HEDONIC PRICING MODEL FOR THE UKRAINIAN MARKET OF SMARTPHONES

by

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Date _____

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LIST OF ABBREVIATIONS

CPU Central Processing Unit

GB Gigabytes

MP Megapixels

OS Operation System

RAM Random Access Memory

TRS connector Tip, Ring, Sleeve connector

UAH Ukrainian Hryvnia (the official currency of Ukraine)

CHAPTER 1. INTRODUCTION

The mobile phone industry has grown rapidly over the last 30 years. As of April 2018, 85% of Internet users aged 16 and older in Ukraine use smartphones (GfK, 08.2018). Modern smartphones perform many functions in addition to their primary one – mobile communication. Therefore, mobile phones evolved into complicated multi-component products with comparable sets of characteristics. Different features such as screen size, the performance of CPU, battery capacity, camera quality, storage size, and many others are likely to affect the smartphone's price. A brand name that also includes perceived social value may also capture some explanatory power for the price.

This kind of analysis is providing useful business and product-oriented insights. The main one is the consumer's willingness to pay for a particular feature. The manufacturers need to realize how much consumers are willing to pay for an extra 1 GB of internal memory, how they feel about increasing screen size, decide whether to implement bigger battery capacity or make the smartphone thinner, etc. Answers for these questions will lead the company to a better understanding of consumers' needs, data-driven decision making, and achieving product-market fit accompanied by higher profits. This study will also reveal how much consumers are willing to pay for a particular brand. Put it differently, it shows how much people are ready to pay for reliability, status, design, etc. Such non-technical features also contribute to profits. Significant brand power could be used to increase switching cost for the consumers.

The empirical analysis in the thesis uses the hedonic price models where price of a smartphone is a function of 21 product characteristics. Our sample includes 213 distinct models sold in the Ukrainian market. Hedonic price theory implies that the price of a particular multi-component product could be represented as the sum of its characteristics' prices. Therefore, it is possible to estimate the contribution of each feature to the overall

product's price. There are a lot of studies on applying hedonic pricing mostly to the housing market. Lancaster (1971), and Rosen (1974) introduced new approaches the theory of consumption where the price of the good could be defined as a sum of the monetary value of a heterogeneous set of characteristics. Studies of hedonic pricing model implementation in the smartphone industry are represented by Sidak and Skog (2019), Zheng-Sheng Lin and Chih-Cheng Chen (2013), Ahmad, Ahmed, and Ahmad (2019) and others. Sidak and Skog (2019) is the most recent one. Authors revealed the significant brand power of the vendors, and consumers' willingness to pay for particular features.

For the variable selection, the best subset selection machine learning algorithm was utilized. The data was web-scraped from the biggest e-commerce retailer in Ukraine – "Rozetka"[1] as of April 2020.

To describe the industry, let start with main vendors on the market. Xiaomi captured the first position in the Ukrainian market with market share of 29.49%, then goes Samsung (23.7%), Apple (17.46%), Huawei (10.52%), and Lenovo (2.33%). The mean and median price for the smartphone on sale in Ukraine in April 2020 was 5 861.71 UAH and 3 333 UAH respectively. More than 80% of the smartphones on sale in Ukraine are in the price range from 1100 to 7000 UAH.

The hedonic price models results revealed that consumers are willing to pay up to 11 600 UAH premium on brand names. Consumers value such features in smartphones as increased RAM and battery life, possibility to charge a smartphone wirelessly. For the cheaper smartphone models, customers value fast charge feature. Models show that consumers do not value increased screen size, TRS connector (mini-jack), CPU performance, low-sized internal storage options.

[1] https://rozetka.com.ua/

Brand names seem to have signifficant explanatory power of predicting the smartphones' prices. Vendors should take it into account and invest in Research and Development and market positioning to obtain unique features in the market which bears the brand name.

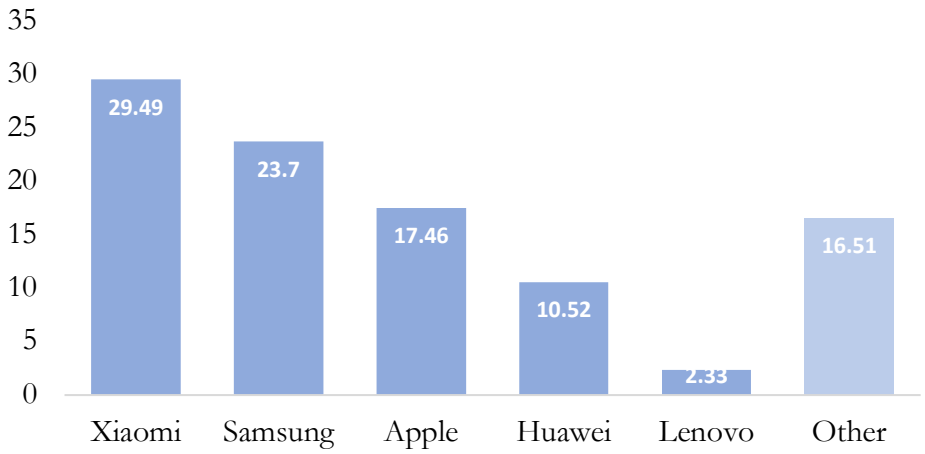
To my knowledge, as of April 2020, this work about the hedonic prices of the smartphones in the Ukrainian market is the first publicly published in Ukraine.

CHAPTER 2. INDUSTRY OVERVIEW AND RELATED STUDIES

2.1 Industry overview

In 2018 5.4 million smartphones and 1.5 million regular phones were bought in Ukraine and more than 30 billion UAH were spent for those reasons. The demand for smartphones in Ukraine is constantly growing, total expenditures in 2018 were 34% higher compared to 2017. The average price for the smartphone bought in 2018 was 5 400 UAH (~ $195.30).[2] For the comparison, as of Q4 2018 average selling price of the smartphone worldwide was $384 (GfK's Consumer Life Study, 22.02.2019)[3]

Figure 2.1. Mobile Vendor Market Share in Ukraine in April 2020, %



[2] ITC: Point of Sales Tracking GfK Ukraine. https://itc.ua/news/gfk-ukraine-v-2018-godu-ukraintsyi-potratili-30-mlrd-griven-na-mobilnyie-telefonyi-ezhednevno-priobretalos-15-tyis-smartfonov-i-4-tyis-knopochnyih-telefonov-infografika/

[3] GfK's Consumer Life Study – 22.02.2019. https://www.gfk.com/press/global-smartphone-sales-reached-522-billion-in-2018

The Ukrainian market of smartphones is dominated by 5 main vendors: Xiaomi, Samsung, Apple, Huawei, and Lenovo.[4] Figure 2.1 illustrates market shares of biggest vendors. The highest market share belongs to Xiaomi – 29.49% as of April 2020. For comparison, as of January 2016, the market share of Xiaomi in Ukraine was only 0.46%. Therefore, Xiaomi has also the highest rate of growth and in February 2019 it has overcome Samsung and captured the first place. It is important to note, that Xiaomi has a much lower market share worldwide with 10.28% and fourth position. Such a big market share in Ukraine could be explained by the affordability of their devices in a developing country. Xiaomi has also the biggest fan base in Ukraine among Electronic companies. According to Socialbakers "Xiaomi Ukraine," the Facebook page has 270 855 fans which are the largest audience among competitors. Its Facebook page is also the fastest-growing electronics page in Ukraine.[5] There is a clear tendency for expanding Xiaomi's market share in Ukraine in the nearest future taking into account economic, social, political, and other factors.

Samsung has the second place with a market share of 23.7% and Apple the third one with a market share of 17.46%. Huawei possesses 10.52% of the market of smartphones in Ukraine. On the contrary, worldwide Samsung (30.41%), Apple (28.79%), and Huawei (10.28%) capture the first three positions respectively. Lenovo is the last of the top five Vendors with the highest market share capturing only 2.33%. In contrast to Xiaomi, Lenovo experiences the fastest drop in market share for the last years. For instance, in January 2016 market share of Lenovo in Ukraine was 16.29%. In Figure 2.2 worldwide vendor's market shares are represented.

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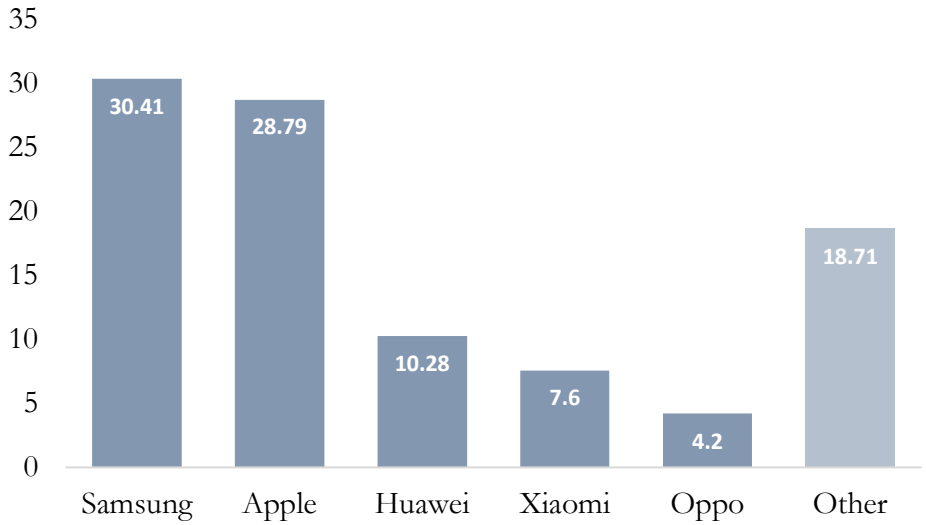
[4] Statcounter: Mobile Vendor Market Share in Ukraine - April 2020. https://gs.statcounter.com/vendor-market-share/mobile/ukraine

[5] Socialbakers: Facebook stats in Ukraine – Electronics. https://www.socialbakers.com/statistics/facebook/pages/total/ukraine/brands/electronics

Figure 2.2. Mobile Vendor Market Share Worldwide in April 2020, %



According to the Vodafone Retail analytical report of the smartphone market in Ukraine, Ukrainians prefer smartphones with large screen size and 4G (LTE) standard for wireless broadband communication. As of the second quarter of 2019, 57% of all smartphones sold were equipped with a screen size of 6 inches and more. In the second quarter of 2019 43% of the smartphones in the Vodafone Ukraine network had 4G (LTE) standards for wireless broadband communication. Vodafone Ukraine is the second-largest mobile operator in Ukraine with 19.7 million subscribers at the end of 2019 and the market share of roughly 35%.[6]

According to the same study, Ukrainians tend to be conservative in buying new models, most of the consumers buy a new model of the same brand name. The highest level of loyalty corresponds to Apple consumers, 71.39% of consumers buy a new iPhone in order to substitute the old one. Apple is famous for its eco-system and convenient interactions between all the devices. The loyalty level of Xiaomi and Samsung is 54.06%

[6] Vodafone Ukraine Q4 & FY 2019 Group Results. Published on April 22, 2020. https://www.vodafone.ua/images/files/368615IR-2019-Results.pdf

and 50.16% respectively. Owners of Apple and Samsung phones use them, on average, for 2 years, while consumers of Chinese brands have a shorter time of usage – 15-16 months. There are also differences in gender: males change their smartphones more frequently than females.[7]

"The worldwide smartphone market was valued at USD 714.96 billion in 2019 and is expected to reach USD 1351.8 billion by 2025, at a CAGR of 11.2% over the forecast period 2020 - 2025. Increased consumer spending across regions has driven the sales of Smartphone markers for years."[8]

2.2 Related studies

The hedonic pricing model primarily has been used by different authors to explain and break up prices of real estate. As smartphones became multi-component products, this approach gained popularity again. In this section implementation of the hedonic price theory for the market of smartphones will be reviewed.

Sidak and Skog (2019) is one of the most recent papers on the implementation of hedonic pricing theory on the market of smartphones in the United States and the first one using LASSO (least absolute shrinkage and selector operator) regression based on machine learning algorithms for variable selection. The authors' data contained 711 smartphone models and 370 characteristics. For the regression only 331 models with complete information on them were used. As a result of the analysis, brands possess significant explanatory power. Consumers are willing to pay a premium for such brands compared to base category (HTC): Andy Rubin ($237.51), Apple ($299.39), Blackberry ($126.84),

[7] Vodafone Retail Analytics: Ukrainian Market of Smartphones. Published on August 14, 2019. https://www.vodafone.ua/uk/news/vodafone-retail-market-analytics

[8] Smartphones Market - Growth, Trends, and Forecast (2020 - 2025). https://www.mordorintelligence.com/industry-reports/smartphones-market

Caterpillar ($213.94), Google ($165.46), HP ($225.11), Kodak ($264.85), Meitu ($202.84), Razer ($302.93), Samsung ($56.89), Sonim ($436.68). Other features are also significant, and affecting smartphone's price like LTE-A, VoWiFi, Removable Battery, TV-Out, Handsfree, Voice Commands, HDVoice, Infrared, DLNA, Wireless Display Support, Haptic Feedback, Pressure Sensor, Fingerprint Sensor, Hall Sensor, Primary Display Size (Inch), Pixels Per Inch (PPI), Max DL Speed (Mbps), and NAND Flash (GB).

Zheng-Sheng Lin and Chih-Cheng Chen (2013) used hedonic price analysis for the Taiwan market of smartphones. Data consisted of 336 models from 12 vendors over the period 2010-2013. According to this study, consumers positively value the possibility to send MMS, MP3 coding format, Ringtones, and Bluetooth. The weight of the smartphone has also a positive effect on price. Actually, the high weight of the smartphone is not a desirable feature for consumers, but higher weight means bigger battery life, larger screen, etc. In the smartphone industry, 7-10 years is a very big-time range and technological progress is rapid. Nowadays, most of the features listed above are taking by consumers for granted, and are not valued as much as 10 years ago.

Ahmad, Ahmed, and Ahmad (2019) conducted the research on 348 smartphones and their characteristics in Pakistan from November 2016 to February 2017. For that propose authors have estimated log-linear hedonic price model. Ahmad, Ahmed, and Ahmad: "brand, battery capacity, weight, operating system, RAM, memory size and display size have a significant positive effect on mobile phone prices. Given the significant premium associated with various characteristics, manufacturers need to formulate strategies to emphasize the battery capacity of 2000-3000 mAH, RAM of more than 1GB, a screen size of more than 5 inches, the memory size of more than 8GB, back camera of over 15MP, 4G network mode, front camera, and FM radio."

Holbrook (1992) in his paper measures the brand premiums and overall brand significance of home-theater and audio-video products using the hedonic price theory. For home-theater products, there was no brand power found, while for audio and video, the

only vendor Carver had a significant brand premium. The author doubts the existence of brand premiums on the electronics market for such industries.

Nazari, Kalejahi, and Sadeghian in 2010 published the research on hedonic prices in the Iran market for mobile phones. Data consists of 111 distinct handsets from 5 mobile vendors and was collected from the local daily newspaper. Handsets' characteristics were taken from official vendor's websites. Despite price it includes battery duration, weight, availability of Wi-Fi connection, touch screen, GPS, radio availability, camera, and guarantee. Empirical model was constructed using the OLS regression. Authors' analysis revealed that HTC brand has $161 price premium compared to the base brand – Nokia. Handset's features such as touch screen, GPS availability, camera quality, and wireless standard of connection have positive effect on price. It should be taken into account that this research was conducted almost 10 years ago and mobile phone market has been changed dramatically.

The smartphone industry is evolving very rapidly, and new features are implementing constantly. Some of them are becoming cheaper with time, new ones could be more expensive. This work is going to reveal the price of each characteristic along with a brand name for models that are on sale so far in Ukraine.

CHAPTER 3. METHODOLOGY

In this chapter, the methodology is being discussed for underlying hedonic price theory (1), and empirical model (2).

3.1. Hedonic price theory

Modern smartphones consist of numerous and some standardized characteristics. When a consumer is choosing the smartphone, he/she is definitely looking and comparing the features of different smartphone models. Such smartphone's characteristics as screen size, battery life, CPU, RAM, storage size, brand name, etc. are affecting the price and consumer's willingness to pay. Therefore, the main idea is to decompose the smartphone's price into its features that consumers value. Lancaster (1971) introduced his new approach to the theory of consumption, where customers choose products based on their relevant properties or characteristics and deriving utility from them. Utilizing Lancaster's paper, Rosen (1974) presented the hedonic price model based on the hedonic hypothesis that products are valued on the market for the utility of each characteristic. The price of the good could be defined as a sum of the monetary value of a heterogeneous set of characteristics. Primarily hedonic price theory was implemented to the housing market. In the case of a smartphone, its price is regressed on relevant characteristics. This could be expressed as follows:

$$P = f(x_1, x_2, \dots, x_n) \qquad (1)$$

where P is market price of a smartphone and $x_1, x_2, \dots, x_n$ are a set of smartphone characteristics (features). In this model partial derivatives of the price with respect to a set of characteristics gives information on the marginal implicit price for an additional unit of each feature.

The hedonic price model has also its empirical issues. It is not clear which functional form to choose: linear, log-lin or logarithmic. In this paper author uses linear dependency between price and characteristics due to the better fit for a particular industry and interpretation of marginal willingness to pay for particular features. On the other hand, hedonic price model does not incorporate market segmentation and unobservable features of the smartphones. It is tricky to derive the price and utility of the handset's materials, operational system, extra protection, design, comfort of exploitation and so on. Therefore, estimated marginal willingness to pay for a brand implies the sum of pure monetary value for the brand and all the unobservable characteristics of the smartphone. There are also assumptions that hedonic price model rests on that smartphones are homogenous goods and market operates under perfect competition. Both assumptions could be argued.

3.2. Empirical model

The smartphones have many attributes which are correlated. Therefore, in order to receive neither overfitting nor underfitting model the best subset selection machine learning algorithm was utilized. Hocking and Leslie (1967) presented the methodology for the best subset selection of independent variables. This approach consists of comparing different models given the set of predictors. The algorithm finds the best subset of k variables for each k-variable model in terms of squared error. In other words, the best subset's output gives information on the best fitting variable(s) for the model with 1 predictor, 2 predictors, and so on. There is also information on each model about adjusted R squared, residual sum of squares, Bayesian information criteria, and Mallow's Cp to compare the models and choose the best one. Formally, this approach could be explained through the expression 2.

$$minimize \ \|Y - X\beta\|_2^2 \ subject \ to \ \|\beta\|_0 \leq k, \quad (2)$$

where Y is a response vector, X – matrix of independent variables, $\|\beta\|_0 = \sum_{i=1}^{p} 1\{\beta_i \neq 0\}$ is a count of non-zero β values and should be less or equal to k (subset

size). The best subset is being used on a full set of variables except for factor variables with 3 and more options like a brand name and internal storage.

After choosing the number and the set of variables with a help of the best subset selection algorithm, the following linear OLS model for the hedonic price model is estimated:

$$Price = \alpha + \sum_{i=1,2,\dots,13}(\beta_i * Selected\ Variable\ by\ Best\ Subset_i) + \beta_j * Internal\ Memory, GB_j + \sum_{k=1,2,\dots,39}(\beta_k * Brand\ Name_k) + \varepsilon \quad (3)$$

Hence price is regressed on smartphone's features selected by best subset selection, internal memory variable, and brand name. There are 13 variables for the best subset selection, 7 specifications of internal memory, and 39 distinct brand names.

Best subset selection machine learning algorithm is a combination of numerous OLS regressions with all possible combinations of variables. Therefore, BSS ML algorithm do not only choose the best functional form but also gives valuable information about significant dependency between features and price. At BSS stage we have already information about consumer's preferences on the smartphone market in Ukraine.

Taking into account that the hedonic price model is estimated using ordinal least squares (OLS) methodology, it is important to check the consistency with its assumptions.

Outliers can affect the OLS model and bias its predictions. For that reason, the top 1% of models by price were excluded from the data to estimate a proper regression. It is also reasonable to create additional hedonic price models filtering by prices due to the not normal distribution and different consumer's preferences for a particular class of smartphones (by price).

CHAPTER 4. DATA

Data consisting of smartphones' characteristics and their prices have been web scraped from the biggest in Ukraine e-commerce retailer Rozetka. In order to obtain that, the web scraping techniques were utilized using R programming language. On "Rozetka" there is the largest list of actual smartphone models officially on sale. Additionally, there are detailed and well-structured characteristics lists for each model. "Rozetka" is selling products on its behalf, and also embodies a marketplace where the third-party sellers may conduct trade activities. For that reason, the filter was imposed to scrape only from the seller "Rozetka", and overcome the problem of duplicates, and not a full list of characteristics. For the portion of smartphones' prices discounts were applied. Hence, the discounted (lower) price was taken into account as it better reflects market equilibrium.

Web-scraping and data preparation were performed using xml2, rvest, jsonlite, selectr, stringr, dplyr libraries in R programming language, and "R Studio" Integrated Development Environment. From the first page with smartphones filtered by seller all pagination URLs were scraped and after that URLs for each model were obtained. Having URLs for each smartphone, price, and title were scraped. The next step was to create a new list of URLs pasting "characteristics/" in the end in order to scrape features into the list of data frames. The final data set was created for the name of the smartphone, its price, a brand name derived from the name, and matched characteristics for each product from the list of data frames.

The process of cleaning the data was also performed using R programming language. For the continuous variables, all non-numeric characters were deleted, while for factor variables – 0 and 1 (for binary variable) and levels of options (for more than 2 levels) were pasted. In case of the CPU variable, only the first value was used, meaning not taking into account overclocking. If information is not available for a particular feature and model, then "NAs" is written into the data frame. There were a few "NAs" and they were filled manually with the corresponding information on other recourses.

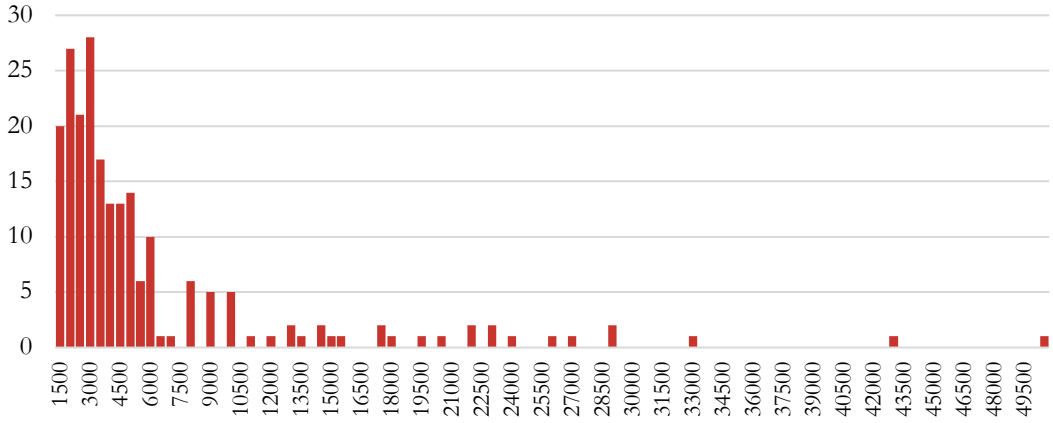
As of May 2020, there were 213 distinct smartphone models on sale, and in the data. It is important to note, that for products on discounts a new price was taken into account. It is reasonable as new (discounted) price better reflects demand-supply equilibrium.

The following 21 characteristics were scraped for each smartphone including price:

- screen size, inch
- number of SIM cards
- RAM, GB
- internal memory, GB
- expandable memory, Y/N
- front camera resolution, MP
- CPU, GHz
- main camera resolution, MP
- battery capacity, mAh
- possibility to charge wirelessly, Y/N
- possibility for fast charge, Y/N
- availability of mini-jack, Y/N
- color of the phone case
- weight, g
- width, mm
- height, mm
- thickness, mm
- availability of fingerprint scanner, Y/N
- possibility to unlock by face, Y/N
- a country where the vendor's brand is registered
- brand name (vendor)

The mean price for those 213 smartphones is 5 861.71 UAH and median one – 3 333 UAH. 79% of the smartphones on sale in Ukraine are in the price range from 1100 to 6000 UAH.

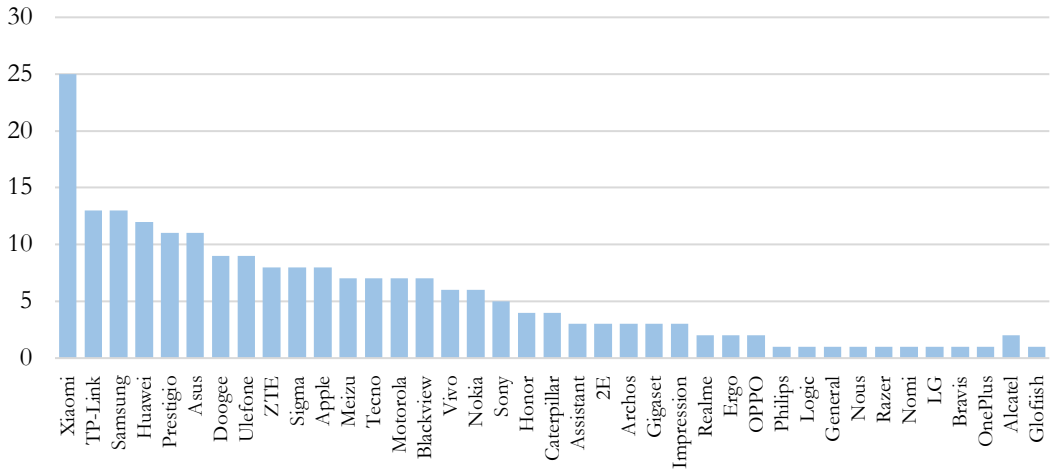
Figure 4.1. Price distribution of the smartphones' prices



Looking at the price distribution, which is skewed positively skewed with a coefficient of 3.21 and far from the normal, heteroscedasticity problem is likely to occur. Testing is made by visual inspection of residuals' distribution and Breusch-Pagan test. To remedy this, robust standard errors are implemented in case of need.

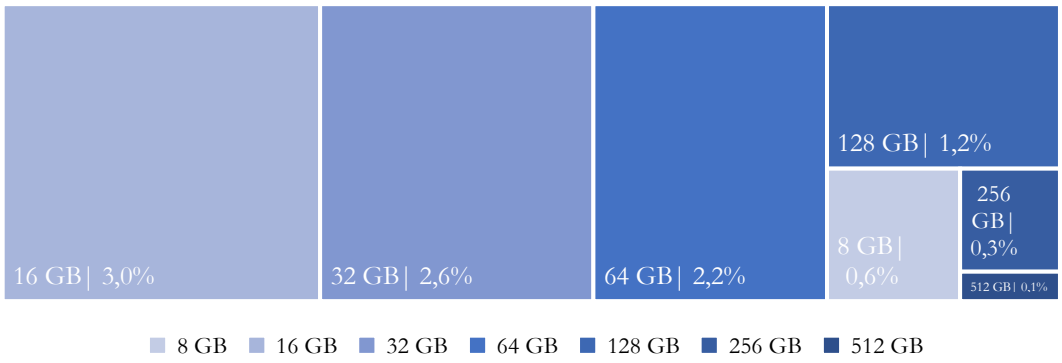
There are 39 distinct vendors selling smartphones in the Ukrainian market. The biggest number of smartphone specifications on sale possesses Xiaomi, 25 different models are presented on the Ukrainian market in April 2020. TP-Link and Samsung share the second position with 13 models on the market. In this case, the same models, for instance, with different internal storages are counted as different models, they have different specifications.

Figure 4.2. Number of smartphones' propositions by a vendor



The most popular capacity of internal storage is 16 GB, 30% of smartphones have this characteristic. 32 GB and 64 GB versions are also quite popular and together with 16 GB make up 77.9% of all smartphones. 8 GB, 256 GB, and 512GB specifications are the least popular. It is worth noticing that 86.9% of smartphones have the option to expand the internal memory by using memory cards.

Figure 4.3. Frequency of internal storage's options

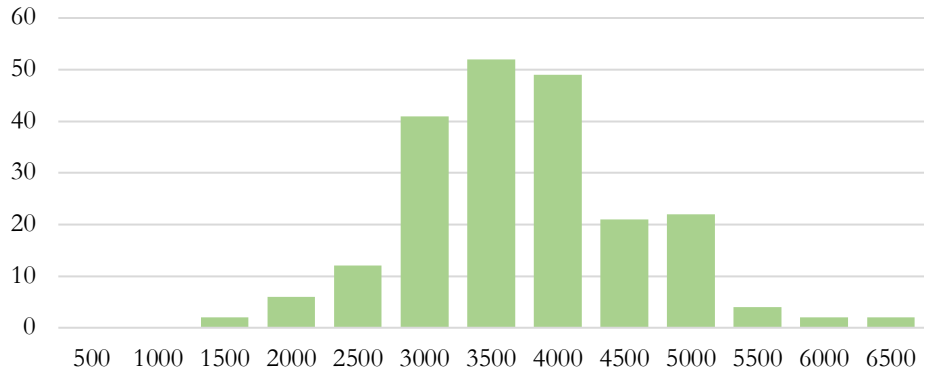


Median screen size is 5.99 inches, 95.3% of the smartphones have 2 slots for SIM cards. Median values for main and front camera resolution are 13 and 8 megapixels respectively. The median CPU clock speed is 1.8 GHz.

9.9% of all smartphones can be charged wirelessly and 47.9% have a "fast charge" feature. There is a trend in new models of the absence of a TRS connector (3.5 audio jack) due to the increasing adoption of wireless headphones. Nevertheless, 87.3% of the smartphones on sale in Ukraine still have this connector.

Battery life is one of the most important features in this market and manufacturers always make a trade-off decision about its capacity as a battery itself takes most of the space inside of the smartphones. The median battery capacity installed in smartphones is equal to 3 400 mAh. The distribution of battery capacities is presented below.

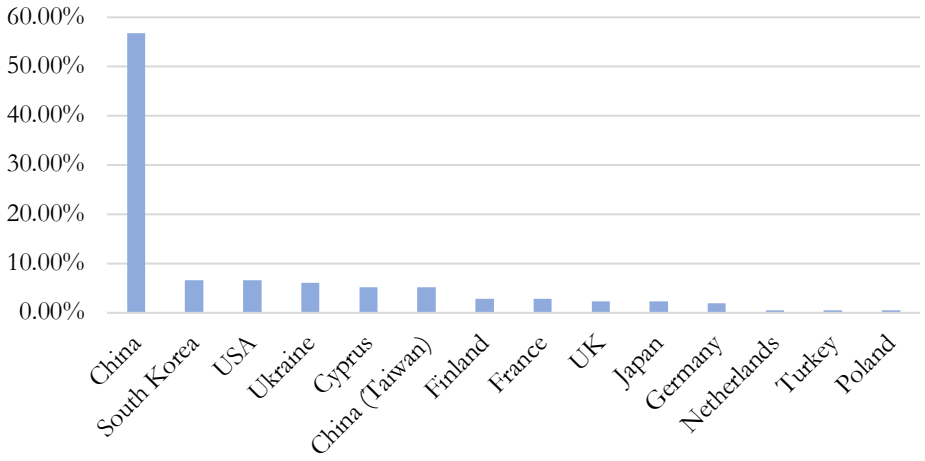
Figure 4.4. Battery capacity distribution, mAh



69% of the smartphones have the feature of unlocking the screen by finger and 52% allows the user to unlock the phone by face. 83% of the models have at least one of the features listed above.

Smartphones on sale in Ukraine are originated (their brand) from different countries. China's brands are the leaders and captured 61.97% of the market (China and Taiwan brands). South Korea has the second position with 6.57%. Ukraine vendors are located in the fourth position with 6.10%. Ukrainian smartphones are presented by Sigma, Glofiish, Impression, and 2E vendors.

Figure 4.5. Country of the brand's origin distribution



CHAPTER 5. RESULTS

This chapter presents the estimation results of the hedonic price for smartphones in Ukraine on sale on Rozetka.

5.1. Selecting independent variables

There are 21 characteristics for each smartphone, but not all of them possess the same explanatory power for consumers' willingness to pay. For that purpose, the best subset selection machine learning algorithm was utilized on the entire set of variables except for price, internal storage, brand name and thickness, weight, height, and width. Internal storage and brand name are factor variables; therefore, they are excluded at this stage but will be added to the final hedonic price regression. Thickness and weight, in turn, has a high correlation with other independent variables such as battery capacity. Height and width were excluded because of difficulties in comparison and low explanatory power.

Best model fit is achieved with 10 out of 13 following variables into the model: a number of SIM cards, RAM, CPU, main camera resolution, Battery capacity, wireless charging, fast charge, TRS connector (mini jack), fingerprint, and unlock by face. Model exactly with these variables has the highest adjusted R squared and other criteria.

5.2. Estimation results

Two OLS hedonic price regression models were estimated. The first regression was estimated using explanatory variables chosen by the best subset selection algorithm adding the internal storage and brand name variables. There are outliers in terms of price in the data set, therefore top 1% of observations by price were excluded. Only 2 observations were bypassed, two new iPhone 11 models with an internal storage of 512 GB. It means that in the second model there is no 512 GB option for internal storage as these models represent the entire population for a particular storage option.

Table 5.1. Estimation results for the hedonic price model (significant brand names)

	Regression on a full data set			Regression without top 1% models by prices		
Variable	Estimate	Std. Error		Estimate	Std. Error	
(Intercept)	2921.83	3872.48		2980.00	3867.50	
`Number of SIM cards`	-1324.62	1144.47		-1312.00	1142.90	
`RAM, GB`	1627.70	252.42	***	1630.00	252.61	***
`CPU, GHz`	628.55	622.10		632.90	620.27	
`Main Camera Resolution`	-25.88	18.09		-25.61	18.20	
`Battery, mAh`	0.62	0.17	***	0.58	0.17	***
`Wireless Charging`	4353.63	1155.35	***	4370.00	1155.30	***
`Fast Charge`	-25.22	262.53		-17.97	259.51	
`Mini Jack`	-2172.36	1024.86	*	-2156.00	1024.00	*
Fingerprint	-899.68	335.61	**	-895.10	334.92	**
`Unlock by Face`	-263.72	261.07		-263.80	260.54	
`Internal Memory, GB`16	-737.08	294.94	*	-722.10	288.43	*
`Internal Memory, GB`32	-1714.01	542.74	**	-1685.00	536.74	**
`Internal Memory, GB`64	-1977.96	786.18	*	-1961.00	781.28	*
`Internal Memory, GB`128	-995.05	1141.98		-983.80	1140.40	
`Internal Memory, GB`256	-1169.76	2641.38		-1159.00	2645.20	
`Internal Memory, GB`512	19492.46	4300.17	***	-	-	
`Brand Name`Alcatel	-1243.79	542.71	*	-1247.00	3536.50	*
`Brand Name`Apple	11543.89	3534.47	**	11530.00	1271.70	**
`Brand Name`Caterpillar	9221.07	2819.19	**	9239.00	529.62	**
`Brand Name`General	1536.49	587.20	**	1539.00	430.93	**
`Brand Name`Glofiish	-1766.14	522.09	***	-1786.00	644.20	***
`Brand Name`LG	1179.47	461.21	*	1144.00	497.25	*
`Brand Name`Logic	11659.15	498.68	***	11690.00	733.55	***
`Brand Name`Meizu	-2080.83	731.42	**	-2097.00	751.84	**
`Brand Name`Nous	-1101.19	487.52	*	-1123.00	1245.20	*
`Brand Name`Razer	8988.40	2179.31	***	9003.00	923.04	***
`Brand Name`Samsung	1168.80	614.42	.	1180.00	642.45	.
`Brand Name`Sony	2097.49	999.17	*	2070.00	632.71	*
`Brand Name`Ulefone	-1484.17	818.49	.	-1440.00	688.74	.
Observations	213			211		
Adjusted R^2	0.937			0.912		

Note: ` indicates statistical significance at the 90% confidence level, * 95% confidence level, ** 99% confidence level, *** 99.9% confidence level.

In Table 5.1 first column shows coefficients, standard errors, and significance for the model that was estimated on a full data set, while the second column corresponds to model free of two outliers. This table shows brand names that have significant explanatory power to spare the space, the full output is placed in appendix B.

Both models have non-constant error variance according to the visual inspection (appendix C) and the Breush-Pagan test. It is a violation of the OLS assumption that error variance is homoscedastic (constant). To remedy the heteroscedasticity, robust standard errors were used in both regressions.

Coefficients in both columns in Table 5.1 represent consumers' willingness to pay for a particular smartphone's feature. Some of the variables are continuous and some – factors. For continuous variables, coefficient stands for how much consumer is willing to pay for an additional unit of a variable over the average and keeping other things constant. The coefficient for the factor variables shows the consumer's valuation of a particular feature ceteris paribus compared to the base category.

In particular, for an additional 1 GB of RAM consumers are willing to pay 1630 UAH controlling for other variables. Battery life coefficient has a positive sign indicating consumers are willing to pay 0.58 UAH for 1 additional mAh over the average or 580 UAH for 1000 mAh ceteris paribus. Wireless charging is a relatively new and not cheap feature, therefore preferably expensive smartphone models have this feature. The median and average price for smartphones with this feature is 9 999 UAH and 21 412.76 UAH respectively. Hence, according to the model, the availability of wireless charging is valued for 4 370 UAH compared to the models without this characteristic and keeping other ones constant. TRS connector or simply mini-jack is not present in modern and expensive handsets due to the increasing popularity of wireless headphones. Therefore, the existence of a mini-jack connector is associated with a cheaper model and the effect is negative on price. Fingerprint has also a negative effect on price.

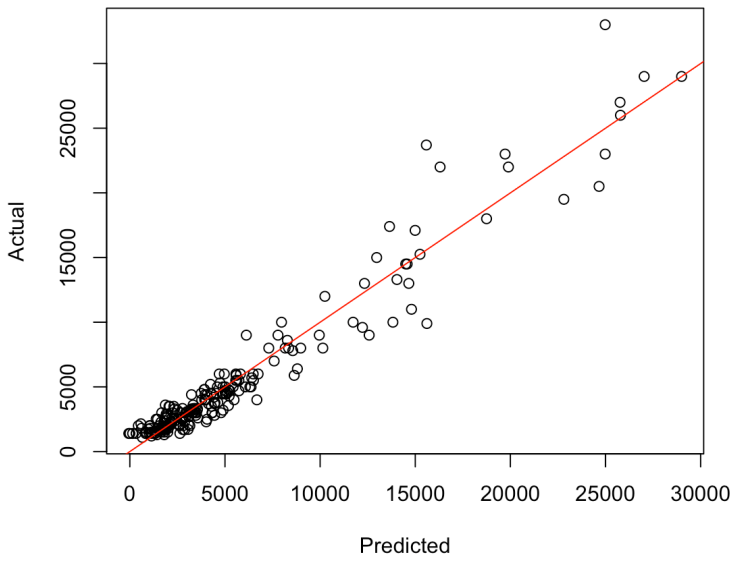
Internal storage is an essential feature of each modern smartphone and its market price, as of a component, is nearly proportional to the storage size. Regression results on a full range of models show that 16, 32, 64 GB specifications have negative consumer's willingness to pay. It does not mean that consumers do not value bigger storage size, a possible explanation, in this case, is that modern and expensive models have more storage available. Even more, a lot of new models do not have less than 64 GB options for internal storage. Also, there is always a possibility to expand storage by using memory cards. 512 GB internal storage option is only available in two iPhone 11 models as was mentioned before and consumers are willing to pay additionally almost 20 thousand UAH compared to the base category (8 GB), holding other features constant.

The hedonic price model for the Ukrainian market of smartphones shows that brand names possess high explanatory power. The brand captures such effect as reliability and reputation of the smartphone, design, operational system (for Apple), ecosystem, unique software and hardware features, and other unobservable characteristics in the data. Apple (11 530.00 UAH), Logic (11 690.00 UAH), Caterpillar (9 239.00 UAH), and Razer (9 003.00 UAH) have demonstrated that consumers are willing to pay a high premium for these brands compared to the Asus brand name and controlling for the rest of the features. Asus was chosen as a base category because its median price 4 444 UAH (5 745.63 UAH - mean price) is close to the median price on the market 3 333 UAH (5 861.71 UAH – mean price) and Asus is on the 6th place by the number of handsets on sale. For Apple, it is not surprising as handsets of this brand are in the Ultra-Premium segment. Apple also has created a unique ecosystem among its full list of devices. As switching cost is higher for the consumers, the company has the possibility to charge more. As of Logic, Caterpillar, and Razer, a high premium on brand is due to the fact that particular models on sale in the data have enhanced protection and were developed for special purposes. Unfortunately, there is no variable for capturing the enhanced protection in this data set.

The rest of the brand names that possess significant explanatory power are Alcatel (-1 243.79 UAH), Archos (-2 180.46 UAH), General (1 536.49 UAH), Glofish (-1 766.14 UAH), LG (1 179.47 UAH), Meizu (-2 080.83 UAH), Nous (-1 101.19 UAH), Samsung (1 168.80 UAH), Sony (2 097.49 UAH), and Ulefone (-1 484.17 UAH). Some brand names contribute negatively to the price. Consumers, holding other characteristics constant, demand "remuneration" for these brands compared to Asus. They do not value those brands, and this case it means that reliability, OS, design, production materials, prestige, ecosystem, and other features are values less than for brand Asus. Statistically insignificant variables mean that its coefficients are indifferent from zero. Therefore, insignificant brands stand for zero-premium on brand compared to Asus.

Does the estimated hedonic price model predict the price of the smartphone accurately? For the lower-price range, where most of the observations lie, prediction accuracy is pretty high, but for the upper-price level, enhanced deviation takes place.

Figure 5.1. Actual and predicted smartphones' prices (without the top 1% by price)



It is reasonable to estimate hedonic price model for smartphones price 7000 UAH or lower. Price is a dependent variable and type of its distribution is crucial for the correct modeling. Prices are highly skewed to the right in the range of 7 000 UAH and more. On the other hand, consumers of such category of smartphones may have different preferences.

For this reason, best subset selection recommends to include a slightly different set of variables into the model: screen size, RAM, possibility to expand the internal memory, front camera resolution, CPU, battery life, wireless charging, fast charge, TRS connector (mini-jack), fingerprint, and unlock by face.

Estimation results are presented in the Table 5.2. Full estimation output is located in appendix D. As expensive models were excluded from the model, the overall marginal willingness to pay is lower. For instance, one additional gigabyte of RAM over the average is going to be valued by consumers for 467.70 UAH instead of 1 630 UAH in the full model. In cheaper smartphones, front camera resolution and fast charge have a significant effect on price unlike in previous results. Fast charge feature is valued by consumers for 439.40 UAH holding other characteristics constant. For additional megapixel of the front camera, over the average, consumers are willing to pay 27.50 UAH, ceteris paribus.

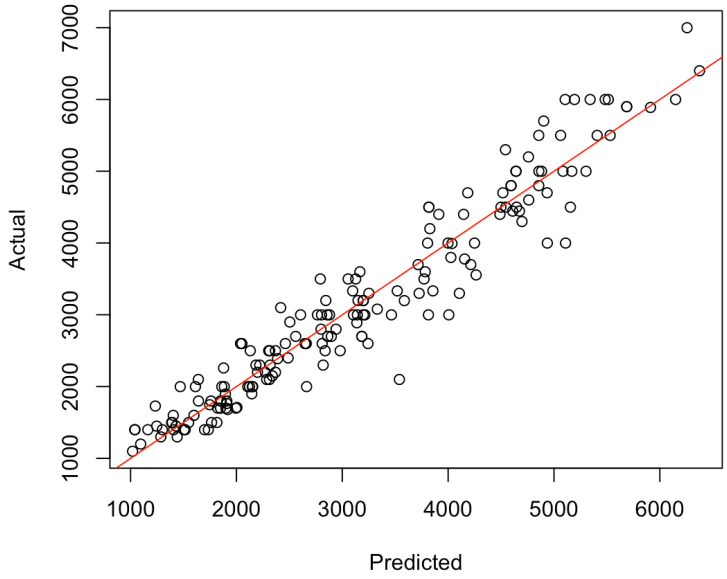
Table 5.2. Estimation results for the hedonic price model for the smartphones priced 7 000 UAH and less (significant brand names)

Variable	Estimate	Std. Error	Significance
(Intercept)	908.60	891.60	
`Screen Size`	64.95	142.80	
`RAM, GB`	476.70	97.44	***
`Expandable Memory`	173.30	408.40	
`Front Camera Resolution, MP`	27.51	10.64	*
`CPU, GHz`	32.77	186.70	
`Battery, mAh`	0.22	0.06	***
`Wireless Charging`	1278.00	352.70	***
`Fast Charge`	439.40	118.20	***
`Mini Jack`	-726.80	302.60	*
Fingerprint	-65.95	111.50	
`Unlock by Face`	-167.60	97.01	.
`Internal Memory, GB`16	-100.60	180.80	
`Internal Memory, GB`32	138.50	245.40	
`Internal Memory, GB`64	590.20	336.10	.
`Internal Memory, GB`128	635.90	389.00	
`Brand Name`Alcatel	-1070.00	376.10	**
`Brand Name`Archos	-769.30	389.60	.
`Brand Name`Assistant	-570.40	333.90	.
`Brand Name`Doogee	-663.20	241.50	**
`Brand Name`Gigaset	-928.10	325.90	**
`Brand Name`Glofiish	-1229.00	500.70	*
`Brand Name`Huawei	551.20	245.50	*
`Brand Name`Impression	-909.30	335.80	**
`Brand Name`Meizu	-683.20	295.60	*
`Brand Name`Prestigio	-482.10	234.60	*
`Brand Name`Samsung	823.60	239.40	***
`Brand Name`Sigma	963.10	251.20	***
`Brand Name`Sony	813.00	297.40	**
Observations	171		
Adjusted R^2	0.8974		

Note: ` indicates statistical significance at the 90% confidence level, * 95% confidence level, ** 99% confidence level, *** 99.9% confidence level.

The accuracy of price prediction is quite high and is presented below in the Figure 5.2.

Figure 5.2. Actual and predicted smartphones' prices up to 7 000 UAH



Unlike the previous models, hedonic price estimation on smartphone models priced up to 7 000 UAH has constant error variance (homoscedastic) according to Breusch-Pagan test and visual inspection presented in appendix E.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

In this work, the hedonic price models were estimated for the Ukrainian market of smartphones. Such models reveal a consumer's willingness to pay for particular features and brands. The results concluded that the brand possesses significant explanatory power and for some brands customers are willing to pay a premium up to 11 700 UAH compared to the Asus brand. Brand name premiums may also include unobservable features, that other brands do not provide. Premiums for the brand vary: Apple (11 530.00 UAH), Logic (11 690.00 UAH), Caterpillar (9 239.00 UAH), Razer (9 003.00 UAH), Alcatel (-1 243.79 UAH), Archos (-2 180.46 UAH), General (1 536.49 UAH), Glofish (-1 766.14 UAH), LG (1 179.47 UAH), Meizu (-2 080.83 UAH), Nous (-1 101.19 UAH), Samsung (1 168.80 UAH), Sony (2 097.49 UAH), and Ulefone (-1 484.17 UAH).

The main features in smartphones that consumers value are Random-access memory (RAM), battery life, the possibility to charge a smartphone wirelessly, and internal memory of 512 GB. Fingerprint and TRS connector (mini-jack) are regarded as old features and prevalently are installed in cheaper models. Therefore, consumers are not willing to pay for these characteristics. As of smartphones for the price less or equal 7 000 UAH, consumers in this category value front camera resolution and are willing to pay almost 440 UAH for the possibility to charge smartphone quickly, controlling for other features. Possibility to unlock the smartphone by face is not valued by consumers of a cheaper tier, which may be caused by poor technology that uses only the front camera without any additional hardware as in more expensive models. According to the estimation results of the hedonic model for smartphones priced up to 7 000 UAH, consumers of cheaper smartphones are not willing to pay for additional internal storage compared to the base option (8 GB). It could be explained that more than 98% of the smartphones in this price range have the possibility to expand the internal memory. The overall significance of hedonic price models and prediction accuracy is pretty high.

As results confirmed that brand names possess significant explanatory power of the price and reveal the consumer's willingness to pay a premium for that, mobile vendors and related third parties should take it into account. Customer retention is cheaper than acquisition. A significant positive brand premium means that vendor has unique features on the market that for consumers are willing to pay. Expenditures for research and development are valued by users and it is paid off. GfK's Consumer Life Study report states the trend, that for the consumers, experience of using the smartphone is becoming more valuable than its technical characteristics. Hence, brand names in hedonic price modelling are explaining all non-technical features of the device and overall experience.

It is complicated for the vendors to compete in the plane of technical characteristics. There is a lot of supply in the market for each tier by prices with the same hardware. Taking into account demand side, consumers are actively using the Internet to choose the best option for them by price, appearance, case materials, productivity and the balance between them. Price comparison web sites deserve special attention, because of decreasing again the possibility to compete in prices. Though we should remember that smartphone industry is likely to have oligopolistic competition. It means that vendors should present unique experience, high switching cost, ecosystem of products and outstanding marketing campaign to improve their market position. All the factors listed above make up the vendor's brand name power.

Modern smartphones are already well-performing and some models are equipped with PC-like hardware. Therefore, and according to the models, vendors should provide their smartphones with additional gigabytes of RAM and enhanced battery life. Battery production techniques, in turn, are one of the main obstacles on the way of the rapid development of the industry.

Fast and wireless charging is in demand, as hedonic prices show, implementation of these features is almost compulsory for the nearest future. More and more devices in

our homes need to be charged on a daily basis. Implementing fast and wireless charging makes it easier for consumers.

For the smartphones priced up to 7 000 UAH, vendors should pay attention to the front camera resolution. The possibility to expand memory is not valued by customers, therefore it is recommended to provide models with increased internal memory. Both models also pointed out that consumers are not willing to pay for a TRS connector. If its absence can spare some room, it is better to increase battery life instead or substitute for another feature mentioned above.

Ukrainian market of smartphones is mostly captured by foreign manufactures and handsets are imported to Ukraine. Only a small share of the market belongs to domestic vendors. Importers are more flexible than manufactures, and can adjust their strategy what specifications to import. Recommendations given in this section could be utilized also by importers for the better understanding of needs and willingness to pay for particular features on the Ukrainian market of smartphones.

Smartphone industry is rapidly developing and fast changing. Methods and approaches that perform well nowadays most likely will not do the same in the nearest future.

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APPENDIX A

Price	
Mean	5861.70892
Standard Error	483.0453754
Median	3333
Mode	2999
Standard Deviation	7049.81516
Sample Variance	49699893.79
Kurtosis	12.58856881
Skewness	3.210587958
Range	49400
Minimum	1099
Maximum	50499
Sum	1248544
Count	213
Confidence Level(95.0%)	952.1872618

APPENDIX B

	Regression on full data			Regression without top 1% models by prices		
Variable	Estimate	Std. Error		Estimate	Std. Error	
(Intercept)	2921.83	3872.48		2980.00	3867.50	
`Number of SIM cards`	-1324.62	1144.47		-1312.00	1142.90	
`RAM, GB`	1627.70	252.42	***	1630.00	252.61	***
`CPU, GHz`	628.55	622.10		632.90	620.27	
`Main Camera Resolution`	-25.88	18.09		-25.61	18.20	
`Battery, mAh`	0.62	0.17	***	0.58	0.17	***
`Wireless Charging`	4353.63	1155.35	***	4370.00	1155.30	***
`Fast Charge`	-25.22	262.53		-17.97	259.51	
`Mini Jack`	-2172.36	1024.86	*	-2156.00	1024.00	*
Fingerprint	-899.68	335.61	**	-895.10	334.92	**
`Unlock by Face`	-263.72	261.07		-263.80	260.54	
`Internal Memory, GB`16	-737.08	294.94	*	-722.10	288.43	*
`Internal Memory, GB`32	-1714.01	542.74	**	-1685.00	536.74	**
`Internal Memory, GB`64	-1977.96	786.18	*	-1961.00	781.28	*
`Internal Memory, GB`128	-995.05	1141.98		-983.80	1140.40	
`Internal Memory, GB`256	-1169.76	2641.38		-1159.00	2645.20	
`Internal Memory, GB`512	19492.46	4300.17	***	-	-	
`Brand Name`2E	-236.61	489.60		-263.70	531.82	
`Brand Name`Alcatel	-1243.79	542.71	*	-1247.00	3536.50	*
`Brand Name`Apple	11543.89	3534.47	**	11530.00	1271.70	**
`Brand Name`Archos	-2180.46	1272.81	.	-2189.00	903.65	.
`Brand Name`Assistant	-24.94	910.48		-54.05	561.77	
`Brand Name`Blackview	-656.17	563.48		-634.50	475.52	
`Brand Name`Bravis	-723.25	476.51		-725.50	2818.70	
`Brand Name`Caterpillar	9221.07	2819.19	**	9239.00	529.62	**
`Brand Name`Doogee	-477.70	536.15		-459.50	494.54	
`Brand Name`Ergo	-353.72	496.43		-374.10	588.37	
`Brand Name`General	1536.49	587.20	**	1539.00	430.93	**
`Brand Name`Gigaset	-397.12	430.64		-395.10	522.24	
`Brand Name`Glofiish	-1766.14	522.09	***	-1786.00	644.20	***
`Brand Name`Honor	407.39	648.02		397.40	730.99	

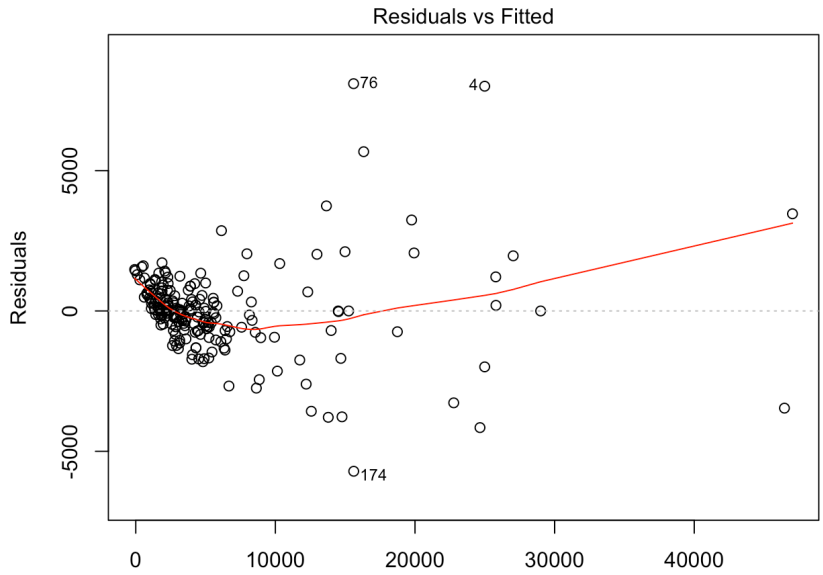
APPENDIX B (CONTINUED)

	Regression on full data			Regression without top 1% models by prices		
Variable	Estimate	Std. Error	Variable	Estimate	Std. Error	Variable
`Brand Name`Huawei	900.19	729.59		894.70	776.24	
`Brand Name`Impression	-1302.34	793.43		-1263.00	459.53	
`Brand Name`LG	1179.47	461.21	*	1144.00	497.25	*
`Brand Name`Logic	11659.15	498.68	***	11690.00	733.55	***
`Brand Name`Meizu	-2080.83	731.42	**	-2097.00	751.84	**
`Brand Name`Motorola	1203.61	756.21		1197.00	515.81	
`Brand Name`Nokia	-146.82	516.36		-150.00	573.16	
`Brand Name`Nomi	695.14	576.20		646.70	486.76	
`Brand Name`Nous	-1101.19	487.52	*	-1123.00	1245.20	*
`Brand Name`OnePlus	403.18	1244.85		408.20	1043.30	
`Brand Name`OPPO	-1480.88	1037.90		-1462.00	546.43	
`Brand Name`Philips	-57.83	546.14		-70.75	472.88	
`Brand Name`Prestigio	-756.27	475.93		-762.20	2183.10	
`Brand Name`Razer	8988.40	2179.31	***	9003.00	923.04	***
`Brand Name`Realme	686.94	927.71		691.50	615.06	
`Brand Name`Samsung	1168.80	614.42	.	1180.00	642.45	.
`Brand Name`Sigma	-243.66	653.60		-195.50	999.78	
`Brand Name`Sony	2097.49	999.17	*	2070.00	632.71	*
`Brand Name`Tecno	-169.49	641.22		-162.50	478.88	
`Brand Name`TP-Link	15.96	479.05		-0.01	814.52	
`Brand Name`Ulefone	-1484.17	818.49	.	-1440.00	688.74	.
`Brand Name`Vivo	-258.64	697.27		-223.50	677.38	
`Brand Name`Xiaomi	-35.75	673.38		-31.46	535.90	
`Brand Name`ZTE	237.07	536.30		221.80	907.20	
Observations		213			211	
Adjusted R^2		0.937			0.912	

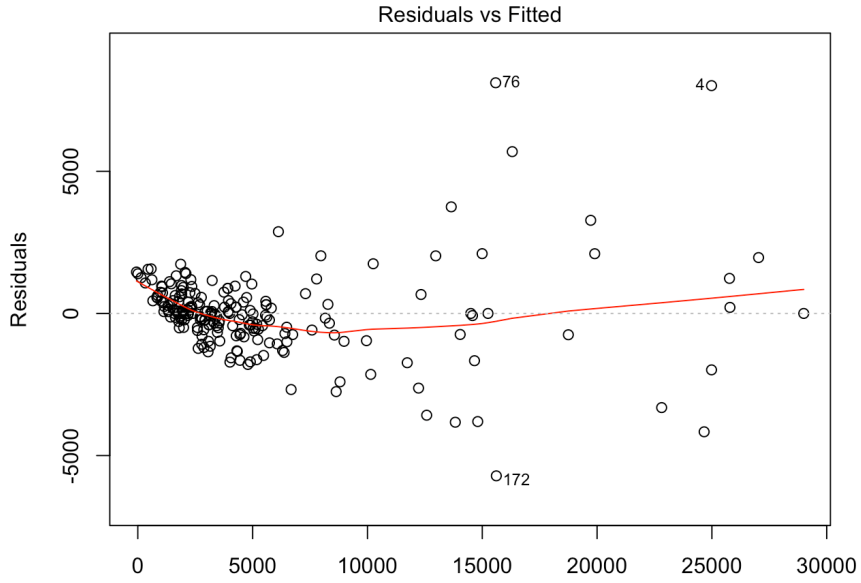
Note: · indicates statistical significance at the 90% confidence level, * 95% confidence level, ** 99% confidence level, *** 99.9% confidence level.

APPENDIX C

Regression on full data



Regression without top 1% models by prices



APPENDIX D

Variable	Estimate	Std. Error	Significance
(Intercept)	908.60	891.60	
`Screen Size`	64.95	142.80	
`RAM, GB`	476.70	97.44	***
`Expandable Memory`	173.30	408.40	
`Front Camera Resolution, MP`	27.51	10.64	*
`CPU, GHz`	32.77	186.70	
`Battery, mAh`	0.22	0.06	***
`Wireless Charging`	1278.00	352.70	***
`Fast Charge`	439.40	118.20	***
`Mini Jack`	-726.80	302.60	*
Fingerprint	-65.95	111.50	
`Unlock by Face`	-167.60	97.01	.
`Internal Memory, GB`16	-100.60	180.80	
`Internal Memory, GB`32	138.50	245.40	
`Internal Memory, GB`64	590.20	336.10	.
`Internal Memory, GB`128	635.90	389.00	
`Brand Name`2E	-413.90	339.60	
`Brand Name`Alcatel	-1070.00	376.10	**
`Brand Name`Archos	-769.30	389.60	.
`Brand Name`Assistant	-570.40	333.90	.
`Brand Name`Blackview	-139.50	258.40	
`Brand Name`Bravis	-760.40	498.10	
`Brand Name`Doogee	-663.20	241.50	**
`Brand Name`Ergo	-452.70	381.60	
`Brand Name`General	-38.95	503.10	
`Brand Name`Gigaset	-928.10	325.90	**
`Brand Name`Glofiish	-1229.00	500.70	*
`Brand Name`Honor	285.60	336.80	
`Brand Name`Huawei	551.20	245.50	*
`Brand Name`Impression	-909.30	335.80	**
`Brand Name`LG	407.30	481.90	
`Brand Name`Meizu	-683.20	295.60	*
`Brand Name`Motorola	280.80	251.20	
`Brand Name`Nokia	-170.10	265.40	

APPENDIX D (CONTINUED)

Variable	Estimate	Std. Error	Significance
`Brand Name`Nomi	272.70	500.70	
`Brand Name`Nous	-544.70	496.20	
`Brand Name`OPPO	221.00	504.20	
`Brand Name`Philips	-255.00	500.60	
`Brand Name`Prestigio	-482.10	234.60	*
`Brand Name`Realme	29.60	499.80	
`Brand Name`Samsung	823.60	239.40	***
`Brand Name`Sigma	963.10	251.20	***
`Brand Name`Sony	813.00	297.40	**
`Brand Name`Tecno	-412.60	270.00	
`Brand Name`TP-Link	-326.10	225.10	
`Brand Name`Ulefone	68.70	260.90	
`Brand Name`Vivo	47.36	293.70	
`Brand Name`Xiaomi	-186.70	226.00	
`Brand Name`ZTE	-290.70	255.90	
Observations	171		
Adjusted R^2	0.8974		

Note: · indicates statistical significance at the 90% confidence level, * 95% confidence level, ** 99% confidence level, *** 99.9% confidence level.

APPENDIX E

Regression on smartphone models priced up to 7 000 UAH