

University of Nevada, Reno

**An Applied Time Series Study of The Stock  
Market Boom and Crash of 1929**

A thesis submitted in partial fulfillment of the requirements for the degree of  
Master of Science in Economics

by

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THE GRADUATE SCHOOL

We recommend that the thesis  
prepared under our supervision by

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Entitled

**An Applied Time Series Study of The Stock Market Boom and Crash of 1929**

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requirements for the degree of

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## **Abstract**

This endeavor is an effort to study the price dynamics of 26 publicly traded companies in the New York Stock Exchange (NYSE) during the years 1926-1933 using data (monthly and daily) from the Wharton Research Data Service (WRDS) database. We find evidence against the hypothesis of random walks in stock prices. There was a bubble during the years 1927-29, which began in the fall of 1927. Companies introducing new technologies, such as Radio Corporation of America (RCA), had their price peak first, and led the boom. Companies in traditional sectors had their peaks last, and were followers. In addition, there is significant price undershooting in the aftermath of the crash, in contrast to the typical experimental bubbles. Our results not only reinforce Kindleberger-Minsky hypothesis, but also highlight potential for further research in the realm of financial economic research and policy.

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## **Introduction**

Numerous empirical studies on the stock market crash of 1929 have focused on the events preceding the crash as the cause of this catastrophic event. We hypothesize that the 1929 crash was a consequence of ‘contagion’ from certain specific companies, in new (‘non-traditional’ or ‘innovative’) industries, to other companies operating in old (or ‘traditional’) industries. We found that investors encouraged by the existence of speculative bubble in the innovative industries expected similar results from companies in traditional industries. This indicates transmission of price shocks from non-traditional companies to traditional companies when this bubble burst.

## **Data & Methodology**

Disaggregated data for 26 companies is collected from WRDS database<sup>1</sup>, maintained by Wharton School of Business. This data is time series of stock prices for these companies from 1926 to 1933. Initially we analyze monthly data for these companies. Encouraged by the results of our analysis on monthly data, we conduct specific tests on daily data for the same companies using same methodology. The motivation behind using daily data is to focus on dynamics of short-run price movements during most critical years of this event. Since we are primarily interested in transmission of price shocks from the four innovative companies to traditional companies, study of daily data yields interesting findings in our ongoing endeavor.

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<sup>1</sup> <http://wrds-web.wharton.upenn.edu/wrds/>

Since this project is a follow up of our ongoing research, we continue with the same set of companies, and in same arrangement. Companies are pooled under three groups: Subset 1, Subset 2 and Subset 3. Allied Chemical, American Can, American Car & Foundry, American Locomotive, American Sugar Refining, General Electric, International Harvester, Kennecott, Paramount, Sears, Texas, US Rubber, US Steel, and Woolworth are included in Subset 1. These fourteen companies along with six others comprised the Dow Jones Industrial Average (DJIA, henceforth) as of December 7, 1925. The data for five out of those six, American Smelting, American Tobacco, Mack Trucks, Western Union, and American Telephone & Telegraph Company is not available in WRDS, while sixth company, General Motors, is included in another Subset 3, for reason explained below.

Subset 2 includes following eight companies: Bethlehem Steel, Canadian Pacific Railroad, Reynolds Tobacco, Pennsylvania Railroad, American Woolen, Standard Oil California, Lambert Consumption, and Goodyear. These were 'traditional' companies but were not a part of the DJIA. These were included in our analysis based on our learnings regarding their role during the 1929-33 period. Inclusion of these companies also helps to study the transmission of price shocks beyond DJIA, if any. Though not part of the index, these companies were large enough to wield substantial influence in the economic, political and social milieu during this period.



Subset 3 consists of four companies: RCA (Radio Corporation of America), GM (General Motors), DuPont, & Union Carbide. These are the companies that introduced breakthrough products in the economy, which further created markets for new goods, which had never existed earlier, something that in Minsky's words can be aptly regarded as *cause* of "technological displacement". According to Kindleberg-Minsky, *a technological displacement is a shock that has the potential to capture investors' imagination leading them to believe with some degree of empirical plausibility that the radically new technologies, goods, and sectors being introduced give rise to a fundamentally different world, one in which stock valuations have to be totally reassessed, thus opening the possibility for the start of a price bubble.*

RCA, GM, DuPont, & Union Carbide introduced product(s) that created new markets in broadcasting, automobile, clothing & food industry, and chemical industry, respectively. This subset of companies, henceforth, would be referred to as 'Innovative Companies'.

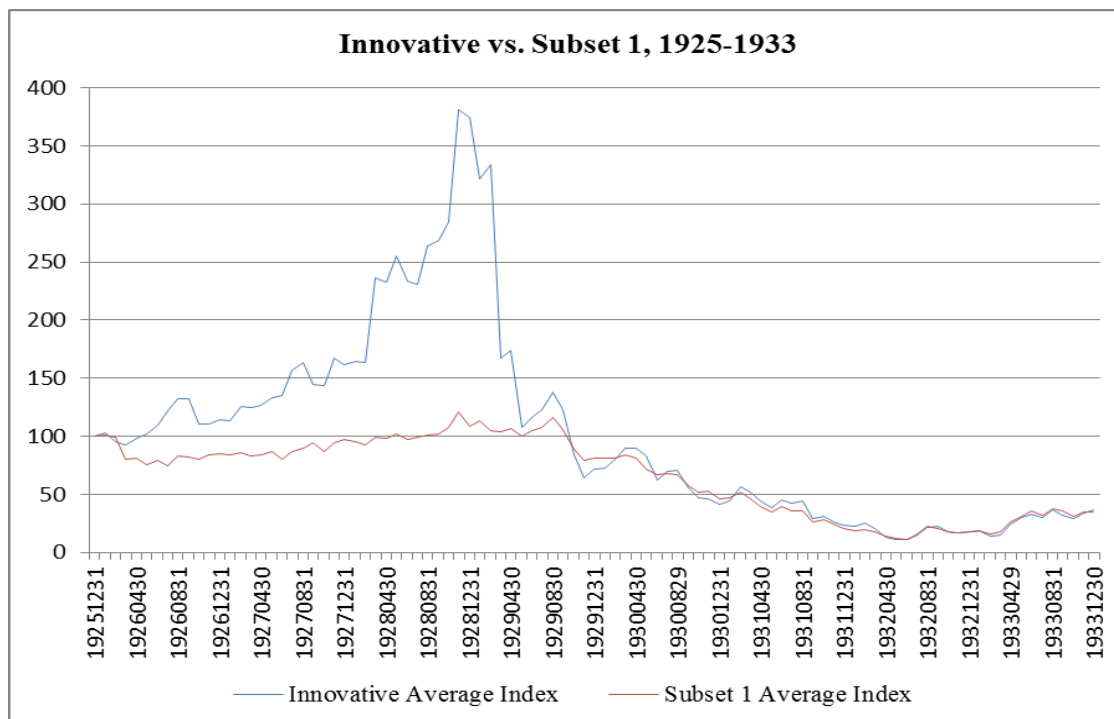
### **Methodology to Test for Random Walks:**

The paper is organized as follows:

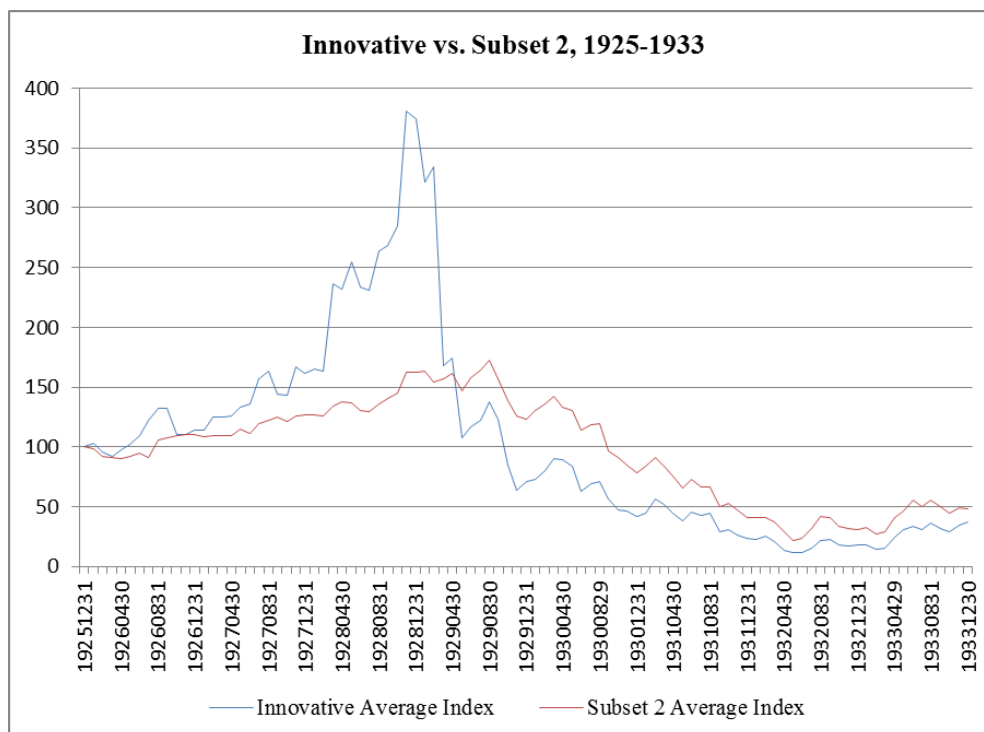
To highlight the pattern of price indexes across companies and between subsets of data, we average the price indexes across companies in each subset and then comparing the average of price index of innovative companies with those of subset 1, subset2, and DJIA, respectively. Following graphs depict the pattern

between innovative companies and each subset, respectively:

**Figure 1.a: Innovative Companies Vs Subset 1 (1925-1933)**



**Figure 1.b: Innovative Companies Vs Subset 2 (1925-1933)**



### **Methodology to study pairwise Granger causality:**

To test for the type of causality between the price indexes of traditional and innovative companies, we ran multiple sets of pairwise Granger causality tests. RCA is chosen as the representative company to use in pairwise comparisons with traditional companies. Below is the effect of the four innovative companies' (unweighted) average price index on the DJIA index.

The methodology for this process is as follows:

First, we applied the pairwise Granger causality tests to identify the exogenous variable in the pairs (RCA, traditional companies in subset 1 and subset 2). The tests were performed by adding cross lags to the pair of auto-regressive equations.

Then, checks for the jointly added explanatory power of the cross lag terms in the expanded auto-regressive models were performed by means of the F-test.

Then we ran unrestricted VAR models with the optimal number of lags chosen using the Schwartz Information Criterion (SIC) (for monthly data only), Akaike Information Criterion(AIC), Hannan-Quinn Information Criterion(HQ), Final Prediction Error(FPE), and sequential modified LR test statistic (LR), for daily data.

Next we re-ran Granger causality tests by means of the exclusion of variables' tests based on the Chi-Squared distribution.

Following, we checked whether the inverted roots of the characteristic polynomials were within the unit circle so as to guarantee valid impulse-response functions.

Lastly, accumulated impulse-responses were calculated over different time horizons, namely 12 months, and 48 months, to capture short-term and medium-term responses, respectively.

## **Results & Discussion:**

The main empirical results are organized around four critical research questions:

- 1) Was there a bubble or not?
- 2) If there was a bubble, how did it start?
- 3) How did the bubble evolve over time? (In other words, how was the bubble transmitted across companies?)
- 4) What were the consequences of the crash?

### **Was there a bubble?**

The short answer is a definitive yes. Our regression analyses show clear evidence that stock prices behaved as near random walks (“approximate random walks” in the choice of words of Fama, 1965) in the period December 1925-December 1933. However, ERS tests rejected the presence of unit roots in the price series decisively. Furthermore, KPSS tests showed overwhelming evidence against exact random walks. In cases in which the peak of the series happens to lie in the middle of the sample, such as in most cases in Table 1 and 2 below, the KPSS tests display severe size distortion and are biased toward rejecting the null of stationarity (Badillo et al., 2002). Nevertheless, as Table 1 below shows, the null hypothesis is still accepted in the majority of cases for companies in subset 1.

**Table 1: Unit root tests for Subset 1 (1925/12-1933/12)**

Companies	Basic Regression Coeff.	KPSS test $H_0$ : p is stationary			ARMA		ERS test $H_0$ : p is non-stationary		
		LM stat	Accept $H_0$	Reject $H_0$	Yes	No	P-statistic	Accept $H_0$	Reject $H_0$
Allied Chemical	0.997	0.241		x	(2,2)		40.74		x
American Can	0.737	0.179	x			x	19.93		x
American Locomotive	0.987	0.157	x			x	34.21		x
American Sugar	0.983	0.118	x			x	5.05		x
American Car & Foundry	0.968	0.166 a	x			x	4.43		x
International Harvester	0.971	0.144	x			x	9.6		x
Kennecott	0.986	0.194	x			x	21.03		x
Sear	0.945	0.156	x			x	23.34		x
US Rubber	0.972	0.138 a	x			x	11.45		x
US steel	0.991	0.28		x	(2,2)		24.16		x
Woolworth	0.978	0.116	x			x	9.8		x
General Electric	0.949	0.122	x			x	14.33		x
Texas	0.995	0.209	x			x	27.01		x
Paramount	0.979	0.086	x			x	6.44		x

Significance level of KPSS tests is 1%. Critical value at 1%: 0.216. Constant & linear trend used in all tests. Note: ARMA applied only if KPSS test is rejected at 1% level

a. These companies did not have its price peak in the middle of the sample

ERS tests: spectral OLS, max lag used = 12, optimal number of lags chosen by SIC. Constant & linear trend used in all tests. Critical value at 1%: 4.25.

As evident in Table 2, the bias of the KPSS test to reject the null of stationarity in the presence of a price peak in the middle of the sample is more visible for companies in subset two, as half of them now display rejection of the null hypothesis.

**Table 2: Unit root tests for Subset 2 (1925/12-1933/12)**

Companies	Basic Regression	KPSS test $H_0$ : $p$ is stationary			ARMA		ERS test $H_0$ : $p$ is non-stationary			
		Coeff.	LM stat	Accept $H_0$	Reject $H_0$	Yes	No	P-statistic	Accept $H_0$	Reject $H_0$
American Woolen	0.905	0.202 a	x			x		7.76		x
Bethlehem Steel	0.992	0.246		x	(2,2)			27.41		x
Canadian Pacific Railroad	0.992	0.321		x	(2,2)			38.00		x
Goodyear	0.987	0.132	x			x		20.88		x
Lambert Consumption	0.996	0.303		x	(2,2)			86.46		x
Pennsylvania Railroad	0.994	0.211	x			x		23.43		x
Reynolds Tobacco	0.987	0.123	x			x		16.21		x
Standard Oil California	0.993	0.255		x	(2,2)			18.38		x

Significance level of KPSS tests is 1%. Critical value at 1%: 0.216. Constant & linear trend used in all tests. Note: ARMA applied only if KPSS test is rejected at 1% level  
a: This company did not have its price peak in the middle of the sample.  
ERS test: spectral OLS, max lag used = 12, optimal number of lags chosen by SIC. Constant & linear trend used in all tests. Critical value at 1%: 4.25.

### How did the bubble start?

The 'bubble' started with self-induced increases in the stock prices of a few companies pioneering the use of new technologies. These companies' stock prices displayed temporarily self-sustaining price increases, led the way, and peaked first. Table 3, displays the (unweighted) average price index for the four innovative companies in new sectors (RCA, Union Carbide, GM, and DuPont) versus the average Dow Jones Index.

As Figure 1 clearly illustrates, the 4 companies' price indexes started to increase first and reached their peaks before subset 1 & 2, respectively. Table 3.a shows Granger causality tests confirming the temporal precedence of the price increases of these 4 innovative companies over the Dow Jones index. Causality

is unidirectional in all four cases. All four companies in new sectors, namely RCA, Union Carbide, GM, and DuPont Granger-cause the Dow Jones, but as evident from Table 3.b, the Dow Jones does not Granger-cause any of these four companies.

**Table 3.a.: Granger Causality test between Innovative Companies & Dow Jones Industrial Average**

<i>H<sub>0</sub>: No Causality from Innovative Companies to Dow Jones</i>			
Company	Chi-Squared	Probability	Optimal Lags
RCA → Dow Jones	5.235	0.022	1
GM → Dow Jones	8.255	0.004	1
Union Carbide → Dow Jones	8.781	0.003	1
Dupont → Dow Jones	8.924	0.003	1

**Table 3.b.: Granger Causality test between Dow Jones Industrial Average & Innovative Companies**

<i>H<sub>0</sub>: No causality from Dow Jones to innovative companies</i>			
Company	Chi-squared	Probability	Optimal lag(s)
Dow Jones → RCA	0.00	0.96	1
Dow Jones → GM	1.32	0.25	1
Dow Jones → Union Carbide	0.06	0.80	1
Dow Jones → Dupont	0.44	0.51	1

Note: The optimal lag number is suggested by Schwarz information criterion (SC)



## **How did the bubble spread?**

What emerged as a relatively clear pattern were the following connections:

- (1) Innovative companies' → Subset 1 companies', and
- (2) Innovative companies' → Subset 2 companies'

### ***Innovative Companies to Traditional Companies Granger causality***

#### ***evidence***

In our first subset, based on companies in the Dow Jones, there is evidence that the boom started in the companies operating in new sectors and was transmitted later to many individual companies operating in traditional sectors. As a representative example, we show evidence that RCA Granger-caused seven companies in the Dow Jones (GE, US Steel, US Rubber, Sears, Allied Chemical, American Can, and American Locomotive), and caused and was caused in another three cases of companies included in the Dow Jones (Woolworth, Kennecott, and International Harvester). Only in two cases no pattern of causation could be identified (those were the cases of American Car & Foundry and American Sugar). Table 4 (panels A & B) summarizes this evidence.

**Table 4.a: Granger Causality between RCA & Subset 1**

<i>Ho: No Causality from RCA to Company in Subset1</i>					
<b>Company</b>	<b>Chi-Squared</b>	<b>Probability</b>	<b>Optimal Lags</b>	<b>Causality</b>	<b>Inference</b>
Allied Chemical	5.580	0.018	1	RCA -> Allied	Clear Causation
American Can	5.210	0.022	1	RCA -> American Can	Clear Causation
American Locomotive	3.670	0.055	1	RCA -> American Locomotive	Clear Causation
American Sugar Refining	0.910	0.340	1		<i>No Causation</i>
American Car & Foundary	1.320	0.732	2		<i>No Causation</i>
General Electric	2.774	0.096	1	RCA -> GE	Clear Causation
International Harvester	4.500	0.034	4	RCA -> Intl Harvester	Mutual Causation
Kennecortt	33.500	0.000	4	RCA -> Kennecort	Clear Causation
Paramount	7.100	0.526	8		No Causation
Sears	11.600	0.000	1	RCA -> Sears	Clear Causation
Texas	2.630	0.104	1		No Causation
US Rubber	3.800	0.051	1	RCA -> US Rubber	Clear Causation
US Steel	6.650	0.010	1	RCA -> US Steel	Clear Causation
Woolworth	73.060	0.000	5	RCA -> Woolworth	Clear Causation

**Table 4.b: Causality from Subset 1 to RCA**

<i>Ho: No Causality from Company in Subset 1 to RCA</i>					
<b>Company</b>	<b>Chi-Squared</b>	<b>Probability</b>	<b>Optimal Lags</b>	<b>Causality</b>	<b>Inference</b>
Allied Chemical	0.410	0.519	1		No Causation
American Can	0.414	0.520	1		No Causation
American Locomotive	1.359	0.244	1		No Causation
American Sugar Refining	0.634	0.426	1		<i>No Causation</i>
American Car & Foundary	2.678	0.444	2		<i>No Causation</i>
General Electric	0.044	0.833	1		No Causation
International Harvester	20.613	0.000	4	International Harvester -> RCA	Mutual Causation
Kennecortt	145.158	0.000	4	Kennecort -> RCA	Mutual Causation
Paramount	0.000	0.000	8	Paramount -> RCA	Clear Causation
Sears	0.469	0.494	1		No Causation
Texas	3.605	0.058	1	Texas -> RCA	Clear Causation
US Rubber	0.127	0.722	1		No Causation
US Steel	0.000	0.998	1		No Causation
Woolworth	19.233	0.002	5	Woolworth-> RCA	Clear Causation

In second subset, RCA Granger-caused all but one of the traditional companies outside the Dow Jones, namely, Reynolds Tobacco. In the case of Reynolds Tobacco, RCA caused and was caused by it. In almost all cases, the optimal lag structure involved just one lag, contrary to what was the case in the Dow Jones subset in which the lag structure was frequently richer. Table 5 summarizes this evidence.

**Table 5: Granger Causality between RCA and Subset 2**

$H_0$ : : No causality from RCA to Dataset 2				
Company	Chi- Squared	Probability	Optimal lag(s)	Inference
American Woolen	2.720	0.099	1	RCA → American Woolen
Bethlehem Steel	7.580	0.003	1	RCA → Bethlehem
Canadian Pacific Railroad	2.710	0.100	1	RCA → Canadian Pacific
Goodyear	19.360	0.000	1	RCA → good year
Lambert Consumption	9.320	0.002	1	RCA → Lambert Consumption
Pennsylvania Railroad	2.830	0.092	1	RCA → Pennsylvania
Standard Oil California	6.080	0.000	1	RCA → Standard Oil California
Reynolds Tobacco	11.090	0.001	2	RCA ↔ Reynolds
	21.72 (*)	0.000	2	Reynolds ↔ RCA
(*) H0: no causality from Traditional company to RCA				
Note: The optimal lag number is suggested by Schwarz information criterion (SC)				

## Impulse Responses

In order to isolate the effects of orthogonalized shocks from RCA to traditional companies, we entered RCA first in the Cholesky factorization, according to the Granger causality results reported in the previous section. Accumulated impulse-responses are displayed in two different panels. To capture the short-run

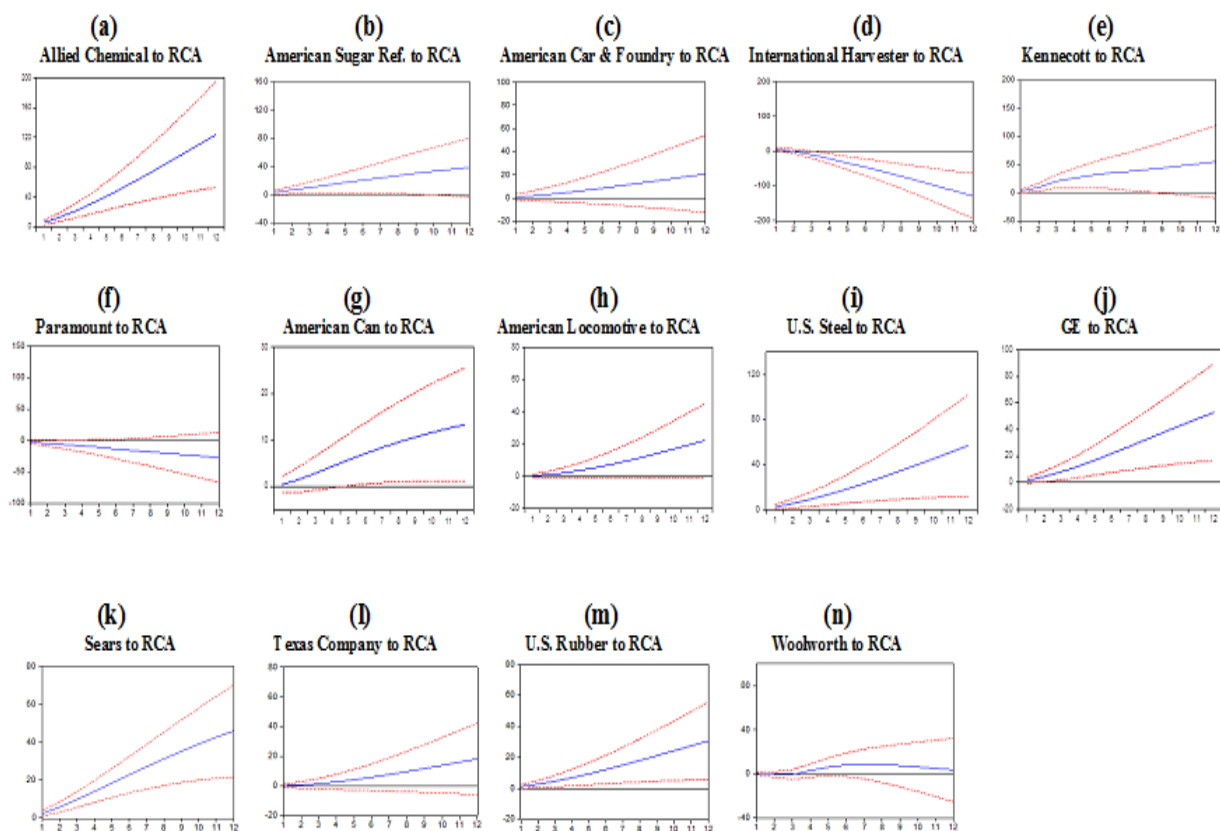
responses, a 12-month panel is displayed in each table. To capture the medium-term responses, we choose a panel with a window of 48 months. Finally, in order to save space, we only report 'cross-companies' accumulated responses. In other words, responses of companies to their own price shocks are not reported.

Accumulated impulse-responses from Panel A, Figure 5, show that a one standard deviation increase to the price of RCA leads to twelve of the fourteen companies in Subset 1 to display price increases during the first twelve months after the shock to the price of RCA (the only two exceptions are Paramount and International Harvester). The largest quantitative response was the one by Allied Chemical with a gain of 120 points in the first 12 months after the shock to the price of RCA. On average, the majority of companies displayed gains in the range of twenty to sixty points. Accumulated impulse-responses from Panel B, Figure 5, show that after 48 months the qualitative patterns remain quite similar to those in Panel A. Interestingly Allied Chemical accumulated gains for roughly 200 points.

**Figure 2: Accumulated Responses of Dow Jones' companies to RCA**

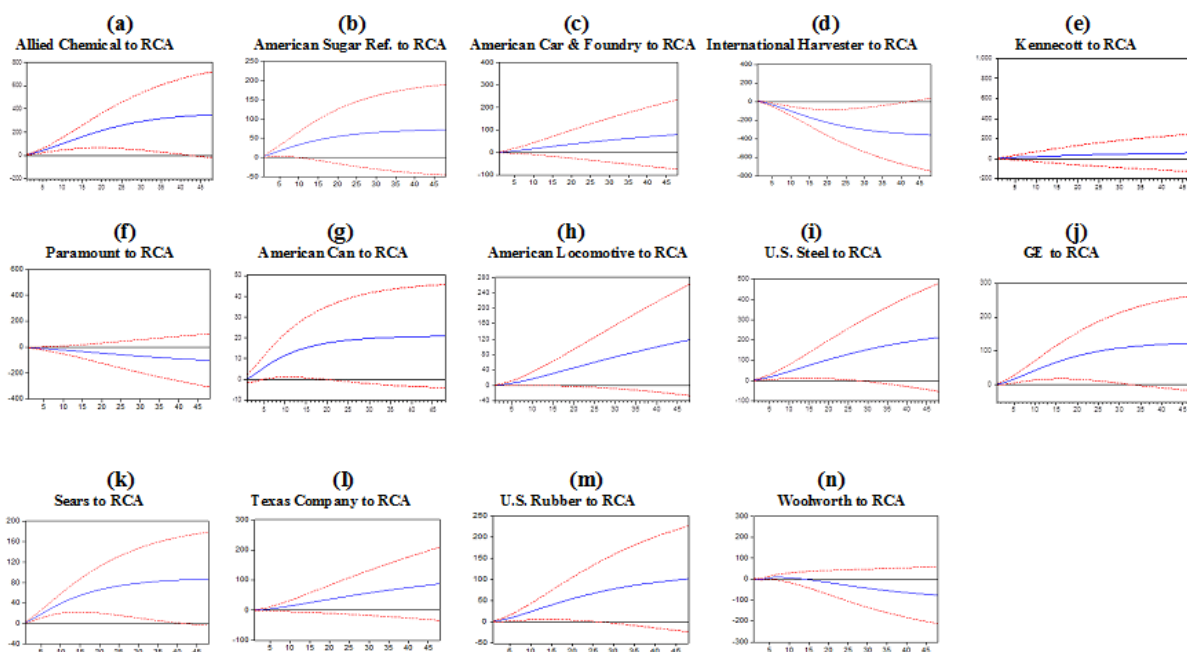
**Impulses**

**Panel A: 12 months**



Note: Impulses obtained from Cholesky factorization. Responses to one standard deviation shock to RCA price

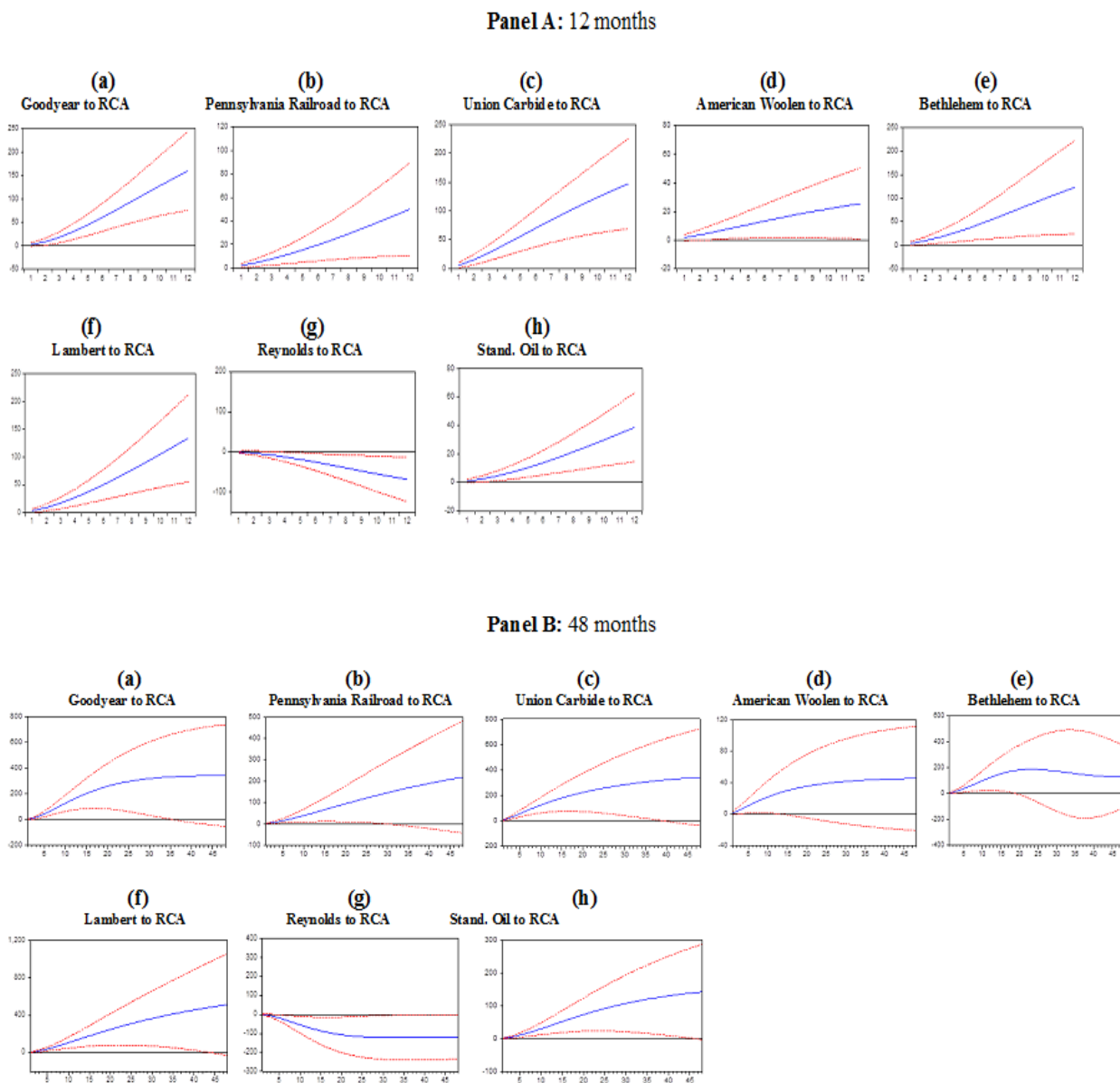
Panel B: 48 months



Accumulated impulse-responses from Panel A, Figure 3, show that a one standard deviation increase to the price of RCA leads to 7 of the 8 companies in Subset 2 displaying price increases during the first twelve month after the shock to the price of RCA (the only one exception is Reynolds Tobacco). The companies outside the Dow Jones seem to have a larger quantitative response to the shocks from RCA price. For example, three companies (Goodyear, Lambert Consumption, and Union Carbide) showed price gains in the range of 150 points 12 months after the shock to the price of RCA.

In a period of 48 months after the shock to the price of RCA, shown in Panel B, Figure 3, most of the companies display accumulated gains in excess of 200 points, with the exception of American Woolen, Reynolds Tobacco, Standard Oil California, and Bethlehem Steel.

**Figure 3: Impulse Responses of Subset 2 companies' to RCA Price Index**



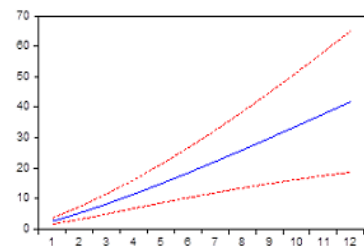
In Figure 4 accumulated responses show that the average price of the Dow Jones' companies increased about 50 points during the first 12 months after the shock to RCA's price, and roughly a 150 point gain 48 months after the shock to the price of RCA. Since four companies that belonged in the Dow Jones as of

December 1925 are missing in Subset 1, we checked that their absence did not significantly change our results by calculating the response of the entire Dow Jones Industrial Average Index to a one standard deviation change to the price of RCA. We do not include those graphs to save on space but results were as follows: The accumulated response of the DJIA after 12 months showed a 90 point increase and a 150 point gain after 48 months. There was literally no feedback response by RCA from the shock to the Dow Jones Industrial Average, either after 12 months or 48 months.

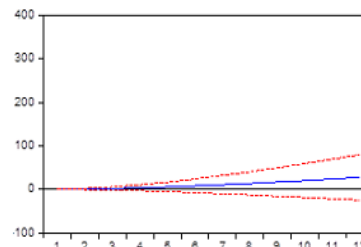
**Figure 4: Accumulated Impulse Responses: Average Subset 1 vs. Average of 4 Innovators**

**Panel A: 12 months**

**Average response of Subset 1 to average 4 Innovative**

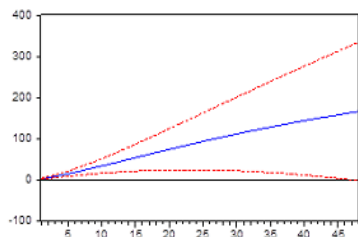


**Average response of 4 Innovative to Subset 1**

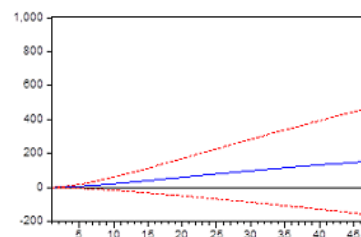


**Panel B: 48 months**

**Average response of Subset 1 to average 4 Innovative**



**Average response of 4 Innovative to Subset 1**



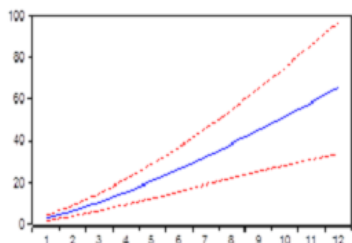


Similarly, in the case of Subset 2 accumulated responses displayed an increase of 60 points and 200 points after 12 and 48 months, respectively. We observe no feedback response; in other words, innovative companies were not affected by the increase of the price indexes from companies outside the Dow Jones.

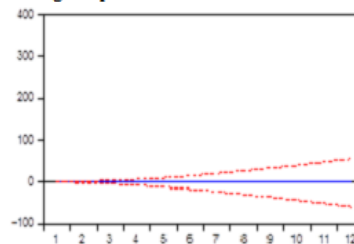
**Figure 5: Accumulated Impulse Responses: Average Subset 2 vs. Average of 4 Innovators**

**Panel A: 12 months**

Average response of Subset 2 to average 4 Innovative

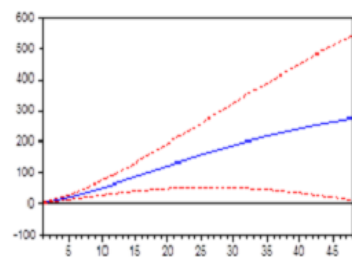


Average response of 4 Innovative to Subset 2

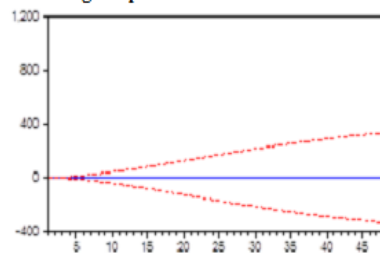


**Panel B: 48 months**

Average response of Subset 2 to average 4 Innovative



Average response of 4 Innovative to Subset 2



Note: Impulses obtained from Cholesky factorization. Responses to one standard deviation shock to RCA price

**What were the consequences of the crash?**

The short answer is that the crash was followed by a severe and protracted price undershooting that lasted at least until December 1941, the beginning of the U.S. involvement in World War II, as shown by Figures 6 & 7 below for Subsets 1 and 2, respectively.

Figure 6 shows two important pieces of evidence. First, prices stayed depressed after the crash of 1929 until the end of 1941 for 10 out of 14 companies in Subset 1. Second, prices reconciled with dividends for only 5 out of 14 companies after the crash (Allied Chemical, International Harvester, Kennecott, Texas, and GE), and furthermore in three of those 5 cases, namely Allied Chemical, International Harvester, and Kennecott, prices led dividends on the way down, instead of the other way round, as standard theory suggests.

Figure 6: Price undershooting until 1941, Subset 1

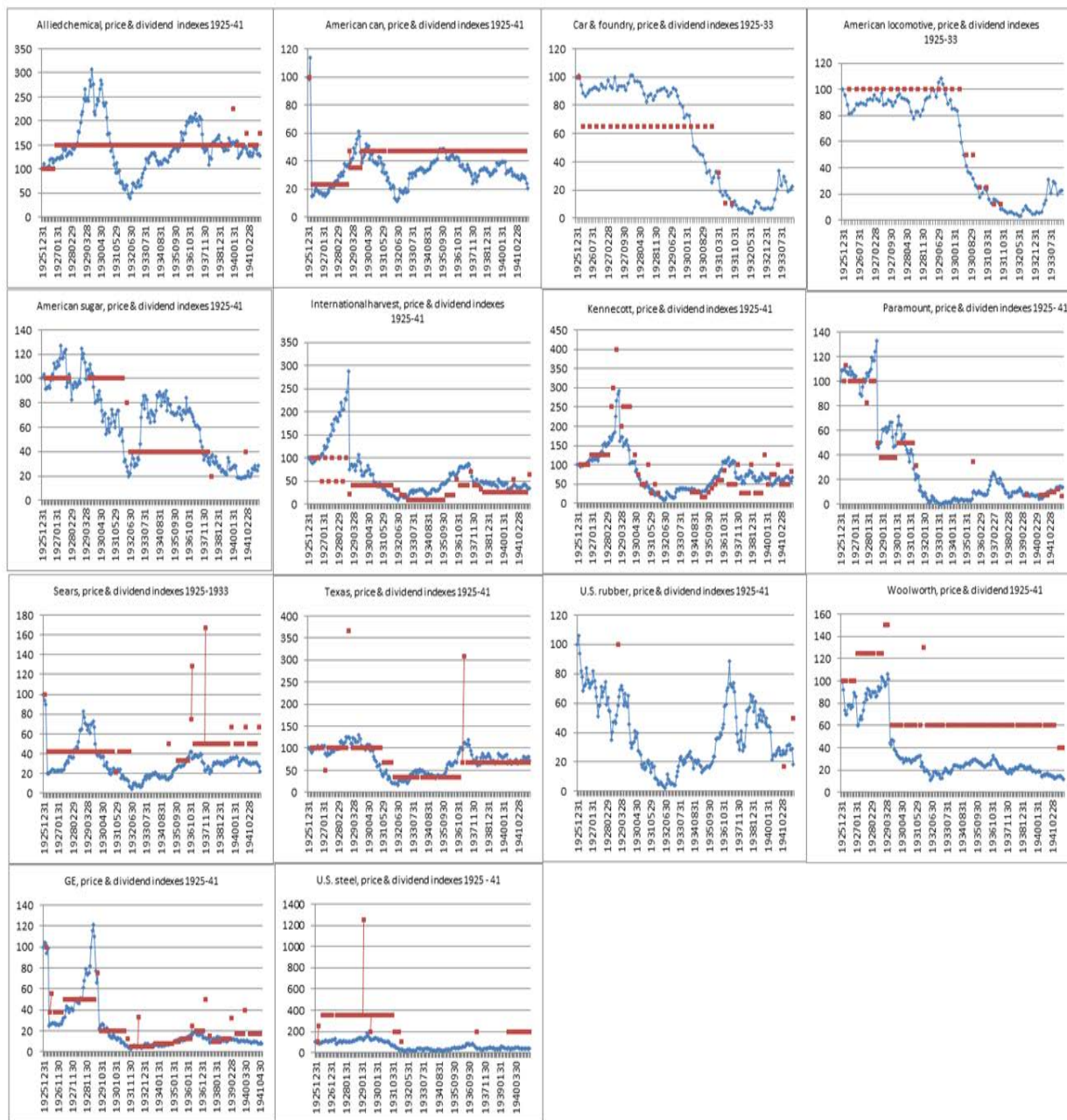
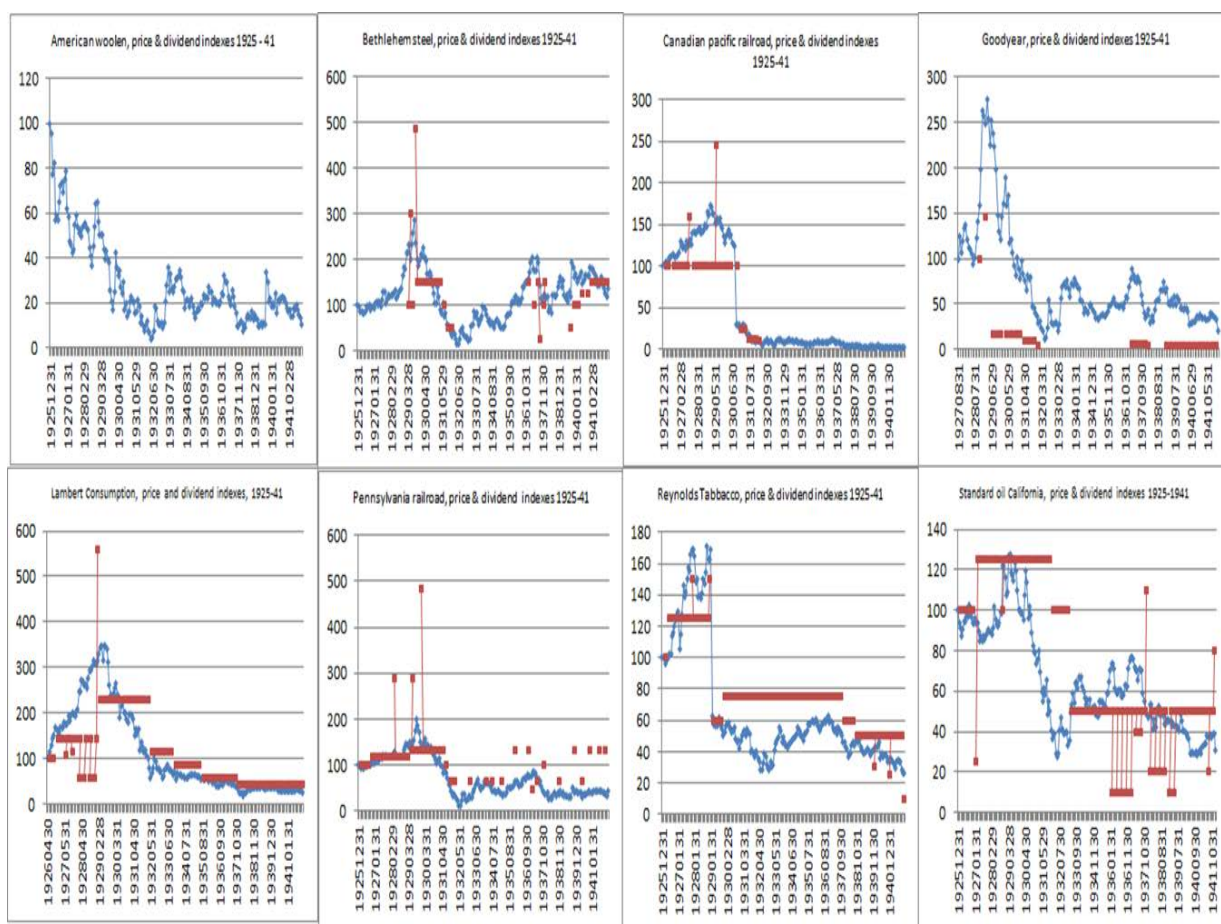


Figure 7, refers to companies' in Subset 2, shows two important pieces of evidence. First, prices stayed depressed until the end of 1941 for 7 out of 8 companies, the exception being Bethlehem Steel. Second, only in the case of two companies (Lambert Consumption and Canadian Pacific Railroad) did prices reconcile with dividends. However, in those two cases, prices seemed to lead dividends, and not the other way around.

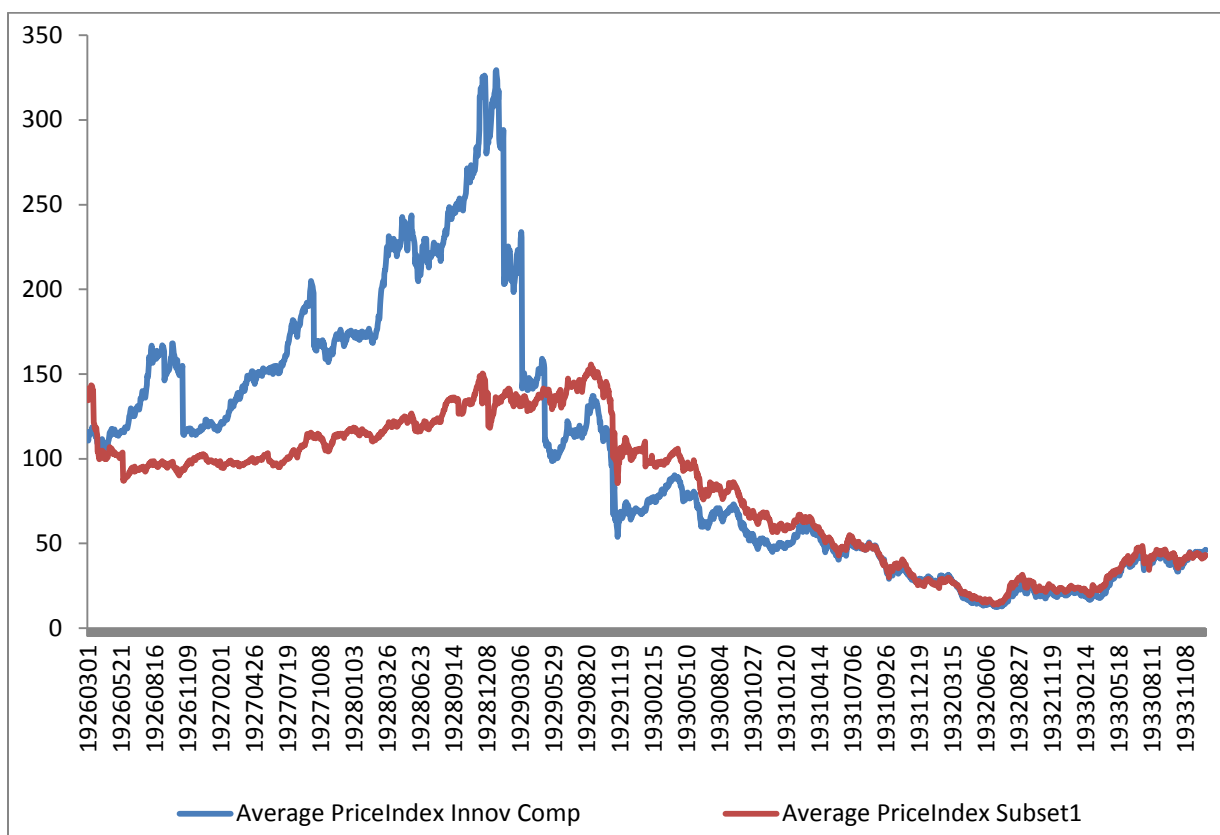
**Figure 7: Price undershooting until 1941, Subset 2**



## Results from Analysis of daily data:

In order to reinforce our findings from monthly data, we collect daily price data, from Dec 1925 to Dec 1933, for all these companies and analyze it in similar fashion. However, unlike monthly data, data on daily prices does not include dividends declared by companies during this period. As expected, results are quite similar to our anticipation, and at the same time highlight interesting insights into the results found earlier.

**Figure 8: Innovative Companies Vs Subset 1 (1926-1933)**



**Figure 9: Innovative Companies Vs Subset 2 (1927-1933)**

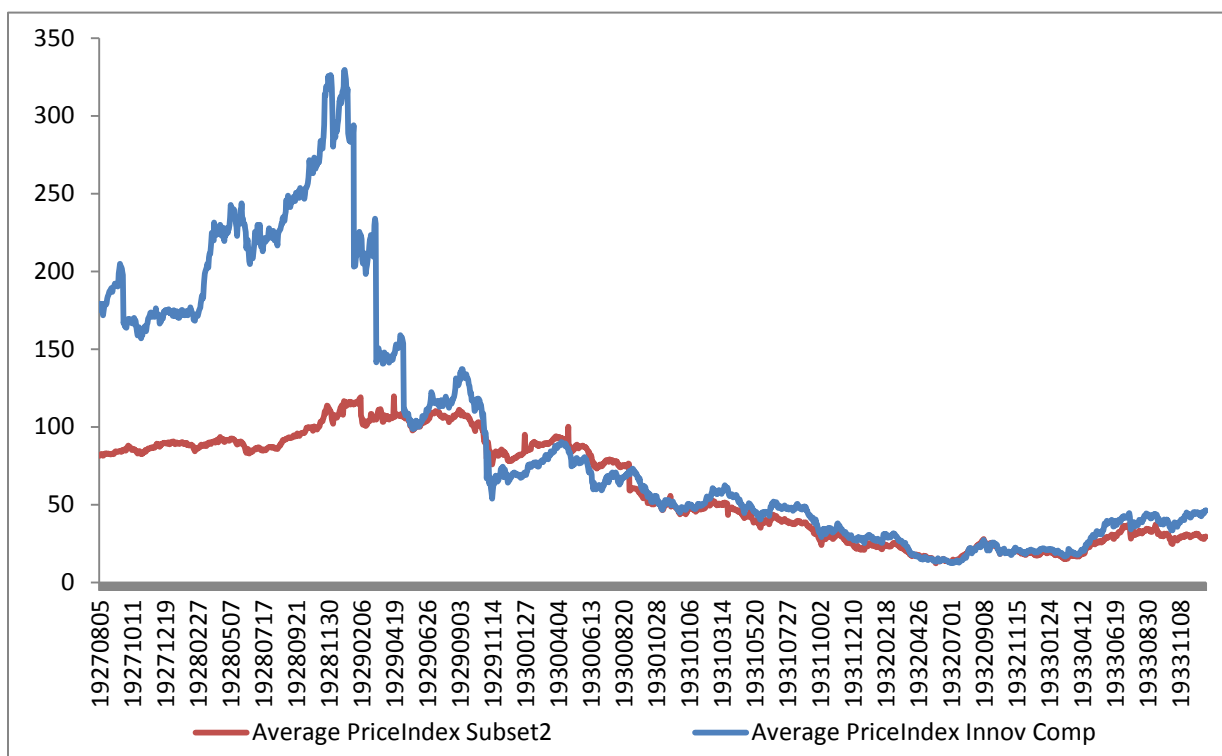
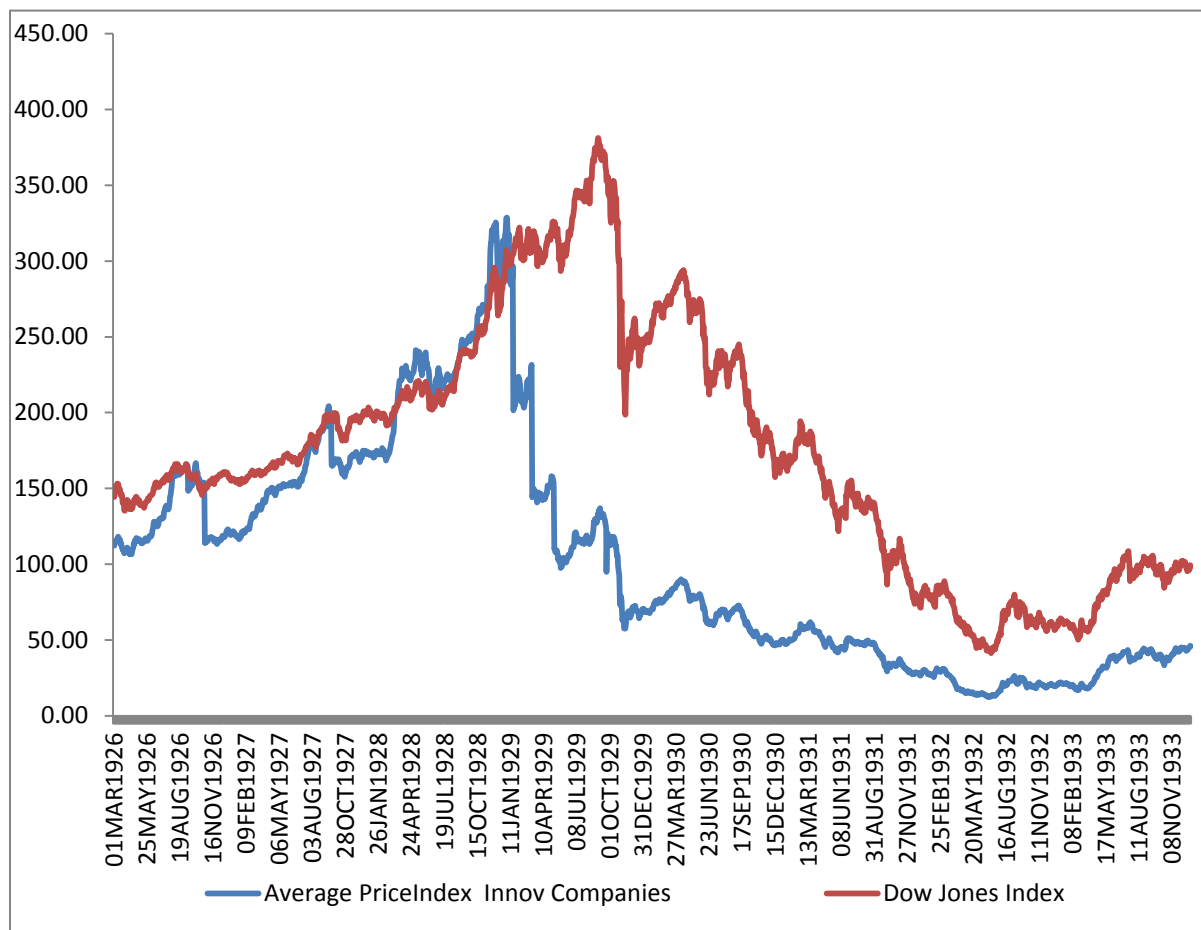


Figure 8 and 9 display the pattern of price movements of average price indices of Innovative companies' vis-à-vis subset 1 and subset 2, respectively. In both cases, the average price index of Innovative companies displays unprecedented bull run. The gap between indices in both cases widens over the years during which sustained rise in price indices of companies in both subsets is also observed. Around a year before the crash, the price index for innovative companies' reaches its crescendo before it falls sharply, but gradually in fall of 1929. The average price indices of Subset 1 and Subset 2, show sustained rally in rise in prices, though clearly not as dramatic as that of innovative companies, before they observe steep fall at the time of crash.

**Figure 10: Innovative Companies Vs DJIA (1926-1933)**



Similarly, Figure 10 exhibits the pattern between average price index of innovative companies and DJIA. There is parallel movement between both indices during the bull-run, but average price index of innovative companies' experienced drastic crash ahead of that of DJIA. Subsequently, there is wide gap between the two indices from November 1929 till May 1932.

The wide gap between the price indices of innovative companies and subsets 1 & 2, respectively, not only indicates existence of bubble in prices of innovative companies, but also a visual evidence of transmission of this exuberance, in

varying degrees, in price levels from innovative companies' to that of companies' in each subset, respectively.

In the spirit of analysis of monthly data, we conduct Granger causality test between set of innovative companies and DJIA. As shown in table 6, we find clear causation from each Innovative company to Dow Jones, but no causation from Dow Jones to any Innovative company.

**Table 6: Granger Causality Test between Innovative Companies & DJIA  
(daily data)**

<i>Ho: No Causality from Innovative Companies to Dow Jones</i>							
Company	Chi-Squared	Probability	Optimal Lags				
			LR	FPE	AIC	SC	HQ
RCA → Dow Jones	6.130	0.047	26	22	22	1	5
GM → Dow Jones	6.417	0.040	30	7	7	1	3
Union Carbide → Dow Jones	66.388	0.000	29	13	13	1	1
Dupont → Dow Jones	94.270	0.000	30	7	7	1	3

<i>Ho: No Causality from Dow Jones to Innovative Companies</i>							
Company	Chi-Squared	Probability	Optimal Lags				
			LR	FPE	AIC	SC	HQ
Dow Jones → RCA	5.388	0.068	26	22	22	1	5
Dow Jones → GM	1.187	0.553	30	7	7	1	3
Dow Jones → Union Carbide	33.160	0.271	29	13	13	1	1
Dow Jones → Dupont	0.186	0.911	30	7	7	1	3



To gauge the influence of innovative companies of other companies in each subset, we test the Granger causality from each company in the innovative set to companies in subset 1 and subset 2, respectively. Results are presented in table 7.

**Table 7.a.: Granger Causality test between RCA & Subset 1 (daily data)**

<i>Ho: No Causality from RCA to Company in Subset1</i>										
Company	Chi-Squared	Probability	Optimal Lags					Causality	Inference	
			LR	FPE	AIC	SC	HQ			
Allied Chemical	9.330	0.009	19	6	6	1	5	RCA -> Allied	Clear Causation	
American Can	1.328	0.249	30	5	5	1	1		No Causation	
American Locomotive	10.961	0.004	30	19	19	1	5	RCA -> American Locomotive	Clear Causation	
American Sugar Refining	1.164	0.281	30	6	6	1	1		No Causation	
American Car & Foundary	12.769	0.002	17	13	13	2	4	RCA -> American Car & Foundary	Clear Causation	
General Electric	5.699	0.058	30	5	5	1	1	RCA -> GE	Clear Causation	
International Harvester	3.255	0.196	30	6	6	1	5		No Causation	
Kennecortt	1.539	0.463	30	30	30	13	30		No Causation	
Paramount	1.381	0.501	30	5	5	1	5		No Causation	
Sears	12.784	0.002	30	5	5	1	1	RCA -> Sears	Clear Causation	
Texas	3.679	0.159	30	18	18	1	5		No Causation	
US Rubber	5.630	0.060	30	17	17	1	5	RCA -> US Rubber	Clear Causation	
US Steel	3.057	0.217	30	25	25	1	5		No Causation	
Woolworth	1.254	0.534	30	5	5	1	1		No Causation	

<i>Ho: No Causality from Company to RCA</i>									
Company	Chi-Squared	Probability	Optimal Lags					Causality	Inference
			LR	FPE	AIC	SC	HQ		
Allied Chemical	3.014	0.222	19	6	6	1	5		No Causation
American Can	0.045	0.832	30	5	5	1	1		No Causation
American Locomotive	8.404	0.015	30	19	19	1	5	American Locomotive -> RCA	Clear Causation
American Sugar Refining	1.190	0.169	30	6	6	1	1		No Causation
American Car & Foundary	18.063	0.000	17	13	13	2	4	American Car & Foundary -> RCA	Clear Causation
General Electric	2.103	0.349	30	5	5	1	1		No Causation
International Harvester	32.392	0.000	30	6	6	1	5	International Harvester -> RCA	Clear Causation
Kennecortt	35.280	0.000	30	30	30	13	30	Kennecortt -> RCA	Clear Causation
Paramount	2.798	0.247	30	5	5	1	5		No Causation
Sears	3.696	0.158	30	5	5	1	1		No Causation
Texas	8.593	0.014	30	18	18	1	5	Texas -> RCA	Clear Causation
US Rubber	5.576	0.062	30	17	17	1	5	US Rubber -> RCA	Clear Causation
US Steel	6.402	0.041	30	25	25	1	5	US Steel -> RCA	Clear Causation
Woolworth	7.838	0.020	30	5	5	1	1	Woolworth->RCA	Clear Causation

Results from the top panel display clear causation from RCA to Allied Chemicals, American Locomotive, American Car & Foundry, GE, Sears, and US Rubber, respectively, while that from bottom panel display causation from American Locomotive, American Car & Foundry, International Harvester, Kennecortt, Texas, US Rubber, US Steel, and Woolworth to RCA. We find mutual causation from RCA to American Locomotive and from American Locomotive to RCA. Similar mutual causation also existed between RCA and American Car & Foundry, and RCA and US Rubber, during this period. There seems to be no influence of RCA price movements on that of American Can, American Sugar, and Paramount, as well as no impact of price movements of these three companies on that of RCA in any way.

**Table 7.b.: Granger Causality test between RCA & Subset 2 (daily data)**

<i>Ho: No Causality from RCA to Subset2</i>										
Company	Chi-Squared	Probability	Optimal Lags					Causality	Inference	
			LR	FPE	AIC	SC	HQ			
American Woolen	4.534	0.104	30	17	17	2	5		No Causation	
Bethlehem Steel	20.646	0.000	30	25	25	3	5	RCA -> Bethlehem	Clear Causation	
Canadian Pacific Railroad	1.869	0.393	30	5	5	1	1		No Causation	
Goodyear	14.614	0.001	30	30	30	1	15	RCA -> Goodyear	Clear Causation	
Lambert Consumption	7.962	0.019	30	7	7	3	5	RCA -> Lambert	Clear Causation	
Pennsylvania Railroad	3.545	0.170	30	5	5	1	5		<i>No Causation</i>	
Standard Oil California	3.122	0.210	30	26	26	1	8		<i>No Causation</i>	
Reynolds Tobacco	14.299	0.001	30	30	30	27	27	RCA -> Reynolds	Clear Causation	

<i>Ho: No Causality from Subset2 to RCA</i>										
Company	Chi-Squared	Probability	Optimal Lags					Causality	Inference	
			LR	FPE	AIC	SC	HQ			
American Woolen	10.777	0.005	30	17	17	2	5	American Woolen -> RCA	Clear Causation	
Bethlehem Steel	11.903	0.003	30	25	25	3	5	Bethlehem -> RCA	Clear Causation	
Canadian Pacific Railroad	5.567	0.062	30	5	5	1	1	Can Pacific -> RCA	Clear Causation	
Goodyear	2.908	0.234	30	30	30	1	15		No Causation	
Lambert Consumption	2.601	0.272	30	7	7	3	5		No Causation	
Pennsylvania Railroad	2.024	0.364	30	5	5	1	5		<i>No Causation</i>	
Standard Oil California	3.207	0.201	30	26	26	1	8		<i>No Causation</i>	
Reynolds Tobacco	18.538	0.000	30	30	30	27	27	Reynolds -> RCA	Clear Causation	

Results from top panel depict clear causation from RCA prices to that of Bethlehem, Goodyear, Lambert, and Reynolds, respectively. Bottom panel depicts causation in price movements of American woolen, Bethlehem, Canadian Pacific Railroad, and Reynolds to that of RCA. We find mutual causation between prices of RCA and Bethlehem, and RCA and Reynolds. There is no impact on prices between RCA and Standard Oil, and Pennsylvania Railroad respectively.

We did similar tests to check for transfer of 'bubble' in price movements from other three innovative companies, DuPont, GM, & Union Carbide, to companies in Subset 1 and Subset 2, respectively. The results from Granger causality tests with each of these companies are summarized in the following:

***Granger Causality Test Between DuPont & Subset 1:***

- Causation from DuPont to GE, Kennecort, Sears, & Woolworth
- Causation from Allied Chemicals, International Harvester, Paramount, US Steel, & Woolworth, respectively to DuPont
- Mutual Causation between DuPont & Woolworth
- Mutual Non-Causation between DuPont & American Can, American Locomotive, American Sugar, American Car & Foundry, Texas, & US Rubber, respectively.

***Granger Causality Test Between DuPont & Subset 2:***

- Causation from DuPont to Canadian Pacific, & Pennsylvania Railroad
- Causation from Bethlehem Steel to DuPont
- Mutual Causation between DuPont & American Woolen, Goodyear, Lambert, & Reynolds, respectively.
- Mutual Non-Causation between DuPont & Standard Oil

***Granger Causality Test Between GM & Subset 1:***

- Causation from GM to American Locomotive, American Sugar, American Car & Foundry, Kennecott, Sears, & Texas, US Rubber, US Steel, & Woolworth, respectively.
- Causation from Paramount to GM
- Mutual Causation between GM & International Harvest
- Mutual Non-Causation between GM & Allied Chemicals, GE, & American Can, respectively

***Granger Causality Test Between GM & Subset 2:***

- Causation from GM to American Woolen, Bethlehem Steel, Canadian Pacific, Goodyear, & Lambert, respectively.
- Mutual Non-Causation between: GM & Pennsylvania Railroad, GM & Standard Oil CA, respectively

***Granger Causality Test Between Union Carbide & Subset 1:***

- Causation from UC to American Can, GE, Sears, US Rubber, & Woolworth, respectively.
- Causation from Allied Chemical, Paramount, American Locomotive, Texas, & Kennecort, respectively to UC.
- Mutual Causation between UC & American Sugar, UC & American Car & Foundry, UC & Intl Harvest.
- Mutual Non-Causation between UC & US Steel.

***Granger Causality Test Between Union Carbide & Subset 2:***

- Causation from UC to Bethlehem Steel, Goodyear, Lambert, Penn Railroad, & Standard Oil, respectively.
- Causation from Canadian Pacific Railroad, & Reynolds Tobacco to UC, respectively.
- Mutual Non-Causation between UC & American Woolen

## **Comparison of Granger Causality Results between Monthly data & Daily Data**

### *Causality Results between Innovative Companies & Dow Jones:*

Results from Daily data reinforce the results from monthly data that there is causation from innovative companies to DJIA, but no causation from DJIA to innovative companies.

### *Causality Results between RCA & Subset 1 and Subset 2, respectively:*

#### **RCA & Subset 1:**

- We find causality from RCA to Allied Chemicals, American Locomotive, GE, Sears, & US Rubber both in monthly data and daily data.
- Mutual causation between RCA & International Harvester, Woolworth, & Kennecott, respectively, found in monthly data disappears in daily data, and is reduced to causation from each of these companies to RCA.
- We found no causation (to and/or from) between RCA, and American Car & Foundry in monthly data but we discovered mutual causation between these two companies in daily data.
- The causation from RCA to US Steel, found in monthly data, disappears in daily data. However, we discover causation from US Steel to RCA in daily data, which was missing in monthly data.

**RCA & Subset 2:**

- Similar to findings from monthly data, we find causation from RCA to Bethlehem, Goodyear, & Lambert, respectively.
- Similarly, mutual causation between RCA & Reynolds, found in monthly data, also exists in daily data. Interestingly in the latter case, we discover mutual causation between RCA & Bethlehem, which did not exist earlier.
- Causation from RCA to Standard Oil, and Pennsylvania Railroad, found in monthly data, does not exist in daily data.
- Similarly, causation from RCA to American Woolen, found in monthly data, disappears in daily data. However, we discover causation from American Woolen to RCA, which was not found earlier.

**Results from analysis of causal relationship ,using daily data, reinforce those found in monthly data in case of most of the companies, both in subset 1 & 2, while at the same time these results help discover new relationships, as well as explore deeper insights into the nature of relationships, those found in earlier analysis.**



## **Discussion and relevance for financial economics research and policy**

### *Relevance of our research for Minsky's "displacement" hypothesis:*

The evidence presented in Table 4 (panels A, B) and Table 5 seems broadly in line with the existence of a technologically-driven displacement a la Minsky (1982). Nicholas (2008) used the number of patents under each company's name as his main indicator of innovation and found that it did not correlate well with the price increases observed in the run-up to the Great Crash. We instead tried to use qualitative criteria, an admittedly more risky and elusive exercise, as a first attempt to try to operationalize the Kindleberger-Minsky hypothesis of technological displacement, an issue on which we have been unable to identify much prior research.

### *Relevance of our study for the conduct of lab experiments on bubbles:*

The kind of bubbles that have been studied in the laboratory have all followed in the footsteps of Smith et al. 1988 (Porter and Smith, 1995; Ackert et al. 2001; Haruvy and Noussair, 2006, among others) and are characterized by a period in which prices significantly deviate from fundamentals followed by an eventual convergence between the two. The faithful adherence of subsequent researchers to the original experimental design by Smith et al. (1988) implies that the types of experimental bubbles studied so far cannot have significant and protracted price

undershooting after the crash. Why is the issue of price undershooting important? Because there are large economic costs associated with significant and protracted price undershooting. If, as the evidence contained in our time series suggests, prices were roughly aligned with fundamentals by 1926, the fact that they do not return to fundamentals for most of the companies in our dataset for a long time hints that bubbles produce significant economic waste. If the evidence discussed in this study were to be confirmed by other studies, then models of bubbles and experimental bubbles themselves will have to be modified to account for this important feature of real world bubbles.

*Relevance for financial economic theory (EMH):*

In this section we extend the sample period of our study until the last data point available in the WRDS database to test for the validity of the random walk hypothesis in a sample that is not dominated by boom-bust dynamics.

Table 1 presents the results of the KPSS stationarity tests and the ERS unit root tests for the companies in our first Subset. The picture is quite clear: the random walk hypothesis is rejected in a majority of cases. This finding stands in full support of well-established economic literature (Le Roy, 1973; Lucas, 1978). In standard economic theory, such as the C-CAPM model, the EMH hypothesis is just a special restrictive case in which utility is linear and the representative agent is risk-neutral. In the words of Stephen Le Roy (1973, pp. 444-445), "Except

under very special circumstances (particularly risk aversion), the martingale property will be violated...and under general conditions there is no rigorous theoretical justification for it available.” Lucas (1978, p. 1443) concludes that “evidently asset prices themselves do not possess the martingale property...it is clear that the presence of a diminishing marginal rate of substitution of present for future consumption is inconsistent with this property.”

The picture that emerges from Table 2, in which the tests of the random walk hypothesis for our second subset are presented, is much more varied than the one for Subset number one. In this case, the random walk hypothesis is rejected almost half the times and accepted for the other half of the companies in the subset, suggesting that the random walk hypothesis retains significant explanatory power under general conditions, if not under the specific ones of the 1926-33 subsample. In a sense, the EMH may be a special case, as noted by Le Roy (1973) and Lucas (1978), but it seems to be an important special case, as also noted by Le Roy (1973) and Lucas (1978).

## **Concluding remarks and open lines for further research**

Most of the empirical studies examining whether the crash of 1929 was the consequence of a stock market bubble in the years preceding the crash have assessed the issue using time series data, but have done so with low frequency data and weak unit root tests. Although there has been significant progress in the theoretical time series literature since the mid 1990's, we have been unable to find papers that apply these innovations to reassess the boom and crash episode centered around the year 1929. Throughout the present study we tried to fill this gap using more disaggregated company-level price data, appropriate unit root tests, and higher frequency time series for stock prices. Our results indicate that a bubble occurred during the years 1927-1929. The cause of the bubble was probably "contagion" from the Innovative Companies towards the more traditional ones.

A central implication of our findings is that investors seemed to be able to anticipate higher future prices during the speculative bubble, which initially encouraged the dynamics of stock prices to deviate from its fundamentals prior to the time of the crash. In particular, our findings regarding the transmission of price shocks from the four innovative companies towards the more traditional ones suggest that these bubbles may have originated in investors' imagination upon the arrival of new technologies invented by RCA, GM, Union Carbide, and DuPont. This financial contagion spread out rapidly, severely destroyed financial

as well as economic values, and lasted at least until the beginning of the U.S. involvement in World War II.

We suggest some interesting extensions to our study. First, the inclusion of more episodes is useful to continue to test for the existence of bubbles (or lack thereof). Secondly, the inclusion of more cases would allow us to keep testing for the Kindleberger-Minsky hypothesis of technological displacement as the potential origin of bubbles. In this regard, we plan to examine similar episodes in period subsequent to the Great crash.

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