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PRICE-COST MARGIN IN THE PHARMACEUTICAL INDUSTRY: EMPIRICAL EVIDENCE FROM FINLAND****

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ABSTRACT: Aim of this paper is to estimate price-cost margin in the Finnish pharmaceutical industry. The estimation is based on the method developed by Hall (1988), who shows that, under constant returns to scale, the total factor productivity depends on the growth rate of output-capital ratio if the market is imperfectly competitive. The measurement of price-cost margin is based on this theoretical result. We utilize data on the Finnish pharmaceutical industry. The data covers the years 1975-1999 and includes information on output, labor hours and capital stock both in nominal and real terms. According to the results, the estimated price-cost margin is in the range 0.59 - 0.67, which is close to the estimates obtained in the US markets.

Keywords: Pharmaceuticals, pricing, competition, regulation.

1 Introduction

International comparisons of pharmaceutical prices are used for regulatory purposes in several countries. Comparisons are made to gather information on relative price levels of pharmaceuticals in different countries. This information, added with the information on costs of producing the pharmaceutical, $R\&D$ costs and the cost-effectiveness is then utilized in the decision-making concerning the price regulation of pharmaceuticals.

Direct price comparison studies have been subject to criticism. Danzon and Chao (2000) demonstrate that international comparisons might lead to biased results if based on unrepresentative samples and unweighted indexes of pharmaceuticals. Furthermore, this kind of price comparisons may also be also insufficient, because price comparisons do not provide information on factors behind the observed price differences. Price differences may be the result of different degrees of competition, differing regulatory practices, differences in the costs of production, or income differences across countries. Direct measurement of price-cost margins would provide some information on these factors influencing price differences in pharmaceutical markets. This article takes a step into that direction.

The aim of this article is to estimate the price-cost margin in the pharmaceutical industry. This study concentrates on a single country, Finland, for two reasons. First, international data which would allow us to make more general conclusions on price-cost margins were not available. Despite that, we are able to compare our results to the US markets (Scherer and Ross, 1990). Second, we wanted to test the functionality of the applied method in measuring the performance of pharmaceutical markets in one country to see if this method could be utilized in forthcoming international comparisons.

The method developed by Hall (1988,1986), and later applied by Domowitz, Hubbard and Petersen (1988), is utilized in this study. The estimation of the price-cost margin is

based on the Solow's residual, as the method for the measurement of technical progress originally invented by Solow (1957) is sometimes called. Hall (1988) proved that the residual is independent of the growth rate of the output-capital ratio in a competitive industry while under imperfect competition a positive correlation between the two variables appears. The total factor productivity growth is therefore pro-cyclical under imperfect competition and the estimation of the price-cost margin can be based on this observation.

This paper is organized as follows. The following section provides theoretical background, empirical methods and data used in this study. Section 3 displays the results of the estimation. Section 4 discusses the interpretation that the results might have when assessed from the perspective of the $R\&D$ process and price regulation of pharmaceuticals. Results are also compared with other studies. Section 5 then concludes the paper.

2 Methods and data

The measurement of the price-cost margin has been considered problematic due to the lack of appropriate marginal cost data. Scherer and Ross (1990) (see also Scherer, 2000) approximate price-cost margins using accounting data. Such approximations may be biased measures of price-cost margins because they typically contain cost measures which do not approximate marginal costs (see Scherer and Ross, 1990, and Bresnahan, 1989). Bresnahan (1981,1982) and Hall (1988) develop methods for the estimation of the market power directly from the sales and industry data. Due to the nature of the data we utilize the Hall's method, which concentrates on comparing the total factor productivity growth under perfect and imperfect competition.

2.1 Theoretical setup

Solow's residual in competitive markets. Let us first derive the Solow's residual in a perfectly competitive industry. Consider a linearly homogenous production function with neutral technological progress

$$Q(t) = A(t)f(L(t), K(t)), \tag{1}$$

where A is a measure for the technological progress, Q measures the output, and L and K measure labour and capital inputs, respectively. It is assumed that all the variables are measured at the certain point in time, which is signified by making all the variables depend on time, t. To simplify the notation, however, the time variable will be dropped out from the following derivation. Totally differentiating the production function (1) with respect to time and then multiplying the resulting equation by the output yields

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + A\frac{f_l(L,K)}{Q}\dot{L} + A\frac{f_k(L,K)}{Q}\dot{K}. \tag{2}$$

Here f_l and f_k denote the partial derivatives of the production function with respect to labour and the capital, respectively, and all the dotted variables denote the time derivatives. Let us rewrite the equation (2) as

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + A\frac{f_l(L,K)L}{Q}\frac{\dot{L}}{L} + A\frac{f_k(L,K)K}{Q}\frac{\dot{K}}{K}. \tag{3}$$

In a perfectly competitive industry, labor and capital are compensated according to their marginal productivity. Suppose that labor and capital use are $\tilde{K}$ and $\tilde{L}$ and let c and p denote the equilibrium marginal cost and the market price, respectively. Perfect competition

implies that the price is equal to the marginal cost, and labor obtains an equilibrium real wage $\frac{w}{p} = Af_l(\tilde{L}, \tilde{K})$ and the capital is remunerated as $\frac{r}{p} = Af_k(\tilde{L}, \tilde{K})$. The equation (3) can then be rewritten as

$$\frac{\dot{Q}}{Q} = \frac{\dot{A}}{A} + \frac{wL}{pQ}\frac{\dot{L}}{L} + \frac{rK}{pQ}\frac{\dot{K}}{K} \tag{4}$$

$$= \frac{\dot{A}}{A} + \frac{wL}{cQ}\frac{\dot{L}}{L} + \frac{rK}{cQ}\frac{\dot{K}}{K}. \tag{5}$$

In the equation (4), $\frac{wL}{pQ}$ and $\frac{rK}{pQ}$ are the ratios of labor and capital compensation to the value of production to be called the shares of labor and capital in what follows. Let us denote the shares of labor and capital by w_l and w_k, respectively, and competitive labor and capital shares as $\tilde{w}_l$ and $\tilde{w}_k$. The assumption that the production process is linearly homogenous implies that the shares of labor and capital add up to one. Under the assumption that the production process satisfies linear homogeneity, the equation (4) implies

$$\frac{\dot{Q}}{Q} - \frac{\dot{K}}{K} - \tilde{w}_l(\frac{\dot{L}}{L} - \frac{\dot{K}}{K}) = \frac{\dot{A}}{A}. \tag{6}$$

The left-hand side of the equation (6) measures the difference between the growth rate of the output-capital ratio and the growth rate of the labor-capital ratio weighted by labor's share. Since Solow (1957) this measure has been used to quantify the growth rate of the total factor productivity and has also been called Solow's residual[1].

[1]The residual can also be written as the total differential $dln(A) = dln(\frac{Q}{K}) - w_l dln(\frac{L}{K})$, where the diffential is taken with respect to time.

Solow's residual under imperfect competition. We then assume that the market is imperfectly competitive, and define the Lerner index as $I = \frac{p-c}{p}$. Under imperfect competition the price exceeds the marginal cost, and the Lerner index obtains a strictly positive value. Now the competitive share of labor can be rewritten as

$$\tilde{w}_l = \frac{p}{c}\frac{wL}{pQ} = (1-I)^{-1}\frac{wL}{pQ} \tag{7}$$

Using the competitive share of labor, the equation (6) can be rewritten as follows

$$\frac{\dot{A}}{A} = \frac{\dot{Q}}{Q} - \frac{\dot{K}}{K} - (1-I)^{-1}w_l(\frac{\dot{L}}{L} - \frac{\dot{K}}{K}). \tag{8}$$

Multiplying both sides of the equation (8) by $(1-I)$ one obtains

$$\frac{\dot{A}}{A}(1-I) = (\frac{\dot{Q}}{Q} - \frac{\dot{K}}{K})(1-I) - w_l(\frac{\dot{L}}{L} - \frac{\dot{K}}{K}), \tag{9}$$

which implies

$$(\frac{\dot{Q}}{Q} - \frac{\dot{K}}{K}) - w_l(\frac{\dot{L}}{L} - \frac{\dot{K}}{K}) = \frac{\dot{A}}{A}(1-I) + I(\frac{\dot{Q}}{Q} - \frac{\dot{K}}{K}). \tag{10}$$

The left hand side of the above equation (10) is the original residual, which no longer is independent of the growth of the output-capital ratio but the technological progress is now pro-cyclical. This is because under imperfect competition the price exceeds the marginal cost and $I > 0$. Properly specifying an econometric model on this result allows one to make inferences on the Lerner index using data on the output, the labor and the capital.

This model specification differs from the model used originally by Hall (1988) but is consistent with the specification estimated by Domowitz et al. (1988). Hall's specification allows one to estimate the price-cost ratio of a particular industry while in the above specification the Lerner-index is the unknown parameter. It can be shown that the two approaches are equivalent and that there is no loss in using either model specification. If the price-cost margin is estimated, then the price-cost ratio can be directly derived and vice versa.

2.2 Empirical model

Our empirical model is based on the generalized residual derived in the previous subsection. To develop some notation for empirical modeling, let us denote

$$q_t = \frac{\dot{Q(t)}}{Q(t)} - \frac{\dot{K(t)}}{K(t)} \tag{11}$$

and

$$l_t = \frac{\dot{L(t)}}{L(t)} - \frac{\dot{K(t)}}{K(t)} \tag{12}$$

as relative changes in the output-capital and the labour-capital ratios. Furthermore, let

$$wl_t = \frac{w(t)L(t)}{p(t)Q(t)} \tag{13}$$

be the labor's share in the pharmaceutical industry in year t. The Solow's residual for year t can then be computed as

$$r_t = q_t - wl_t l_t. \tag{14}$$

In order to estimate the price-cost margin in the Finnish pharmaceutical industry, we estimate the following linear model

$$r_t = \alpha_1 + \alpha_2 q_t + u_t \tag{15}$$

where $t = 2, ..., T$, and unknown parameters α_1 and α_2 measure technical change in the pharmaceutical industry and Lerner index, respectively. The positive value of α_2 signifies that there is market power in the industry. Theoretical considerations suggest that the value of α_2 should be constrained between 0 and 1.

We make the following assumptions concerning the model. It is assumed that the statistical error terms u_t are normally distributed with zero mean and variance σ^2. Furthermore, it is assumed that there is no autocorrelation of any order in the error term.

The above assumptions added with the assumption that the explanatory variable of the model has no correlation with the error term would be sufficient for the OLS estimates of α_1 and α_2 to have all desirable properties. It should be observed, however, that any shock causing a change in the growth rate of the output-capital ratio and less than a proportional change in the labor-capital ratio causes a simultaneous change in the independent variable of the model, the growth rate of the total factor productivity. Therefore, the dependent and independent variables are jointly determined which creates a correlation between the error term and the independent variable of the model and renders the OLS estimates of the parameter α_2 inconsistent and biased. We applied $2SLS$ estimation techniques to correct the problems due to an endogenous dependent variable.

2.3 Data

The data set was aggregated from the firm-level data and it contains all Finnish pharmaceutical firms, which have more than 20 workers. The firm-size restriction was made in order to avoid the problem of inconsistent data in the capital stock variable. The capital stock figures for the smallest places of business were assessed to be unreliable over time.

The data set covers the time period from 1975 to 1999 and contains information on nominal and real output, nominal and real value added, working hours, the number of workers, labor cost, and capital stock. The capital stock series was constructed from data on capital stock per labor hours. The Table 1 below presents the descriptive statistics of the original variables used in this study. Output, value added, wages, and capital stock variables are measured in Finnish Markkas (FIM).

Volume indexes for output and value added were constructed in Statistics Finland and are presented in 1995 prices. Excluding the instrument variables, we received ready-made data in both value and volume terms. As instruments we used nominal expenditure on pharmaceuticals and gross domestic income. Data on the first instrument were obtained from the Social Insurance Institution of Finland while all the other data came from Statistics Finland.

Table 1 *Descriptive statistics of original data*

Variable	*Minimum*	*Maximum*	*Mean*	*Std. dev*
Places of business	8.00	15.00	11.76	1.96
Number of workers	1874.00	3787.00	3130.64	565.83
Working hours$^{\tau}$	3318.00	6182.00	5162.75	815.16
Wages$^{\gamma}$,	47806.00	522209.01	296170.28	164955.10
Value added$^{\gamma}$, 1995 *prices*	332638.74	1415464.13	952073.34	305810.44
Value added$^{\gamma}$, *current prices*	135820.00	1469393.31	758821.37	404348.98
Total output$^{\gamma}$, 1995 *prices*	581338.98	2774158.08	1921561.05	636518.61
Total output$^{\gamma}$, *current prices*	237367.00	2879853.50	1541262.82	818856.61
Capital stock / working hours	80.28	295.50	213.90	78.49
$N = 25$				
$\tau =$ *thousands*				
$\gamma =$ *thousand FIMs*				

Our data set is unique in a sense that it was constructed from the micro data sources for our purposes. The privacy protection of single firms usually causes a problem of data availability in a small country like Finland. This causes difficulties in data releases, especially in the industries with few large companies. In our data set, which is based on the micro-level places of business, this information problem did not arise. The data do not include the smallest places of business for each year of the observation period. Therefore, the time series are consistent during the entire period.

2.4 Variable construction

In order to construct theoretically based variables, we first computed the growth rates of production (value added and output), capital stock and labor hours. We then took the difference between the growth rates of output and capital stock, labor hours and capital stock, and the residual difference between these two. In the residual, the growth rate of the labor-capital ratio was weighted by the labor's share.

The used instrument for the growth rate of the output-capital ratio was the prediction from the linear model in which the growth rate of the output-capital ratio was regressed on the growth rate of pharmaceutical expenditures. A priori, one could argue that the growth rate of pharmaceutical expenditures should be correlated with the output growth in the pharmaceutical industry but there is no reason to expect that the variable would be correlated with the error term of the econometric model (15).

Pharmaceutical expenditures were not deflated to 1995 prices on the ground that the prices of pharmaceuticals are expected to affect the quantity of pharmaceuticals produced in the pharmaceutical industry. The correlation of the used instrument with the growth rate of the output-capital ratio was 0.62, while the correlation of the growth rate of pharmaceutical expenditures in 1995 prices with the growth rate of the output-capital ratio was 0.55. Hence, pharmaceutical expenditures in current prices has a higher correlation with the explanatory variable of the model (15) than pharmaceutical expenditures in 1995 prices, which supports our theoretical idea used to select the instruments.

We also used gross national income as another instrument for two reasons. First, we wanted to test the sensitivity of the results with respect to the chosen instrument. Second, only a part of the pharmaceuticals consumed in Finland is also produced domestically which is why pharmaceutical expenditures may not correlate perfectly with domestic production. As in other industrial branches, a part of the domestic production of pharmaceuticals is exported. Gross domestic income was selected as another instrument, since exports are an important determinant of the gross domestic income. Obviously, this choice relies on the assumption that pharmaceutical exports vary in parallel to aggregate exports.

In order to increase the correlation between the independent variable of the model (15) and the instrument, we subtracted the growth rate of the capital stock from the growth rates of the two instrument variables.

3 Results

Table 2 in the appendix displays the rates of the growth of the value-added, labor, capital and productivity, and the labor's share in the Finnish pharmaceutical industry in the period $1975-1999$. The average rate of growth of the value-added has been approximately 7.6% in the period $1976-99$, while the average rates of the growth of capital and labor have been 8.6% and 2.0%, respectively. This implies that the labor productivity has been increasing while the productivity of capital has been declining in the Finnish pharmaceutical industry during the time period $1976-1999$. The rate of growth of the total factor productivity, measured as Solow's residual, has been on average 1.4% over the same time period. The average labor's share has been approximately 0.38 and slightly increasing over time.

The data suggests that the total factor productivity growth in the Finnish pharmaceutical industry is strongly pro-cyclical. This is evidenced by the positive correlation between the rate of growth of total factor productivity and the rate of growth of the output-capital ratio. The estimated correlation coefficient is 0.978, which differs significantly from zero ($p < 0.01$). Table 3 displays the OLS estimation results of the linear model (15), in which the Solow's residual is regressed on the rate of growth of the output-capital ratio. As expected on the basis of the above correlation estimate, the explanatory power of the model is high and the growth rate of output-capital ratio significantly explains the variation of the Solow's residual.

Table 3 *OLS results of the model* (15)

Parameter	*Estimate*	*Std. Error*	$p-value$
α_1	2.1986	0.8927	0.0221
α_2	0.8818	0.0402	< 0.01
R^2	0.96		
$F-test$	480.46		< 0.01
N	24		
$DW-statistics$	1.8139		

As already argued, the OLS estimate of the parameter α_2 is inconsistent and biased. The following table 4 presents the results based on $2SLS$ estimation, which aims at correcting the problems of the OLS estimates. The instrument used in the model 1 is the growth rate of pharmaceutical expenditures, and in the model 2 the instrument is the growth rate of gross domestic income. The following table 4 displays the results of $2SLS$ estimation for both instruments.

Table 4 $2SLS$ *results of the model* (15)

	Model 1			*Model* 2		
Parameter	*Estimate*	*Std. Error*	$p-value$	*Estimate*	*Std. Error*	$p-value$
α_1	1.9954	1.2928	0.1227	1.9194	1.5849	0.2259
α_2	0.6683	0.0943	< 0.01	0.5884	0.1481	< 0.01
R^2	0.90			0.85		
$F-test$	198.27		< 0.01	125.01		< 0.01
N	24			24		
$DW-statistics$	1.4068			1.3330		

According to the results of the model 1, the estimated Lerner index is positive and differs significantly from zero. The estimated value of the price-cost margin is 0.67, which implies an approximate price-cost ratio 3.01. Both variables in the model jointly explain the variation

of the Solow's residual in a significant way, as the value of F-test shows. The high value of F-test is consistent with the relatively high value of the coefficient of determination, R^2.

In the model 2, the estimated price-cost margin is 0.59 which is below the estimate obtained in the model 1. As compared to the first instrument, the correlation of the second instrument with the rate of growth of output-capital ratio is lower. This leads to a higher standard error of the parameter estimate of α_2 in the model 2 than in the model 1. In the model 2 the estimated price-cost margin implies a price-cost ratio 2.4.

4 Discussion

The above section provides estimates for the Lerner index in the Finnish pharmaceutical industry. As the results indicate the estimated price-cost margin falls into the range $0.59 - 0.67$ depending on the used instrument. Carlton and Perloff (1994) list results from studies estimating price-cost margins in different industries. Highest price-cost margins appear in the regulated banking ($\hat{I} = 0.88$) and coconut oil industry ($\hat{I} = 0.89$). Our estimates on price-cost margin are below these two estimates. Scherer and Ross (1990) utilize accounting data and find that the US pharmaceutical industry has the sixth highest price-cost margin when industries are ranked according to the estimated price-cost margins. The authors estimate the price-cost margin to be 0.614. On the basis of informal discussions, Berndt et al. (1995) assess that price-cost margins for the H_2 antagonists would fall into the range $0.75 - 0.9$.

Our estimates are close to the results obtained by Scherer and Ross (1990) in the US. This is slightly surprising when the market environment of the pharmaceutical industry is taken into a consideration. There is no price regulation in the US while the prices of pharmaceutical products are subject to price regulation in Finland. Previous studies (see

Danzon and Chao, 2000) have shown that the prices of pharmaceuticals are higher in the US than in Europe, and the main underlying reason is believed to be price regulation. What is interesting is that, according to our results, there seems to be no significant difference in the price-cost margin between unregulated and regulated pharmaceutical markets. One should stress, however, that more comprehensive data sets and comparable methods are needed in order to draw more general conclusions on the differences between price-cost margins in regulated and unregulated pharmaceutical markets.

As compared to efficient pricing practices, namely marginal cost pricing, it seems that the estimated price-cost margins in pharmaceutical markets are high. Marginal cost pricing may not be a realistic pricing scheme in the pharmaceutical industry, as has been pointed out by several authors (see e.g. Scherer, 2000, and Danzon, 1997). Before launching their products, pharmaceutical firms use resources on research and development, which tends to lower the firm profitability after entering the market. It has been shown that if $R\&D$ costs are taken into consideration, the annual profitability of the firms in the pharmaceutical industry is not much higher in comparison to other industries (Scherer, 2000).

Before concluding the paper, we would like to raise two methodological questions related to the method and data used in this study. First, the methodology used to estimate the price-cost ratio is built on the assumption that the production technology is characterized by constant returns to scale. Hall (1988) demonstrated that the correlation between the Solow's residual and the rate of growth of the output-capital ratio may also appear if there are increasing returns to scale in the production technology. Time-series data, utilized in this study, does not allow us to directly test if the assumption on constant returns to scale holds true in our data set. This is because there may be technological progress, shifting the production function of pharmaceuticals inwards or outwards, and any conclusions concerning the economies of scale might be erroneous because technological progress cannot be controlled

at the same time. Firm- or country-level panel data would be sufficient for direct tests concerning the economies of scale.

The second question concerning the data comes from the properties of the $2SLS$ estimates, which are biased but consistent (see Greene, 1993). Our data set is relatively small and, hence, there may be some bias in our estimates. Longer time series data or panel data sets would be preferable so that one could resort to large sample properties of the estimates.

5 Conclusion

This article estimated the price cost margin in the pharmaceutical industry. We used data on the Finnish pharmaceutical firms and applied the methodology introduced by Hall (1988). This methodology essentially rests on measuring correlation between the growth rates of total factor productivity and the output-capital ratio. We utilized the $2SLS$ estimation methodology in the empirical section of this study. According to the results, the estimated range for the price-cost margin was $0.59 - 0.67$, which is close to the obtained estimates elsewhere (Scherer and Ross, 1990).

The used data set is unique in the sense that it is aggregated from firm-level observations and contains all Finnish pharmaceutical firms, which have more than 20 workers in their payroll. The time series cover the years $1975 - 1999$. The nature of the data also puts some limitations to our study. First, since we had no access to panel data, we were not able to test whether the assumption concerning the constant economies of scale holds true in our data. Second, the obtained data set is quite small which also puts some limitations to the obtained results.

Future work could extend (with the help of international data sets) the estimates of price-cost margins to settings in which several countries would be present simultaneously.

This could provide interesting information on price-cost margins in different countries with different market environments. This kind of information could be used in the price regulation of pharmaceuticals.

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6 Appendix

Table 2 *Share of labor and growth rates of output, capital, labor hours, and total factor productivity in the Finnish pharmaceutical industry*

Year	*Value added*	*Capital*	*Hours*	*Productivity*	*Share of labor*
1975					0,351980563
1976	82,85288659	12,08778258	7,866184448	71,84514082	0,255836007
1977	9,982133547	19,51564173	6,649902207	-5,923424453	0,280596675
1978	5,031929787	21,24379438	1,88629814	-10,67414165	0,286076405
1979	-14,872986	-21,08612888	9,231164824	-4,509190496	0,353670532
1980	1,376829348	41,57365372	10,35781544	-28,55749856	0,372866034
1981	14,7804666	41,64634195	2,602389078	-13,28220103	0,347907251
1982	4,03928512	29,68529799	-2,266112266	-14,80930435	0,339162135
1983	-8,620245842	26,43427206	9,976600723	-28,29198614	0,410904534
1984	14,83228542	8,512026713	10,15473888	5,612767148	0,430685043
1985	16,52748979	8,449896616	3,072870939	10,34856824	0,42234782
1986	-14,69996291	-0,234726047	-1,95911414	-13,61505207	0,493035644
1987	25,66423207	11,72444954	-1,80712424	19,60557129	0,418708781
1988	24,92096977	-5,242389318	-1,327198726	28,73286862	0,365369305
1989	9,164808061	5,802558816	2,994978479	4,356414657	0,354100433
1990	1,476340627	9,164061708	7,644088456	-7,066675073	0,40859009
1991	1,462616954	-1,401142004	-6,470397929	4,861372125	0,394064375
1992	-8,291223045	4,356077716	-2,836388793	-9,737775707	0,404523963
1993	-10,49270128	-3,587701839	4,182983268	-10,05668767	0,405586919
1994	0,609658181	0,756231585	-1,674355032	0,889018721	0,426066744
1995	13,05697062	0,751071649	3,405734144	11,23730149	0,4025361
1996	-1,619386022	-2,681673926	-5,780541086	2,282907408	0,393892168
1997	-1,653574418	-5,943574534	-6,937756376	4,668116108	0,380328805
1998	1,687774981	5,824574529	2,752914121	-2,858672785	0,416102887
1999	15,63090153	-1,668191194	-2,436696362	17,57221247	0,355390897
average	7,618645812	8,570091896	2,053457425	1,359568713	0,379931231

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