Estimating Hedonic Price Indexes for Personal Computers in Russia

Parkhomenko, Alexander and Redkina, Anastasia and Maslivets, Olga

Higher School of Economics

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Econometric Estimates of Hedonic Price Indexes for Personal Computers in Russia

Alexander Parkhomenko*
Redkina Anastasia†
Olga Maslivets‡

Higher School of Economics

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Abstract

Economists have noted for decades that Consumer Price Index (CPI) in the developed countries is overstating inflation by 0,5-2,0% per year. A significant part of this bias is found to be caused by the effects of new goods and quality change. Information and communication technology (ICT) products are mostly subject to these effects. An increasing weight of these products in the Russian CPI may lead to a substantial upward bias in the Russian CPI. Nowadays hedonic price indexes are believed to be one of the most efficient ways to eliminate the bias. They can be used in two ways: to estimate the bias in CPI and to elaborate an alternative to official price indexes for ICT products. In this study we estimate hedonic price and quality indexes for Personal Computers, the most widespread ICT product, in Russia. Using 21 months data (03.2004-11.2005) we estimated a 25% fall in PC prices for 20 months (about 16% on 12 months scale). We have also estimated that elementary price index for PC may be biased upward by 17-27% per year due to the usage of traditional matched models. Hence, the Russian CPI can be overstated by 0,19-0,31% per year. Hedonic quality indexes indicate a significant quality growth of PC (GAGR 19% per year) which is the best explanation for the rapidly falling prices.

Keywords: *Hedonic Regression, COLI, CPI, Hedionic index, Personal Computer, CPI bias, Consumer Price Index, Quality-adjustment, ICT*

JEL Classification: C 43, E31

*alex.parkhomenko@par-ma.com www.par-ma.com
†redray@newmail.ru
‡olga.maslivets@par-ma.com

Contents

1 Introduction

In the last two decades considerable attention has been drawn to the methods of computing price indexes for Information and Communication Technology (ICT) products: the discussion started in the USA and then has been continued throughout the entire world. Report prepared by Boskin Commission (1996) raised the problem of biases in the price indexes for ICT products: it showed that traditional matched models indexes can substantially overestimate inflation, because they are not able to measure the peculiarities of ICT industries (i.e. fast rotation of goods, huge quality differences among products on the market, short product life cycle, etc.). The Commission showed that the usage of matched model indexes leads to an overestimation of inflation by 0,6% per year in the US official CPI (CPI-U). Similar result were obtained by Crawford (1998) for Canada, Shiratsuka (1999) for Japan, Hoffmann (1998) for Germany and Cunningham (1996) for the UK (See Table 6 in Appendix).

But the growing discussion dose not only concerns price (inflation) measurement or price indexes, but also deflators. Deflators are crucial for such items of national accounts as investment in ICT products, labor productivity and economics growth measures, etc. For example, in the USA growth acceleration after the 1995 was mainly driven by the increased investment in ICT products that lead both to an increase in capital stock and labor productivity growth (Bosworth and Triplett, 2001). So, in this respect, correct measurement of deflators is crucial for understanding of sources of economics growth and productivity. Another issue to be solved, concerns international comparability in deflators for ICT between countries. Papers by Wyckoff (1995) and Eurostat (1999) show that there is a huge dispersion in ICT deflators in OECD and European countries, accordingly.[1]

These differences are so huge that it cannot be explained by any means of market conditions, regulation, etc. As both studies suggest, most part of it comes from the differences in quality adjustment procedures across countries and that, in turn, makes international comparison of investment in ICT impossible (as its calculated

[1]Wyckoff (1995) estimated that the range for ICT deflators in the 1980s for OECD countries was from -72% to +80% per year. Eurostat (1999) estimated a smaller dispersion for later period of the early 1990s for European countries – from -47% to -10%.

through deflation). So, it also makes challenging any attempt to estimate the impact of ICT on economy across countries.

Despite the fact that price indexes are the main measures of inflation and are used to calculate real (deflated) values of macroeconomic indicators, little attention is paid to them in Russia and other former USSR countries (CIS). So the inability of Russian statisticians to eliminate biases in price indexes used will lead to biased measures of inflation (deflators) and economic growth. Given that Russian Government is stimulating the development of ICT industries, the inability to eliminate biases for these products would lead to inefficient policy decisions, because the price indexes for ICT products would be most likely biased up, while productivity growth, investments, consumption would be underestimated. In this paper we would like estimate hedonic price and quality indexes for personal computers (PC) in Russia. That would help us to find out whether there should as much concern about ICT products price methodology as in the OECD countries. Hedonic indexes and hedonic method are very useful and often used tools for calculating quality-adjusted price indexes. Choosing PC as the most studied ICT product will help in comparing our results with those from OECD countries.

Recent studies of hedonic price indexes for PC show that quality adjusted prices decline by 25-35% per year in the USA (Pakes, 2002, Berndt, Ernst R. and Neal J. Rappaport, 2001, Berndt, Ernst R., Zvi Griliches and Neal Rappaport,1995), 34% in Germany (Moch, 2001), 33-36% in France (Bourot, 1997), 28-34% in Taiwan (Jang et al.,1996). There is no evidence about quality-adjusted price indexes for PC in Russia: Russian statistical agency (Rosstat) computes a price index for PC in the CPI, but it is not publicly published.[2] Investment deflators for ICT are not developed as well.

This study provide evidence on quality-adjusted prices for PC's in Russia for the period of 03.2004-11.2005. We are using characteristic hedonic method to compute them. As it is almost impossible to collect data for the whole country we have had collected data for the most representative, from our point of view, city in Russia Yekaterinburg, which is located in the most center of Russia. Using these data we

[2]Problems with methodology for such goods like PC might be the main reason why Russian statistical agency do not publish these indexes.

calculate 10 hedonic price indexes and 8 hedonic quality indexes: to the commonly used in hedonic literature Laspeyres, Paasche and Fisher indexes we have added "superlative" Edgeworth-Marshall and Walsh indexes.

The paper is organized in the following way: in Section 2 the basic set up of hedonic price and quality indexes and hedonic regression are briefly discussed . Section 2 also presents the classification of hedonic price and quality indexes. Section 3 describes the data and variables, presents descriptive statistics. Section 4 presents and discusses empirical results – econometric estimates of hedonic regressions, price and quality indexes. It also discusses the international comparability of results and presents estimates of possible biases in the Russian CPI and elementary price index for PC.

2 Hedonic Indexes

Hedonic index is any price index, which uses information from hedonic regression. Hedonic regression describes how product price could be explained by its product characteristics.

For example, for a linear econometric model ~~specification~~, assume that at each period t we have n_t goods, which could be described by a vector of k characteristics. Thus the hedonic cross-sectional regression is:

$$P_{it} = c_{0t} + \sum_{j=1}^{k} c_{it} z_{jit} + \xi_{it} \tag{1}$$

where P_{it} – price for ith product at period t, $i \in \{1, ..., n_t\}$, $t \in \{1, ..., T\}$ and n_t is the number of observation in period t. And it is also typically assumed that ξ_{it} *i.i.e* $N(0, \sigma^2 I)$, where I – diagonal matrix.

2.1 Hedonic Price Indexes

There are several way hedonic price indexes are constructed. Following Triplett (2004) there are two method – direct and indirect.[3] The direct method uses only

[3]About Pakes hybrid

information obtained from the hedonic regression, while the second method – combines information derived from the hedonic regression and matched models[4]. In the last case, data, used for estimating hedonic regression and calculating matched models indexes are different. In our study it is almost impossible to use indirect methods, because we neither know the quality-adjustment method used by Russian statistical agency (Rosstat) nor have any available data for matched models.

Direct method could be divided into two method – Time Dummy Variable and Characteristic methods. The first one is the most simple one, because it assumes implicit prices (coefficients of the hedonic regression (1) - c_{it}) to be constant over adjacent time periods. This assumption generally does not hold (for example, see evidence in Silver and Heravi, 2002, 2003, Berndt and Rappaport, 2003) since implicit prices reflect both demand and supply (See Pakes, 2002 for a discussion). In this study we will use characteristic method, that relax this assumption, based on the usage of fitted prices from hedonic regression. This method generally should lead to a more stable estimates, because ordinary least squares (O.L.S.) estimate guarantees that the regression always comes through it's mean.[5]

Given (1), the corresponding chain hedonic price index[6] would look like:

$$HPI(0,T) = \prod_{t=0}^{T} \frac{\widehat{P}_{t+1}(z^{\tau})}{\widehat{P}_{t}(z^{\tau})}$$

where $HPI(0,T)$ – hedonic price index (chain) for period from 0 to T, $\widehat{P}_{t+1}(z^{\tau})$ – estimate of price obtained from hedonic regression at period $t+1$ with mean characteristics of period τ – z^{τ}. $HPI(0,T)$ shows how much price of a bundle

[4]This Difference in sources of information might be quite crucial, especially for a statistical agency. Matched models are computed on monthly basis and data are usually gathered by statistical agency. In contrast information for hedonic regression is gathered by vendors or other marketing companies. The size of the sample is larger than for a matched models, but regression is usually updated on an annual- or semiannual basis.

[5]As it will be shown later, fitted prices are calculated using mean characteristics of the specified periods, which are quite close to the sample mean. This automatically means that fitted price estimates should not be very sensitive to different errors.

[6]In the study we also calculate base indexes, which are defined as a relative of price of T period for the good with mean characteristic and price of 0 period for the good with the same mean characteristics. See detailed description in Table 1.

of characteristics changed over time from period 0 to period T. A specification of z^τ – mean characteristics for the certain period, determines the type of HPI. For example, if we set z^τ equal to the mean of the characteristics for the previous period t : z^t, we would get a Laspeyres-type index. Setting z^τ equal to z^{t+1} – Paasche-type index and so on. Fisher-type index is defined as a square root of production of Laspeyres- and Paashce-type indexes. Edgeworth-Marshall – uses arithmetic mean of the mean characteristics of two periods t and $t+1$. Walsh-type index uses geometric average of two periods. And finally, base quality index does not update characteristics (quality) and every time uses fixed base characteristics – z^0. A detailed taxonomy of hedonic price indexes is presented in Table 1.

Analogously, the base hedonic price index would look like:

$$HPI(0,T) = \frac{\widehat{P}_T(z^\tau)}{\widehat{P}_0(z^\tau)}$$

The base index would directly compare a bundle of mean characteristic z^τ at just two points of time – 0 and T. Hence, it is independent of track that prices had between 0 and T periods of time – $\{1, ..., T-1\}$.

2.2 Hedonic Quality Indexes

Hedonic quality index is analogous to quantity indexes in traditional index theory – it measures how the price for obtaining new set characteristics had changed over time. For example, if we are willing to estimate the effect that characteristic growth(or decline) has had on the price of a computer for one period – from t to $t+1$, then the hedonic quality index would look like:

$$HQI(t,t+1) = \frac{\widehat{P}_\eta(z^{t+1})}{\widehat{P}_\eta(z^t)} \tag{2}$$

where η – ,as in the case with price indexes, determines the type of the index. So, the chain quality index would look like:

$$HQI(0,T) = \prod_{t=0}^{T} \frac{\widehat{P}_\eta(z^{t+1})}{\widehat{P}_\eta(z^t)}$$

and base index:

$$HQI(0,T) = \frac{\widehat{P}_\eta(z^T)}{\widehat{P}_\eta(z^0)}$$

If we choose past period prices – i.e. $\eta = t$ as a mean for estimating (2) then we will get a Laspeyres-type index. If we choose current prices $\eta = t+1$ – Paasche-type index. Fisher-type index is defined as a square root of production of Laspeyres- and Paasche-type indexes. Edgeworth-Marshall – as a fraction of two prices – for period t and $t+1$. And finally, the most simple example is when we use base price for all estimates. In hedonic quality indexes we do not use Walsh-type index because it could not be calculated for some cases when the estimates of implicit prices(i.e. coefficients of hedonic regression (1) - c_{it}) are negative. The detailed taxonomy is presented in Table 1.

2.3 Functional Form

Despite a long history of research of hedonic regressions only several functional forms were used – linear, double log and semilog form. In our study we would like use a linear specification for our cross-section data, that is presented in (1). We do it for a number of reason. First of all, our final goal is to estimate hedonic price, but nor log-price. So, using log or semilog form requires usage of either non-linear least square estimator (or other appropriate method) or O.L.S., correcting estimated price for an error term (Pakes, 2002).Secondly, we would like to make the result more transparent for a broad set of readers, especially for policy makers. With the modest and noisy data the usage of Box-Cox test for each month may be a seen as a step towards increasing statistical significance in exchange for robustness of results. Thirdly, there is no evidence that choice of functional form has a significant influence on the hedonic indexes. Moreover, Box-Cox test may give preference to nonlinear models as a compensation for omitted variables, even if the true functional form is linear.

Table 1

Classification of Hedonic Indexes within characteristic method*

	Chain	Base
Price index		
Laspeyres	$\prod_{t=0}^{T} \frac{P_{t+1}(\mathbf{z}^t)}{P_t(\mathbf{z}^t)}$	—
Paasche	$\prod_{t=0}^{T} \frac{P_{t+1}(\mathbf{z}^{t+1})}{P_t(\mathbf{z}^{t+1})}$	$\frac{P_T(\mathbf{z}^T)}{P_0(\mathbf{z}^T)}$
Fisher	$\sqrt{\prod_{t=0}^{T} \left\{ \frac{P_{t+1}(\mathbf{z}^{t+1})}{P_t(\mathbf{z}^{t+1})} \frac{P_{t+1}(\mathbf{z}^t)}{P_t(\mathbf{z}^t)} \right\}}$	$\sqrt{\frac{P_T(\mathbf{z}^T)}{P_0(\mathbf{z}^T)} \frac{P_T(\mathbf{z}^0)}{P_0(\mathbf{z}^0)}}$
Edgeworth-Marshall	$\prod_{t=0}^{T} \frac{P_{t+1}((\mathbf{z}^{t+1}+\mathbf{z}^t)/2)}{P_t((\mathbf{z}^{t+1}+\mathbf{z}^t)/2)}$	$\frac{P_T((\mathbf{z}^T+\mathbf{z}^0)/2)}{P_0((\mathbf{z}^T+\mathbf{z}^0)/2)}$
Walsh	$\prod_{t=0}^{T} \frac{P_{t+1}(\sqrt{\mathbf{z}^{t+1}\mathbf{z}^t})}{P_t(\sqrt{\mathbf{z}^{t+1}\mathbf{z}^t})}$	$\frac{P_T(\sqrt{\mathbf{z}^T\mathbf{z}^0})}{P_0(\sqrt{\mathbf{z}^T\mathbf{z}^0})}$
Base quality	$\frac{P_T(\mathbf{z}^0)}{P_0(\mathbf{z}^0)}$	
Quality index		
Laspeyres	$\prod_{t=0}^{T} \frac{P_t(\mathbf{z}^{t+1})}{P_t(\mathbf{z}^t)}$	—
Paasche	$\prod_{t=0}^{T} \frac{P_{t+1}(\mathbf{z}^{t+1})}{P_{t+1}(\mathbf{z}^t)}$	$\frac{P_T(\mathbf{z}^T)}{P_T(\mathbf{z}^0)}$
Fisher	$\sqrt{\prod_{t=0}^{T} \left\{ \frac{P_{t+1}(\mathbf{z}^{t+1})}{P_{t+1}(\mathbf{z}^t)} \frac{P_t(\mathbf{z}^{t+1})}{P_t(\mathbf{z}^t)} \right\}}$	$\sqrt{\frac{P_T(\mathbf{z}^T)}{P_T(\mathbf{z}^0)} \frac{P_0(\mathbf{z}^T)}{P_0(\mathbf{z}^0)}}$
Edgeworth-Marshall	$\prod_{t=0}^{T} \frac{P_{t+1}(\mathbf{z}^{t+1})+P_t(\mathbf{z}^{t+1})}{P_{t+1}(\mathbf{z}^t)+P_t(\mathbf{z}^t)}$	$\frac{P_T(\mathbf{z}^T)+P_0(\mathbf{z}^T)}{P_T(\mathbf{z}^0)+P_0(\mathbf{z}^0)}$
Base (implicit) prices	$\frac{P_0(\mathbf{z}^T)}{P_0(\mathbf{z}^0)}$	

*For simplicity of representation, we skip the sign of fitted value "^". However, all estimates are done with the usage of fitted values (estimate of price from hedonic regression). All price fitted values are calculated for the mean characteristics of the corresponding time periods

3 Data Description

The econometric estimate of hedonic regression requires detailed data on prices and relevant characteristics of PC. In our study we used a data base on monthly commercial advertisements "Puls Cen"[7], that contained both prices and characteristics of PC, for the Russian city – Yekaterinburg. With population over one million people and central location, Yekaterinburg is the most representative city in Russia: we expect pricing information from the city to be representative of all Russia, because PC is an internationally tradable commodity and large price differences would be impossible due to the arbitrage. Moreover, a large fraction of PC in Russia is sold via larger national retailers that use the same price patterns in all the city of the presence.

Personal Computer is a set components and nowadays most companies assemble computers from different parts through outsourcing or buying them on a market. Consumers can combine and upgrade these components. Each component described by a set of measurable technical characteristics that can be used as a proxy for quality measures or product characteristics of PC. Consumers are not interested in technical characteristics but rather in product characteristics, like PC speed, capacity and video. These product characteristics are hard to measure, this is why in literature most researchers use technical characteristics as a proxy. For example, microprocessor speed might be a good proxy for speed, video memory – good proxy for video, etc. In this study we use the following characteristics, classified into three groups (Analogous classification could be found at Moch, 2001):

- **Speed.** As a proxy for speed we use microprocessor speed measured in MHz. In addition to that we used a dummy variable for processor type – either Intel or others.
- **Capacity.** Hard Disk capacity in Gb and PC memory capacity in Mb.
  - **ODD Dummy.**[8] We used four dummies for CD-ROM, CD-RW, DVD-

[7] `www.pulscen.ru`

[8] Optical Disk Drive

ROM/CD-RW and DVD-RW.

- **Video.** Video memory in Mb
- **Price.** Price is the Dependent variable. It is a finall price to consumer that includes all taxes. The price is Russian Rubles

3.1 Descriptive Statistics

Table 2 shows a mean values of PC's characteristics. We can see a fast growth of characteristics – almost every month average model is upgraded by a more powerful PC. For the 21 months data (03.2004-11.2005) PC's microprocessor speed has had grown by about 30%, PC's memory – about 50%, hard disk capacity – around 80%, video memory – near 90% and the usage of more productive ODD, like DVD-RW and DVD-ROM/CD-RW, has had grown up significantly. Average ruble price has had grown only by 19% for this period of 21 months what is slightly higher than CPI growth for that time period. Such a development of mean value of characteristics is typical for a PC market in most countries, i.e. fast goods rotation, when new products often enters the market and the old one exits, quality change, etc.[9]

4 Empirical Results

This section consists of three parts. In the first one we would discuss econometric estimates of hedonic regressions. The second part is devoted to the discussion of hedonic indexes estimates. The last part is examining possible biases in elementary price index for PC, which can arise due to the usage of traditional matched models, and in the Russian CPI due to the bias in the elementary price index for PC.

4.1 Econometrics Estimates of Hedonic Regressions

Table 7 (Appendix) shows the econometric estimates of hedonic regressions. Table 8 (Appendix) shows heteroscedastic-consistent p-values of t-statistics.

[9]For a discussion see paper by Moch and Triplett (2002).

Table 2

Descriptive statistics of Yekaterinburg city market for PCs

Month	Pentium-IV Dummy	MHz	Memory. Mb	Hard Disk, Hb	Video memory, Mb	CD-ROM	CD-RW	CR-RW-DVD-ROM	DVD-RW	Mean Price, Ruble
03.2004	39,36%	2119,50	253,76	52,45	75,62	58,89%	9,91%	8,75%	0,87%	12638,38
04.2004	39,48%	2140,32	253,10	52,49	68,74	44,98%	10,68%	10,36%	0,32%	13171,16
05.2004	42,81%	2169,59	273,20	57,88	83,76	47,19%	20,63%	7,81%	1,88%	12655,87
06.2004	41,02%	2188,12	275,93	57,51	82,25	52,40%	12,57%	10,18%	0,60%	12965,10
07.2004	42,21%	2220,84	275,12	57,89	87,06	55,84%	13,96%	10,06%	0,97%	13433,98
08.2004	47,10%	2285,41	301,96	62,47	97,61	44,40%	18,92%	15,44%	4,25%	13604,48
09.2004	45,41%	2263,63	303,51	60,39	96,49	44,98%	6,11%	19,21%	3,49%	13486,31
10.2004	47,62%	2336,15	301,71	62,95	98,29	47,14%	27,14%	14,76%	4,76%	14215,24
11.2004	43,64%	2380,18	304,27	58,35	102,85	47,03%	24,15%	16,10%	3,39%	13656,82
12.2004	49,80%	2402,64	319,74	60,49	120,88	52,65%	21,22%	17,55%	3,67%	13758,77
01.2005	48,79%	2488,31	318,45	65,99	115,32	53,14%	10,63%	21,74%	7,25%	13742,91
02.2005	35,68%	2550,80	359,19	79,38	112,97	22,47%	38,33%	13,22%	9,69%	13981,04
03.2005	34,82%	2553,49	360,57	79,20	115,14	27,68%	36,16%	16,07%	8,93%	13668,07
04.2005	34,21%	2565,63	364,21	79,61	121,05	28,29%	30,92%	12,83%	12,17%	13835,54
05.2005	37,74%	2575,10	350,67	80,49	117,13	27,92%	12,45%	18,11%	15,09%	14282,16
06.2005	37,50%	2578,76	341,54	79,71	123,55	22,60%	9,62%	15,38%	7,69%	13379,99
07.2005	52,58%	2584,43	353,65	76,70	131,63	13,40%	10,31%	18,56%	9,28%	13945,28
08.2005	48,44%	2562,34	359,00	78,75	104,25	12,50%	6,25%	11,72%	11,72%	13241,38
09.2005	47,92%	2602,40	370,67	77,92	98,67	16,67%	5,21%	19,79%	14,58%	13679,58
10.2005	42,24%	2671,17	391,72	88,97	121,10	7,76%	5,17%	35,34%	10,34%	14590,80
11.2005	38,69%	2687,27	372,79	91,09	141,55	10,22%	2,19%	24,09%	17,52%	15015,71

As for statistical properties of hedonic regression estimates, we would like to admit two points. First of all, most part of independent variables are significant at the 5-10% confidence levels almost in all regressions and have expected signs in most cases. However, there are some variables with p-value "blowing-up" in some periods - Hard disk, Video Memory, CD-ROM and CD-RW. This is might be due to a combination of multicollinearity and data errors.[10] However, in this study multicollinearity cannot bring a significant fraud, because it does not seriously affect the estimate of hedonic price near mean characteristics.

Secondly, estimates of coefficients are not very stable over time due to a number of reasons. First, we should admit that coefficient instability is not only a consequence of a noisy data. Hedonic regression or hedonic function represents equilibrium prices. This makes hedonic function sensitive to changes in preferences, technologies or level of competition on the market. Indeed, Pakes (2002) using IDC data reports significant instability of some estimates of coefficients over time. For example, his estimates of PC's speed coefficient ranges from -4,72 to 16,79 in a basic specification and from - 2,7 to 5,12 for augmented specification in different years.[11]

Secondly, omitted variables in combination with multicollinearity and data errors might be also responsible for the instability. With this evidence it becomes clear that quality-adjustment methods, like time-dummy or "option cost" method that was for PC's in UK, that uses just a subset of all coefficient estimates, should be avoided, because single coefficients might be substantially biased. However, fitted price calculated near the mean characteristics tends to be very stable, independent of omitted variables and other issues, because of the O.L.S. properties.

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[10]Hedonic regression requires a quality data, that is really hard to find in Russia, because no attempts have been made by Rosstat to consult sample collection procedures with PC's vendors, which potentially can provide these data. The USA BLS and Statistics Canada experience suggests that these consultation programs can lead a significant improvement in data quality. For evidence – Triplett (2004) at pages 177-178.

[11]For more empirical evidence – see also paper by Berndt and Rappaport, 2001.

4.1.1 Omitted Variables

Omitted variables (characteristics) can lead to a biases in coefficients estimates. It might occur in the case when omitted variables are correlated with the variables in regression.In our case, data base does not have a large number of variables and it's very likely that some variables are omitted. Moreover, it seems that these omitted variables very correlated with the included (present) ones. Penetration of DVD-RW was quite low in 2005 and only expensive and very powerful PC were equipped with it. So, if an expensive PC, had a more productive TV card or had additional accessories, that are not captured by the present characteristics, we might expect a biased estimated for DVD-RW dummy variable. Indeed, if we look at the estimates in January estimate for a DVD-RW dummy was 9234,85[12] (about $300) while the price of DVD-RW was only $150. So, the difference in $150 is attributable to the omitted variable bias.[13]

As this example suggests, there are might be several omitted variables. And each of them influence present in regression variables, the extent of bias depends on the partial correlation and could be assessed only empirically.[14] But the bias in coefficients estimates does not automatically mean a bias in the corresponding hedonic indexes. Triplett (2004), using large BLS data, shows that omission of variables significantly biases the estimates of coefficients, but leads only to a small bias in the hedonic price index. Benkard and Bajari (2003) also show that the bias in hedonic price index exist, but it quite modest. They have estimated just a small upward bias about 1,4% per year.

4.2 Estimates of Hedonic Indexes

In a situation of a fast technological progress markets are characterized by fast goods rotation, i.e. fast product entrance and exit, and quality change. In such a situation calculation of price indexes is a challenging task. We used direct hedonic

[12]Data from Table 7(Appendix).

[13]Triplett (2004, p.154) received the same result with CD-RW dummy variable with the BLS data when he was testing for omitted variables bias.

[14]For an empirical assessment see papers by Triple (2004) and Benkard and Bajari (2003).

method – or more precisely, characteristic method.

4.2.1 Hedonic Price Indexes

In table 4 you can find estimates of hedonic price indexes. As the table shows all indexes show a significant price decline, even though average prices are growing with a pace of Russian official CPI. Base quality index shows the most rapid price decline: GAGR about 20-25% while other chain indexes are around 16% GAGR. Possibly, it can be explained by the properties of PC short life cycle – older, out-of-date PC are experiencing faster price decline, because they are loosing their market share with the emergence of new goods.

Base indexes also show a more rapid price fall (except Paasche) than chain indexes with a greater difference between laspeyres and Paasche indexes: base indexes fall with more than 20% GAGR in comparison with 16% GAGR of chain indexes.

Generally speaking, the usage of base indexes should be avoided until there is a possibility to calculate chain indexes for at least two reasons. First, calculating price change for several periods using only starting and ending points – 0 and T means that we ignore the track, the way the price developed over the period $[0; T\,]$. Traditional index theory and cost of living index theory strongly support indexes that use more information between $[0; T\,]$ (Divisia index, for example). Second argument concerns econometric issues – base indexes are calculated using only two regressions. That in turn, suggests that the error for a base index should be higher than for a chain index, which in our case uses 21 regression. This should be true due to the diversification of errors which may arise while collecting a sample, errors in prices or characteristics, etc.

Indeed, if we look at the absolute difference between chain and base indexes (Figure 1) we would find out that larger number of observation usually leads to lower difference: simple correlation coefficient are from -0,13 up to -0,42.

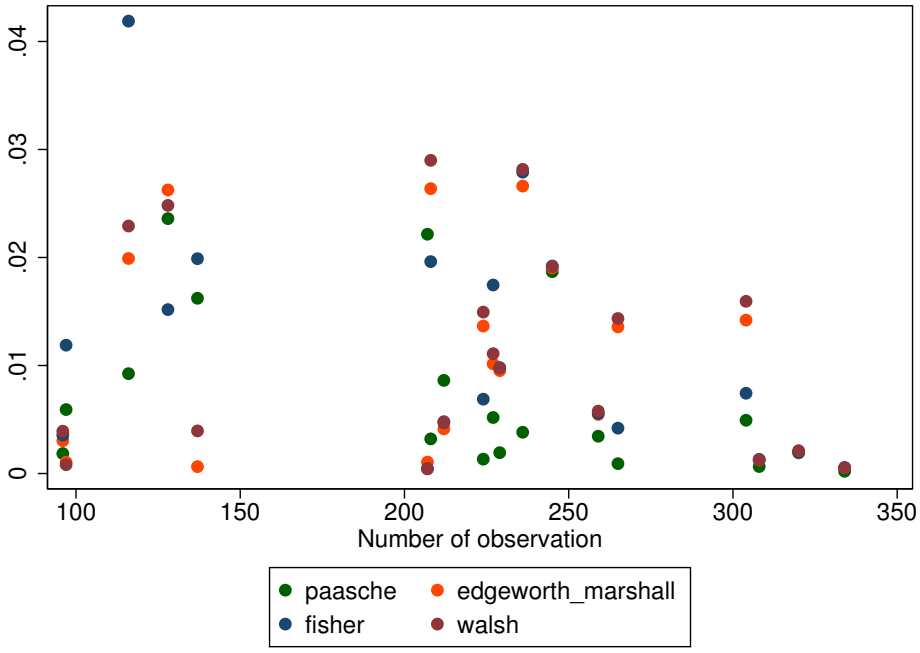

Figure 1: Price indexes: absolute value of difference between hedonic chain and base indexes

4.2.2 Hedonic Quality Indexes

In table 5 estimates for hedonic quality indexes are presented. These indexes show a significant quality growth. That supports an idea that rapid quality growth leads to a decreasing quality-adjusted prices, while the nominal prices are rising significantly.

Base prices index shows the most rapid quality growth: GAGR from 18 to 28% while other chain indexes are around 19% GAGR. As in the case with price indexes, base indexes are significantly different from chain indexes. The first ones grow with GAGR of 18-28%, while the the latter with GAGR of near 19%. It is also worth mentioning the dispersion of estimates within these two group: chain indexes seem give very close estimates - GAGR from 19,12% to 19,23%. While the dispersion for base indexes are several times larger. We think that explanation for this is the same as for the price indexes. Indeed, regarding to the econometric issues, if you look at the absolute difference between base and chain indexes (Figure 2), one can

find that size of a sample has a negative influence on the difference.[15]

[15]Simple correlation coefficient ranges from -0,43 to -0,38.

Table 4

Estimates of hedonic price indexes on month-to-month basis										
	Chained Indexes					Base Indexes				
Month	Laspeyres	Paasche	Edgeworth-Marshall	Fisher	Walsh	Base quality	Paasche	Edgeworth-Marshall	Fisher	Walsh
03.2004	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
04.2004	107,40%	107,87%	107,63%	107,63%	107,64%	107,40%	107,87%	107,63%	107,63%	107,64%
05.2004	92,40%	92,61%	92,51%	92,51%	92,49%	93,00%	92,41%	92,70%	92,71%	92,70%
06.2004	95,70%	95,93%	95,82%	95,82%	95,82%	95,62%	95,91%	95,76%	95,76%	95,76%
07.2004	100,61%	100,80%	100,70%	100,70%	100,70%	100,29%	100,86%	100,58%	100,57%	100,58%
08.2004	92,94%	92,18%	92,55%	92,56%	92,56%	93,71%	92,53%	93,10%	93,12%	93,14%
09.2004	95,40%	95,36%	95,38%	95,38%	95,38%	93,64%	95,17%	94,43%	94,40%	94,41%
10.2004	100,97%	100,52%	100,75%	100,75%	100,75%	99,18%	101,38%	100,33%	100,27%	100,27%
11.2004	104,53%	104,92%	104,73%	104,73%	104,73%	110,58%	104,54%	107,39%	107,52%	107,55%
12.2004	96,78%	98,28%	97,53%	97,53%	97,50%	94,81%	96,41%	95,63%	95,61%	95,59%
01.2005	95,06%	92,72%	93,83%	93,88%	93,78%	92,75%	94,93%	93,93%	93,84%	93,82%
02.2005	98,58%	97,70%	98,13%	98,14%	98,14%	94,60%	98,22%	97,11%	96,39%	97,04%
03.2005	94,51%	94,52%	94,52%	94,52%	94,52%	93,01%	94,66%	93,15%	93,83%	93,02%
04.2005	96,90%	96,77%	96,83%	96,83%	96,83%	94,93%	97,26%	95,41%	96,09%	95,24%
05.2005	101,03%	100,56%	100,80%	100,80%	100,80%	100,28%	100,47%	99,44%	100,38%	99,36%
06.2005	102,43%	101,91%	102,17%	102,17%	102,18%	106,07%	102,23%	104,81%	104,13%	105,08%
07.2005	98,61%	99,61%	99,11%	99,11%	99,10%	101,59%	99,02%	99,21%	100,30%	99,02%
08.2005	97,47%	97,77%	97,61%	97,62%	97,63%	96,80%	95,41%	94,99%	96,10%	95,14%
09.2005	105,49%	106,41%	105,95%	105,95%	105,95%	104,96%	106,23%	106,25%	105,59%	106,34%
10.2005	93,18%	94,75%	93,99%	93,96%	93,96%	84,24%	95,68%	92,00%	89,78%	91,67%
11.2005	101,96%	100,73%	101,34%	101,34%	101,36%	104,32%	102,36%	101,27%	103,33%	100,96%
Total	-25,96%	-26,08%	-26,06%	-26,02%	-26,10%	-34,69%	-24,82%	-31,37%	-29,93%	-31,98%
GAGR	-16,50%	-16,58%	-16,57%	-16,54%	-16,59%	-22,56%	-15,73%	-20,22%	-19,21%	-20,65%

Table 5

Estimates of hedonic quality indexes on month-to-month basis								
	Chained Indexes				Base Indexes			
Month	Laspeyres	Paasche	Edgeworth-Marshall	Fisher	Base prices	Paasche	Edgeworth-Marshall	Fisher
03.2004	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%	100,00%
04.2004	99,54%	99,97%	99,76%	99,75%	99,54%	99,97%	99,76%	99,75%
05.2004	103,21%	103,44%	103,32%	103,32%	103,43%	102,78%	103,09%	103,10%
06.2004	100,15%	100,38%	100,26%	100,27%	100,17%	100,48%	100,32%	100,32%
07.2004	100,81%	100,99%	100,90%	100,90%	100,75%	101,32%	101,03%	101,03%
08.2004	103,93%	103,08%	103,52%	103,50%	103,54%	102,23%	102,91%	102,89%
09.2004	99,40%	99,35%	99,38%	99,37%	99,60%	101,22%	100,35%	100,41%
10.2004	101,84%	101,39%	101,61%	101,61%	100,98%	103,22%	102,00%	102,09%
11.2004	100,18%	100,55%	100,36%	100,36%	100,54%	95,05%	97,94%	97,76%
12.2004	100,83%	102,40%	101,60%	101,61%	102,79%	104,53%	103,62%	103,66%
01.2005	111,44%	108,70%	110,10%	110,06%	108,84%	111,40%	110,00%	110,11%
02.2005	103,94%	103,01%	103,48%	103,48%	103,39%	107,35%	105,10%	105,35%
03.2005	100,38%	100,39%	100,38%	100,38%	100,23%	102,01%	100,90%	101,12%
04.2005	101,25%	101,11%	101,18%	101,18%	100,74%	103,21%	101,68%	101,96%
05.2005	99,13%	98,67%	98,90%	98,90%	99,22%	99,41%	99,31%	99,31%
06.2005	100,33%	99,82%	100,07%	100,07%	100,01%	96,39%	98,55%	98,19%
07.2005	100,39%	101,41%	100,89%	100,90%	100,99%	98,43%	99,89%	99,70%
08.2005	95,86%	96,16%	96,00%	96,01%	98,23%	96,82%	97,61%	97,52%
09.2005	100,23%	101,11%	100,68%	100,67%	100,40%	101,61%	100,95%	101,01%
10.2005	105,08%	106,85%	105,93%	105,96%	104,06%	118,20%	109,47%	110,91%
11.2005	102,50%	101,27%	101,88%	101,88%	100,87%	98,97%	100,21%	99,92%
Total	34,06%	33,85%	34,00%	33,96%	31,81%	51,73%	39,68%	41,42%
GAGR	19,23%	19,12%	19,19%	19,17%	18,02%	28,42%	22,20%	23,11%

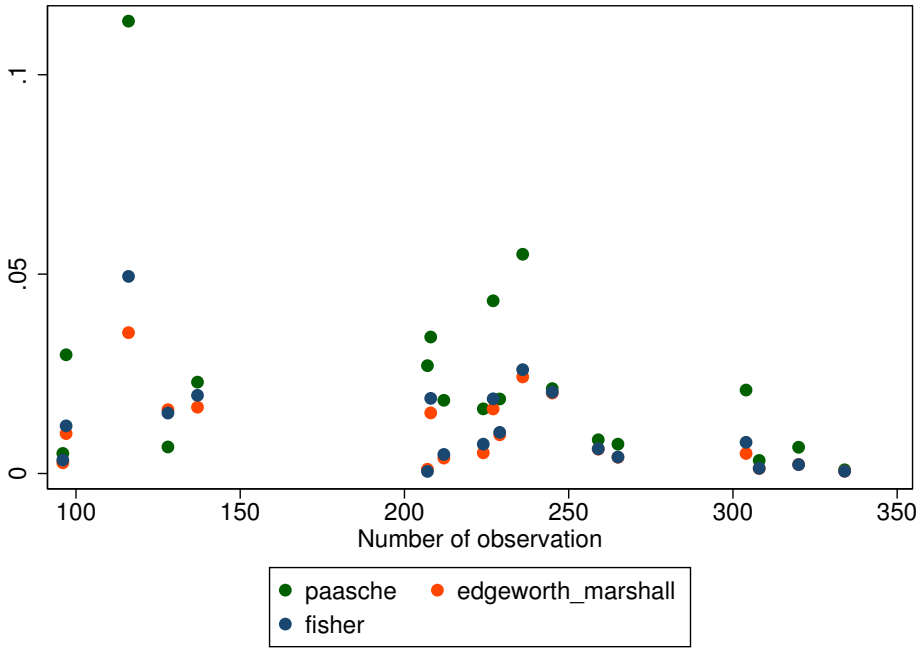

Figure 2: Quality indexes: absolute value of difference between hedonic chain and base indexes

4.2.3 International Comparison

Personal Computers are the most studied ICT product. Nowadays, we have about more than two decades of research in this field with large number of papers devoted to the hedonic method with application to PC. A very good overview of hedonic studies can be found in Triplett (2004), Moch and Triplett (2002) present a good international comparison of hedonic price indexes for PC and Berndt and Rappaport (2001) present excellent quarter-century overview. The mentioned studies suggests that the hedonic price index should fall from 20-35% per year in US dollars. In our study we have estimated a 17% decline in rubles, that have depreciated against the dollar for 1% for a period of 03.2004-11.2005. So the final estimate in dollars is -18%.

From one point, this confirms that the PC price trend in Russia and OECD countries is the same. However, the difference in 2-17% is too significant to be ignored. We see at least three different explanation for that:

- **Market conditions and competition.** Most OECD countries have well developed laws protecting competition, preventing collusions, etc. On contrary,

Russia, as any other former USSR country ,does not have a lot of experience in developing and forcing competitive policy. This, in turn, may lead to a higher barrier of entry to PC market, higher probability of collusion and so on. Companies facing less competition would demand higher mark-ups and prevent price decline.

- **Consumer heterogeneity.** As pakes (2002) notes that estimated coefficients (and so indexes) and seller mark-ups may be affected by the distribution of consumer tastes. So place-to-place differences in price indexes could be explained simply by consumer heterogeneity. For example, demand for higher quality products may be lower in Russia because of the network effect – less people are using PC's for communication and social networking. That might decrease a demand for additional characteristics, like hard disk capacity, that otherwise would be required for sharing photos and videos, etc.
- **Sample bias.** The sample can be biased because companies might tend to place advertisements on the most valuable PC in terms of price-quality relation. While this type of PC may be attributable just to a fraction of total sales.
- **Currency volatility.** The major aim of any price index is to measure a long term inflation. However, current currency volatility may be associated with short term fluctuation and shock which can bias inflation measures in international comparison. Also, Russia is not fully integrated in the international trade and is not a member of WTO.

4.3 CPI and elementary price index bias

Traditional matched model indexes usually leads to an overestimation of inflation, because they cannot account for a fast goods rotation and quality change (for an overview, see Triplett, 2004). In order to estimate a bias in elementary price index we need to compare traditional matched model index with the hedonic counterpart. We suppose that chain "superlative" hedonic index is the most precise and i.e. appropriate for bias estimation.

We also need a matched model index that is currently used by Rosstat. Unfor-

tunately, Rosstat does not publish official elementary indexes for PC's. So in our study we would estimate an interval in which the bias should be lying. In order to estimate bias we use the following scheme: as for the low bound, we assume that official price index would be at least 100%. (i.e., show no price change)[16] Upper bound is derived on the assumption that official price index would not exceed the average price growth. Average price growth for the sample is 18,81% for 20 months or 10,90% per year.

Based on this assumptions an upward bias in elementary price index for PC is lying within the interval from 26,06% to 44,87% for 20 months or from 16,57% to 27,47% on 12 months scale.

Personal computers have a 1,13% share in the Russian CPI, so given this, an upward bias in the CPI due to the bias in the price index for PC could be from 0,19 to 0,31% per year (12 months scale).

5 Conclusion

Our results demonstrate the importance of quality-adjustment in Russia for PC's and other similar ICT goods, as well. The hedonic PC prices are falling with GAGR from -22,56% to -16,50% during 21 months period (03.2004-11.2005). Falling prices are accompanied by a significant growth in characteristics and quality. Hedonic quality indexes grow with GAGR of 19,12-28,42%. According to an overview by Triplett (2004), Berndt and Rappaport (2001), Moch and Triplett (2002) hedonic price indexes for the USA, Germany, other countries decline at a 20-35% rate per year. In our paper we estimate a fall in prices about -17% in rubles. Taking into account currency rate change we would receive an estimate of -18% per year what is lower than on average in OECD countries. We think this fact is connected with several facts: level of competition on the PC market, consumer heterogeneity, sample bias and method of calculating currency volatility.

We have also calculated a possible bias in CPI and elementary price index for

[16]The validity of this assumption could be tested through the inspection of the CPI elementary price indexes – you can hardly find an official elementary price that shows a decline in prices. The official site of Russian Statistical Agency – `www.gks.ru`

PC's which can arise due to the usage of traditional matched models. The interval estimate for the elementary price index is 16,57-27,47% per year and 0,19-0,31% per year for the Russian CPI.

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Appendix

Table 6

Biases in CPI, % per year

Source of bias	**Canada**[1]	**France**[2]	**U.S.A.**[3]	**Japan**[4]	**Germany**[5]	**U.K.**[6]
Substitution effect: high level	0,10	—	0,15	0,00	0,10	0,05-0,10
Substitution effect: low level	0,00-0,10	0,05-0,10	0,25	0,10	—	—
Outlet substitution bias	0,07	0,05-0,15	0,10	0,10	0,05	0,10-0,25
Total	**0,17-0,27**	**0,10-0,25**	**0,50**	**0,20**	**0,20**	**0,15-0,35**
Quality change and new goods	0,30	—	0,6	0,70	0,60	0,20-0,45
Total	**0,47-0,57**	**0,10-0,25**	**1,10**	**0,90**	**0,75**	**0,35-0,80**

Based on:[1](Crawford, 1998), [2](Lequiller, 1997), [3](Boskin et al., 1996), [4](Shiratsuka, 1999), [5](Hoffmann, 1998), [6](Cunningham, 1996)

Table 7

Estimates of hedonic regressions for Yekaterinburg market for PCs

Month	Constant	Pentium-IV Dummy	MHz	Memory. Mb	Hard Disk, Hb	Video memory, Mb	CD-ROM	CD-ROM	CD-RW	CR-RW-DVD-ROM	DVD-RW	R2-adjusted	F-statistics	No. of observations
03.2004	2577,492	2756,832	1,578	9,208	14,788	14,362	852,194	852,194	2567,557	5961,297	17655,386	80,35%	156,42	343
04.2004	433,578	2209,127	2,746	9,326	26,171	8,250	1324,931	1324,931	2431,992	7358,506	21645,262	72,42%	90,86	309
05.2004	3943,462	2546,807	1,271	10,289	2,864	17,781	711,144	711,144	1132,225	5779,356	18422,944	80,50%	147,29	320
06.2004	1446,208	2422,462	2,513	10,175	2,525	10,104	933,347	933,347	622,731	5500,407	19126,740	75,16%	112,98	334
07.2004	36,425	1968,418	3,256	10,354	0,241	11,257	1065,613	1065,613	775,562	6268,021	16277,795	65,40%	65,49	308
08.2004	1614,255	1776,872	2,461	6,221	20,822	2,075	849,980	849,980	1152,203	5776,364	15518,609	85,35%	168,05	259
09.2004	-459,433	2605,971	3,171	9,183	17,040	1,047	996,464	996,464	774,169	4269,933	10074,500	81,74%	114,38	229
10.2004	2340,920	2271,440	2,040	14,554	26,282	4,209	-924,382	-924,382	-2381,862	2889,042	5987,404	65,74%	45,99	212
11.2004	4389,910	1647,061	2,147	7,163	4,346	-2,337	-654,085	-654,085	608,705	5756,836	14116,167	75,72%	82,42	236
12.2004	2152,393	1951,696	1,715	5,656	23,706	9,665	412,702	412,702	1483,783	5535,731	16325,193	78,98%	102,88	245
01.2005	72,621	1655,040	2,640	4,892	20,292	10,857	174,280	174,280	2407,564	5181,727	9234,853	86,77%	151,06	207
02.2005	336,362	2429,160	2,172	6,115	9,370	21,354	1027,257	1027,257	377,556	4834,244	8986,832	87,96%	184,40	227
03.2005	-1935,516	2831,782	2,694	4,071	17,775	22,292	1867,839	1867,839	885,381	4048,559	9043,333	85,65%	148,88	224
04.2005	-2898,818	2708,786	2,833	8,632	22,506	14,527	1564,575	1564,575	680,794	2935,114	6694,799	84,16%	179,86	304
05.2005	-3441,562	1627,676	2,959	10,808	11,388	22,499	2590,836	2590,836	761,746	2245,770	6116,202	39,86%	20,44	265
06.2005	-1913,460	2412,073	2,892	6,440	31,059	6,995	1061,151	1061,151	1529,034	4109,553	4854,140	82,35%	108,28	208
07.2005	298,698	2187,562	1,739	5,373	19,540	23,650	2075,281	2075,281	1677,358	3417,243	4351,429	83,77%	56,04	97
08.2005	-541,898	1675,773	2,464	5,845	20,537	21,073	760,776	760,776	1592,097	2009,104	2696,909	78,02%	51,08	128
09.2005	-3531,834	2467,168	3,602	8,545	0,474	14,408	1711,655	1711,655	3407,598	4265,898	4947,470	86,98%	71,52	96
10.2005	-6001,258	2783,891	4,778	6,298	4,187	19,745	866,104	866,104	239,042	2321,040	5043,277	82,38%	60,73	116
11.2005	-5765,723	3849,195	4,046	9,063	23,343	12,141	1534,547	1534,547	1339,171	1635,547	3510,645	85,26%	88,39	137

Table 8

P-value of variables										
Month	Constant	Pentium-IV Dummy	MHz	Memory. Mb	Hard Disk, Hb	Video memory, Mb	CD-ROM	CD-RW	CR-RW-DVD-ROM	DVD-RW
03.2004	0,02%	0,00%	0,00%	0,00%	1,73%	0,19%	0,56%	0,00%	0,00%	0,00%
04.2004	66,00%	0,00%	0,00%	0,00%	0,58%	16,75%	0,11%	0,04%	0,00%	0,00%
05.2004	0,00%	0,00%	0,54%	0,00%	62,69%	0,00%	4,02%	1,81%	0,00%	0,00%
06.2004	8,76%	0,00%	0,00%	0,00%	68,41%	0,01%	0,79%	23,90%	0,00%	0,00%
07.2004	97,49%	0,00%	0,00%	0,00%	97,65%	0,12%	3,93%	28,74%	0,00%	0,00%
08.2004	6,66%	0,00%	0,00%	0,00%	0,01%	36,37%	3,87%	3,29%	0,00%	0,00%
09.2004	62,72%	0,00%	0,00%	0,00%	2,61%	68,31%	1,52%	29,61%	0,00%	0,00%
10.2004	10,14%	0,00%	0,21%	0,00%	0,31%	53,52%	22,36%	1,23%	0,69%	0,21%
11.2004	0,01%	0,00%	0,00%	0,00%	57,16%	54,45%	28,62%	42,08%	0,00%	0,00%
12.2004	5,96%	0,00%	0,03%	0,00%	0,06%	0,01%	61,26%	10,11%	0,00%	0,00%
01.2005	94,71%	0,00%	0,00%	0,00%	1,06%	0,00%	76,92%	0,09%	0,00%	0,00%
02.2005	75,98%	0,00%	0,00%	0,00%	6,26%	0,00%	2,59%	43,06%	0,00%	0,00%
03.2005	12,59%	0,00%	0,00%	0,01%	0,07%	0,00%	0,04%	7,30%	0,00%	0,00%
04.2005	1,47%	0,00%	0,00%	0,00%	0,00%	0,00%	0,05%	12,34%	0,00%	0,00%
05.2005	30,03%	6,80%	5,18%	0,26%	50,58%	1,89%	2,78%	60,66%	9,64%	0,02%
06.2005	9,79%	0,00%	0,00%	0,00%	0,00%	0,01%	1,19%	0,82%	0,00%	0,00%
07.2005	86,18%	0,00%	2,95%	0,41%	3,36%	0,00%	0,82%	3,61%	0,00%	0,00%
08.2005	70,06%	0,02%	0,03%	0,02%	0,65%	0,00%	24,89%	6,76%	1,09%	0,13%
09.2005	1,70%	0,00%	0,00%	0,00%	95,52%	0,54%	0,79%	0,06%	0,00%	0,00%
10.2005	0,06%	0,00%	0,00%	0,03%	64,19%	0,00%	35,47%	83,43%	0,06%	0,00%
11.2005	0,03%	0,00%	0,00%	0,00%	0,09%	0,03%	4,61%	32,79%	0,23%	0,00%