ABSTRACT

Title: THREE ESSAYS IN VOLAITLITY CHANGE AND PRIVATE AND GOVERNMENT INVESTMENT

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Studies of the volatility of the U.S. economy suggest a noticeable change in mid 1980s. There is some empirical evidence that the aggregate volatility of the U.S. economy has been decreasing over time. The response of firms to the change of economic volatility and economic fluctuation has been studied in terms of many margins a firm can adjust –capital, labor, capacity, material, etc. However, we have not studied the most important margin – the product.

My dissertation studies the effect of profit volatility on the firm/plant level product diversification. Chapter 2 profiles diversification and shows that there is a downward trend of aggregate diversification in many industries. Cyclicality of diversification is not clear at the aggregate or industry level. Firms change their diversification very frequently and very differently from one another. Chapter 3 verifies the trend of volatility at the aggregate, sectoral, and firm level and studies the relationship between diversification and volatility at the firm level. Firm level diversification decreases as the aggregate, sectoral and idiosyncratic volatility decreases.

Research on the volatility change is concentrated on recent U.S. history. However, new data allow us to study events of significant volatility change in early 19th century. Chapter 4 of my dissertation studies the causes and effects of the volatility change in early 19th century in U.S. and U.K.

THREE ESSAYS IN VOLAITLITY CHANGE AND PRIVATE AND GOVERNMENT INVESTMENT

By

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Dedication

To my love, Tai Hwa

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Research results and conclusions expressed are those of the author and do not necessarily indicate concurrence by the Bureau of the Census, the CES, or the World Bank.

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Chapter 1: Introduction

Studies of the volatility of the U.S. economy suggest a noticeable change in the mid 1980s. There is some empirical evidence that the aggregate volatility of the U.S. economy has decreased over time.[1] The volatility of real GDP growth in the United States has fallen by half since the early 1980s relative to the prior postwar experience. Not only output, but many other economic indicators show less volatility. Inflation also stabilized after the mid 1980s. Some studies have argued that an improvement in U.S. monetary policy can explain both the lower output and inflation volatility.[2] Others have attributed the decreased volatility of GDP to a reduction in the size of shocks hitting the U.S. economy-in other words, 'good luck'.[3] Recent studies argue that both policy and good-luck played a role and that changes in inventory behavior stemming from improvements in information technology have played a role in reducing real output volatility.[4] The causes of change in volatility have been studied, although a consensus has yet to be reached.

Research on the effects of the volatility change has accumulated as well. The response of firms to changing economic volatility or economic fluctuations has been studied along many margins –capital, labor, capacity, material, etc.[5] However, the most important margin – the product – has not been studied thoroughly.

Throughout the history of 20th century U.S. business, diversification was a strategic option pursued by corporate entities. High diversification was a virtue, and big conglomerates were regarded as the engine of fast growing economies. In the late 20th century, many big companies were split either by antitrust lawsuits or for strategic purposes, but we still observe

[1] Blanchard and Simon (2001), McConnell and Perez-Quiros (2000)
[2] Clarida, Gali, and Gertler (2000)
[3] Ahmed, Levin, and Wilson (2001), Blanchard and Simon (2001)
[4] Stock and Watson (2002), Kahn et al (2002)
[5] See Sakellaris (2000) for a survey.

massive mergers and acquisitions toward horizontal and/or vertical integration in many industries, such as petroleum, telecommunications, printing, and so on.[6]

Economists have followed the trend of multi-output production of manufacturing plants and firms, but despite theoretical advances, the variation in diversification across industry and time still remains a mystery. Although there are thousands of papers on corporate diversification, most of them focus on the diversification in the financial portfolio of the firm and its effect on productivity or the value of the firm.[7] A comprehensive empirical study on product diversification is long overdue. Except for some anecdotal evidence, there are few publicly available statistics measuring the extent of establishment, firm, or industry diversification at a short-term frequency over the long run. Because of this lack of data, it was not possible to study diversification along with business activity, although product diversification is one of the most important aspects of a firm's behavior over time.

Research on volatility changes is concentrated on recent U.S. history. However, new data allow us to study events of significant volatility change in the early 19th century. I developed a new econometric technique, an ARCH model that deals with sparse datasets with missing observations, and did a complete analysis of financial market fluctuations. A study on the radical volatility change in the early 19th century in the U.S. and U.K sheds light on the causes and effects of the volatility change.

In my thesis, I study the cause and effect of the volatility change related to the firm level product diversification and government investment. First, I establish a detailed profile of firm/plant level product diversification in manufacturing sector. Second, I study the relationship

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[6] Federal Trade Commission(2004, 1999), Samli (2004), Kirkpatrick (2002), and Wilcox et al (2001)

[7] 3,190 papers are found by a key work "firm-level diversification" in Google-scholar. See Schoar(2002) and Lins and Servaes(1999) for example.

between the firm level diversification and volatility of the U.S. manufacturing sector. Third, I investigate volatility change in early 19th century U.S. and U.K.

Chapter 2 discusses the quality and limitations of the datasets as well as the measure of diversification, provides a conceptual discussion of diversification and describes stylized facts regarding the long-term and short-term dynamics of diversification. Chapter 3 provides a conceptual discussion of the relationship between diversification and profit volatility, describes stylized facts regarding volatility change, and estimates the relationship between firm level diversification and aggregate, industrial and idiosyncratic profit volatility. Chapter 4 briefly explains the history of government financing in the early 19th century, and explains the causes and effects of the volatility change during the crises of the 1840s.

Chapter 2: Product Diversification: Profile

Section 1. Introduction

Although diversification is one of the big issues in business history for a long time, most of studies concentrate on large conglomerates or certain industries for a relatively short time period. This chapter develops a thorough longitudinal analysis of diversification for the manufacturing sector.

Gollop and Monahan(1991) is the one of a few existing studies of micro level diversification for the whole manufacturing sector in the long run. They showed that manufacturing firms specialized within plants, while they diversified among plants, until 1982 (see Figure 1). However, there are no empirical studies on diversification covering the last two decades, and it still remains unclear why firms change their product portfolios and how they change diversification over time.

There are quite a few researches on the cyclicality of product diversification. Many of them suggest the diversification moves pro-cyclically, while a few others suggest counter-cyclical diversification.[8] One of the goals of this chapter is to verify whether the diversification is pro- or counter-cyclical over the long time period.

In this chapter, a detailed profile of diversification is described. I construct diversification index using 5-digit and 7-digit SIC product codes to see long term trends, short term cyclicality, and the evolution of diversification by firm/plant level characteristics. Diversification at the firm and establishment level will be analyzed from various perspectives.

Section 2 discusses the quality and limitations of the datasets as well as the measure of diversification. Section 3 provides a conceptual discussion of diversification. Section 4 describes

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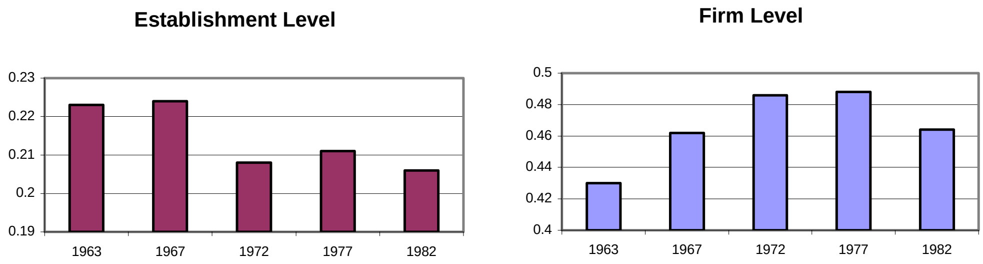
[8] See Axaloglou (2003), Keuschnigg (2001), Jovanovic (1993), for instance.

Figure 1 Diversification Indexes



Note: Shipment weighted aggregate series
Source: Gollop and Monahan(1991), Table 4, pp.328

stylized facts regarding the long-term and short-term dynamics of diversification. Section 5 summarizes the facts and analyses.

Section 2. Data

The three datasets I use are the Census of Manufactures (CM), Annual Survey of Manufactures (ASM) and Longitudinal Business Database (LBD) from 1974 to 1998.[9] CM and ASM compose the Longitudinal Research Database (LRD). LRD is a time series of economic variables collected from manufacturing establishments in CM and ASM programs. LRD contains establishment level identifying information; information on the factors of production (inputs, such as levels of capital, labor, energy and materials) and the products produced (outputs); as well as other basic economic information used to define the operations of a manufacturing plant.[10]

LBD provides longitudinally linked data for all employer establishments (i.e., those with paid employees) contained in the Census Bureau's business register, the Standard Statistical Establishment List (SSEL). Basic data items, such as payroll, employment, location, industrial

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[9] CM is available in 1977, 1982, 1987, 1992, and 1997. ASM is available annually, 1973-76, 1978-81, 1983-86, 1988-91, 1993-96, and 1998-2000. LBD is currently available 1975 to 1999. ASMs in 1999 and 2000 are not used because the product codification was changed from SIC to NAICS in 1998. See Appendix A for a discussion.

[10] Some product data that are imputed by Census Bureau are excluded from the sample.

activity and firm affiliation are included in LBD. LBD is used to get data on firm age, total employment, and the number of plants of multi-unit firms.

Using LRD product files, I use a Herfindahl-type index as a measure of establishment and firm level diversification.[11] My diversification index satisfies the following requirements: it varies directly with the number of different products produced; it varies inversely with the increasingly unequal distribution of products across product lines; and it is bounded between zero and unity.

$$D1 \equiv 1 - \sum s_i^2, \quad where\ s_i = \text{share of product i that is identified by 5 digit SIC code}$$

$$D2 \equiv 1 - \sum \left(\frac{\sigma_{ij} + 1}{2} \right) s_j^2, \quad where\ s_j = \text{share of product j that is identified by 5 digit SIC code}$$

$$\sigma_{ij} = \text{correlation of shipments between product j and Firm i's primary product i by 4 digit SIC}$$

$$D3 \equiv 1 - \sum s_i^2, \quad where\ s_i = \text{share of product i that is identified by 3 digit SIC code}$$

$$D4 \equiv 1 - \sum s_i^2, \quad where\ s_i = \text{share of product i that is identified by 4 digit SIC code}$$

D1 is the simplest diversification index which incorporates the number of products and share of the products' shipments. Since it is simple, we can apply this method to any years in LRD data. D1 can show a very consistent time series of diversification and accounts the most detailed product information collected in ASM.

One disadvantage of D1 is that it equally accounts products no matter how different they are: how they are related in terms of sales or production. In order to include the information on how the industries in which the firm diversifies are related, D2 uses the correlation coefficient of shipments of the industries as a distance weight between diversified products. Example 2 shows the difference between D1 and D2.

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[11] This measure has been widely used in the literature. See Gollop and Monahan(1991)

Example 1: Firm I produces A and B (5 digit SIC) in two different industries (4 digit SIC) with equal share		
Diversification Measure	Case	Index
D1		D1=1-(.25+.25)=.5
D2	corr(A,B)=1	D2=1-(.25+.25)=.5
	corr(A,B)=0	D2=1-(.25+.5*.25)=.625
	corr(A,B)=-1	D2=1-(.25+0*.25)=.75

Example 2: Firm I produces A, B, C and D (5-digit SIC) with equal share

	5-digit SIC	4-digit SIC	3-digit SIC	Shipment share
Product A	28124	2812	281	.25
Product B	28331	2833	283	.25
Product C	28332	2833	283	.25
Product D	28343	2834	283	.25

D1=1-(.0625-.0625-.0625-.0625)=.75
D4=1-(.0625-.25-.0625)=.625
D3=1-(.0625-.5625)=.375

Therefore, D2 will be generally higher than D1 unless the firm diversifies all its products in same 4 digit industry. A comparison of D1 and D2 will shed light on how different industries firms diversify with their products.

One may ask a question: Is diversification in different 5-digit SIC products a real diversification? There are cases where those products are so similar and ordinary people would not distinguish them easily. In such cases, it is better to use less detailed product classification to construct diversification index. D3 and D4 are additional measures of diversification to show only across-industry not within-industry diversification. Example 2 shows the difference across D1, D3 and D4. In this example, D4 is 17% lower than D1, suggesting that 17% of this firm's diversification came from within-4-digit-industry diversification. The fact that D3 is 50% lower than D1 shows a half of its diversification is due to within-industry diversification by 3-digit SIC. By showing D3 and D4 along with D1, we can see that Firm I is a highly diversified firm by 5-

digit SIC, but a rather specialized firm by 3-digit. By comparing these indexes with D1, it will be clear how much the within-industry diversification contributes to the total diversification.

For the long-term trend analysis, I focus on the quinquennial CMs. The number of observations in CM is quite stable around 300,000 establishments. For a multi-unit firm level diversification index, the value of shipments of seven or five digit Standard Industrial Classification System (SIC) products is aggregated across the establishments of the firm and divided by the total value of shipments of the firm to get the share of each product. [12] The detailed calculation method is described in Appendix A.[13]

For the short-term analysis, I produce annual diversification indices at the establishment and firm levels using ASM and CM. The annual number of observations is stable around 70,000 establishments. I can use up to 5-digit SIC product codes to construct the annual diversification index because only 5-digit product codes are consistently available in ASM.

With the same logic behind D1, D3 and D4, it is not clear which of the 5-digit or 7-digit SIC product code is better for the analysis of diversification. When the 7-digit code is used to construct the diversification index, I get higher index values, and we can study product variety in detail. However, the 7-digit code is very detailed and 7-digit products in the same 5-digit product

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[12] A single-unit firm is defined as a firm with only one location. A multi-unit firm is defined as a firm that owns multiple establishments. See Appendix A for detail of SIC.

[13] Gollop and Monahan(1991) included a product heterogeneity component in their index construction, available only in CM. Their index is as follows:

$$Diversification\ Index(D) \equiv 1/2\left[1 - \sum_i s_i^2 - \sum_i \sum_{k \neq i} s_i s_k (z_{ik} - \sigma_{ik})\right]$$

where

s_i = share of a seven – digit product

$$z_{ik} = \begin{cases} 1 & \text{if the } i^{th} \text{ and } k^{th} \text{ products are identical} \\ 0 & \text{if the } i^{th} \text{ and } k^{th} \text{ products are not identical} \end{cases}$$

$$\sigma_{ik} \equiv \left(\sum_j \frac{|w_{kj} - w_{ij}|}{2}\right)^{1/2}$$

$w_{kj} \equiv$ input cost share of the j^{th} input in the k^{th} product code are often very similar to the each other.[14] If we are interested in product diversification across a variety of "different" products, the 5-digit, 4-digit or even 3-digit code would be better. In this chapter, all 7-digit, 5-digit, 4-digit and 3-digit are reported, if available.

Section 3. Why Diversification?

Diversification has been treated as a firm characteristic in numerous studies. Many empirical studies on Total Factor Productivity (TFP) include the firm's diversification level as a control variable.[15] Studies of the performance of the q-theory of investment also include multi-product dummy variables.[16] Multi-product dummy variables are also used to proxy financial constraints in some studies.[17] Some have conjectured that diversified firms have different investment and entry/exit decisions, yet these empirical studies did not examine the firm's diversification directly.[18] Many studies find that multi-product firms behave differently from single-product firms, but the diversification decision has not been incorporated endogenously in the empirical literature.[19] The adjustment of a firm's product portfolio has only recently drawn attention from researchers.[20]

There are many important studies on diversification in the area of strategic behavior studies and corporate finances. Campa and Kedia (2002) focuses on the relationship between the

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[14] An example of product classification in the chemical industry is given in Appendix A.

[15] Giandrea(2002), Gemba and Kodama(2001)

[16] Bond and Cummins(2000), Fazzari, Hubbard and Petersen(1988), Abel and Blanchard(1986), Hayashi and Inoue(1991), Dwyer(2001).

[17] Abel and Eberly(2001a and 2001b), Barnett and Sakellaris(1999), Gilchrist and Himmelberg(1995), Gross(1994)

[18] Caballero, Engel and Haltiwanger(1995), Chatterjee and Cooper(1993), Dunne, Roberts and Samuelson(1989). Firm's exit and investment decisions are combined with financial constraints in Whited(1992) and Winter(1999).

[19] The product portfolio decision has been considered in I/O literature in terms of business management. For example, Anderson, de Palma and Nesterov(1995), Ottaviano and Thisse(1999), Pepall and Norman(2001).

[20] Cooper and Haltiwanger(2000), Sakellaris(2000)

decision of diversification and firm value. When they use panel data and instrumental variables to control for the exogenous characteristics that predict the decision to diversity, the evidence in favor of the assertion that diversification destroys value is weaker. When they jointly estimate the decision of a firm to diversify and its firm value, diversification seems a value-enhancing strategy. The diversification discount is more likely to be a premium in this case. They also find that firms that refocus their operations would have suffered a significant decreased in value if they had remained diversified, suggesting that the observed correlation between diversification and firm value is rather the outcome of actions by profit-maximizing firms reacting to shocks in their environments. In their estimation, they include a dummy variable for diversification, firm size, proxied by the log of total assets, profitability, investment, lagged variables and organizational aspects of industry (fraction of firms that are conglomerates, fraction of industry sales accounted for by conglomerates), economic environment (number of M&A, GDP, business cycle) and other firm publicity (listed on Nasdaq, NYSE, AMEX or part of S&P index, incorporated outside US).

Villalonga (2004) also estimates the value effect of diversification by matching diversifying and single-segment firms on their propensity score – the predicted values from a probit model of the propensity to diversify. He also finds that on average, diversification does not destroy value. These papers suggest that the decision of diversification is consistent with profit-maximization and that it is a reaction to exogenous environment.

Maksimovic and Phillips (2002) develop a model where the firm optimally chooses the number of segments in which it operates depending on its comparative advantage and industry demand shocks. Their model predicts firm-size distributions and investment and growth decisions of focused single-industry and multiple-segment firms. Plants of conglomerates are found less productive than plants of single-segment firms of a similar size, but this is consistent with the fact that conglomerates are value-maximizing, supporting the hypothesis that firms invest in industries in which they have a comparative advantage. Conglomerate firms also grow less in an industry if their other plants in other industries are more productive and if their other industries have a larger positive demand shock.

My dissertation extends these studies to build a more detailed profile of diversification and to examine its relationship to exogenous environment. The segment, the traditional definition of industry in which firms diversify, is 3-digit SIC in most of the papers mentioned above. The decision of diversification is often captured by dummy variable that takes value of 1 when firms diversify into multiple segments. Summary statistics in my paper will show diversification indexes measured by various definitions, including 2-digit, 3-digit, 4-digit, 5-digit and 7-digit SIC and also distance measure between industries. These results will shed light on various aspects of diversification, depending on how we define "diversification".

Papers mentioned above focus on the relationship between diversification and firm performance (value or productivity). They show that diversification is a rational choice of profit maximization as a reaction to the exogenous environment, including GDP, demand shock by industry, other firms' performance. My paper will focus on the effect of exogenous factor, that is, what affects the decision of diversification, especially changes in economic volatility at the aggregate, industry and firm level. The variables in my estimation are similar to those in previous studies, including firm size proxy, profitability, age or organizational aspects. However, because I explicitly use various measures of degree of diversification and volatility, it will show not only whether to diversify or how many segments to diversify, but also how much to diversify as a response to economic volatility.

Only a few papers pay attention to the short-term dynamics of product diversification. Chatterjee and Cooper(1993) link product diversity with the business cycle, but only at the aggregate level.[21] Product choice is determined by the production technology and technology is

[21] Chatterjee and Cooper (1993) analyzed the product diversity fluctuation with a firm exit/entry model.

usually regarded as something that changes only in the long run. This explains why short-run dynamics of diversification have seldom been studied in the short run.

There are several potential motives for diversification. Jovanovic(1993) lists: (1) *Gaining Market Power*: A firm with market power in two substitute products can have higher profits than two single-product monopolies. (2) *Avoiding Risk*: With liquidity constraints, firms' investment, especially for small firms, depends on cash flows. Firms may diversify over the products to smooth their sales. (3) *Having Access to Funds*: In an imperfect capital market, funds tend to go to the large firms, not necessarily to the efficient ones. Firms may want to diversify across products to keep their size big. (4) *Making Products Compatible*: A set of products may be produced more efficiently together than individually. The optimal set of products is determined by the technology. (5) *Reaping Efficiency Gains*: By making several products, a firm can exploit cost synergies in producing, selling, promoting, and advertising. The diversified firm can also have a richer internal labor market to meet the demand of various production tasks. (6) *Pursuing Managerial Goals*: The manager may have a motive other than profit maximization. A diversified firm can reduce unemployment fluctuations, increase the volume of sales (though not necessarily profit), and discourage shareholder monitoring through complicated financial statements.

Among these potential motives, risk-avoidance dominates the literature. To verify the effect of risk on diversification, stylized facts of diversification are profiled in the next section. The relationship between risk and diversification is analyzed in Chapter 3.

Section 4. Stylized Facts of Diversification

This section describes the trend and cyclicality of diversification from various viewpoints. Section 4-1 is about the long-term trend, and Section 4-2 is about the short-term dynamics. Section 4-2 also includes a description of annual diversification changes.

4-1. Long-term Trend

The Census of Manufactures surveys all establishments in the US manufacturing sector every five years. This allows us to study the long run behavior of diversification at the firm and establishment level. In CM, basic data obtained for all establishments include kind of business, geographic location, type of ownership, total revenue, annual and first quarter payroll, and number of employees in the pay period. For some establishments, much less data detail is requested and no information on materials consumed is collected.[22]

Product diversification is regarded as a firm level decision. However, it is important to study the establishment level diversification because a multi-unit firm can diversify not only within the firm but also within plants. The analysis allows us to see the trend of diversification within plants.

Average diversification indexes are generated by 5 digit and 7 digit SIC product codes. Figure 2 plots the trend of the average diversification index at the establishment level. Diversification has steadily decreased at the establishment level since 1967 as measured using by either 5 or 7 digit SIC product codes. At the firm level, diversification stayed high until 1982 and then started to decrease. As Gollop and Monahan(1990) argued, until early 1980s, firms were diversifying while plants were specializing. Since then, however, both firm and plant level diversification has declined.

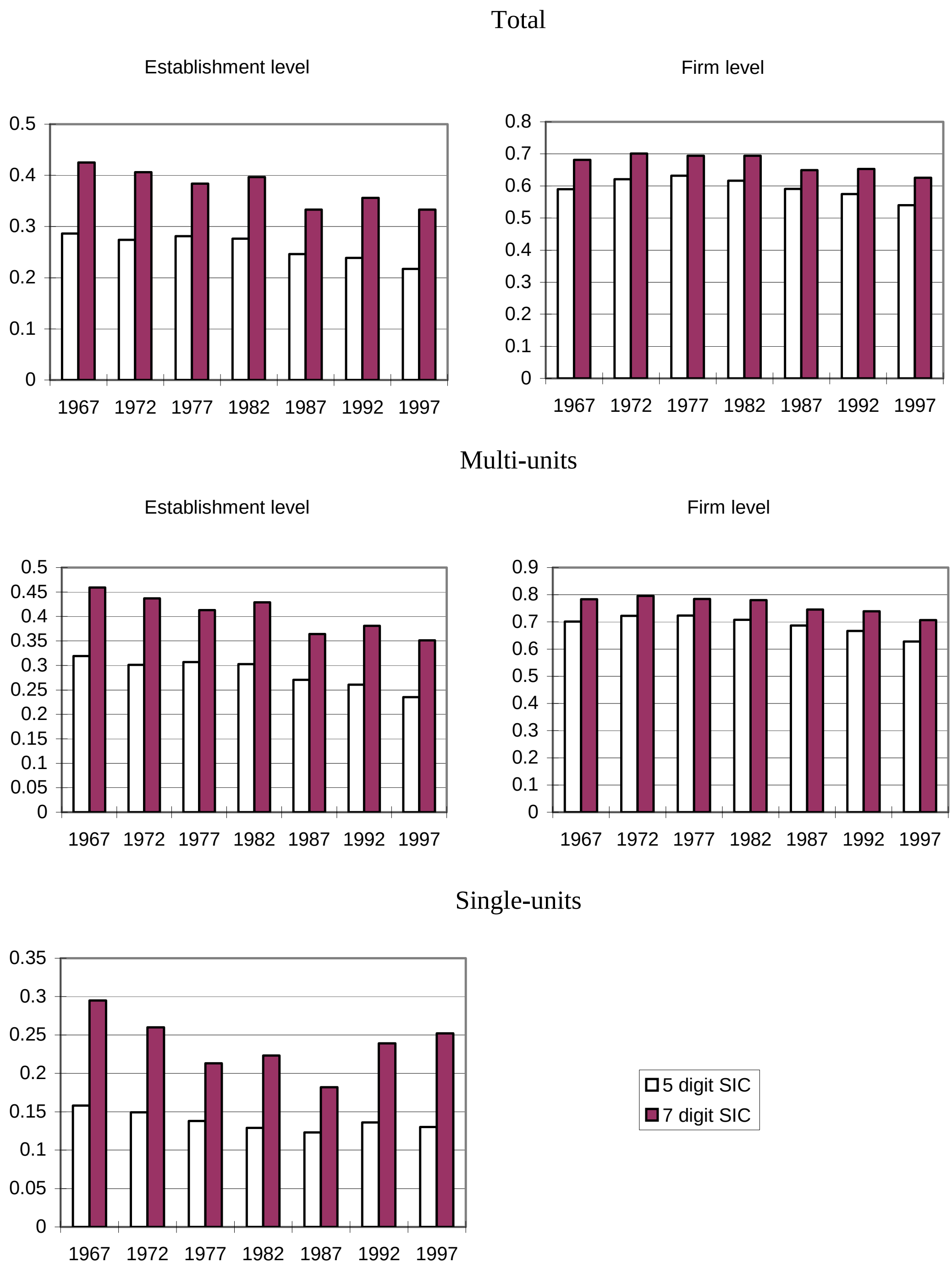
The downward trend of aggregate diversification is surprising because many researchers have conjectured that firms should diversify more and more for various reasons. However, it is

[22] CM is widely used in economic analysis and forecasting by many organizations, such as the Bureau of Economic Analysis, the Bureau of Labor Statistics, the Federal Reserve Board, state and local agencies, trade associations, companies, researchers, national and local news media.

premature to conclude that every firm decreased its diversification, because there is heterogeneity in firm level diversification.

First, the trend is different for multi unit (MU) and single unit firms (SU). The diversification of MU firms and establishments is the driving force of the aggregate trend. Diversification decreased for the MU establishments, but increased for MU firms, up to 1982. Beginning in 1982, diversification decreased both at the establishment and firm level for multi-unit firms. Diversification of SU establishments (or firms) has had a completely different trend, decreasing until 1987 and then increasing.

Figure 2 Average Diversification Index(D1) 1967-1997, CM



Note: Diversification index is shipment weighted series
Source: Author's calculation

Table 1 Percentage change of Diversification (1967-1997)

	Industry	Establishment			Firm		
		Total	SU	MU	Total	SU	MU
20	Food	-0.07	-0.24	-0.10	-0.00	-0.24	-0.00
22	Textile	-0.27	-0.18	-0.31	-0.25	-0.18	-0.26
23	Apparel	0.36	0.54	0.15	-0.21	0.54	-0.18
24	Lumber	-0.12	-0.20	-0.12	0.01	-0.20	0.04
25	Furniture	-0.19	-0.12	-0.29	-0.16	-0.12	-0.24
26	Paper	-0.30	-0.13	-0.31	0.03	-0.13	0.00
27	Printing	-0.23	-0.22	-0.26	0.06	-0.22	0.06
28	Chemical	-0.23	-0.43	-0.22	-0.05	-0.43	-0.06
29	Petroleum	-0.02	-0.55	-0.01	-0.08	-0.55	-0.09
30	Rubber	-0.42	-0.13	-0.46	-0.28	-0.13	-0.21
31	Leather	-0.19	0.21	-0.33	1.61	0.21	1.00
32	Stone	-0.16	-0.01	-0.20	0.14	-0.01	0.00
33	Metal	-0.37	-0.12	-0.38	-0.17	-0.12	-0.15
34	Fabricated Metal	-0.29	-0.03	-0.35	-0.36	-0.03	-0.23
35	Machinery	-0.17	-0.09	-0.21	-0.03	-0.09	-0.09
36	Electronic	-0.57	-0.49	-0.56	-0.28	-0.49	-0.25
37	Transportation	-0.41	-0.43	-0.41	-0.06	-0.43	-0.07
38	Instruments	-0.49	-0.41	-0.48	-0.09	-0.41	-0.10
39	Miscellaneous	-0.19	-0.09	-0.25	0.00	-0.09	-0.02

Note: Food (Industry 20) includes Tobacco due to the disclosure issue.

Figure 4 explains why the overall trend of aggregate diversification is dominated by the movements due to multi-unit establishments or firms. Single-units firms comprise 30-50% of all establishments, but the share of economic activity attributable to single-units is a mere 5-7%. At the firm level, the non-weighted share of single-units is 50-70%.

The trend of diversification is also different by industry. In Table 1, eighteen of nineteen industries exhibit declining diversification at the establishment level. The one exception is Apparel (36% increase). The rate of increase in the SU index in Apparel (54%) far exceeds the corresponding rate for the MU index (15%). For the eighteen industries with declining diversification, the decline is more severe in MU establishments in thirteen cases.

At the firm level, twelve of nineteen industries exhibit declining diversification. The seven exceptions are Food, Lumber, Paper, Printing, Leather, Stone and Miscellaneous Manufacturing. The increase in firm-level diversification in these seven industries is driven largely by multi-unit firms. For the twelve industries with declining diversification, the decline is more severe in SU firms in six industries.

To summarize, the aggregate diversification index declined both at the establishment and firm level. However, there is great heterogeneity across MU/SU and by industry at the establishment and firm level. Diversification declined in the majority of industries both at the establishment and firm level. The decline is most severe in establishments that are part of MU firms. The evidence suggests that within-plant diversification of MU firms is decreasing. This will be verified in Section 4-2.

4-2. Short-term dynamics

This section investigates short-run dynamics using the ASM sample. The number of observations decreases when we use only ASM plants in CM, and we lose some analytical power when we focus on ASM data. However, ASM enables us to construct an annual diversification index to study short-term variations, which has never been attempted in the literature.

Establishment level Analysis: Aggregate level

Figure 2 and 3 show the same aggregate trend of diversification at the establishment level. The difference between them is the sample size and frequency; Figure 2 uses quinquennial CM data with roughly 300,000 establishments, while Figure 3 uses annual ASM data with roughly 70,000 establishments. At the aggregate level, the annual diversification index has a downward trend. The trend is mostly explained by the movement of MU establishments.[23]

[23] By design, the average diversification index is higher for establishments that produce more products. Roughly 50% of sample establishments produce only one product each year. About 25% produce 2 products, 10% produce three, 5% produce four, and 5% produce five or more products. See Figure 6 for analysis of changes in the number of products.

Figure 3 Establishment Level Diversification Index(D1)

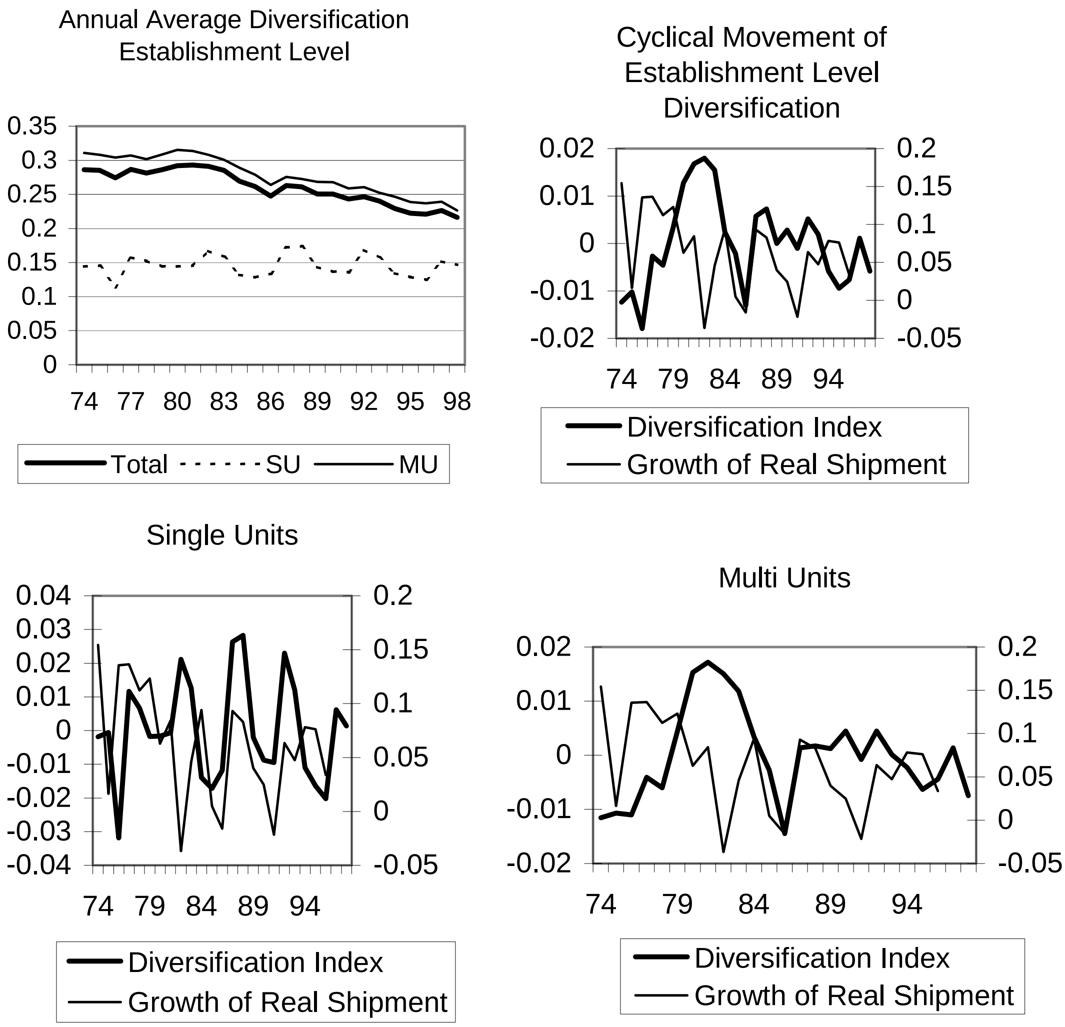
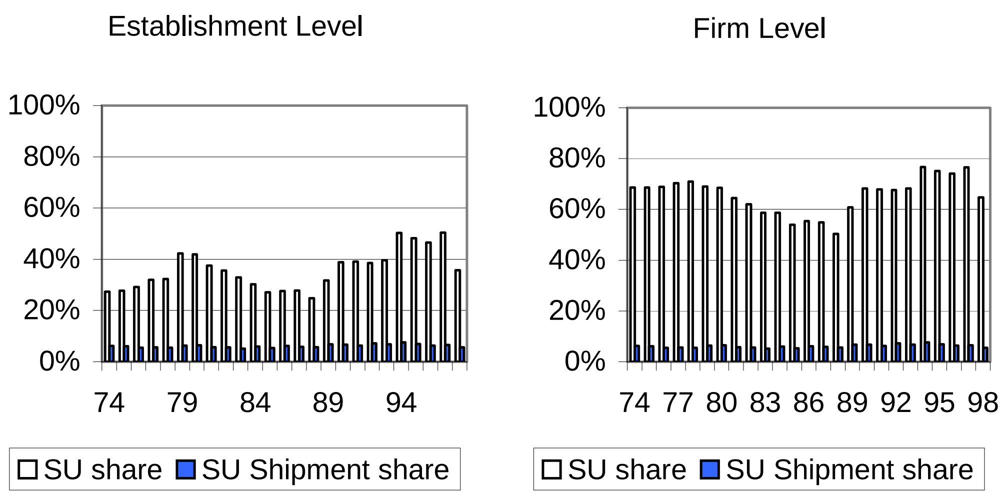


Figure 4 Share of Single Unit Establishments (Firms)



Is aggregate diversification is pro-cyclical? In the second graph of Figure 3, the diversification index seems to move pro-cyclically until 1990, then starts diverging. The diversification index is linearly detrended and the growth of real shipment in the manufacturing sector is obtained from ASM statistics published by Census.[24] The aggregate cyclical behavior is driven by multi-unit establishments (fourth graph of Figure 3), while single-unit firms show clear counter-cyclical movements. It seems that single-unit firms diversify more in recessions than in booms. On the other hand, multi-unit establishments diversify more in booms than in recessions.

Establishment level Analysis: Industry level

The average diversification index shows large variations across industry, as shown in Table 2.[25] Overall, establishments in Food, Printing, Chemical, Petroleum, and Metal industries have higher diversification on average over the period 1974-1998. For single-unit establishments, Food, Lumber, Printing, Chemical and Petroleum have high diversification. For multi-unit establishments, Printing, Chemical, Petroleum, Metal and Machinery have high diversification. To summarize, Printing, Chemical, and Petroleum industries have high diversification both in single-unit and multi-unit establishments. The high diversification of Food and Lumber is driven by their highly diversified single-unit establishments. Multi-unit establishments in Metal and Machinery crank up the average diversification level in those industries.

Cyclicality is also heterogeneous by industry. The sign of the correlation between the sectoral diversification index and the sectoral growth rate of real shipments is mixed across industries. Out of nineteen industries, eleven have positive correlations. Among the significant six correlations, four industries have positive signs. For single-unit establishments, thirteen industries have positive signs and four of five significant correlations are positive. For multi-unit

[24] See Appendix A
[25] Industry is classified by 1987 basis SIC. See Appendix A for detail.

Table 2 Average Establishment Level Diversification Index and Correlation with Growth of Real Shipment by 2 digit SIC Industry

Industry	Total		SU		MU	
	Mean	Corr. coeff.	Mean	Corr. coeff.	Mean	Corr. coeff.
20 Food	0.26	0.09	0.19	-0.28	0.27	0.14
22 Textile	0.19	0.37	0.13	0.26	0.20	0.36
23 Apparel	0.19	0.71*	0.17	0.53*	0.22	0.64*
24 Lumber	0.19	-0.51*	0.18	-0.34	0.20	-0.57*
25 Furniture	0.23	-0.21	0.16	-0.03	0.27	-0.14
26 Paper	0.21	0.10	0.12	0.07	0.22	0.19
27 Printing	0.30	0.08	0.24	0.45*	0.33	0.11
28 Chemical	0.35	-0.09	0.18	-0.42*	0.37	-0.45*
29 Petroleum	0.58	0.75*	0.27	0.36	0.59	0.65*
30 Rubber	0.19	0.61*	0.15	0.25	0.20	0.66*
31 Leather	0.15	0.39	0.13	0.55*	0.16	0.41*
32 Stone	0.11	-0.03	0.10	0.17	0.12	0.00
33 Metal	0.29	0.50*	0.16	-0.11	0.30	0.52*
34 Fabricated Metal	0.16	0.15	0.14	0.03	0.17	0.39
35 Machinery	0.28	-0.31	0.15	0.30	0.31	-0.18
36 Electronic	0.20	-0.24	0.12	-0.25	0.21	-0.17
37 Transportation	0.22	-0.42*	0.13	0.25	0.22	-0.44*
38 Instruments	0.21	-0.16	0.11	0.09	0.23	-0.33
39 Miscellaneous	0.15	0.20	0.09	0.56*	0.18	0.20

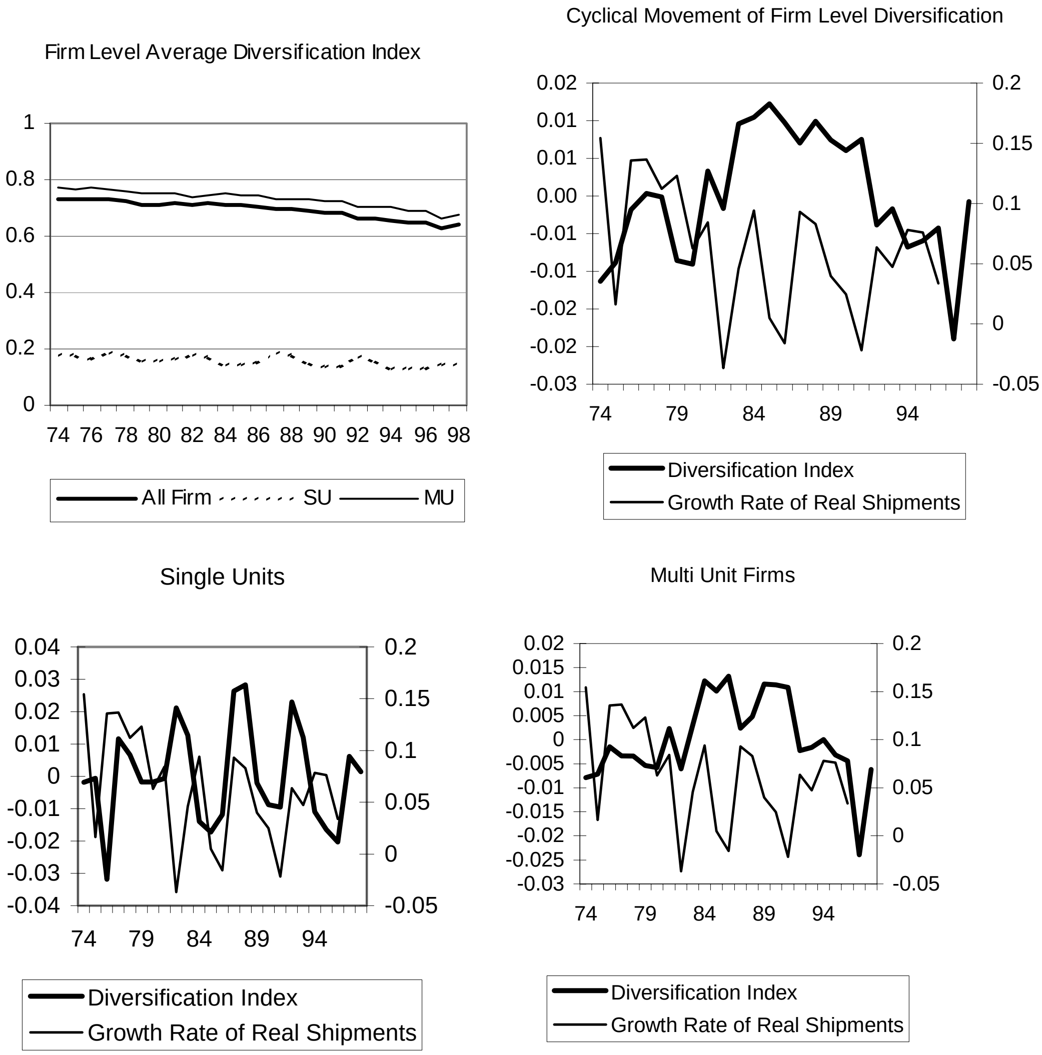
*significance at the 95% level
Note: Industry 20 includes industry 21 (Tobacco) due to the private information disclosure issue.
Source: Diversification index from author's calculation, Growth rate of real shipments from Census Bureau

establishments, eleven industries in total and five out of eight significant correlations have positive signs.

Firm level analysis: Aggregate level

At the aggregate level, the annual diversification index computed at the firm level shows a downward trend from 1974 to 1998 in the first graph of Figure 5. The level of firm diversification is higher than the establishment level index, mainly because of the high diversification of multi-unit firms. Single-unit firms comprise 60% of the sample but account for less than 10% of total shipments in average in Figure 4.

Figure 5 Firm Level Average Diversification Index (D1)



There is not a clear cyclicality of diversification at the aggregate level. The second graph of Figure 5 plots the average diversification index and the growth rate of real shipments in the manufacturing sector.[26] SU firms seem to have countercyclical diversification, i.e., firms specialize in booms and diversify in recessions. There is no clear co-movement for MU firms.

[26] I use the linearly detrened diversification index the growth rate of real value of shipment.

Figure 6 Firm Level Average Diversification Index (D1, D2, D3 and D4)

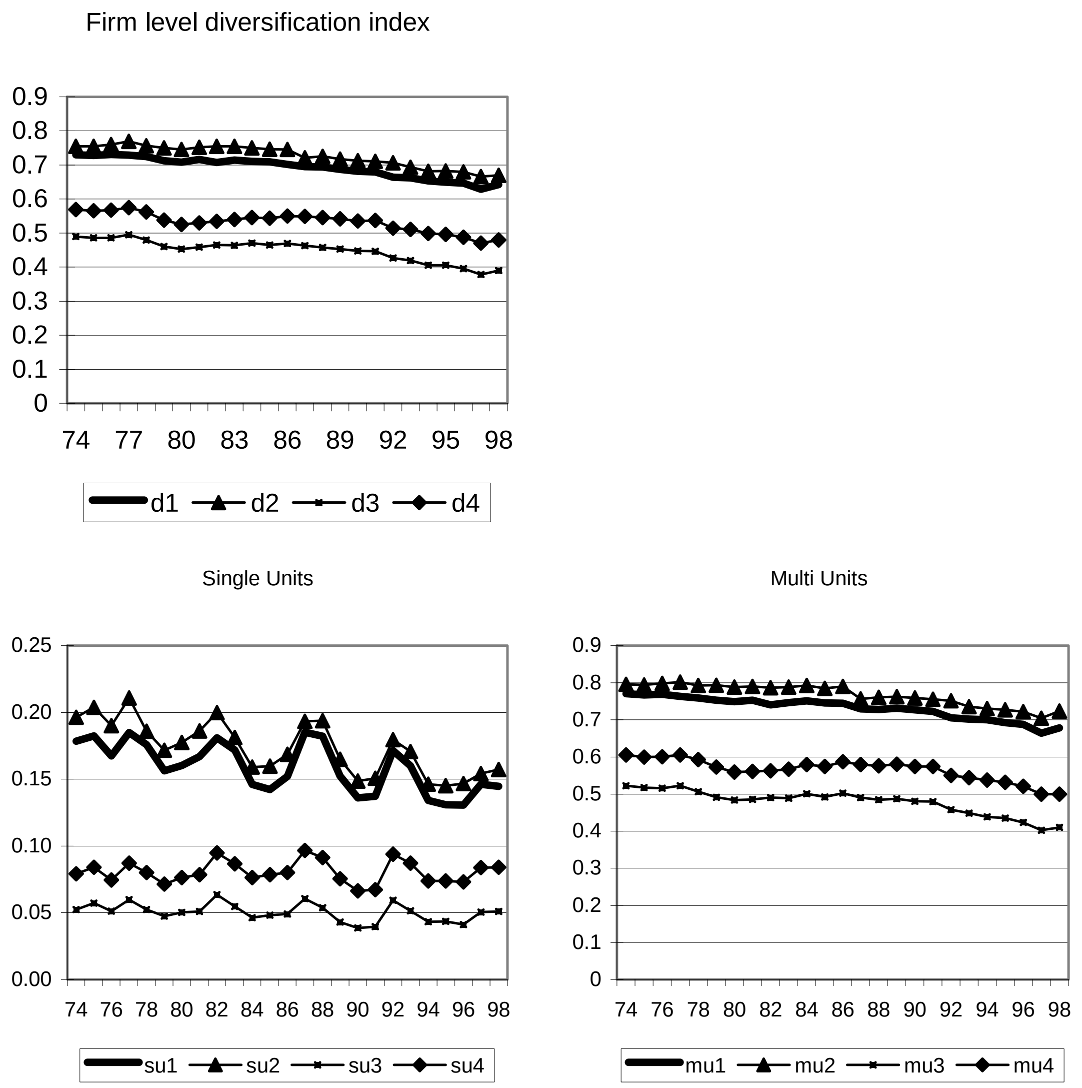


Figure 6 compares different measures of diversification. Since D2 uses distance weights to incorporate the relationship across industries, D2 is higher than D1. However, the gap between D1 and D2 is not so big. Recalling that D1 is close to D2 for a firm if all the industries are positively correlated to the primary industry of the firm, it means that firms do not diversify into really different industries. For single unit firms, the gap between D1 and D2 becomes smaller in the 1990s. This suggests that specialization in closely related industries is more prevalent in single units.

Since D3 and D4 use less detailed product classification, they are much lower than D1. Using the 4-digit SIC, D4 is about 20% lower than D1 which means the intra-industry diversification contributes about 20% of the total 5-digit product level diversification. Using 3-digit SIC, D3 is about 30% lower than D1. However, the proportion of D3 to D1 or D4 to D1 doesn't change much over time. This suggests the composition of inter- or intra-industry diversification remains stable in my sample period.

Different measures of diversification show different levels of index but the trends and cyclicality look remarkably similar to one another. Since almost all aspects of diversification analyses share similar trends across different measures, I will use D1 to explain trends of diversification for the rest of the paper. However, I'll also show other measures of diversification if discussions about magnitude of different indexes are needed.

Firm level analysis: Industry level

In Table 3, the average diversification index shows great variation by industry.[27] Overall, firms in Paper, Chemical, Petroleum, Transportation, and Instruments have a higher mean diversification index in 1974-1998. Single-unit firms in Food, Lumber, Printing, Chemical and Petroleum industries have high diversification. For multi-unit firms, Paper, Chemical, Machinery, Transportation Equipment and Instruments have high diversification. The Chemical industry has high diversification both in single-unit and multi-unit firms. The high diversification of Paper, Transportation and Instruments is driven by their highly diversified multi-unit firms.

Table 3 also displays the estimates of correlation coefficients between the diversification index and the value of shipments by sector. Out of nineteen industries, twelve have negative

[27] SIC is based on 1987 changes. See Appendix A for detail.

Table 3 Firm Level Average Diversification Index(D1) and Correlation with Growth of Real Shipment by 2 digit SIC Industry

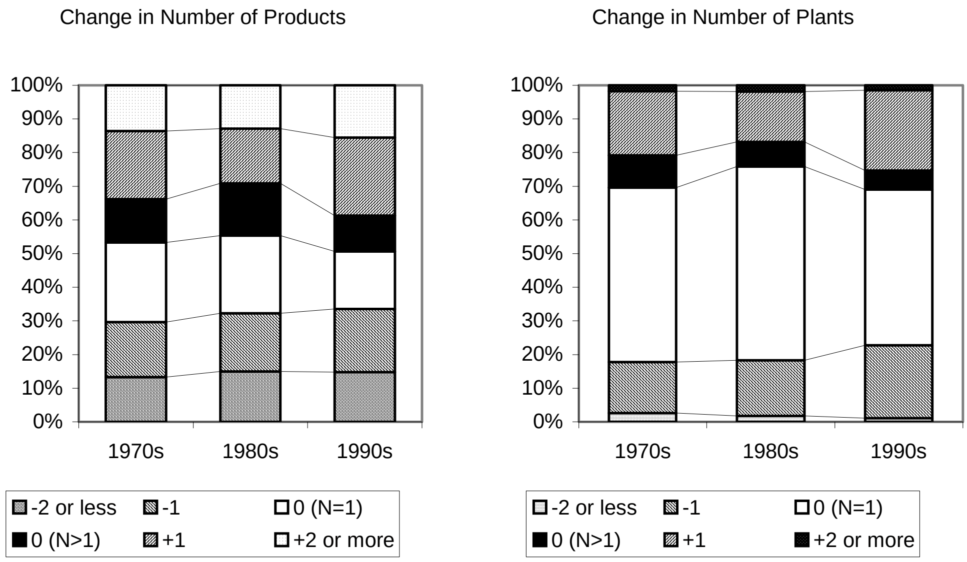
Industry	Total		SU		MU	
	mean	Corr. Coeff.	mean	Corr. Coeff.	mean	Corr. Coeff.
20 Food	0.53	-0.20	0.19	-0.28	0.51	-0.30
22 Textile	0.55	-0.17	0.13	0.26	0.57	-0.02
23 Apparel	0.54	0.44*	0.17	0.53*	0.61	-0.08
24 Lumber	0.47	-0.34	0.18	-0.34	0.63	-0.53*
25 Furniture	0.50	0.07	0.16	-0.03	0.56	-0.44
26 Paper	0.73	0.27	0.12	0.07	0.75	0.10
27 Printing	0.56	-0.57*	0.24	0.45*	0.58	-0.67*
28 Chemical	0.74	-0.64*	0.18	-0.42*	0.77	-0.71*
29 Petroleum	0.70	0.07	0.27	0.36	0.71	0.00
30 Rubber	0.66	0.52*	0.15	0.25	0.71	0.53*
31 Leather	0.49	-0.13	0.13	0.55*	0.55	0.04
32 Stone	0.63	0.35	0.10	0.17	0.68	0.10
33 Metal	0.63	-0.10	0.16	-0.11	0.70	-0.26
34 Fabricated Metal	0.65	-0.02	0.14	0.03	0.72	0.34
35 Machinery	0.69	-0.49*	0.15	0.30	0.73	0.45
36 Electronic	0.69	-0.52*	0.12	-0.25	0.70	-0.28
37 Transportation	0.73	0.08	0.13	0.25	0.75	-0.01
38 Instruments	0.77	-0.18	0.11	0.09	0.80	0.07
39 Miscellaneous	0.78	-0.30	0.09	0.56*	0.81	-0.30

*significance at the 95% level
Note: Industry 20 includes industry 21 (Tobacco) due to the private information disclosure issue.
Source: Diversification index from author's calculation, growth rate of real shipments from Census Bureau

correlation coefficients. Among the six significant correlations, four have negative signs. As discussed in Section 4-1, thirteen industries have positive signs and four of five significant coefficients are positive for SU firms. For MU firms, twelve industries in total and three of four significant correlations have negative signs.

To summarize, it is very difficult to draw a clear conclusion regarding the cyclicality of aggregate or industry level diversification from the data. It is necessary to see the distribution of firms and to study diversification directly at the firm level to see how firms change their diversification.

Figure 7 Change in the Number of Plants and Products



Firm level analysis: Change of diversification

Since the choice of number of products is discrete, it is interesting to see how firms adjust their number of products over time. The first graph of Figure 6 displays the distribution of firms over year-to-year changes in the number of products. Firms are classified into six groups every year: Firms that discontinue producing two or more products compared to the previous year (-2); Firms that discontinue producing one product (-1); Firms that produce a single product in both years (0 with N=1); Firms that produce the same number of multiple products (0 with N>1); Firms that produce one more product than previous year (+1); Firms that produce 2 or more products than previous year (+2). We get an annual distribution of firms by this classification. Figure 6 shows the distribution of the annual series averaged by decade, showing that the number of single-product producers decreased in the 1990s (white-colored block).[28] Firms with no change in the number of products (black-colored block) also decreased, while there was an increase in the

[28] From the bottom, N(t)-N(t-1)<=-2, -1, 0 given that N(t)-N(t-1)=1, 0 given that N(t-1)>1, +1, and +2 are displayed in Figure 6.

share of firms that increased or decreased one product (slashed blocks). These firms are "product-switchers" that adjust their product portfolio with one marginal product.

Multi-unit firms make a discrete choice regarding the number of plants that operate. The second graph in Figure 7 shows the decade average of the distribution of firms by the annual change in number of plants, with the same categories as the first graph of Figure 7. The shares of single plant firms (white-colored block) and of firms with the same number of plants in any two consecutive years (black-colored block) decreased in the 1990s. There are many multi-unit firms that adjust the number of plants up or down by one.

Even when two multi-unit firms produce identical products, they can be different in terms of how they allocate production. For example, in Table 4, Firm I produces product X in plant A and product Y in plant B. Firm II produces both X and Y in plant A and only X in B. Firm I owns two specialized plants while Firm II has one diversified plant and one specialized plant, although they have the same firm level diversification index. The diversification index can be decomposed to distinguish these two firms. Equation 1 groups the products into two categories: those produced in multiple plants or in a single plant. The share of production diversification factor (r_{pd}) reflects the diversification of production, not the diversification of products. r_{pd} is 0 for Firm 1 and 0.5 for Firm II.

Equation 2 investigates further the link between establishment and firm diversification. Since a firm is defined as the sum of its establishments, a firm's diversification must be a function of diversification within and among its plants. Consider adding and subtracting a shipments-weighted average of diversification indexes for a firm's establishments to the right-hand side of an identity equating the firm's diversification index with itself. The within-plant factor reflects the contribution of within-establishment diversification to overall firm level diversification. The among-plant factor recognizes that differences in product mix across plants are captured in the firm measure but not in the individual plant measure. It quantifies the contribution of diversification among a firm's plants. In the example of Table 4, the within plant factor is .375 for Firm II.

Equation 1 Production Diversification

$$d = 1 - (\underbrace{\sum_{i \in A} S_i^2}_{\text{Diversified Production}} + \underbrace{\sum_{i \in B} S_i^2}_{\text{Specialized Production}}) = (r_{pd} + r_{ps})d$$

where,

$$r_{pd} = \sum_{i \in A} S_i^2 / \sum_i S_i^2,\ r_{ps} = 1 - r_{pd}$$

$i \in A$ product i produced in multiple plants

$i \in B$ product i produced only in one plant

Equation 2 Within/Among-plant Diversification

$$d^f = \underbrace{\sum_j a_j d_j^{est}}_{\text{Within-plant}} + \underbrace{(d^f - \sum_j a_j d_j^{est})}_{\text{Among-plant}} = (r_{wp} + r_{ap})d^f$$

where,

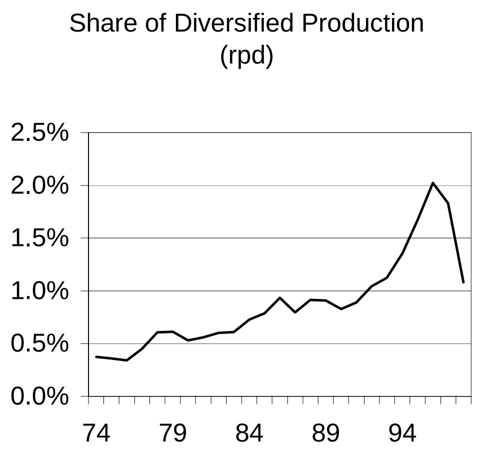
a_j = shipment share of the jth plant

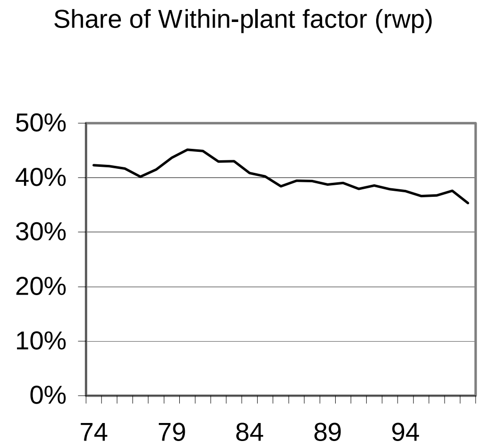
d^f = firm level diversification, d^{est} = plant level diversification

$$\mathrm{r_{wp}} = \sum_j a_j d_j^{est} \Big/ d^f,\ \mathrm{r_{ap}} = 1 - \mathrm{r_{wp}}$$

The first graph in Figure 8 plots the share of diversified production (r_{pd}) from 1974 to 1998. The production diversification factor increased in 1990s but is below 2% for the whole sample period. Therefore, specialized production is much more common. The second graph in Figure 8 plots the share of within plant diversification in overall diversification (r_{wp}). Within-plant

Figure 8 Share of Diversified Production (r_{pd}) and Share of Within-plant diversification (r_{wp})





diversification declined over the last three decades. The two graphs in Figure 8 imply that firms are specializing productions more and more.

The aggregate statistics suggest that the average firm doesn't change its diversification much in short time period. Figure 9 plots the average net change of firms' diversification in two consecutive years, that is, NET=avg(d(t)-(d(t-1)) for firms that are operating in both years. NET is very small throughout the sample period. One might be tempted to conclude that fluctuations in diversification do not matter much because of the small annual changes. However, we see much bigger fluctuation when we break down the net changes into two components, the positive changes (POS=avg(d(t)-(d(t-1)) for the firms with d(t)>(d(t-1)) and negative changes(NEG=avg(d(t)-(d(t-1)) for the firms with d(t)<(d(t-1)). NET is equal to POS minus NEG (NET=POS-NEG). Figure 9 suggests there are many firms that increase or decrease their diversification keeping the overall average change small.

Figure 9 Positive, Negative and Net change of diversification

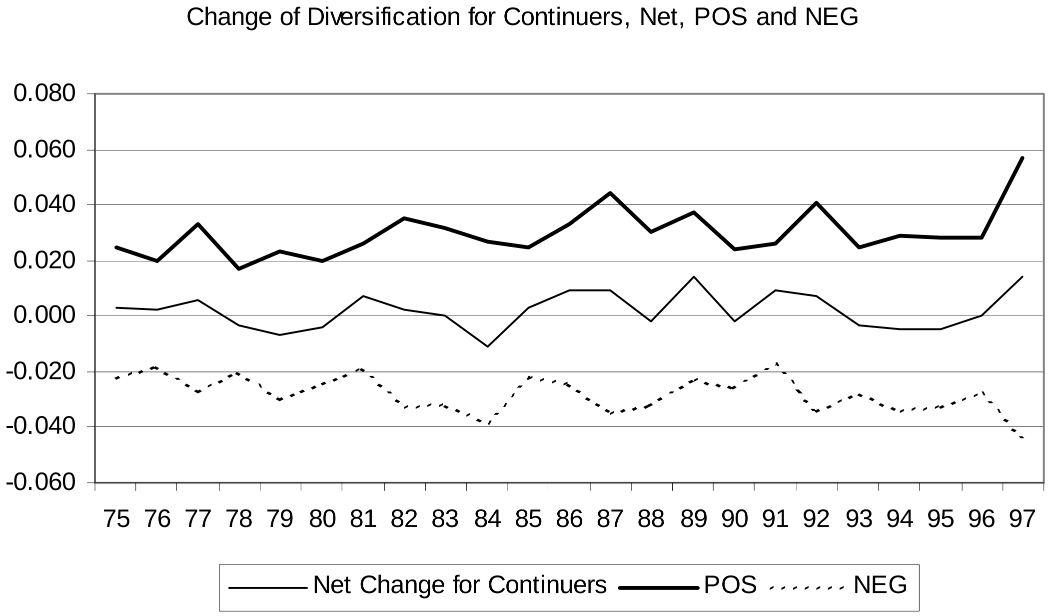


Table 5 Distribution (percentiles) of Firms' correlation coefficients between new/lost industry and the primary industry

	5th	10th	Median	90th	95th
Firms with increasing number of industries	.02	.32	.87	.97	.98
Firms with decreasing number of industries	-.1	.2	.86	.97	.98

It is important to know which industry the firm diversifies. Does the firm diversify into industries which have positive correlation coefficients with current primary industry? We can shed a little bit of light on this issue by looking at the distribution of firms' correlation coefficients between new/lost industry and the primary industry when the firm increases/decreases number of products. Table 5 shows percentiles of correlation coefficients of firms. Among the group of firms with increasing number of industries in two consecutive years, the median firm's correlation coefficient between the new industry and its primary industry is .87. Even the 5th percentile of firms has positive correlation (.02). This suggests that when the firm increases its product portfolio, it usually diversifies into similar industries with positive correlation with its primary product. Likewise, among the group of firms with decreasing number of industries, the median firm's correlation coefficient is .86. The correlation is .2 for the 10th percentile firm and -.1 for 5th percentile firm. This means many firms shut down products that have positively correlated industries but some firms withdraw from negatively correlated industries. This suggests that the avoiding-risk factor is less important and the trend of specialization is more important in the firm's decision of diversification.

Firm level analysis: average diversification index by firm characteristics

Appendix C includes average diversification indexes by various firm characteristics. Single unit firms have lower diversification than multi unit firms (Table AC-2 and AC-3). Big firms have higher diversification (Table AC-10), as old firms (Table AC-11). There is no clear regional difference in diversification (Table AC-12). If the firm is vertically integrated, the firm will diversify into the products that are consumed within the firm to produce the final product. The share of Interplant Product Transfers to the total value of shipments of the firm (IPT) is used as an indicator for vertical integration. Table AC-13 shows that diversification increases with IPT but starts to decrease if IPT is too high, suggesting that a firm with very high vertical integration diversifies less and specializes more. Table AC-14 shows that diversification is higher for firms with lower labor cost share. Labor intensive firms tend to specialize. A high ratio of organizational workers may be needed facilitate the complicated process of multi-product production. Diversification increases with the share of non-production worker wage to the total wage cost but starts to decrease when the share gets very high (Table AC-15). The relationship between diversification and exporting is not clear in Table AC-16, although non-exporting firms tend to have lower diversification because they are relatively small firms.

With the limited information from ASM product data, we can see how heterogeneous products are by looking at the number of industries (at the 2-digit SIC level) spanned by the number of products of the firm. In Table AC-17, for example, firms which produce 10 products diversify across 2.7 industries in the 1970s, while they diversify across 2.3 industries in the 1990s (row 10). The number of industries declines for firms that produce many products. The second panel of Table AC-17 shows the number of industries by 3-digit SIC. Table AC-18 shows the geographical dispersion of plants within firms by displaying the number of different counties where plants are located as a function of the number of plants. For example, firms with 10 plants locate them in 8.3 counties in the 1970s and 8.7 counties in 1990s (row 10). In general, firms diversify more geographically in 1990s than in 1970s.

In summary, firm-level diversification is very heterogeneous by firm characteristics, but most of the statistics confirm our conjecture about what types of firms have high diversification: Big firms, old firms, capital-intensive firms, firms with many organizational workers, etc. Furthermore, the trend of diversification is common across regions in US. It is worth a notice that firms seem less diversified horizontally but more diversified geographically: Even the highly diversified firm specializes in a couple of 2-digit industries, but firms have operated their plants in more diversified locations over time.

Section 5. Conclusion

There have been a lot of studies on firm level diversification but none have covered the whole manufacturing sector over a long period of time. In this chapter, I studied firm level diversification of the manufacturing sector between 1974 and 1998 and described the trend and cyclicality of diversification in detail. From the rich description in this chapter, the new findings of firm level product diversification can be summarized as follows:

(1) Aggregate diversification declined both at the establishment and firm level since the early 1980s. The downward trend is common across many industries. The declining diversification is quite surprising because diversification has been regarded as a virtue of firms in last several decades.

(2) Whether diversification is pro-cyclical or counter-cyclical is not clear at the aggregate or industry level. Many studies have argued on the pro- or counter-cyclicality of diversification, but this chpater shows that there is heterogeity in cyclicality of diversification.

(3) A large fraction of firms change the number of products and plants annually. The declining diversification measure suggests that firms have become more specialized, but it is clear that the number of products is not fixed for firms even in the short run.

I constructed different indexes of diversification to capture different aspects of diversificaiton. Diversification index using across-indsutry correlation as distance weights shows that firms, especially single unit firms, have not diversified into remotely related indsutries. Diversificaion indexes using less detailed product classification show that within-industry diversification (at 3 or 4-digit SIC level) contributes 20%-30% of total diversification.

From anecdotal evidence, it is widely known that product diversification is a decision variable for firms, which is contrary to assumptions of fixed diversification in many theoretical models in the literature. This chapter shows that firms actively change their product diversification at a short-term frequency. The number of products and plants behaves like an adjustment margin. These stylized facts can be a benchmark against which firm production models should be verified.

The fact that firms can change the number of products frequently sheds light on studies of flexible capital. If firms adopt more flexible capital to produce their outputs, the degree of diversification doesn't need to be fixed over time. Firms will have more margins to respond to the business cycle if they have more flexible capital as well as more flexible labor contracts. The new findings in this chapter can be added to the set of the evidence that firms have flexible capital in US manufacturing sector.

A question naturally arising from the evidence of declining diversification is whether this fact is unique in U.S. Especially in East Asia, big conglomerates that diversify across a variety of industries have been regarded as the engine of fast growth. A cross-country study on diversification trends will be one of the next research topics in this field.

Chapter 3: Volatility Change and Diversification

Section 1. Introduction

Some of the studies on economic volatility in US were introduced in Chapter 1. The significant change in mid-1980s was not restricted to any one sector, level or indicator. Many economic indicators show less volatility. Stock and Watson (2002) show that the moderation in volatility is widespread and appears in both nominal and real series. The decline in volatility is most pronounced for residential investment, output of durable goods and output of structures. The decline in volatility appears both in measures of real economic activity and in broad measures of wage and price inflation. The decline in aggregate volatility is pervasive.

Recent studies show that volatility has decreased not only at the aggregate level but also at sectoral level. They find that the decrease is not confined to any one sector, but is common to many sectors. Kim et al (2004) shows that the volatility reduction in aggregate output is visible in more sectors of output than simply durable goods production. Specifically, there is an evidence of a volatility reduction in the production of structures and non-durable goods.

Comin and Mulani (2003) investigate the evolution of volatility at the firm level. They find 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 at the firm level has increased. They argue that idiosyncratic firm-level volatility diverges from the aggregate trend. But they use the data only for only public firms.[29] It has not been confirmed whether idiosyncratic volatility has been increasing for all firms, including small non-public firms.

This chapter verifies these findings on volatility with ASM and CM data. Then I study the effect of volatility on the firm level diversification decision. Among the suggested motives for

[29] They use COMPUSTAT data.

diversification, risk-avoidance dominates the literature: With liquidity constraints, firm investment depends on cash flows.[30] If firms diversify over products to smooth their profits, then they should respond to the volatility of profit shocks on every level. In particular, aggregate, sectoral and idiosyncratic profit shocks can affect firm level diversification. My main findings confirm the decrease in aggregate, sectoral and idiosyncratic volatility of the profit rate, and show that a less volatile profit rate leads to less diversification.

Section 2 provides a conceptual discussion of diversification and examines the relationship between diversification and profit volatility. Section 3 describes stylized facts regarding the volatility change. Section 4 tests the relationship between firm level diversification and the aggregate, industrial and idiosyncratic profit volatility. Section 5 summarizes the facts and analyses.

Section 2. Volatility and Diversification

Changes in volatility can affect diversification at different levels. More formally,

$$(1) \qquad d_{it} = f(\sigma(A_{it})) \quad , \text{ where } \mathrm{i} = 1,2,...,\mathrm{N} \ , \mathrm{t} = 1,2,...\mathrm{T}$$

$$(2) \qquad A_{it} = \underbrace{A_t}_{\text{Aggregate factor}} + \underbrace{\left(A_{st} - A_t\right)}_{\text{Industrial factor}} + \underbrace{\left(A_{it} - A_{st}\right)}_{\text{Idiosyncratic factor}}$$

$$\text{where} \qquad A_t = \frac{1}{N}\sum_i A_{it} \quad , \quad A_{st} = \frac{1}{N_s}\sum_{i \in s} A_{it}$$

$$(3) \qquad \sigma(A_{it}) = \sqrt{\frac{\sum_{j=t-4}^{t+5}(A_{ij} - \overline{A}_{it})^2}{10}}, \quad \overline{A}_{it} = \frac{\sum_{j=t-4}^{t+5} A_{ij}}{10}$$

[30] Jovanovic(1993)

where the diversification for firm i (d_i) is a function of the volatility of the profit rate (A_{it}). In Equation (2), the profit rate consists of three factors, aggregate, industrial, and idiosyncratic factors. There are profit shocks at three levels ($A_t, A_{st} - A_t, A_{it} - A_{st}$) and the equation holds as an identity. So the industrial and idiosyncratic components are defined as deviations from the average industry or firm profit shocks.[31] Equation (3) defines the volatility of the time series for firm level profits as $\sigma(A_{it})$ by computing the series of standard deviations of 10-year rolling windows of A_{it}.[32]

Profit shocks at the aggregate, industrial and idiosyncratic level are assumed to be orthogonal to one another by construction. Since the shocks are orthogonal, the standard deviations of the shocks over time (volatility) are orthogonal to one another. Therefore, orthogonality is preserved for the volatility of observed profit rates at the aggregate ($\sigma(A_t)$), industry ($\sigma(A_{st} - A_t)$) and firm level ($\sigma(A_{it} - A_{st})$).

We can test the following hypotheses regarding the partial effect of profit shocks on the firm level diversification:

(1) $H_0 : \frac{\partial f}{\partial \sigma(A_t)} > 0$

(2) $H_0 : \frac{\partial f}{\partial \sigma(A_{st} - A_t)} > 0 \qquad , s = Two - digit\ SIC\ Industry$

(3) $H_0 : \frac{\partial f}{\partial \sigma(A_{it} - A_{st})} > 0 \qquad , i = 1,2,..., N$

[31] This is similar to a Cholesky decomposition.
[32] The standard deviation of a 10-year window is used as the measure of volatility in Comin and Mulani (2003). Stock and Watson (2002) uses the standard deviation by decade. Kahn et al(2002) uses the standard deviation in three sample periods (1953-1968, 1968-1983, and 1984-2000).

It is very intuitive that the sectoral and idiosyncratic volatility affect the diversification decision. Firms can insure themselves against bad profit shocks by diversifying into different industries and products. However, firms cannot avoid the aggregate shock because no matter how many products they produce, the aggregate shock will hit them equally.

The aggregate shock in this analysis includes not only aggregate profit fluctuations of manufacturing sector but any disturbance that is not captured by sectoral or idiosyncratic volatility in the economy. For example, fluctuations in the service sector or financial sectors will show up as aggregate volatility change. A time trend is not identified separately from this aggregate component.

Section 3. Stylized facts: Volatility

Figure 1 shows that the aggregate profit volatility ($\sigma(A_t)$) has constantly decreased over my sample period. Since I use a rolling standard deviation across 10 years as the measure of volatility, the volatility measure for the first 4 years is only forward looking, and volatility fro the last 5 years is backward looking. Therefore, only the data between 1978 and 1993 are appropriate. Profit rates are measured as sales minus variable costs, divided by the capital stock.[33]

Table 1 shows the volatility of the average firm level profit rate by industry. Almost all industries had lower profit volatility in 1993 than in 1978. The first graph of Figure 2 displays industries that had low volatility in the 1980s. The second graph of Figure 2 shows industries with high volatility in the 1980s – Rubber, Leather, Machinery and Instruments. The volatility of industries not shown in Figure 2 is constant or slightly decreasing over time. The downward trend

[33] See Appendix A for detail.

Table 1 Profit Volatility by Industry ($\sigma(A_{st} - A_t)$)

Industry	1978	1983	1988	1993
20 Food	0.19	0.13	0.13	0.11
22 Textile	0.14	0.10	0.12	0.15
23 Apparel	0.52	0.36	0.42	0.38
24 Lumber	1.07	0.06	0.11	0.12
25 Furniture	0.35	0.32	0.29	0.22
26 Paper	0.20	0.22	0.18	0.09
27 Printing	0.30	0.14	0.17	0.09
28 Chemical	0.21	0.28	0.31	0.13
29 Petroleum	0.82	0.72	0.33	0.41
30 Rubber	0.17	0.56	0.65	0.24
31 Leather	1.33	1.31	1.52	1.28
32 Stone	0.10	0.13	0.16	0.20
33 Metal	1.22	0.30	0.39	0.37
34 Fabricated Metal	0.07	0.18	0.20	0.04
35 Machinery	0.58	1.20	1.25	0.52
36 Electronic	0.94	0.73	0.31	0.54
37 Transportation	1.11	0.81	0.55	0.47
38 Instruments	0.44	0.28	0.52	0.47
39 Miscellaneous	1.21	1.08	0.36	0.21

Note: Food (Industry 20) includes Tobacco (Industry 21) due to the private information disclosure policy of the Bureau of Census

of volatility is widespread across industries, but not universal. This is consistent with evidence in the literature.

At the idiosyncratic level, some firms have higher volatility, and other firms have lower volatility in the 1990s than in the 1970s. I calculate the volatility for each firm, then take the mean ($\underset{i}{avg}(\sigma(A_{it} - A_{st}))$) and cross-sectioned standard deviation ($\underset{i}{std}(\sigma(A_{it} - A_{st}))$) in every year. Figure 3 shows the evolution of firm level volatility. The mean of idiosyncratic volatility increased in the early 1980s but fell in the late 1980s as shown in the first graph of Figure 3. Although there is an increase in the late 1990s, the standard deviation of firm level volatility remained the same or slightly increased between 1979 and 1994 as shown in the second graph of Figure 3.

Figure 1 Mean and Average Volatility of Firm Level Profit Rates

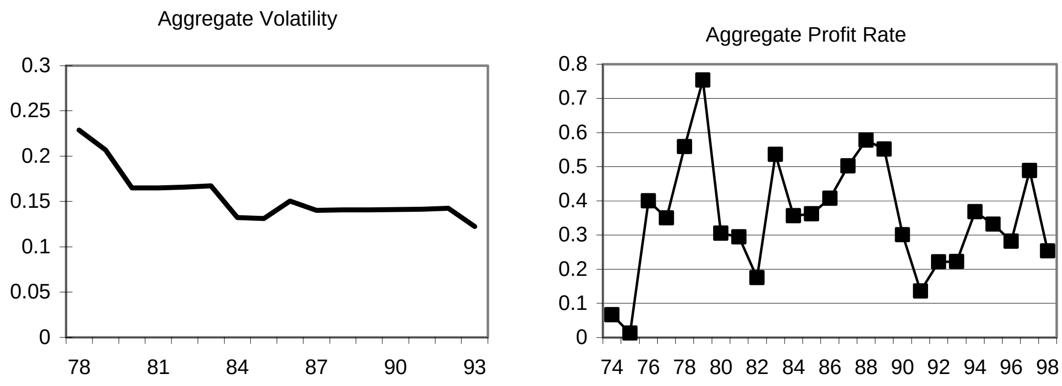


Figure 2 Volatility of average firm level profit rates by industry

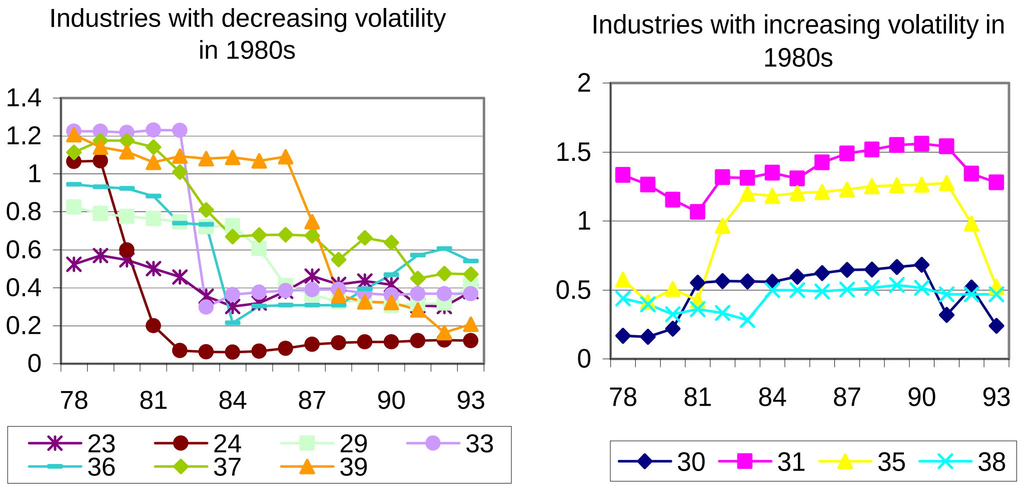


Figure 3 Mean and standard deviation of firm level idiosyncratic volatility

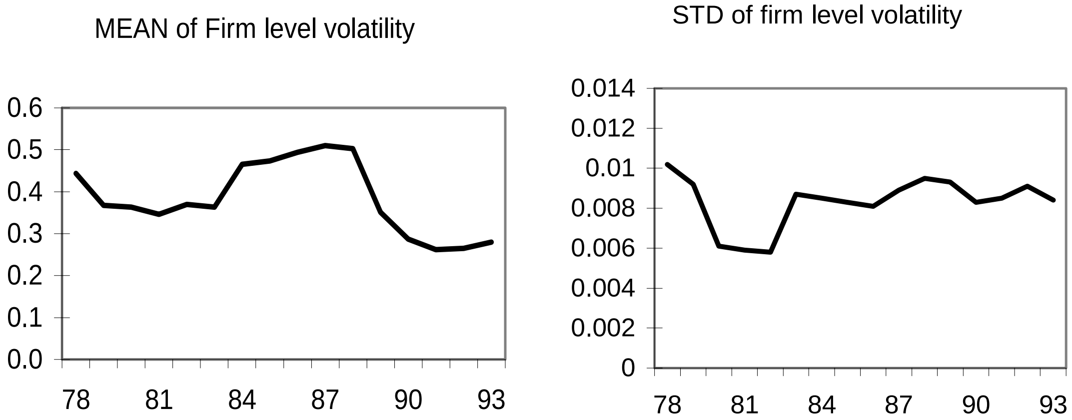
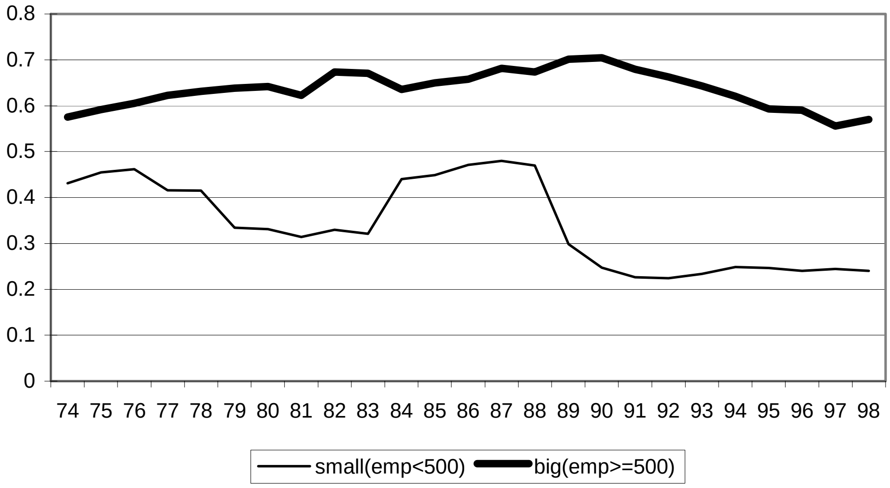


Figure 4 Average Idiosyncratic Volatility by Size of Firm



The downward trend of idiosyncratic volatility is different from evidences in the literature. Comin and Mulani (2003) showed an upward trend of idiosyncratic volatility for relatively big firms in COMPUSTAT data. Although they showed the result is not coming from the sample bias in the paper, I verified the trend of idiosyncratic volatility for big and small firms, separately. Figure 4 shows the idiosyncratic volatility by the two size group of firms.[34] An increasing volatility is not observed even for big firms. Unlike the downward trend of aggregate or sectoral volatility, the trend of idiosyncratic volatility is not unarguable.

Section 4. Diversification and Volatility: Estimation

The three key stylized facts of diversification from Chapter 2 are (1) a strong downward trend of diversification, (2) industrial variation in the cyclicality of diversification and (3) heterogeneous movement of firm level diversification. And the three key empirical results of volatility in Chapter 3 are (1) decreased aggregate volatility, (2) decreased volatility in many

[34] I used total employment as the size measure.

industries and (3) decrease of firm level volatility. Risk-avoidance is an incentive to diversity which links these sets of findings. The hypothesis is that the change of volatility at the aggregate, industrial and firm level can affect a firm's diversification.

The firm level diversification index is regressed on the volatility of aggregate, industrial and firm level profit rate.

$$d_{it} = \beta_0 + \beta_1 AGGVOL_t + \beta_2 INDVOL_{st} + \beta_3 IDIVOL_{it} + \beta_4 X_{it} + \varepsilon_{it}$$

, where

i = firm i

s = 2 - digit industry of firm i

X = firm level characteristics

d is one of the firm level diversification measures.. AGGVOL is the volatility of the average of firm level profit rates($\sigma(A_t)$). INDVOL is the volatility of the industry level average of the deviation from aggregate profit rates ($\sigma(A_{st} - A_t)$). IDIVOL is the volatility of the deviation of firm level profit rates from the industry average($\sigma(A_{it} - A_{st})$). Firm level characteristics(X) include Firm Size(SIZE), Firm Age (AGE), and the Share of Organizational Workers to the total employment(FOE).

By using four measures of diversification as dependent variable, we can capture different effects of volatility and firm characteristics on diversification. D1 uses 5-digit SIC which is the most detailed information available on products in ASM firms and it is the benchmark case of estimations. D2 adds distance measure to D1 using correlation of industries in which the firm diversifies. D2 is bigger than D1 when the firm diversifies in uncorrelated or negatively correlated industries. Therefore, effects of right hand side variables will be magnified for firms with D2 higher than D1. When we use 3-digit or 4-digit SIC (D3 and D4), we only consider across-industry diversification. The same amount of change in right hand side variable has different effects on these different measures of diversification and a comparison of coefficients shows whether the firm reacts most sensitively with its diversification across 3-digit, 4-digit or 5-digit industry.

Table 2 shows the results of firm level regressions using the left-censored Tobit estimation method. By definition, single-product producers have a diversification index equal to 0. Therefore, the left-censored Tobit model is appropriate because we have a mass point at 0 for the dependent variable. I use 10 year rolling window to get volatility, but volatility in 1974-1977 and 1994-1998 can use less than ten years of observation. Therefore, I showed the estimation results for the total sample period (1974-1998) and the period of 1978-1993 to check the robustness of estimation. I repeated the regression using Diversification Index(D1), Index with distance weight(D2), Index using 3-digit SIC(D3) and Index using 4-digit SIC(D4) as the left-hand side variable. Time trend(YEAR) and location(REGION) are controlled as fixed effects.

In the sample period of 1974-1998, the coefficient estimates for volatility (AGGVOL, INDVOL, IDIOVOL) are in all cases and they are statistically significant for most cases. Coefficients for AGGVOL are different by the specification, but coefficients for INDVOL and IDIOVOL are relatively stable and robust. Coefficients for AGGVOL, INDVOL and IDIOVOL are different depending which measure of diversification is used as the left-hand side variable. However, the sign of the estimates remains positive and the order of magnitude (AGGVOL>IDIOVOL>INDVOL) are the same with D1 and D3 as the dependent variable. Estimation result for time period 1978-1993 is very similar to the result for 1974-1998. The sign and order of magnitude are not affected by the choice of left-hand side variable or specification. The result shows that diversification responds to aggregate volatility, industry volatility, and the idiosyncratic volatility of firm performance relative to those of other firms in the sector. When other idiosyncratic firm level characteristics (SIZE, AGE, FOE) are included in the estimation, they reduce the level of IDIOVOL and INDVOL coefficients.

Decreased aggregate volatility can reduce diversification by a great amount. In the specification IV for sample period 1978-1994, on average, 1% change in aggregate volatility (AGGVOL) will reduce diversification by .9% in 3-digit (D3), .93% in 4-digit (D4), and 1.4% in 5-digit (D1). When the aggregate volatility falls, firms reduce diversification at all levels, 3, 4 or 5-digit industries, but the biggest decrease occurs at the 5-digit SIC level diversification (D1). It suggests that firms specialize within (3 or 4 digit) industries but relatively diversify across multiple industries when volatility declines, which is consistent with other results in the previous chapter. The decrease of diversification is even bigger when we consider the distance between diversified industries (D2). If the aggregate volatility decreases by 1%, diversification decreases by 1.73% for D2.

Estimates for coefficients of INDVOL or IDIOVOL do not show much difference among one another. On average, 1% change in the industry volatility will reduce diversification measures by 0.01-0.05%. Likewise, 1% change in the idiosyncratic volatility will reduce an average firm's diversification measures by 0.01-0.02%.

The results in Table 2 show that the effect of aggregate volatility change on diversification is sensitive to the measurement of diversification. D3 uses 3-digit SIC and it is most closely linked to the "segment" which is widely used in diversification literature as the definition of industry. From the fact the aggregate volatility have decreased in last three decades in U.S., I find that the decrease in aggregate volatility can have contributed to the decrease in diversification. There is little difference in magnitude of this effect on D3 and D4, which suggests that the average firm has changed its diversification by changing the product portfolio across 3-digit industries, not 4-digit when aggregate volatility falls. However, the fact that the magnitude of this effect is much bigger for D1 suggests that the average firm has reduced its diversification across 5-digit industries by a lot. The coefficient is biggest for D2 where the firm diversifies across non-correlated or negatively correlated industries. A firm that has diversified across many 5-digit industries and across non-correlated or negatively correlated industries will have biggest decreased in its diversification with the same amount of changes in volatility if we measure diversification as D2. It predicts that we will observe much bigger decrease in diversification by industry (5-digit) than diversification by segments (3-digit) when the aggregate volatility declines. If we study diversification only using segments of firms, we may not be able to capture this high underlying degree of specialization at 5-digit industry level.

Regression results suggest that firm diversification responds positively to the volatility of aggregate, industrial, and idiosyncratic profit shocks. As the aggregate volatility has decreased in the U.S. manufacturing sector, firms have had less incentive to diversify against bad aggregate shocks. Industrial volatility has the same effect on firm level diversification. Idiosyncratic volatility decreased in the late 1980s, suggesting that firms have less incentive to diversify to hedge against idiosyncratic shocks.

Aggregate volatility plays a big role in explaining the change of diversification. Although firms cannot hedge themselves against aggregate volatility by diversification, they still adjust diversification in response to the aggregate shocks, which might include business trend, changes in the financial environment, or business regulation changes.

Table 2 Left-censored Tobit Estimation (Firm Level)

Dependent Variable=D1, D2, D3, and D4 (Firm level diversification index)
Fixed Effects= YEAR, REGION   Name of Distribution=Normal   Sample Period: 1974-1998
Number of Observations=561,565   Non-censored Values=234,490

		I			II			III			IV		
		coeff		std	coeff		std	coeff		std	coeff		std
d1	Intercept	-0.37	**	0.006	-0.71	**	0.006	-0.80	**	0.006	-0.84	**	0.006
	Aggvol	0.61	**	0.150	0.40	**	0.013	0.85	**	0.014	0.87	**	0.014
	Indvol	0.04	**	0.020	0.02	**	0.002	0.02	**	0.002	0.02	**	0.002
	Idiovol	0.05	**	0.010	0.01	**	0.001	0.01	**	0.001	0.01	**	0.001
	Aggprof	0.18	**	0.040	0.02	**	0.003	0.02	**	0.003	0.02	**	0.003
	Indrpof	0.04	**	0.010	-0.03	**	0.001	-0.02	**	0.001	-0.02	**	0.001
	Idioprof	0.05	**	0.010	-0.01	**	0.001	0.01	**	0.001	-0.01	**	0.001
	Size				0.13	**	0.001	0.11	**	0.000	0.11	**	0.000
	Age							0.01		0.000	0.01	**	0.000
	Foe										0.17	**	0.005
d2	Intercept	-0.32	**	0.006	-0.66	**	0.006	-0.75	**	0.006	-0.79	**	0.006
	Aggvol	0.85	**	0.150	0.67	**	0.013	1.10	**	0.014	1.12	**	0.014
	Indvol	0.03	**	0.020	0.02	**	0.002	0.01	**	0.002	0.01	**	0.002
	Idiovol	0.05	**	0.010	0.02	**	0.001	0.02	**	0.001	0.02	**	0.001
	Aggprof	0.14	**	0.040	-0.01	*	0.003	-0.01	**	0.004	-0.01	**	0.004
	Indrpof	0.04	**	0.010	-0.02	**	0.001	-0.02	**	0.001	-0.02	**	0.001
	Idioprof	0.05	**	0.010	-0.01	**	0.001	-0.01	**	0.001	-0.01	**	0.001
	Size				0.13	**	0.001	0.11	**	0.000	0.11	**	0.000
	Age							0.01		0.000	0.01	**	0.000
	Foe										0.16	**	0.006
d3	Intercept	-0.68	**	0.009	-1.08	**	0.008	-1.18	**	0.008	-1.22	**	0.008
	Aggvol	0.43	**	0.021	0.13	*	0.010	0.55	**	0.019	0.57	**	0.019
	Indvol	0.04	**	0.003	0.04	**	0.003	0.05	**	0.003	0.05	**	0.003
	Idiovol	0.06	**	0.002	0.03	**	0.002	0.02	**	0.002	0.02	**	0.002
	Aggprof	0.12	**	0.006	-0.04	**	0.005	-0.04	**	0.005	-0.05	**	0.005
	Indrpof	0.02	**	0.002	-0.07	**	0.001	-0.06	**	0.001	-0.06	**	0.001
	Idioprof	0.04	**	0.001	-0.04	**	0.001	-0.04	**	0.001	-0.04	**	0.001
	Size				0.16	**	0.001	0.14	**	0.001	0.14	**	0.001
	Age							0.01		0.000	0.01	**	0.000
	Foe										0.17	**	0.008
d4	Intercept	-0.60	**	0.008	-1.00	**	0.007	-1.11	**	0.007	-1.15	**	0.008
	Aggvol	0.44	**	0.010	0.16	**	0.010	0.67	**	0.010	0.69	**	0.010
	Indvol	0.00		0.003	0.01	**	0.003	0.01	**	0.003	0.01	**	0.003
	Idiovol	0.06	**	0.002	0.02	**	0.001	0.02	**	0.001	0.02	**	0.001
	Aggprof	0.16	**	0.005	0.00		0.004	0.00		0.004	0.00		0.004
	Indrpof	0.04	**	0.002	-0.03	**	0.001	-0.03	**	0.001	-0.03	**	0.001
	Idioprof	0.05	**	0.001	-0.01	**	0.001	-0.01	**	0.001	-0.01	**	0.001
	Size				0.15	**	0.001	0.13	**	0.001	0.13	**	0.001
	Age							0.01		0.000	0.01	**	0.000
	Foe										0.15	**	0.007

Note: * significance at the 95% level, ** significance at the 99% level
REGION: represents 9 different geographical locations in the data. See Appendix C.

Table 2 Left-censored Tobit Estimation (continued)

Dependent Variable=D1, D2, D3 and D4 (Firm level diversification index)
Fixed Effects= YEAR, REGION Name of Distribution=Normal Sample Period: 1978-1993
Number of Observations=359 177 Non-censored Values=156 234

		I			II			III			IV		
		coeff		std	coeff		std	coeff		std	coeff		std
d1	Intercept	-0.26	**	0.007	-0.63	**	0.006	-0.74	**	0.006	-0.78	**	0.007
	Aggvol	-0.07		0.040	0.04	**	0.030	1.36	**	0.030	1.40	**	0.030
	Indvol	0.04	**	0.003	0.02	**	0.002	0.02	**	0.002	0.02	**	0.002
	Idiovol	0.07	**	0.002	0.01	**	0.002	0.01	**	0.002	0.01	**	0.002
	Aggprof	0.18	**	0.006	-0.03	**	0.005	-0.06	**	0.005	-0.07	**	0.005
	Indrpof	0.02	**	0.002	-0.02	**	0.001	-0.01	**	0.001	-0.01	**	0.001
	Idioprof	0.05	**	0.001	-0.01	**	0.001	0.00	**	0.001	0.00	*	0.001
	Size				0.13	**	0.001	0.11	**	0.001	0.11	**	0.001
	Age							0.01		0.000	0.01	**	0.000
	Foe										0.16	**	0.007
d2	Intercept	-0.21	**	0.007	-0.59	**	0.006	-0.69	**	0.006	-0.73	**	0.007
	Aggvol	0.27	**	0.040	1.00	**	0.030	1.69	**	0.030	1.73	**	0.030
	Indvol	0.02	**	0.003	0.01		0.002	0.00		0.002	0.00		0.002
	Idiovol	0.07	**	0.002	0.01	**	0.002	0.01	**	0.002	0.01	**	0.002
	Aggprof	0.12	**	0.006	-0.10	**	0.005	-0.13	**	0.005	-0.13	**	0.005
	Indrpof	0.03	**	0.002	-0.02	**	0.001	-0.01	**	0.001	-0.01	**	0.001
	Idioprof	0.05	**	0.001	-0.01	**	0.001	0.00	**	0.001	-0.01	**	0.001
	Size				0.13	**	0.001	0.11	**	0.001	0.11	**	0.001
	Age							0.01		0.000	0.01	**	0.000
	Foe										0.15	**	0.007
d3	Intercept	-0.56	**	0.010	-0.98	**	0.009	-1.11	**	0.008	-1.15	**	0.010
	Aggvol	0.57	**	0.050	0.20	*	0.047	0.87	**	0.019	0.90	**	0.049
	Indvol	0.04	**	0.004	0.05	**	0.003	0.05	**	0.003	0.05	**	0.003
	Idiovol	0.10	**	0.003	0.03	**	0.002	0.02	**	0.002	0.02	**	0.002
	Aggprof	0.14	**	0.008	-0.12	**	0.007	-0.14	**	0.005	-0.14	**	0.007
	Indrpof	0.00	*	0.002	-0.07	**	0.002	-0.06	**	0.001	-0.06	**	0.002
	Idioprof	0.03	**	0.001	-0.04	**	0.001	-0.04	**	0.001	-0.04	**	0.001
	Size				0.16	**	0.001	0.14	**	0.001	0.14	**	0.001
	Age							0.01	**	0.000	0.01	**	0.000
	Foe										0.16	**	0.010
d4	Intercept	-0.47	**	0.009	-0.89	**	0.008	-1.03	**	0.009	-1.07	**	0.009
	Aggvol	0.67	**	0.050	0.11	*	0.040	0.90	**	0.040	0.93	**	0.040
	Indvol	0.00		0.004	0.01	**	0.003	0.01	**	0.003	0.01	**	0.003
	Idiovol	0.09	**	0.002	0.02	**	0.002	0.02	**	0.002	0.02	**	0.002
	Aggprof	0.20	**	0.008	-0.05	**	0.006	-0.08	**	0.006	-0.08	**	0.006
	Indrpof	0.02	**	0.002	-0.03	**	0.002	-0.02	**	0.002	-0.02	**	0.002
	Idioprof	0.04	**	0.001	-0.01	**	0.001	-0.01	**	0.001	-0.01	**	0.001
	Size				0.15	**	0.001	0.13	**	0.001	0.13	**	0.001
	Age							0.01		0.000	0.01	**	0.000
	Foe										0.14	**	0.009

Note: * significance at the 95% level, ** significance at the 99% level
REGION: represents 9 different geographical locations in the data. See Appendix C.

Section 5. Conclusion

This chapter shows a new empirical relationship between the diversification and profit volatility. Micro level data for the manufacturing sector allow us to verify some of the stylized facts about volatility which are discussed in the literature. Using firm level profit rates, I find:

(1) Aggregate volatility declined over my sample period.

(2) Volatility decreased since the 1980s for most industries.

(3) The mean of firm level idiosyncratic volatility decreased in the late 1980s and the cross-sectional standard deviation of volatility did not change much.

Findings (1) and (2) are consistent with trends of volatility that have been established with aggregate data in the literature. Finding (3) is contrary to the upward trend of idiosyncratic volatility which has been found in other studies with large firm data. Although I cannot find evidence of a discontinuous drop in the middle of the 1980s as has been argued in the literature, the volatility of aggregate, industrial and idiosyncratic profit shocks has been falling in the manufacturing sector since 1980s.

The left-censored Tobit regression shows that firm level diversification is positively affected by aggregate, industrial and idiosyncratic profit volatility. Therefore, the decrease of volatility in US manufacturing has contributed to the decrease of diversification. As we have seen in the text, the overall volatility decreased, industry level volatility also decreased in many industries, and finally, idiosyncratic volatility has been reduced over my sample period. Firms have less incentive to diversify and the diversification index clearly shows a downward trend. I have not settled the arguments about the cause of the decreased volatility, but the effect of the volatility change on firm level diversification is clearly shown in this chapter.

The comparison of estimation results across different measures of diversification shows us that changes in volatility strongly affect diversification across 5-digit SIC industries rather than 4 or 3-digit industries. With volatility decreasing over time, firms specialize within (3 or 4-digit) industries, and diversify across multiple industries. This is consistent with other results in the paper and this trend of diversification may continue if the volatility keeps decreasing.

This chapter is a stepping stone for empirical analysis of the motives for diversification. If risk-avoidance is the biggest motive for diversification, firms don't need to diversify as much when volatility decreases. But I have not examined other factors that could cause changes of diversification. For example, firms may specialize to enhance productivity. One of the next research topics would be whether the trend toward specialization indeed increased productivity at the firm level.

Another research topic would be a counterfactual analysis. If volatility did not decrease, then would diversification have increased? It is not easy to answer this counterfactual question in U.S., but it can be answered by looking at other countries, especially developing countries. Many countries in Asia and Latin America have been struggling with high economic volatility over the last several decades. If firm level diversification trends are analyzed for these countries, we will be able to clarify the relationship between the diversification and economic volatility.

Chapter 4: Volatility Change and Government Investment[35]

Section 1. Introduction

During the 1830s and 1840s, the British and American economies experienced a series of shared macroeconomic fluctuations. A sharp financial crisis in May of 1837 was followed by a brief recovery in 1838 and 1839. A second financial crisis in October of 1839, while less severe than the panic in 1837, nonetheless produced a recession and deflation that lasted until 1843. A third financial crisis, in the winter of 1842, affected primarily the United States, although conditions continued to deteriorate in Britain through 1842 as well. These fluctuations lead to a violent change in the volatility of economy. Figure 1 plots the volatility which is measured by the standard deviation of bond price in 12 months.[36] It shows a sharp increase of the volatility both in US and UK after 1839.

The US and UK economies were closely linked by trade and finance, leading historians to speculate about the role of each country in provoking the crises. Temin's *Jacksonian Economy* attributes the Panic of 1837 and the Crisis of 1839 to the Bank of England and international factors, absolving the Bank of the United States, Nicholas Biddle (the bank's president from 1823 to 1839), and President Andrew Jackson. Biddle himself criticized the Bank of England for its policies in 1839, as did Jenks and Hammond.[37] On the other side, in *A Study in Trade-Cycle*

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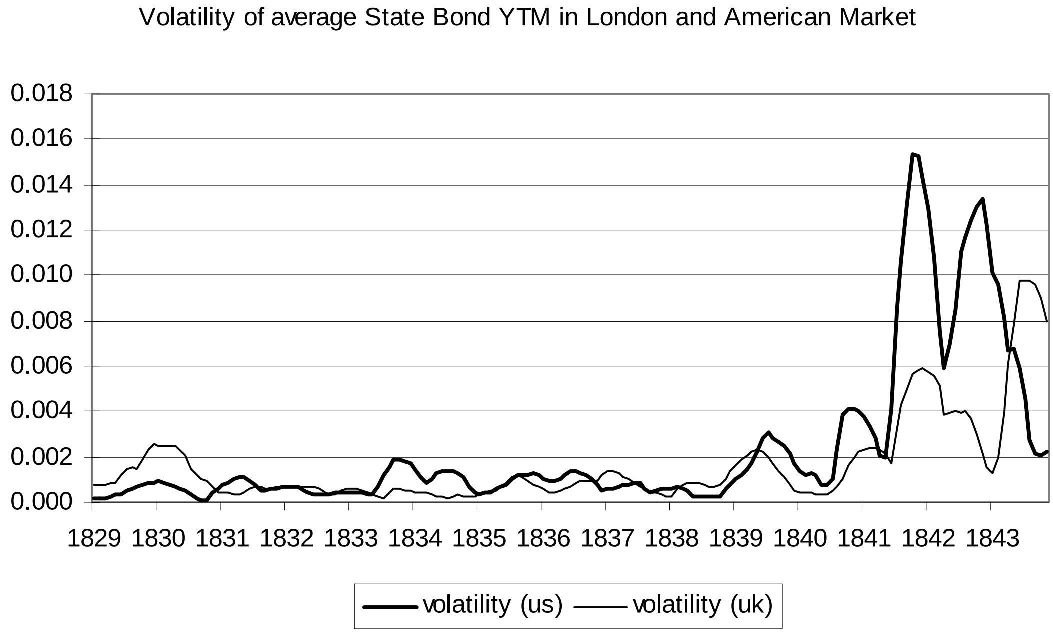
[35] This chapter is co-authored with John Joseph Wallis in University of Maryland. A revised version of this chapter, "The Market for American State Government Bonds in Britain and the United States, 1830 to 1843," will be published in Economic History Review, November 2005 (forthcoming).

[36] See Chapter 3 for a formal definition.

[37] Leland Jenks, Migration of British Capital, pp. 90-95, and Bray Hammond, Banks and Politics in America, pp. 500-513, stress the importance of British capital markets and international forces in bringing on the crises. Nicholas Biddle, in a letter to John Clayton dated April 9, 1841, in which he defended his actions at the Bank of the United States and attempted to

Figure 1 Volatility of average state bond yield to maturity



History, Matthews concluded that '... it is in the nature of things futile to try and draw any hard-and-fast line assigning to either country causal primacy in the cycle as a whole or in its individual phases. But enough has been said in the present chapter to indicate the powerful nature of forces making for instability from within the United States in this period.'[38]

The market for American state debts played a central role in financial relationships

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explain why the bank had failed after his departure as President, Biddle wrote: 'I have just stated that the winter of 1838-'39 was a season of great abundance and ease in moneyed concerns, both in England and this country; but England was soon after startled by the discovery that the grain crop was deficient, and a demand arose for specie to export for grain, combined with some continental loans, that changed the whole surface of affairs. The Bank of England itself, after borrowing ten millions of dollars from the Bank of France, was still so much drained for coin that it was forced into very severe restrictive measures, which raised the interest of money to twice or three times its usual rate. The most injurious effect was on the stocks of this country [the U.S.], which were no longer convertible in England, accept at great sacrifices. These causes immediately reacted on this country, producing the usual effects of embarrassment in the community and alarm among the banks.' In House Document #226, 29th Congress, First Session, p. 488.

[38] Matthews, Trade-Cycle, p. 69.

between Britain and the United States. In the late 1830s American states embarked on an internal improvement boom, raising the amount of state debt outstanding from $81 million in 1835 to $198 million in 1841. American states authorized and issued bonds worth $13 million in 1836, $21 million in 1837, $35 million in 1838, $22 million in 1839, $19 million in 1840, and $6 million in 1841. By 1841, estimates are that half of the $200 million in state debt was held abroad, primarily in Britain.[39] State bonds provided a critical link between financial markets in the two countries. By 1836, state bonds were the only long-term American debt instrument traded in Britain. The United States federal government retired all its debt in 1835. The single American corporation whose stock traded regularly in London was the Second Bank of the United States, which lost its national charter in 1836. Millions of dollars of identical state bonds traded in London, New York, and Philadelphia. Movements in bond prices give us a window into the connections between British and American financial markets.

The boom in state transportation and banking projects, and the associated wave of new state bond issues, also play a critical role in our understanding of macroeconomic events. Temin attributed the quick recovery of the American economy from the Panic of 1837 to state expenditures for canals and railroads, financed largely by British lending. 'The recession of 1837-38... was brought to a speedy end by the restoration of the capital flow from Britain to the United States and by the expansion of demand stemming from the rise in state government expenditures.' Temin attributed the 1839 crisis to credit tightening by the Bank of England and the long recession that followed to tightening markets in Britain for American state debts: 'The state projects initiated in the late 1830s had been started in the expectation of external [*British*] financing.... Unfortunately, the new inflow of foreign capital did not continue [in 1839]... and the

[39] See, for example, Scheiber's Ohio Canal Era estimates of foreign holders of Ohio bonds, Ratchford's American State Debts, and McGrane Foreign Bondholders.

manifold projects of the states were abandoned.'[40] By the summer of 1842, eight states and the Territory of Florida were in default on their debts, and Mississippi and Florida had repudiated their bonds outright. The collapse of state credit was the most serious consequence of the depression that began in 1839.[41]

The purpose here is to determine whether credit markets for American state bonds in and between the three major financial crisis were tighter in the United States or in Britain, and whether shocks to the volatility of bond markets originated in the United States or in London.[42] Although there are some subtleties of interpretation, the major questions are straightforward and their answers are quantitative. First, were British and American financial markets well integrated? Not surprisingly, we find that they were. Figure 2 gives the average bond yield for state bonds in London and for state bonds in New York.[43] Financial markets effectively arbitraged the prices of American state bonds in London and the U.S. within a band of plus or minus roughly 1 percent (100 basis points), attributable to the high transaction costs of trans-Atlantic commerce in this period, with a lag of roughly two months.

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[40] The first quote is from Temin, The Jacksonian Economy, p. 151 and the second quote from p. 153.

[41] Temin, Jacksonian Economy, p, 157, citing Gallman's unpublished estimates of annual GNP, argues that the crises in the United States had a much larger effect on prices than on output. Also see Temin, 'The Anglo-American Business Cycle' where he shows that the American economy experienced greater price fluctuations over these business cycles, while the British economy experienced greater fluctuations in real economic activity.

[42] By tighter we mean simply that bond yields were higher, as we have no information on credit rationing in either market. It appears, however, that states willing to pay market rates could issue bonds in New York and London up to 1842.

[43] Source: Sylla, Wilson, and Wright, Price Quotations. Figure 2 shows average yields to maturity in the London market between 1831 and 1843 for the bonds of New York, Pennsylvania, Ohio, Indiana, Illinois, and Massachusetts; and average yield to maturity in the United States for the bonds of New York, Pennsylvania, Ohio, and Illinois.

Figure 2

All State Bond Yields
Average in US and in London

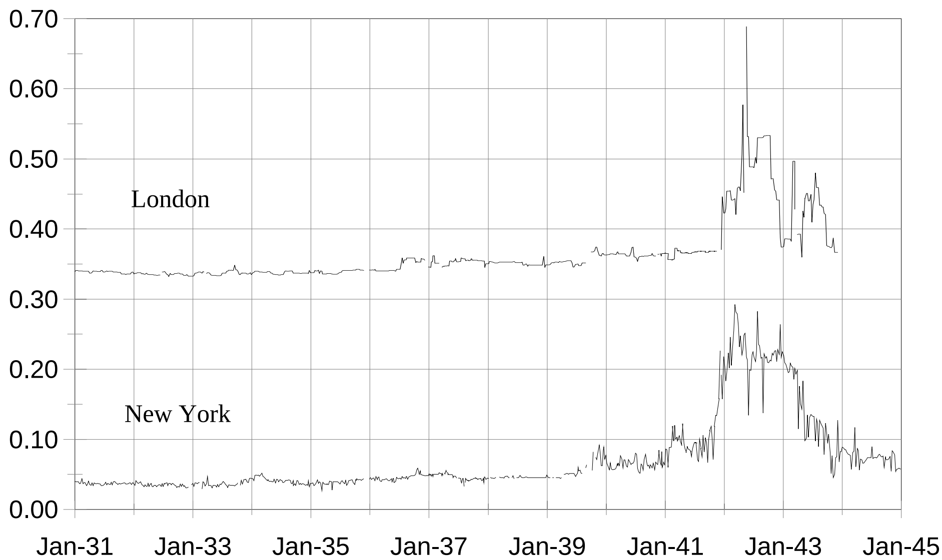
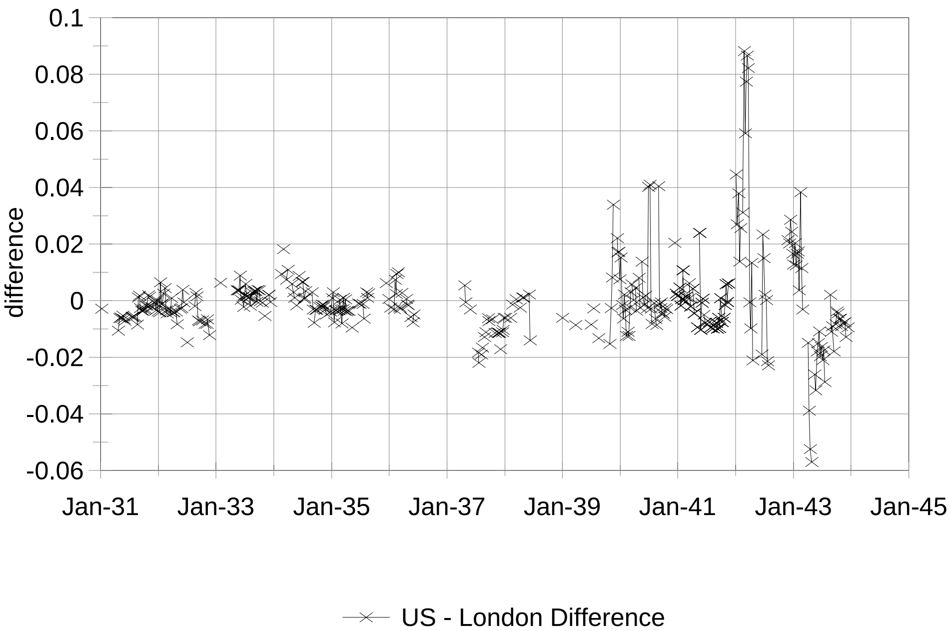


Figure 3

Difference in Ohio Bond Yields
New York minus London



Because markets were integrated we can ask whether the pattern of bond price movements in the Crisis of 1839 and the Collapse of 1842 were consistent with shocks originating in the United States, in Britain, or neither country. We find clear evidence that shocks in both crises originated in the United States. Figure 3 shows the difference in contemporaneous bond yields for Ohio bonds in New York and London, and Figure 4 shows the contemporaneous bond yields for New York state bonds in New York and London.[44] Because of the lag with which price shocks were transmitted from one market to the other, we can see where shocks originate. In October of 1839 and again in the winter of 1842, bond prices moved sharply higher in New York, two months before prices moved in London. This is clear evidence that the "shocks" of 1839 and 1842 originated in the United States.

Finally, as Temin suggests, we ask whether bond price movements show whether British investors were more willing to lend to American states, relative to American investors, during the state borrowing boom from 1837 to 1839, and then became less willing to lend to states after October of 1839. Table 1 presents average bond yields for New York and Ohio bonds in New York and London, as well as the average difference in bond yields for both states, for the three relevant time periods. Before the Panic of 1837 (January 1831 to March 1837), yields on New York and Ohio bonds were close to the same in both markets. After the Panic (July 1837 to July 1839), when states began borrowing in earnest, bond yields were distinctly higher in London for bonds from both states. New York state bonds paid yields of 4.49 percent in New York and 5.01 percent in London, while Ohio bonds paid yields of 4.16 percent in New York and 5.06 percent in London. Conversely, after the Crisis in October of 1839 (January 1840 to October 1841), yields on American state bonds were generally lower in London than they were in US. New York state bonds paid yields of 6.92 percent in New York and only 6.06 percent in London, while Ohio

[44] Source: Sylla, Wilson, and Wright, Price Quotations. All bond yields are calculated yields to maturity, averaged over all the bonds for an individual state.

bonds paid 6.53 percent in New York and 6.51 percent in London. There is nothing in these numbers to suggest that British lenders cut off credit to US, after the Crisis of 1839.

The crises of 1839 and 1842 clearly began in the United States. Between the Panic of 1837 and the Crisis of 1839 credit markets for state bonds were distinctly tighter in London than in the United States. Between the Crisis of 1839 and the Collapse of 1842, credit markets for state debt in the United States were tighter than markets in London. We find little evidence that state borrowing and the market for state bonds collapsed because of pressures emanating from Britain after 1839. The next section provides a brief history of state borrowing and the macro-economy in the 1830s. The second section looks at the data sources on state bonds and the question of market integration. The final section of the paper examines the pattern of state borrowing in the 1830s and identifies the forces operating in America that moved the market for state bonds. Economic historians have focused on the Panic of 1837, paid some attention to the Crisis of 1839, and ignored the Collapse of 1842. Figure 2 suggests that as far as the market for state bonds was concerned, 1839 and 1842 are more interesting years to study, and that by overlooking the Collapse of 1842, a crisis neglected in virtually all accounts of this era, we may have missed the biggest crisis of them all. What happened in 1842?

Figure 4

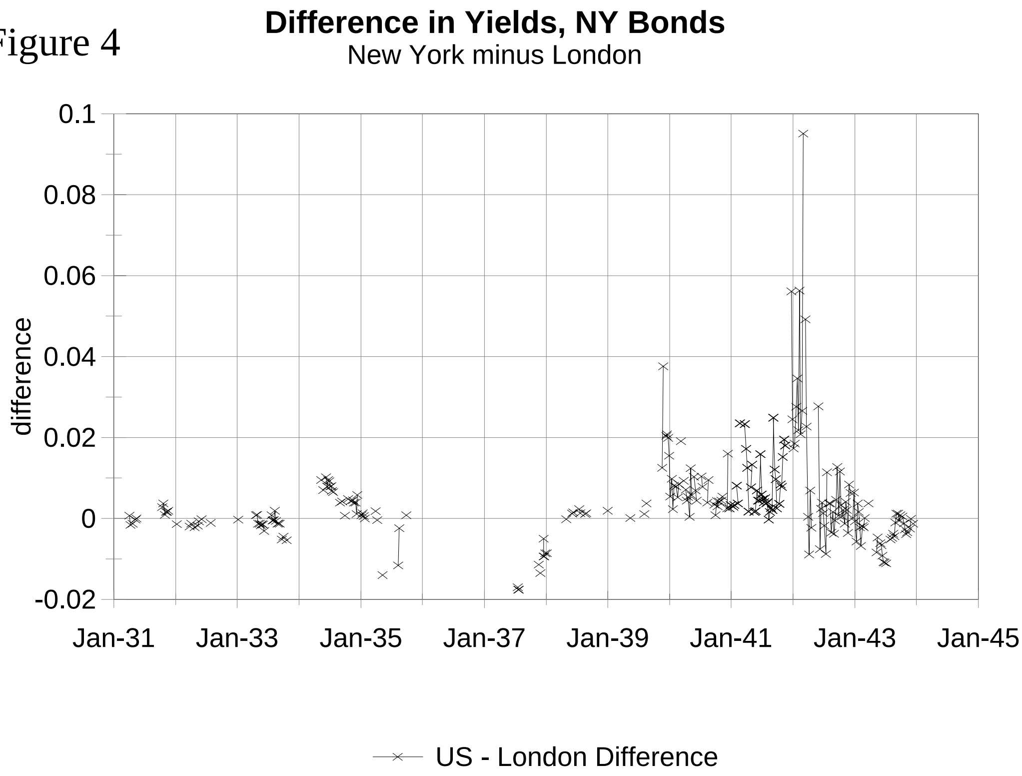


Table 1 Average Bond Yields for New York and Ohio Bonds In London and New York, and difference in yields

	Average Bond Yield New York Bonds in		Average Bond Yield Ohio Bonds in		NY-London Yield Difference	
	London	NY	London	NY	New York	Ohio
Average Yield 1/31 to 3/37	3.28%	3.34%	3.76%	3.76%	0.10%	-0.08%
Standard Deviation	0.52%	0.55%	0.31%	0.59%	0.43%	0.48%
Average Yield 7/37 to 7/39	5.01%	4.49%	5.06%	4.16%	-0.56%	-0.88%
Standard Deviation	0.35%	0.36%	0.28%	0.50%	0.72%	0.62%
Average Yield 1/40 to 10/41	6.06%	6.92%	6.51%	6.53%	0.76%	0.06%
Standard Deviation	0.44%	0.84%	0.43%	1.02%	0.64%	1.07%

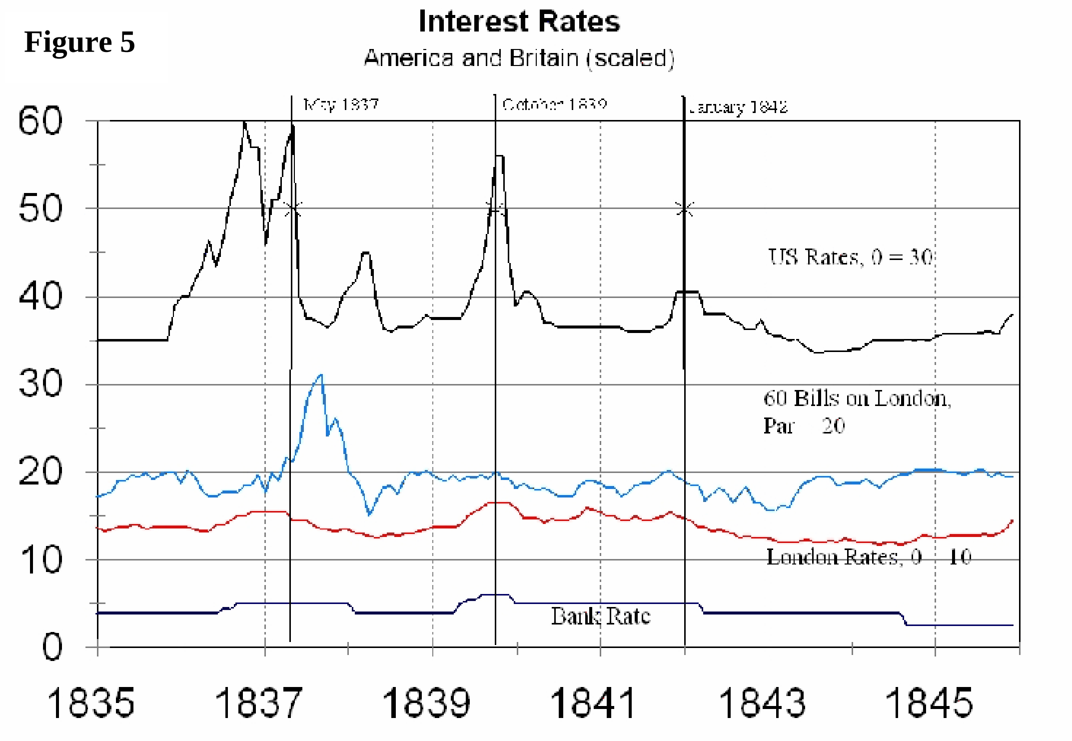
Calculated from Sylla, Wilson, and Wright, *Price Quotations.*
Note that average yields are for all dates with an observation.
The difference in yields is calculated only for dates with observations in both markets.

Section 2. The History

The early 1830s were a period of general economic expansion in both Britain and the United States, marred by a brief recession in 1834. The expansion turned into a boom in 1835, driven by a rapid increase in public land sales in the United States. The boom was reflected in rising prices in both countries, an increase in international trade, and an increase in the flow of capital from Britain to the United States. Prices stopped rising in early 1837, and a sharp break in cotton prices combined with tight credit conditions in Britain and the United States to produce a financial panic in May of 1837. In the United States the panic resulted in the suspension of specie payments by banks throughout the country, and in Britain the failure or near failure of several large commercial houses engaged in the American trade. The Bank of England did its part to bring about the panic by raising the Bank Rate from 4 to 5 percent.[45] Figure 5 shows the Bank Rate, short term interest rates in London and New York, and the New York price of 60 day bills payable in London.[46]

[45] Clapham, Bank of England, p. 153, and Hidy, House of Baring, pp. 205-24.
[46] Interest rates in the New York and Boston are the average of the high and low rates reported in Smith and Cole, Fluctuations, Table 74, pp. 192-3. Interest rates in London: From National Bureau of Economic Research. Bank Rate: Clapham, Bank of England, vol II, Appendix B, p. 199. Exchange Rates on 60 day bills, Smith and Cole, Fluctuations, p. 190 and Officer, "Integration in the American Foreign Exchange Market," p. 563.

Figure 5



The effects of financial tightening were compounded in the United States by the decision of the federal government to distribute the federal fiscal surplus of $36 million to the states in 1837, and by President Jackson's specie circular requiring that all public land purchases be redeemed in specie. The two measures together disrupted the normal allocation of gold reserves within the banking system, further exacerbating the liquidity problems of New York banks brought on by tightening international markets. Whether the Panic of 1837 in the United States was caused primarily by international or domestic forces is a question with a long pedigree that we do not attempt to answer.[47]

The Panic of 1837 was followed by a year of bank specie suspensions in the United

[47] See Rousseau, 'Jacksonian Monetary Policy;' Temin Jacksonian Economy and 'The Anglo-American Business Cycle, 1820-60;' and Timberlake, 'The Specie Circular and the Distribution of the Surplus' and 'The Specie Standard and Central Banking in the United States Before 1860;' and Macesich 'Sources of Monetary Disturbances in the United States, 1834-1845.'

States, financial distress in Britain, deflation in both countries, and a sharp decline in the volume of trade in 1838. But the recession was short lived. By the fall of 1838 land sales, international trade, prices, and capital flows had all turned up again. Banks in the United States resumed specie payments in the summer of 1838. As Temin stressed, the quick recovery in the United States was partly the result of fiscal stimulus created by the rapid expansion of state borrowing to build canals, railroads, and banks. Mid-Atlantic states had been borrowing since the 1820s to build canal networks, beginning with New York's Erie Canal in 1817. In 1836 a second wave of borrowing began, both in the older states - New York, Pennsylvania, Maryland, and Ohio - and in a new group of states in the west - Indiana, Illinois, Michigan, Arkansas, and Mississippi. Table 2 provides debt outstanding by state in1841, the share of debt outstanding authorized after 1836, and the total amount authorized in 1839, 1840, and 1841.[48] This was peacetime fiscal expansion on a scale never witnessed in the young United States.

[48.]Table 1 reports debt outstanding on September 1, 1841. The information is taken from the William Cost Johnson Report, Report of Committees, House of Representatives, 27th Congress, 3d session, Report No. 296.. The Report gives debt outstanding by year of authorization, not by year of issue. So debt authorized in 1836 was issued in or after 1836.

Table 2 Amount of State Debt Outstanding on Sept.1, 1841, Percentage of Debt authorized between 1836 and 1841, and amount authorized between 1839 and 1841.

State	Total Debt Outstanding	Share Authorized 1836 and later	Debt Authorized 1839, 1840, 1841
Alabama	$15,400,000	64%	$0
Arkansas	$2,676,000	100%	$0
Florida	$4,000,000	3%	$100,000
Georgia	$1,324,550	100%	$0
Illinois	$13,527,293	100%	$9,862,293
Indiana	$12,751,000	83%	$1,363,000
Kentucky	$3,085,500	94%	$1,445,500
Louisiana	$23,985,000	7%	$1,185,000
Maine	$1,734,861	100%	$1,465,085
Maryland	$15,214,761	68%	$994,854
Massachusetts	$5,969,137	100%	$1,869,137
Michigan	$5,611,000	98%	$40,000
Mississippi	$7,000,000	71%	$0
Missouri	$842,261	100%	$410,261
New York	$21,796,768	71%	$8,049,755
Ohio	$10,924,123	59%	$3,994,123
Pennsylvania	$36,336,043	36%	$13,202,084
South Carolina	$3,691,234	74%	$600,000
Tennessee	$3,416,166	84%	$0
Virginia	$8,744,308	45%	$2,416,729
Total Outstanding	$198,030,005	59%	$46,997,820

Source: "The William Cost Johnson Report." House Report, 296, 27th Congress, 3rd Session, 1843.
The numbers for Ohio in the Johnson report are unreliable for the later years. We include Scheiber's, *Ohio Canals,* estimates of borrowing for 1840 and 1841, pp. 143-151, and the $20 million figure cited in the Census of 1880.

The transportation boom, however, died quickly in the Northwest. Indiana, Illinois, and Michigan all sold bonds on credit to eastern investment banks. These new states issued bonds for which they were liable for interest payments immediately, but for which they would receive payments only in installments.[49] In July of 1839, the Morris Canal and Banking Company of New Jersey defaulted on Indiana, and the state quickly was forced to curtail construction on its network of canals and railroads. By the fall, Illinois and Michigan were forced to slow or stop

[49] The installments were fixed in time and amount. The states were not paid when the banks sold the bonds, these were not consignment or commission sales.

Table 3 Default, Resumption, and Repudiation Dates

State	Date	Resumed or Repudiated	Date
Indiana	January 1841	Resumed	July 1847
Florida	January 1841	Repudiated	February 1842
Mississippi	March 1841	Repudiated	February 1842
Arkansas	July 1841	Resumed	July 1869
		Repudiated	July 1884, Holford Bonds
Michigan	July 1841	Resumed	January 1846
		Repudiated Partially	Part paid bonds, July 1849
Illinois	January 1842	Resumed	July 1846
Maryland	January 1842	Resumed	July 1848
Pennsylvania	August 1842	Resumed	February 1845
Louisiana	February 1843	Resumed	1844
		Repudiated	?

Source: English, "Sovereign Default"
Note: Louisiana never formally repudiated any bonds, thus the uncertainty of the date of Louisiana's repudiation. See English for a discussion of Louisiana's repayment of these bonds.

construction when investment banks defaulted on their obligations to the states. Land sales and land values in these northwestern states had been rising steadily through the 1830s. When transportation construction stopped, land values and property tax revenues began falling and, by late 1839, it was apparent that these states would soon have trouble servicing their debts.[50] In January of 1841, Indiana was the first state to default on interest payments. Table 3 lists the states that defaulted on interest payments, the date of default, whether the state resumed payments or repudiated their debts, and if they resumed, the date of resumption.

The collapse of internal improvement projects in the Northwest was not the only economic problem in 1839. The Bank of England, again facing drains on its specie reserves, began raising the Bank Rate in the summer (Figure 5). A crisis broke out in the United States

[50] For detailed consideration of land values and property tax revenues in Indiana in these years see Wallis 'The Property Tax.' Only Illinois continued to borrow, at extremely high rates, in an attempt to maintain its credit and to continue construction. The state was not successful at either goal. Heavy borrowing in 1840 saddled the state with debts the state would struggle to pay into the 1850s, without any significant physical accomplishments. The best overall history of state investments in transportation is Goodrich Government Promotion. Goodrich has recently been supplemented by Larson Internal Improvements. Details about Indiana can be found in Fatout Indiana Canals and Illinois in Krenkel Illinois Internal Improvements. The default crisis is discussed at length in Wallis, Sylla, and Grinath, 'Soveriegn Default and Repudiation.'

when the Bank of the United States of Pennsylvania (the BUSP) suspended specie payments in October. This was followed by suspensions throughout the western and southern parts of the United States, but not in New York and New England. As Hammond and Smith emphasize, the BUSP's immediate problem in 1839 was domestic, not foreign. Pressure from New York and Boston banks forced the BUSP to suspend.[51]

Although 1839 marked the end of the Northwestern transportation boom, New York, Ohio, and Pennsylvania continued to authorize new debt issues for their canals (Table 2). Despite rising interest rates, $47 million in debts were authorized and issued in 1839, 1840, and 1841. We can test Temin's conjecture that the end of British willingness to lend to American states after 1839 brought on the crisis and contributed to the depression that followed.

Section 3. Data sources and Market Integration Tests

Figure 2 is constructed from data collected by Richard Sylla, Jack Wilson, and Robert Wright (SWW).[52] They gathered quotations on debt and equity prices from contemporary newspapers in London, New York, Philadelphia, Boston, Baltimore, and other American cities.[53] Prices are available for American markets from the early 1790s up to the 1850s. Prices in London

[51] By 1839 the BUSP had an extensive operation in Britain headed by Samuel Jaudon, so attributing the causes of the bank's demise to domestic and international forces is complicated. But the causes of the suspension in October of 1839 were a run on the Philadelphia bank by banks in New York and Boston. Hammond, 'Chestnut Raid on Wall Street;' Smith, Economic Aspects.

[52] Their database will soon be available at ICPSR: 'Price Quotations in Early U.S. Securities Markets.'

[53] Price quotations were typically reported weekly, recorded by the date of the newspaper issue. Prices were not quoted on the same day in each market, and in several cases quotes were provided for more than one day in each week. Our analysis focuses on weekly quotations, except where noted. The Boston market data are not available from June 1841 to September 1843, and the New York series on Massachusetts bonds is incomplete. The Baltimore market data include complete data on generic 'Maryland 5s' and 'Maryland 6s' without maturity dates, and the prices for specific Maryland bonds is spotty.

are only available from 1811 to 1843. State government bonds typically traded in New York, Philadelphia, and London, as well as in the regional market of issue (for example, Maryland bonds in Baltimore and Massachusetts bonds in Boston). SWW list over 100 bonds from 18 states trading at some point in London. Trading occurred in new issues and the secondary market. Bonds traded actively for a few months after they were issued, but perhaps because bonds were held mostly by long-term investors, relatively few bonds continued to trade regularly in the secondary market. The most consistent series are available for New York, Ohio, and Pennsylvania.

New issues were marketed by the states themselves and through the agency of investment banking intermediaries. Legislation authorizing bond issues typically required that bonds be sold at par or better. The par restriction clearly applied to new issues marketed by states, sometimes applied to issues by intermediaries, and never applied to the secondary market.[54] When prices in the secondary market dropped below par, states and their agents could not sell new bonds at par. States could accurately claim that new bonds could not be sold in New York or London, even when simultaneously there was an active secondary market in state bonds in both markets. What states often failed to say is that there was no market for bonds with par sales restrictions when the market price fell below par. The inability of states to market their bonds was usually a function of their unwillingness (or their agents' inability) to borrow at higher interest

[54] The restrictions states placed on intermediaries are difficult to track. When the state appointed a state official to sell bonds in New York or London, the official was clearly bound by the par restriction. When states used investment bankers the situation was less clear. One would think that once investment bankers had paid for the bonds, they would no longer be bound by the par restriction. Investment bankers who took consignment of bonds would be bound by the par restriction. Yet, for example, Nicholas Biddle and the BUSP took almost all of Mississippi's 1838 issue of $5 million, paid for it on credit over the following year, and then failed to sell the bonds in London. The BUSP used $3,008,000 in Mississippi bonds as collateral for European loans, Smith, Economic Aspects, p. 218. Altogether, the BUSP used almost $13,000,000 in state bonds as collateral for loans in the fall of 1839 and winter of 1840. It is not clear why Biddle didn't sell the bonds, unless, perhaps, he could not because of concerns about par restrictions.

rates. States that were willing to borrow at market rates could always borrow.

Fortunately, most state bonds are reported with their yield and maturity, e.g., 'New York 5's 1854.' This enables us to calculate, for each individual bond, its yield to maturity.[55] For each state we calculate the average yield to maturity for all the bonds traded in each market, e.g., 'Ohio Bonds trading in New York.' This is a simple average because there is no information available on trading volumes to provide us with weights. There are often significant gaps in the series, and some of the short-term fluctuation results from changes in the bonds reported in a particular week. The 'United States' yields we quote for Ohio, New York, and Illinois bonds come from the New York market, and for Pennsylvania bonds the yields are from the Philadelphia market.

Visual examination of the bond yields in Figure 2 suggests that the market for state bonds in London and in the United States were closely related. To investigate the relationship more formally, we ran a series of ARCH tests. Y_{it} is log of the average bond yield in country 'i' on date 't', a_i is the constant term for country i, and $,_{it}$ is the market specific disturbance term:

(1) $Y_{it} = a_i + \varepsilon_{it}$

(2) $E(\varepsilon_{it}) = a_{ij} + b_{ij} E(\varepsilon_{i,t-1} \varepsilon_{j,t-1})$

The errors in Equation (1) follow a multivariate normal distribution with auto regressive conditional heteroscedasticity (ARCH) as in Equation (2). [56]

The dependent variable, Y_i is average yield to maturity in market i, of bonds that were commonly traded in both markets. The a_i are constant terms measuring the log of the average

[55] For simplicity, we assumed that all bonds matured on January 1 and paid a single annual premium. Bond yields for the last two years proceeding maturity were dropped from the calculated averages. Yields were calculated for bid and ask prices, and both bid and ask yields were included in the market averages.

[56] The ARCH estimator is more fully described in Appendix B.

bond yield in each market. The a_{ij} estimate the constant element of the covariance between yields in the two markets. The b_{ij} estimate the effect of the lagged disturbances on the covariance between the prices in the two markets. The b_{ij} measure whether the covariance of the disturbances are related to lagged disturbances. That is, for example, whether last period's errors in London affects this period's errors in New York. In an integrated market the b_{ij} should be close to one. If the errors in the two markets were related, and they were, this is evidence that the two markets were integrated.

The calculation of yield to maturity for a bond requires the maturity, coupon rate and the weekly prices of the bond, and there are missing observations on Y when not all of these data are available. Missing observations can be dealt with in several ways. First, we linearly interpolate for the unobserved data, and then run regressions using weekly and monthly data.[57] Second, monthly data contain far fewer missing observations and give us a check on the robustness of the results using weekly data, but at a loss of significant number of observations. The monthly data are realistic, however, given the time lags involved in the flow of information between the U.S. and Britain in the early 19th century. Finally, we estimate a regression using only observed weekly data, using our own method of analysis as ARCH with Missing Observations (described in the Appendix B) to account for missing observations in the data.

The regression results are provided in Table 4. The first column uses the weekly sample of linearly interpolated bond yields, the second column the monthly sample of linearly interpolated yields, and the third column is based only on the observed monthly data using our adjustment for missing observations. The results indicate strong evidence for integration. The constant covariance of returns in the two markets, the a_{ij} , are very close to zero. The effect of lagged disturbances on the covariance of returns, the b_{ij}, are positive and very close to one,

[57] This is the first step of an EM algorithm which is a popular tool for finding maximum likelihood estimates in incomplete data problems. See Meng and Rubin (1993).

Table 4 Bond market integration test (Multivariate ARCH with 2 equations)			
	Y=Observed and interpolated data		Y=Only observed data (Monthly)
Parameter	Weekly	Monthly	
a_1	.051 (1400.7)**	.039 (74.2)**	.039
a_2	.047 (1648.4)**	.039 (68.5)**	.04
a_{11}	.000 (7.26)**	.000 (8.35)**	.001
b_{11}	1.01 (3.12)**	.86 (5.53)**	.70
a_{21}	.000 (4.80)**	.000 (6.54)**	.001
b_{21}	1.01 (3.11)**	.65 (4.41)**	.68
a_{22}	.000 (10.81)**	.000 (13.19)**	.001
b_{22}	1.01 (3.12)**	.85 (5.83)**	.68
Number of Observations	1230	366	289
Time Period	1829-1843		

Technical Note:
(1) 1: London market, 2: American market
(2) The first dependent variable is the average YTM of NY, PA and OH bonds in London. The second dependent variable is the average YTM of NY and OH bonds in NYC and PA in Philadelphia.
(3) ** denotes significance at 99%

indicating that shocks to one market are quickly reflected in yields in the other market. These results are unaffected by the use of linearly interpolated weekly or monthly data, or controlling for the presence of missing observation in the design of the estimator.

For comparison, Table 5 performs a similar exercise on stock price indexes in London and in American markets. Missing observations are not a problem with the market indices. We have run regressions on weekly prices, the change in weekly prices, and monthly prices. Unlike the bond markets, where the underlying securities are the same in both markets, the equities traded in the London market are different from the equities in the American markets. As with the

Table 5 Stock market integration test (Multivariate ARCH with 2 equations)			
	Weekly data		Monthly data
Parameter	Y=Log of Stock Price=log(p_t)	Y=Capital Gain=log(p_t)-log(p_{t-1})	Y=Capital Gain =log(p_t)-log(p_{t-1})
a_1	4.72 (6078.15)**	-.00 (-.5)	-.00 (-.0)
a_2	4.60 (4585.44)**	-.00 (-.1)	-.00 (-.7)
a_{11}	.001 (22.96)**	.00 (40.7)**	.00 (10.4)**
b_{11}	.95 (6.88)**	.47 (9.5)**	.62 (5.5)**
a_{21}	-.000 (-.21)	-.00 (-.1)	.00 (.1)
b_{21}	.94 (6.69)**	-.13 (-1.6)	.11 (.6)
a_{22}	.000 (10.5)**	.00 (52.2)**	.00 (11.9)**
b_{22}	1.03 (7.04)**	.31 (6.1)**	.49 (2.9)**
Number of Observations	711		177
Time Period	1821-1836		

Technical Note:
(1) 1: American market (Baltimore, Boston, New York and Philadelphia), 2: London market
(2) The average price in London is indexed by the average of the first years stock prices, because the stock prices denoted in sterling and stayed around 25, where American prices stayed around 100.
(3) ** denotes significance at 99%

bond market, however, there is substantial evidence of market integration.

The results clearly show that the market for state bonds was well integrated. Transacting between the two markets, however, was not costless. Differences in interest rates between London and New York of one half to a whole percentage point in yields (100 basis points) were not uncommon. The transaction cost wedge between the markets is not surprising. In the 1830s bank notes of Philadelphia banks typically traded at 1 percent discount in New York in times when there was no default risk. The discount merely reflected the time and effort involved in presenting the bank note to the issuing bank for redemption. It was possible for bond yields to be higher in New York than in London, but not too much higher. We find episodes when contemporaneous prices in the United States and Britain diverge, but they always return to the transaction cost bounds within a few months. There is no evidence that the trans-Atlantic market for state bonds ever became disintegrated.

Section 4. American State Bonds in London and the United States

Figure 2 shows the average yields of state bonds traded in London and the United States, but disentangling what happened in the three financial crises requires examining states individually. The five largest state borrowers were Pennsylvania, Louisiana, New York, Ohio, and Maryland (Table 2).[58] Louisiana and Maryland were not steady borrowers and we do not have consistent records on their bond yields. New York began borrowing in 1817 and Ohio in 1825. Both states completed their major canal projects in the early 1830s. Both states resumed borrowing in 1837, and borrowed heavily and regularly through 1842. Hence, there are long and fairly complete bond yields for those states before 1834 and after 1837, but only sporadic information in 1835, 1836, and 1837. Pennsylvania began borrowing in the 1820s and continued to borrow through the 1830s, so there are long and fairly complete records for Pennsylvania. Illinois, Indiana, and Massachusetts did not begin borrowing heavily until 1837. We have only sporadic quotations for those three states. We focus, therefore, our analysis on the bonds of New York, Ohio, and Pennsylvania.

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[58] In table 2, Ohio is eighth in total debts. By 1841, Ohio had already paid back a substantial amount of its debts issued in the 1820s. Ohio would also continue to borrow in 1841, 1842, and 1843.

Table 6 Bond Yields of New York and Ohio Bonds in the United States and London

		NY Bond			Ohio Bond		
		London	US	US-London Diff	London	US	US-London Diff
1831	mean	3.46%	3.49%	0.03%	4.04%	3.75%	-0.29%
	st. dev.	0.18%	0.13%		0.25%	0.26%	
1832	mean	3.16%	3.03%	-0.12%	3.74%	3.35%	-0.38%
	st. dev.	0.18%	0.17%		0.26%	0.37%	
1833	mean	2.97%	2.84%	-0.13%	3.53%	3.69%	0.16%
	st. dev.	0.14%	0.12%		0.08%	0.34%	
1834	mean	2.90%	3.60%	0.70%	3.55%	3.86%	0.30%
	st. dev.	0.04%	0.34%		0.07%	0.61%	
1835	mean	3.20%	3.06%	-0.14%	3.61%	3.50%	-0.11%
	st. dev.	0.08%	0.48%		0.19%	0.54%	
1836	mean	4.57%	4.69%	0.12%	4.13%	4.48%	0.35%
	st. dev.	0.46%	0.39%		0.11%	0.78%	
1837	Q1	4.71%	4.87%	0.16%	---	4.63%	---
	Q2	---	4.80%	---	5.09%	4.89%	-0.20%
	Q3	5.46%	3.94%	-1.52%	5.28%	3.54%	-1.74%
	Q4	5.53%	4.44%	-1.08%	4.97%	3.95%	-1.02%
	st. dev.	0.40%	0.39%		0.27%	0.60%	
1838	Q1	5.03%	4.34%	-0.69%	5.02%	4.34%	-0.68%
	Q2	4.76%	4.82%	0.05%	4.74%	4.79%	0.04%
	Q3	4.66%	4.83%	0.17%	4.91%	3.76%	-1.15%
	Q4	4.69%	---	---	4.81%	---	---
	st. dev.	0.19%	0.25%		0.15%	0.36%	
1839	Q1	4.96%	5.00%	0.04%	5.22%	4.51%	-0.71%
	Q2	4.95%	4.94%	-0.01%	5.30%	4.32%	-0.98%
	Q3	5.04%	5.19%	0.15%	5.96%	4.83%	-1.12%
	Q4	6.19%	7.76%	1.57%	6.62%	7.46%	0.84%
	st. dev.	0.47%	1.67%		0.61%	1.69%	
1840	Q1	5.62%	6.83%	1.21%	6.25%	6.51%	0.26%
	Q2	5.55%	6.23%	0.68%	6.01%	6.30%	0.29%
	Q3	5.50%	6.27%	0.77%	6.08%	6.73%	0.65%
	Q4	5.70%	6.22%	0.52%	6.12%	6.26%	0.14%
	st. dev.	5.60%	6.41%		6.12%	6.50%	
1841	Q1	5.87%	6.89%	1.02%	6.30%	6.45%	0.15%
	Q2	6.47%	7.46%	0.99%	6.92%	7.01%	0.09%
	Q3	6.53%	7.16%	0.62%	7.01%	6.20%	-0.82%
	Q4	6.75%	7.99%	1.24%	6.88%	7.31%	0.43%
	st. dev.	0.34%	0.90%		0.36%	1.03%	
1842	Q1	6.62%	9.89%	3.27%	8.86%	12.78%	3.93%
	Q2	7.70%	8.53%	0.83%	11.98%	11.70%	-0.28%
	Q3	7.37%	7.45%	0.09%	10.71%	10.94%	0.23%
	Q4	7.32%	7.72%	0.40%	9.78%	11.86%	2.08%
	st. dev.	0.50%	1.67%		1.51%	2.53%	
1843	Q1	6.64%	6.53%	-0.11%	10.43%	12.08%	1.66%
	Q2	5.85%	5.80%	-0.05%	11.56%	9.62%	-1.93%
	Q3	5.51%	4.92%	-0.59%	8.77%	7.23%	-1.54%
	Q4	4.86%	4.74%	-0.12%	6.61%	5.76%	-0.85%
	st. dev.	0.74%	0.81%		2.17%	2.71%	

Notes to Table 6, 7, and 8: All bond yields are taken from Sylla, Wilson, and Wright. Each weekly observation is converted to yield to maturity. Differences between US and London yields for a year or quarter are the simple differences in the annual or quarterly average in the table. Pennsylvania prices in the United States are those quoted in Philadelphia. New York and Ohio in the United States are those quoted in New York.

Figure 6

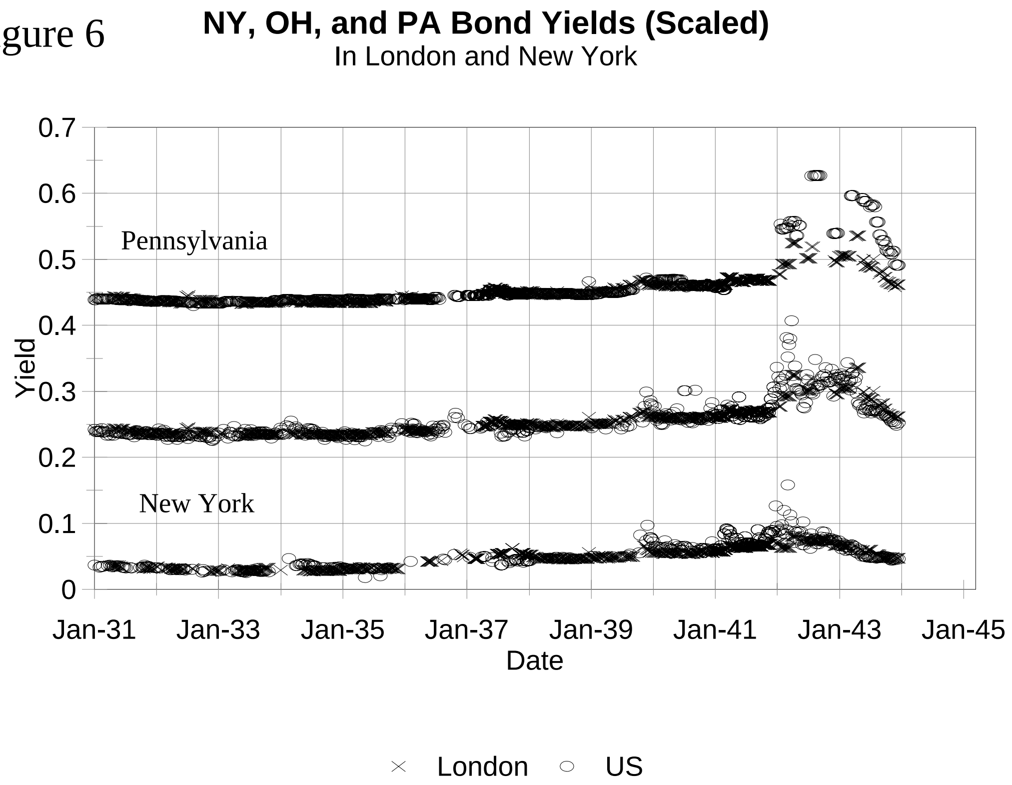

Table 6 gives average bond yields to maturity for New York and Ohio bonds in both London and the United States by year from 1831 to 1836 and by quarter from 1837 to 1843; the standard deviation of the yields in each year; and the average difference in yields in the two markets.[59] Table 7 presents the same information for Pennsylvania bonds, as well as the difference between the yield of Pennsylvania bonds in Philadelphia and the average yield of New York and Ohio bonds in New York.[60] Table 8 presents the infrequently reported yields we have for Illinois, Massachusetts, and Indiana. These three tables provide the detailed statistics underlying the summary findings in Table 1.[61] Figure 6 graphs weekly bond yields for New York, Ohio, and Pennsylvania bonds in both London and in the US.

[59] The difference is the arithmetic difference in the average prices for the year or quarter.
[60] Sylla, Wilson, and Wright, Price Quotations.
[61] Sylla, Wilson, and Wright, Price Quotations.

Table 7 Bond Yields in the United States and London Pennsylvania Bonds, and New York/Ohio average yield

		PA				
		London	US	US-London Diff	NY & Ohio US Avg	PA - NY & Ohio Diff
1831	mean	3.92%	3.95%	0.03%	3.62%	0.33%
	st. dev.	0.11%	0.03%			
1832	mean	3.59%	3.74%	0.16%	3.19%	0.55%
	st. dev.	0.16%	0.08%			
1833	mean	3.61%	3.96%	0.34%	3.26%	0.69%
	st. dev.	0.10%	0.20%			
1834	mean	3.89%	4.39%	0.50%	3.73%	0.66%
	st. dev.	0.08%	0.27%			
1835	mean	3.97%	4.14%	0.16%	3.28%	0.85%
	st. dev.	0.06%	0.18%			
1836	mean	4.12%	4.55%	0.43%	4.59%	-0.04%
	st. dev.	0.17%	0.26%			
1837	Q1	4.56%	5.02%	0.47%	4.75%	0.28%
	Q2	4.94%	5.06%	0.13%	4.84%	0.22%
	Q3	5.06%	4.40%	-0.66%	3.74%	0.66%
	Q4	4.78%	4.42%	-0.37%	4.19%	0.22%
	st. dev.	0.29%	0.35%			
1838	Q1	4.87%	4.56%	-0.31%	4.34%	0.22%
	Q2	4.86%	4.55%	-0.31%	4.80%	-0.25%
	Q3	4.83%	4.56%	-0.27%	4.29%	0.27%
	Q4	4.72%	4.55%	-0.17%	---	---
	st. dev.	0.07%	0.02%			
1839	Q1	4.96%	4.55%	-0.41%	4.75%	-0.20%
	Q2	5.02%	4.87%	-0.14%	4.63%	0.24%
	Q3	5.31%	5.38%	0.07%	5.01%	0.37%
	Q4	6.91%	6.14%	-0.77%	7.61%	-1.47%
	st. dev.	0.62%	0.58%			
1840	Q1	6.73%	5.87%	-0.86%	6.67%	-0.79%
	Q2	6.99%	5.96%	-1.04%	6.27%	-0.31%
	Q3	6.30%	5.42%	-0.87%	6.50%	-1.07%
	Q4	6.03%	5.80%	-0.23%	6.24%	-0.44%
	st. dev.	6.45%	5.76%			
1841	Q1	5.78%	8.05%	2.27%	6.67%	1.38%
	Q2	---	8.34%	8.34%	7.23%	1.11%
	Q3	---	8.43%	8.43%	6.68%	1.75%
	Q4	---	11.42%	11.42%	7.65%	3.77%
	st. dev.	0.15%	1.90%			
1842	Q1	14.87%	17.99%	3.12%	11.34%	6.65%
	Q2	15.09%	21.86%	6.77%	10.12%	11.75%
	Q3	22.72%	23.55%	0.83%	9.20%	14.36%
	Q4	13.98%	18.85%	4.88%	9.79%	9.07%
	st. dev.	3.51%	2.99%			
1843	Q1	15.89%	21.02%	5.13%	9.31%	11.71%
	Q2	19.26%	19.20%	-0.06%	7.71%	11.49%
	Q3	16.21%	15.68%	-0.53%	6.08%	9.61%
	Q4	10.91%	12.53%	1.62%	5.25%	7.28%
	st. dev.	3.67%	3.51%			

See notes in Table 6.

Table 8 Bond Yields in the United States and London Illinois, Massachusetts, and Indiana Bonds

		Illinois	Illinois	MA	Indiana
		London	US	London	London
1831	mean	---	---	---	---
	st. dev.	---	---	---	---
1832	mean	---	---	---	---
	st. dev.	---	---	---	---
1833	mean	4.35%	---	---	---
	st. dev.	0.00%	---	---	---
1834	mean	---	---	---	4.27%
	st. dev.	---	---	---	0.01%
1835	mean	5.28%	---	---	5.11%
	st. dev.	0.00%	---	---	0.45%
1836	mean	---	---	---	5.97%
	st. dev.	---	---	---	0.18%
1837	Q1	---	---	---	6.19%
	Q2	---	---	---	---
	Q3	---	---	---	7.07%
	Q4	---	---	---	6.93%
	st. dev.				0.38%
1838	Q1	---	---	4.05%	6.37%
	Q2	5.65%	4.89%	---	6.45%
	Q3	5.64%	---	4.39%	6.79%
	Q4	---	---	4.41%	5.71%
	st. dev.	0.02%	0.03%	0.07%	0.48%
1839	Q1	5.83%	5.69%	4.42%	5.92%
	Q2	5.89%	---	4.68%	5.92%
	Q3	---	5.92%	4.06%	---
	Q4	---	10.81%	5.95%	8.76%
	st. dev.	0.06%	2.69%	0.66%	0.96%
1840	Q1	7.10%	10.88%	---	---
	Q2	7.32%	8.89%	---	8.41%
	Q3	7.67%	8.80%	4.84%	8.10%
	Q4	8.05%	7.97%	4.91%	8.22%
	st. dev.	7.36%	8.76%	4.88%	8.16%
1841	Q1	8.06%	12.65%	4.94%	8.36%
	Q2	---	13.60%	---	---
	Q3	---	12.68%	---	---
	Q4	---	23.53%	---	---
	st. dev.	0.00%	6.37%	0.00%	0.09%
1842	Q1	26.78%	43.74%	---	26.00%
	Q2	29.81%	53.83%	---	35.68%
	Q3	---	46.85%	---	39.02%
	Q4	---	47.91%	5.03%	37.95%
	st. dev.	4.89%	5.21%	0.00%	4.28%
1843	Q1	---	43.37%	5.11%	35.41%
	Q2	26.98%	31.52%	4.93%	---
	Q3	26.99%	23.24%	---	26.75%
	Q4	---	20.14%	---	24.80%
	st. dev.	0.01%	9.82%	0.09%	3.03%

See notes in Table 6.

The individual state series show the same pattern as the aggregate series: bond yields rise gradually in 1837, rise sharply in the fall of 1839, and rise and fluctuate wildy in the winter of 1842. The spread in bond yields between the U.S. and London, however, moved differently in each crisis. The bond yield spreads reflect how expectations and information differed in the United States and London. To exploit the yield spreads, however, we first need to appreciate the situation in Pennsylvania.

Pennsylvania:

New York began the Erie Canal in 1817 and completed it in 1825; Ohio began construction on two canals in 1825 and completed them in 1832; and Pennsylvania began work on its canal system in 1826 and completed the Main Line in 1835. By 1836, the New York and Ohio canals were returning revenues to the state Treasury in excess of operating costs and interest payments, while the Pennsylvania canals were a financial disaster. Financial markets priced the bonds of the three states accordingly. In the early 1830s, yields on Pennsylvania bonds were consistently higher than the yields on New York and Ohio bonds, usually 0.5 percent or more (Table 7, column 5).[62]

Pennsylvania's situation changed in 1836. When Nicholas Biddle lost the Bank War to Andrew Jackson, the Bank of the United States sought a charter from the state of Pennsylvania. In 1836, the BUS was rechartered as the Bank of the United States of Pennsylvania. The charter was very generous to the state, including a promise by the BUSP to underwrite $6 to $8 million in state bond issues:

[62] The near equivalence of New York, Ohio, and Pennsylvania yields in 1836 is misleading, since there were only 4 observations on New York bond yields in New York that year. Most of the New York bonds were paid off in 1836.

> The Bank committed to pay an additional twenty installments of $100,000 each, beginning June 1, 1836 and continuing for the next nineteen years, to pay $500,000 on March 3, 1837, to subscribe for various specifically designated public improvement stocks amounting to $675,000, to make long term loans to the state up to $6,000,000 for which the state agreed to turn over to the Bank bonds redeemable in 1868 (at par if they were 4 per cent bonds at one hundred and ten if they were 5's) and to make temporary loans up to a maximum of $1,000,000 in any one year at 4 per cent interest. (Smith, *Economic Aspects,* p. 179)

In 1837, the yields on Pennsylvania bonds suddenly became fixed within narrow limits. Between November 1837 and April 1839 the maximum yield on Pennsylvania bonds in Philadelphia was 4.56 percent, the minimum yield was 4.42 percent (Table 8). The standard deviation on the Pennsylvania yield in 1838 was .02 percent, the lowest standard deviation for any state's bonds in any year in Tables 4, 5, and 6. Deliberately or not, the BUSP pegged the price of Pennsylvania bonds as a result of its obligations to purchase state bonds over this 18 month period. Other lenders were not so optimistic about Pennsylvania, however. From 1837 to 1840 yields on Pennsylvania bonds in London remained considerably higher than yields in Philadelphia.[63]

The BUSP's condition worsened in 1839, when its extensive operations in the state bond market, the cotton market, and the market for international and domestic exchange went sour.[64] In October of 1839, the BUSP was forced to suspend convertibility of its demand liabilities into specie because of a run by New York and Boston Banks. The suspension of payments precipitated a banking crisis in the United States; with banks in the south and west suspended until 1842. But the suspension did not release the BUSP from its obligations to the state of Pennsylvania. Until early 1841, although the BUSP no longer pegged the yield, Pennsylvania bonds continued to enjoy lower yields in Philadelphia, despite steady borrowing by the state, than

[63] The BUSP's willingness to purchase state bonds kept the yields on Pennsylvania bonds in Philadelphia lower (prices higher) than either New York or London after late 1837. The use of the Pennsylvania bond yields for cross country comparisons is, as a result, problematic.

[64] Details of the bank's demise can be found in Smith, Economic Aspects, Hammond, Banks and Politics in America, and Govan, Nicholas Biddle.

did the bonds of Ohio and New York in New York or London.

In February 1841, the state attempted to force the BUSP to resume specie payments, whereupon the bank closed its doors and went out of business. With BUSP out of the market, yields on Pennsylvania bonds in Philadelphia jumped immediately, from 6.01 percent on January 2 to 9.5 percent on March 7. For the remainder of 1841, Pennsylvania bond yields were above 8 percent in Philadelphia, and prices on Pennsylvania bonds were no longer quoted in London. Yields on Pennsylvania bonds were now 2 percentage points higher than yields on New York and Ohio bonds. The BUSP's artificial support of state credit between 1837 to 1840 makes problematic the use of Pennsylvania bond prices as a indicator of market conditions in those years.

Pennsylvania was in deep financial trouble in 1841. The state's credit returned to a level consistent with its financial situation when the failure of the BUSP forced the state back into regular credit markets. In late 1841, yields on Pennsylvania bonds in Philadelphia began rising rapidly. Pennsylvania defaulted on its bond obligations in 1842, with devastating consequences for the state bond market on both sides of the Atlantic.

The Crises of 1837 and 1839:

The Panic of 1837 occurred in a window of time where bond price data are hard to come by. First, New York completed work on its canals in the 1820s and Ohio in the early 1830s. New York paid off most of its debt by 1835. Although both New York and Ohio started new projects in 1836 (New York authorized a $2,000,000 bond issue in 1836), neither state borrowed heavily until later in 1837. As a result, there are gaps in the quotation series for both states in 1837, reflecting the absence of marketable bonds in both New York and London. Second, western states had just begun issuing bonds when the Panic hit, and we do not have usable price series for

Indiana or Illinois in 1837. With the exception of Pennsylvania, not many state bonds traded in the spring of 1837.

Between 1831 and 1836, the yield differential between the United States and London was small on average: .0013, only13 basis points. Yields were slightly lower in London than New York, consistent with the general idea that credit markets were deeper and interest rates lower in London, as well as with higher transaction costs of marketing American bonds in Britain.[65] The average difference for Pennsylvania bonds was .003, for New York bonds .001, and for Ohio bonds -.0008 (on average Ohio bonds had slightly higher yields in London than in New York). As we saw earlier, these markets were well integrated.

Bond yields began rising in 1836, a full percentage point in the U.S. and almost 3/4 of a percentage point in London. Credit markets tightened everywhere in 1836 (Figure 5). Yields continued to rise through early 1837 in both London and the U.S., but more quickly in the U.S.. When the Panic broke out in May, however, yields moved in opposite directions in the U.S. and in Britain. In the third quarter of 1837, yields on New York bonds in London rose to 5.46 percent, while in the U.S. they fell to 3.94 percent (Table 6, columns 1 and 2). For the remainder of 1837, all of 1838, and the first three quarters of 1839, it was more expensive for state governments to borrow in London than in New York (Table 1). Both 1838 and 1839 were years of heavy new state borrowing and there were frequent quotations in every market. In the aftermath of the Panic of 1837, credit markets for American state bonds were significantly tighter in London than in the United States.

The summer of 1839 was a turning point for the transportation boom in the northwest. The Morris Bank defaulted on its July installment to Indiana. As the year progressed it became

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[65] The idea that British credit markets were deeper than American goes back at least to Callender, 'Early Transportation and Banking Enterprises,' whose essay lays out the importance of British capital for American development and the role of American states in tapping foreign and domestic credit markets to support internal improvements.

clear that Indiana, Michigan, and Illinois were in serious trouble, a concern immediately reflected in yields on their bonds. Indiana bond yields in London rose from 5.92 percent in June, to 8.76 percent in November (Table 8, there are no quotes in between those dates in London, and there are no quotes for Indiana bonds in New York before 1840).[66] Illinois bonds in New York went from a yield of 4.9 percent in July to 11.1 percent in November and 13 percent in December, while in London Illinois bonds went from a yield of 5.98 percent in July to 7.32 percent in January. Financial markets acknowledged that it was primarily the western states whose credit was threatened. Yields on eastern state bonds rose in 1839, but not nearly to the extent of yields on western bonds.

The BUSP once again suspended specie payments in October, 1839. This crisis hit U.S. markets for state bonds much harder than it hit the London market. In the third quarter of 1839, the average yield on New York bonds was 5.19 percent in the U.S. and 5.04 percent in London. In the fourth quarter of 1839, the average yield on New York bonds was 7.76 percent in the U.S. and 6.19 in London. For the remainder of 1840 and 1841, average yields stayed higher in the U.S. than in London. The New York-London differential on New York bonds was over 0.5 percent throughout both years (Figure 4); for Ohio bonds, between 0.1 and 0.5 percent (Figure 3); and for Illinois bonds over a full percentage point or more. Unlike the aftermath of the Panic of 1837, when markets for state bonds were tighter in London than they were in the United States, after the Crisis of 1839 yields on state bonds were higher in the United States than in London.

We are now in a position to examine the origin of the shock to bond markets. Figures 2

[66] This may be because the Indiana bonds sold on credit to the Morris Bank were sent to London, and from there to Amsterdam. The Morris Canal and Banking Company took the Indiana bonds it purchased on credit and used them to pay off the mortgage held on the canal by Dutch creditors. By the summer of 1839, the Morris Bank did not hold any Indiana bonds, it had already sold or hypothecated all of them. The story is not told anywhere, but can be tracked through the Company minutes at the New Jersey State Archives.

and 3, the difference in Ohio and New York bond yields in the United States and London, show distinct spikes in the U.S.-London yield differentials at the end of 1839.[67] This is the first spike in the bond differentials, small compared to what was to come in 1842, but telling nonetheless. Up to 1839, markets in New York, Philadelphia, and London shared the same information. In the fall of 1839, news hit the markets in America first. Bond prices dropped and yields rose in New York about two months before yields rose in London. Unlike 1837, when credit conditions tightened on both sides of the Atlantic and the news about the Panic of 1837 did not originate in either country, in 1839 the event that shocked bond markets clearly originated in the United States.[68]

Temin suggested that American states were forced to abandon their internal improvement projects after the Crisis of 1839 because British capital dried up. His conjecture finds no support in the financial market data. After the Panic of 1837, it was consistently more expensive for states to borrow in London than in New York and Philadelphia. After the Crisis of 1839, it was consistently cheaper for states to borrow in London than in New York and Philadelphia, and this was true for all states. States, of course, found it harder to borrow everywhere in 1840 and 1841, when yields on New York and Ohio bonds reached 7 percent, and yields on Illinois and Indiana bonds went to 8 percent and higher. But it was not relatively harder to borrow in London than it was in America. The idea that the depression that developed in the United States after October 1839 was due to the tightening of British capital markets is not supported by the bond yields.

Although yields were more favorable to borrowers in London than in the U.S., states found it difficult to borrow in both the U.S. and London in 1840. States with par restrictions on their bonds could not market any bonds at prevailing rates. But they could sell bonds if they were

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[67] This is in the time interval when Pennsylvania bond prices are supported by the BUSP, so the yield differential between Philadelphia and London becomes more negative. This, however, is a function of the BUSP support.

[68] There is no possibility that a positive shock hit the London markets in October of 1839. Equity prices in London were falling, not rising in the late 1839, see Gayer, Rostow, and Schwartz, Growth and Fluctuation.

willing to pay market rates. For example, Illinois had issued bonds to state contractors in lieu of cash payments, bonds the contractors had accepted at par. When state agents went to London in July of 1840, they took both new state bonds with par restrictions and contractor bonds. The contractor bonds were identical to the new bonds in every respect except the par restriction. 'None of the state bonds were sold, but an agreement was made to sell $1,000,000 of the contractors' bonds to Magniac, Smith and Company of London at a rate of eighty-three.'[69] Ohio continued to borrow through 1843, authorizing new bond issues at less than par. The state was able to sell $400,000 in bonds in July of 1840 to Barings at a price of 95 and an additional $400,000 in bonds in May of 1842 at 'the distressingly low price of 60.'[70] States could borrow, but not if they insisted on selling 5 or 6 percent bonds at par.

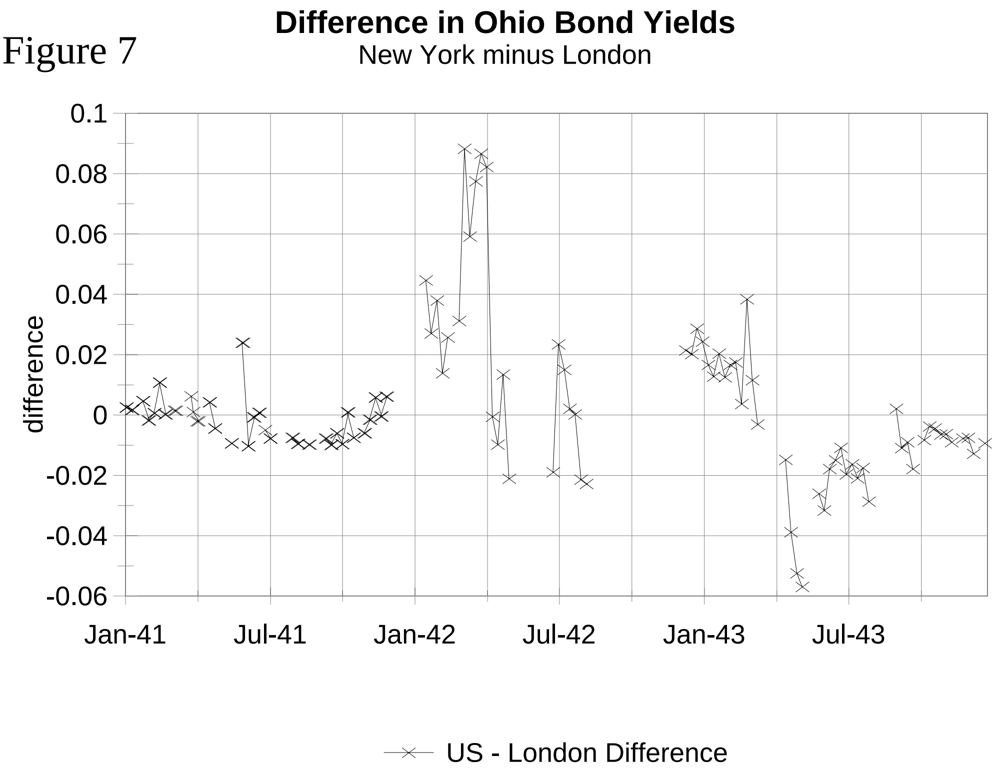
The Collapse of 1842:

Financial historians have paid little attention to the Collapse of 1842, but big things were happening that year in the market for state bonds. The collapse in state debt markets is traditionally attributed to state defaults (Table 3). The timing of defaults and bond yield movements shows that the onset of the default crisis cannot account entirely for the collapse of state debt markets. In 1841, Indiana and Florida defaulted in January, Mississippi in March, and Michigan and Arkansas in July. Yet yields on New York and Ohio bonds were not noticeably higher in the first quarter of 1841 than they had been for most of 1840. Although yields rose in the second and third quarter of 1841, the increase was small compared to the jump that occurred

[69] Krenkel, Illinois Internal Improvement, p. 122.

[70] Scheiber, Ohio Canals,pp. 140-158, quote from p. 152. At a price of 60, the yield on a 6 per cent bond was roughly 10 percent. Ohio did not include a par restriction in the legislation authorizing bond issues in 1836, so most Ohio bonds could be sold at any price. Ohio did have problems with price restrictions, however. One issue of bonds had been sold for less than the legislated minimum and at one point markets in New York believed, erroneously, that the state was about to default on bonds that had been sold in violation the legislated price.

Figure 7



in the fourth quarter of 1841 and the first quarter of 1842. Something happened in the winter of 1842 that shook American credit markets. And it wasn't just the defaulting states that experienced a crisis in the winter of 1842: yields for issues of Ohio and New York bonds, states that avoided default, spiked in the U.S. market as well.

The crisis in the winter of 1842 originated in the United States. The news hit American markets first, American markets quickly increased the risk premium placed on American state bonds, and London did not digest the news from American markets for several months. In the first quarter of 1842, the yield on New York bonds was 9.89 percent in New York and 6.62 percent in London; on Ohio bonds, 12.78 percent in New York and 8.86 percent in London; on Illinois bonds, 43.74 percent in New York and 26.78 percent in London. Figure 7 focuses on bond yield differences for Ohio between January 1841 and December 1843 (this figure expands the time scale of Figure 3; a graph for New York is similar). As the default crisis unfolded in 1841, yields in Ohio stayed close to yields in London. But in December of 1841 and January of 1842, yields moved sharply higher in the United States, peaking in late March.[71] Yields on New York and Ohio bonds were at least 8 percentage points higher in New York than the contemporaneous prices in London.

The shock was not transitory. Bond yields remained higher in both markets through 1842. But the disjunction between bond yields in the United States and in London was transitory. By April 17, 1842, New York and Ohio bonds were again trading for the same prices in London, New York, and Philadelphia.[72] For the second quarter as a whole, yields were only 0.0028 (28 basis points) higher in New York than in London. Markets were well integrated, but the shock hit America first and, given the time it took information to propagate to Britain, London did not react for two months.

What happened? Pennsylvania was the locus of the crisis. As early as 1839, Pennsylvania was in deep financial trouble, but BUSP loans masked the state's weakness until the state was forced back into regular credit markets. After the BUSP failed in February 1841, the yields on Pennsylvania bonds in Philadelphia began rising: from 5.76 percent in the last quarter of 1840, to 8.05 percent in the first quarter of 1841, 8.43 percent in the third quarter, 11.42 percent in the fourth quarter, and 17.99 percent in the first quarter of 1842.

State chartered banks were not at liberty to refuse loans to the state government that chartered them. Throughout 1841, Pennsylvania leaned on its banks. In November of 1841, Pennsylvania announced that it would require a loan from all banks in the state equal to 5 percent of their capital. The news that hit American markets in December 1841 and January 1842, as the

[71] Yields on Ohio and New York bonds began moving higher in December, but Figure 7 shows a widening gap in January. We do not have London prices for Ohio bond between December 5, 1841 and January 9, 1842. The difference in yields began widening in early December.

[72] Bond prices moved sharply upward in London that week, New York bonds went from yields of 6.38 percent to 8.05 percent and Ohio bonds from yields of 9.34 percent to 12.5 percent. At the same time, yields moved down in New York, bring yields in the two markets back into parity. By this time, Pennsylvania bonds were no longer trading in London.

state began gathering loans from its banks, was that Pennsylvania was actually carrying out its threat to make the banks sustain the state credit through forced loans. In February of 1842, the state precipitated a banking panic in Philadelphia, when it attempted to withdraw funds from the Bank of Philadelphia necessary to cover the interest payments due that month.[73] At that point, the state had not yet decided whether it would rescue the state credit by extorting more money from state chartered banks. When Pennsylvania made it clear that it would not force more loans from state banks in April of 1842, the crisis was over. As a result of the state's decision not to press its banks it became inevitable that Pennsylvania would default on its August 1842 interest payment, and Pennsylvania bond yields accordingly rose steadily until the third quarter. Yields on Pennsylvania bonds would not fall back below 10 percent until April of 1844, and the state resumed interest payments in February 1845.

Conditions were similar in New York, where the state pressed state chartered banks to purchase state bonds. New York bank holdings of state 'stock' rose from nothing in 1839 to almost $7 million in 1842. The New York state legislature met in emergency session in March to consider how to deal with the impending state default. It responded with the 'Stop and Tax' law of 1842, stopping borrowing, stopping construction on canals, and re-instituting the state property tax. These measures ended the crisis in New York bonds.

Ohio relied heavily on its banks for funds. Ohio raised $900,000 in 1842, $500,000 from state chartered banks and the $400,000 borrowed through Barings in London.[74] As long as Ohio

[73] The funds Pennsylvania withdrew were the funds they had borrowed from other banks in the state. Pennsylvania did not default on its bonds until 1842, but they were several days late on an interest payment in February because of the banking crisis. The crisis in Pennsylvania and the state's interaction with its banks is described in Kettell 'Debts and Finances' and the Pennsylvania Report in House Document 226, 29th Congress, First Session.

[74] Scheiber, Ohio Canals, pp. 140-158. 'During the remainder of 1842, the fund board sustained installment payments on the three-year loans by issuing bonds to Ohio banks at prices of 70 to 75 [yields of roughly 8 percent]. In this manner, nearly $700,000 of bonds were sold for cash payments of only $500,000.' p. 152. As noted earlier, Ohio borrowed sold its bonds to Barings for a price of 60.

continued its internal improvement projects, financial markets continued to purchase Ohio bonds at prices significantly below par. Yields on Ohio bonds in New York and London remained over 10 percent until the second quarter of 1843. Because Ohio could pressure its banks in a way that it could not pressure financial markets, as interest rates rose the state issued more bonds to its banks and fewer directly to financial markets. When it did place new bonds, it placed them in London, not in New York.

Rising yields on Ohio and New York bonds in late 1841 were not a response to the default crisis in Mississippi, Florida, Arkansas, Indiana, and Michigan. The Governor of Mississippi announced that he supported repudiation in early 1841. When Mississippi and Florida repudiated their bonds by legislative act in February of 1842 this was old news. The news in the winter of 1842 was the threat that New York, Ohio, and Pennsylvania would cannibalize their banks to keep state finances afloat. Pennsylvania's announcement of the forced loan program in November 1841 gave concrete expression to the threat. Throughout the winter of 1842 it was not clear what additional steps states would take to deal with the crisis. Fundamental uncertainty drove bond prices down, bond yields up, and brought an end to any hopes that states would be able to raise large amounts of capital at reasonable rates to continue their internal improvement projects. News of the threat and an appreciation of its magnitude took several months to reach Britain.

The Collapse of 1842 was not brought on by tight credit markets in Britain after the Crisis of 1839, but by a political crisis in the United States in the winter of 1842. Even so, financial markets sorted themselves out quickly. Interest rates on all state debts were higher in April of 1842 than in October of 1841, but markets in London and New York paid the sample yields on Ohio and New York bonds.

Section 5. Conclusion

In 1841, Nicholas Biddle argued that European conditions played an important role in the economic crisis in 1839, and one need go no further than Leland Jenks's *Migration of British Capital* or Bray Hammond's *Banks and Politics in America* to see how much economic historians have laid the blame for the depression of 1839 to 1842 at the feet of international conditions. Peter Temin made no bones about the centrality of British credit in bringing on the Crisis of 1839 and the collapse of state internal improvement projects: 'The state projects initiated in the late 1830s had been started in the expectation of external [*British*] financing.... Unfortunately, the new inflow of foreign capital did not continue [in 1839]... and the manifold projects of the states were abandoned.' Three clear findings of this paper challenge this traditional interpretation.

First, the conditions that brought on the Panic of 1837 could not have anything to do with the crisis in American state debts after 1839. The majority of state debt outstanding in 1841 was incurred after Panic, not before. The vast majority of debt in New York, Ohio, Massachusetts, Indiana, Illinois, Michigan, Arkansas, Maryland, and Mississippi involved in the default crisis was authorized in 1837 or later and issued long after the Panic of 1837 was over. New York, Ohio, and Pennsylvania continued to issue and market bonds in 1840 and 1841.

Second, before 1837 state bonds had marketed for slightly higher prices (lower yields) in London than New York and Philadelphia. After the Panic of 1837, London markets for American state bonds became noticeably tighter than American markets, during the three years of the heaviest borrowing: 1837, 1838, and 1839. Yet, when the BUSP suspended payments in October 1839, the economic crisis set in, and bond yields rose sharply in both countries, yields in London became significantly lower than yields in the U.S.. States such as Ohio and Illinois could borrow at lower cost in London than in New York, and so they borrowed in London. There is no evidence that British credit markets dried up relative to American markets after 1839. States had more trouble borrowing in both markets, of course, and states were forced out of the market entirely if they insisted on borrowing at par. The collapse of state transportation projects in Indiana, Illinois, and Michigan in 1839 had nothing to do with credit markets in London, and everything to do with the defalcation of American banks such as the Morris Canal and Banking Company, which failed to pay states for bonds they had already accepted and on which the states were liable to pay interest immediately.

Third, the movement of bond yields during the Crisis of 1839 and the Collapse of 1842 indisputably show that the shocks to financial markets originated in the United States and spread to London, not the other way around. As the economic crisis deepened in 1840 and 1841, New York, Ohio, and Pennsylvania put greater pressure on their own state chartered banks to buy state bonds. This was not because the states could not sell bonds in London, but because the yields on those bonds in London, New York, and Philadelphia were justifiably rising. Pennsylvania's forced loan policy, beginning in November of 1841, tipped American markets into crisis.

The Panic of 1837 has received the lion's share of attention from economic historians, but, as the macroeconomic situation deteriorated, the North Atlantic economy was hit by two more crises in 1839 and 1842. It seems clear that the impetus for these crises came from the United States and was intimately tied to the market for American state government bonds and the failing efforts of American states, particularly in the west, to finance public investments in finance and transportation. The Crisis of 1839 and the Collapse of 1842 were not caused by the same forces as the Panic of 1837. The collapse of American state finances in the 1840s was predicated on events that occurred after 1837.

Chapter 5: Conclusion

One of the achievements of my thesis is to discover the trend and cyclicality of diversification in the entire U.S. manufacturing sector in the last 30 years. Findings are summarized as follows: (1) Aggregate diversification declined both at the establishment and firm level since the early 1980s. The downward trend is common in many industries. The declining diversification is quite contrary to the conjecture that the diversification has been increasing in the last three decades. (2) Whether the diversification is pro-cyclical or counter-cyclical is not clear at the aggregate or industry level. The conjecture that the diversification is pro-cyclical cannot be confirmed by the data. (3) A large fraction of firms change the number of products and plants annually. The declining diversification measure suggest that firms becomes more specialyzed, but it is certain that the number of product is not fixed for firms even in the short run. It is shown that product diversification is a decision variable for firms, which is contrary to assumptions of fixed diversification in many theoretical models in literature. I show that firms actively change their product diversification at a short-term frequency. More Firms specialize in one product and the number of products and plants behaves like an adjustment margin.

Trend of volatility is verified by the micro level data and new empirical relationship between diversification and volatility is found. Using the firm level profit rates, I find: (1) the aggregate volatility declined. (2) The volatility decreased since the 1980s for most industries. (3) The mean of firm level idiosyncratic volatilities decreased in late 1980s and the standard deviation doesn't change much. The left-censored Tobit regression shows that the firm level diversification is positively affected by the aggregate, industrial and idiosyncratic profit volatility. Therefore, the decrease of volatility, in other words, the reduced risks in US manufacturing sector contributes to the decrease of diversification.

In summary, firms specialize more in the past 30 years in U.S. manufacturing sector. It is because the profit volatility decreased at the aggregate, industrial and firm level. Therefore, firms have less incentive to diversify over different products to insure themselves against profit shocks. However, a large fraction of firms adopt flexible production lines which allow them to adjust the number of products at the short term frequency responding to the economic fluctuation.

A lot of questions about diversification have been raised and partially answered. But it was not easy to see the whole picture of evolution of diversification because there hadn't been enough data. With rich description and analysis in my thesis, we now better understand diversification of firms and the role of volatility on diversification. It is now possible to move on to next questions on diversification and specialization: whether specialization enhanced productivity, whether diversification increased the profits by reducing idiosyncratic risks, whether the high volatility played a role in high diversification in developing countries.

Historically, the volatility change gravely affects the economy in many ways in U.S. The event of 1840s shows an example of volatility change caused by the investment of U.S. government. The bond markets in U.K and U.S were integrated across Atlantic Ocean in early 19^{th} century. The movement of bond yields during the Crisis of 1839 and the Collapse of 1842 indisputably show that the shocks to financial markets originated in the United States and spread to London, not the other way around.

The Panic of 1837 has received the lion's share of attention from economic historians, but, as the macroeconomic situation deteriorated, the North Atlantic economy was hit by two more crises in 1839 and 1842. It seems clear that the impetus for these crises came from the United States and was intimately tied to the market for American state government bonds and the failing efforts of American states, particularly in the west, to finance public investments in finance and transportation. The Crisis of 1839 and the Collapse of 1842 were not caused by the same forces as the Panic of 1837. The collapse of American state finances in the 1840s was predicated on events that occurred after 1837.

Appendix A: Data in Chapter 2 and Chapter 3

Primary Data source: LRD and LBD

LRD: LRD provides a company-level database containing detailed statistics on research and development activities; and supports research on the issues of productivity, profitability, and the use of research and development. The database contains detailed company-level research and development information compiled from the annual Industrial Research and Development survey for survey years 1972 through 2001. Over the 30 year period, the total sample for the survey size has varied considerably. Since 1992, the total sample size has been fairly stable at approximately 25,000 companies. The sample design strategy has evolved over the years. The company has been defined as both the sample unit and the data collection unit since inception. Prior to 1992, a given sample would be used for a number of years before being replaced. The probability of selection was a direct function of total company employment; companies with more than 500 employees were included with certainty.

LBD: LBD is a research dataset constructed at the Census Bureau's Center for Economic Studies. LBD is an establishment based file created by linking the annual snapshot files from Census Bureau's Business Register over time. It contains high quality longitudinal establishment linkages. Firm level linkages are currently under development at CES. Currently, LBD contains the universe of all U.S. business establishments with paid employees from 1976 to present. LBD covers almost 24 million unique establishments from 1975 to present.

Supplementary Data source: NBER R&D and Productivity file from NBER, and statistics from *ASM: Annual Survey of Manufactures* published by Census Bureau.

Diversification Index: I measure 5-digit product diversification using LRD as described in the text. 5-digit product shares are calculated by TVPS/TVS where TVS (Total Value of shipments) is the sum of TVPS (Total Value of Product Shipment) at the establishment level. For a firm level index, the product shares are calculated by FTVPS/FTVS, where FTVPS is the sum of TVPS of a product produced in every plant of the firm and FTVS is the sum of TVS across plants. Some product data are imputed and they are eliminated from the sample.

ASM sample base is the establishment rather than the firm, some establishments of a multi-unit firm may not be selected in ASM sample. This can distort the firm-level diversification measure of multi-unit firms. In most cases, however, all the establishments of a multi-unit firm are included in ASM sample. All the plants of a company, so-called Certainty Companies, are included in ASM for certain, but many of the non-certainty multi-unit firms also have all of their plants in ASM.[75] Matching ASM and LBD enables us to find the establishments of a multi-unit firm which are not selected for the ASM sample. After shipment weighted, the share of those establishments is negligible. The aggregated diversification index is not sensitive to this sample problem. See LRD documentation for detail.

Industry Classification: LRD classifies establishments by industry using the Standard Industrial Classification System (SIC). The structure of SIC makes it possible to tabulate, analyze, and publish establishment data on a 2-digit, a 3-digit, or a 4-digit industry code basis, according the level of industrial detail considered most appropriate. In addition to industry, the Census Bureau also collects and publishes information on product classes and individual products produced by manufacturing establishments. Product classes (5-digit codes) and products (7-digit codes) of manufacturing industries are assigned codes based on the industry from which they originate.

[75] Those companies are usually big firms with no less than 250 employees. The establishments that had been dropped out of sample were added with zero statistical weight and called 'McGuckin Adds'.

Beginning in 1997 the US, Canada, and Mexico began publishing and collecting statistics under the new North American Industrial Classification Systems (NAICS). NAICS is based on a consistent, economic concept: Establishments that use the same or similar processes to produce goods or services are grouped together. The SIC, developed in the 1930s and revised periodically over the past 50 years, was not based on a consistent economic concept. A major change in SIC occurred in 1987. Some industries are demand based while others are production based. From 1998 ASM, the product class is coded by NAICS.

Table AA-1 Description of SIC codes

	SIC Code	Level	Description
2-digit	28	Major industry group	Chemicals and allied products
4-digit	2834	Industry	Pharmaceutical Preparations
5-digit	28347	Product class	Vitamin, nutrient, and hematinic preparations, for human use
7-digit	2834711	Product	Multivitamins, plain and with minerals (except B complex vitamins and fish livers oils)

Establishment and Firm Identifier: Permanent Plant Number (PPN) assigned to each establishment by Census is used as the establishment identifier. For the single-unit firms/establishments, PPN begins with 0. For multi-units, the first six digits of the ten-digit PPN identify the firm.

Profit rate: Profit rate is measured by the nominal sales (TVS) minus the variable costs, divided by the capital stock. The variable costs are composed of total wage cost (SW) and the total material costs (CM). Profit is deflated by GDP deflator. Book value of capital stock(MA and BA) is collected in ASM and CM and it is deflated by the 2-digit industry level deflator. The Bureau of Economic Analysis publishes 2-digit industry capital stock both in nominal and real values. I use the ratio of the nominal capital stock to real capital stock as the 2-digit industry level capital deflator. The base year for the deflator is 1996. The growth rate of real shipment (RTVS) is the symmetric growth measure: Growth of RTVS at time t = $(RTVS_t - RTVS_{t-1}) / [(RTVS_t + RTVS_{t-1})/2]$

Appendix B: Multivariate ARCH with missing data in Chapter 4

The multivariate ARCH model for stock/bond market integration test in Chapter 4 has the following feature:

$$Y_{it} = X_{it} B_i + \varepsilon_{it} \qquad ,i = 1,2,\cdots,n$$
$$\varepsilon_t | \Lambda_{t-1} \sim N(0,\Omega)$$
$$E(\varepsilon_{it} | \Lambda_{t-1}) = 0$$
$$E(\varepsilon_{it}\varepsilon_{jt} | \Lambda_{t-1}) = \Omega_{ij} = a_{ij} + b_{ij}\varepsilon_{it-1}\varepsilon_{jt-1}$$

We are maximizing the log likelihood function to estimate parameters, (a,b,B):

$$\log L = -\sum_{t=2}^{T}\frac{n}{2}\log(2\pi) - \sum_{t=2}^{T}\frac{1}{2}\log|\Omega_t| - \sum_{t=2}^{T}\frac{1}{2}\varepsilon_t{}'\Omega_t^{-1}\varepsilon_t$$

where

$$\Omega_t = \Omega_t(a,b,\varepsilon_{t-1}) \ \ and \ \ \Omega_{ijt} = a_{ij} + b_{ij}\varepsilon_{it-1}\varepsilon_{jt-1}$$
$$\varepsilon_t = Y_t - X_t B$$

$$\therefore \log L = \log L(a,b,B|data)$$

Since the bond prices are not observed sometimes, the YTM series that are necessary for bond market integration test have some missing data. To get a bench mark result, we linearly interpolated the surrounding observations for these missing observations and used this imputed series for the ARCH estimation. For example, the data are available in week 3 and week 5 in London, the price interpolated from these two prices is used for week 4. This imputation may cause a consistency problem in our estimates, since the imputation is not likely to be the true data generating process. We develop a new method to handle the missing observations directly.

Suppose an observation is missing at time t-1. For example, the data are not available in London in week 4, while the data are available in week 3 and week 5 in both markets. We take the covariance matrix of time t, conditional on time t-2 disturbance terms, instead of time t-1 disturbance terms. That is, the covariance of week 5 is conditional on week 3, not week 4:

$$E(\varepsilon_{it}\varepsilon_{jt}|\Lambda_{t-2}) = a_{ij} + b_{ij}E(\varepsilon_{it-1}\varepsilon_{jt-1}|\Lambda_{t-2})$$
$$E(\varepsilon_{it-1}\varepsilon_{jt-1}|\Lambda_{t-2}) = a_{ij} + b_{ij}\varepsilon_{it-2}\varepsilon_{jt-2}$$
$$\therefore\ E(\varepsilon_{it}\varepsilon_{jt}|\Lambda_{t-2}) = a_{ij}(1+b_{ij}) + b_{ij}^2\varepsilon_{it-2}\varepsilon_{jt-2}$$

In this fashion, we can represent the conditional covariance of time t with the time t-2 error terms. Generalizing this method to calculate recursively to the case where time (t-s) data are the latest observations before t, we get

$$E(\varepsilon_{it}\varepsilon_{jt}|\Lambda_{t-s}) = a_{ij}^* + b_{ij}^*\varepsilon_{it-s}\varepsilon_{jt-s}$$
$$where$$
$$\begin{cases} a_{ij}^* = a_{ij}(1+b_{ij} + \cdots + b_{ij}^{s-1}) \\ b_{ij}^* = b_{ij}^s \end{cases}$$

Therefore, (a*, b*) has one-to-one nonlinear relationship to (a, b). Using this relationship, we can adjust the likelihood function without changing the number of parameters we are estimating:

$$\log L = -\sum_{t\in A}\frac{n}{2}\log(2\pi) - \sum_{t\in A}\frac{1}{2}\log|\Omega_t| - \sum_{t\in A}\frac{1}{2}\varepsilon_t{}'\Omega_t^{-1}\varepsilon_t$$
$$where$$
$$\Omega_t = \Omega_t(a,b,\varepsilon_{t-s})\ \ and\ \ \Omega_{ijt} = a_{ij}(1+b_{ij}+\cdots+b_{ij}^{s-1}) + b_{ij}^s\varepsilon_{it-s}\varepsilon_{jt-s}$$
$$A = time\ \ periods\ when\ the\ data\ are\ observed$$

$$\therefore\ \log L = \log L(a,b,B|observed\ data)$$

The covariance matrix is conditional on the latest observations available. The likelihood function is still determined by a, b and B conditional on the actual data. There is a computational problem because the likelihood function is highly nonlinear on a and b, but the consistency of the estimate is preserved.

Appendix C: Additional Statistics of Annual Firm-level Product Diversification

Table AC-1 Average Firm level Diversification Index

year	frequency	Not weighted	Shipment weighted
74	21018	0.17204	0.72984
75	20605	0.17327	0.72827
76	20913	0.16792	0.73121
77	24889	0.17545	0.72929
78	23973	0.17235	0.72479
79	25306	0.15597	0.71227
80	25024	0.15612	0.70771
81	23277	0.15839	0.71600
82	22770	0.19000	0.70695
83	20079	0.18967	0.71414
84	20055	0.16184	0.71090
85	18089	0.16478	0.70861
86	17914	0.16314	0.70209
87	19085	0.20029	0.69528
88	16835	0.20881	0.69410
89	21211	0.16033	0.68754
90	29814	0.10996	0.68208
91	29975	0.12077	0.67950
92	30728	0.16033	0.66403
93	30744	0.13381	0.66211
94	40298	0.09048	0.65296
95	38547	0.09355	0.64973
96	36961	0.09561	0.64735
97	42766	0.11777	0.62857
98	25359	0.13921	0.64273

Table AC-2 Average Firm level Diversification Index of Single Unit firms

year	frequency	Not weighted	Shipment weighted
74	17495	0.10282	0.17855
75	17228	0.10550	0.18238
76	17655	0.10258	0.16741
77	20925	0.11449	0.18504
78	20061	0.11005	0.17599
79	21503	0.10384	0.15623
80	21465	0.10621	0.16029
81	19897	0.10692	0.16702
82	18864	0.13812	0.18113
83	16364	0.13223	0.17185
84	16533	0.10144	0.14605
85	14717	0.10125	0.14244
86	14760	0.10396	0.15206
87	15141	0.13981	0.18516
88	12818	0.14349	0.18218
89	17434	0.10485	0.15249
90	26218	0.06756	0.13617
91	26592	0.08218	0.13718
92	26532	0.12504	0.17138
93	26704	0.09106	0.16005
94	36439	0.05728	0.13421
95	34846	0.06069	0.13091
96	33426	0.06310	0.13068
97	38635	0.08861	0.14643
98	22226	0.09980	0.14477

Table AC-3 Average Firm level Diversification Index of Multi Unit firms

year	frequency	Not weighted	Shipment weighted
74	3523	0.51578	0.77045
75	3377	0.51901	0.76725
76	3258	0.52204	0.76902
77	3964	0.49729	0.76322
78	3912	0.49183	0.75931
79	3803	0.45077	0.75342
80	3559	0.45714	0.74905
81	3380	0.46143	0.75328
82	3906	0.44055	0.74102
83	3715	0.44266	0.74617
84	3522	0.44536	0.75148
85	3372	0.44204	0.74545
86	3154	0.44010	0.74465
87	3944	0.43247	0.72989
88	4017	0.41725	0.7284
89	3777	0.41640	0.7313
90	3596	0.41907	0.72715
91	3383	0.42409	0.72277
92	4196	0.42149	0.70572
93	4040	0.41641	0.70243
94	3859	0.40397	0.70013
95	3701	0.40291	0.69309
96	3535	0.40299	0.68796
97	4131	0.39044	0.6645
98	3133	0.41877	0.67831

Table AC-4 Share of Diversified Production (r_{pd})

year	Share of Diversified Production (r_{pd})
74	0.003744
75	0.003589
76	0.003430
77	0.004498
78	0.006080
79	0.006118
80	0.005320
81	0.005597
82	0.006016
83	0.006107
84	0.007289
85	0.007863
86	0.009350
87	0.007971
88	0.009129
89	0.009075
90	0.008278
91	0.008905
92	0.010446
93	0.011226
94	0.013564
95	0.016755
96	0.020226
97	0.018314
98	0.010821

Note:

$$d = 1 - (\underbrace{\sum_{i \in A} S_i^2}_{\text{Diversified Production}} + \underbrace{\sum_{i \in B} S_i^2}_{\text{Specialized Production}}) = (r_{pd} + r_{ps})d$$

where,

$$r_{pd} = \sum_{i \in A} S_i^2 / \sum_{i} S_i^2, \; r_{ps} = 1 - r_{pd}$$

$i \in A$ product i produced in multiple plants

$i \in B$ product i produced only in one plant

Table AC-5 Share of Within-plant Factor in Firm Level Diversification(r_{wp})

year	Share of Within-plant factor(r_{wp})
74	0.422879
75	0.421189
76	0.416774
77	0.402075
78	0.414824
79	0.436601
80	0.451316
81	0.448953
82	0.429708
83	0.430263
84	0.408616
85	0.402632
86	0.384211
87	0.394595
88	0.393574
89	0.387701
90	0.39031
91	0.37973
92	0.385892
93	0.378976
94	0.375346
95	0.366295
96	0.367318
97	0.375907
98	0.353448

Note:

$$d^f = \underbrace{\sum_j a_j d_j^{est}}_{\text{Within-plant}} + \underbrace{(d^f - \sum_j a_j d_j^{est})}_{\text{Among-plant}} = (r_{wp} + r_{ap}) d^f$$

where,

a_j = shipment share of the jth plant

d^f = firm level diversification, d^{est} = plant level diversification

$\mathrm{r_{wp}} = \sum_j a_j d_j^{est} \Big/ d^f$, $\mathrm{r_{ap}} = 1 - \mathrm{r_{wp}}$

Table AC-6 Annual Diversification Index Change Decomposed by POSC, NEGC, POSB and NEGD

year	Net D change	POSC	NEGC	POSB	NEGD
75	0.003	0.025	-0.022	0.421	0.448
76	0.002	0.020	-0.018	0.391	0.447
77	0.006	0.033	-0.027	0.540	0.564
78	-0.003	0.017	-0.020	0.342	0.393
79	-0.007	0.023	-0.030	0.294	0.511
80	-0.004	0.020	-0.024	0.405	0.463
81	0.007	0.026	-0.019	0.361	0.509
82	0.002	0.035	-0.033	0.518	0.580
83	0.000	0.032	-0.032	0.297	0.514
84	-0.011	0.027	-0.038	0.342	0.395
85	0.003	0.025	-0.022	0.479	0.607
86	0.009	0.033	-0.024	0.372	0.673
87	0.009	0.044	-0.035	0.558	0.569
88	-0.002	0.030	-0.032	0.389	0.498
89	0.014	0.037	-0.023	0.303	0.564
90	-0.002	0.024	-0.026	0.398	0.568
91	0.009	0.026	-0.017	0.334	0.500
92	0.007	0.041	-0.034	0.533	0.509
93	-0.003	0.025	-0.028	0.336	0.459
94	-0.005	0.029	-0.034	0.324	0.379
95	-0.005	0.028	-0.033	0.450	0.567
96	0.000	0.028	-0.028	0.413	0.532
97	0.014	0.057	-0.043	0.514	0.570

Note:
POSC=average diversification change of continuing firms with positive change
NEGC=average diversification change of continuing firms with negative change
POSB=average diversification change of starting firms
NEGD=average diversification change of shutting-down firms

Table AC-7 Firm level Diversification Index Change Decomposed by Diversified/Specialized Plants (MU Firms)

year	D(t-1)	D(t)	D(t)-D(t-1)	Diversified Production	Specialized Production	Net Entry Plant
75	0.77045	0.76725	-0.0032	0.001	0	0.002
76	0.76725	0.76902	0.001771	0	0.006	-0.001
77	0.76902	0.76322	-0.00581	0.002	-0.008	0
78	0.76322	0.75931	-0.00391	0.001	0.017	-0.009
79	0.75931	0.75342	-0.00589	0.006	0.072	-0.039
80	0.75342	0.74905	-0.00437	0	0.004	0
81	0.74905	0.75328	0.004227	0	-0.007	0.007
82	0.75328	0.74102	-0.01226	-0.002	-0.017	0.007
83	0.74102	0.74617	0.00515	0	0.004	0.001
84	0.74617	0.75148	0.005311	0.006	0.001	-0.001
85	0.75148	0.74545	-0.00602	0.001	0.009	-0.002
86	0.74545	0.74465	-0.0008	0.004	0.006	-0.003
87	0.74465	0.72989	-0.01476	-0.011	-0.019	0.012
88	0.72989	0.7284	-0.00149	0.008	0.004	-0.001
89	0.7284	0.7313	0.002899	0.004	0.005	-0.003
90	0.7313	0.72715	-0.00415	0	-0.004	0.005
91	0.72715	0.72277	-0.00438	0	0.001	0
92	0.72277	0.70572	-0.01705	-0.002	-0.03	0.018
93	0.70572	0.70243	-0.00329	0	0.015	-0.007
94	0.70243	0.70013	-0.00231	0.006	0.035	-0.025
95	0.70013	0.69309	-0.00704	0.001	0	0.003
96	0.69309	0.68796	-0.00513	0.003	-0.002	0.003
97	0.68796	0.6645	-0.02346	-0.003	-0.01	0.007
98	0.6645	0.67831	0.013819	0.003	-0.006	0.005

Note:

$$\Delta d_t = -\underbrace{\left(\sum_{i\in PN,PC} S_{i,t}^2 - \sum_{i\in PC,PX} S_{i,t-1}^2\right)}_{\text{Diversified Production Factor}} - \underbrace{\left(\sum_{i\in PC} S_{i,t}^2 - \sum_{i\in PC} S_{i,t-1}^2\right)}_{\text{Specialized Production Factor}} - \underbrace{\left(\sum_{i\in PN} S_{i,t}^2 - \sum_{i\in PX} S_{i,t-1}^2\right)}_{\text{Plant Net Enry Factor}}$$

Where,

$i \in PC,PN$ product i which is produced both in plant *PC* and *PN*

$i \in PC$ product i which is produced only in plant *PC*

PC = Continuously operating plant at time t-1 and t

PN = new plant in time t

PX = exiting plant in time t

Table AC-8 Firm Level Diversification Change Decomposed by Intensive/Extensive Components (Continuing MU Firms)					
year	D(t-1)	D(t)	D(t)-D(t-1)	intensive	extensive
75	0.72984	0.72827	-0.00157	0.014	-0.065
76	0.72827	0.73121	0.002944	0.013	-0.063
77	0.73121	0.72929	-0.00192	-0.008	-0.326
78	0.72929	0.72479	-0.0045	0.022	-0.054
79	0.72479	0.71227	-0.01253	0.087	-0.078
80	0.71227	0.70771	-0.00456	0.008	-0.084
81	0.70771	0.716	0.008293	0	-0.072
82	0.716	0.70695	-0.00905	-0.032	-0.425
83	0.70695	0.71414	0.007188	0.008	-0.35
84	0.71414	0.7109	-0.00324	0.008	-0.218
85	0.7109	0.70861	-0.00229	0.02	-0.083
86	0.70861	0.70209	-0.00652	0.021	-0.167
87	0.70209	0.69528	-0.00681	-0.016	-0.659
88	0.69528	0.6941	-0.00118	0.033	-0.119
89	0.6941	0.68754	-0.00656	0.009	-0.114
90	0.68754	0.68208	-0.00546	0	-0.077
91	0.68208	0.6795	-0.00258	0.006	-0.104
92	0.6795	0.66403	-0.01547	-0.034	-0.464
93	0.66403	0.66211	-0.00192	0.026	-0.103
94	0.66211	0.65296	-0.00915	0.037	-0.089
95	0.65296	0.64973	-0.00323	0.011	-0.067
96	0.64973	0.64735	-0.00237	0.012	-0.078
97	0.64735	0.62857	-0.01878	-0.017	-0.412

Note:

$$\Delta d_t = \underbrace{-\sum_{i \in NC}\left(S_{it}^2 - S_{it-1}^2\right)}_{\text{Intensive Component}} \underbrace{-\left(\sum_{i \in NN} S_{it}^2 - \sum_{i \in NX} S_{it-1}^2\right)}_{\text{Extensive Component}}$$

where,
NC = Products which are continuously produced at time t and t-1
NN = New products at time t
NX = Exiting products at time t

Table AC-9 Firm Level Diversification Change Decomposition (Continuing MU Firms)									
year	D(t-1)	D(t)	D(t)-D(t-1)	I	II	III	IV	V	VI
75	0.729	0.728	-0.002	-0.001	0.000	-0.003	0.002	-0.001	0.000
76	0.728	0.731	0.003	0.000	0.000	-0.009	0.001	0.002	0.000
77	0.731	0.729	-0.002	-0.001	-0.001	0.008	0.003	-0.003	-0.001
78	0.729	0.725	-0.005	-0.001	0.000	-0.017	0.001	0.007	0.000
79	0.724	0.712	-0.013	-0.005	0.000	-0.071	0.001	0.033	0.004
80	0.712	0.708	-0.005	0.000	0.000	-0.004	0.000	0.000	0.000
81	0.707	0.716	0.008	0.000	0.000	0.006	0.001	-0.006	-0.001
82	0.716	0.707	-0.009	0.002	0.000	0.018	-0.002	-0.005	0.000
83	0.706	0.714	0.007	0.000	0.000	-0.003	0.000	0.000	-0.002
84	0.714	0.711	-0.003	-0.006	0.000	-0.001	0.001	0.003	-0.002
85	0.710	0.709	-0.002	-0.001	0.000	-0.010	0.002	0.002	0.000
86	0.708	0.702	-0.007	-0.003	0.000	-0.008	0.004	0.001	0.000
87	0.702	0.695	-0.007	0.005	0.005	0.007	0.009	-0.006	-0.003
88	0.695	0.694	-0.001	-0.008	0.000	-0.005	0.006	-0.003	-0.001
89	0.694	0.688	-0.007	-0.004	0.000	-0.002	0.000	0.000	0.000
90	0.687	0.682	-0.005	0.001	0.000	0.001	0.002	-0.002	-0.001
91	0.682	0.680	-0.003	0.000	0.000	-0.003	0.001	0.000	0.000
92	0.679	0.664	-0.015	0.002	0.000	0.031	0.001	-0.017	-0.002
93	0.664	0.662	-0.002	0.000	0.000	-0.020	0.004	0.007	0.000
94	0.662	0.653	-0.009	-0.006	0.000	-0.033	0.000	0.021	0.001
95	0.652	0.650	-0.003	-0.001	0.000	-0.001	0.001	-0.003	0.000
96	0.649	0.647	-0.002	-0.003	0.000	0.002	0.002	-0.005	0.000
97	0.647	0.629	-0.019	0.003	0.000	0.009	-0.001	-0.004	-0.001

Note:

$$\Delta d_t = \left\{ \begin{array}{l} \underbrace{-\Big(\sum_{\substack{i\in PN,PC\\ i\in NC}} S_{it}^2 - \sum_{\substack{i\in PC,PX\\ i\in NC}} S_{it-1}^2\Big)}_{I} \underbrace{-\Big(\sum_{\substack{i\in PN,PC\\ i\in NN}} S_{it}^2 - \sum_{\substack{i\in PC,PX\\ i\in NX}} S_{it-1}^2\Big)}_{II} \underbrace{-\Big(\sum_{\substack{i\in PC\\ i\in NC}} S_{it}^2 - \sum_{\substack{i\in PC\\ i\in NC}} S_{it-1}^2\Big)}_{III} \\ \underbrace{-\Big(\sum_{\substack{i\in PC\\ i\in NN}} S_{it}^2 - \sum_{\substack{i\in PC\\ i\in NX}} S_{it-1}^2\Big)}_{IV} \underbrace{-\Big(\sum_{\substack{i\in PN\\ i\in NC}} S_{it}^2 - \sum_{\substack{i\in PX\\ i\in NC}} S_{it-1}^2\Big)}_{V} \underbrace{-\Big(\sum_{\substack{i\in PN\\ i\in NN}} S_{it}^2 - \sum_{\substack{i\in PX\\ i\in NX}} S_{it-1}^2\Big)}_{VI} \end{array} \right.$$

where,

$i \in PC,PN$ product i which is produced both in plant *PC* and *PN*

$i \in PC$ product i which is produced only in plant *PC*

PC = Continuously operating plant at time t-1 and t

PN = new plant in time t

PX = exiting plant in time t

NC = Products which are continuously produced at time t and t-1

NN = New products at time t

NX = Exiting products at time t

Table AC-10 Average Diversification index by Firm Size Quartile (using Total Employment)				
year	Q1	Q2	Q3	Q4
74	0.07024	0.11382	0.14729	0.75515
75	0.08011	0.10555	0.15428	0.75116
76	0.06637	0.08019	0.1505	0.75283
77	0.07045	0.1081	0.16285	0.74781
78	0.07293	0.10058	0.15412	0.74418
79	0.07987	0.09921	0.13989	0.73631
80	0.07995	0.1018	0.14419	0.73015
81	0.08231	0.10548	0.14073	0.73629
82	0.11481	0.13247	0.16729	0.72735
83	0.10931	0.12754	0.17919	0.73425
84	0.07759	0.10823	0.15079	0.73811
85	0.07221	0.10397	0.15143	0.73414
86	0.07345	0.10293	0.15335	0.72898
87	0.10895	0.1343	0.1843	0.72023
88	0.12096	0.1465	0.19893	0.72184
89	0.06612	0.10534	0.14494	0.71398
90	0.0256	0.05889	0.10398	0.7002
91	0.06967	0.07131	0.09999	0.69605
92	0.09566	0.11621	0.14918	0.67995
93	0.04253	0.08192	0.13201	0.67592
94	0.02035	0.04344	0.07967	0.66692
95	0.03054	0.05187	0.08986	0.66235
96	0.02431	0.05761	0.08899	0.65909
97	0.04765	0.08467	0.11322	0.6391
98	0.06216	0.08942	0.12658	0.65602

Table AC-11 Average Diversification index by Firm Age Quartile				
year	Q1	Q2	Q3	Q4
74	0.10838	0.73304		
75	0.09881	0.73066		
76	0.10149	0.7334		
77	0.11194	0.74246	0.20676	
78	0.10493	0.7389	0.21242	
79	0.11248	0.73188	0.18803	
80	0.1119	0.7268	0.18362	
81	0.13044	0.73308	0.19815	
82	0.18572	0.72829	0.23278	
83	0.21439	0.73565	0.22702	
84	0.16314	0.74176	0.21376	
85	0.16239	0.73685	0.22128	
86	0.15152	0.73123	0.21645	
87	0.20567	0.72757	0.24972	
88	0.2022	0.72996	0.25988	
89	0.1482	0.71243	0.21835	
90	0.01702	0.72989	0.13726	0.25671
91	0.06007	0.71629	0.10023	0.27856
92	0.17508	0.71894	0.17977	0.2963
93	0.14875	0.70952	0.16359	0.26939
94	0.00988	0.6992	0.15489	0.24911
95	0.00819	0.70008	0.14159	0.22522
96	0.03105	0.69624	0.13328	0.23635
97	0.033	0.67854	0.09753	0.25665
98	0.0651	0.69799	0.18122	0.28749

Note: The firm age variable is very limited in the data and it is not easy to determine the exact age if the firm is already old in early years of the panel. For example, most of firms are one year old or eleven years old in 1974. Therefore, we get only Q1 and Q2 in 1974.

Table AC-12 Average Diversification Index by Region									
year	1	2	3	4	5	6	7	8	9
74	0.77	0.73	0.75	0.68	0.75	0.70	0.68	0.63	0.70
75	0.76	0.72	0.75	0.68	0.75	0.69	0.67	0.69	0.72
76	0.73	0.72	0.73	0.71	0.72	0.75	0.67	0.81	0.75
77	0.71	0.75	0.75	0.68	0.70	0.71	0.70	0.73	0.74
78	0.72	0.76	0.74	0.71	0.71	0.71	0.67	0.72	0.71
79	0.74	0.73	0.70	0.68	0.74	0.69	0.69	0.67	0.70
80	0.68	0.69	0.71	0.75	0.74	0.68	0.72	0.67	0.69
81	0.69	0.72	0.70	0.73	0.72	0.73	0.73	0.72	0.72
82	0.66	0.69	0.70	0.70	0.69	0.75	0.70	0.69	0.74
83	0.64	0.71	0.73	0.72	0.72	0.71	0.70	0.72	0.72
84	0.67	0.70	0.72	0.71	0.71	0.77	0.70	0.70	0.69
85	0.65	0.66	0.72	0.72	0.75	0.74	0.70	0.77	0.66
86	0.64	0.68	0.74	0.68	0.70	0.68	0.70	0.76	0.68
87	0.61	0.70	0.73	0.69	0.66	0.72	0.70	0.71	0.68
88	0.66	0.70	0.71	0.70	0.68	0.77	0.70	0.76	0.61
89	0.55	0.70	0.68	0.67	0.73	0.69	0.68	0.75	0.62
90	0.69	0.63	0.69	0.64	0.71	0.66	0.72	0.69	0.66
91	0.69	0.64	0.70	0.68	0.68	0.73	0.69	0.69	0.65
92	0.58	0.70	0.65	0.63	0.69	0.68	0.68	0.62	0.64
93	0.56	0.67	0.69	0.55	0.68	0.70	0.67	0.62	0.63
94	0.53	0.61	0.66	0.62	0.67	0.68	0.69	0.65	0.66
95	0.54	0.66	0.68	0.62	0.68	0.66	0.65	0.67	0.56
96	0.60	0.64	0.63	0.61	0.68	0.68	0.67	0.69	0.62
97	0.67	0.59	0.59	0.56	0.67	0.67	0.72	0.56	0.53
98	0.53	0.63	0.63	0.60	0.66	0.69	0.64	0.71	0.64
growth	-0.30	-0.14	-0.16	-0.11	-0.12	-0.01	-0.07	0.12	-0.08
avg	0.65	0.68	0.70	0.67	0.70	0.71	0.69	0.70	0.67

Region: Census divides the survey coverage area into nine regions

1- New England
2- Middle Atlantic
3- East North Central
4- West North Central
5- South Atlantic
6- East South Central
7- West South Central
8- Mountain
9- Pacific

Table AC-13 Average Diversification Index by Quintile of Share of Interplant Transfer (IPT/TVS)					
year	Q1	Q2	Q3	Q4	Q5
76	0.42182	0.7558	0.79679	0.82443	0.79593
80	0.3851	0.73711	0.7877	0.80484	0.79789
81	0.37644	0.71383	0.80569	0.81557	0.78551
83	0.37729	0.72743	0.79797	0.81067	0.79484
84	0.35734	0.74381	0.78309	0.82224	0.80036
85	0.69318	0.88635	0.84501	0.84354	0.82585
86	0.64833	0.87164	0.85129	0.8146	0.76701
87	0.35649	0.69586	0.77471	0.80134	0.79128
88	0.3628	0.71831	0.79106	0.80681	0.77924
89	0.34989	0.7215	0.77604	0.81465	0.78827
90	0.33929	0.7307	0.76133	0.79746	0.78621
91	0.3516	0.7363	0.77439	0.80103	0.76788
92	0.36359	0.69286	0.75283	0.80838	0.76168
93	0.3722	0.72572	0.801	0.8011	0.75524
94	0.3642	0.75497	0.78134	0.80233	0.76531
95	0.37081	0.74259	0.77943	0.79182	0.768
96	0.38238	0.72306	0.78326	0.79478	0.74925
97	0.35028	0.70035	0.75996	0.77148	0.73377
98	0.3979	0.71243	0.75979	0.77466	0.72153
avg	0.401102	0.741612	0.787509	0.805354	0.775529
growth	-0.05671	-0.05738	-0.04644	-0.06037	-0.09348

Note: If the firm is vertically integrated, the firm will diversify into the products that are consumed within the firm to produce the final product. The share of Interplant Product Transfer (IPT) to the total value of shipment of the firm (TVS) can be used as an indicator for vertical integration. IPT is not available in 1974, 1975, 1977-1979 and 1982. IPT is imputed by Census in 1985 and 1986.

Table AC-14 Average Diversification Index by Quartile of Share of Labor Cost (Wage/Total variable cost)

year	Q1	Q2	Q3	Q4
74	0.73195	0.77103	0.70465	0.47082
75	0.73183	0.77237	0.68039	0.42186
76	0.74156	0.75945	0.68572	0.39776
77	0.74148	0.75151	0.68137	0.4805
78	0.73501	0.75453	0.66543	0.46308
79	0.72745	0.72381	0.70646	0.42038
80	0.7181	0.739	0.67844	0.408
81	0.72583	0.74206	0.68887	0.42501
82	0.71783	0.73063	0.68983	0.39111
83	0.72828	0.72869	0.69865	0.40078
84	0.72607	0.73752	0.68569	0.4363
85	0.72517	0.72687	0.68406	0.48524
86	0.71799	0.72963	0.66074	0.46496
87	0.70771	0.72373	0.66228	0.50532
88	0.71597	0.70859	0.64846	0.42453
89	0.71136	0.69815	0.61738	0.45333
90	0.70265	0.70381	0.60421	0.42153
91	0.69841	0.69354	0.60926	0.32964
92	0.67997	0.68176	0.63447	0.36963
93	0.69016	0.65971	0.57821	0.36207
94	0.68736	0.64837	0.54104	0.41022
95	0.68482	0.61582	0.55917	0.38524
96	0.68435	0.59943	0.55329	0.33004
97	0.66233	0.56502	0.52385	0.32556
98	0.6649	0.63352	0.56906	0.31085
average	0.710342	0.703942	0.640439	0.41175
growth	-0.0916	-0.17835	-0.19242	-0.33977

Table AC-15 Average Diversification Index by Quartile of Share of Non-production Worker Labor Cost (Non-production worker wage/Total labor cost)

year	Q1	Q2	Q3	Q4
74	0.55187	0.75475	0.76206	0.70286
75	0.56427	0.7471	0.76438	0.70123
76	0.57483	0.75197	0.75958	0.70622
77	0.59947	0.7513	0.76723	0.69581
78	0.69377	0.74991	0.74476	0.70855
79	0.69686	0.72402	0.74055	0.68786
80	0.66241	0.72518	0.73253	0.69428
81	0.6767	0.72763	0.73707	0.7065
82	0.54637	0.72389	0.73332	0.70329
83	0.69501	0.71472	0.74301	0.69907
84	0.69692	0.7192	0.74217	0.68599
85	0.68971	0.7229	0.73595	0.68724
86	0.63953	0.73491	0.73584	0.67633
87	0.45808	0.6935	0.73113	0.71745
88	0.69406	0.70099	0.73571	0.64684
89	0.68519	0.70169	0.71826	0.64999
90	0.66614	0.70691	0.70374	0.66552
91	0.60434	0.71988	0.72284	0.63657
92	0.37518	0.65645	0.68251	0.68811
93	0.65794	0.68016	0.69868	0.61852
94	0.64731	0.67238	0.68941	0.60972
95	0.65646	0.68186	0.65506	0.60829
96	0.61303	0.71463	0.63529	0.60625
97	0.6275	0.66142	0.68409	0.56785
98	0.58693	0.68624	0.66646	0.58956
average	0.622395	0.712944	0.720865	0.666396
growth	0.063529	-0.09077	-0.12545	-0.1612

Table AC-16 Average Diversification Index by Quartile of Share of Exported Good (Vale of exported good/Total value of shipment)

year	zero	Q1	Q2	Q3	Q4
76	0.39333	0.73924	0.782	0.79292	0.79241
80	0.37168	0.715	0.77888	0.79276	0.74343
81	0.35137	0.72602	0.78731	0.77326	0.77691
83	0.35646	0.71234	0.76977	0.7855	0.76804
84	0.35952	0.71027	0.78391	0.78461	0.74787
85	0.69156	0.84352	0.53336	0.16977	0.1389
86	0.63121	0.83046	0.73142	0.62301	0.15634
87	0.33951	0.67881	0.75178	0.77366	0.75517
88	0.34016	0.65229	0.7524	0.77518	0.74045
89	0.31167	0.68086	0.73958	0.77748	0.73457
90	0.30347	0.65271	0.75553	0.76801	0.71493
91	0.29289	0.66419	0.7519	0.7608	0.69294
92	0.29181	0.60629	0.73559	0.7554	0.66064
93	0.32628	0.68021	0.73716	0.75447	0.63553
94	0.31695	0.65814	0.7278	0.76065	0.65382
95	0.30225	0.67236	0.72279	0.74663	0.65976
96	0.29083	0.65728	0.73251	0.73671	0.64809
97	0.29153	0.57485	0.71318	0.72691	0.61513
98	0.33604	0.71924	0.61496	0.72717	0.67017
Average	0.36308	0.693373	0.731675	0.725521	0.647637
growth	-0.14565	-0.02705	-0.21361	-0.08292	-0.15426

Table AC-17 Decade Average of Number of Industries of Firms by Number of Products (5-digit SIC) of Firms

Number of 2-digit SIC industry

Number of Products	1970s	1980s	1990s
1	1	1	1
2	1.14	1.17	1.16
3	1.29	1.34	1.31
4	1.45	1.47	1.43
5	1.61	1.61	1.52
6	1.78	1.75	1.69
7	2.04	1.99	1.84
8	2.23	2.12	1.99
9	2.54	2.41	2.12
10+	2.73	2.53	2.37

Number of 3-digit SIC industry

Number of Products	1970s	1980s	1990s
1	1	1	1
2	1.25	1.28	1.27
3	1.58	1.63	1.59
4	1.93	1.95	1.86
5	2.24	2.30	2.15
6	2.66	2.64	2.47
7	3.11	3.11	2.89
8	3.58	3.44	3.16
9	4.12	3.96	3.49
10+	4.46	4.23	3.93

Table AC-18 Decade Average of Number of Counties Where Plants Are Located by Number of Plants

Number of Plants	1970s	1980s	1990s
1	1	1	1
2	1.7767	1.8325	1.82546
3	2.5164	2.64582	2.68428
4	3.3936	3.52944	3.51556
5	4.19915	4.33805	4.43135
6	5.02278	5.25762	5.0979
7	5.96204	6.0732	6.11653
8	6.47792	6.91824	6.88664
9	7.30809	7.66521	7.63317
10+	8.398	8.1173	8.7455

Table AC-19 Evolution of Aggregate and Idiosyncratic Volatility

Year	Aggregate Volatility	Idiosyncratic Volatility	
		Mean	Standard deviation
74	0.2829	0.45160	0.53751
75	0.25907	0.47257	0.55326
76	0.24071	0.47965	0.56108
77	0.23216	0.44162	0.54740
78	0.22878	0.44330	0.54637
79	0.20681	0.36748	0.45144
80	0.165	0.36301	0.44863
81	0.16504	0.34636	0.42912
82	0.16587	0.36942	0.46405
83	0.16741	0.36309	0.47956
84	0.13238	0.46554	0.54460
85	0.13134	0.47380	0.55781
86	0.15054	0.49389	0.56556
87	0.14018	0.50964	0.59999
88	0.14104	0.50290	0.61146
89	0.14093	0.35073	0.51840
90	0.1411	0.28708	0.44155
91	0.14162	0.26169	0.42493
92	0.14266	0.26486	0.47525
93	0.12227	0.27937	0.56882
94	0.10086	0.28571	0.54273
95	0.10776	0.27957	0.52498
96	0.09622	0.26822	0.49589
97	0.09772	0.27511	0.51267
98	0.09138	0.27344	0.50223

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