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Industry Concentration Dynamics and Structural Changes: The Case of Aerospace & Defence

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Abstract:

In this paper we present a general approach and methodology for modelling concentration dynamics on industrial level. The majority of research in this field has usually been focused on estimating adjustment models, where the speed of adjustment of actual level of concentration to the long-run concentration was considered to be responsible for concentration dynamics. The long-run concentration is usually modelled implicitly by the means of often complex industry characteristic variables. We model the changes in concentration through a) long-term structural changes in the specific industry, b) short-term structural changes, stemming from individual company conduct, and c) changes in number of companies constituting the industry. On the sample of quarterly data from 1999 to 2009 using total assets for the companies in Aerospace & Defence Industry in the U.S. we have confirmed the existence of short-term, but lacked evidence for the long-term structural changes.

Keywords: Production, Pricing, Market Structure; Size Distribution of Firms

JEL: L11, D40

INTRODUCTION

Industry concentration may be broadly defined as an extent to which one or more companies influence the aggregate development of their (horizontal and vertical) industries.¹ The general idea behind analysing industry concentration is that different industries may have different concentration levels. Naturally, one is interested in whether the variability in this concentration explains, or can help to explain some relevant economic question. It is therefore straightforward to study the influence of concentration together with some other economic problem of interest. Researchers in industrial economics, industrial organization, and generally empirical finance are routinely using industry concentration as a measure of industry structure since early 1950-ties. Just to mention few of the more current works:

¹ This definition is similar to OECD. 1993. Glossary of Industrial Organization Economics and Competition Law. OECD compiled by Khemani, S. – Shapiro, M.

Mueller – Raunig (1999) made use of concentration measures to explain the long-run projected profit rate on a firm and industry level and industry price-cost margin adjusted for advertising and R&D outlays, Bikker – Haaf (2002) and similarly Claessens – Laeven (2004) have linked the bank industry competitiveness H -measure to industry concentration, Nerkar – Shane (2003) have included industry concentration as one of the variables for modelling the likelihood function of a start – up failure, Zhao – Zou (2002) have measured the effect of industry concentration (among others) on the export activities of Chinese companies. A rich area of research works covers the changes in concentration due to mergers and acquisitions (M&A) (e.g. Eckbo 1985, 1992 or more lately Andrade – Stafford 2004). Government authorities are using changes in industry concentration as an indicator for undesirable industry structure, Cetorelli (1999). Whenever one wants to explain the relationship of industry specific characteristics to a specific dependent variable of interest, it is very likely, that some form of industry concentration measure will be used.

Two of the most common proxies for industry concentration include the k th firm concentration ratio (C_k) and Herfindahl index (HHI). For a brief summary, advantages and limitation of these measures see Curry – George (1983) or Biker – Haaf (2002). An interesting and rigorous debate about suitable properties of a concentration measure emerged after the seminal paper of Hall – Tideman (1967).

After choosing a suitable measure of concentration, it is usually necessary to choose a suitable economic variable to measure the market power (size) of a company. One of such measures used is the amount of sales of a company, generated within the studied industry. Unfortunately, data in such detail is rarely available. A problem by itself stems from the fact, that cross industrial comparison of concentration is problematic, as for example Curry – George (1983) note, that “*If size is measured by sales alone there will be bias towards firms engaged in distribution as opposed to manufacture...*”, and this is to large extent also true for concentration measures within a sector or more heterogeneous industry. Other measures typically used include sales less the costs of inputs and assets. For example, Bikker – Haaf (2002) used total assets as a measure of market power, Nerkar – Shane (2003), Eckbo (1985, 1992), Andrade – Stafford (2004), Bharadwaj et al. (1999) have also used sales. However, both measures tend to be highly correlated. For the purposes of higher credibility and comparison, there is always the option to use more than one measure of market power, as for example Hou – Robinson (2003) used assets, sales and equity when explaining the average stock returns by the means of industry concentration.

Understanding concentration remains an important problem in empirical research. What a researcher usually computes is an observed level of concentration, which might be considered as an estimate of the true concentration. What we do not know is the “story” behind these numbers. When turning from comparative statics to dynamical analysis, a concentration which randomly fluctuates around some constant might imply vigorous competition. If the value of concentration is higher in comparison to other industries, one can mistakenly come to conclusion, that companies exhibit their power to obtain higher profits. This might not be true, as even in high concentrated industries the competition can be vigorous, thus driving companies to lower profit margins. This idea is not new and was explored in concentration and mobility studies (e.g. Deutsch – Silber 1995).

Some changes in concentration might be the result of short term competitive actions and reaction of competing companies. Others might be the result of trends in technologies, deregulation or industry cycle, with their influence prevailing longer. While there is clearly a rich set of different possibilities, we refer to the former as *short-term structural changes* and to the latter as *long-term (industry specific) structural changes*.

The goal of this paper is to present a general methodology for modelling concentration dynamics through long-term and short-term structural changes, while controlling for the changes in number of companies, which is clearly to the notion of concentration.

The presented model of concentration`s dynamics can be directly compared with the commonly used adjustment models (and their assumptions). As we use only data commonly needed for calculating a measure of concentration, our approach might be considered as endogenous. An interesting contribution of our approach is the estimation of an industry specific function for quantifying the effect of the change of number of companies on the concentration measure. We believe that this may further increase our knowledge about the evolution of industry.

In the next section we make a short review of the existing approaches for modelling concentration dynamics. We will then proceed with our model. As we only have limited access to reliable data, our empirical section in this working paper is presented as only a preliminary exercise. For the purposes of this study we have chosen Aerospace & Defence, a relatively stable industry (sector) in the U.S.

METHODOLOGY

The concentration dynamics is a well studied concept, generally based on concentration adjustment models, which take the following form:

$$\Delta C_{t,i} = \lambda_i (C_{t,i}^* - C_{t-1,i}) + e_{t,i} \quad (1)$$

Change in concentration from time $t-1$ to t in industry i is denoted as $\Delta C_{t,i} = C_{t,i} - C_{t-1,i}$. The $C_{t,i}^*$ is the equilibrium or long-run concentration. The dynamics of concentration is considered to be explainable as an adjustment process from the observed level of concentration to the long-run concentration $C_{t,i}^*$. The λ_i relates to the speed of adjustment and $e_{t,i}$ is the error term. The long-run concentration is assumed to be a function² of some vector of industry specific characteristics. For example, Amel – Liang (1990) modelled the long-run concentration in banking using: bank deposits, market per capita income and its variability, population growth in industry and a set of dummy variables. Other general characteristics often used include domestic industry production, ratio of capital stock to industry production, minimum efficient size firm, cost disadvantage ratio, import and export intensity variables, marketing intensity, technology acquisition intensity and company / industry size measures (Geroski – Pomroy, 1990; Bhattacharya – Bloch, 2000; Jeong – Masson, 2003; Athreye – Kapur, 2003). The model (1) is usually estimated as a cross – sectional regression with an initial concentration level at time $t-1$. The period from $t-1$ to t varies from study to study from 1 year period to several decades. A time series approach is also possible (see Athreye – Kapur, 2003). The more recent studies focused on some enhancement of the existing methodology by adding different industry specific variables to the estimation of $C_{t,i}^*$, using panel estimations or adding other latent variables (like long-run profits, see Jeong – Masson, 2003).

Our approach of modelling concentration dynamics is more general in a sense, that it models the change in concentration without using explicit measures of industry structure. Our assumption is, that concentration dynamics is a function of long and short-term structural changes in industry. This assumption is not in conflict with model (1). One might assume that concentration dynamics in an industry is an adjustment process evolving towards the long-run concentration in that industry. Therefore an analysis could be performed as an alternative for (1), where the differences in concentration would be treated as time-series. We will refer to this model in further text as:

$$\Delta C_t = \lambda (C_t^* - C_t) \quad (1a)$$

In our approach, we do not make any assumptions about the composition of structural variables, nor about the functional form of their effect on concentration dynamics. We assume

² Usually a linear function in a form: $C_{t,i}^* = \beta_{i,0} + \sum_k \beta_{i,k} X_{t,i,k}$ where X represents industry specific characteristics, for which suitable proxy measures are used.

that the combined effect of structural changes can be decomposed into a constant effect ω (long-term structural changes) and a short-term effect (structural changes) represented by a latent variable s_t , which is unobservable.

We interpret the short-term structural changes as a consequence of company conduct in the industry. For example: the introduction of a new product on the market of one company may increase its market share, thus (*ceteris paribus*) also increasing the concentration measure. What might be interesting to measure is how persistent are those changes and how fast the industry reacts. In its simplest form, structural changes are assumed to be following an autoregressive process of first order:

$$s_t = \rho s_{t-1} + u_t \quad (2)$$

The persistency of short-term structural changes is denoted as $|\rho| < 1$. For example in Aerospace & Defence industry where governments are major buyers, winning a contract for supplying aircrafts will increase sales for several quarters. Such industries should have higher ρ .

Another component of concentration's dynamics is a constant change in concentration ω , which corresponds to a possible trend. The presence of this component in concentration's dynamics might well have similar reasons as that for s_t . With comparison to the previous example, one would assume the presence of ω , when new technologies or innovations in industry have long term consequences and thus establish a trend.

Finally, we introduce the effect of changes in number of companies in an industry. Let assume that the function $F: R \rightarrow [-1, 1]$ returns the change in concentration due to the change in the number of companies x_t . Although we do not know the exact form of this function, we make a rational assumption, that if $x_t=0$, then $F(x_t)=0$. This allows us to make use of the Maclaurin series, and model this effect as:

$$F(x_t) = F'(0)x_t + F''(0)x_t^2 / 2 \quad (3)$$

The use of the second order in (3) is arbitrary. Changes in number of companies may be caused by a number of reasons, which we do not try to address. The bias however depends on the extent how many participants are present in the industry, how concentrated it actually is and the cause of the changes. In an industry with higher number of companies and lower true concentration the bias should be smaller³.

³ This also suggests the scope under which our model is expected to be valid. As to the reason why changes in number of companies occur, we have two examples in mind: a) if the number of companies decreases due to an exit or if a company simply does not report their results for the specific period, the market share of other companies proportionally increases (market power changes), b) if the number of companies decreases due to an M&A, the market share does not increase proportionally. The same magnitude of change in concentration might

The contribution of the equation (3) lies in fact, that by estimating the coefficients, one can ascertain the impact of changes in the number of companies. Again, this might be an industry specific variable, which can be used in other industry organization studies. For example, comparing the results across industries may reveal the extent of possible barriers to entry and exit. In a specific time period, the form of empirical function (3) might be of interest. Industries may have not just different elasticities but also different forms of (3).

The theoretical model of concentration dynamics is⁴:

$$\Delta C_t = \omega + s_t + F(x) \quad (4)$$

The empirical form of (4) can be deduced from (2), (3) and can be estimated via *NLS*:

$$\Delta C_t = \omega(1-\rho) + F(0)(x_t - \rho x_{t-1}) + \frac{F''(0)}{2}(x_t^2 - \rho x_{t-1}^2) + \rho \Delta C_{t-1} + u_t \quad (5)$$

If the constant term $\omega(1-\rho)$ is not significant, there is no deterministic trend in the evolution of concentration. This might mean that no long-term structural changes are present. If both approaches ((1a) and (4)) are correct, we might write (6). If we estimate (5) independently from (1a), and the constant term in (5) is significant, it seems very unlikely that the observed concentration will converge to the long-run concentration:

$$\lambda(C_t^* - C_{t-1}) = \omega(1-\rho) + F(0)(x_t - \rho x_{t-1}) + \frac{F''(0)}{2}(x_t^2 - \rho x_{t-1}^2) + \rho \Delta C_{t-1} + u_t \quad (6)$$

If the short-term structural changes are persistent, the ρ should be significant and positive. One might assume that in a more competitive environment, the ρ will not be significant. Much more interesting are situations, where the ρ are significant and negative, implying possible counter changes, thus the short-term structural changes should have even less inner persistence. We call the case of negative ρ as “responsive”, to emphasize the reversing nature of short-term changes. A more detailed evolution of these changes and their relationship to concentration's dynamics would be reflected by using higher order autoregressive processes⁵.

correspond to very different market conditions. Our model could be accounted also for these effects; however it is not our goal to control for these factors.

⁴ The approach has been inspired by the procedure of Mueller – Raunig (1999).

⁵ Due to the nonlinear structure of equations, the relationship of ρ to model (1) is ambiguous. One needs to make further assumptions about the remaining terms, e.g. if $x_t=0$ and $\omega(1-\rho)=0$ the adjustment to the long-run concentration depends on the adjustment made in $t-1$ and the direction and the magnitude of this effect depends on ρ . We can express this as: $\lambda(C_t^* - C_{t-1}) = \rho \lambda(C_{t-1}^* - C_{t-2}) + u_t$. Similarly as before, a negative and significant ρ could be explained as counter reactions to the previous adjustments. However it is difficult to ascertain the resulting effects. Giving just one deterministic example; let the unknown $C_{t-1}^* = 0.6$ and $C_{t-2} = 0.5$ than $\Delta C_{t-1} = 0.05$ if $\lambda = 0.5$. If due to other structure variables the C_t^* decreases to 0.56 the adjustment process (with $\rho < 0$) will actually not adjust towards the new long-run concentration. If C^* is assumed to be constant, than the adjustment process is somehow erratic, but feasible. Therefore if C^* is assumed not to be a constant, than without further analysis of the data generating process of C^* (i.e. model 1a) it seems hard to make plausible interpretations.

Estimating equation (5) allows us to model industry's structure dynamics. To sum it up, if by $\omega(1-\rho)=0$ we mean no significant, by $\rho>0$ significant and positive, by $\rho<0$ significant and negative and by $\rho=0$ non-significant, we have six possible concentration dynamics situations:

- A. $\omega(1-\rho)=0$ and $\rho>0$ – persistent short-term structural changes.
- B. $\omega(1-\rho)=0$ and $\rho=0$ – no persistent short-term structural changes.
- C. $\omega(1-\rho)=0$ and $\rho<0$ – responsive short-term structural changes.
- D. $\omega(1-\rho) \neq 0$ and $\rho>0$ – persistent long and short-term structural changes.
- E. $\omega(1-\rho) \neq 0$ and $\rho=0$ – persistent long-term and no persistent short-term structural changes.
- F. $\omega(1-\rho) \neq 0$ and $\rho<0$ – persistent long-term and responsive short-term structural changes.

If model (5) has low *coefficient of determination* and the terms are not significant, it still has explanation power to us, as it suggests type B of concentration dynamics. If our model is correctly specified, then the changes in concentration would be interpreted as random (or only due to random increase/decrease in number of companies) in nature. There are other empirical questions which might be interesting to answer. For example, as we mentioned earlier, the relationship of ρ to the model (1a) is not straightforward. One could estimate (5) for various industries and compare the results with (1a). These results are not reported here. Another approach might be using the estimate of ρ and a dummy variable for the significance of $\omega(1-\rho)$ to explain industry profits.

THE CASE OF AEROSPACE & DEFENCE INDUSTRY

We follow the publicly available sector classification of Morningstar's 31 industries. We have also used publicly available quarterly balanced-sheet data from 1999 3rd quarter to 2009 2nd of publicly-listed companies on NASDAQ, NYSE and AMEX. We use the HHI as a measure of concentration and total assets reported in balanced sheets as a measure of market power. The time series of HHI consisted of 40 observations. The data are available in Appendix 1.

The changes in HHI and number of companies were modelled using logarithmic differences. Both variables were tested for presence of unit-root with Phillips-Perron test. In both cases the null hypothesis was rejected. The model (5) had been estimated by nonlinear least squares techniques, with starting values set to 0. We tested heteroscedasticity of

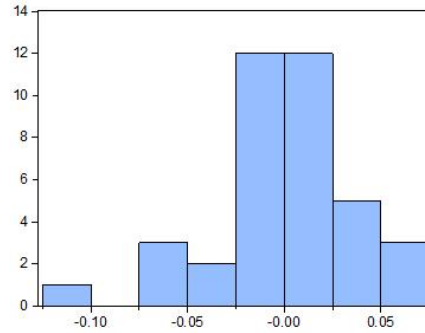
residuals with Breusch-Pagan-Godfrey test and the null of equal variance was not rejected (p-value = 0.4404). As we use quarterly data, the serial correlation had been tested with Breusch-Godfrey LM test with 4 lags and the null of no autocorrelation was again not rejected (p-value = 0.4962), see table 1.

Lags	AC	PAC	Q-Stat	Prob
1	-0.031	-0.031	0.0391	0.843
2	-0.177	-0.178	1.3624	0.506
3	-0.202	-0.221	3.1393	0.371
4	-0.065	-0.13	3.3268	0.505

Table 1: Autocorrelation and Ljung-Box Q

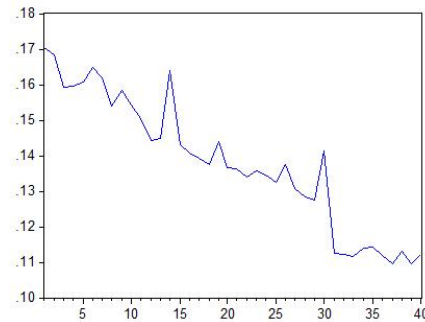
According to Yazici – Yolacan (2007) “For symmetric distributions with small sample sizes, researchers should choose Kolmogorov–Smirnov, modified Kolmogorov–Smirnov, or Anderson–Darling test of normality“. For the histogram of residuals, see Figure 1. As we have relatively small sample size of only 38 observations, the normality of residuals was tested using three normality tests: Jarque-Berra (p-value=0.0945), Shapiro-Wilk (p-value=0.195) and Anderson-Darling (p-value=0.231). In all cases, normality was not rejected. Finally, the significance of $\omega(1-\rho)$ was tested using a Wald test. The time series plot of the HHI suggests that some form of long-term structural changes is present, see Figure 2. However, statistically the long-term structural changes were not confirmed, for complete results, see table 2.

Figure 1: Histogram of residual



Note: y axis – frequency, x axis - residuals

Figure 2: Time series plot of HHI



Note: y axis – HHI, x axis – quarters as No. observations

Our industry classification is almost at a sector level; therefore many quite heterogeneous companies (in term of their production) are grouped together. The analyzed relationships are thus at a vertical level as well, e.g. between industries, within one supply chain. The ρ was significant and negative, corresponding to responsive short term changes. This analysis of concentration dynamics suggests that changes in concentration leads to contrary changes in the following quarter. The magnitude of these responses is measured by $|\rho|$. The higher the values of $|\rho|$, the more intensive are these industry responses. These results indicate industry case C from previous section, i.e. competitive environment. The negative value of ρ was surprising as the industry supposed to be characteristic for long-term business contracts, which should make counter reactions less probable. As Aerospace & Defence market in U.S. may be considered as mature, one possible explanation might be that while companies know that this possesses a threat, they are adjusting themselves by not allowing a single contractor to win a series of consecutive contracts.

There were two observations, for which we obtained somewhat suspicious values. In both cases, a company that is significantly large in terms of total assets (General Dynamics) had not been reported in our dataset. This naturally influenced the NLS estimates and residuals significantly.

In the Figure 2, one can see the swings which correspond to this suspicious values, obs. No. 14 and No. 30.

	Coefficient	Std. Error	t-Statistic	Prob.
ω	-0.008	0.005	-1.639	0.110
ρ	-0.445	0.151	-2.946	0.006
$F'(0)$	-0.976	0.189	-5.158	0.000
$F''(0)$	2.507	1.751	1.432	0.161
Adjusted R-squared	0.542			
S.E. of regression	0.038			
$\omega(1-\rho) = 0$	0.112			

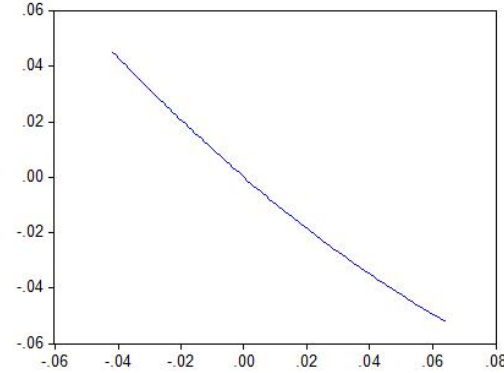
Table 2: Results of industry concentration dynamics – Aerospace & Defence

Partial contribution of model (5) is the estimation of effect of the percentage change in number of companies on the change of concentration measure. For Aerospace & Defence, we obtained values -0.976 and 2.507. From (3) one can see that we are able to estimate the function of change in concentration with regard to percentage change in number of companies. However, one needs to specify the domain around 0 (for x_t), for which the results are reasonable. We believe that we made a rather conservative approach, although more rigorous would be perhaps more appropriate:

- Lower boundary is $\min_i[x_i]/2 = -0.0834/2 = -0.0417$
- Upper boundary is $\max_i[x_i]/2 = 0.1278/2 = 0.0640$

The function (3) can be seen in figure 3. The shape of the function at the specified domain corresponds to the expected. Increase in number of companies decreases the observed concentration and vice versa. Judging just from the figure 3 (apart from the coefficient values), this relationship seems to be almost linear.

Figure 3 Concentration change as a function of x_t



Note: y axis – logarithmic differences of HHI
x axis – logarithmic changes in number of comp.

CONCLUSION

Over the last half a century, the notion of concentration in industry has established itself as one of the main characteristic of industry structure, both in academic works and practical economic conduct. Our aim in this working paper was to propose a methodology for endogenous modelling of shifts in concentration over time, and thus contribute to the understanding of sources of concentration dynamics.

Basic assumption of our approach is that shifts in concentration over one period can be decomposed to three sources of the change, specifically changes caused by long-term industry-specific evolution, changes stemming from short-term conduct of firms, and changes in concentration resulting from changes in number of firms in industry.

In chapter on methodology we discussed underlying assumptions on independent variables and their behaviour, as well as the way each of them enters the model. Resulting equation of the model (5) is directly deduced from assumptions and is estimated by non-linear-least-squares (NLS). We would particularly like to note the introduction of a function that relates percentage change of number of firms in given industry to change in concentration. Specific knowledge of the form of the function is not necessary; zero change in

number of firms implies zero change in concentration, what suffices for us to use Maclaurin series of arbitrary order to approximate the shape of the function around zero.

According to informational content as to the nature of sources of dynamics of concentration, we proposed a classification of results to six sub-groups, depending on the significance and value of estimated coefficients. Conveniently, the model investigates the sources of concentration dynamics without need for measures of exogenous characteristics of industry, which so far has been the usual approach of concentration dynamic's estimation.

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APPENDIX

obs.	quarter	HHI (level)	HHI (log diff)	no. companies	no. companies (log diff)	residuals
1	1999Q3	0.1705		23		
2	1999Q4	0.1684	-0.0121	22	-0.0445	
3	2000Q1	0.1594	-0.0549	25	0.1278	0.0147
4	2000Q2	0.1597	0.0018	25	0.0000	0.0273
5	2000Q3	0.1608	0.0065	25	0.0000	0.0200
6	2000Q4	0.1650	0.0259	23	-0.0834	-0.0574
7	2001Q1	0.1621	-0.0178	26	0.1226	0.0445
8	2001Q2	0.1539	-0.0517	26	0.0000	-0.0105
9	2001Q3	0.1586	0.0300	25	-0.0392	-0.0225
10	2001Q4	0.1542	-0.0278	26	0.0392	0.0139
11	2002Q1	0.1506	-0.0241	25	-0.0392	-0.0506
12	2002Q2	0.1444	-0.0416	28	0.1133	0.0200
13	2002Q3	0.1449	0.0030	29	0.0351	0.0632
14	2002Q4	0.1641	0.1248	27	-0.0715	0.0701
15	2003Q1	0.1432	-0.1359	29	0.0715	-0.0475
16	2003Q2	0.1407	-0.0177	29	0.0000	-0.0402
17	2003Q3	0.1393	-0.0099	29	0.0000	-0.0051
18	2003Q4	0.1376	-0.0125	29	0.0000	-0.0043
19	2004Q1	0.1441	0.0459	28	-0.0351	0.0156
20	2004Q2	0.1365	-0.0536	29	0.0351	-0.0060
21	2004Q3	0.1363	-0.0016	29	0.0000	0.0011
22	2004Q4	0.1341	-0.0167	29	0.0000	-0.0047
23	2005Q1	0.1358	0.0125	29	0.0000	0.0177
24	2005Q2	0.1347	-0.0076	29	0.0000	0.0106
25	2005Q3	0.1325	-0.0169	29	0.0000	-0.0076
26	2005Q4	0.1377	0.0386	29	0.0000	0.0437
27	2006Q1	0.1308	-0.0514	30	0.0339	0.0086
28	2006Q2	0.1285	-0.0176	31	0.0328	0.0149
29	2006Q3	0.1276	-0.0067	30	-0.0328	-0.0236
30	2006Q4	0.1414	0.1022	29	-0.0339	0.0604
31	2007Q1	0.1126	-0.2279	32	0.0984	-0.1139
32	2007Q2	0.1122	-0.0034	32	0.0000	-0.0601
33	2007Q3	0.1115	-0.0059	32	0.0000	0.0053
34	2007Q4	0.1140	0.0222	32	0.0000	0.0322
35	2008Q1	0.1143	0.0026	32	0.0000	0.0251
36	2008Q2	0.1121	-0.0201	32	0.0000	-0.0062
37	2008Q3	0.1096	-0.0223	32	0.0000	-0.0185
38	2008Q4	0.1132	0.0329	31	-0.0317	0.0021
39	2009Q1	0.1095	-0.0341	31	0.0000	-0.0217
40	2009Q2	0.1124	0.0266	30	-0.0328	-0.0106

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