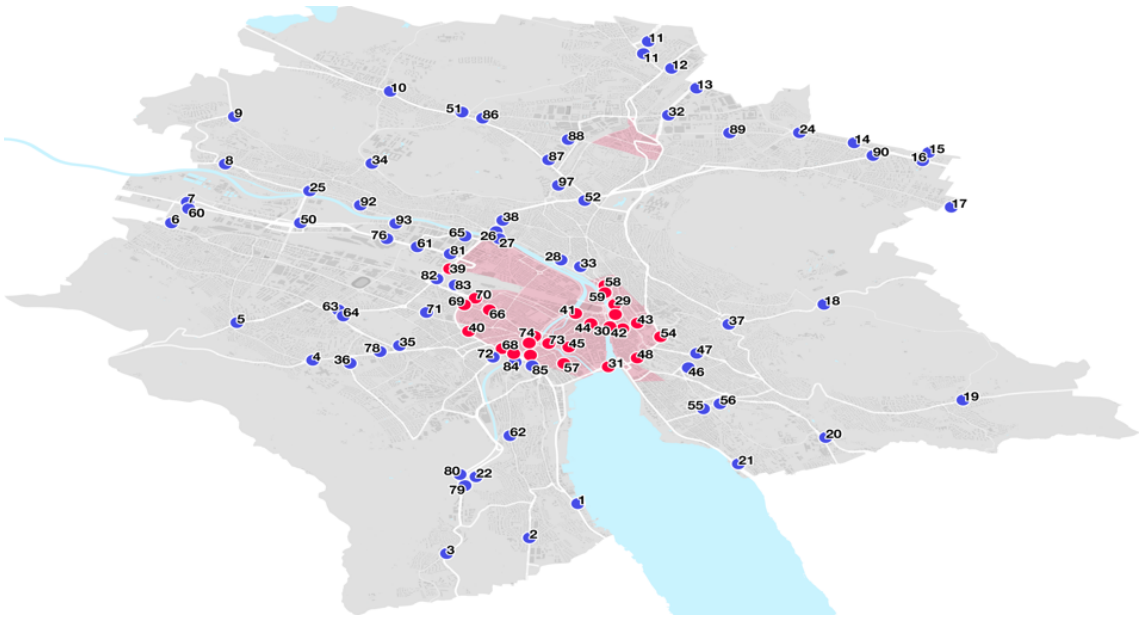

Figure 1: Measurement locations with identifiers on map; the Hochtarifzone is shaded pale red, and measurement locations within it are also marked red.

[5] "Verkehrszählstellen - Stadt Zürich." `https://www.stadt-zuerich.ch/pd/de/index/dav/themen_projekte/zaehlstellen.html`. Accessed 19 Dec. 2018.

Mean traffic volume for entire data set

		Before incr.	**After incr.**	**Ratio**
at night and on Sundays (free parking)	inside zone	236.4293	239.1715	1.0116
	outside zone	239.5072	233.6888	0.9757
during parking meter operational hours	inside zone	490.8431	484.1337	0.9863
	outside zone	535.6916	519.8859	0.9705

Mean traffic volume for restricted data set (39 locations with 99.5% data)

		Before incr.	**After incr.**	**Ratio**
at night and on Sundays (free parking)	inside zone	251.5084	254.2116	1.0107
	outside zone	261.22352	264.5335	1.0127
during parking meter operational hours	inside zone	508.7763	498.9716	0.9807
	outside zone	567.6991	568.4197	1.0013

Table 4: Mean traffic volume before and after parking price increase in Zürich.

Descriptive statistics

One simple way of testing the hypothesis that the parking price increase lead to a decrease in traffic is to compare the mean traffic volume during parking meter operational hours before and after April 1, 2017.

One can see (Table 3) that the results do not clearly support the hypothesis with the entire data set. However, if only the restricted data set is considered, it can be seen that mean traffic decreased only in one place: when motorists were subject to the new fee (after April 1, 2017, during parking meter operational hours, inside high tariff zone).

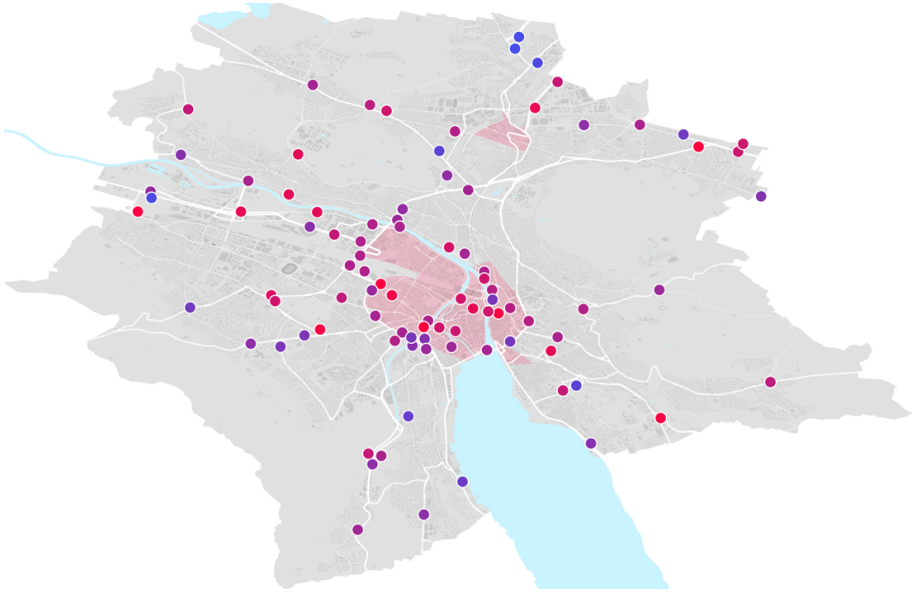

Figure 2: Relative change of traffic volume during parking meter operational times before and after August 1, 2017. Blue indicates an increase in traffic, red a decrease.

Linear model

The goal is to model traffic volume in response to price increase. To capture the effect of the parking fee increase, we use an indicator variable "price_increase" which is set to 1 whenever:

a) the measurement location lies within the "Hochtarifzone", and

b) the parking meter is operational (see table for operational hours and days), and

c) the measurement date is after or on April 1, 2017, i.e. the price increase date

Intuitively, the "price_increase" variable indicates whether motorists were subject to the new higher parking fees at a given location and time (1) or not (0). Of course, traffic volume is the result of countless other factors besides parking fees, which is why the model further contains the variables:

1. D_l *"location"*: Captures spatial differences (e.g. main transit axis vs. residential road)

2. D_h *"hour"*: Time of day (e.g. rush hour vs. at night)

3. D_w *"weekday"*: We expect traffic volume to be smaller on weekends.
4. D_m *"month"*: Seasonal effects, such as worse driving conditions in winter or holidays.
5. d *"days"*: Amount of Days since July 16, 2015, intended to capture effects such as population growth, which would lead to an overall growth trend.

Mathematically, variables (1) - (4) are categorical terms: For each value in their domain, an dummy variable is introduced, which is 1 if it takes that value. This gives the following model:

$$\text{traffic\_volume} = \alpha + \text{location} * D_l + \text{hour} * D_h + \text{weekday} * D_w + \text{month} * D_m + \text{days} * d$$

Wherein α is the constant, location, hour, weekday and month are row vectors of coefficients for the respective dummy variables and D_l, D_h, D_w, D_m are column vectors of dummy variables with all entries 0 except for one which represents the location, time of day, weekday or month respectively.

Results

Performing a linear regression with above model supports the hypothesis with both the entire data set as well as the restricted data set. Using the whole data set, the coefficient for the variable "price increase" takes on a value of -20.42, with a p-value well below the 0.01-level. An even stronger result is attained when performing linear regression on the restricted data set. Here, the "price increase"-coefficient takes a value of -29.96. This indicates that whenever motorists were subject to the new, higher parking fees, this decreased traffic by an average of 20.42 vehicles per hour and measurement location.

All of this suggests that the increase in parking fees might indeed have had a positive effect on traffic reduction in the city center. However, one must also consider other effects that might have biased traffic volume which could have coincided with the parking fee increase. One can imagine, for example, that a construction site that was established in the city center after April 1, 2017 would negatively affect traffic and be strongly connected to the price-increase variable. Public transit pricing, gasoline prices, weather conditions and many more factors should be considered as additional distortions which affect traffic