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Joseph Richard Pollack

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Université Paris1
UFR 02 Sciences Economiques
Master 2 Recherche - Economie Appliquée

Convergent Trends in Aggregate and Firm Volatility

Nom du directeur de thèse : Prof. Angelo Secchi
Présenté et soutenu par : Joseph Richard Pollack – Juin, 2013

Convergent Trends in Aggregate and Firm Volatility

Abstract

This article unearths the determinants of the volatility of aggregate and firm-level production proxied by output and turnover respectively. This article re-visits Comin and Mulani's Note on the diverging trends between aggregate and firm volatility. Similarly to their conclusions, I establish that firm volatility is not driven by a compositional bias in my sample and that it's entirely driven by its covariance element. Contrary to their conclusions, I find a convergence between firm-level and aggregate level volatility due in part to the 2007 financial crisis.

1 Introduction

In this article I attempt to increase our understanding of the European economies¹ in the period 1997-2012 by comparing firm-level volatility to aggregate volatility because there is a lot to learn about how any given economy functions by comparing how the experience of individual firms is reflected at the aggregate level. This article is inspired by Comin and Mulani (Comin & Mulani, 2006), who find that trends at the firm-level diverge from the aggregate level, but who also find identical (symmetric) trends at the aggregate and firm-level for the US economy in the period 1945-1991. For the European economies I've discovered that firm-level and aggregate level volatilities converge in this period.

This article analyses the volatility of turnover at the firm-level and compares it to the aggregate output volatility. I've found that the volatility at the firm level converges with the volatility at the aggregate level. This could be due to a three empirical factors: due to sample composition, due to firm-specific factors, and due to sectorial determinants. I refute these eventualities, and then discover which components of firm-level volatility explain the aggregate volatility. Finally, I use my findings to address the theoretical hypotheses advanced by contemporary scholars to explain either convergence or divergence between firm and aggregate volatility.

Whereas Comin and Mulani (Comin & Mulani, 2006) find diverging and symmetric trends by comparing firm-level and aggregate volatilities, I've discovered a convergence between firm-level and aggregate volatility. I attempt to increase our understanding of firm-level volatility by comparing it to aggregate volatility because this phenomenon speaks directly to a given economy's fundamental character. Namely, how a firm's experience is reflected at the aggregate level speaks volumes about how that economy functions.

There are seven theories in the literature which attempt to explain trends in firm-level and aggregate volatility. Comin and Mulani explain their symmetrical trend as due to increasing investment in embodied innovations at the expense of disembodied innovations. Sector-level shocks thus increase due to a focus on product rather than fundamental research. Wang and Wen (Wang & Wen, 2009) argue that it's financial development driving this trend. Davis and Kahn (Davis & Kahn, 2008) argue by contrast that it's greater investment in durable inventory that's the cause for decreasing aggregate output and firm-level volatility. This study lends credence to the latter's conclusions with my focus on non-listed firms but doesn't discover empirical evidence to support Wang and Wen's claim. Another theory posits that it is credit constraints and financial development that contribute to aggregate productivity volatility (Aghion, Angeletos, Banerjee, & Manova, 2010). An associated theory (Aghion, Bacchetta, Ranciere, & Rogoff, 2006), argues that it's the exchange rate volatility that drives volatility at the aggregate level. This study supports the former's conclusion in as much as quantitative easing policies mark a notable decrease in aggregate and firm volatility and its cessation heralds a marked increase in volatility. The second study's conclusions are not verified in this study inasmuch as the question was not directly addressed nonetheless covariance of volatility between countries and a break down by country doesn't of volatility does not find evidence of the required magnitude for the theory posited by Aghion et.al. .

¹ France, Germany, Ireland, Greece, Austria, Italy, the Netherlands, and Sweden

The contribution of this article to the literature is that it rules out some theories or restricts their domain to the data used by those who proposed this theory, whilst offering qualified support for some other theories. In addition it finds a trend in the European data hitherto undiscussed. This is the first firm-level study to date that looks at European firms, first of all, and looks at the tumultuous 1997-2011 period second of all. Europe is woefully neglected in the empirical literature dealing with volatility. Furthermore most firms in the sample are small to medium sized firms and thus this study is novel in a third way, that is that we're looking at how the "rest of the economy" behaves rather than how publicly listed companies behave. Therefore this study takes the relay from Comin and Mulani's study in terms of time and brings us to a different geography all the while focussing on a different kind of firm. I discover a tendency towards convergence between firm and aggregate level productivity, and notably and almost by definition, that there are significant upward trends in volatility during years of financial crises.

The first section of this paper explores the empirical literature pertaining to this field of study notably recent studies on the increasing volatility of listed firms, the decreasing volatility of the aggregate-level, and theoretical literature on these phenomena. Although there was more attention paid to volatility in between the mid-nineties to the mid noughties, relatively few studies were undertaken directly comparing the two volatilities, the articles by Comin and Mulani's and Davis and Kahn's are the only two which directly address this.

The third and fourth sections present this studies' data and novelty. Whereas previous studies are exclusively restricted to data from the USA, this study presents findings based on European data of mainly small firms. The fifth and sixth sections present a panoply of robustness checks correcting for compositional bias at the firm and sectorial-level and firm-level fixed-effects. The final two sections present the principle empirical findings and associated conclusions. We find that the trends mostly hold for changes in the composition of the sample.

2 Literature Review

There's been more attention paid to the aggregate-level output than the firm-level in the literature studied, that mostly focusses on the recovery after the recession of the early 1990s. Oliver Blanchard and John Simon argue (Blanchard & Simon, 2001) that the decline in output is driven by a decrease in inventory investment, a decrease in consumption and a decrease in government spending based data from the period 1947-1981 and 100,000 simulated observations for the 1982-2000 period. They focussed on chain-weighted GDP measures to decompose volatility into its standard deviation and growth components. Campbell et.al. discover a significant and positive trend (Campbell, Lettau, Malkiel, & Xu, 2001) in volatility based on the CRSP dataset using 8927 firms to compute market, industry and firm-level variances by calculating 30-day T-bill returns divided by the number of trading days of that month. Margret McConnell et.al. argue that it's changes in inventory behaviour that has driven decreasing output volatility (McConnell & Perez-Quiros, 2000) based on a dataset of GDP ranging from June 1962 to December 1997. Xavier Gabaix argues that individual firm's idiosyncratic shocks account for a significant share of aggregate shocks (Gabaix, 2011) based on a sample of top-20 firms in 1980. Thomas Phillipon (Phillipon, 2003) argues that it may be competitive pressure that drives the divergent trend in aggregate and firm's volatility using the same data at Comin and Mulani, namely the COMPUSTAT database from 1965 to 2001. He measured growth rate to examine volatility. Stock and Watson argue that it is good luck and better monetary policy that accounts for the great moderation (Stock & Watson, 2003) based on 168 quarterly macro-economic time-series from 1959-2001. They used NIPA decomposition of real-GDP; based on variables for money, credit, interest rates, and stock prices; housing industrial production, inventory, orders, and sales variables; and employment variables, they transformed growth-rates to measure volatility and come to their conclusion. Davis et.al argues that there's in fact a convergence between private and publicly traded firms' volatility based on the LBD census for the 1976-2001 period and COMPUSTAT from the 1950-2004 period (Davis, Haltiwagner, Jarmin, & Miranda, 2006) by using employment, listing variables, age, growth and size to size- and employment- weighted volatility. Another approach focusses on institutional endowments (Easterly, Islam, & Stiglitz, 2000) to find that it is institutional endowments that mediate micro-economic variables to impact aggregate volatility. This study used simple cross-country differences in volatility from 1970 until 1997 using output as a proxy for growth and a diverse set of dependent variables including exchange rates, inflation and government consumption. Aghion et.al. use a panel of 21 OECD countries

over the 1960 to 2000 period using appropriate proxies for short-term shocks, long-term productivity, and credit constraints as a proxy for financial development (Aghion, Angeletos, AbhijitBanerjee, & Manova, 2010). They find that financial development drives aggregate volatility.

3 Data

This study uses the Amadeus Database newly published in 2012. It contains 891,707 firm-level observations from 1997-20011 on an annual basis. It's a study of exclusively European firms from a variety of countries namely Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, and the United Kingdom. This study focussed exclusively on the turnover of each firm although the dataset contained many more variables. Before 2002 each measure was entered using local currencies so each of these measures for each different country has been converted into the euro using yearly exchange rates. In order to examine the volatility of growth at the firm level, annual turnover data is gathered from the sample only for firms that have non-zero values for sales for any three consecutive years. Both currently active and currently bankrupt firms are kept, and due to the international nature of the dataset, international firms are also kept. Only firms with 3 or more consecutive yearly observations were retained because that's what's needed to create one window to measure variance (see below) and therefore only 301,745 firm observations were kept.

The total sales by year and country for the retained firms constitute on average 0.001%, a breakdown by country is given in Annex 2 along with some general descriptive statistics. Nonetheless there are years, notably the 2005 to 2008 windows where the total sample of firms sometimes constitutes upwards of 5% of the aggregate GDP. Therefore we have a sample that's at best a snapshot of minute portion of the economy. Even so the sample is large in number of firm observations and seemingly random in its selection of them which is good for analysis. Thus, I will need to control for a variety of possible sample-selection and composition bias possibilities.

Summary Statistics

Year	Number of observations	Mean ²	Mode ²	Median ²	Sum ²	Std Dev ²
2011	0	.	.	.	.	.
2010	0	.	.	.	.	.
2009	10802	135.629	0.1	38.19	1465066	207.8344
2008	58762	6375.77	0.1	404	374653234	40318.21
2007	63807	6861.29	1000	425	437798452	41811.52
2006	65750	3045.04	1000	405.43	200211470	9565.03
2005	65451	2935.53	1000	390.53	192133536	9358.19
2004	61476	2834.35	0.11	368.52	174244220	9214.11
2003	58925	245.095	106	154	14442201	249.6599
2002	56879	246.313	103	156	14010028	249.2583
2001	54206	45.17	15.85	32.37	2448482	43.43776
2000	52188	45.47	15.24	33.39	2373085	41.05117
1999	16917	37.66	11.46	24.07	637123	46.20644
1998	1094	44.47	0	16.66	48660	78.25408
1997	411	39.99	17.34	15.72	16437	70.47851

Table 1 - Summary Statistics

² In thousands

4 Firm-Level Volatility

Consider the time series of a random variable X_t the volatility of X_t is defined as the time series of standard deviations of 3-year windows of X_t . Formally we compute the time series for volatility of X_t as

$$\sigma(X_T) = \sqrt{\frac{\sum_{t-1}^t (X_t - \bar{X}_t)^2}{2}}$$

Where \bar{X}_t is the average between t-1 and t+1.

For every firm a time series $\sigma(y_{sales\ it})$ where $y_{sales\ it}$ is represents the growth-rate of real sales for the company, the deflator being the PPI – the aggregate producer price index for the European Economic Area. These standard deviations are then averaged across all the firms in a year to arrive at the average volatility for every year. Therefore we remove the average growth rate for a given firm in a given 3-year window and thusly control for firm-specific aspects that affect the growth rate of sales. If on the contrary, we would have computed the standard deviation across all the firms, then this cross section would have been (more) vulnerable to a compositional bias through the medium of fixed firm-effects.

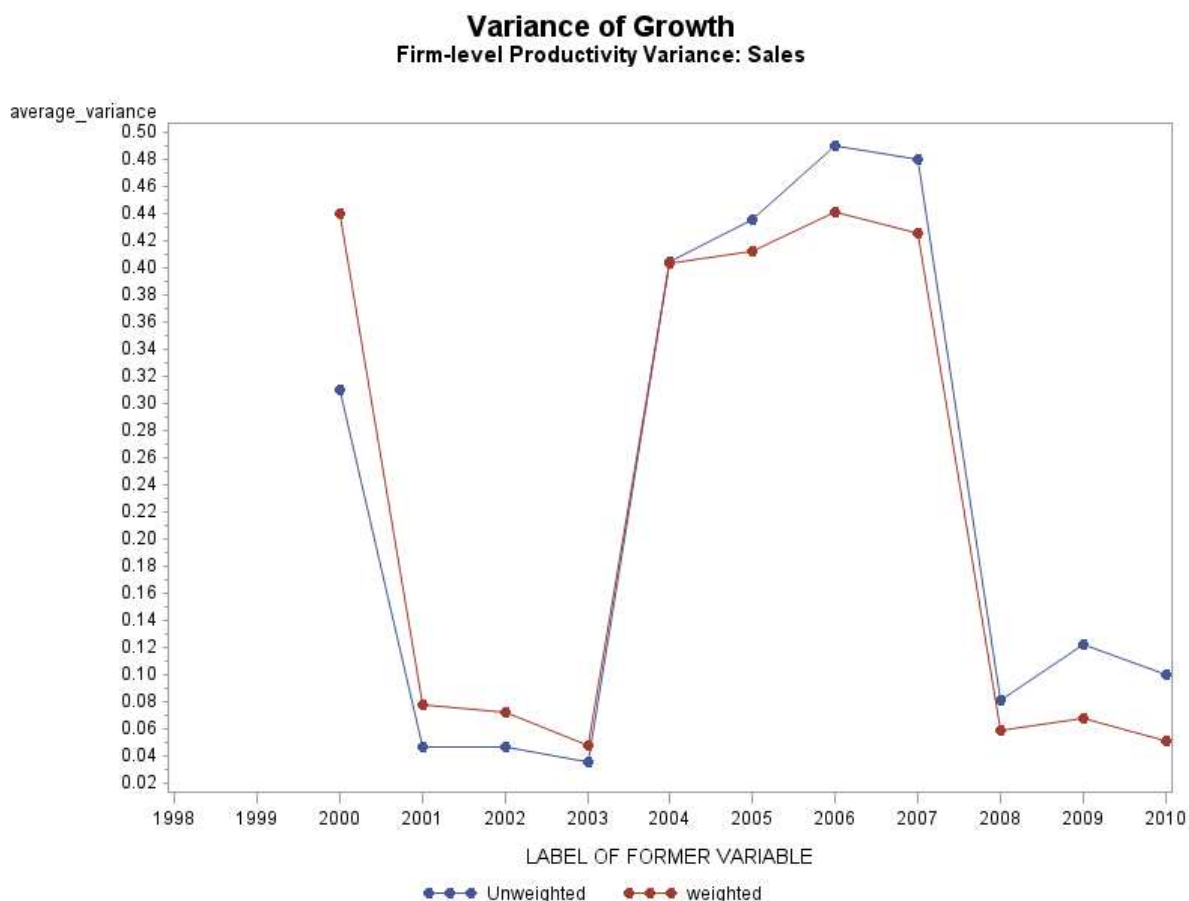


Figure 1- Firm-level volatility for the whole sample

As illustrated in Figure 1, volatility at firm-level exhibits a persistent 'leveling' trend after the boom years of the noughties and its correction in 2007. The graph plots volatility per year as a decimal of percentages. In order to build a more representative measure, firm-level volatility measures are weighted by the firm's share of turnover of a given year in its country's total turnover in the sample of that same year. This weighted measure is also graphed in Figure 1. Although both weighted and unweighted measures display the 'leveling' tendency, it's source may be called into question. That's because it could very well be a feature specific to the sample or the variable in use. Although in this exercise a different proxy for performance could not be used, I need to respond to these eventualities.

4.1 Bias due to Price Divergence

The levelling of volatility at firm level may be due to differences in the prices at firm level. However, price deflators at sector-level don't exist, therefore I cannot analyse the volatility of growth rates of real sales, and must be content with nominal values. To examine the eventuality of firm-level price divergence, a subset of our sample is examined. I separated all manufacturing firms to see if there was a price divergence at the 2-digit NACE code level. Then four-digit deflators are used to adjust net-sales to real measures. Figure 2 presents the average weighted and unweighted measures of volatility of the sub-sample of manufacturing firms and compares this to the whole sample on the same graph.

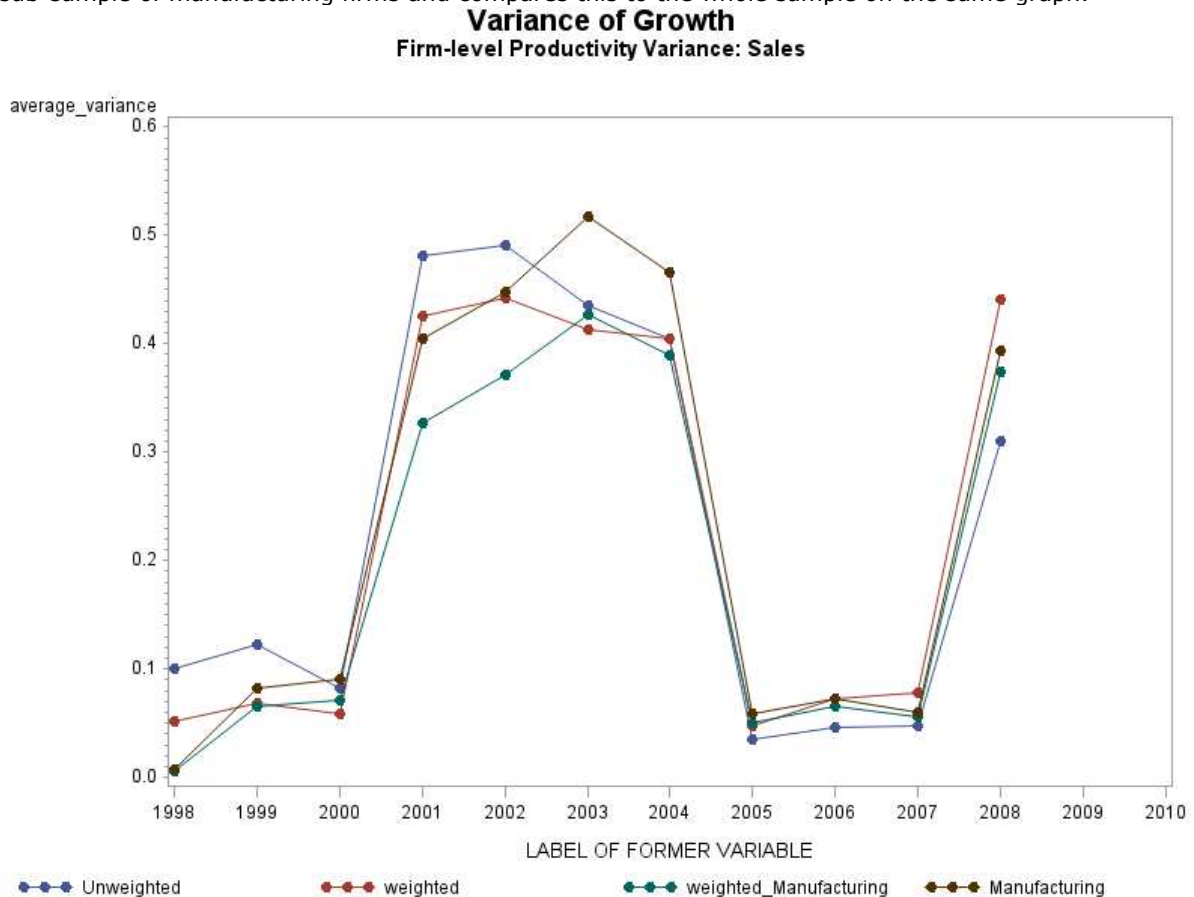


Figure 2 - Comparison of Manufacturing Subsample with Total Sample - Detail and whole graph

The figure suggests that the evolution of average volatility is similar to the growth rate of nominal sales for the firms in the full sample and for firms in the manufacturing subsample. Furthermore the figure shows that the growth rate of nominal and weighted real sales is the same. This result suggests that the levelling trend in volatility is not driven by firm-level price divergence. Nonetheless it may be the case that price-divergence operates at the four-digit level. Further studies could rule out that possibility by using the number of employees as a real measure of growth rate.

4.2 Bias due to Sample Composition

The sample is taken from the AMADEUS database for all years from 1997-2011, but the sample increases drastically between the years 2001-2007. This is because certain reporting laws can into effect or were changed on a country-basis which means that there is an increase in available data notably in Austria. As a consequence this raises the possibility that the observed trend is due to a compositional bias. Firms that are incorporated into the dataset from that period may potentially be more exposed to the financial crisis' exogenous shock either because their sectors are more vulnerable or due to firm-specific attributes such as age, size, management competence, independence, debt-levels, or provenance. One remedy to this problem is simply to track the evolution of the firms initially in the sample's volatilities, but this would induce a survivorship bias which doesn't remedy the source of the

concern. Therefore in order to show that the trend is not due to a compositional bias, four exercises are undertaken.

First, the sample of firms is divided up every year into five quintiles according to the level of sales. A firm enters a given quintile if it remained in the quintile for two consecutive years. The top quintile, for example is defined as follows:

$$Market_{Leaders}_{I,t} = P\left(\left(Z_{i,t_a+1} < Z_{t_a+1}^{top,I(i)} \mid Z_{i,t_a} > Z_{t_a}^{top,I(i)}\right) \& \left(Z_{i,t_b+1} < Z_{t_b+1}^{top,I(i)} \mid Z_{i,t_b} > Z_{t_b}^{top,I(i)}\right)\right)$$

Where t_a and t_b are consecutive windows.

Next I examined whether the observed trend in volatility is driven by any specific quintile by seeing whether or not the levelling effect is a product of averaging with quintiles driving volatilities in opposite directions, or whether it's a pervasive phenomenon across quintiles. Figure 3 clearly shows that the levelling of volatility is not driven by any specific quintile but rather that it's pervasive across the sample and not restricted to any section of the distribution. Nonetheless, this finding does not fully account for the possibility that firms in the sample and in each quintile are composed by firms more exposed or susceptible to shocks after 2002: all the quintiles may be composed of firms that were intrinsically more vulnerable to 2006's exogenous shock.

It could also be that it's in fact firms from a given country instead of firms of a given size that are driving the trends in volatility across the sample. That's why I checked each country against the others to see if any given country leads the sample or flattened an otherwise pervasive upward trend. I find that there is an averaging effect in the years 2001 to 2005 whereby the Dutch sample lowers the aggregate variance whilst the Italian and German samples increase in volatility. Then it's the turn of the Dutch section to be victim of an averaging effect. Nevertheless we see all the countries eventually converge. This means that it's likely that some measure of bias due to sample composition is present but that the sample 'responds' well to it once the initial 'shock' of a sharp increase in observations has passed and large numbers of observations become pervasive across countries of origin.

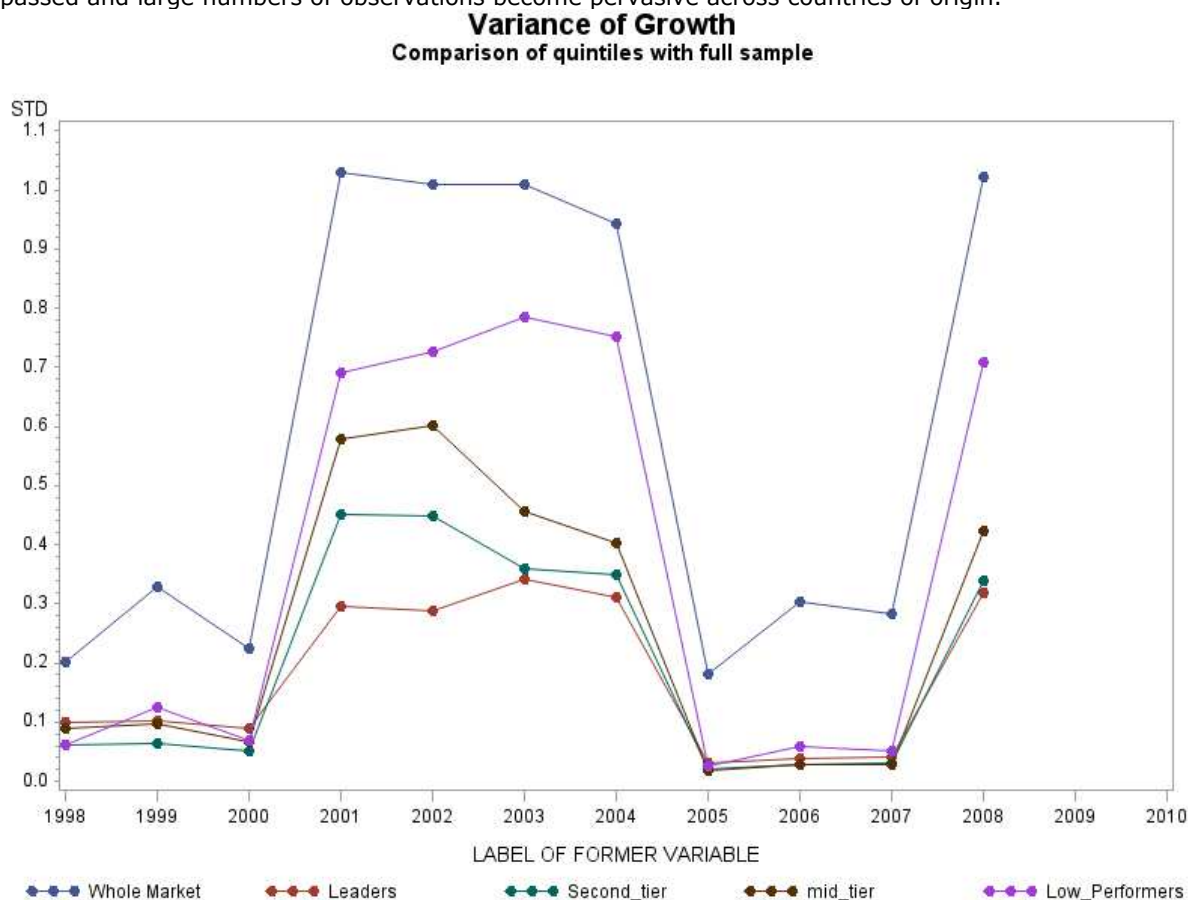


Figure 3 - A comparison of the volatility of different quintiles

Variance of Growth Comparison of Countries with the full Sample

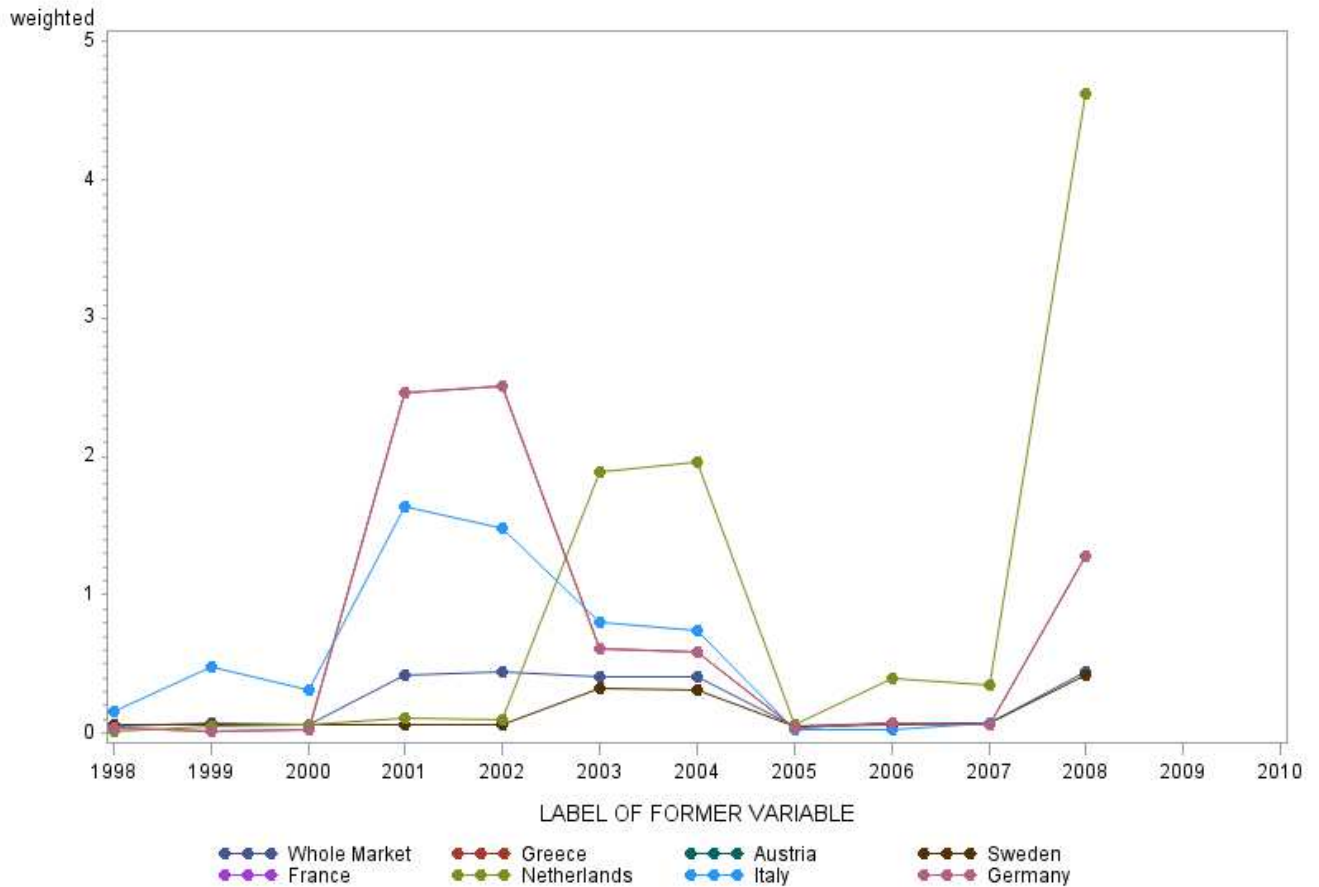


Figure 4 - Comparison of Countries to the full sample.

4.3 Firm-specific uncertainty

As a second exercise to control for the eventuality that firms that enter the sample in 2002 are more vulnerable to the financial crisis, I looked for the component of volatility that is not explained by firm-level characteristics that are changing in the sample. Therefore I ran a pooled regression of the firm-level standard deviations (σ_{it}) on a vector of firm characteristics (X_{it}) that contains the log of the share of firm sales in the total of the sample retained by country and the log of the firm's age:

$$\sigma_{it} = \alpha_0 + \beta_1 X_{it} + \varepsilon_{it}^\sigma$$

The residual (ε_{it}^σ) is then aggregated to produce a time-series of the unpredictable component of firm-level volatility. This exercise was repeated for weighted measures of variance. Unfortunately a suitable proxy for firms' activity levels was not present in the dataset and this could not be included as a component of the vector X_{it} .

Nonetheless the observed time series, although able to refute that the observed trend is the product of compositional bias, begs the question of whether or not there may be other firm-specific variables that account for the levelling trend. Indeed there may be omitted firm-specific variables that lead to a compositional bias. To rule out this possibility, I ran fixed-effect regressions³ with firm-dummies to remove the observable and unobservable effects of firm-specific variables on volatility. Removing these effects thus leave only the orthogonal component of unpredictability to fixed firm characteristics. Formally, I ran the following regression where α_i is the set of firm dummies and X_{it} is the set of controls, namely the log of age and the firm's share of sales for the sample:

³ Of a random sample of 30000 firms 10 times (a naïf Monte Carlo experiment) and used their averages in order to find the values that asymptotically converge towards the real value.

$$\sigma_{it} = \alpha_i + \beta X_{it} + \varepsilon_{it}^{\sigma}$$

Figure 4 plots and compares the time series of the unpredictable components volatility of the weighted and unweighted pooled and fixed-effect regressions. The figure plots the unweighted pooled effect on the left axis and the rest of the regressions on the right axis. As we can see the 'level' trend is evidenced by the collapse of the curve and we can rule out that the uncertainty is simply the result of including more firms in the sample in 2002. If the observed trend was simple the result induced by the fact that the firms chosen in 2002 were simply less volatile, removing firm-specific components of all firms in the sample eliminates the component that is less volatile for new firms. Therefore if the observed trend still persists, we can rule out that a compositional bias is the driver of the trend.

Variance of residuals

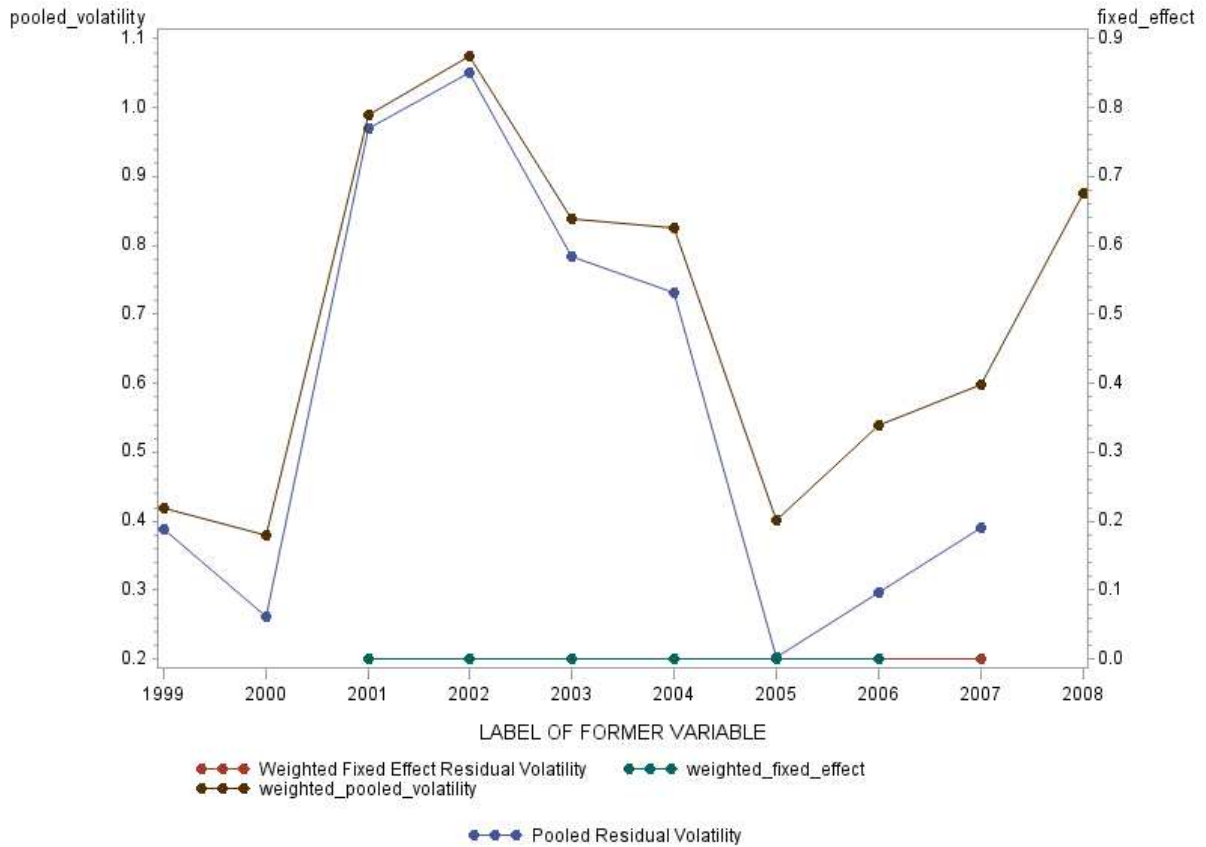


Figure 5 - Residual volatility after controlling for age and size

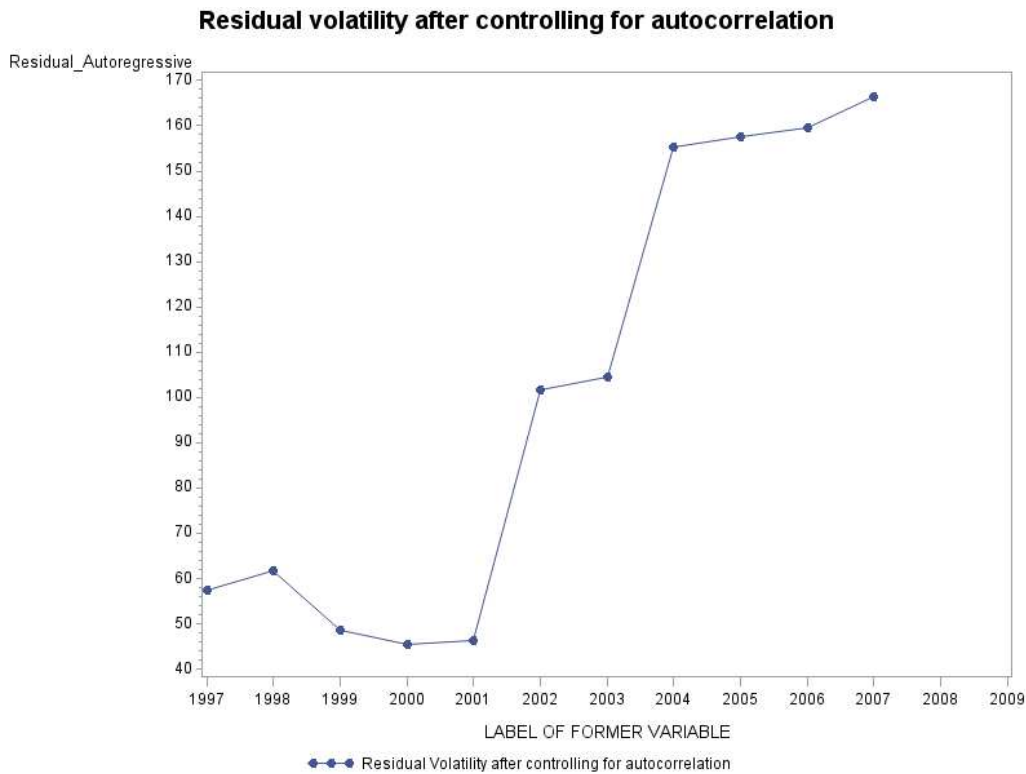


Figure 6 - Residual volatility after controlling for autoregressive effects

5 Firm Level Volatility by Sector

After I verified the robustness of the 'level' trend discovered in the volatility of the sample, I analysed the volatility by sector. That's because any given sector might be at the root of the observed trend. Thus, to verify that this is not the case I ran the following regressions for each two digit sector:

$$\sigma_{it} = \alpha + \beta X_{it} + \delta D_{st} + \varepsilon_{it}^{\sigma} ;$$

$$\sigma_{it} = \alpha_i + \beta X_{it} + \delta D_{st} + \varepsilon_{it}^{\sigma} ;$$

where D is a set of sector specific time dummies. I ran both these regressions on weighted and unweighted measures of growth for all sectors. By running all these regressions I can construct a time-series for the weighted and unweighted average firm-level volatility after controlling for age and size and a firm-specific intercept. For each two digit sector, Table 2 reports the average estimated coefficient on for each year from the pooled regression without firm-level fixed effects. Table 2 shows that the all changes in variance were reflected in each sector, with a notable exception being the computer and optical in the wake of the internet bubble and their associated industries namely, fabricated metals like rare earth products and non-metallic minerals like quartz, which have coefficients about twice the gradient of other sectors. These are joined only one year later by petroleum, together they drive a short-lived uptick in volatility at the firm-level between 2001 and 2002. Looking at the evolution of the petroleum sector over the full time period leads me to hypothesise that shocks to both demand and supply will be compensated in the short run by governments.

5.1 AVERAGE FIRM-LEVEL VOLATILITY BY TWO-DIGIT NACE CODE

SECTOR	UN-WEIGHTED										WEIGHTED								
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	1999	2000	2001	2002	2003	2004	2005	2006	
Water Collection and Supply			0.0097	0.00778	-0.0033	-0.0027				-0.0079			0.0097	0.00778	-0.0033	0.0004			
Electricity, gas, air, steam			0.008	0.0069	-0.0023	-0.0016		-0.00059		-0.0058			0.008	0.0069	-0.0023	0.0006			-0.0006
Repair and Installation of Machinery and Equipment	-0.002		0.0052	0.0053	-0.0035	-0.0023		-0.0004	-0.0012	-0.0057	-0.002		0.0051	0.00538	-0.00345	-0.0023			-0.0004
Other Manufacturing			0.0114	0.0114	-0.002	-0.002				-0.0037			0.0114	0.01138	-0.00197	-0.002			
Manufacture of furniture			0.0118	0.0111	-0.0024	-0.0019		-0.00017		-0.002			0.0117	0.011	-0.00239	-0.0019			-0.0002
Transport equipment			0.003	0.003	-0.0063	-0.0053		-0.00072					0.0031	0.003	-0.00633	-0.0053			-0.0007
Motor vehicles			0.0072	0.0065	-0.0031	-0.0024	0.0001	-0.00008		-0.0055			0.0072	0.0065	-0.00313	-0.0024	0.0001		-0.0001
Machinery			0.0097	0.0098	-0.0024	-0.0018	0.0001	-0.00006		-0.0042			0.0097	0.0098	-0.00236	-0.0018	0.0001		-0.0001
Electrical Equipment			0.0111	0.0113	-0.0028	-0.0026	0.0001	-0.0004	-0.0004	-0.0057			0.0111	0.0113	-0.0028	-0.0026			-0.0004
Computer and Optical	-0.0005		0.0212	0.0212	-0.0012	-0.0009	0.0001			-0.0043		-0.00051	0.0212	0.0212	-0.0012	-0.0009			0.0001
Fabricated Metals	-0.0006		0.0181	0.0173	-0.0013	-0.001	0.00004		0.0001	-0.0039		-0.00064	0.0181	0.0173	-0.00134	-0.001			0.00004
Basic Metals	-0.0003		0.0126	0.0118	-0.0022	-0.0018	0.0002			-0.0033		-0.00032	0.0126	0.0117	-0.00215	-0.0018			0.00017
Non metallic Minerals			0.0254	0.0263	0.0023	0.0022							0.0254	0.0263					
Rubber and Rubber Products	-0.0003		0.0095	0.0092	-0.0018	-0.0014	0.0002			-0.0019		-0.00034	0.0095	0.0092	-0.00183	-0.0014			0.00017
Basic Pharmaceuticals			0.0152	0.0154	-0.0014		0.0001			-0.004			0.0152	0.0154	-0.00144				0.00014
Chemical and Chemical Products			0.007	0.0064	-0.0017	-0.0011	0.0001			-0.0052			0.007	0.0064	-0.00169	-0.001			0.00011
Coke and Petroleum	-0.0028		0.023	0.0207	-0.0008	-0.001						-0.00283	0.023	0.0207	-0.00081	-0.001			

6 Aggregate Volatility

I've discovered that the evolution of aggregate volatility converges towards that of the firms' in my sample after the financial crisis whereas during the boom years firm-level volatility increases markedly and diverges. Many authors have remarked that aggregate growth has become more stable in recent years, and some have suggested that there is an association between the aggregate level volatility and non-listed firms' volatility. Figure 5 plots the time series $\sigma(\cdot)$ for growth rates of both nominal and real aggregate final sales of the European Union 17. The volatility of aggregate sales displays a large increase starting from 2007 to 2009 coinciding with rises in firm-level volatility in 2005 and 2007. As we can see from the fact that nominal and real GDP growths are similar until 2007, inflation is not a concern for my purposes. Inflation becomes an issue in the 2007 to 2010 windows, the duration of the first dip of the financial crisis characterised notably by a massive quantitative easing among other non-conventional responses. When this time series is compared to that of the firm-level volatility we see that convergence and levelling trends are evident.

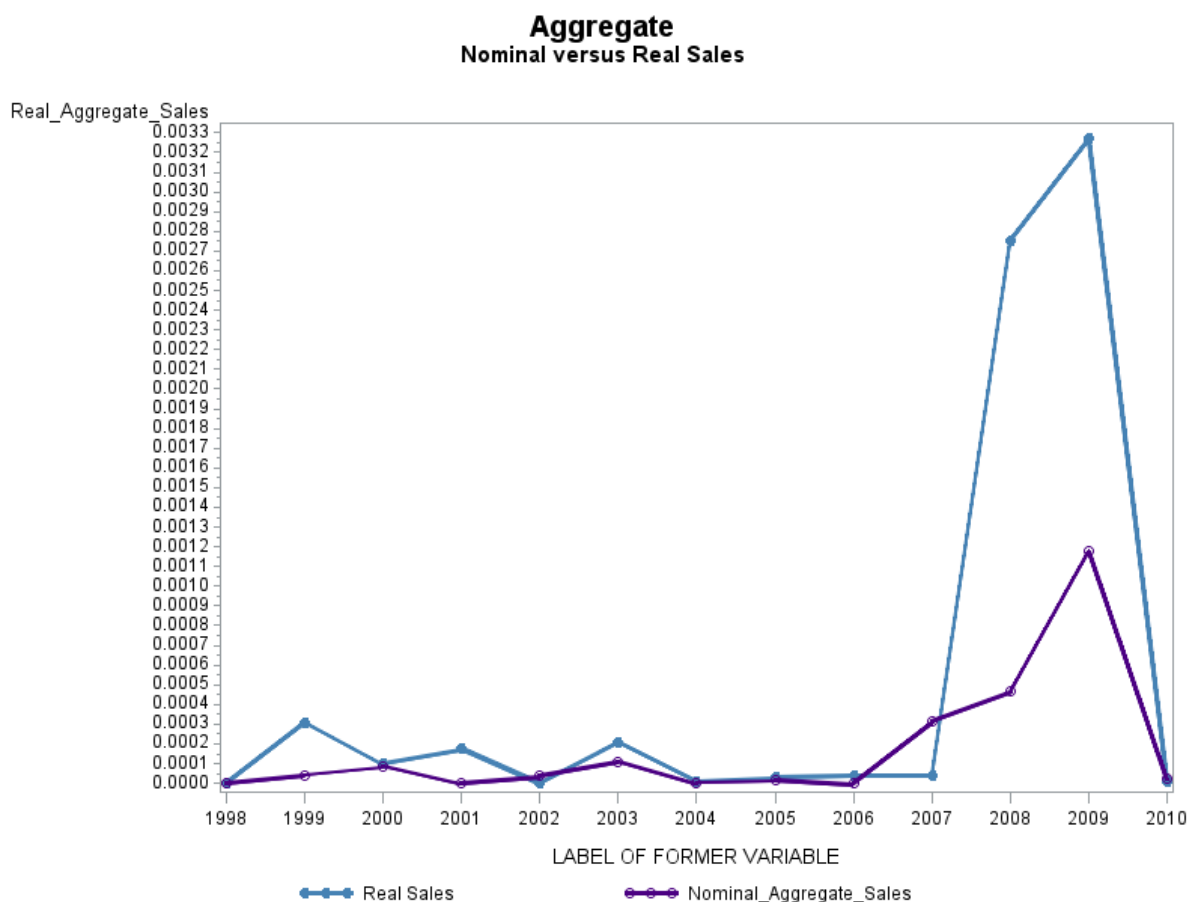


Figure 7 - Volatility of Growth Rates of Real and nominal aggregate sales

Convergence in Volatility Aggregate Volatility Versus Firm-Level volatility

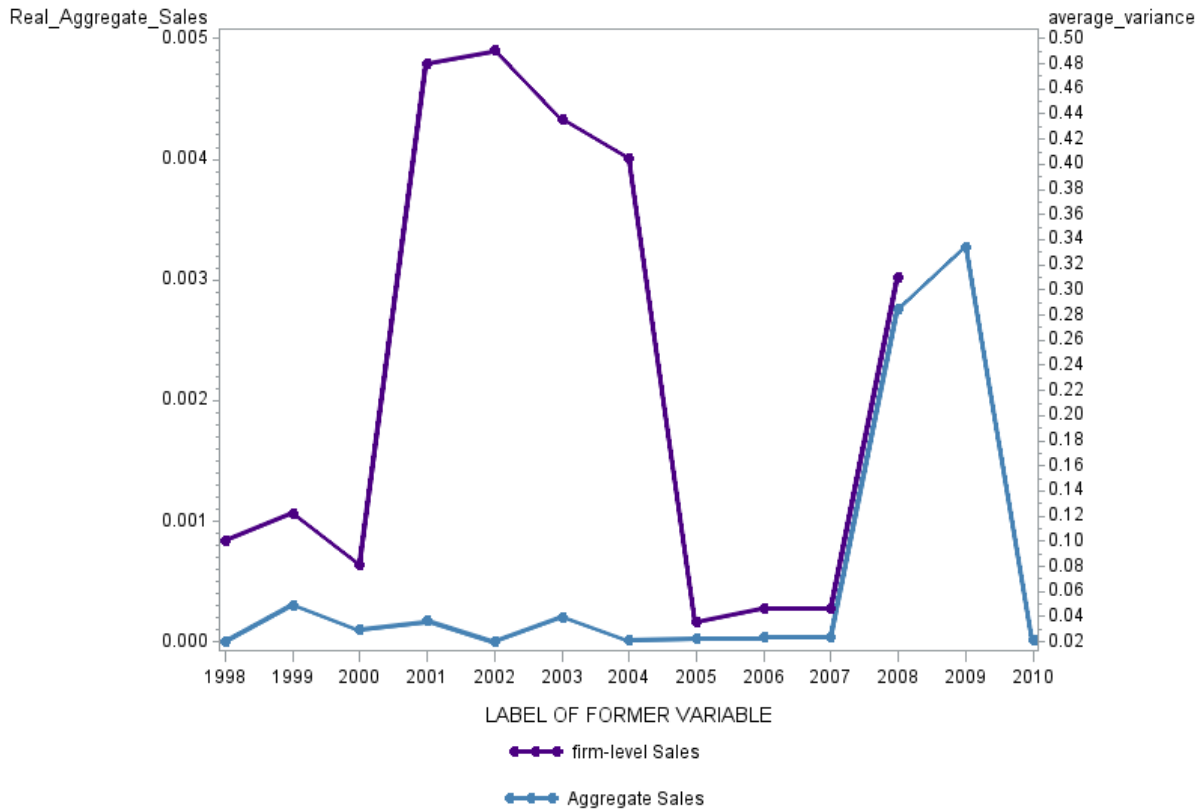


Figure 8 - Volatility of Growth Rate of aggregate final sales and firm-level sales

7 Variance Decomposition

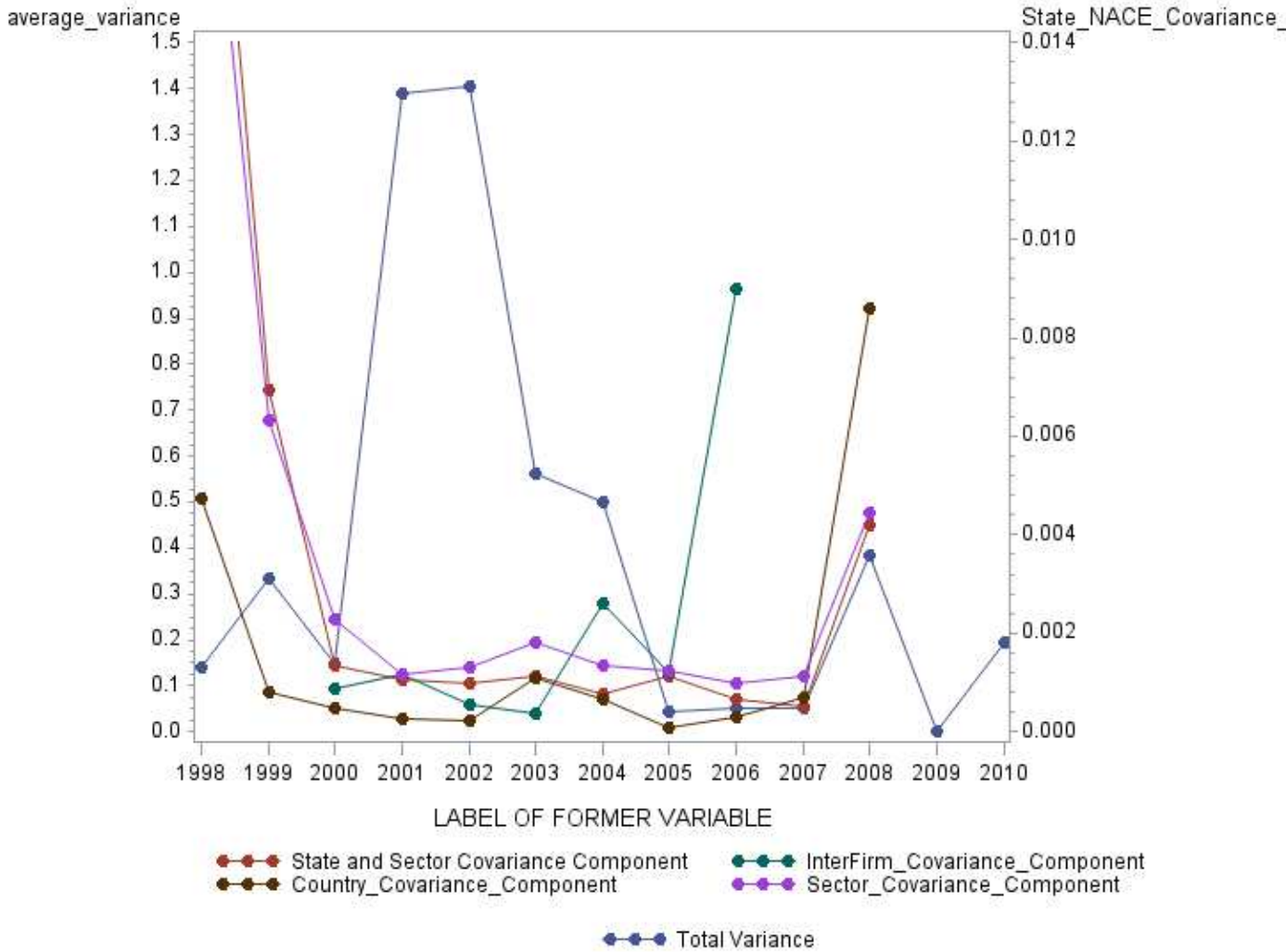
To understand the mechanics of convergence in my sample, I've decomposed the variance of the aggregate growth rate of turnover in the Amadeus Database into a variance and covariance component. Firstly I verified that my sample displayed similar characteristics at the aggregate level to those of GDP for the European Union. Contrary to aggregate total sales, my sample exhibits a recovery of sorts in 2008. This is due to the fact that although aggregate total sales was still steeped in recession there was a moderate recovery as part of the European Union's double dip recession that evidently mostly affected firms the size of our sample. Another reason is the fact that our sample's size varies. Both of these facts together mean that there is a certain level of noise to the growth rate of the AMADEUS database's aggregate sales. This influence may tend to induce an upward bias in the trend of volatility of the growth rate of total sales in my sample precisely at those periods with more observations. This problem is particularly evident in the year 2001 of my sample where a sharp increase in the number of observations induces a notably sharp rise in the volatility of growth. Another way to observe this problem would be to look at lower levels of aggregation, for example two-digit NACE sector levels. To conduct variance decomposition, the following notation is introduced. Let γ_{x_t} be the growth rate of aggregate real sales deflated by the aggregate PPI for the EU17, $\gamma_{x_{it}}$ be the growth rate of real sales for firm i , and s_{it} be the share of sales for firm i in the total sales of its country from the AMADEUS sample, all in year t . Let $\varphi_{x_{mt}}$ be the growth rate of real sales for each sector m deflated by sector-specific deflators. Let $\theta_{x_{kt}}$ be the growth rate of rate of real sales for each country k deflated by the aggregate PPI for the EU17. Also, let $V([Z_t]_{t-1}^{t+1})$ denote the variance of $\{Z_{t-1}, Z_t, Z_{t+1}\}$ for any generic variable Z , and $Cov([Y_t]_{t-1}^{t+1}, [Y_t]_{t-1}^{t+1})$ be the covariance between $\{Z_{t-1}, Z_t, Z_{t+1}\}$ and $\{Y_{t-1}, Y_t, Y_{t+1}\}$.

Note that $\gamma_{x_t} = \sum_i \gamma_{x_{it}} s_{it}$. Then, using the definition of variance, and assuming that $s_{it} = s_i$ for all the firms i and all the years t , the variance of aggregate growth in year-on-year, $V([Z_t]_{t-1}^{t+1})$, can be decomposed into two terms: the first is related to the firm-level variance of turnover (simply the variance) and the second reflects the covariances between the growth rates of sales at different firms (covariance component):

$$\begin{aligned}
V([\Delta_{\tau}]_t^{t+1}) &= \frac{1}{3} \sum_{\tau=t-1}^{t+1} \left(\sum_k \sum_m \sum_i (\Delta_{x_{it}} \omega_m^{Sector} \omega_k^{Country} \omega_i^{Firm}) - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \sum_k \sum_m \sum_i (\Delta_{x_{it}} \omega_i^{Firm} \omega_m^{Sector} \omega_k^{Country}) \right)^2 \\
&= \sum_i \omega_m^2 \omega_k^2 \omega_i^2 V([\gamma_{x_{it}}]_{t-1}^{t+1}, [\varphi_{x_{mi}}]_{t-1}^{t+1}, [\theta_{x_{kt}}]_{t-1}^{t+1}) \\
+ \sum_m \sum_{n \neq m} \sum_k \sum_{l \neq k} \sum_i \sum_{j \neq i} &\omega_m^{Sector} \omega_n^{Sector} \omega_k^{Country} \omega_l^{Country} \omega_i^{Firm} \omega_j^{Firm} Cov([\gamma_{x_{it}}]_{t-1}^{t+1}, [\gamma_{x_{jt}}]_{t-1}^{t+1}, [\varphi_{x_{mi}}]_{t-1}^{t+1}, [\varphi_{x_{nr}}]_{t-1}^{t+1}, [\theta_{x_{kt}}]_{t-1}^{t+1}, [\theta_{x_{lr}}]_{t-1}^{t+1})
\end{aligned}$$

The first part of that equation is the variance component and the second part represents the covariance component. Figure 7 shows the evolution of each of these terms and compares them to total variance.

Variance by Component
Firm-level Productivity Variance: Decomposed



7.1 Conclusions

The European economy is experiencing a convergence of aggregate- and firm-level volatility of small and medium businesses. This study demonstrates interesting differences between the 1999 crisis, driven by the internet-bubble and the 2007 crisis driven by the financial sector's (partial) collapse. Whereas during the internet bubble in year 1999 we can see that variance is driven by the sectoral covariance component versus the country covariance component, in the wake of the financial crisis, we see that the aggregate variance of the Eurozone was driven by the country covariance component. What's more the 2006 financial crisis was preceded by an increase in inter-firm covariance, forewarning of the

momentous corrections to come. This fundamental difference between these two events has hopefully informed government policy in its wake.

In fact consensus macro-economic policy would explain this quite well. Whereas the first's response focussed on easing the process of correction, the second should and did (in the beginning) focus on fundamental arbitrage between the private and public sector spending and compensate the reduced private spending. Thus from this perspective, the current focus on austerity doesn't seem as judicious as it's trumpeted.

Davis and Kahn's study's conclusions are in line with the findings in this article. If firms' revenue is further into the future due to increasing investment in durable inventory (Davis & Kahn, 2008), it makes sense that they are more sensitive to expectations about the future proxied by interest rates and income.

Whereas Comin and Mulani find that McConnell and Perez-Quiroz's conclusions do not fit with their findings, from this study, their explanation of the decrease in volatility of firm and aggregate levels are consistent with this study's findings. They argue that new inventory management methods such as just-in-time inventory management (which leads to a decline in stocks and losses due to stock levels) are the source of a decline of volatility at the firm-level.

Research of macro-determinants of volatility argue that part of the decline in aggregate volatility is due to more effective monetary policy that helps stabilise shocks to the economy at the aggregate level. Although an increase in the efficacy of monetary policy may account for only 30% of the observed reduction in aggregate volatility, we can see that these mechanisms have had an effect at the firm level when decomposed. Indeed looking at the 2008 and 2009 windows in our study we find that when momentous monetary easing tactics have been implemented in the beginning of the crisis in Europe, they did lead to a decrease in the average variance and an increase in the variance is observed once a more stringent focus on austerity measures was implemented. This explanation is therefore relevant to this study.

Comin and Mulani's argue that it's a focus on embodied versus disembodied innovations that may explain their observed symmetric trends in volatility at the firm- and aggregate-levels. That's because firms have less incentive to invest in fundamental research than product research, and that means that their marketed widgets will demonstrate the commonly observed volatile market reactions: new products are more volatile than disruptive innovations. This argument is inconsistent firstly because not all disruptive technology gains a foothold (not all great ideas make it to and in the market) and secondly because we would expect product-focussed spinoffs and product-associated firms to demonstrate the increased volatility they observed. Presumably these types of companies would fall in the AMADEUS sample, and our study displays the opposite trend.

Aghion et.al. argue that credit constraints proxied by financial development (Aghion, Angeletos, Abhijit Banerjee, & Manova, 2010) play a central role in firm-level and aggregate level volatility. The complementary theory of Easterly et.al. would add that it's a given country's institutional endowment that induces this effect (Easterly, Islam, & Stiglitz, 2000). Although these authors would recognise that the effect is less pronounced in developed countries like those found in the Amadeus sample, I find that countries with very different levels of financial development like Ireland and Greece have broadly similar volatility levels over the time period analysed.

Conversely, it may in fact be the case that what we're observing in my antagonistic conclusions is the divergent character of two very different industrial organisations. Whereas industrial policy or business regulation in America is geared towards promoting entrepreneurship and the growth of companies, in Europe there are severe impediments to the growth of medium size firms into large ones. These impediments include social charges on salaries, restrictive employment contracts, and the loss of tax breaks once the Small and Medium size Enterprise threshold is crossed.

8 Works Cited

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9 ANNEX 1 : Variance Decomposition

This annex is dedicated to the decomposition of aggregate variance into the variance of sectorial growth, the variance of growth between counties, and inter-firm covariance. The growthrate of the aggregate variable of interest (Δ_t) is related to interfirm, sectoral and country growths as follows ($\gamma_{x_{it}}, \varphi_{x_{mt}}, \theta_{x_{kt}}$) by :

$$\Delta_t = \sum_k \sum_m \sum_s \omega_m^{Sector} \omega_k^{Country} \omega_i^{Firm} (\gamma_{x_{it}}, \varphi_{x_{mt}}, \theta_{x_{kt}})$$

Where $\omega_m^{Sector}, \omega_k^{Country}$ are the relevant weights. Aggregate variance of Δ_t between $\tau = t - 1$ and $t + 1$ can be expressed as:

$$V([\Delta_\tau]_t^{t+1}) = \frac{1}{3} \sum_{\tau=t-1}^{t+1} \left(\sum_k \sum_m \sum_i (\Delta_{x_{it}} \omega_m^{Sector} \omega_k^{Country} \omega_i^{Firm}) - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \sum_k \sum_m \sum_i (\Delta_{x_{it}} \omega_i^{Firm} \omega_m^{Sector} \omega_k^{Country}) \right)^2$$

Imposing the restriction that sectoral and country weights are constant during the interval $[t - 1, t + 1]$

$$V([\Delta_\tau]_t^{t+1}) = \frac{1}{3} \sum_{\tau=t-1}^{t+1} \left(\sum_m \sum_k \omega_m^{Sector} \omega_k^{Country} \left(\Delta_{m,k,\tau} - \sum_{\tau=t-1}^{t+1} \Delta_{m,k,i,\tau} \right) \right)^2$$

Expanding and manipulating we obtain the variance-co-variance decomposition:

$$V([\Delta_\tau]_t^{t+1}) = \frac{1}{3} \sum_{\tau=t-1}^{t+1} \left(\sum_i \sum_j \sum_m \sum_n \sum_k \sum_l \omega_m^{Sector} \omega_n^{Sector} \omega_k^{Country} \omega_l^{Country} \omega_i^{Firm} \omega_j^{Firm} \left(\varphi_{m,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \varphi_{m,\tau} \right) \left(\varphi_{n,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \varphi_{n,\tau} \right) \right. \\ \left. - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \varphi_{n,t} \right) \left(\theta_{k,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \theta_{k,\tau} \right) \left(\theta_{l,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \theta_{l,\tau} \right) \left(\gamma_{i,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \gamma_{i,\tau} \right) \left(\gamma_{j,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \gamma_{j,\tau} \right)$$

$$V([\Delta_\tau]_t^{t+1}) = \frac{1}{3} \sum_i \sum_j \sum_m \sum_n \sum_k \sum_l \omega_m^{Sector} \omega_n^{Sector} \omega_k^{Country} \omega_l^{Country} \omega_i^{Firm} \omega_j^{Firm} \left(\frac{1}{3} \sum_{\tau=t-1}^{t+1} \left(\left(\varphi_{m,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \varphi_{m,\tau} \right) \left(\varphi_{n,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \varphi_{n,\tau} \right) \right. \right. \\ \left. \left. - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \varphi_{n,t} \right) \left(\theta_{k,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \theta_{k,\tau} \right) \left(\theta_{l,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \theta_{l,\tau} \right) \left(\gamma_{i,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \gamma_{i,\tau} \right) \left(\gamma_{j,\tau} - \frac{1}{3} \sum_{\tau=t-1}^{t+1} \gamma_{j,\tau} \right) \right)$$

$$V([\Delta_\tau]_t^{t+1})$$

$$= \sum_i \omega_m^2 \omega_k^2 \omega_i^2 V([\gamma_{x_{it}}]_{t-1}^{t+1}, [\varphi_{x_{mt}}]_{t-1}^{t+1}, [\theta_{x_{kt}}]_{t-1}^{t+1})$$

$$+ \sum_m \sum_{n \neq m} \sum_k \sum_{l \neq k} \sum_i \sum_{j \neq i} \omega_m^{Sector} \omega_n^{Sector} \omega_k^{Country} \omega_l^{Country} \omega_i^{Firm} \omega_j^{Firm} Cov([\gamma_{x_{it}}]_{t-1}^{t+1}, [\gamma_{x_{jt}}]_{t-1}^{t+1}, [\varphi_{x_{mt}}]_{t-1}^{t+1}, [\varphi_{x_{nt}}]_{t-1}^{t+1}, [\theta_{x_{kt}}]_{t-1}^{t+1}, [\theta_{x_{lt}}]_{t-1}^{t+1})$$

10 ANNEX 2 : Breakdown of Representativeness by Country

year	Austria				France			
	Number of Observations	total sum of firm turnover ⁱ	Aggregate Turnover ⁱⁱ	Percentage	Number of Observations	total sum of firm turnover ⁱ	Aggregate Turnover ⁱⁱ	Percentage
1997					1	17	1254700	<0.001
1998					7	456	1312730	<0.001
1999					3404	177650	1367005	<0.01
2000					31976	1650070	1439603	<0.01
2001					32689	1705342	1495554	<0.01
2002					33974	11578891	1542928	0.7
2003	4	1677	224993	<0.001	34496	11689960	1587903	0.7
2004	23	627432	234708	<0.1	35355	90405639	1655572	0.7
2005	31	864046	245243	<0.5	35904	93126649	1718048	0.6
2006	31	896543	259035	<0.5	36064	96784394	1798116	0.5
2007	30	4061163	274020	<0.5	34767	1.69E+08	1886792	7
2008	17	2933310	282744	1	30916	1.59E+08	1933195	6
2009	2	327	276151	<0.001	3498	1192398	1885763	<0.01

year	Italy				Netherlands			
	<u>Number of Observations</u>	<u>total sum of firm turnover _i</u>	<u>Aggregate Turnover _{ii}</u>	<u>Percentage</u>	<u>Number of Observations</u>	<u>total sum of firm turnover _i</u>	<u>Aggregate Turnover _{ii}</u>	<u>Percentage</u>
1997	11	2	1058144	<0.001	41	7562	341139	<0.001
1998	28	5	1093914	<0.001	133	24549	359859	<0.01
1999	91	249	1133998	<0.001	442	83107	386193	<0.1
2000	106	22	1198292	<0.001	480	92910	417960	<0.1
2001	104	19	1255738	<0.001	527	101970	447731	<0.1
2002	156	66445	1301873	<0.001	608	253144	465214	<0.1
2003	158	62836	1341850	<0.001	648	277750	476945	<0.1
2004	219	1230033	1397728	<0.01	694	27458320	491184	5
2005	225	1261141	1436380	<0.01	716	27833312	513407	5
2006	221	1317821	1493031	<0.01	707	28849126	540216	5
2007	218	1740712	1554199	<0.01	655	1.09E+08	571773	20
2008	206	1688620	1575144	<0.01	482	79793763	594481	16
2009					6	2719	573235	<0.001

year	Germany				Greece			
	<u>Number of Observations</u>	<u>total sum of firm turnover</u> <i>i</i>	<u>Aggregate Turnover</u> <i>ii</i>	<u>Precentage</u>	<u>Number of Observations</u>	<u>total sum of firm turnover</u> <i>i</i>	<u>Aggregate Turnover</u> <i>ii</i>	<u>Precentage</u>
1997			1904279		119	149	119937	<0.001
1998	8	2408	1946465	<0.001	218	247	121985	<0.001
1999	72	15951	2000200	<0.001	2539	2985	131936	<0.001
2000	161	29949	2047500	<0.001	2947	3350	137930	<0.001
2001	370	73777	2101900	<0.001	3196	3502	146428	<0.001
2002	652	259904	2132200	<0.001	3412	1257597	156614	0.6
2003	1093	420191	2147500	<0.001	3679	1368418	172432	0.6
2004	1666	28772853	2195700	1.1	3866	19645823	185266	12
2005	4072	41761453	2224400	2.3	4037	20923706	193048	12
2006	4020	42398600	2313900	2.3	4049	22929963	208622	15
2007	3731	99032012	2428500	3	3993	42038283	223160	20
2008	3224	77877936	2473800	1.2	3788	41993091	233198	17
2009	29	12702	2374500	<0.001	186	69451	231081	<0.001

	Sweden			
year	Number of Observations	total sum of firm turnover ⁱ	Aggregate Turnover ⁱⁱ	Percentage
1997	237	7925	223437	<0.001
1998	696	19245	227124	<0.01
1999	10365	355570	242796	<0.1
2000	16513	595044	268253	<0.1
2001	17307	559802	253743	<0.1
2002	18064	590033	266740	<0.1
2003	18834	617150	278914	<0.1
2004	19640	6086709	291634	3
2005	20466	6363229	298353	3.2
2006	20678	7035023	318171	1
2007	20413	12938581	337944	3
2008	20129	11424974	333256	3
2009	7081	187469	292472	<0.1

ⁱ In thousands

ⁱⁱ In millions