ECONOMIC RESEARCH REPORTS

Diverging Trends in Macro and Micro Volatility: Facts

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RR#: 2003-08 **September 2003**

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September 6, 2003

Abstract

In this paper, we document the diverging trends in volatility of the growth rate of sales at the aggregate and firm level. We establish that the upward trend in micro volatility is not simply driven by a compositional bias in the sample studied. We argue that this new fact renders obsolete the proposed explanations for the decline in aggregate volatility and that, given the symmetry of the diverging trends at the micro and macro level, a common explanation is highly likely. We conclude by describing one such theory driven by market integration.

Keywords: Aggregate Volatility, Firm-Level Volatility, COMPUSTAT, Market Integration.

JEL Classification: E3, F1, D2.

1 Introduction

Interest in the volatility of macroeconomic variables has increased substantially in recent years. McConnell and Perez-Quiros [2000] show that since the mid 1980's the volatility of aggregate sales has declined significantly. Blanchard and Simon [2002] establish a downward trend in volatility of GDP starting in the 50's with the exception of the 70's. In addition, Stock and Watson [2002] analyze the time series of 124 macro variables since 1960 and show that the decline in aggregate volatility, beginning in 1984, is pervasive.

This paper intends to increase our understanding of the evolution of volatility by investigating the volatility of sales at the firm-level. Specifically, we want to compare the evolution of the volatility of the growth rates of firm-level and aggregate sales. To conduct this analysis, we use firm-level data from the COMPUSTAT database and aggregate sales data from the Bureau of Economic Analysis (BEA). Our main finding is that while the growth rate of aggregate sales has become more stable over time, at the firm level, the volatility of the growth rate of sales has increased. Hence, the volatility of aggregate and firm-level sales has followed diverging trends.[1]

An important concern when using the COMPUSTAT database to establish firm-level facts is the possibility of a bias due to the change in the composition of the sample that does not correspond to changes in the composition of the US economy. To establish that our results are not driven by a compositional bias, in section 4 we show that the pattern holds for all the quintiles in the distribution of sales, that it also holds once we remove the predictable effect of age and size on the firm-level volatility and, finally, that the increase in micro-volatility is also robust to controlling for fixed firm-specific attributes.

In section 5, we use our empirical findings to evaluate the explanations proposed to understand the decline in aggregate volatility. These can be divided in two groups. The first group attempts to explain the decline in macro volatility through mechanisms that lead to a decline in volatility at

[1] There exists some prior evidence of increasing uncertainty in the firm's economic environment. Comin [2000] finds that the volatility of individual stock returns has increased (almost) monotonically since the 1950's. Campbell et al. [2001] find the same upward trend in firm specific risk i.e. the component of returns that is orthogonal to the average return in the 4-digit sector. However, aggregate stock returns have also become more volatile. The volatility of monthly aggregate stock returns in the US markets (measured by the standard deviation of a ten year rolling window of returns) remained low between the end of WW II and 1968. It then increased, reaching a high plateau, between 1968 and 1983. It declined over the next decade until 1993, after which it restarted its increase reaching the high volatility levels of the 70's.

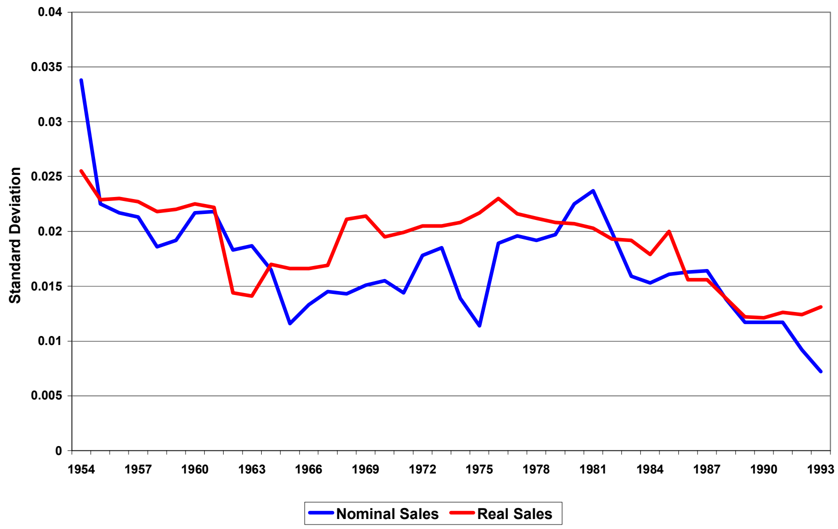

Figure 1: Volatility of growth rate of aggregate sales.

the firm level and then, trivially, aggregate up the micro trends. The second group of explanations tries to explain directly the decline in macro volatility. Both of these approaches are unsatisfactory in the light of the facts presented in this paper. The first is at odds with the increase in micro volatility. The second, though not completely inconsistent, is clearly insufficient to account per se for the upward trend in firm-specific uncertainty. To fill this gap, in section 5 we propose a simple explanation that simultaneously accounts for the opposite trends observed in micro and macro volatility.

2 Aggregate volatility

Consider the time series for a random variable X_t. We study the evolution of the volatility of X_t by computing the series of standard deviations of a 10-year rolling windows of X_t. Formally, we compute the time series for the volatility of X_t as:

$$\sigma\left(X_t\right) = \sqrt{\frac{\sum_{i=t-4}^{t+5}\left(X_i - \bar{X}_t\right)^2}{10}},$$

where $\bar{X}_t$ is the average of X_t between $t-4$ and $t+5$. Figure 1 plots this measure of volatility for both the growth rate of nominal and real aggregate final sales from the BEA.

We find three observations from this figure remarkable. First, the growth rate of aggregate sales shows a significant decline in volatility beginning in the 1980's. Second, as emphasized by Blanchard and Simon [2002] for GDP, the time series volatility of aggregate sales is best characterized by a secular decline that started in the 1950's and was interrupted from the mid 60's through the 70's. Finally, given the similar downward trends in both nominal and real sales, inflation adjustment does not seem to be a significant issue.

In the next section, we examine the evolution of volatility at the micro level using annual firm-level net nominal sales data from COMPUSTAT.[2] Before doing so, we want to verify whether this sample we use exhibits the downward trend in the volatility of the growth rate of the total sales. To this end, we aggregate up the net sales of individual firms in our sample, calculate growth rates, and construct the time series measures of volatility mentioned above. Note, however, that there is one potential problem with this exercise. The growth rate of the total sales in the COMPUSTAT sample varies as the comprehensiveness of the sample varies. Fluctuations in the comprehensiveness of the sample accentuated by the addition of firms incorporated in the NASDAQ will add noise to the growth rate of aggregate sales in the post 1970 period. Hence, this force may tend to induce an upward bias in the trend of the volatility of the growth rate of total sales in COMPUSTAT.[3] However, in spite of this upward bias, figure 2 shows that the sample aggregate volatility tracks relatively closely the corresponding measure for the economy.

3 Firm-level volatility

We now turn our attention to the computation of volatility at the firm level. As mentioned above, we start by extracting data on net nominal sales at the firm level, dropping the firms for which we do not have 11 consecutive observations. These represent a mere 3 percent of the total sample. We then compute, for every firm, a series of standard deviations for the growth rates of the firm's sales using 10 year rolling windows. These standard deviations are then averaged across firms to arrive at the standard deviation for every year. Volatility at the firm level clearly exhibits a significant upward trend as illustrated by figure 3. When examined along with the data at the aggregate level,

[2]This variable is defined as gross sales (the amount of actual billings to customers for regular sales completed during the year) reduced by cash discounts, trade discounts, and returned sales and allowances for which credit is given to customers.

[3]A similar bias can be attributed to the upward trend in the share of intermediate goods in the economy.

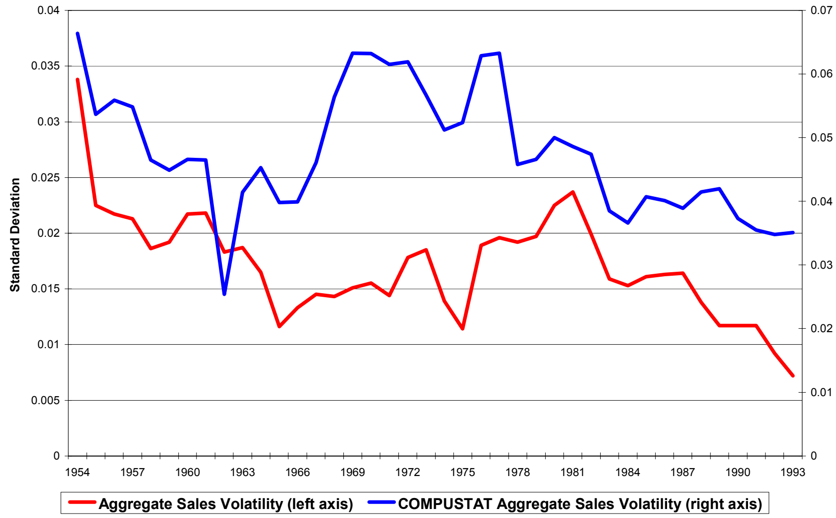

Figure 2: Aggregate volatility of growth rate of sales in the economy and in the COMPUSTAT sample

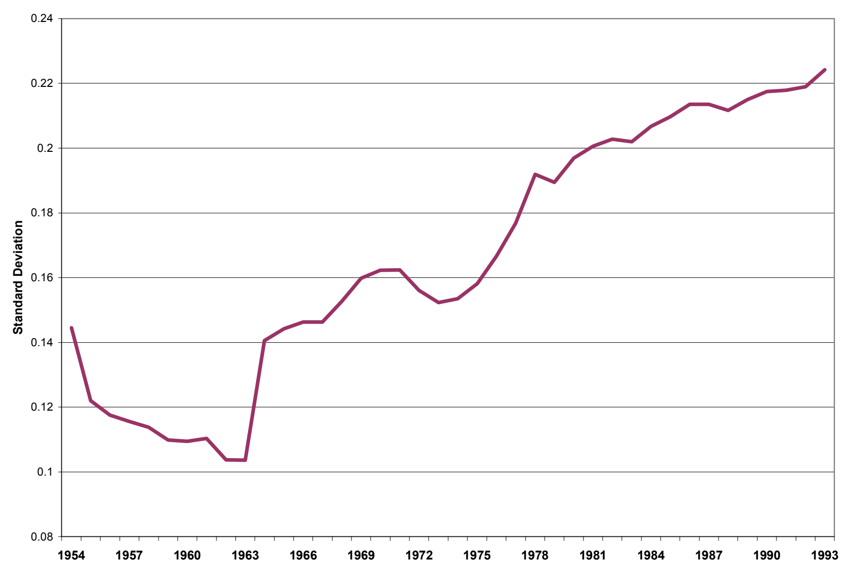

Figure 3: Firm-level volatility in the growth rate of sales.

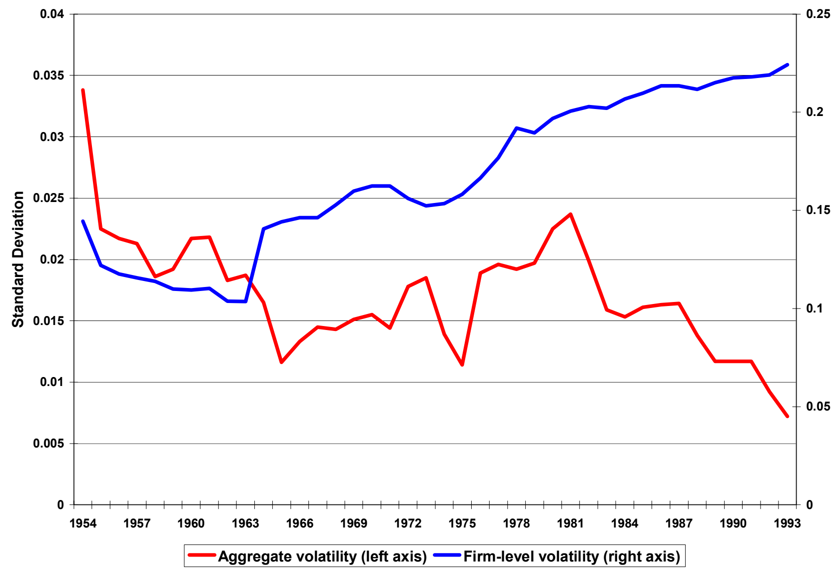

Figure 4: Diverging trends in aggregate and firm-level volatility of the growth rate of sales.

the diverging trends are evident (figure 4).

In order to build a more representative measure of volatility, we weight the volatility of firms by their size. Naturally, we use the share of the firm's sales in the total sales in sample during the year as weight. Figure 5 shows that the upward trend in volatility persists after introducing these weights.

Another way of measuring the volatility inherent in the firm's environment is by focusing on the cross-section.[4] This involves computing standard deviations of growth rates across all the firms in a given year. Figure 6 reflects the steady increase in volatility at the firm level when measured by this cross-sectional statistic.

The source of this increase in volatility, however, is subject to question. While the upward trend may, as we claim, accurately reflect changes in the economy, the increase in volatility may be a feature specific only to the sample in use. Our claims necessitate discrediting the latter possibility.

The data set used was extracted from the COMPUSTAT database for years 1950 through to

[4]This is the measure used by Campbell et al. [2001]. We believe that the time series measure of volatility used in this paper is more appealing than the cross sectional measure since the time series is less likely to be affected by compositional biases. When computing the standard deviation of the window in the time series, we remove the average growth rate for the firm in the window, hence controlling for firm specific aspects. These aspects, however, potentially show up in the cross sectional measure and may be the medium through which a compositional bias operates.

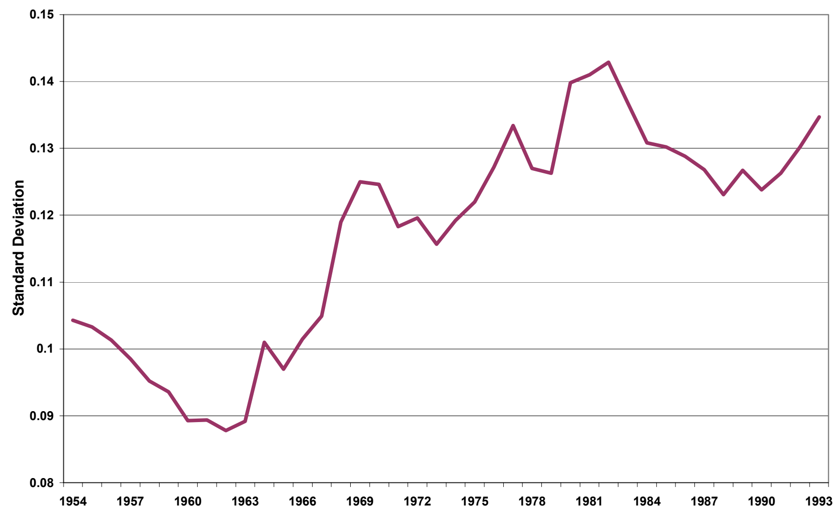

Figure 5: Firm-level weighted volatility.

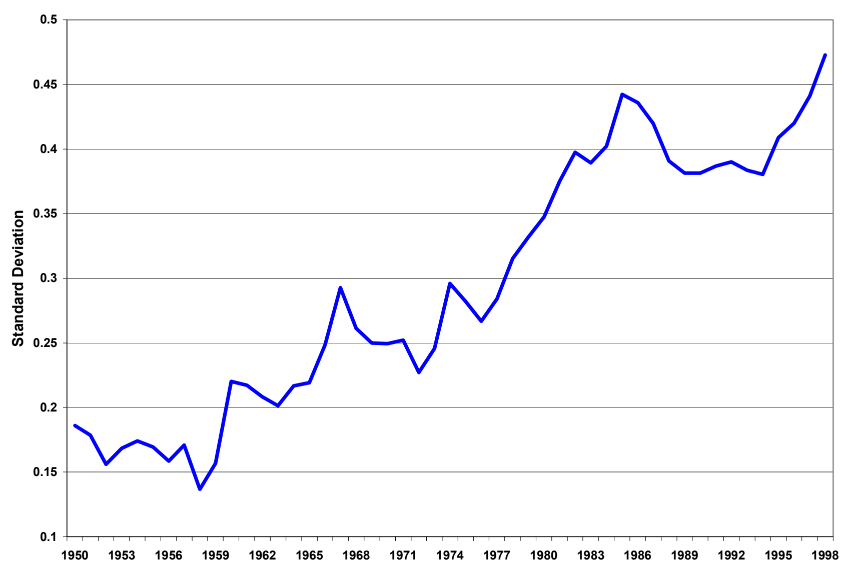

Figure 6: Evolution of the volatility of the growth rate of sales in a cross section of firms.

2000. The size of the sample increases drastically in the 70's raising some concerns regarding the possibility that the upward trend in the firm-level volatility is the consequence of compositional bias. This compositional bias crops up since the firms that are incorporated in the data set in the post 70's period are potentially more volatile than the firms in the pre 70's period either because the sector in which they operate is more volatile, or on account of firm specific attributes such as being younger or smaller. The following section checks the robustness of the claimed upward trend in firm level volatility by controlling for compositional changes.[5]

4 Controlling for changes in the sample composition

In order to show that the upward trend in micro volatility is not due to a compositional bias in the sample studied, we conduct three exercises. First, we divide up the sample at any point in time in to five quintiles according to the level of sales and examine whether the increase in volatility is driven by any specific quintile or if it holds across the distribution.

In figure 7, we observe that the increase in firm-level volatility is not confined to any one section of the distribution but is rather pervasive across the sample as one would expect if the firm's environment has become more uncertain. This finding, though, does not necessarily negate the compositional bias argument. In theory, given the higher probability of sampling smaller (and/or younger) firms in the post-1970 period, all the quintiles may be composed to a larger extent of smaller, more volatile firms.

To further control for changes in composition, we focus our analysis on the component of volatility that is not explained by some firm-level characteristics that are changing in the sample. Specifically, we run a pooled regression of the firm-level standard deviations on a vector of the firms characteristics (X_{it}) as in equation (1).

$$\sigma_{it} = \alpha_0 + \alpha_1 \; X_{it} + \epsilon_{it}^{\sigma} \tag{1}$$

We then aggregate up the unpredictable component of volatility (ϵ_{it}^{σ}) resulting in a time series for the firm-level volatility. As in the previous section, we consider both weighted and unweighted measures of residual volatility, where the weights are given by the firm's share in total sales in the year. First, we use the logarithm of age as a regressor, controlling for the fact that over time, the

[5] An alternative approach is to track down the evolution of the volatility of the firms initially in sample but this would generate survivorship bias.

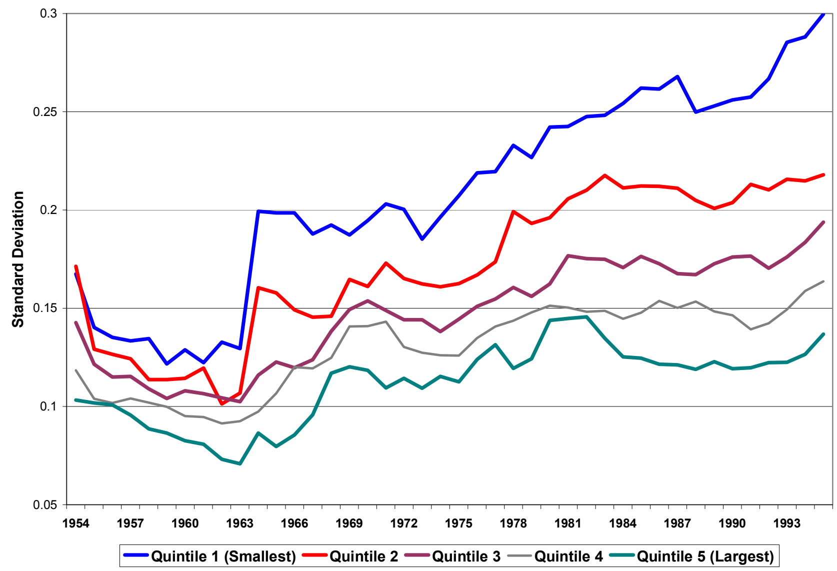

Figure 7: Weighted firm-level volatility by size quintiles.

share of younger (more volatile) firms in the sample has increased faster than in the US economy. In figure 8, we can see that removing the volatility that can be attributed to changes in age does not diminish the upward trend.

In addition to age, size is an important determinant of firm-level volatility. To control for the effect of changes in the size distribution in the sample, we consider two additional variables in X_t. In figure 9, we report the series of the residual volatility after having included in X_t the logarithm of the firm share of sales in GDP in addition to the log of age. In figure 10, we report the evolution of residual volatility when we control for the log of the share of firm sales in the nominal value added of the sector apart from the log of age. In both figures we observe a prominent upward trend in volatility, though in the weighted measures there is a flattening of the trend in the 80's and 90's.

The evidence presented thus far refutes the hypothesis that the observed upward trend in firm specific uncertainty is simply the result of the inclusion of a larger share of smaller or younger (more volatile) firms in the sample since 1970. However, it may still be argued that factors other than size or age induce higher volatility in the new population of firms sampled leading to a compositional bias. To rule out this possibility, we use firm dummies to eliminate the effect of firm specific variables (both observable and unobservable) on volatility. After removing this firm specific component of volatility, we are left with the component that is orthogonal to any fixed firm characteristic and,

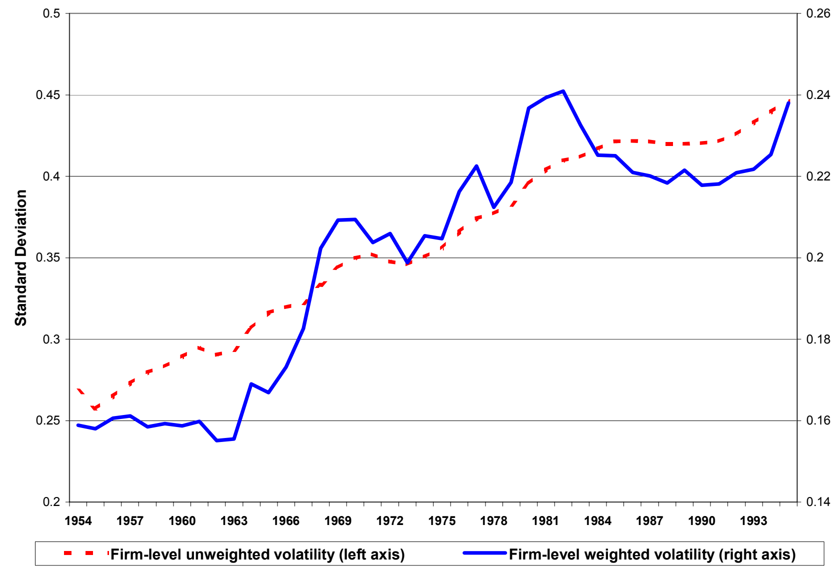

Figure 8: Residual volatility from the regression $\sigma_{it} = \alpha_0 + \alpha_1 \ln(age_{it}) + \epsilon^{\sigma}_{it}$.

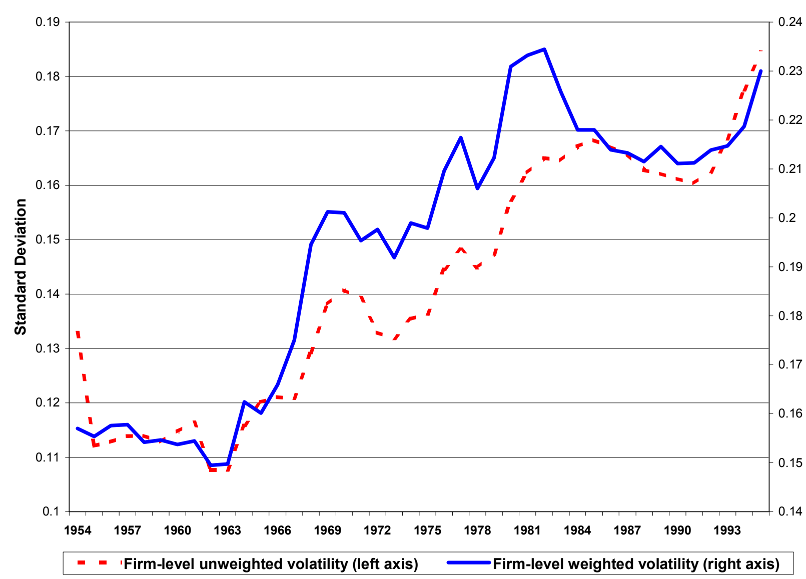

Figure 9: Residual volatility from the regression $\sigma_{it} = \alpha_0 + \alpha_1 \ln(age_{it}) + \alpha_2 \ln\left(\frac{sales_{it}}{GDP_t}\right) + \epsilon^{\sigma}_{it}$.

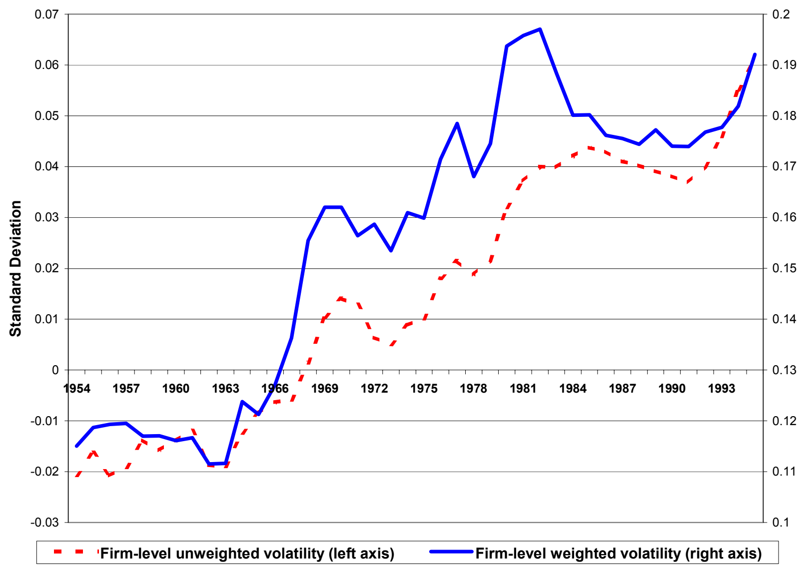

Figure 10: Residual volatility from the regression $\sigma_{it} = \alpha_0 + \alpha_1 \ln (age_{it}) + \alpha_2 \ln \left(\frac{sales_{it}}{Value\ Added_{st}} \right) + \epsilon^{\sigma}_{it}$.

therefore, immune to any compositional bias in the sample.[6]

Note that, this exercise constitutes a stringent test of the upward trend in micro volatility hypothesis. To illustrate this point, suppose that the trend is due to the fact that new firms *in the economy* are just more volatile. By removing the firm specific component of all the firms in sample, we would be eliminating the component that is more volatile for new firms and therefore denying a true fact. Nevertheless, throwing a firm fixed effect in the regression is an informative exercise because if the upward trend still holds we can claim that it is not due to a compositional bias in the sample studied.

Formally, we run the following regression where α_i is a set of firm specific dummies and the set of controls included in X_{it} contains the log of age and the log of the share of sales in GDP.

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

Figure 11 plots the average residual volatility series (ϵ^{σ}_{t}).

It is clear from this picture that even after removing the firm specific component in volatility, the upward trend persists.

[6] One such bias is the associated with the change in the industry composition of the sample.

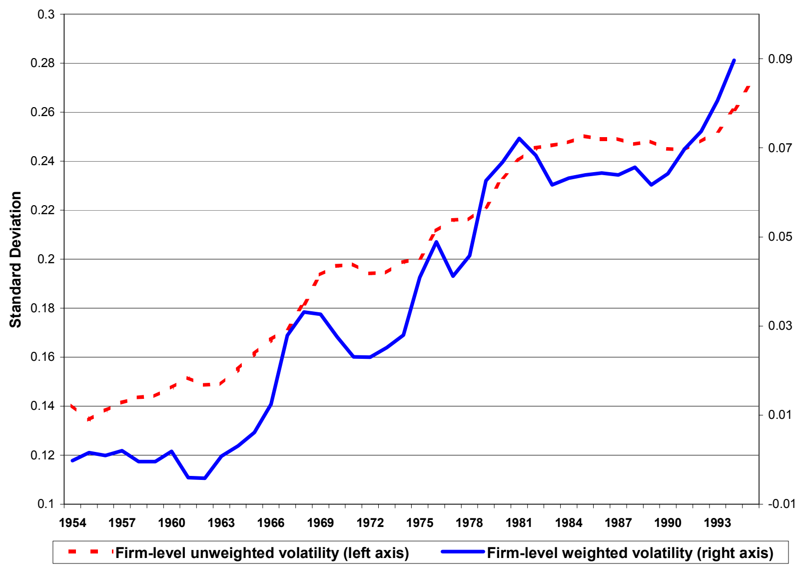

Figure 11: Residual volatility from the regression $\sigma_{it} = \alpha_i + \beta_1 \ln(age_{it}) + \beta_2 \ln\left(\frac{sales_{it}}{GDP_t}\right) + \epsilon^{\sigma}_{it}$.

5 Conclusions

The US economy has experienced two opposite trends in several variables. At the aggregate level, these variables have become less volatile, with an interruption of this trend during the 70's and early 80's. At the micro level, however, the trend has been upwards, indicating that firm level volatility has increased. Examining these two patterns together (figure 3), the symmetric nature of the diverging trends is evident and makes a common explanation (or set of explanations) highly likely. As we shall see next, the upward trend in micro volatility, has interesting implications while evaluating the proposed explanations for the decline in aggregate volatility.

McConnell and Perez-Quiros [2000] proposed that new inventory management methods, such as just-in-time inventory management, are the source of the reduction in volatility in GDP. This mechanism operates at the firm level and, therefore implies that the volatility of net sales at the firm level should decline as well.[7] This contradicts the evidence presented in this paper.

Another line of research argues that part of the decline in aggregate volatility is due either to a reduction in the volatility of the shocks that hit the US economy or to an increase in the effectiveness

[7]That would not be true if there was an independent (and large) surge in firm-level volatility that cancel out at the aggregate level. The question then is why firm-level volatility increased so much and why this happened approximately at the time aggregate volatility declined.

of monetary policy to stabilize these shocks (Boivin and Gianonni [2002], Clarida, Gali and Gertler [2000], Congley and Sargent [2001], Gali, Lopez-Salido and Valles [2002], Primiceri [2002] and Sims and Zha [2002]). Though interesting and possibly true, this approach cannot constitute the primary mechanism to explain the decline in aggregate volatility since, in principle, there is no reason to think that a decline in the aggregate volatility of shocks (or of their effect on the economy) is going to increase the uncertainty faced by individual firms. This consequence is, at the very least, not obvious.

This argument is consistent with Stock and Watson [2002]'s conclusion about the fraction of the decline that different candidate explanations can account for. They claim that after considering the reduction in the volatility of shocks and the increase in the effectiveness of monetary policy, at least half of the decline in aggregate volatility remains unexplained.

Since we are skeptical of theories attempting to explain any one of the two symmetric trends in isolation, we are going to devote the last paragraphs of the paper to sketch a new explanation for the decline in aggregate volatility, one that simultaneously explains the increase in firm level volatility.[8]

The simplest way to understand our theory is in the context of the Dornbush, Fisher, Samuelson [1977] Ricardian trade model with trade costs (i.e. transport costs) and country specific productivity shocks. The force that drives the two divergent trends in volatility is a decline in the trade costs that represents the process of market integration between the US and the rest of the world. When this happens, the fraction of goods exported to the rest of the world increases. As a result, the demand faced by U.S. firms depends now more on the productivity shocks in the rest of the world. Similarly, U.S. consumers spend a larger fraction of their income in foreign goods. This implies that the demand faced by U.S. firms depends less on domestic wages and hence on domestic productivity shocks. As a result of these two mechanisms, market integration leads U.S. output to depend in a more even manner on the productivity shocks in the U.S. and in rest of the world. Consequently, the relevant productivity shock is smoothed out, and the decline in trade costs generates a reduction in the volatility of U.S. GDP.

At the firm level, a decline in the trade costs increases the probabilities of the extreme outcomes. Specifically, in highly integrated markets, a larger fraction of U.S. firms can capture the markets in the rest of the world. However, a larger fraction is also susceptible to being driven out of the

[8]Comin and Mulani [2003] develops the model that underlies this explanation and calibrates its quantitative importance.

market by international competitors. This leads to a higher volatility of demand at the firm level and therefore to an increase in the volatility of sales. In this way, a unique shock such as a decline in the trade costs simultaneously accounts for the decline in aggregate volatility and the increase in firm level volatility.

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