The Role of Copper Prices as a Transmission Mechanism of the Panic of 1907 and the Noyes Hypothesis

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Abstract

Purpose: The study deepens the scholarly understanding of how financial crises spread by testing a hypothesis first suggested in 1908 that the Panic of 1907 was not simply a US domestic crisis but, rather, one that erupted in various banking systems around the globe.

Design/methodology/approach: The Toda-Yamamoto causality tests are employed to infer the causal dynamics between copper prices and the Bank of England discount rate utilizing dummy variables to capture the San Francisco earthquake, insurance claim payments, and the recessionary period.

Findings: Using commodity prices, interest rates and timelines, our results indicate that changes in the Bank of England's discount rate had a unidirectional causal relationship to copper prices. In terms of the dummy variables capturing the San Francisco earthquake and the resulting insurance claims, only the coefficient on the second wave of payments on insurance claims is positive and statistically significant in explaining copper prices. The coefficient on the dummy variable representing the recessionary period is negative and statistically significant with respect to copper prices. In regards to the discount rate equation, with the exception of the time trend variable, only the dummy variable for the second wave of payments on insurance claims is statistically significant. This finding is consistent with previous researchers who found that the second wave of gold outflows in early autumn 1906 prompted the Bank of England to undertake an eventual 250 basis point increase in the bank rate to maintain its desired level of reserves and a fixed sterling-dollar exchange rate.

Research limitations: The scarcity of data on the microstructure of the failed banks' balance sheets is a potential limitation.

Practical implications: The practical implications of our findings reveal that unexpected channels can transmit monetary policy shocks leading to banking problems in unexpected locations.

Social implications: The social implications of our findings show that even when societies choose to form institutions and policies intended to insulate themselves from monetary policy shocks generated in other countries, they may not be able to prevent price shocks from traded commodities from causing disruptions to their banking systems.

Originality/value: We contribute new evidence to the literature that banking crises in five countries shared a bank failure related to a borrower leveraged to copper in the transmission of shocks to copper prices in the 1907 financial panic.

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I.Introduction

We examine international linkages during the 1907 financial crisis and revisit the hypothesis of Alexander Noyes, contemporary financial market observer, that the causes of the 1907 crisis were international in scope, not domestic. We find evidence that a copper price shock may have provided a channel for contractionary monetary policy in London to affect the global banking system. Banking crises in five countries share a bank failure related to a borrower leveraged to copper. We find support for the notion that changes in the Bank of England's discount rate had a unidirectional causal relationship to copper prices. Inelastic with respect to supply and demand, copper prices were volatile, making loans to companies in the copper industry highly risky. We also find that liquidity injections in September 1906 in San Francisco to settle earthquake claims and disruptions to the Chilean copper export infrastructure following the Valparaiso earthquake in August 1906 may have a positive relationship with copper prices.

The study is organized as follows. Section II describes Noyes' hypothesis and the context in which he formulated his hypothesis which supported his case for a new U.S. currency system as documented in his contribution to the National Monetary Commission in 1910. Section III provides context with respect to the tightening of monetary policies by the Bank of England, especially in light of British insurance companies' shipments of gold to settle the claims arising from the 1906 San Francisco earthquake and fire. The monetary tightening likely set the stage for disturbances in the 1907 global banking system. Section III also provides background on the supply and demand factors in regards to copper prices during the years preceding the 1907 financial crisis. Section IV analyzes the banking crises for each of the five international locations, identifying the collateral upon which the failed banks had relied. We present our data and results in Section V, providing evidence that changes in the Bank of England discount rate had a unidirectional causal link to copper prices after controlling for stages of the business cycle. When a steep run-up in copper prices reversed sharply, companies dependent on copper prices failed and prompted failures of their lenders. The spike in copper prices beginning in September 1906 is positively associated with two important events: the arrival of gold to settle insurance claims from the San Francisco earthquake and the earthquake in Valparaiso, Chile that disrupted copper exports, temporarily reducing global supply. In Section VI, we discuss the results. We conclude that while the Bank of England's tightening monetary policy stance has been considered in the literature as a precipitating factor of the 1907 financial crisis, the role of copper price changes may not have been fully appreciated as a mechanism for the policy to be transmitted to banking systems around the world.

II. Noyes' Hypothesis: The Original and Current Approaches

The Noyes hypothesis states that if the shock was felt in localities in which American finance has no connection, then it would follow that the cause was something not peculiar to America (Noyes, 1909). Noyes (1909) cites the three most popular 1908 explanations for the 1907 crisis: Roosevelt's efforts to restrain large corporations, reckless trust company banking, and flaws in the American currency system. He argues that each of these causes only reflects an environment in which banking and finance systems operate in America. He discredits each of the causality arguments by using a timeline analysis, pointing out that none of these explanations served as triggers to the stock market collapse or on the runs of the trust companies. Roosevelt's anti-trust stance began well before the 1907 panic. Reckless trust company lending in New York had been revealed continuously during the 1904 to 1905 Armstrong hearings as self-dealing and favorable lending among members of interlocking directorates at financial firms was understood before 1907. Finally, the shortcomings of the currency system had been debated for decades, yet the system had supported tremendous economic growth during the national banking era. The shortcomings of the currency system offered no surprises in 1907 either.

Instead, Noyes (1909) points to the timeline of commodity price increases and increases in asset prices of stocks and real estate related to those commodities as the instigators of the global banking crises in 1907. Inflated collateral was used to back large, speculative loans in each city that experienced a banking crisis: New York, Santiago, Alexandria, Tokyo, Hamburg, Amsterdam, Copenhagen and Genoa. He argues that two cities had banking panics that were unrelated to the commodity price increases: Genoa and Copenhagen. He further argues that those two crises were related to idiosyncratic malfeasance in banks within each location. He also postulates that the exogenous shocks associated with the earthquakes in San Francisco and Santiago disrupted global liquidity flows that strained the system in addition to the commodity price shocks.

Noyes (1909) presents three types of data to support his claims: (1) rising and volatile commodity and security prices; (2) new equity issuances at record levels; and (3) high money rates at central bank discount windows. Using a general index of commodity prices published by *The Economist*, Noyes notes that price increases had been apparent over a year before the panic. While Noyes (1909) does not cite his source, he provides data for net new securities offered in London and New York in 1905 and 1906 as a comparison to the 1900-1901 “extravagant period”. Finally, Noyes (1909) uses year-end discount rates at seven money centers from 1904 to 1907 to demonstrate that short-term rates had risen throughout the period.

Next, Noyes (1909) describes the timeline over which banking crises erupted in the seven cities other than New York and provides a brief background narrative for each instance. He draws his conclusion in constructing a timeline in his argument that the crises in other countries occurred before or coincident with the crisis in New York to support his assertion that the causes of crises were more likely found in lending problems related to the run-up and subsequent collapse in commodity prices.

[Insert Table 1 here]

However, we approach the data somewhat differently than Noyes (1909). We trace each bank failure to the collateral upon which the bank loan was most likely based, a step not taken by Noyes. Given we find that five of the eight countries' bank failures were related to borrowers' sensitivity to copper prices, we explore in more detail the Noyes hypothesis in asking whether monetary policy pursued by the Bank of England was related to copper prices. While Noyes (1909) uses a general commodity price index, we address this question using more detailed weekly changes in copper prices. Furthermore, while Noyes (1909) uses annual central bank discount rates, we collect weekly data on the discount rate of the Bank of England.

[Insert Figure 1 here]

O'Dell and Wiedenmier (2004) found that gold outflows from London to settle San Francisco earthquake claims may have precipitated two policy responses from the Bank of England: (1) raising the discount rate in 1906 and (2) refusing to renew American finance bills during the fall of 1906 and the spring of 1907. As a result, we explore whether the arrival of London gold to rebuild San Francisco, including its nascent electrical infrastructure grid, was associated with changes in copper prices. Therefore, we use an event study framework to test whether three dates associated with gold flows related to the earthquake are useful predictors of copper prices, a step not considered by Noyes (1909).

We turn now to a brief discussion on Alexander Dana Noyes and why his hypothesis and findings matter. Noyes was a journalist who covered Wall Street and financial issues for several newspapers including the *Commercial Advertiser*, the *New York Evening Post* and the *New York Times*. He was among a group of amateur writers who began to study social issues with a scientific line of inquiry in which hypotheses and systematic consideration of issues emerged.

Born in 1862 in Montclair, New Jersey in a politically conservative family, he declared his political sympathies with the Republican Party Reformers in his memoir (Noyes, 1938). In the late 1890's, both Republicans and Democrats favored reforming the banking and political establishment. Though each group wanted greater transparency in the relationship between Wall Street and politicians, the Republican Reformers supported the gold standard and "sound money" while the Democrats supported the silver agitation from the western farmers who struggled during the deflation of the 1890's.

During the time Noyes wrote for the *New York Evening Post*, the newspaper's editorial posture had changed from a more laissez-faire policy that traced back to its founder, Alexander Hamilton to a Republican Reformer stance. Horace White, an editor of the *New York Evening Post* at the time Noyes was with the paper, was an early supporter of the 1894 Baltimore Plan, a proposal for altering the collateral of the U.S. banking system from government bonds to other high quality assets (Wicker, 2005).

Noyes' (1909) paper on the global causes of the 1907 financial crisis supported his argument in the essay he contributed for the National Monetary Commission in 1910. Consistent with Horace White's views in the Baltimore Plan, Noyes argued in "The History of National

Bank Currency" that the American currency should not be based on government bonds. From his understanding of the business expansion that preceded the 1907 crisis and prior crises, Noyes argued that when business conditions expanded the banking system was constrained by the lack of expanding collateral upon which to issue notes.

III. Copper Price Behavior, 1990-1908

Between the mid-1870's and the late-1930's there was approximately a ten-fold increase in world per capita primary copper consumption (Schmitz, 1997). As noted by Schmitz (1997), the U.S. emerged as the world's largest single copper consumer and producer between 1876 and 1920. In the decade 1900 to 1909 the U.S. had the largest production-consumption surplus in the world with Japan and Chile joining the U.S. as two of the other major copper producers between 1899 and 1909 (Schmitz, 1997).

By the first decade of the twentieth century, approximately half of the primary copper consumption in the U.S. was claimed by the electrical industry (Schmitz, 1997). Indeed, the electrical grid was being built at a rapid pace at the turn of the century. Between 1890 and 1900, central power stations increased from 1,000 to 3,620, each using copper wire for electricity conduction (Hunter and Bryant, 1991). Not only was wire demanded for the burgeoning telecommunications industry as telephone usage expanded, but it was also the backbone for constructing the lighting infrastructure and the electrification of transportation such as the urban subways and railways (Richter, 1922). The miles of rail track operated by electricity increased from 21,907 in 1902 to 34,059 by 1907.[1] In 1890, 126 out of 706 electric transportation systems reported using electricity as compared to 904 out of 945 in 1907.[2]

Both the supply and demand for copper exhibit a high degree of price inelasticity.[3] On the supply side, producers were unable to respond rapidly to a price increase because of the high degree of capital intensity at each stage of processing the metal, from mining to smelting, and then to refining and shaping. Bringing on new capacity at each stage takes years rather than months.[4] By the same token, large-scale, capital intensive operations continue production even in the face of short-run price declines.[5] Demand to build out the electrical infrastructure tended to be price inelastic because municipal projects were large in scope and could not be easily scaled back in periods of high copper prices. The inelasticity of both supply and demand resulted in sharp fluctuations in the prices of copper in the short-run (Schmitz, 1997). Consistent with our conjecture that copper consumption increased as a result of the rebuilding of San Francisco after the earthquake on April 18, 1906, the U.S. Geological Survey reports the consumption of copper was at 318,000 tons up 19.5% in 1906 as compared to 1905, the largest increase since 1902. U.S. production was up 14.8% in 1906 compared to 1905 and global production was up only 1.5% to 724,000 tons, compared to a price increase of 23%, all of which supports the inelasticity in both the quantities supplied and demanded with respect to price. The inventory of copper at the end of 1906 was only 21,000 metric tons, down 57% from the end of 1905 and only

[1] Street and Electric Railways, Department of Commerce and Labor, United States Bureau of the Census, Washington Government Printing Office, 1910. Table 3, p. 26.
[2] Ibid., p. 28.
[3] Copper prices were the most volatile of commodities during the period based on the standard deviation in parentheses: copper (18.35), coal (3.18) and iron (0.52), calculated from prices quoted in *The Economist* between January 1906 and May 1908.
[4] Ibid., p. 310.
[5] Ibid., p. 310.

33% of average year-end inventory for the period 1900 to 1909.[6] Consumption of copper in the U.S. remained constant in 1907, but dropped 8% in 1908 to 294,000 metric tons.

Anecdotal evidence also supports the notion that copper usage increased during the rebuild of San Francisco. Interviewed on May 8, 1906, Senator Francis G. Newlands was quoted in the *New York Times* saying, "The City is going to be restored on a greater scale than before."[7] On September 30, 1906, the same paper announced, "The steel mills and furnaces will start tomorrow to make record runs. Orders have been issued to get everything in readiness for the largest operations on record. The structural mills are beginning to get the orders for steel which is needed on the Pacific Coast."[8] It would be likely that a similar impact was felt in the copper wire market, needed for lighting the new steel buildings.

Damage from the earthquake and fires in San Francisco was catastrophic, estimated at $350 million to $500 million or 1.3 to 1.8 percent of U.S. GNP in 1906 (Odell and Weidenmeir, 2004). The response of the Bank of England to stem the $115 million gold outflows from London fire insurers to San Francisco are thoroughly documented by Odell and Weidenmier (2004). The discount rate was raised 250 basis points between September and November 1906 and British companies were pressured to stop discounting American finance bills for the next year. Odell and Weidenmier (2004) cite three dates that seem to have been pivotal in the response of securities prices and gold flows: the date of the earthquake, April 18, 1906; the arrival of the first relief funds by May 12, 1906 amounting to about $50 million; and the arrival of approximately $100 million in claims settlement funds by September 1, 1906. We use these three dates to test for associations with copper stock prices. Noteworthy too is the event of the

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[6] U.S. Geological Survey, 2014, Copper statistics, in Kelly, T.D., and Matos, G.R., comps., Historical Statistics for Mineral and Material Commodities in the United States: U.S. Geological Survey Data Series 140, accessed April 30, 2015, at http://minerals.usgs.gov/minerals/pubs/historical-statistics/.

[7] *New York Times*, May 8, 1906.

[8] *New York Times*, September 30, 1906.

earthquake in Valparaiso, Chile on August 17 1906. Approximately 80% of Valparaiso's exports were copper.[9] Freighted copper shipped from Valparaiso before August 17 continued supplies to European importers for the next few weeks, but damaged infrastructure likely contributed to Chile's reduced mineral exports in 1907, dropping from $92,000,000 in 1906 to $88,000,000 in 1907.[10] Reduced supply likely contributed to the spike in copper prices beginning in September.

Copper prices had been generally steady throughout 1906, hovering around £87 per ton until early September. During the week of September 8, 1906, the price broke £90 and quickly rose to a peak of £116 during the week of March 9, 1907. Over the next year, perhaps in response to recessionary conditions in the economy, the abatement of spending in San Francisco and the resumption of copper shipments from the port of Valparaiso, it subsided irregularly ending at £60 during the week of March 7, 1908.[11] As a result, failures of banks leveraged to copper industry borrowers occurred from April 1907 through January 1908. Could the liquidity provided by insurance companies been used to bid up the price of copper?

[Insert Figure 2 here]

IV. Sources for Banking Crises in Other Countries

This section begins our review of Noyes' hypothesis that the source of the panic in New York was rooted in broad, global conditions. Since the trigger to the American panic was the failure of a brokerage house heavily levered to copper securities, we start by exploring whether sharp drops in the prices of copper commodities and commodity-related securities are associated with bank failures in the countries that experienced banking failures. We find the collateral at

[9] Commercial Relations of the United States with Foreign Countries during 1907, p. 312, Department of Commerce and Labor, Washington DC, GPO, 1908.
[10] Ibid., p. 313.
[11] *The Economist*, Commercial Time Weekly Price Current, January 1906 through May 1908 editions.

failed banks in Fukui, Genoa, Hamburg, New York, and Santiago were related to copper.[12] Contrary to Noyes' assertion that the Genoa crisis was brought about by idiosyncratic governance issues at the Genoa stock exchange, we find that it, too, was related to the collapse in copper prices.

[Insert Table 2 here]

Japan

The Yokohama Specie Bank was the chief instrument of the Bank of Japan to facilitate foreign trade, acting as the vehicle to coordinate the import and export of gold. By managing the flow of gold, the Bank of Japan may have insulated the Japanese domestic economy from some of the immediate effects of the rise in the discount rate by the Bank of England. However, the Bank of Japan could not apparently insulate the domestic economy from the depreciation of silver that impacted the purchasing power of its chief trading partner, China, for its cotton yarn exports or from the drop in copper prices during 1907.[13] Bank failures in Japan occurred in regions that produced cotton and copper. The region of Aichi, located in central Japan, was one of the top cotton textile production areas in Japan, accounting for about 20% of the national total. The cotton thread industry dominated the Nagoya economy, the prefectural seat of Aichi. The run on the Nagoya Bank in the cotton yarn-producing region was followed by the failure of banks exposed to copper exporters. Yabushita and Inoue (1993) provide a succinct timeline of events in Japan as shown in Table 3.

[Insert Table 3 here]

Today, we think of Japan as a nation with limited natural resources, but copper, gold and silver were once crucial exports. By 1885, the Ashio copper mine, 75 miles north of Tokyo, was

[12] The study of Alexandria, Copenhagen, and Amsterdam await future research.

[13] Commercial Relations Commercial Relations of the United States with Foreign Countries during 1907, p. 431, Department of Commerce and Labor, Washington DC, GPO, 1908.

producing 4,131 tons annually comprising 39% of Japans' total copper output. In 1906, as the largest mine in the nation, it produced 6,787 tons, 18% of Japan's total and employed 11,000 workers. That compares to total Japanese copper production of 34,000 tons, about a tenth the size of U.S. production. As a result of the Ashio riot in February 1907, sparked by poor working conditions, a number of Japanese banks failed that were located in copper producing regions, like the Ashio copper mine (Kazuo, 1997).

The reduction in aggregate demand in New York for Japan's exports of silk, copper, and cotton yarn has also been mentioned as a reason for the extension of the financial crises in Japan (Ono, 1922). In May 1908, however, signals emerged from the copper market that the liquidation phase of the Japanese banking crisis was unfolding as "fairly large quantities of copper were pressed on the market by Japanese holders owing to a severe financial crisis then existing in the Far East and tended to unsettle prices which declined toward the middle of the month."[14]

Genoa, Italy

By 1906, Italy was well on its way to developing a universal banking system, not unlike Germany. Like the German banks, the two Italian universal banks, Banca Commerciale and Credito Italiano, forged close ties with their client companies (Gigliobianco et al. 2009). Societa Bancaria Italiana (SBI) had expanded to become the "third credit pillar" of the rapidly industrializing northwestern region of Italy (Bonelli, 1971). However, by 1907 SBI was controlled by a group of Genoese businessmen that speculated heavily in stocks on the Genoese exchange.[15] The insolvency of one of SBI's important client companies, Ramifera, the largest copper operation in Italy, highlighted the vulnerability of SBI.[16] In September 1907, with a drop

[14] *Engineering and Mining Journal*, January 9, 1909., Volume 87, p. 58
[15] Riva, Angelo. "Microstructure et Risque de Contrepartie: Les Bourses de Milan et de Genes a L'Epreuve de la Crise de 1907," *Entreprises et Histoire*, 2012, No. 67, pp. 37-53.
[16] Ibid., p. 41.

in the Genoese stock market and especially the shares of Ramifera, and subsequent freeze in Genoese trading, corporate clients, pressed for liquidity drew on their deposits as did members of the general public (Gigliobianco et al 2009).

[Insert Figure 3 here]

It became clear that SBI was in urgent need of a liquidity injection. As a result the Bank of Italy coordinated capital injections from new investors to SBI. Lax regulations at the Genoa Stock Exchange are also cited as part of the Italian institutional setting that may have contributed to the volatility in stock prices (Tusset, 2011). By late spring 1908, the crisis had passed (Gigliobianco et al. 2009).

Hamburg, Germany

On October 18, 1907 newspapers in North America reported the biggest German banking failure since the failure of the Leipziger Bank in June 1901.[17] Haller, Soehler & Co. failed with liabilities reaching $7.5 million and partners' capital of $2.25 million. The failure was linked to one of its largest customers, a mining concern in Teplitz, Bohemia, exposed to declining metal and coal prices. Haller, Soehle & Co. seemed not to only have been over exposed to mining securities, but also to have been saddled with the settlement with the heirs of a recently deceased partner. Rumors also circulated that the bank was heavily hit the by the fall in copper prices and affected by the difficulties of Otto Heinze in New York.[18]

New York, United States

Augustus Heinze was one of three prominent developers of the Butte Montana copper veins, the largest single deposit when it was developed in the 1880's (Glasscock, 2002). Marcus Daly built the first smelter at Anaconda Montana close to Butte, eventually joining forces with

[17] *Montreal Gazette*, October 18, 1907, p. 5.
[18] Ibid, p. 6.

Rockefeller interests to create Amalgamated Copper Mining Co., the largest copper monopoly. Heinze provided one of the few strong competitors to Amalgamated, exploiting a loophole in mining rights laws by extracting ore from beneath Amalgamated's ore claims. Heinze combined his interests into United Copper in 1902 with production capacity about one third that of Amalgamated. Even though Heinze sold most of United Copper's producing assets to Amalgamated in 1906, he retained claims to copper veins in the company and continued to litigate in Montana courts.

In 1907, under the impression that the Heinze family controlled enough of the stock to corner a large group of short-sellers, his brother Otto began an aggressive purchase of the outstanding shares on October 14, 1907, hoping to force the short sellers to cover in order to meet expensive margin calls. Informed traders, such as the Heinze brothers, might have been most likely to initiate the short squeeze at a time short sellers would be most likely to cover, once the dramatic collapse in copper prices was over and the copper prices stabilized at lower levels. The Heinze family funded their purchases of the stock with loans from the State Savings Bank of Butte and Mercantile National Bank in New York. Underestimating the number of shares available for sale to cover the shorts, the Heinze brothers' shares initially rallied from $39 to $60, but quickly fell after short sellers were able to cover with cheaper shares purchased from other sources. Gross and Kleeberg, a brokerage used by Heinze, failed as did the State Savings Bank in Butte. The New York Clearing House backed the affected New York banks with the condition that the Heinze brothers resign their positions as board members of the institutions. Fear that the Heinze family had borrowed funds from Knickerbocker Trust for their speculation resulted in a run on the Knickerbocker Trust, sparking the cascade of events we know as the Panic of 1907 (Bruner and Carr, 2007).

Santiago, Chile

Eighty percent of the Chilean export economy was comprised of nitrate of soda and copper shipments in 1907.[19] Unlike the Japanese case, no central bank existed in 1906 and 1907 to mitigate the effects of the contractionary British monetary policy. Rather the Congress and President passed rules regarding the banking system. Congress suspended gold specie payments in 1878, albeit with a failed three-year attempt at returning to the gold standard in 1895. A fiat paper money system existed with the peso floating in exchange for sterling until 1926 (Kemmerer, 1926). Successive fiscal note issues devalued the peso from 1905 through 1907 with exchange dropping from 15.02d to 8.5d (Kemmerer, 1926). Congress attempted to mitigate the economic problems that arose from the floating currency by adjusting the import tariffs to offset the depreciated peso. For example, in 1907 tariffs on imported shoes, cotton apparel and woolen goods were reduced by 50% until 1909.[20]

The failed Banco Mobiliario in Santiago suspended payments to depositors on December 7, 1907. The Parliament authorized an immediate issuance of $30 million of new paper money to relieve tight monetary conditions.[21] Sixty percent of the bank's assets were loans to nitrate and copper producers.[22] Nitrate prices had gradually weakened during 1907, likely in response to the global economic slow-down, but copper prices had collapsed quickly.[23] Stock prices related to the copper industry had generally collapsed across the board as well (Briones and Villela, 2006). Banco Mobiliario's two largest loans to the copper mining companies, Gatico and San Bartolo,

[19] Commercial Relations of the United States with Foreign Countries during 1907, p. 308, Department of Commerce and Labor, Washington DC. GPO 1908.
[20] Commercial Relations of the United States during 1907, p. 312.
[21] *New York Times*, December 10, 1907.
[22] Superintendencia de Bancos e Instituciones Financieras de Chile, Proceedings from the Fourth Civil Court of Santiago, Liquidator of the Banco Mobiliario, April 17, 1914.
[23] Commercial Relations of the United States, 1907, p. 313.

were eventually exchanged for equity in a reorganized copper venture.[24] It is not clear if the Bank of Chile, which had guaranteed some of the nitrate loans, organized a capital infusion or simply coordinated an orderly liquidation of the failed bank. The failure of Banco Mobilario did not spread to other banks or losses to depositors, but did absorb the total capital of the bank (Behrens Fuchs, 1985). Attempts to auction off the bank's assets continued through 1914 when the bank was finally liquidated.

Additionally, the Chileans experienced an earthquake shock in Valparaiso on August 18, 1906, only four months after the San Francisco earthquake. The damage from the Chilean earthquake was estimated at only about $20 million, much less than the estimated losses from the San Francisco earthquake, but was still thought to have negatively impacted liquidity conditions in Chile throughout 1907.

V. Data, Methodology, and Results

Weekly data over the period January 6, 1906 to May 30, 1908 on copper prices and the discount rate was obtained from Saturday editions of *The Economist* from the London Prices Current column. Dummy variables were constructed to capture the San Francisco earthquake (D418) taking a value of 1.0 for April 21, 1906 onwards and 0.0 otherwise; the first wave of relief payments in the aftermath of the earthquake (D512) taking a value of 1.0 for May 12, 1906 onwards and 0.0 otherwise; the second wave of payments from claims settlements arrive in San Francisco (D901) taking a value of 1.0 for September 1, 1906 onwards and 0.0 otherwise; and the recessionary period (RECESSION) taking a value of 1.0 from May 4, 1907 to May 30, 1908 and 0.0. otherwise based on NBER business cycle dating. Also included is a time trend variable.

[24] Superintendencia de Bancos e Instituciones Financieras de Chile, Proceedings from the Fourth Civil Court of Santiago, Liquidator of the Banco Mobiliario, April 17, 1914.

The Toda-Yamamoto (1995) causality test is used to infer the causal dynamics between copper prices and the Bank of England discount rate. As noted by Zapata and Rambaldi (1997), the Toda-Yamamoto (1995) procedure addresses concerns regarding the power and size properties of standard unit root and cointegration tests by minimizing the risk of incorrectly identifying the order of integration and the cointegration properties of the variables through the estimation of a vector autoregressive (VAR) model in levels. To test for causality within this framework, the order of the VAR, k, is augmented by the maximum order of integration (d_{max}) of the respective variables in the model. Moreover, within this modeling framework, inferences drawn from the test statistics for Granger-causality follow the standard asymptotic distribution.

We employ three unit root tests: Augmented Dickey-Fuller (ADF, Dickey and Fuller, 1979), Phillips-Perron (PP, Phillips and Perron, 1988), and Dickey-Fuller GLS (DF-GLS, Elliott et al., 1996) to determine the maximum order of integration, d_{max}. The Augmented Dickey-Fuller unit root test uses a parametric correction to account for higher order serial correlation while the Phillips-Perron unit root test uses a nonparametric approach. The Dickey-Fuller GLS unit root test parallels the ADF test by first de-trending the data prior to testing for the presence of a unit root. The null hypothesis for each of these unit root tests is the presence of a unit root. Table 4 displays the results of the above unit root tests revealing the maximum order of integration is one ($d_{max} = 1$) for each of the variables.

[Insert Table 4 here]

In light of the unit root test results, a $(k + d_{max})^{th}$order VAR model in levels is estimated with the lagged d_{max} vector ignored when testing for long-run causality using a modified Wald test. The $(k + d_{max})^{th}$order VAR model in levels is specified as follows:[25]

[25] The Schwarz information criterion is used to determine the number of k lags.

$$COPPER_t =$$

$$\alpha_{10} + \sum_{i=1}^{k} \theta_{11i}\, COPPER_{t-i} + \sum_{j=k+1}^{d_{max}} \theta_{12j} COPPER_{t-j} + \sum_{i=1}^{k} \theta_{13i}\, DISCOUNT_{t-i} +$$

$$\sum_{j=k+1}^{d_{max}} \theta_{14i} DISCOUNT_{t-j} + \gamma_{15}\, D418 + \gamma_{16} D512 + \gamma_{17} D901 + \gamma_{18} RECESSION +$$

$$\gamma_{19} TIME + \varepsilon \qquad (1)$$

$$DISCOUNT_t =$$

$$\alpha_{20} + \sum_{i=1}^{k} \theta_{21i}\, COPPER_{t-i} + \sum_{j=k+1}^{d_{max}} \theta_{22j} COPPER_{t-j} + \sum_{i=1}^{k} \theta_{23i}\, DISCOUNT_{t-i} +$$

$$\sum_{j=k+1}^{d_{max}} \theta_{24i} DISCOUNT_{t-j} + \gamma_{25}\, D418 + \gamma_{26} D512 + \gamma_{27} D901 + \gamma_{28} RECESSION +$$

$$\gamma_{29} TIME + v \qquad (2)$$

[Insert Table 5 here]

As shown in Table 5, the Toda-Yamamoto causality results reveal unidirectional causality from the Bank of England discount rate to copper prices at the 10 percent level of significance with the sum of the lagged coefficients with respect to the discount rate being positive (0.066). In terms of the dummy variables capturing the San Francisco earthquake and the resulting insurance claims, only the coefficient on the second wave of payments on insurance claims (D901) is positive and statistically significant at the 5 percent level in explaining copper prices. The coefficient on the dummy variable representing the recessionary period is negative and statistically significant at the 5 percent level with respect to copper prices. In regards to the discount rate equation, with the exception of the time trend variable, only the dummy variable (D901) for the second wave of payments on insurance claims is statistically significant. This finding is consistent with Odell and Weidenmier (2004) who found that the second wave of gold outflows in early autumn 1906 prompted the Bank of England to undertake an eventual 250 basis point increase in the bank rate to maintain its desired level of reserves and a fixed sterling-dollar exchange rate.

VI. Discussion and Conclusion

Our results indicate that changes in the Bank of England's discount rate had a unidirectional causal relationship to copper prices. Gold outflows from London, meant to be reversed by rate hikes, may have been fueling a rise in copper prices. We find that the event of gold arrivals in San Francisco in September 1906 to settle earthquake claims may have had a positive relationship with copper prices. The inelasticity in both the quantities supplied and demanded for copper likely contributed to volatile copper price behavior. Monetary tightening at the Bank of England likely contributed to a recession period that began in May, 1907; our results about the recessionary period coefficient may be interpreted as finding copper prices declined in response to a decrease in aggregate demand.

Global shocks in copper prices may have translated to solvency and liquidity problems at banks that were especially exposed to borrowers in the copper industry irrespective of the country. While the gold standard may have been a primary transmission mechanism of the contractionary monetary policies of the Bank of England, we find evidence of a separate channel by which the shock may have been propagated, the collapse of copper prices and of those assets related to that commodity. Bank failures in New York, Japan, Germany, Italy, and Chile share in common a bank failure related to a borrower leveraged to copper. While copper prices appear to play a role in the Chilean, American, Japanese, German and Italian cases, a decline in the purchasing power of silver in China may have played a role in the decline of demand for Japanese cotton yarn.

While Noyes suggests that different banking systems experienced commodity price shocks, he does not suggest the common commodity to have been copper. Noyes suggests that the Genoa crisis is idiosyncratic, but we find evidence that it, too, may have been related to copper. We find support for Noyes' hypothesis that the causes of the crisis may have been due to global factors rather than domestic.

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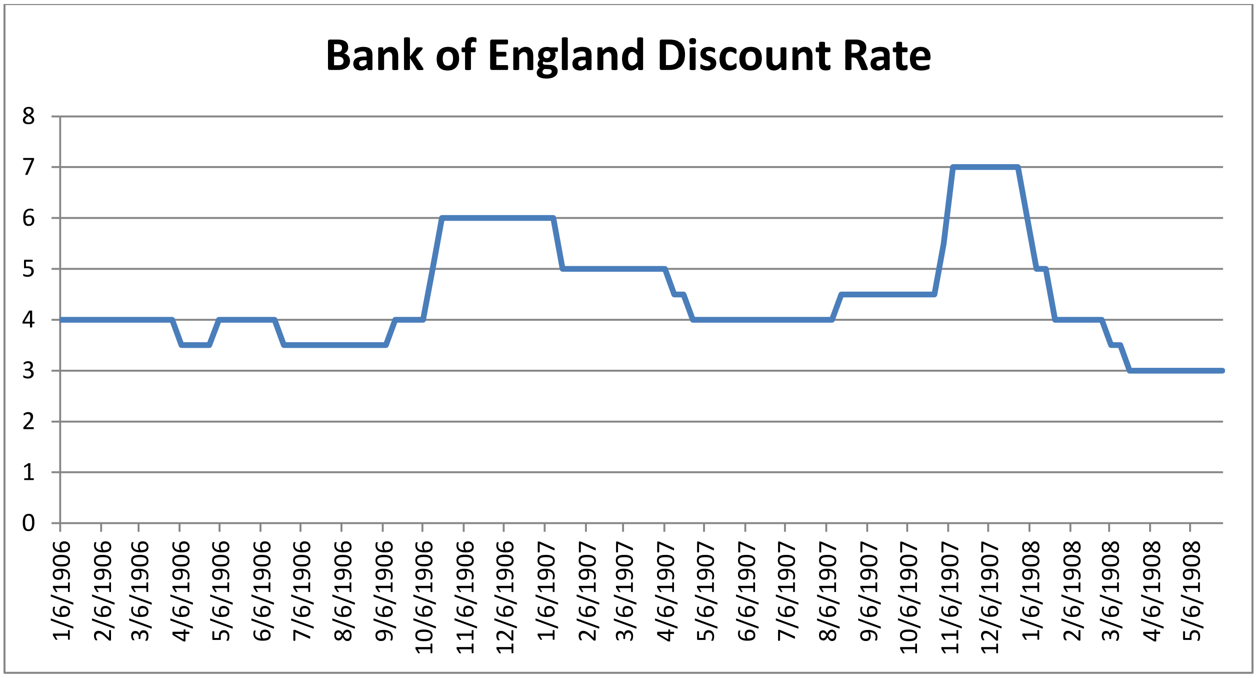
Table 1
Noyes' Time Line of Crises

Location	**Time Line**
Alexandra, Egypt	January 1907 through April 1907
Tokyo and several other Japanese cities	April 1907 through April 1908
Genoa, Italy	September 1907
Hamburg, Germany	October 1907
New York, New York	October and November 1907
Santiago, Chile	November 1907 through January 1908
Amsterdam, Holland	November 1907
Copenhagen, Denmark	December 1907 through June 1908

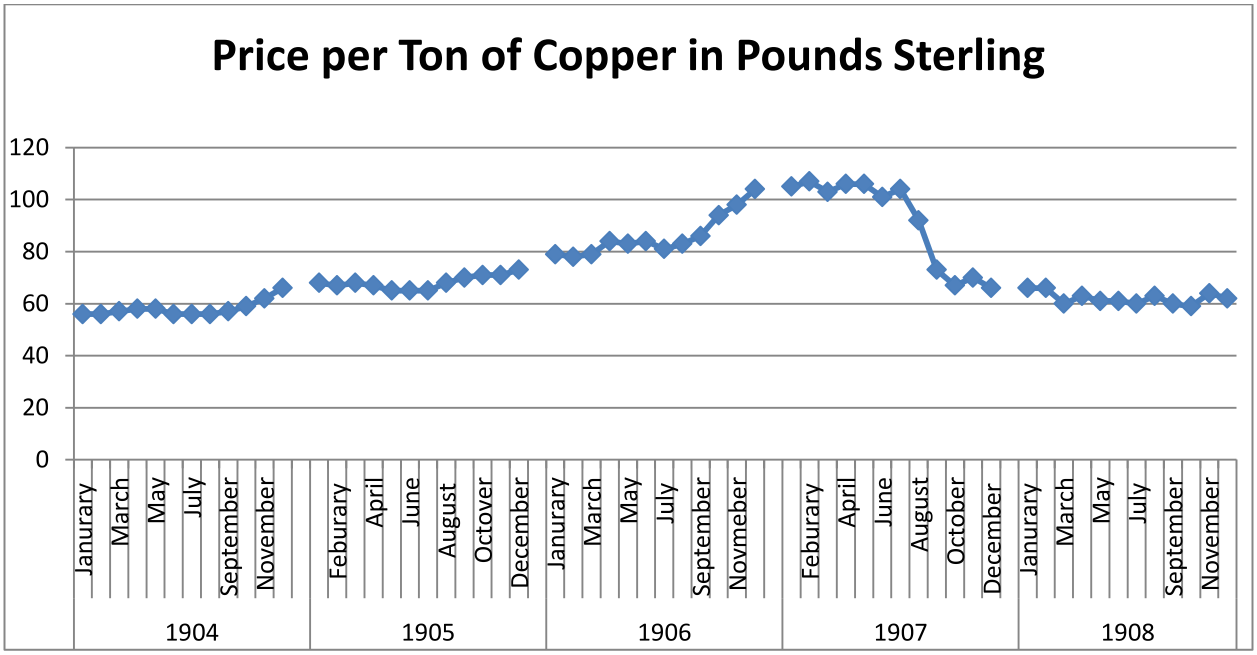
Source: Noyes, A.D. (1909), "A Year After the Panic of 1907", *Quarterly Journal of Economics*, 23, 185-212.

Figure 1
Bank of England Discount Rate
(Weekly)



Source: *The Economist*, Bankers' Gazette, Money Market weekly column, 1906-1908 editions.

Figure 2
Copper Prices
(Peak in January 1907)



Source: *The Economist*, Commercial Times Weekly Price Current column, editions from 1904 through 1908.

Table 2
Bank Failures in Other Countries

Failed Banks	**Defaulting Borrower(s)**
Nagoya Bank and Fukui Bank, Japan	Cotton and copper exporting regions respectively, many defaulting borrowers
Societa Bancaria Italiana, Genoa, Italy	Ramifera, copper fabricator
Haller, Soehler & Co., Hamburg, Germany	Teplitz, Romanian mining operation
Knickerbocker Trust, New York, U.S.	United Copper, stock speculation at Heinze brokerage
Banco Mobilario, Santiago, Chile	Compania Gatico and San Bartolo, copper mining operators

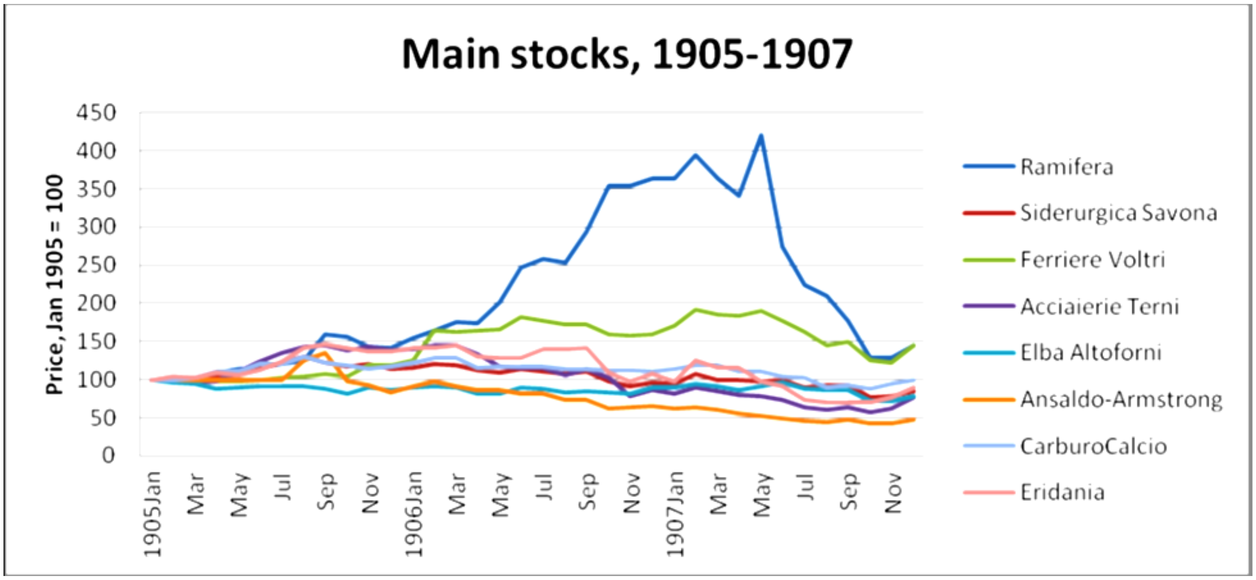
Source: Yabushita and Inoue (1993); Tusset (2011); *Montreal Gazette*, October 7, 1907; Bruner and Carr (2007); Behrens Fuchs (1985).

Table 3
Time Line of Japanese Bank Failure Events

Date	Event	Response
February 1907	Run on Nagoya Bank	2.5 million yen to Nagoya Bank
March 1907	Suspension at One Hundred Thirty-Eighth Bank (Shizuoka)	
April 1907	Several bank closings in Tokyo and other areas	
November 1907	Runs and suspensions at Small banks in Tokyo and Fukui	
February-July 1908	Runs on 42 banks, 23 of which are suspended	Sharp increase in loans to banks

Source: Yabushita and Inoue (1993).

Figure 3
Performance of the Main Stocks Listed at the Genoa Stock Exchange
January 1905 and 1907



Notes: Tusset, G. (2011), "Speculation by the Next-Door Neighbor: The 1907 Italian Financial Crisis", Working Paper, Padua University.

Table 4
Unit Root Tests

Variable	ADF	PP	DF-GLS
Copper	-0.97	-1.11	-0.59
ΔCopper	-9.85[a]	-10.08[a]	-10.01[a]
Discount	-1.97	-1.92	-2.03
ΔDiscount	-8.08[a]	-8.07[a]	-8.14[a]

Notes: Critical values and significance levels denoted as follows: ADF and PP a(1%) -4.03, b(5%) -3.45, and c(10%) -3.15; DF-GLS a(1%) -3.55, b(5%) -3.01, and c(10%) -2.72. Unit root tests include both an intercept and trend. Lag lengths for the ADF and DF-GLS unit root tests are based on the Schwarz information criterion while the PP unit root test is based on the Bartlett kernel.

Table 5
Toda-Yamamoto Causality Tests

Dependent Variables

Variables	Copper	Discount
Copper	-------	1.91 -0.008 [0.39]
Discount	5.29 0.066 [0.07][c]	------
D418	0.117 (0.08)	0.239 (1.29)
D512	0.303 (0.22)	-0.123 (-0.68)
D901	2.556 (2.27)[b]	0.406 (2.77)[a]
RECESSION	-1.880 (-2.10)[b]	0.161 (1.38)
TIME	-0.031 (-1.46)	-0.007 (-2.63)[a]
Intercept	5.806 (2.70)[a]	0.726 (2.59)[a]
Adj.R^2	0.986	0.929

Notes: For Copper and Discount, modified Wald chi-square statistics to test whether the k = 2 lags are equal to zero are displayed with probability values underneath the test statistics in brackets. The sum of the lagged coefficients represents the summation of the lags in the VARs excluding the lagged coefficient with the highest order. For the remaining variables, the coefficient estimates are reported with t-statistics in parentheses. Significance levels are as follows: a(1%), b(5%), and c(10%). Both autocorrelation and heteroscedasticity are absent from the VAR model based on the multivariate Box-Pierce/Ljung-Box Q-statistics up to 12 lags and White's test for heteroscedasticity for a system of equations.