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Abstract

The aggregate output volatility of US economy has declined significantly since the early 1980s, while publicly-traded firms' sales and employment have become more volatile during the same period. The latter fact contradicts many explanations of the "Great Moderation" that imply a direct transfer between macro and firm-level volatilities. In this paper, I argue that firms' organization capital investment is a key factor causing the macro and micro level volatility divergence. Firm-specific intangible capital accumulation is an important source of idiosyncratic risks, but it also makes a firm less susceptible to general market risks. When organization capital becomes increasingly important in the production process, the impact of firm-specific risk factor rises, while that of general risk factor declines. The former raises firm-level volatility; the latter reduces aggregate volatility, mainly through weakening the positive co-movements among firms. In this sense, the decline in macro volatility during the past two decades is rather a story of the "Great Dissolution".

My empirical analysis found that, consistent with the paper's hypotheses, firm-level volatility increases with organizational investment, but general factors' impact on firm performance and a firm's correlation with others decrease with organizational investment. Simulations of the general equilibrium model featuring organization capital investment are capable of replicating the volatility trends at both aggregate and firm level for the past two decades.

Keywords: Organization Capital; Intangible Capital; Great Moderation; Business Cycle; Firm Volatility; Investment.

1 Introduction

The aggregate volatility of economic activities in major developed economies has drastically declined over the past two decades. The phenomenon, dubbed as the "Great Moderation", is well-documented (McConnell & Perez-Quiros (2000), Blanchard & Simon (2001), Stock & Watson (2002)), and has drawn considerable attention from macroeconomists and policy makers. Previous studies offer various explanations to the decline in aggregate fluctuation. The most straightforward answer is probably the "good luck" theory; i.e., smaller volatility is caused by smaller exogenous shocks (Stock & Watson, 2002). Other common suspects include improved monetary policy (Clarida et al., 2000), financial innovation and globalization, (Dynan et al., 2006), and better supply-chain management and inventory control (Kahn et al., 2002).

However, recent empirical studies indicate, contrary to the aggregate trend, sales and employment at the firm level has become more volatile. Comin & Mulani (2006), Comin & Philippon (2005) showed that the volatilities of sales and employment growth for publicly-traded US firms have been increasing in the past 50 years, and the pattern is fairly robust when sample composition change and other exogenous factors are taken into account.[1] Similar upward trend hold for turnover rate of industry leaders and firms' credit default risk. Related studies in finance literature (Pastor & Veronesi (2002), Wei & Zhang (2006), Campbell et al (2001)) have demonstrated strong upward trend in firm stock returns. Outside of US, Thesmar & Thoenig (2004) reported rising sales volatility for French firms. Buch, Dopke & Stahn (2008) showed increasing idiosyncratic firm volatility in Germany.

Figure 1 displayed both aggregate and firm level sales volatilities over the past 5 decades, represented by the rolling standard deviation of growth rate in 9-year windows.[2] In most business cycle models with only aggregate uncertainties, there is basically no differentiation between macro and micro level volatility. Why this is not what we see in real data is an interesting

[1] Davis et al. (2006) showed that rising firm volatility is only present in publicly-traded firms, and hypothesized that it might be due to more risky young firms going public in recent years. But Comin (2008) demonstrated that the upward trend in firm volatility is robust after controlling for age and cohort effects. Thus the phenomenon is not a simple matter of sample selection.

[2] The formula to calculate the rolling standard deviation of variable i's growth rate is: $\sigma_{i,t} = \sqrt{\sum_{\tau=t-4}^{t+4} (g_{i,t} - \overline{g_t})^2}$, where $\overline{g_t}$ is the average growth rate between t-4 and t+4. Firm-level volatility at time t is the average standard deviation across all firms: $1/n \sum_{i=1}^{n} \sigma_{i,t}$.

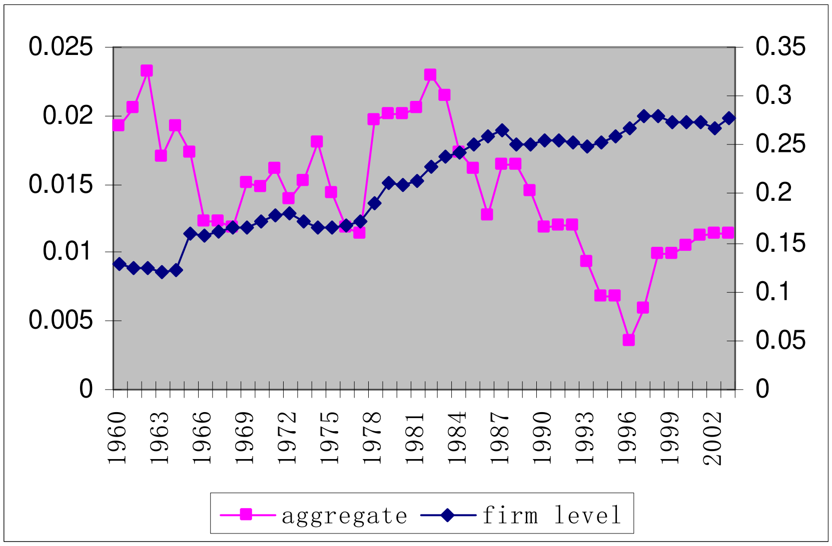
question. As an extreme example, consider the case when all firms in the economy are identical. Then macro and firm-level volatilities would be exactly the same. Even when this unrealistic assumption is abandoned, the reason why the two volatilities are heading opposite directions is still not obvious. To study this volatility divergence is the major focus of the paper. The phenomenon poses challenges to many existing explanations of declining aggregate volatility which assume, directly or implicitly, that the economic environment has become more "tranquil" since the great moderation.

Besides its intellectual appeal, the volatility divergence question is also an important one. From a welfare evaluation point of view, it is relevant to ask what the macro volatility decline actually means to individual agents. Does it imply decreased economic uncertainty for households and firms, as people often intuitively assume, or something else?[3] A study of the question can shed lights on such issues as the evolution of risk factors affecting individual firms, how different firms respond differently to macro-level shocks, and the relevance and limitation of aggregate data in representing business cycle dynamics. All these questions are of central concern to industrial/macro economists and policy makers. Moreover, any trend shifts in business cycle patterns are most likely related to certain fundamental changes in the economic system. Hence, an investigation into the origin of volatility divergence can also serve to deepen our understanding about ongoing structural transformations in the economy.

Though there can be various important causes at work behind the volatility divergence, this paper captures one specific cause—the rise of organization capital (OC) in the business sector. The main hypothesis is the following. As a production factor, organization capital, or firm-specific intangible capital, has become increasingly important over the past decades. Investment in OC involves subjective decision making, trial-and-errors, and unexpected successes and failures for a firm. In other words, it induces firm-specific risks that do not equally affect other firms. But at the same time, accumulation of organization capital protect the firm from general, market-wide risks. As a result of increasing investment in organization capital, firm-level volatility rises, while aggregate volatility declines, mainly due to lowered positive co-movement among firms. In this sense, the observed volatility decrease at the aggregate level should rather be called the "Great Dissolution".

[3]There is another intruguing phenomenon intimately related to the one investigated here: several studies, using household-level data, show that consumption and income volatilities of individual households have actually gone up in the Great Moderation period. See, for example, Dynan et al. (2006), Davis & kahn (2008).

Figure 1: Diverging macro and firm level sales volatilities



The paper is organized in the following way. Section 2 decomposes the aggregate and firm level volatilities, explains in detail the hypotheses that link the rise of OC and the trends of output volatilities, and reviews related literature. Section 3 specifies the empirical strategies to test the hypotheses and presents the results. Section 4 establishes the stochastic general equilibrium model involving OC investment. Section 5 simulates the model and compares the model characteristics with empirical data. Section 6 discusses the sensitivity of simulations. Section 7 adds adjustment cost to the basic model to improve the model's performance in imitating aggregate investment properties. Section 8 concludes.

2 Volatility Trends and the Role of Organization Capital

2.1 Decomposing Volatilities

To see how macro and micro level fluctuations can be trending differently from each other, it's helpful to break volatilities down into different components. Suppose there are n firms in the economy. Write firm i's growth rate $g_{i,t}$as a linear function of two kinds of shocks: macroeconomic shock m_t and firm-specific shock $f_{i,t}$, with σ_m^2 and σ_f^2being respective variance of shocks:

$$g_{i,t} = s_{i,t}^m m_t + s_{i,t}^f f_{i,t}; \quad i = 1, 2, ...n.$$

Therefore, the variance of firm i's growth rate is

$$\left(s_{i,t}^m\right)^2 \sigma_m^2 + \left(s_{i,t}^f\right)^2 \sigma_f^2,$$

and the average firm volatility takes the following form:

$$\begin{aligned} &Weighted\ Average \\ &\quad Firm\ Volatility \quad = \textstyle\sum_{i=1}^n w_i \left(s_{i,t}^m\right)^2 \sigma_m^2 + \sum_{i=1}^n w_i \left(s_{i,t}^f\right)^2 \sigma_f^2, \end{aligned} \tag{1}$$

where$\sum_{i=1}^n w_i = 1$.

The aggregate growth rate of the economy g_t is the weighted average of all firms: $g_t = \sum_{i=1}^n w_{i,t} g_{i,t}$. Thus the aggregate volatility can be written as

$$\begin{aligned} Aggregate\ Volatility \quad = \quad & \sum_{i=1}^n (w_i)^2 \left(s_{i,t}^m\right)^2 \sigma_m^2 + \sum_{i=1}^n (w_i)^2 \left(s_{i,t}^f\right)^2 \sigma_f^2 \\ & + \sum_{i=1}^n \sum_{j \neq i} w_i w_j s_{i,t}^m s_{j,t}^m \sigma_m^2. \end{aligned} \tag{2}$$

Throughout the paper, I assume that the structure of exogenous shocks do not change; i.e., σ_m^2 and σ_f^2 remain constant. It's easy to see that the only way to allow the values of (1) and (2) to shift in different directions is to change the relative importance of the two shocks, $s_{i,t}^m$ and $s_{i,t}^f$. More specifically, if the impact of macro shock $s_{i,t}^m$ decreases, while that of firm-specific, idiosyncratic shock $s_{i,t}^f$ increases, it is possible to have firm-level volatility rising and aggregate volatility declining at the same time, while the variances of shocks remain unchanged. In this scenario, the decline in aggregate volatility would be mainly due to a decrease in the covariance term, which is normally much bigger than the two variance terms, given a large number of firms. In other words, the aggregate volatility decreases as a result of reduced positive co-movements among firms.

Therefore, to understand the volatility divergence, it is crucial to find out what factor(s) are affecting the change in relative impact of different shocks. My main hypothesis is: increasing investment in organization capital, or firm-specific intangible capital, is the source of elevated impact of firm-specific risks, which leads to an increase firm-level volatility; at the same time, organization capital decreases the influence of general risk factor, which results in reduced correlation among firms and decreasing aggregate volatility.

2.1.1 Organization Capital in the Modern Economy

Prescott & Visscher (1980) defines organization capital as firm-specific information and knowledge. Jovanovic & Rousseau (2001) uses the phrase "whatever makes a group of people and assets more productive together than apart." Lev (2001) describes it as "the knowledge used to combine human skills and physical capital into systems for producing and delivering want-satisfying products". Though worded differently, there are a couple common elements in these definitions. First, organization capitals are firm-specific resources. Two, they are mostly intangible assets. Thus, I use organization capital and firm-specific intangible capital interchangeably in this paper. Examples of organization capital abound, such as a firm's brand equity, customer network, R&D resources, management expertise, business processes and other intangible production resources that live beyond one period.

Faced with ever increasing speed of technological change and intensified market competition, a modern firm can no longer rely on the physical assets it possesses for a unique competitive advantage. Indeed, a major difference between industrial-age production and the so-called knowledge economy is that the state-of-art intangible know-hows is no longer embodied in mega-size machines, but carried by workers and organizations. Firms have to distinguish themselves from the peers by developing optimal allocation of decision rights, organization-specific human capital, efficient incentive mechanism, capacity to cope with disruptive technological changes, and extensive customer/supplier network. These "soft" assets have become crucial differentiating factors for modern businesses.[4]

Furthermore, the advancement of IT technology drastically changed the cost of information processing and communication, which often requires complementary investment in organizational structure and management processes. Bresnahan, Brynjolfsson & Hitt (2002) found that greater level of IT investment is associated with increasing organizational redesign. They also found that on average, every $1 of corporate investment in IT is correlated with

[4] There is abundant literature in management and business economics on the importance of different intangible asset classes. See, for example, Karl Erik (1997), Blair (2001), Teece, Pisano & Shuen (1997).

\$10 increase in firm's market value, suggesting complementary organizational investment of about \$9, far exceeding the investment in technology itself. At the same time, thanks to the IT revolution and other technological innovations that boost efficiency in direct production processes, more working hours are allocated to building intangible capitals– creating new ideas, products, establishing new categories, managing different resources,etc., so as to "give the world something it didn't know it was missing".

Organization capital is highly firm-specific. The value of a brand, for example, may depend on patent rights to the underlining technology, and expenditures on advertising and other reputational investments. The value of these assets largely depends on the functioning of the organization behind them, thus making them very difficult to trade on an outside market. Changes in firm's organization capital are by no means riskless. It involves innovation, trial-and-error, and very likely, unexpected success and failure. Same amount of investment expenditure may bring about very different results. Studies have found different effects for various companies' advertising expenses in a same industry (Schmalensee, 1972). Empirical researches also suggest high failure rates of business process redesign (e.g., Sauer & Yetton, 1997), and IT related organizational change projects (Kemerer & Sosa, 1991), just like new investment in other technological innovations which involve a high level of uncertainty. Therefore, when the production process requires more organization capital, individual firms' volatilities are likely to rise.

At the same time, organization capital investment can change the risk profile that a firm is faced with. On one hand, the risk incurred in OC investment is largely firm-specific, or idiosyncratic, in nature. This is because, first, the high cost incurred in copying other firms organizational practice may prevent a quick spread of any new OC innovation across firms; second, even when firms can imitate a winner's practice, the complexity due to complementarity among different investments can make the outcome highly contingent (For example, Kmart may try to emulate Wal-mart; Compaq tries to learn from Dell; but these investments are not likely to achieve the same result as the originator's.). On the other hand, accumulation of organization capital can make a firm less susceptible to general market shocks. Traditionally, companies in the same industry competed with each other on price and quality, which makes firms' performances highly homogeneous, and largely dependent on general market conditions. But today, when reasonable quality and price have become only the entry tickets to the marketplace, unique and inimitable assets, resources, skills, and investments are becoming the primary sources of a firm's competitive advantage.[5] Firms of high OC thus tend to be less prone to market fluctuations, and the demand of their products less affected by common risk factors.

There is abundant evidence suggesting that the business sector's intangible capital investments have been on the rise over the past few decades. Companies' market value as a percentage of GDP has been increasing since the 1980s', while tangible assets relative to GDP declining during the same period. Many researchers argue that an important source for the increase in firms' market capitalization is accelerated accumulation of intangible assets (e.g., Hall, 2001). Nakumura (2001) inferred the amount of business intangible investment in US economy, using data on industrial expenditures, labor inputs and corporate operating margins. He concluded that by 2000, private firms invest at least \$1 trillion annually in intangible assets, and 1/3 of US corporate assets are in intangibles. Corrado, Hulten and Sichiel (2005, 2006) directly estimated and aggregated different components of business intangible capitals. They showed that business sector intangible capital accumulation has been growing fast in the past half century, especially since the 1980s. By the end of the 20th century, intangible capital investment had exceeded private firms' physical capital investment, amount to about 13% of business outputs. Atkeson & Kehoe (2005) emulated plant-life dynamics based on organization capital accumulation. They estimated that the payments to intangible capital owners are on average 110% of those to physical capital owners. Therefore, it is a reasonable conjecture that given the large amount of intangible investment in the business sector, if such investment has any impact on firms' risk characteristics, the impact should be considerable.

2.2 Other Related Literature

Just like any insightful theoretical concepts, the idea of organization capital or business intangible capital provide unique perspectives into different economic issues. In fact, the literature related to intangible capital is rapidly expanding. Prescott & Visscher modeled the information accumulation and transfer process within a firm (a type of organization capital investment), and used it to explain stylized characteristics of firm growth rates and size distributions. Hall (2001) argued that US firms' intangible asset accumulation helps explain the persistent high valuation of common stocks compared

[5] Researches in business strategies have emphasized the importance of various kinds of organization capital in shaping a firm's market competence. See, for example, Barney (1986), Lippman& Pumelt (1982), Montgomery & Wernerfelt (1988).

to companies' book values. Atkeson & Kehoe (2005) linked the amount of organization capital a plant accumulated with the size of plant-specific rents. They simulated plant distribution dynamics driven by organization capital accumulation, and showed that the result fit the real data well. Jovanovic & Rousseau (2001) hypothesized that the quality of organization capital differs across generations of firms, which explained the "cohort effects" in firms' stock market performance. Brynjolfsson, Hitt & Yang (2002) found that investment in organization capital complements investment in IT technology, and the combined investment has a significantly larger impact on firms' output and market valuation than isolated investments. McGrattan & Prescott (2007) introduced business intangible investment in a standard growth model and demonstrated that it helped explain US productivity and investment boom in the 1990s. Danthine & Jin (2007) modeled different stochastic processes in intangible capital accumulation and argued that it contributed to high volatility in equity returns.

Although the literature related to business intangible capital is fairly diverse, this paper, to my best knowledge, is the first to investigate the relationship between intangible capital accumulation and changes in the volatility characteristics of the economy. Some authors have approached the volatility divergence puzzle from other perspectives. Comin & Mulani (2006) constructed a quality-ladder model where aggregate and firm-level volatilities are driven by "general" and "applied" innovations respectively. They argued that when industry leaders' positions are less stable, resources will be shifted from general to applied technological progress, which increases firm volatility and suppresses aggregate fluctuation. An elegant model as it is, attributing decreases in macro volatility to less frequent general technology shocks is probably not the most convincing. Philippon (2003) contended that intensified market competition causes firm volatility to increase, but at the same time, it leads firms to adjust prices faster, which in turn reduces the impact of aggregate demand shocks. The explanation didn't accommodate the fact that co-movements among firms decrease during the Great Moderation, and it is in fact an important element contributing to the aggregate volatility decline (Comin & Philippon, 2005). Thesmar & Thoenig (2004) linked volatility divergence to financial market innovations. In their paper, financial development, while stabilizing at the macro level, increases firms' willingness to take on more risks by improving risk sharing among firms. Firm-level volatility can rise due to the latter factor. While the theory is intuitively appealing, a financial-market centered explanation is not very likely the most crucial mechanism behind the phenomenon. In sum, the current literature on volatility divergence leaves large room for better theories and further empirical investigations. This paper presented a theory from the perspective of structural change in the production process, and made initiatory attempts to empirically test the theory.

3 Empirical Tests

3.1 Hypotheses

The volatility decomposition in section 2 demonstrates the mechanism, from an accounting standpoint, that can generate volatility divergence at macro and firm level. To reiterate, when the impact of firm-specific shocks increases and that of general shocks decreases, firm-level volatility can rise while aggregate volatility is declining due to reduced positive co-movements among firms. I argued in the previous section that the accumulation of organization capital is a fundamental reason that causes the "power shift" in different risk factors.

The goal of the empirical exercises is essentially to examine how organizational investment relates to the impacts of different risk factors. I broke the task down to three hypotheses and designed regressions to test them separately.

- **Hypothesis1: firm volatility increases with the level of organizational investment.**

If the conjecture is true that investment in organization capital involves large firm-specific risk, we shall observe s_i^f increases with organizational investment. In other words, more volatile firms should be associated with higher OC investment intensities.

- **Hypothesis 2: the more a firm invests in organization capital, the less its performance is affected by general risk factor.**

Firms with high OC possess unique competitive advantage, and thus are less susceptible to fluctuations in general market conditions. If this is true, OC investment should help lower s_i^m. And we shall observe a negative correlation between market influence on a firm and its OC investment level.

- **Hypothesis 3: organization capital investment decreases the co-movement among firms.**

In decomposing aggregate volatility, I showed that the bulk of decline in aggregate fluctuation is caused by reduced covariance term. If organizational investment does make firms more heterogeneous and thus reduces aggregate volatility, we should observe that a firm's correlation with other firms decreases with more investment in organization capital. This test thus complements the second hypothesis.

3.2 Data Description

To test the above conjectures, we first need a measure of firm-level organizational investment. Estimating the amount of organization capital at firm level is by no means a straight forward task. Historically, intangible capital generated within an organization is not counted as assets on the balance sheet for various reasons. One of the reasons is that for any data to be reported in the financial statement, the information represented must be objective and reliable. But unlike physical assets, intangible asset reporting is more likely to be faced with such problems as uncertain investment returns, asymmetric information, lack of market price, and subjective probability calculation. Therefore, most organization capital investments are traditionally categorized as operating expenditures. The effect of expensing organizational investment is fairly obvious if we compare the cost composition of intangible-intensive companies in emerging industries with that of more traditional manufacturing companies. Table 1 compares the cost structures of three well-known companies.

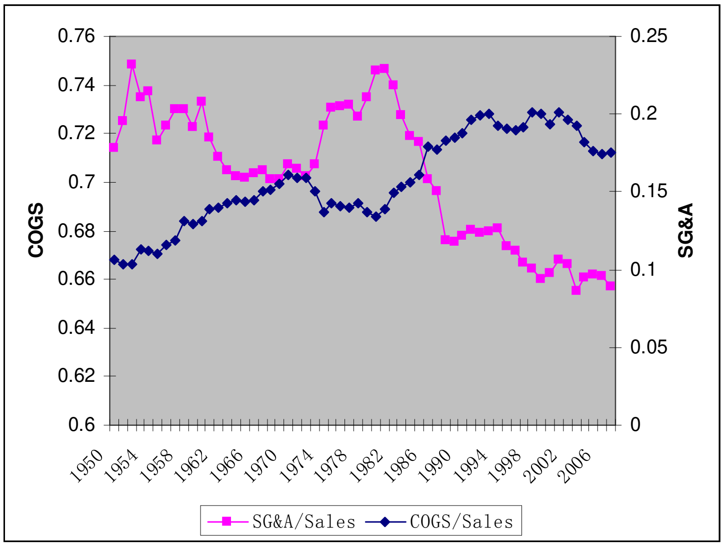
Table 1: Cost Structure of Three Companies

	Sales	COGS	As % of Sales	R & D	As % of Sales	SG&A	As % of Sales
Pfizer (2001)	32259	5034	15.6	4847	15.0	11299	35.0
Microsoft (2002)	28365	5191	18.3	4307	15.2	6957	24.5
Boeing (2001)	58198	48778	83.8	1936	3.3	2389	4.1

For intangible-intensive firms like Pfizer and Microsoft, the cost directly related to goods/services production (cost of goods sold) is relatively small, compared to sales, general & administrative cost (SG&A), which includes various intangible investment items, such as costs of marketing, advertising, research & development, and software, as well as management fees and incentive packages.

In the following regressions, I use SG&A expenditure as an approximation for firm-specific intangible investment. Similar treatment has appeared

Figure 2: COGS and SG&A as percentage of total sales



in various accounting studies (see, for example, Lev and Radhakrishnan, 2005), though the emphases of those researches are very different than this paper. Imperfect as it is, SG&A expenditure is arguably the best approximate for OC investment by far, considering data availability and accuracy.

Figure 2 calculated COGS and SG&A as % of sales for publicly-traded, nonfinancial US firms. It is clear that especially since the 1980s, the share of COGS in the total cost has gone down dramatically, while SG&A expenditure has been steadily increasing. The trend of SG&A is generally in line with other estimates of business intangible investments (e.g., Corrado et al., 2006).

The database I used is COMPUSTAT North America, which covers the financial statement and stock price information for publicly-traded firms since the 1950s. The firms included in the sample are US-based nonfinancial firms that have at least 10 years of continuous sales and expenditure records, which add up to 218,324 firm-year observations from 1950 to 2007. Table 3 lists summary statistics for the sample firms.

Table 2: Summary Statistics of Sample Firms

	Mean	**Std**
Sales ($mn)	996.28	6230.54
SG&A ($mn)	180.35	1060.61
COGS ($mn)	674.95	4616.63
Employees (thousands)	7.33	30.30
Gross Fixed Asset	686.62	5167.58
SG&A/Sales	1.04	27.01
COGS/Sales	0.77	14.41
Fixed Assets/Sales	1.68	73.54

3.3 Regression Strategies

To test hypothesis 1, I regressed a firm's sales volatility, captured by rolling standard deviation of sales growth, on "SG&A/Sales", the intensity of organization capital investment. To compare the impact of OC investment on volatility with that of other production inputs, I also included "fixed assets/sales" and "employment/sales" as explanatory variables, which capture physical capital and labor intensities of the firm. The estimation equation is as follows:

$$\begin{aligned}\ln\left(\sigma_{g_{i,t}}\right) &= \beta_0 + \beta_1 \ln\left(sga_{i,t}/sales_{i,t}\right) + \beta_2 \ln\left(fixed\ assets_{i,t}/sales_{i,t}\right) \\ &\quad + \beta_3 \ln\left(employees_{i,t}/sales_{i,t}\right) + e_{i,t}\end{aligned}$$

where $\sigma_{g_{i,t}} = \sqrt{\sum_{\tau=t-4}^{t+4}\left(g_{i,t} - 1/9\sum_{\tau=t-4}^{t+4} g_{i,\tau}\right)^2/9}$. If hypothesis 1 is true, we should expect the sign of β_1 to be positive.

The second hypothesis states that OC investment reduces the impact of market risks on a firm's performance. The test consists of two steps. First, I carried out rolling regressions of a firm's sales growth on industry and total sample sales growth in 9 year windows:

$$\ln\left(g_{i,\tau}\right) = \gamma_0 + \gamma_1 \ln\left(g_{industry,\tau}\right) + \gamma_2 \ln\left(g_{market,\tau}\right) + \varepsilon_{i,\tau}, \qquad t-4 < \tau < t+4.$$

The R^2 of the regression indicates how much a firm's sales performance can be explained by general risk factors, and thus provides a measure of market impact on a firm's production. Next, I regressed the R^2 of the first regression on firms' organization capital, physical capital and labor intensities:

$$\ln(R2_{i,t}) = \alpha_0 + \alpha_1 \ln(sga_{i,t}/sales_{i,t}) + \alpha_2 \ln(fixed\ assets_{i,t}/sales_{i,t}) + \alpha_3 \ln(employees_{i,t}/sales_{i,t}) + \upsilon_{i,t}$$

If hypothesis 2 holds, the coefficient for $\ln(sga_{i,t}/sales_{i,t})$ should be negative.

Thirdly, I tested whether the correlation between a firm's sales growth and the rest of the sample firms is negatively affected by its OC investment intensity. I ran the following regression:

$$\ln(\rho_{i,t}) = \mu_0 + \mu_1 \ln(sga_{i,t}/sales_{i,t}) + \mu_2 \ln(fixed\ assets_{i,t}/sales_{i,t}) + \mu_3 \ln(employees_{i,t}/sales_{i,t}) + \eta_{i,t}$$

Where $\rho_{i,t}$ is the correlation between firm i's sales growth and that of all other firms in the sample from t-4 to t+4. The necessary condition for hypothesis 3 to be true would be a negative coefficient for the variable $\ln(sga_{i,t}/sales_{i,t})$.

3.4 Results

Table 3 lists the results of regressing firms' rolling standard deviation of sales on the intensities of organization capital, physical capital and labor, for the years from 1955 to 2003. The time point of standard deviation is placed in the middle of the 9-year rolling window.[6] I carried out the estimation using different regression methods. Specifically, the regression are: (1) pooled OLS; (2) least-square regression controlling for industries;[7] (3) least-square regression controlling for years; (4) firm fixed effect panel regression; (5) between-effect panel regression.

Table 3: Impact of SG&A on Firm Volatility

[6] The result doesn't differ much if the time point is put at the beginning of the 9-year window.

[7] The sample firms cover 61 SIC two-digit industries.

	Std of firm growth ($\ln(std)$)				
	(1)	(2)	(3)	(4)	(5)
$\ln(sga_{i,t}/sales_{i,t})$	**0.15***** (0.002)	**0.18***** (0.003)	**0.11***** (0.003)	**0.08***** (0.005)	**0.28***** (0.009)
$\ln(fixed\ assets_{i,t}/sales_{i,t})$	0.05*** (0.002)	-0.02*** (0.003)	0.05*** (0.003)	-0.01** (0.004)	0.06*** (0.007)
$\ln(employees_{i,t}/sales_{i,t})$	-0.13*** (0.003)	-0.10*** (0.003)	-0.04*** (0.004)	-0.03*** (0.003)	-0.14*** (0.008)
observations	84698	84589	84698	84698	84698

The results show that the coefficients for SG&A investments are all positive and significant across different regressions, suggesting a positive correlation between organizational investment and firm volatility. In contrast, the signs of coefficients for the other two inputs are either inconsistent across different specifications (for physical capital) or negative (for labor). The result thus confirms Hypothesis 1.

Next, I regressed firm growth rate on market and industry growth rate, used the R^2 of the regression as a measure of general shocks' impact on firm performance, and then regress the R^2on firm's production inputs. Table 4 listed the results across different regression methods.

Table 4: Relationship between SG&A and general risk factor's impact

	R^2 of regressing firm growth on system growth $\ln(R^2)$				
	(1)	(2)	(3)	(4)	(5)
$\ln(sga/sales)$	**-0.13***** (0.004)	**-0.10***** (0.005)	**-0.08***** (0.005)	**-0.08***** (0.01)	**-0.07***** (0.01)
$\ln(fixed\ assets/sales)$	0.06*** (0.004)	0.03*** (0.004)	0.07*** (0.004)	-0.04** (0.008)	0.03*** (0.008)
$\ln(employees/sales)$	0.03*** (0.004)	0.05*** (0.004)	-0.07*** (0.005)	0.06*** (0.006)	0.01 (0.009)
observations	91980	91785	91980	91980	91980

The coefficients for SG&A investments are all negative and significant. In other words, the more a firm invests in organization capital, the less it is susceptible to general risk factor's influence, which confirms Hypothesis 2. The same characteristic is not present for the other two inputs.

Table 5 presented results for the third regression. Here the focus is how SG&A may affect a firm's co-movement with other firms. I first calculated the correlation between a firm's sales growth and that for the rest of the sample in 9 year rolling windows, then regressed this correlation on the firm's production inputs. As the result shows, the more a firm invests in organizational assets, the less a firm is correlated with the rest of the sample, which is in support of hypothesis 3.

Table 5: Impact of SG&A on Correlation with Other Firms

	Correlation between firm growth and market growth (ρ)				
	(1)	(2)	(3)	(4)	(5)
$\ln(sga/sales)$	**-0.06*** **	**-0.06*** **	**-0.04*** **	**-0.04*** **	**-0.05*** **
	(0.002)	(0.002)	(0.002)	(0.003)	(0.004)
$\ln(fixed\ assets/sales)$	0.03***	0.02***	0.04***	-0.02**	0.02***
	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)
$\ln(employees/sales)$	0.02***	0.03***	-0.04***	0.03***	0.009***
	(0.001)	(0.001)	(0.002)	(0.002)	(0.004)
observations	81369	81369	81369	81369	81369

In sum, the empirical tests generally support the hypothesis that organization capital investment increases the impact of firm-specific risks, and decreases that of global risks. As a result of increasing organizational investment, firm-level volatility rises while co-movements among firms decline.

However, the result doesn't mean that organizational investment has the same impact across different time periods. In fact, when I conducted the fixed effect regression by decades, the results show that the impact of organizational investment on firm volatility is only significant for more recent decades. Table 6 presents the result of regressing firm volatility on production input intensities by decade. The coefficients for SG&A are only positive and significant starting from the 1980s. So how to explain this result? First, as will be modeled in the next section, production structure in the modern economy is constantly evolving, and intangible capital was recognized as an important production input only recently. Before the 80s, its impact might not have been large enough to influence firms' risk characteristics on a large scale. Second, SG&A expenditure is an imperfect measure of firms' intangible investment, especially in the earlier years when the amount of such investment was relatively small. In those cases, SG&A might be too noisy an indicator for OC investment.

Interestingly, the lack of significance for organizational investment in early periods corresponds to the simulation result I will present later in the paper—the general equilibrium model featuring firm-specific intangible investment can imitate macro and firm level volatilities fairly well for the 1980s and beyond; but the model didn't do as well in generating realistic macro volatility for the earlier decades.

Table 6: Firm fixed effect regression by decade

	standard deviation of firm growth ($\ln(\sigma)$)		
time	$\ln(sga/sales)$	$\ln(fixed\ assets/sales)$	$\ln(employees/sales)$
1960-1969	0.0002	-0.0578***	0.0896***
1970-1979	-0.0057	-0.0083	0.0673***
1980-1989	0.0772***	-0.0166*	-0.0010
1990-1999	0.1083***	-0.0487***	-0.0335***
$\geqq$ 2000	0.0732***	-0.0832***	0.0537***

4 A General Equilibrium Model of Organization Capital Accumulation

4.1 Model

The economy contains a infinitely-living, representative household and n firms. The household offers labor and capital to firms and receives wage income and profits. She derives utility from consumption and leisure. The household's optimization problem is as follows:

$$\max_{\{C_t,[I^k_{i,t},I^o_{i,t}]^n_{i=1}\}^{\infty}_{t=0}} E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) + \theta \frac{(1-L_t)^{1-\mu}}{1-\mu}\right]$$
$$s.t. \quad C_t + \sum_{i=1}^{n} I^k_{i,t} + \sum_{i=1}^{n} I^o_{i,t} \leq w_t L_t + \sum_{i=1}^{n} \pi_{i,t}$$

where w_t is wage rate and $\pi_{i,t}$ firm i's profit at time t. Firms produce identical goods, using labor (L), physical capital (K) and organization capital (O) as inputs. The production function takes a Cobb-Douglas form:

$$Y_{i,t} = K^{\alpha_t}_{i,t} O^{\gamma_t}_{i,t} (A_t L_{i,t})^{1-\alpha_t-\gamma_t}$$

where A_t is a global productivity shock common to all firms. It evolves according to an AR(1) process:

$$\ln(A_{t+1}) = \rho_a \ln(A_t) + \varepsilon_{t+1}, \quad \varepsilon_{t+1} \tilde{}\, N(0, \sigma^2_{\varepsilon}).$$

The shares of different inputs in the production function are subject to change through time. The changes in the relative importance of inputs are purely exogenous, not anticipated by agents.

The accumulation of physical capital is governed by the standard process:

$$K_{i,t+1} = (1-\delta)K_{i,t} + I^k_{i,t}$$

where δ is the depreciation rate for physical capital, and $I^k_{i,t}$ the investment in K at time t.

An important feature of the model is the dynamic process of organization capital accumulation:

$$O_{i,t+1} = (1-\varphi)O_{i,t} + B_{i,t}I^o_{i,t}$$

Here φ and $I^o_{i,t}$ are depreciation rate and investment in organization capital respectively. And $B_{i,t}$ is a firm-specific productivity shock capturing the investment effectiveness in organization capital. In other words, firm i's OC stock at time t+1 depends on un-depreciated OC from time t, investment in OC made in period t and investment specific productivity shock that is known at the beginning of t. $B_{i,t}$ is given by the AR(1) process:

$$\ln(B_{i,t+1}) = \rho_b \ln(B_{i,t}) + \eta_{i,t+1}, \quad \eta_{i,t+1}\tilde{\ } N(0,\sigma^2_\eta), i.i.d. \;\; i = 1, 2, ...n.$$

The intuition is, again, that when a firm invests in organization capital, it is faced with its own path of success and failure, though at the same time, all firms are affected by general productivity shocks.

Given wage rate and its physical and organization capital stocks at time t, a firm makes its hiring decision to maximize the single period profit:

$$\max_{L_{i,t}} \pi_{i,t} = K^{\alpha_t}_{i,t} O^{\gamma_t}_{i,t} (A_t L_{i,t})^{1-\alpha_t-\gamma_t} - w_t L_{i,t} - I^k_{i,t} - I^o_{i,t}$$

Output $Y_{i,t}$ can be used for consumption or investments in both physical and organization capital, which leads to the following aggregate resource constraint:

$$C_t + \sum_{i=1}^{n} I^k_{i,t} + \sum_{i=1}^{n} I^o_{i,t} = \sum_{i=1}^{n} K^{\alpha_t}_{i,t} O^{\gamma_t}_{i,t} (A_t L_{i,t})^{1-\alpha_t-\gamma_t}$$

4.2 Equilibrium and Solution

An equilibrium of the economy is given by a time path of labor prices $\{w_t\}_{t=0}^{\infty}$, and decision rules $\{C_t, (L_{i,t})_{i=1}^{n}, \left(I_{i,t}^{k}\right)_{i=1}^{n}, \left(I_{i,t}^{o}\right)_{i=1}^{n}\}_{t=0}^{\infty}$, such that given the wages, the household's consumption and investment choices maximize her life time utility; firms' hiring decisions maximize their profits; labor and goods markets clear.

Since the market is essentially complete in the economy, the competitive equilibrium allocation is identical to the solution of the following social planner's problem:

$$\max_{\{C_t,[I_{i,t}^k,I_{i,t}^o]_{i=1}^n,[L_{i,t}]_{i=1}^n\}_{t=0}^{\infty}} E_0 \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) + \theta \frac{(1-L_t)^{1-\mu}}{1-\mu}\right]$$

$$s.t. \quad C_t + \sum_{i=1}^{n} I_{i,t}^k + \sum_{i=1}^{n} I_{i,t}^o = \sum_{i=1}^{n} K_{i,t}^{\alpha_t} O_{i,t}^{\gamma_t} (A_t L_{i,t})^{1-\alpha_t-\gamma_t}$$

$$\begin{aligned} K_{i,t+1} &= (1-\delta)K_{i,t} + I_{i,t}^k \\ O_{i,t+1} &= (1-\varphi)O_{i,t} + B_{i,t} I_{i,t}^o \\ \ln(A_{t+1}) &= \rho_a \ln(A_t) + \varepsilon_{t+1}, \quad \varepsilon_{t+1} \tilde{} N(0,\sigma_\varepsilon^2) \\ \ln(B_{i,t+1}) &= \rho_b \ln(B_{i,t}) + \eta_{i,t+1}, \quad \eta_{i,t+1} \tilde{} N(0,\sigma_\eta^2) \\ \sum_{i=1}^{n} L_{i,t} &= L_t \end{aligned}$$

To solve the model, I derived the first order conditions from the social planner's problem, log-linearized the first order conditions around the steady states, and numerically computed the policy functions.

The Lagrangian of social planner's problem is:

$$\begin{aligned} \mathcal{L} = & \max_{\{C_t,[K_{i,t+1},O_{i,t+1}]_{i=1}^n,[L_{i,t}]_{i=1}^n\}_{t=0}^{\infty}} E_0 \{\sum_{t=0}^{\infty} \beta^t [\ln(C_t) + \theta \frac{(1-L_t)^{1-\mu}}{1-\mu} \\ & +\lambda_t [\sum_{i=1}^{n} K_{i,t}^{\alpha_t} O_{i,t}^{\gamma_t} (A_t L_{i,t})^{1-\alpha_t-\gamma_t} + \sum_{i=1}^{n} (1-\delta) K_{i,t} + \sum_{i=1}^{n} (1-\varphi) O_{i,t} \\ & -C_t - \sum_{i=1}^{n} K_{i,t+1} - \sum_{i=1}^{n} \frac{O_{i,t+1}}{B_{i,t}}] + \varsigma_t (L_t - \sum_{i=1}^{n} L_{i,t})]\} \end{aligned}$$

The appendix explains in more details the procedure used to solve the model.

5 Calibration

5.1 Strategy

To see how well the model can replicate the volatility divergence in data, I calibrated the model economy, assuming that the relative importance of different inputs in the production process has undergone significant changes in the past 50 years.

Recall that the production function in the model takes the form $Y_{i,t} = K_{i,t}^{\alpha_t} O_{i,t}^{\gamma_t} (A_t L_{i,t})^{1-\alpha_t-\gamma_t}$. Structural shifts in the relative importance of production inputs can be represented by changing coefficients for K, O and L in the production function. Such changes in factors' shares result in different steady state variable values and ratios, which, with reasonable parameter choices, should approximate the data trend in US economy.

The steady state equations for the model economy are as follows:

$$\begin{aligned}
\theta(1-\sum_{j=1}^{n} L_j)^{-\mu} &= \frac{1}{C}(1-\alpha-\gamma)AK_i^{\alpha}O_i^{\gamma}L_i^{-\alpha-\gamma} \\
\frac{1}{\beta} &= \alpha AK_i^{\alpha-1}O_i^{\gamma}L_i^{1-\alpha-\gamma} + (1-\delta) \\
\frac{1}{\beta} &= \gamma AK_i^{\alpha}O_i^{\gamma-1}L_i^{1-\alpha-\gamma} + (1-\varphi); \quad i = 1, 2, ...n \\
& C + \delta\sum_{j=1}^{n} K_j + \varphi\sum_{j=1}^{n} O_j = \sum_{j=1}^{n} AK_j^{\alpha}O_j^{\gamma}L_j^{1-\alpha-\gamma}
\end{aligned}$$

where K_i, O_i, L_i, C are steady state values for $K_{i,t}, O_{i,t}, L_{i,t}, C_t$, and A=1. The 3n+1 equations determine the 3n+1 steady state variables $\{K_1, ...K_n, O_1, ...O_n, L_1, ...L_n, C\}$, with 8 exogenously given parameters $\{\beta, \delta, \varphi, \alpha, \gamma, \mu, \theta, n\}$.

I use the standard quarterly discount factor 0.99, which implies an annual discount rate β=0.96. The annual depreciation rate for physical capital is set at 0.048, as in Cooley & Prescott (1995). There is very few information available about the depreciation rate of organization capital. Here I assume an annual depreciation rate of 0.5, which is a mix of the depreciation rates for different classes of business intangibles appeared in the literature.[8] I set μ equal 4, and calculated the value of θ to keep the fraction of total hours worked equal to 0.31. For the autocorrelation coefficients of the two shocks, I assume they are both equal to 0.9. I adopt the standard assumption for the volatility of aggregate technology shocks—the standard deviation of global shocks is set at 0.007. No estimation is available for the standard deviation of idiosyncratic shocks that hit individual firms. In the baseline calibration, I assume it is equal to that of the general shocks.

For physical capital's share in the production function, I assume the usual value α=0.4. To obtain the share of organization capital, notice that from the steady state equations, we can write the relative share of the two capitals as

$$\frac{\alpha}{\gamma} = \frac{1/\beta - (1-\delta)\, K}{1/\beta - (1-\varphi)\, O}.$$

The ratio of the two capital stocks in the steady state is $\frac{K}{O} = \frac{\varphi}{\delta}\frac{I^k}{I^o}$. Substitute it into the above equation, and we obtain the share of organization capital in the production function:

$$\gamma = \frac{1/\beta - (1-\varphi)\, \delta}{1/\beta - (1-\delta)\, \varphi} \left(\frac{I^k}{I^o}\right) \alpha.$$

Corrado et al. (2006) provided time-series estimates for the amount of business intangible investments in the economy by decade. Using their estimation, combined with the total amount of private physical investment from BEA, we can get the decade-average organization capital/physical capital investment ratios (Table 7). I take the ratios as mid-decade steady-state I^o/I^ks, which can then be used to obtain a time series of γ. To make the jumps between steady states relatively smooth, I assumed that the shares in production function—therefore steady state variable values—change every half decade, and interpolated a series of steady state I^o/I^k ratios from the numbers given in Table 7. Parameter θ is adapted accordingly to preserve the steady state labor supply characteristics. Table 8 listed the steady-state I^o/I^k and the calibrated γs. Table 9 listed other major parameter values discussed above, which are kept fixed throughout the calibration.

Table 7: Business Sector Investments and Ratios

[8]For example, Corrado et al (2006) advocates the following depreciation schedules: 33% for computerized information, 20% for R&D, 60% for brand equity, 40% for firms' structural resources.

($bn, annual average)[9]

	1950-1959	1960-1969	1970-1979	1980-1989	1990-1999	2000-2003
Business Tangible Investment,I^k	19.4	41.9	103.4	349.3	749.8	1,226.20
Business Intangible Investment,I^o	35.6	67.3	171.4	421.1	676.5	893.4
Ratio:I^o/I^k	0.55	0.62	0.60	0.83	1.11	1.37

Table 8: Calibrated values of gamma

Time	I^o/I^k	γ	θ
1955-1959	0.545	0.126	0.518
1960-1964	0.584	0.135	0.514
1965-1969	0.623	0.145	0.510
1970-1974	0.613	0.142	0.511
1975-1979	0.603	0.140	0.512
1980-1984	0.716	0.166	0.502
1985-1989	0.829	0.192	0.490
1990-1994	0.969	0.225	0.474
1995-1999	1.108	0.257	0.457
2000-2004	1.24	0.288	0.439
$\geq$ 2005	1.373	0.318	0.419

Table 9: Baseline Parameter Values

β	δ	φ	μ	α	σ_ε	σ_η	ρ_a	ρ_b	n
0.96	0.048	0.5	4	0.4	0.007	0.007	0.9	0.9	50

5.2 Calibration Results

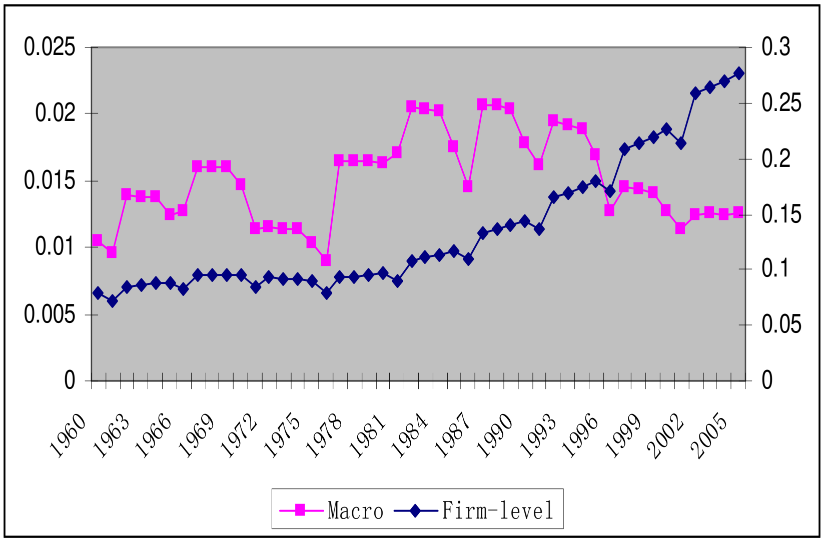
I simulated the model 100 times, each simulation being sixty years from 1950-2010. I then logarithmed and first differenced the simulated output series, and calculated 9-year rolling standard deviations for both aggregate and firm-level output growths. Table 10 presents the average rolling standard deviations by decade, using the baseline parameters listed above. For comparison, the corresponding values in empirical data are also listed. To give a more straightforward representation of the model's volatility trends, Figure 3 plots the simulated time series for both macro and micro level rolling standard deviations by year.

Table 10: Simulation result: average rolling standard deviation of outputs

[9]Source: Corrado et al. (2006) and BEA.

	Average aggregate volatility (%std)		Average firm-level volatility (%std)	
Time	Model	Data	Model	Data
1955-1959	1.2729	2.4550	7.1262	14.1237
1960-1969	1.3473	1.6802	8.6236	14.2859
1970-1979	1.2937	1.5563	9.0610	17.7532
1980-1989	1.8821	1.7858	11.5345	24.0382
1990-1999	1.6425	0.8828	17.8298	26.1928
2000-2003	1.2316	1.1129	25.1664	27.2878

Figure 3: Simulated aggregate and firm-level volatilities



How well does the model economy replicate the stylized facts in data? The first thing to notice in Figure 3 is that the model does produce a divergence in aggregate and firm-level volatility for the past two decades or so. At the macro level, the model generates decreasing aggregate volatility since the early 1980s, which period was recognized by many researchers as the beginning of significant decline in macroeconomic fluctuations. For the period from 1990 to 1999, the volatility decrease in the model economy is not as sharp as in data, but in general, the model imitates the drop in macro volatility reasonably well. At the firm level, the model is able to generate a trend of consistently increasing volatility, though the magnitude is smaller than in empirical data. The level of firm volatility that the model can produce has a lot to do with the choice of standard deviation for idiosyncratic shocks, which we basically have no reliable information on. I will discuss this relationship in the sensitivity analysis section later.

For the period before 1980s, the simulation did not do very well. The model produces much lower macro volatilities for the 50s and 60s than is seen in data. At the firm level, the simulated volatility is also lower than data, though the model does produce a mildly rising volatility trend for this period, which is consistent with the data.

To sum up, the model successfully captures the divergence in macro and firm-level volatility since the 1980s, in both qualitative and quantitative sense. But the model is not able to generate high macro volatility for earlier periods.

Turning to business cycle properties of other key variables, Table 10 reports the average standard deviation, correlation with output and 1st order auto-corelation coefficient for consumption, aggregate investments and hours worked. For consumption and hours, the results are broadly in line with stylized business cycle facts, except that the autocorrelation coefficients for both variables are higher than in real data. The part that deviates most from reality is the volatility of investment. The model produces large swings for investments in both K and O. Especially, the volatility of I^k is much higher than in the data. In addition, I^k and I^o are negatively correlated with output, which is obviously counterfactual. There are two reasons why the model doesn't generate realistic investment volatility at the aggregate level. First, in the calibration, I changed γ multiple times and also the corresponding steady states. The "jumps" between steady states are mostly accomplished by relatively abrupt changes in investments. In periods of transition between steady states, the output level would temporarily decrease because of unexpected change in the production function, while at the same time, investment is going up because of higher intangible capitals' share. This feature of the model largely contributes to the negative correlations between output and investments, and the large swings in investment. In fact, when I carried out the same simulation, but without any increase in γ, the correlation between Y and I^k increases to 0.41 and that between Y and I^o to 0.82, while standard deviations of investments decrease significantly. Second, unlike the standard business cycle model where there are only aggregate productivity shocks, the model generates n+1 i.i.d. shocks every period, n of which are investment specific shocks to individual firms. This induces larger volatility at the firm level, and increases aggregate investment volatility as well. Both volatilities decrease with the choice of n. For example, when I ran the simulation with n=2, the standard deviations of I^k and I^o decreased to 12.5 and 13.46 respectively, while correlations between Y and investments increased remarkably; but at the same time, the divergence between firm-level and aggregate output volatilities disappeared. In section 7, I will present an alternative version of the model with additional restrictions on investments, which makes aggregate investment less volatile, yet at the cost of reduced firm-level volatilities.

Table 11: Business cycle properties of the simulated economy

Variables	%std (std across simulations)	Correlation with output	1st order autocorrelation
Output	1.72 (0.086)	1.00	0.95
Consumption	1.36 (0.023)	0.52	0.86
I^k	321.54 (59.603)	-0.25	0.59
I^o	15.58 (0.547)	-0.45	0.95
Hours	1.40 (0.078)	0.90	0.96

6 Sensitivity Analysis

In the baseline calibration, the share of organization capital in the production function is inferred from parameter values and empirical estimations of I^k/I^o investment ratios. Therefore, the values of γ, steady states and policy functions are highly dependent upon assumptions about relevant parameters. In this section, I adopted alternative assumptions for physical capital's share α, organization capital's depreciation rate φ, standard deviation of idiosyncratic shocks σ_η,and simulated the model for the respective scenarios.

Table 12: Sensitivity analysis—alternative values of α

	Aggregate Volatility			Firm-level Volatility		
	$\alpha = 0.2$	$\alpha = 0.3$	$\alpha = 0.45$	$\alpha = 0.2$	$\alpha = 0.3$	$\alpha = 0.45$
1955-1959	1.2492	1.3462	0.6622	5.3576	4.3895	9.2729
1960-1969	1.5482	1.0771	0.7171	6.0324	4.9731	10.8682
1970-1979	1.7968	1.2575	1.1698	6.5189	5.2664	11.8300
1980-1989	3.4898	2.4938	1.7972	8.4908	6.7111	15.3040
1990-1999	3.3714	2.4516	1.7557	11.8223	9.5216	25.5043
2000-2003	2.6557	1.7738	1.7319	14.7713	11.9644	36.7032

Table 12 reports the average rolling standard deviations by decade at both macro and firm level for alternative choices of α (the steady states and time series of γ are adjusted accordingly). The starting value 0.2 is from Atkeson & Kehoe (2005)'s estimation of physical capital's share in the output of US manufacturing sector. The result shows that no matter what the choice of α is, the model generates decreasing macro volatility since the 1980s and consistently rising firm-level volatility.

Table 13: Sensitivity analysis—alternative values of φ

	Aggregate Volatility			Firm-level Volatility		
	$\varphi = 0.25$	$\varphi = 0.45$	$\varphi = 0.65$	$\varphi = 0.25$	$\varphi = 0.45$	$\varphi = 0.65$
1955-1959	1.0615	1.1741	1.1167	8.6189	7.3765	6.8377
1960-1969	0.6945	1.2292	1.0010	10.5576	8.7617	7.8534
1970-1979	1.2277	1.3117	1.1490	11.3991	9.3464	8.3238
1980-1989	1.3810	1.7435	2.3050	14.6057	12.0093	10.9464
1990-1999	1.4611	1.5259	1.7846	22.6387	18.2716	16.6941
2000-2003	2.6658	1.2015	1.1644	31.5412	25.9397	22.1945

Table 13 presents the volatility statistics across different assumptions for the depreciation rate of organization capital. At the firm level, regardless of O's depreciation rate, firm volatilities all increase through time. But at the macro level, the result is fairly sensitive to the choice of φ. Higher depreciation rates generate a more salient pattern of volatility decline in the past two decades, while a small φ (0.25) fails to produce any decrease in macro volatility.

Table 14: Sensitivity analysis—alternative values of σ_η

	Aggregate Volatility			Firm-level Volatility		
	$\sigma_\eta = 0.006$	$\sigma_\eta = 0.008$	$\sigma_\eta = 0.009$	$\sigma_\eta = 0.006$	$\sigma_\eta = 0.008$	$\sigma_\eta = 0.009$
1955-1959	1.2535	1.2241	1.0903	6.2247	8.0162	9.0585
1960-1969	1.3798	1.4909	1.2911	7.5398	9.8231	11.2579
1970-1979	1.2399	1.4224	1.5003	7.9424	10.4785	11.9206
1980-1989	2.0367	1.8185	1.8987	10.0408	13.2423	14.6813
1990-1999	1.8128	1.5576	1.2919	15.9221	19.5503	22.6511
2000-2003	1.5543	1.2940	1.9666	21.1994	28.0999	31.8900

Finally, Table 14 lists the volatility results with changes in the standard deviation of idiosyncratic shocks. Quite intuitively, a smaller σ_η produces less volatile firms— firm-level standard deviations increase with σ_η. But at the macro level, the effect of change in σ_η is less obvious, especially for earlier years, when γ is small and the aggregate impact of organization-specific shocks very limited.

Overall, the sensitivity analyses indicate that the volatility divergence generated by changes in organization capital's share in the production function is fairly robust to alternative parameter choices. A fall in macro volatility since the 1980s and continuously rising firm volatility are present across most of the alternative scenarios. But quantitatively, how well the model actually matches data is sensitive to some parameter choices.

7 Model with Capital Adjustment Cost

As shown in section 5, a shortcoming of the model is that the business cycle properties of aggregate investments are not very realistic. In this section, I introduce adjustment costs in the capital accumulation process to improve the model characteristics of aggregate investments.

The basic setup is the same as in section 4, except the capital accumulation rule, which is changed to the following:

$$\begin{aligned} K_{i,t+1} - p_k \ln\left(K_{i,t+1} - (1-\delta) K_{i,t}\right) &= (1-\delta_k) K_{i,t} + I^k_{i,t} \\ O_{i,t+1} - p_o \ln\left(O_{i,t+1} - (1-\varphi) O_{i,t}\right) &= (1-\delta_o) O_{i,t} + B_{i,t} I^o_{i,t} \end{aligned}$$

where p_k and p_o are two small positive numbers.

Since the adjustment cost function $-p_x \ln\left(X_{i,t+1} - (1-\delta) X_{i,t}\right)$ converges to $-\infty$ when $[X_{i,t+1} - (1-\delta) X_{i,t}] \to_+ 0$, the term creates a large cost when the new investments in K and O for any firm approach zero, and thus assures that in the solution to the optimization problem, every firm receives positive investments of both capitals in any given period. On the other hand, when a firm's optimal investments are well above zero, the existence of adjustment cost terms will not significantly change the result compared to the original model, as long as p_k and p_o are kept very small.

The Lagrangian for the social planner's problem now takes the following form

$$
\begin{aligned}
\mathcal{L} \;=\; & \max_{\{C_t,[K_{i,t+1},O_{i,t+1}]_{i=1}^n,[L_{i,t}]_{i=1}^n\}_{t=0}^\infty} E_0\{\sum_{t=0}^{\infty}\beta^t[\ln(C_t)+\theta\frac{(1-L_t)^{1-\mu}}{1-\mu} \\
& +\lambda_t[\sum_{i=1}^{n}K_{i,t}^{\alpha_t}O_{i,t}^{\gamma_t}(A_tL_{i,t})^{1-\alpha_t-\gamma_t}+\sum_{i=1}^{n}(1-\delta)K_{i,t}+\sum_{i=1}^{n}(1-\varphi)O_{i,t} \\
& +\sum_{i=1}^{n}p_k\ln(K_{i,t+1}-(1-\delta)K_{i,t})+\sum_{i=1}^{n}p_o\ln(O_{i,t+1}-(1-\varphi)O_{i,t}) \\
& -C_t-\sum_{i=1}^{n}K_{i,t+1}-\sum_{i=1}^{n}\frac{O_{i,t+1}}{B_{i,t}}]+\varsigma_t(L_t-\sum_{i=1}^{n}L_{i,t})]\}
\end{aligned}
$$

It is clear that if p_x=0, we go back to the original solution. In the following simulation exercise, I set $p_k = p_o = 0.000002$. Other parameters are the same as in section 5. Table 15 presents the cyclical behaviors of the model economy after adding adjustment cost. Compared with the baseline model, one improvement is that, though still higher than empirical observation, the volatility of aggregate investment in K is much lower than in the original model. Besides, the correlation between I^k and Y is now positive, though lower than the data.

Table 15: Business cycle properties of model economy with adjustment cost

Variables	%std (std across simulations)	Correlation with output	1st order autocorrelation
Output	1.64 (0.040)	1.00	0.95
Consumption	1.33 (0.021)	0.49	0.91
I^k	52.82 (20.194)	0.28	0.96
I^o	13.28 (0.289)	-0.46	0.87
Hours	1.32 (0.032)	0.89	0.96

The improvements in investment characteristics are not without cost. Table 16 and figure 4 report the output volatility trends of the model with adjustment costs. Although the aggregate volatility is at the same range as before, the firm level volatility turns out to be much lower, due to the fact that the additional restriction on firm's investment curbed the degree of variations among firms. But qualitatively, the model is still able to generate the divergence in macro and firm-level volatility from the 1980s onward.

Figure 4: Volatility trends of model economy with adjustment costs

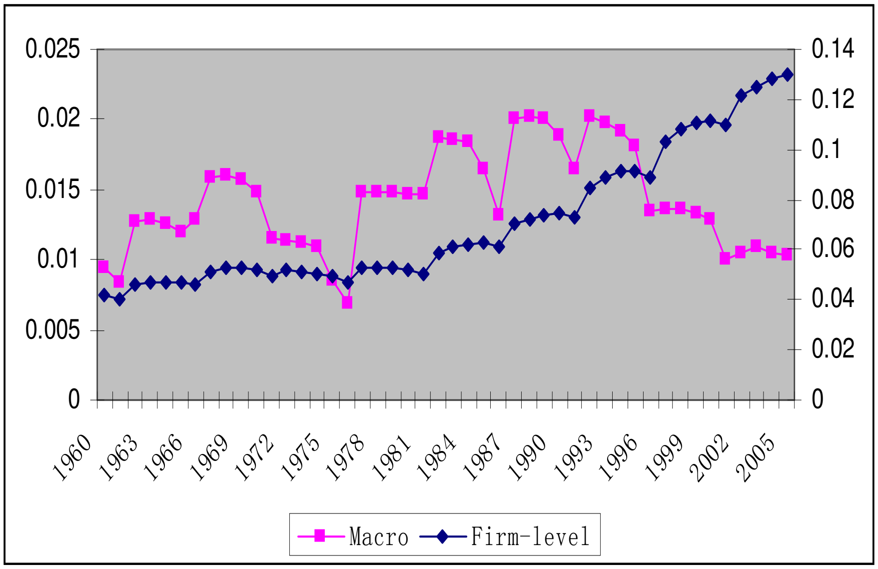


Table 16: Average rolling standard deviations of outputs

	Average aggregate volatility (%std)		Average firm-level volatility (%std)	
Time	Model	Data	Model	Data
1955-1959	1.3541	2.4550	4.0141	14.1237
1960-1969	1.2829	1.6802	4.7188	14.2859
1970-1979	1.1977	1.5563	5.0884	17.7532
1980-1989	1.7510	1.7858	6.2470	24.0382
1990-1999	1.6664	0.8828	9.1524	26.1928
2000-2003	1.0871	1.1129	12.0947	27.2878

8 Conclusion

The aggregate output volatility of US economy has declined significantly since the early 1980s, but at the same time, firm performance has become more volatile. The latter fact contradicts many explanations of the "Great Moderation" that imply a direct transfer between macro and firm-level volatilities. This paper provides a theory to reconcile the two phenomena from the perspective of structural change in production activities.

I argued that organization capital investment is a key factor causing the volatility divergence. During roughly the same period as the great moderation, business sector's organization capital, or firm-specific intangible capital, has been increasing rapidly. Such organizational investment is an important source of idiosyncratic risks, while at the same time it makes a firm less susceptible to general market risks. When firms in the economy invest more in organization capital, the impact of firm-specific risk factor becomes larger and that of general risk factor smaller. The former causes firm-level volatility to increase; the latter, through lowering the positive comovements among firms, reduces aggregate volatility. In this sense, the decline in macro volatility during the past two decades should rather be called the "Great Dissolution".

Using firms' SG&A expenditure as an approximation for organization capital investment, I looked at how a firm's sales volatility, the impact of general risks, and a firm's performance correlation with other firms are affected by its organization capital intensity, compared to the influence of other production inputs. The results show that firms' volatility increases with more investment in organization capital. Meanwhile, organizational investment decreases general shocks' impact and a firm's comovement with others. The result generally supports my hypotheses about the relationship between organizational investment and firms' risk characteristics.

I constructed a general equilibrium model featuring organization capital investment. In the model, a firm is subject to two shocks, a global technology shock that affects all firms alike, and an idiosyncratic productivity shock that is specific to a firm's organization capital accumulation process. With reasonable parameter choices, the model is able to generate volatility divergence during the past two decades and quantitatively match the sales volatility data at both macro and firm level. The simulation result before the 1980s was much less satisfactory, suggesting that organization capital playing a significant role in the production process is a relatively recent phenomenon.

To sum up, the paper shows that organization capital investment provides a constructive perspective in solving the diverging volatility puzzle. The empirical evidence presented in the paper is still preliminary. To extend the current investigation, further empirical analysis at different levels of aggregation, e.g., at sector and industry level, can be very helpful.

A Solution Method

In this section, I explain the solution method of the model.

The first order conditions of the planner's problem are[10]:

$$
\begin{aligned}
\frac{1}{C_t} &= \lambda_t \\
\theta(1-\sum_{j=1}^{n} L_{j,t})^{-\mu} &= \lambda_t(1-\alpha-\gamma)K_{i,t}^{\alpha}O_{i,t}^{\gamma}A_t{}^{1-\alpha-\gamma}L_{i,t}^{-\alpha-\gamma} \\
\lambda_t &= \beta E\{\lambda_{t+1}[\alpha K_{i,t}^{\alpha-1}O_{i,t}^{\gamma}(A_t L_{i,t})^{1-\alpha-\gamma}+(1-\delta)]\} \\
\frac{\lambda_t}{B_{i,t}} &= \beta E\{\lambda_{t+1}[\gamma K_{i,t}^{\alpha-1}O_{i,t}^{\gamma-1}(A_t L_{i,t})^{1-\alpha-\gamma}+\frac{(1-\varphi)}{B_{i,t+1}}]\}. \\
i &= 1,2,...n
\end{aligned}
$$

The steady state equations are:

[10] By taking first order conditions, an interior solution is already assumed. Why can we rule out corner solution? In other words, is it possible that in some periods, certain firms get zero investment because they are hit by low shocks? The answer is no. The reason is as follows. Assume all firms start with the same amount of capitals K and O, but firm A has higher organizational investment-specific shock for the next period. Suppose the social planner chooses to concentrate all the new O investment in firm A and starve other firms, obviously all the new K investment has to be made in firm A, too, otherwise too much O makes the marginal productivity of O in firm A go down so much that it can hardly be optimal. Now think of what happens to other firms. They get zero new investment, but are still in business with the left-over K and O from last period. But K and O have very different depreciation rates. Specifically, in the model, I assume depreciation for K around 5% per year, but for O about 50%. So in the next period, the marginal productivity of O in other firms would be much higher than in firm A, if they don't receive any new O investment. The situation can be improved if social planner had chosen to invest some O in these low-shock firms, which means that the investment schedule I assumed in the beginning cannot be optimal. The key thing here is a much higher depreciation rate for O than for K. And this assumption is by no means unrealistic.

$$
\begin{aligned}
\theta(1-\sum_{j=1}^{n} L_j)^{-\mu} &= \frac{1}{C}(1-\alpha-\gamma)K_i^{\alpha}O_i^{\gamma}L_i^{-\alpha-\gamma} \\
\frac{1}{\beta} &= \alpha K_i^{\alpha-1}O_i^{\gamma}L_i^{1-\alpha-\gamma} + (1-\delta) \\
\frac{1}{\beta} &= \gamma K_i^{\alpha}O_i^{\gamma-1}L_i^{1-\alpha-\gamma} + (1-\varphi) \\
C+\delta\sum_{j=1}^{n} K_j) + \varphi\sum_{j=1}^{n} O_j &= \sum_{j=1}^{n} K_j^{\alpha}O_j^{\gamma}L_j^{1-\alpha-\gamma} \\
A &= 1; B = 1.
\end{aligned}
$$

Let

$$
\begin{aligned}
R^k_{i,t} &= \alpha K_{i,t}^{\alpha-1}O_{i,t}^{\gamma}(A_tL_{i,t})^{1-\alpha-\gamma} + (1-\delta) \\
R^o_{i,t} &= \gamma K_{i,t}^{\alpha-1}O_{i,t}^{\gamma-1}(A_tL_{i,t})^{1-\alpha-\gamma} + \frac{(1-\varphi)}{B_{i,t}}
\end{aligned}
$$

And let lower case letters denote log-deviations of variables from the steady state. Log-linearizing the first order conditions and constraints around the steady state:

$$
\begin{aligned}
r^k_{i,t+1} &= \frac{\alpha K^{\alpha-1}O^{\gamma}L^{1-\alpha-\gamma}}{R^k}[(\alpha-1)k_{i,t+1} + \gamma o_{i,t+1} + (1-\alpha-\gamma)l_{i,t+1} \\
&\quad +(1-a-\gamma)a_{t+1}] \\
r^o_{i,t+1} &= \frac{\gamma K^{\alpha}O^{\gamma-1}L^{1-\alpha-\gamma}}{R^o}[\alpha k_{i,t+1} + (\gamma-1)o_{i,t+1} + (1-\alpha-\gamma)l_{i,t+1} \\
&\quad +(1-a-\gamma)a_{t+1}] - (1-\varphi)b_{i,t+1}
\end{aligned}
$$

$$
\begin{aligned}
-c_t &= \nu_t \\
\mu\frac{L}{1-nL}l_{i,t} &= \nu_t + \alpha k_{i,t} + \gamma o_{i,t} + (-\alpha-\gamma)l_{i,t} + (1-a-\gamma)a_t \\
\nu_t &= E_t(\nu_{t+1} + r^k_{i,t+1}) \\
\nu_t - b_{i,t} &= E_t(\nu_{t+1} + r^o_{i,t+1})
\end{aligned}
$$

$$
\begin{aligned}
& Cc_t + K\sum_{j=1}^{n} k_{j,t+1} + O\sum_{j=1}^{n} o_{j,t+1} \\
= \; & [\alpha K^{\alpha-1} O^{\gamma} L^{1-\alpha-\gamma} + (1-\delta)K]\sum_{j=1}^{n} k_{j,t} + [\gamma K^{\alpha} O^{\gamma-1} L^{1-\alpha-\gamma} \\
& +(1-\varphi)O]\sum_{j=1}^{n} o_{j,t} + nK^{\alpha} O^{\gamma} L^{1-\alpha-\gamma}(1-\alpha-\gamma)a_t \\
& +K^{\alpha} O^{\gamma} L^{1-\alpha-\gamma}(1-\alpha-\gamma)\sum_{j=1}^{n} l_{j,t} + \varphi O\sum_{j=1}^{n} b_{j,t}
\end{aligned}
$$

Exogenous shock processes take the form:

$$a_{t+1} = \rho_a a_t + \varepsilon_{t+1}, \quad \varepsilon_{t+1}\tilde{}iid\ N(0, \sigma_{\varepsilon}^2)$$

$$b_{i,t+1} = \rho_b b_{i,t} + \eta_{i,t+1},\ i = 1, 2, ...n, \quad \eta_{i,t+1}\tilde{}iid\ N(0, \sigma_{\eta}^2)$$

I then solved for the equilibrium law of motion using Schur factorization method proposed by King & Watson (2002).

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