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СОВЕРШЕНСТВОВАНИЕ МЕХАНИЗМА НОРМИРОВАНИЯ НАЧАЛЬНОЙ ЦЕНЫ КОНТРАКТА В СФЕРЕ ГОСЗАКУПОК НА ПРИМЕРЕ ЭКОНОМЕТРИЧЕСКОГО МОДЕЛИРОВАНИЯ ЦЕНЫ НОУТБУКА

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Аннотация
В статье рассмотрены проблемы формирования начальной (максимальной) цены контракта в сфере госзакупок на примере поставки ноутбуков. Для обоснования начальной цены использовались методы эконометрического моделирования. Выявлены основные факторы, которые влияют на цену ноутбуков, то есть при увеличении: объема оперативной памяти, количества пикселей, производительности видеокарты, количество usb-портов цена ноутбука будет резко расти. Результаты исследования могут быть использованы в сфере контроля за расходованием бюджетных средств.

Ключевые слова: эконометрическое моделирование, государственные закупки, начальная цена контракта, бюджетный контроль

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IMPROVEMENT OF THE MECHANISM OF RATIONING THE INITIAL CONTRACT PRICE IN THE FIELD OF PUBLIC PROCUREMENT ON THE EXAMPLE OF ECONOMETRIC MODELLING OF THE PRICE OF LAPTOP

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Abstract
The article deals with the problems of formation of the initial (maximum) price of the contract in the field of public procurement on the example of laptop supply. Methods of econometric modeling were used to justify the initial price. The main factors that affect the price of laptops are revealed, that is, with an increase in: the amount of RAM, the number of pixels, the performance of the video card, the num-

ber of usb ports, the price of the laptop will grow sharply. The results of the study can be used in the field of control over budget spending.
Keywords: econometric modelling, state procurements, initial contract price, budget control.

Введение

In recent years, the number of public contracts for the purchases of laptops has increased. Due to the increasing number of disruptions in the public procurements system, a large number of scientific researches are being conducted into the background causes and for avoiding negative effects of an inefficient use of budgetary funds. Single and clear mechanism of monitoring activities during the state tenders has not yet been developed in Russia. So Rybnikova G.I. states that it is important «to study those stages of public procurement at which the supervisory authorities have difficulties» [Rybnikova G.I., Tevosyan K.M., 2016].

One of the key stages of any public procurement is planning in which the major difficult lies in analysis the price calculation and justification of proposed procurements. Therefore, the purpose of this article is to analyze the factors affecting the initial (maximum) price of laptops at the planning stage of state and municipal procurements with subsequent econometric model specification.

Основная часть

The core of any econometric analysis is based on the correct determining of model parameters which are more likely accounted for estimated value.

Modern laptops are delicate pieces of technology that consist of many elements. The significant factors affecting the laptop's price are listed in Table 1.

Table 1

Data, their designations and units of measurement

Таблица 1

Данные, их обозначения и единицы измерения

Factor	Designation in Gretl	Units of measurement
1. Quantative variables		
CPU frequency	CPU	Number of GHz
Core	Core	Core count
Random access memory (RAM)	memory	Number of GB
Hard disk drive	HDD	Number of GB
Solid state driver	SSD	Number of GB
Monitor inch	screen_size	Number of inches
Pixels	pixel	Number of pixels
Performance of video card	videocard_performance	As the percentage of the best Nvidia Titan V video card at 24.10.2018 [6]
USB port 2.0	usb2	Number of pieces
Usb port 3.x	usb3	Number of pieces
Battery	baterry	Number of hours
2. Dummy variables		
Operation System (OS)	OS	1 – Windows 0 – other Os
DVD-drive	DVDRW	1 – yes 0 – no
Keyboard lightning	keyboard	1 – yes 0 – no

Factor	Designation in Gretl	Units of measurement
Laptop's material	material	1 – metal 0 – plastic
AMD video card	AMD	1 – yes 0 – no
Nvidia video card	Nvidia	1 – yes 0 – no
Intel video card	Intel	1 – yes 0 – no

For this study, 102 laptops were randomly selected from the official websites of the largest Russian online retailers of digital and home appliances: M.Video, DNS, TechnoPoint, Eldorado, Citilink. Laptops were selected into all price categories for accurate and reliable conclusions. The model was specified by Ordinary Least Squares (OLS-model) based on the data obtained using the GRETL program.

```
Модель 1: МНК, использованы наблюдения 1-102
Зависимая переменная: price
Пропущены из-за совершенной коллинеарности: Intel

                         Коэффициент      Ст. ошибка    t-статистика  P-значение
  ------------------------------------------------------------------------------
  const                -26977,6         14984,2          -1,800      0,0754     *
  CPU                    1916,66          2361,97          0,8115      0,4194
  core                  -1000,27          1189,55         -0,8409     0,4028
  memory                 3128,92           377,769          8,283      1,65e-012  ***
  HDD                      -6,66356          2,97879       -2,237      0,0279     **
  SSD                      -5,81346          9,99607       -0,5816     0,5624
  screen_size             800,893          931,236          0,8600      0,3922
  pixel                     0,00714860       0,00109095      6,553      4,30e-09   ***
  videocard_perfor~       778,756          164,676          4,729      9,00e-06   ***
  OS                    -5890,85          2526,20         -2,332      0,0221     **
  DVDRW                  1854,28          2417,29          0,7671      0,4452
  keybord                6598,27          2872,22          2,297       0,0241     **
  material              10206,2           2556,17          3,993       0,0001     ***
  battery                 352,483          467,304          0,7543      0,4528
  AMD                   -3095,83          3616,93         -0,8559     0,3945
  Nvidia                -6406,31          2896,84         -2,211      0,0297     **
  usb2                   4744,72          1468,48          3,231       0,0018     ***
  usb3                   8223,12          1945,79          4,226       6,01e-05   ***

ВНИМАНИЕ: матрица данных близка к сингулярной!

Среднее зав. перемен     50998,50   Ст. откл. зав. перемен  39647,29
Сумма кв. остатков       6,81e+09   Ст. ошибка модели       9006,376
R-квадрат                0,957083   Испр. R-квадрат         0,948397
F(17, 84)                110,1917   P-значение (F)          5,87e-50
```

Fig. 1. Multiple Linear Regression (MLR) model with all variables
Рис. 1. Модель множественной линейной регрессии (МЛР) со всеми объясняющими переменными

It is necessary to assess the quality of the resulting model for further analysis.

1. The significance of the coefficients of the explanatory variables. It is considered in the Gretl program that coefficient is significant at a significance level of 10%», if the achieved level of significance (*p-value*) of the coefficient is less than 0.1 [Econometrics. Regression analysis using the package Gretl: Laboratory Workshop, 2014]. This requirement is satisfied by the variables *const*, *memory*, *HDD*, *pixel*, *videocard_performance*, *OS*, *keyboard*, *material*, *Nvidia*, *usb2* and *usb3* satisfy. For the other variables, the p-value of the coefficients has

turned out to be greater than 0.1, they were insignificant and therefore were excluded from further analysis.

2. t-statistics. Since the sample was 102 observations, so t-critical by t-Student is equal to 1.659 at a significance level of 10%. Comparing the obtained values, it appeared that the coefficients of *const*, *memory*, *HDD*, *pixel*, *videocard_performance*, *OS*, *keyboard*, *material*, *Nvidia*, *usb2* and *usb3* have t-statistics modulo more than t-critical, which indicates their statistical significance. And the remaining coefficients of CPU, core, SSD, screen_size, DVDRW, battery and AMD have t-statistics less than t-critical, it means they are not significant.

3. The significance of the regression equation in general according to Fisher's F-test (P-value (F)). «If the P-value (F) is less than 0.01, the equitation is significant at a significance level of 1% (at an assurance level of 99%)» [Econometrics. Regression analysis using the package Gretl: Laboratory Workshop, 2014]. Because of the P-value(F)=2.33e-26<0.01, the regression equitation is significant and it can be used in further analysis.

4. Standard error of the estimate is 9006.38 RUB with an average laptop's price at 50998.5 RUB (or 17.66%), which indicates the satisfactory accuracy of the model.

5. Goodness of fit to selected data by the adjustable coefficient of determination (adj. R-squared). Using the coefficient of determination, one can be defined «the matching rate of the found equation to the actual data. Adj. R-squares in this model was 0.9484, so the factor of laptop's price change is explained sum of squares by 94.84%. Thus, the quality of the fit equation is very accurate.

6. Goodness of fit to selected data by the mean absolute percentage error (MAPE). In this regression equation was 16.4%. «If the model is fitted with high accuracy, so MAPE<10%, good – 10% <MAPE<20%, satisfactory – 20%<MAPE<50%, unsatisfactory – MAPE>50%». That was, the goodness of fit is good [Absolute approximation error, 2018].

The MLR model after eliminating insignificant explanatory variables is presented in Figure 2.

Модель 2: МНК, использованы наблюдения 1-102
Зависимая переменная: price

	Коэффициент	Ст. ошибка	t-статистика	P-значение	
const	−14295,1	4004,31	−3,570	0,0006	***
memory	3015,16	322,166	9,359	5,60e-015	***
HDD	−4,74393	2,17351	−2,183	0,0316	**
pixel	0,00667310	0,000882544	7,561	3,07e-011	***
videocard_perfor~	685,802	130,763	5,245	1,01e-06	***
OS	−6207,89	2447,57	−2,536	0,0129	**
keybord	5971,24	2503,69	2,385	0,0192	**
material	9596,99	2434,56	3,942	0,0002	***
Nvidia	−5902,24	2474,71	−2,385	0,0192	**
usb2	5216,64	1415,97	3,684	0,0004	***
usb3	10099,6	1663,05	6,073	2,86e-08	***

Среднее зав. перемен	50998,50	Ст. откл. зав. перемен	39647,29
Сумма кв. остатков	7,25e+09	Ст. ошибка модели	8923,054
R-квадрат	0,954363	Испр. R-квадрат	0,949348
F(10, 91)	190,2982	P-значение (F)	1,84e-56
Лог. правдоподобие	−1066,744	Крит. Акаике	2155,488
Крит. Шварца	2184,363	Крит. Хеннана-Куинна	2167,181

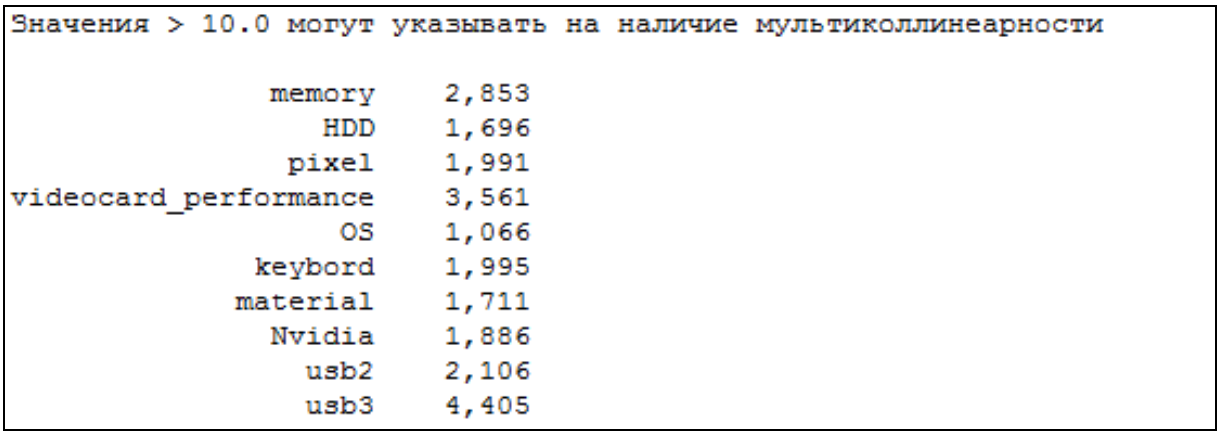
Fig. 2. MLR model after eliminating insignificant explanatory variables
Рис. 2. Модель МЛР после исключения незначимых объясняющих переменных

Adj. R-squared improved from 0.9484 to 0.9493. Thus, the eliminating insignificant explanatory variables has turned out to be true. All coefficients were significant (p-value less than 0.1).

At the next stage, «the existence of the strong correlation between explanatory variables» was determined [Econometrics. Regression analysis using the package Gretl: Laboratory Workshop, 2014], so multicollinearity test was performed (Fig. 3).

All values of variance inflation factors (VIF) of explanatory variables were less than 10; it has shown the absence of multicollinearity between these variables.

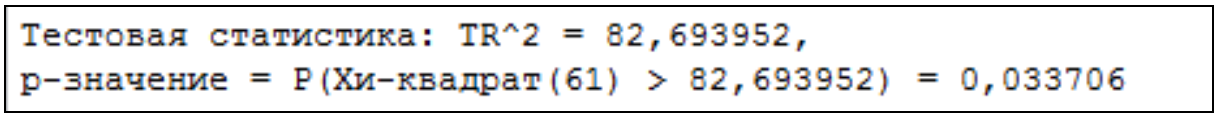
Further, the data were checked for the unequal spread (heteroscedasticity), to the White test for heteroscedasticity was carried out (Fig. 4).



```
Значения > 10.0 могут указывать на наличие мультиколлинеарности

                memory    2,853
                   HDD    1,696
                 pixel    1,991
videocard_performance    3,561
                    OS    1,066
               keybord    1,995
              material    1,711
                Nvidia    1,886
                  usb2    2,106
                  usb3    4,405
```

Fig. 3. Multicollinearity test
Рис. 3. Тест на мультиколлинеарность



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Тестовая статистика: TR^2 = 82,693952,
p-значение = P(Хи-квадрат(61) > 82,693952) = 0,033706
```

Fig. 4. White test for heteroscedasticity
Рис. 4. Тест Вайта на гетероскедастичность

Since the p-value was equal to 0.0337 and it was less than 0.05; this indicated the presence of heteroscedasticity. Therefore, calculations of robust errors were conducted, which has corrected the values of standard errors of the coefficient estimates. The MLR model adjusted on heteroscedasticity is shown in Figure 5.

Thus, from an economic point of view the interpretation of all coefficients of the explanatory variables was correct. All coefficients were significant. The standard error of the model was 8923.05 with a mean of 50998.5 (or 17.5%). Adjusted R-square has increased to 0.9484 (more than 0.9 is considered to be highly accurate) [Afanasev V.N., Semenychev E.V., 2014].

At the final stage, it was important to understand whether the specification of the model was correct or whether it was switching from a linear to a non-linear model. To this end, Regression Equation Specification Error Test (RESET-test Ramsey) was carried out on the correctness of the linear specification. RESET-test is shown in Figure 6.

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Модель 3: МНК, использованы наблюдения 1-102
Зависимая переменная: price
Робастные оценки стандартных ошибок (с поправкой на гетероскедастичность), вариант HC1

                        Коэффициент     Ст. ошибка    t-статистика  P-значение
  ------------------------------------------------------------------------------
  const                -14295,1         3798,60          -3,763     0,0003     ***
  memory                 3015,16         390,561           7,720     1,45e-011  ***
  HDD                      -4,74393        1,89609        -2,502     0,0141     **
  pixel                     0,00667310     0,00107690       6,197     1,65e-08   ***
  videocard_perfor~       685,802         112,826           6,078     2,80e-08   ***
  OS                     -6207,89         2844,68          -2,182     0,0317     **
  keybord                 5971,24         2143,88           2,785     0,0065     ***
  material                9596,99         2335,47           4,109     8,67e-05   ***
  Nvidia                 -5902,24         2148,21          -2,748     0,0072     ***
  usb2                    5216,64         1332,18           3,916     0,0002     ***
  usb3                   10099,6          1695,75           5,956     4,80e-08   ***

ВНИМАНИЕ: матрица данных близка к сингулярной!

Среднее зав. перемен     50998,50   Ст. откл. зав. перемен  39647,29
Сумма кв. остатков       7,25e+09   Ст. ошибка модели        8923,054
R-квадрат                0,954363   Испр. R-квадрат          0,949348
F(10, 91)                193,0951   P-значение (F)           9,77e-57
Лог. правдоподобие      -1066,744   Крит. Акаике             2155,488
Крит. Шварца             2184,363   Крит. Хеннана-Куинна     2167,181
```

Fig. 5. The model adjusted on heteroscedasticity
Рис. 5. Модель МЛР с поправкой на гетероскедастичность

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Вспомогательная регрессия для теста Рамсея
МНК, использованы наблюдения 1-102
Зависимая переменная: price

                        Коэффициент      Ст. ошибка    t-статистика  P-значение
  ------------------------------------------------------------------------------
  const                -2513,36         6238,91          -0,4029     0,6880
  memory                2316,56          426,459           5,432      4,70e-07  ***
  HDD                     -2,67481         2,28382        -1,171      0,2446
  pixel                    0,00531517      0,00102678       5,177     1,37e-06  ***
  videocard_perfor~      495,931          149,628           3,314     0,0013    ***
  OS                    -5935,64         2387,42          -2,486     0,0148    **
  keybord                7567,27         2527,02           2,995     0,0035    ***
  material               8611,90         2406,76           3,578     0,0006    ***
  Nvidia                -2840,67         2722,94          -1,043     0,2996
  usb2                   2216,16         1854,90           1,195     0,2353
  usb3                   7386,80         1970,35           3,749     0,0003    ***
  yhat^2                    9,52363e-07     3,93536e-07     2,420     0,0175    **

Тестовая статистика: F = 5,856467,
p-значение = P(F(1,90) > 5,85647) = 0,0175
```

Fig. 6. RESET-test
Рис. 6. RESET тест

Since p-value was equal to 0.0175 and less than 0.05; the MLR model in Figure 5 was presented in the wrong functional form (with a 95% assurance level). Therefore, non-linear terms were added to this regression equation, so a polynomial was considered (Fig. 7).

Polynomial model. Adding squared variables haven not helped to improve the goodness of the model: all variables were insignificant. As for the multiplication of explanatory variables, there were several significant coefficients

(in this case, quantitative variables were multiplied by dummy):

1. Multiplication of battery (quantitative) and Intel (dummy): battery_OS;
2. Multiplication of SSD (quantitative) and Intel (dummy): SSD_Intel;
3. Multiplication of CPU (quantitative) and OS (fictitious): CPU_OS;
4. Multiplication of screen_size (quantitative) and Intel (dummy): screen_size_Intel.

When non-linear terms were introduced, it was also necessary to introduce the desired variables into the model, so as not to disturb the economic interpretation. The model with new non-linear variables (polynomial model) is presented in Figure 7.

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Polinom: МНК, использованы наблюдения 1-102
Зависимая переменная: price
Робастные оценки стандартных ошибок (с поправкой на гетероскедастичность), вариант HC1

                        Коэффициент       Ст. ошибка    t-статистика  P-значение
  ------------------------------------------------------------------------------
  const                -112491           21744,3           -5,173      1,54e-06  ***
  memory                 2462,94           407,816           6,039      4,07e-08  ***
  pixel                     0,00716890       0,00113523      6,315      1,23e-08  ***
  videocard_perfor~       429,525           161,609           2,658      0,0094    ***
  OS                    34994,6           13530,2             2,586      0,0114    **
  keybord                5636,04           2735,55           2,060      0,0425    **
  material               6510,67           2462,76           2,644      0,0098    ***
  usb2                   5233,82           1345,18           3,891      0,0002    ***
  usb3                   9261,76           1629,82           5,683      1,87e-07  ***
  battery_OS            -3258,75           1018,68          -3,199      0,0019    ***
  battery                3330,49           1053,12           3,163      0,0022    ***
  Intel                 59380,6           21900,8             2,711      0,0081    ***
  SSD                      46,9937           15,6622          3,000      0,0035    ***
  SSD_Intel               -45,8205           17,7638         -2,579      0,0116    **
  CPU                   11206,7            3989,39           2,809      0,0062    ***
  CPU_OS                -8591,80           4196,80          -2,047      0,0438    **
  screen_size            3094,64           1226,40           2,523      0,0135    **
  screen_size_Intel     -3397,57           1379,81          -2,462      0,0158    **

ВНИМАНИЕ: матрица данных близка к сингулярной!

Среднее зав. перемен     50998,50   Ст. откл. зав. перемен  39647,29
Сумма кв. остатков       5,55e+09   Ст. ошибка модели       8131,815
R-квадрат                0,965013   Испр. R-квадрат         0,957932
F(17, 84)                145,6543   P-значение (F)          8,02e-55
```

Fig. 7. Polynomial model
Рис. 7. Полиномиальная модель

From an economic point of view the interpretations of all coefficients of the explanatory variables have turned out to be correct. Compared to the model in Figure 5, all coefficients were significant; the standard error of the estimate decreased from 8923.05 RUB to 8131.81 RUB (or 15.94%); adj. R-squared increased to 0.9579, which means the inclusion of new variables has turned out to be true. MAPE was evaluated to be 14.44% that was a little better than 16.4% in Figure 5. That was, the goodness of fit to selected data was good [Absolute approximation error, 2018].

Because of the result of RESET-test, the hypothesis of a well-chosen model specification has declined, models in nonlinear forms were considered: exponential, logarithmic, power-law, semi-logarithmic.

1. Exponential model: the dependent variable was represented by the logarithm, and the independent variables were in the original form. Verification of all problems: multicollinearity, heteroscedasticity, equality of coefficients. After their recovering the following model was obtained (Fig. 8).

```
Exponent: МНК, использованы наблюдения 1-102
Зависимая переменная: l_price

              Коэффициент   Ст. ошибка   t-статистика  P-значение
  ------------------------------------------------------------------
  const         8,69552      0,237334       36,64      2,87e-056  ***
  CPU           0,159719     0,0463449       3,446     0,0009     ***
  memory        0,0194380    0,00750123      2,591     0,0111     **
  SSD           0,000450035  0,000200036     2,250     0,0269     **
  screen_size   0,0564409    0,0168817       3,343     0,0012     ***
  pixel         4,29085e-08  2,33069e-08     1,841     0,0689     *
  OS           -0,102005     0,0573663      -1,778     0,0787     *
  keybord       0,314172     0,0607564       5,171     1,37e-06   ***
  material      0,280529     0,0568903       4,931     3,66e-06   ***
  Nvidia        0,125090     0,0543187       2,303     0,0236     **
  usb3          0,125623     0,0328594       3,823     0,0002     ***

Среднее зав. перемен     10,62606   Ст. откл. зав. перемен  0,640266
Сумма кв. остатков       4,037548   Ст. ошибка модели       0,210639
R-квадрат                0,902484   Испр. R-квадрат         0,891768
F(10, 91)                84,21824   P-значение (F)          1,49e-41
```

Fig. 8. Exponential model
Рис. 8. Экспоненциальная модель

All coefficient were significant. The standard error of estimate was low: 0.2106 with a mean of 10.6261 (or 2%). Adj. R-squared was equal to 0.8918 (about 0.9 is considered to be highly accurate) [Afanasev V.N., Semenychev E.V., 2014]. MAPE was 1.55%, that was significantly lower than 10%, therefore it indicated a high accuracy fit of the model to the sample data.

2. The logarithmic model: the dependent variable was presented in its original form, and the independent variables were represented by the logarithm (Fig. 9).

```
Logarifm: МНК, использованы наблюдения 1-102
Зависимая переменная: price
Робастные оценки стандартных ошибок (с поправкой на гетероскедастичность), в

                    Коэффициент  Ст. ошибка  t-статистика  P-значение
  ------------------------------------------------------------------
  const              -452619      93388,1      -4,847      4,77e-06  ***
  l_memory             38116,3     7126,49      5,349      5,90e-07  ***
  l_pixel              27774,8     6319,38      4,395      2,83e-05  ***
  l_videocard_perf~     8339,72    2100,04      3,971      0,0001    ***
  l_battery            10322,3     4388,69      2,352      0,0207    **

Среднее зав. перемен     50998,50   Ст. откл. зав. перемен  39647,29
Сумма кв. остатков       3,52e+10   Ст. ошибка модели       19043,20
R-квадрат                0,778434   Испр. R-квадрат         0,769297
F(4, 97)                 20,76482   P-значение (F)          2,19e-12
```

Fig. 9. Logarithmic model
Рис. 9. Логарифмическая модель

All coefficient were significant. The standard error of estimate was high: 19043.20 RUB with a mean of 50998.50 RUB (or 37.34%). Adj. R-squared was equal to 0.7693 (about 0.75 is considered to be the lower acceptable value) [Afanasev V.N., Semenychev E.V., 2014]. MAPE was 34.33%, so the model fit was satisfactory.

3. The power-law model: dependent and independent variables were presented in logarithm (Fig. 10).

stepen: МНК, использованы наблюдения 1-102
Зависимая переменная: l_price

	Коэффициент	Ст. ошибка	t-статистика	P-значение	
const	4,37504	0,858471	5,096	1,73e-06	***
l_core	-0,190388	0,0772941	-2,463	0,0156	**
l_memory	0,657717	0,0707091	9,302	4,71e-015	***
l_pixel	0,306454	0,0652644	4,696	8,84e-06	***
l_videocard_perf~	0,245423	0,0358586	6,844	7,23e-010	***
l_battery	0,210947	0,0657475	3,208	0,0018	***

Среднее зав. перемен	10,62606	Ст. откл. зав. перемен	0,640266
Сумма кв. остатков	5,859630	Ст. ошибка модели	0,247058
R-квадрат	0,858477	Испр. R-квадрат	0,851106
F(5, 96)	116,4669	P-значение (F)	3,61e-39

Fig 10. The power-law model
Рис. 10. Степенная модель

All coefficient were significant. The standard error of estimate was low: 0.2471 with a mean of 10.6261 (or 2.32%). Adj. R-squared was equal to 0.8511 (less than 0.9 indicates a lack of high accuracy). MAPE was 1.87%, that was significantly lower than 10%, therefore it indicated a high accuracy fit of the model to the sample data.

4. The semi-logarithmic model is shown in Figure 11.

polulog: МНК, использованы наблюдения 1-102
Зависимая переменная: l_price

	Коэффициент	Ст. ошибка	t-статистика	P-значение	
const	6,43668	0,716681	8,981	4,11e-014	***
l_memory	0,412848	0,0578832	7,132	2,52e-010	***
l_pixel	0,163844	0,0482918	3,393	0,0010	***
l_videocard_perf~	0,0979744	0,0314642	3,114	0,0025	***
keybord	0,239628	0,0537784	4,456	2,42e-05	***
material	0,189603	0,0488636	3,880	0,0002	***
AMD	-0,118747	0,0587931	-2,020	0,0464	**
usb3	0,100179	0,0271164	3,694	0,0004	***
CPU	0,0989105	0,0430834	2,296	0,0240	**
X11_X12	0,000291091	0,000113619	2,562	0,0121	**
HDD	-0,000374044	0,000114036	-3,280	0,0015	***
OS	-0,206083	0,0708899	-2,907	0,0046	***
screen_size	0,0379929	0,0160810	2,363	0,0203	**

Среднее зав. перемен	10,62606	Ст. откл. зав. перемен	0,640266
Сумма кв. остатков	2,623745	Ст. ошибка модели	0,171698
R-квадрат	0,936631	Испр. R-квадрат	0,928087
F(12, 89)	109,6222	P-значение (F)	7,05e-48

Fig. 11. The semi-logarithmic model
Рис. 11. Полулогарифмическая модель

All coefficient were significant. The standard error of estimate was low: 0.1717 with a mean of 10.6261 (or 1.62%). Adj. R-squared was equal to 0.9281(more than 0.9 is considered to be highly accurate). MAPE was 1.21%, that was significantly lower than 10%, therefore it indicated a high accuracy fit of the model to the sample data.

The next stage, the comparison of the resulting models was carried out. Comparison is possible only if the models are presented in the same type of dependent variables, so in the same units of measurement. The comparative Table 2 is below.

Table 2

Comparative table on models

Таблица 2

Сравнительная таблица моделей

Model/Criterion	Adj. R-squared	Standard error of the estimate	Mean absolute percentage error (MAPE)
1. The dependent variable is in rubles			
Multiple Linear Regression	0.9493	8923.05	16.95%
Polynomial	**0.9579**	**8131.81**	**14.44%**
Logarithmic	0.7693	19043.20	34.33%
2. The dependent variable is presented in logarithm-rubles			
Exponential	0.8918	0.2106	1.55%
Power-law	0.8511	0.2471	1.87%
Semi-logarithmic	**0.9281**	**0.1717**	**1.21%**

Thus, according to all indicators the polynomial model was better in the first case and the semi-logarithmic – in the second case. The choice of the best model was carried out to the non-nested models test (PE-test). Figure 12 shows the models with predictions of a competing model.

For the PE-test, the coefficient of the variable *lin* (the difference between the logarithm of the forecast of the polynomial model and the forecast of the semi-logarithmic model) and *log* (the difference between the forecast of the polynomial model and the exposed forecast of the semi-logarithmic) were calculated [Econometrics. Regression analysis using the package Gretl: Laboratory Workshop, 2014]. For the polynomial model, the coefficient for the variable *lin has* turned out to be significant (the p-value was 0.0041), so the model can be improved.

For the semi-log model, the coefficient of the variable *log* has also turned out to be significant (the p-value was 0.0009), so the model can be improved too. Since the coefficients in the both models are significant, it was not possible to make a definite conclusion. Therefore the models were compared by the value of significance. Since the p-value (0.0041) was larger in the polynomial model than in the semi-logarithmic model (0.0005), then the coefficient in the polynomial was less significant.

	Коэффициент	Ст. ошибка	t-статистика	P-значение	
const	-114949	21875,3	-5,255	1,13e-06	***
memory	2262,53	373,981	6,050	4,01e-08	***
pixel	0,00775341	0,00100198	7,738	2,16e-011	***
videocard_perfor~	467,163	129,704	3,602	0,0005	***
OS	42566,7	10164,7	4,188	6,98e-05	***
keybord	4685,35	2366,98	1,979	0,0511	*
material	6706,07	2326,43	2,883	0,0050	***
usb2	5246,92	1181,76	4,440	2,75e-05	***
usb3	9373,13	1426,37	6,571	4,12e-09	***
battery_OS	-3784,24	745,255	-5,078	2,31e-06	***
battery	4076,93	761,822	5,352	7,59e-07	***
Intel	39901,7	20917,1	1,908	0,0599	*
SSD	48,1242	13,5567	3,550	0,0006	***
SSD_Intel	-45,1367	15,7974	-2,857	0,0054	***
CPU	13085,8	3499,36	3,739	0,0003	***
X2_X7	-10411,4	3562,02	-2,923	0,0045	***
screen_size	2639,72	1136,47	2,323	0,0226	**
screen_size_Intel	-2097,31	1314,45	-1,596	0,1144	
lin	-19889,9	6729,88	-2,955	0,0041	***

	Коэффициент	Ст. ошибка	t-статистика	P-значение	
const	7,10665	0,704300	10,09	2,35e-016	***
l_memory	0,443669	0,0553911	8,010	4,43e-012	***
l_pixel	0,101632	0,0490655	2,071	0,0413	**
l_videocard_perf~	0,102991	0,0297480	3,462	0,0008	***
keybord	0,251649	0,0509041	4,944	3,64e-06	***
material	0,199354	0,0462298	4,312	4,21e-05	***
AMD	-0,128047	0,0555851	-2,304	0,0236	**
usb3	0,106707	0,0256768	4,156	7,50e-05	***
CPU	0,102227	0,0406957	2,512	0,0138	**
X11_X12	0,000325709	0,000107764	3,022	0,0033	***
HDD	-0,000444604	0,000109626	-4,056	0,0001	***
OS	-0,195801	0,0670092	-2,922	0,0044	***
screen_size	0,0480784	0,0154666	3,109	0,0025	***
log	9,19642e-06	2,67650e-06	3,436	0,0009	***

Fig. 12. PE-test results
Рис. 12. Результаты PE-теста

Заключение

Thus, the polynomial model was chosen or further econometric analysis (Fig. 7). Let us give an economic interpretation of the coefficients of the explanatory variables in the total influence of all factors:

1. If the amount of RAM is increased by 1GB, the laptop's price will increase on average by 2,462.94 RUB, other things being equal.

2. If the number of pixels is increased by 1000000, the laptop's price will increase on average by 7168.90 RUB, other things being equal

3. If the performance of the video card is increased by 1% the laptop's price will increase on average by 429.53 RUB, other things being equal.

4. If the number of usb-ports 2.0 is increased by 1 unit, the laptop's price will increase on average by 5233.82 RUB, other things being equal.

5. If the number of usb-ports 3.x is increased by 1 unit, the laptop's price will increase on average by 9,261.76 RUB, other things being equal.

6. If the battery life is increased by 1 hour, the laptop's price will increase on average by 3330.49 RUB.

7. If the CPU's frequency is increased by 1 GHz, the laptop's price will increase on average by 11206.7 RUB.

8. The laptops with keyboard lightning will cost more on average by 5636.04 RUB than laptops with non-lightning.

9. The laptops with a metal case will cost more on average by 6,510.67 RUB than laptops with a plastic case.

10. The price of the laptops with the Windows OS is on average by 34994.60 RUB higher than other operating systems, provided that:

– if the battery life is increased by 1 hour, the price of the laptops with Windows OS will grow less on average by 3,258.75 RUB than laptops with another OS;

– if the CPU's frequency is increased by 1 GHz, the price of the laptops with Windows OS will grow less on average by 8591.80 RUB than laptops with another OS;

11. If the volume of solid-state drive (SSD) is increased be 1 GB, the laptop's price will increase on average by 46.99 RUB;

12. If the diagonal of the screen is increased by 1 inch, the laptop's price will increase on average by 3094.64 RUB;

13. The price of the laptops with Intel graphics card will cost more on average by 59380.60 RUB higher than laptops with AMD and Nvidia under two conditions:

–if the value of SSD is increased by 1 GB, the price of the laptops with Intel graphics cards will grow less on average by 45.82 RUB less than laptops with AMD and Nvidia videocards;

– if the diagonal of the screen is increased by 1 inch, the price of the laptops with Intel graphics cards will grow less on average by 3397.57 less than laptops with AMD and Nvidia videocards.

So during the research the model was built based on econometric analysis which allowed to draw the conclusion on the optimal laptop's price under the influence of various factors. These factors were explained the laptop's price by 95,79%.

The model has an error of 15,95%. The error can be reduced by increasing the number of observations and the number of factors. If an econometric model is built for using in practice, we can add factors such as laptop weight, processor generation, battery capacity, RAM frequency, display matrix type, memory card support, the presence of Kensington lock slot, etc.

Use the resulting econometric model on a specific example. Take from official website of the State Procurement the Purchase №31807033837 to deliver the computers and one laptop, posted on 10.23.2018 [5]. Under the contract, one laptop is purchased with a stated initial contract price of 134750.49 RUB. These terms of purchase are suitable for the resulting econometric model as the delivery is carried out at retail. According to the information that is specified in the technical project, it is expected to purchase a laptop model Dell XPS15 15.6". In this laptop model uses the following parameters, listed in Table 3.

Table 3

Dell XPS15 15.6" laptop settings shown in the information card

Таблица 3

Параметры ноутбука Dell XPS15 15.6", указанные в информационной карте

Factor	Measurement
CPU frequency	2,5 GHz
Core	4 cores
Random access memory (RAM)	8 GB
Hard disk drive	1000 GB
Solid state driver	128 GB
Monitor inch	15,6
Pixels	2073600

Factor	Measurement
Performance of video card	26,9%
USB ports 2.0	0
USB ports 3.x	4
Battery	10 hours
Operation System (OS)	Windows OS (1)
DVD-drive	No (0)
Keyboard lightning	Yes (1)
Laptop's material	Metal (1)
Nvidia video card	Yes (1)

Substituting these data into the econometric model, the average price of a laptop was 80906.75 RUB. Taking into account the standard error of regression, the maximum contract price should not exceed 93807.33 RUB. The stated contact price of 134750.49 RUB significantly exceeds the optimal price of the laptop by 40943.16 RUB.

Thus, using the econometric model allows to create a rationing mechanism for initial (maximum) contract price of purchases and to increase the efficiency of budget spending.

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