The Costs of Banks Engaging in Non-Banking Activities: A Case Study

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The century-long separation of banking and commerce enshrined in U.S. law has weakened in recent decades. The academic literature has thus far focused mainly on conceptual benefits and costs of the trend, arguing that the integration of banking and commerce might lead to efficiency gains through diversification in a greater number of distinct business lines, but that it also might impair the safety and soundness of the banking system, weaken market integrity, and lead to an excessive concentration of economic power.

Our Article contributes to the debate by empirically examining an important episode in the U.S. commodities market following the 2008-2009 financial crisis, when financial institutions sought to take advantage of depressed commodity prices by amassing unprecedented metals inventories. From 2010 through 2014, as financial institutions held over half of the total U.S. aluminum stock in Detroit warehouses, the time it took to remove metal from warehouses increased from days to years and the regional price of aluminum skyrocketed—a surreal phenomenon because aluminum is one of the most actively traded commodities in the world and is used in the production of industrial goods from beverage cans to cars and airplanes.

We first demonstrate that the market distortion was caused by certain banking organizations and then show that the distortion harmed businesses and consumers. We argue that the unprecedented accumulation of commodities was made possible by a statutory loophole created by the Gramm-Leach-Bliley Act of 1999, one that advantages certain investment banks and enables them to undertake activities that are more commercial in nature. We recommend closing the loophole as well as modifying other facets of the banking-and-commerce legal framework. We then propose a detection algorithm to guard against non-bank financial institutions, which are outside the perimeter of the banking-and-commerce framework, from causing similar market distortions in the future.

Notably, the 2010-2014 episode may recur. The legal framework remains unchanged and financial institutions respond to incentives. Solving this problem will require action from Congress as well as coordination among the Department of the Treasury, Federal Reserve, and Commodities Future Trading Commission.

Introduction

Imagine asking your grandparents, "What do banks do?" They would most likely tell you that banks take deposits, make loans to businesses and homeowners, issue and process checks, distribute cash, and do other things of that sort. If you gave them a hundred guesses, would they ever utter the words: store aluminum in warehouses,[1] lease a fleet of oil tankers,[2] stockpile uranium,[3] operate coal mines,[4] or own power plants?[5] Probably not, because these activities were traditionally considered "commercial" in nature and not related to banking. Times have changed.

The legal separation of banking and commerce goes back almost a century in the United States and many more centuries in Europe.[6] The idea was first enshrined in U.S. federal banking law by the Glass-Steagall Act of 1933, due to concerns that banks had disproportionate economic power in the period leading up to the stock market crash in 1929.[7] During that era, bankers sat on the boards of companies that accounted for over half of domestic economic production, and allegations of severe conflicts of interest were widespread.[8] Since the passage of the Glass-Steagall Act, however, significant cracks have emerged in the wall that separates banking and commerce, and those cracks are only growing.

In recent years, some regulators and academics have called for weakening the separation, in the belief that it would lead to greater diversification benefits.

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1. David Kocieniewski, *A Shuffle of Aluminum, But to Banks, Pure Gold*, N.Y. TIMES (July 20, 2013), https://www.nytimes.com/2013/07/21/business/a-shuffle-of-aluminum-but-to-banks-pure-gold.html [https://perma.cc/6XGP-E8M6].

2. Gregory Meyer & Neil Hume, *Morgan Stanley in Talks to Sell Oil Tanker Stake*, FIN. TIMES (Jan. 8, 2017), https://www.ft.com/content/1d8d8af0-d436-11e6-9341-7393bb2e1b51 [https://perma.cc/26WJ-WZWN].

3. *Goldman Puts "For Sale" Sign on Iran's Old Uranium Supplier*, REUTERS (Feb. 11, 2014), https://www.reuters.com/article/us-goldman-uranium-insight/goldman-puts-for-sale-sign-on-irans-old-uranium-supplier-idUSBREA1A0RX20140211 [https://perma.cc/4C6D-Y7V9].

4. Christopher Harder, *Goldman Sachs Sells Colombian Coal Mines*, WALL ST. J. (Aug. 14, 2015), https://blogs.wsj.com/moneybeat/2015/08/14/goldman-sachs-sells-colombian-coal-mines-energy-journal [https://perma.cc/NPR4-N73E].

5. *Table – JPMorgan's U.S. Power Plants – FERC*, REUTERS (July 17, 2013), https://www.reuters.com/article/jpmorgan-ferc/table-jpmorgans-u-s-power-plants-ferc-idUSL1N0FN1UY20130717 [https://perma.cc/PJ49-5DH2].

6. *See* John Krainer, *The Separation of Banking and Commerce,* 2000 FRBSF ECON. REV. 15. Krainer points out that "[r]estrictions of the kind found in U.S. banking law have their antecedents in medieval Europe. . . . Early banks in Venice were not permitted to engage in certain import-export activities or trade in commodities such as copper and linens, partly for fear that these activities were too risky and partly for fear that banks would dominate the trade." *Id.* at 16.

7. *See, e.g.*, Mehrsa Baradaran, *Reconsidering the Separation of Banking and Commerce*, 80 GEO. WASH. L. REV. 385, 392 (2012); Peter J. Ferrara, *The Regulatory Separation of Banking from Securities and Commerce in the Modern Financial Marketplace*, 33 ARIZ. L. REV. 583, 585 (1991); Bevis Longstreth, *Glass-Steagall: The Case for Repeal*, 31 N.Y.L. SCH. L. REV. 281, 282 (1986); Arthur E. Wilmarth, Jr., *Wal-Mart and the Separation of Banking and Commerce*, 39 CONN. L. REV. 1539, 1564, 1586 (2007). For a discussion of the history of the Glass-Steagall Act, *see also* Saule T. Omarova, *The Merchants of Wall Street: Banking, Commerce, and Commodities*, 98 MINN. L. REV. 265 (2013); Melanie L. Fein, *Functional Regulation: A Concept for Glass-Steagall Reform?,* 2 STAN. J.L. BUS. & FIN. 89 (1996).

8. Krainer, *supra* note 6, at 16; Miguel Cantillo Simon, *The Rise and Fall of Bank Control in the United States: 1890-1939*, 88 AM. ECON. REV. 1077, 1081-82 (1998).

The basic idea is that if banking organizations were allowed to engage in traditional lending activities as well as commercial activities, they could derive revenue streams from multiple sources that are not as highly correlated. If one revenue stream dried up, the bank organization would still have access to others. In this vein, the head of the Office of the Comptroller of the Currency (OCC), Keith Noreika, remarked in 2017 that the separation of banking and commerce should be reexamined because "it's not the best thing to put all your eggs in one basket."[9] Similarly, Professor Mehrsa Baradaran has argued that reconsidering the separation could lead to a more diversified and less-risk prone financial structure.[10]

Other regulators and academics have called for strengthening the wall that separates banking and commerce, in an effort to decrease the amount of harmful non-traditional activities that slip through the cracks. In 2016, for instance, the Board of Governors of the Federal Reserve System (Federal Reserve) wrote a report to Congress, advocating for legislative changes that would return the financial sector to a world with much stricter separation.[11] In addition, Professor Saule Omarova has argued that, as a present-day policy matter, these non-traditional activities could impair the safety and soundness of the U.S. banking system, affect the fair and efficient flow of credit in the economy, weaken market integrity, and lead to an excessive concentration of economic power.[12] Furthermore, even if these activities do not weaken market integrity and other negative downstream consequences, they still involve greater downside risks than traditional banking activities. Therefore, banking organizations that are explicitly and implicitly insured by the federal government should not imperil taxpayer dollars in that manner.[13]

Up until now, the academic literature has discussed these matters in mostly theoretical terms and has not focused on estimating the cost to businesses and consumers.[14] The main reason is simply that these non-traditional activities remain relatively hidden.[15] This lack of transparency is not new. In a 1994 survey article addressing the general public policy issues surrounding the separation of

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9. Lalita Clozel, *OCC to Take First Step Toward Rolling Bank Volcker Rule*, AM. BANKER (July 19, 2017), https://www.americanbanker.com/news/occ-to-take-first-step-toward-rolling-back-volcker-rule [https://perma.cc/DUL9-UYW6]; *see also* Peter J. Wallison, *Why Are We Still Separating Banking and Commerce?*, AM. BANKER (July 27, 2017), https://www.americanbanker.com/opinion/why-are-we-still-separating-banking-and-commerce [https://perma.cc/ZTD7-5JCC].

10. Baradaran, *supra* note 7, at 402.

11. BD. GOVERNORS FED. RSRV. SYS., FED. DEPOSIT INS. CORP. & OFF. COMPTROLLER CURRENCY, REPORT TO THE CONGRESS AND THE FINANCIAL STABILITY OVERSIGHT COUNCIL PURSUANT TO SECTION 620 OF THE DODD-FRANK ACT (Sept. 2016), https://www.federalreserve.gov/newsevents/pressreleases/files/bcreg20160908a1.pdf [https://perma.cc/AS3M-9QEM] [hereinafter Section 620 Report].

12. Omarova, *supra* note 7, at 275.

13. Banking organizations are explicitly insured via federal deposit insurance. Some banking organizations, particularly the larger ones that engage in these non-traditional activities, are implicitly insured by the government because the market deems them to be "too big to fail." Thus, market participants are willing to lend them money at rates that do not reflect the true risk of their business models.

14. For a selection, see sources cited *supra* note 7.

15. Omarova, *supra* note 7, at 293.

banking and commerce, Professor Anthony Saunders lamented that "in many cases evaluation of these issues is hindered by the absence of empirical evidence either from the U.S. or overseas."[16] The handful of empirical studies published on this topic—all written in the 1980s and 1990s, prior to the passage of the Gramm-Leach-Bliley Act in 1999—heavily favored one side of the debate and argued that the separation of banking and commerce was unnecessary[17] or was harmful, because it prevented banks from diversifying their risks.[18]

In this Article, we attempt to shed light on the other side of the debate: the existence and magnitude of weakened market integrity as well as harm to consumers that arise from banking organizations pursuing non-traditional activities in the post-Gramm-Leach-Bliley world. Specifically, we employ well-known econometric techniques, difference-in-differences regressions, to examine the market pricing and consumer welfare consequences of an episode in the U.S. commodities market following the 2008-2009 financial crisis, when financial institutions sought to take advantage of relatively depressed commodity prices by amassing unprecedented aluminum inventories.

The manipulation of aluminum inventories is an informative case study for the debate on the separation between banking and commerce. First, it adds a dimension that has been lacking in the empirical literature—namely, estimating the scale of weakened market integrity and showing harm to industrial producers and household consumers. Second, to the extent that banking organizations veer away from traditional banking activities like deposit-taking, lending, and related financial activities, it is frequently to pursue profit opportunities in the commodities realm. Instead of the "separation of banking and commerce," one could be forgiven for mistaking it as the "separation of banking and commodities."[19] Third, aluminum is one of the most actively traded commodities in the world—on financial exchanges, for private institutions, and between countries. It also is widely used in the industrial production process; one can find aluminum in beverage cans, automobiles, and airplanes. In fact, aluminum is the

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16.   Anthony Saunders, *Banking and Commerce: An Overview of the Public Policy Issues*, 18 J. BANK & FIN. 231, 231 (1994).

17.   *See* Randall S. Kroszner & Raghuram G. Rajan, *Is the Glass-Steagall Act Justified? A Study of the U.S. Experience with Universal Banking Before 1933*, 84 AM. ECON. REV. 810, 829 (1994) (arguing that, prior to the Glass-Steagall Act, "[a]llowing commercial and investment banking to take place under one roof did not lead to widespread defrauding of investors"); Manju Puri, *Commercial Banks in Investment Banking Conflict of Interest or Certification Role?*, 40 J. FIN. ECON. 373 (1996).

18.   *See* Anthony Saunders & Pierre Yourougou, *Are Banks Special? The Separation of Banking from Commerce and Interest Rate Risk*, 42 J. ECON. & BUS. 171, 171 (arguing that "eliminating the separation of banking from commerce would produce a banking system that is less sensitive to interest rate risk"). *But see* Michael J. Isimbabi, *The Stock Market Perception of Industry Risk and the Separation of Banking and Commerce*, 18 J. BANK & FIN. 325, 325 (1994) (finding that the banking system would not become less risky if the separation of banking and commerce were removed).

19.   As described in Part II, *infra*, over the fifteen years following enactment of the Gramm-Leach-Bliley Act, the total aluminum storage by financial institutions increased from essentially zero to well over fifty percent, while storage by industrial users of aluminum fell proportionally. The same trend holds for other commodities.

second most commonly consumed metal on earth, behind only iron.[20] If financial organizations could distort the aluminum market in the United States for *four years*, then all bets are off for the impacts on other commodities.

So, what actually happened? After the 2008-2009 global financial crisis, financial institutions around the world were searching for profits in myriad other markets, as traditional lending-and-borrowing markets had not yet returned to their pre-crisis levels. Financial institutions saw a golden opportunity in commodity markets, which had cratered during the crisis. Global prices of aluminum had fallen 56 percent.[21]

Beginning in 2010 and lasting through 2014, a handful of financial institutions amassed unprecedented levels of aluminum inventories in Detroit warehouses that were approved to hold metal inventories traded on the London Metal Exchange (LME), which is a self-regulated exchange. At one point, the storage warehouses owned by these financial institutions in Detroit held over half of the total U.S. aluminum stock. Over those four years, the queue length—the time it takes to remove metal from a warehouse—in those warehouses increased from a few *days* to nearly two *years*, and the regional price of aluminum (i.e., the Midwest premium) rose *threefold* (Figure 1).[22] Using widely accepted difference-in-differences regression analysis, we first show that the operation conducted by these financial institutions artificially contracted the supply of aluminum in the U.S. regional market and caused the abnormal increase in the Midwest premium—a market distortion with negative consequences for downstream producers and consumers.

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20.   According to the U.S. Geological Survey, "[m]easured either in quantity or value, aluminum's use exceeds that of any other metal except iron, and it is important in virtually all segments of the world economy." *Aluminum Statistics and Information*, U.S. GEOLOGICAL SURV. (July 2021), https://www.usgs.gov/centers/nmic/aluminum-statistics-and-information [https://perma.cc/SM42-TH9Z].

21.   *Global Price of Aluminum (PALUMUSDM)*, FED. RSRV. ECON. DATA, https://fred.stlouisfed.org/series/PALUMUSDM [https://perma.cc/7ZWT-FFH2].

22.   As described in more detail in Part II, *infra*, the Midwest premium measures the difference between the transaction prices paid by aluminum market participants and the aluminum cash settlement price on the LME. This premium exists because commodity markets, unlike equity markets, involve physical goods. Physical goods in one regional market cannot be immediately and freely dispatched to other regional markets. When purchasers take delivery of a commodity, they must pay for transportation, and possibly storage, as the commodity is moved from an LME warehouse to the purchaser's storage facility. The Midwest premium, therefore, reflects the cost of transporting aluminum out of LME warehouses as well as the variation in regional supply and demand for aluminum.

Figure 1: U.S. Aluminum Price (Midwest Premium)[23]
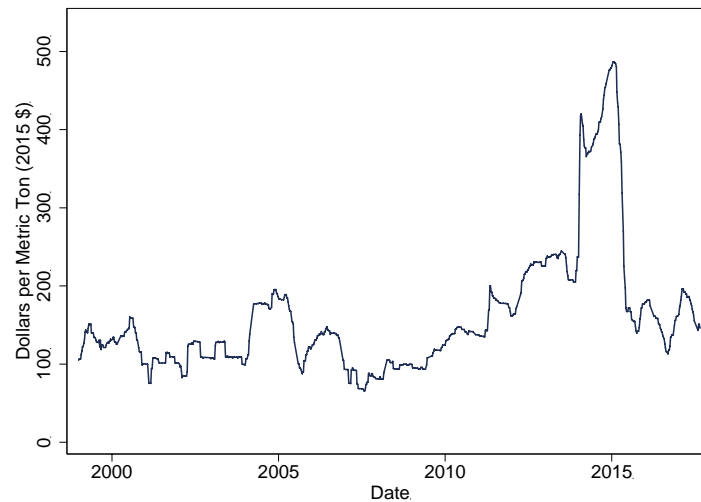
After presenting the factual background in Parts I and II and describing the findings of the empirical analysis in Part III, the Article outlines potential options that might prevent similar market distortions from occurring in the future in Part IV—one set of recommendations for banking organizations within the perimeter of the banking-and-commerce legal framework and another set of recommendations of non-bank financial institutions outside of the perimeter.

The first set of options aims to prevent the sort of commodity market distortions caused by banking organizations, which are illustrated by this Article. These recommendations specifically target U.S. banking law: repealing section 4(o) of the Bank Holding Company Act,[24] which is a loophole created by the Gramm-Leach-Bliley Act; recalibrating the maximum periods allowed for banking organizations to hold "merchant banking investments,"[25] that is, investments in non-financial companies and products; and regulating the volume of these non-traditional activities.[26] To be sure, the recommended changes would

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23. S&P Global Platts (retrieved from Bloomberg).

24. 12 U.S.C. § 1843(o) (2018). As described in further detail in Section IV.A, *infra*, the Bank Holding Company Act of 1956 provides the overarching framework to regulate banking organizations that sought to own both banks and non-banks. Section 4(o) is effectively a grandfather provision that allows a company—one that was *not* a bank holding company prior to November 12, 1999—to continue engaging in activities related to the trading, sale, or investment in commodities that were not permissible for bank holding companies as of September 30, 1997. The only beneficiaries of this section 4(o) loophole in the entire United States financial ecosystem of hundreds of bank holding companies are Goldman Sachs and Morgan Stanley.

25. 12 U.S.C. § 1843(k) (2018). The Gramm-Leach-Bliley Act provided the authority to allow qualifying domestic and foreign financial holding companies to make investments in companies engaged in non-financial activities as part of a bona fide securities underwriting or merchant or investment banking activity. Notably, these activities are not permissible for a bank holding company under section 4 of the Bank Holding Company Act.

26. Risk-Based Capital and Other Regulatory Requirements for Activities of Financial Holding Companies Related to Physical Commodities and Risk-Based Capital Requirements for Merchant Banking Investments, 81 Fed. Reg. 67,220, 67,220 (Sept. 30, 2016).

require action from Congress, the U.S. Treasury, or the Federal Reserve (or combinations of these three institutions). If implemented, these changes would bolster the separation between banking and commerce and would make it much more difficult for banking organizations to engage in the activities described previously, such as storing metal in warehouses, selling oil tankers, stockpiling uranium, operating coal mines, etc.

The second set of options aims to prevent general distortions in regional markets, which are characterized by high transaction costs, regardless of whether the market participants are banking organizations or non-banks like hedge funds or private equity funds. One recommendation, relating to regulatory capture, is tailored to situations in which there are extremely clear conflicts of interest between the organization engaging in the commodity operations and the exchange on which the commodities are traded. The next proposal involves a statistical detection algorithm, built using the insights developed in this Article. Having a statistical screen to detect abnormal movements in regional markets would enable agencies like the Commodity Futures Trading Commission (CFTC) to undertake more effective surveillance and enforcement measures; of note, existing detection algorithms would likely have failed to detect the market distortion caused by the unprecedented backlog of delivery from Detroit warehouses.[27] Finally, our insights could be used to more easily prove or disprove two elements of market manipulation—price artificiality and causality—under the Commodity Exchange Act,[28] which may help the CFTC pursue any market participants involved in similar distortionary operations.[29]

Importantly, the clamor to eliminate the general separation between banking and commerce is likely to grow in the coming years and will come from both sides of the divide, as large banks try their hand at providing technology-related products, and large technology firms try their hand at providing financial services. Thus, policymakers should note that eliminating the existing separation

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27.   *See, e.g.*, Craig Pirrong, *Detecting Manipulation in Futures Markets: The Ferruzzi Soybean Episode*, 6 AM. L. & ECON. REV. 28 (2004) (focusing on global instead of regional markets); *cf.* Rosa M. Abrantes-Metz, Gabriel Rauterberg & Andrew Verstein, *Revolution in Manipulation Law: The New CFTC Rules and the Urgent Need for Economic and Empirical Analyses*, 15 J. BUS. L. 357 (2013) (calling for the creation of more econometric screens to detect market anomalies).

28.   7 U.S.C. § 9 (2018).

29.   Further, this Article also empirically illustrates two important principles in law and economics: regulatory capture and transaction costs. First, as detailed in Part I, we argue that quasi-independent financial exchanges are subject to capture by market participants. As the aluminum premium rose after 2010, the LME changed its interpretation of warehousing rules in a way that benefited its board members, like Goldman Sachs and JPMorgan, and hurt industrial aluminum users and consumers. This episode demonstrates that market distortions can occur when financial exchanges are allowed to self-regulate. Second, in Part II, we argue that transaction costs can lead to distortions in regional markets, but that they do not significantly affect the international market. Unlike a purely financial asset, the cost of transferring ownership of a physical commodity, like aluminum, increases with distance between the buyer and seller. These transaction costs allow regional commodity market distortions to persist for years, imposing large costs on industrial users and consumers, while going relatively unnoticed in the global market. Standard detection algorithms that focus only on aberrations in the spot and future prices of a commodity are therefore unable to alert authorities to distortions in the regional market.

is not simply a theoretical debate. An erosion may have significant costs on markets, businesses, and consumers.

I. Case Study of 2010 to 2014

The wall that separates banking and commerce was constructed a long time ago. Indeed, for most of the twentieth century, federal regulations prohibited financial institutions from trading and storing physical commodities.

The story begins with two statutes passed in 1933 and 1956. The Glass-Steagall Act of 1933 formally introduced the separation between banking and commerce in the United States.[30] The problem was that the Glass-Steagall Act applied only to commercial banks, creating a loophole for bank holding companies.[31] The Bank Holding Company Act of 1956[32] shored up the separation by providing a statutory framework for the supervision and regulation of companies that control an insured depository institution (i.e., a bank holding company). In particular, section 4 of the Bank Holding Company Act closed the loophole by generally prohibiting a bank holding company from acquiring "ownership or control of . . . any company which is not a bank"[33] or engaging "in any activities other than those of banking or of managing or controlling banks and other subsidiaries authorized" under the Act.[34]

The law, however, became more permissive at the close of the century. The Gramm-Leach-Bliley Act of 1999[35] expanded the range of permissible activities and investments for many of the holding companies to include activities that are financial in nature such as (i) securities underwriting and dealing,[36] (ii) insurance underwriting and agency activities,[37] and (iii) merchant banking activities that involve the investment in, and potential ownership of, non-financial companies and products.[38] Within the merchant banking category, the Act permits a financial holding company to make investments, as part of a bona fide underwriting, merchant banking, or investment banking activity, in any type of ownership interest of any non-financial company engaged in an activity not otherwise authorized for a financial holding company under section 4 of the Bank

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30. Pub. L. No. 73-66, 48 Stat. 162.

31. As the name suggests, bank holding companies are parent companies with a bank subsidiary. Bank holding companies can have multiple bank and non-bank subsidiaries.

32. Pub. L. No. 84-511, 70 Stat. 133.

33. 12 U.S.C. § 1843(a)(1) (2018).

34. *Id.* § 1843(a)(2).

35. Pub L. No. 106-102, 113 Stat. 1338.

36. 12 U.S.C. § 1843(k)(4)(E) (2018).

37. *Id.* § 1843(k)(4)(B).

38. *Id.* §§ 1843(k), (o). For a general review of the Act, *see* James R. Barth, R. Dan Brumbaugh Jr. & James A. Wilcox, *Policy Watch: The Repeal of Glass-Steagall and the Advent of Broad Banking*, 14 J. ECON. PERS. 191 (2000).

Holding Company Act.[39] Not surprisingly, cracks in the wall separating banking and commerce began to appear, with significant market ramifications.

The entry of financial institutions transformed physical commodity markets. Prior to the Gramm-Leach-Bliley Act, only minor trading of metals took place on financial exchanges such as the Commodity Exchange (COMEX) and the LME, and less than one percent of total aluminum inventories were held by financiers; almost all aluminum inventories were held by industrial producers.[40] Over the fifteen years following Gramm-Leach-Bliley, and particularly after the 2008-2009 global financial crisis, total aluminum storage by financial institutions increased significantly.[41] The share of metal held through LME and COMEX increased as well—nearly 70 percent was held in LME warehouses alone (Figure 2). As the amount of aluminum traded on financial markets grew, that activity began to have a large effect on physical aluminum markets.

Figure 2: U.S. Aluminum Inventories (Producer and LME)[42]
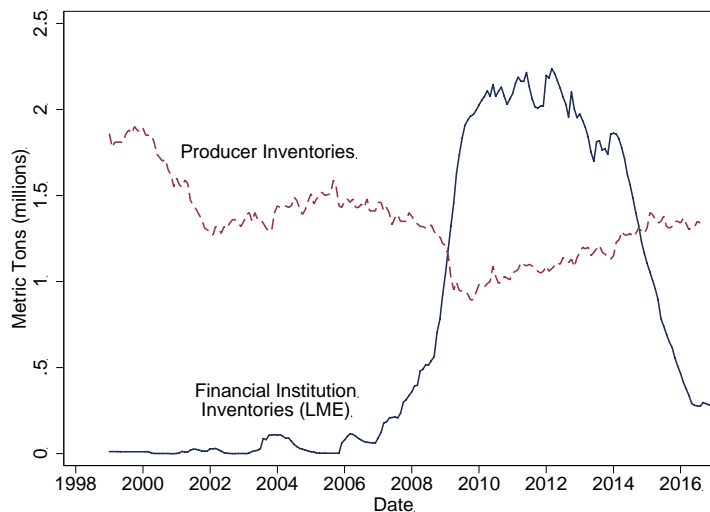
In February 2010, Goldman Sachs purchased Metro International Trade Services, a warehouse operator that specialized in storing metals for LME in Europe and North America.[43] At the time, the purchase was described as a

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39.   12 U.S.C. § 1843(k)(4)(H). As discussed below, there are limitations on merchant banking investments. First, merchant banking investments are subject to a 10-year general holding period. Second, financial holding companies are prohibited from routinely managing or operating a portfolio company.

40.   *See infra* Figure 2.

41.   *See id.*

42.   Financial Institution Inventories, London Metal Exchange (retrieved from Bloomberg); *Aluminum Statistics,* in *Historical Statistics for Mineral and Material Commodities in the United States,* U.S. GEOLOGICAL SURV. (2018), https://www.usgs.gov/centers/nmic/historical-statistics-mineral-and-ma terial-commodities-united-states.

43.   *See Wall Street Bank Involvement with Physical Commodities: Hearings Before the Subcomm. on Investigations of the S. Comm. on Homeland Sec. & Gov't Affairs,* 113th Cong. (2014). The

countercyclical investment in the sluggish commodities industry.[44] In plain English, the decision to pour capital into commodity markets was intended to take advantage of low commodity prices in the aftermath of the 2008-2009 financial crisis and hedge risk in other markets.

But after Goldman purchased Metro International, it aggressively solicited metal for its warehouses by offering steep discounts to metal owners. Goldman paid hundreds of millions of dollars in "freight incentives" (rebates) to attract aluminum to its warehouses. The incentives were so large and attracted so much aluminum that the amount of aluminum in the Detroit warehouses quickly surpassed the amount held by aluminum producers in the rest of the United States combined.[45] Though there were other warehouses in Detroit, Goldman's were the largest and they held almost all the aluminum in Detroit. By 2014, over 80 percent of U.S. inventories on the LME were held in Detroit (Figure 3)—harkening to the critics who assert that weakening the separation of banking and commerce could lead to excessive concentration of economic power. During this time, Goldman also increased its own physical aluminum investments from under $100 million in 2009 to over $3 billion in 2012.[46]
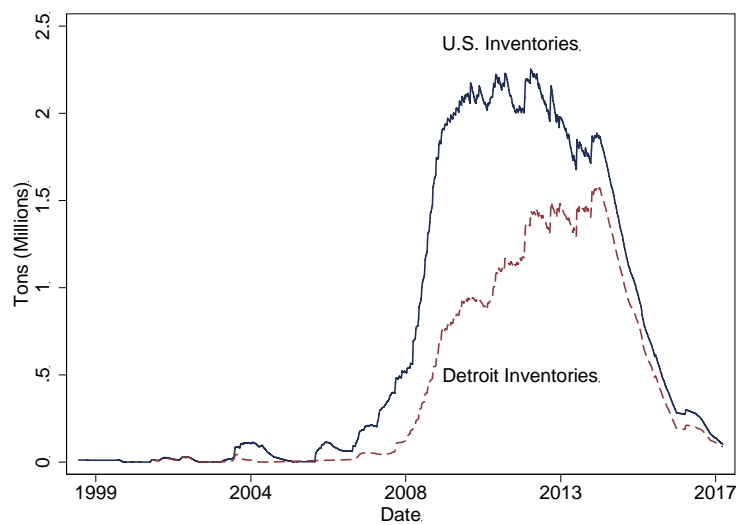
majority and minority staff report was released in conjunction with the hearing. *See* MAJORITY AND MINORITY STAFF OF THE SUBCOMM. ON INVESTIGATIONS OF THE S. COMM. ON HOMELAND SEC. & GOV'T AFFAIRS, 113TH CONG., WALL STREET BANK INVOLVEMENT WITH PHYSICAL COMMODITIES, (Dec. 15, 2014), https://www.hsgac.senate.gov/imo/media/doc/REPORT-Wall%20Street%20Bank%20Involveme nt%20With%20Physical%20Commodities%20(12-5-14).pdf [https://perma.cc/KK8N-FZLQ] [hereinafter Staff Report].

44. *See* Vincent Fernando, *Goldman Sachs and JP Morgan Storage Investments Signal a Commodities Slump*, BUS. INSIDER (Mar. 3, 2010), https://www.businessinsider.com.au/broker-storage-investments-2010-3 [https://perma.cc/3CMS-JRAF].

45. *See* Staff Report, *supra* note 43, at 169 ("At one point in 2012, Goldman owned about 1.5 million metric tons of aluminum."). The U.S. Geological Survey reported that year-end aluminum producer stocks were 1.1 million metric tons in 2012. *See 2013 Minerals Yearbook: Aluminum [Advance Release]*, U.S. GEOLOGICAL SURV. 5.10 tbl.1 (Jan. 2015), https://s3-us-west-2.amazonaws.com/prd-wret/ assets/palladium/production/mineral-pubs/aluminum/myb1-2013-alumi.pdf [https://perma.cc/3EPY-K5 6A].

46. Staff Report, *supra* note 43, at 169.

Figure 3: U.S. and Detroit Aluminum Inventories[47]

As its warehouse inventory grew, Goldman paid a few large clients[48]—holding companies like Deutsche Bank and JPMorgan, and commodity trading firms like Glencore and Red Kite—to transfer their aluminum between Goldman's Detroit warehouses in order to artificially increase the warehouses' queue length (that is, the time it takes to remove metal from the warehouse). The transfer process involved three steps.[49] First, the client would cancel the warrants on their aluminum, which notified the LME that their metal was no longer available for trading. Metal available for trading is referred to as "on-warrant." Second, the cancelled-warrant aluminum would join the queue, thereby awaiting load out from the warehouse. The enormous amount of cancelled-warrant orders far exceeded the daily load-outs, so the queue grew in length. Third, after taking delivery of their metal, the clients would complete the transfer process by placing their aluminum on-warrant in another one of Goldman's Detroit warehouses and restarting the process—that is, canceling that warrant again and reentering the queue.[50] Rinse and repeat. These large clients benefited from this scheme by receiving compensation from Goldman, and Goldman benefited because the long queues gave Goldman control over an enormous aluminum inventory. The queue length in Goldman's Detroit warehouses increased from a few days to *nearly two*

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47.   Aluminum Inventories, London Metal Exchange (retrieved from Bloomberg). The U.S. inventory series includes the Detroit inventory series.
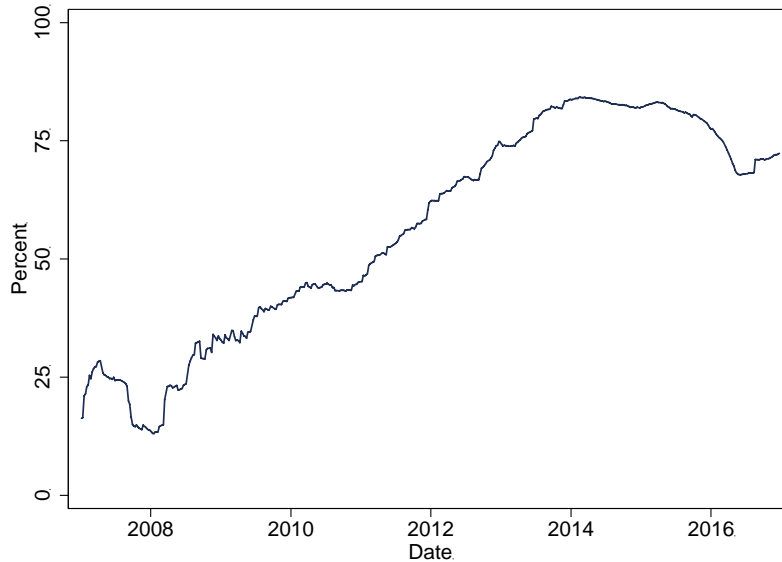
48.   Staff Report, *supra* note 43, at 194.

49.   Kocieniewski, *supra* note 1; *see also* Staff Report, *supra* note 43, at 191-94.

50.   Staff Report, *supra* note 43, at 194-95.

years.[51] With such a long queue length, the aluminum stored in the Detroit warehouses was effectively removed from the market.[52]

Figure 4: Share of Total U.S. LME Aluminum Inventory in Detroit[53]

Goldman increased the queue length by exploiting the load-out requirements for LME warehouses. The self-regulated LME required warehouse owners to load out a minimum of 1,500 tons of aluminum per day.[54] Goldman used its position as a board member on the LME's Warehouse Committee to change the interpretation of that LME rule.[55] The minimum load-out had traditionally been applied to each *individual* warehouse. But after 2010, this requirement was applied at the *city level* for each warehouse owner. This meant that a warehouse owner needed to load out only a total of 1,500 tons each day across all of its warehouses in a given city, like Detroit, to meet the requirement. Information uncovered during the Senate investigation of Goldman's involvement in physical commodity markets suggests that its Detroit warehouses did not exceed the minimum required load-out rate.[56] In other words, Goldman set the maximum load-out rate at the minimum required level.

As the backlog worsened, LME attempted to reduce the queue length at the Detroit warehouses, but with little success. In April 2012, LME increased the

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51. Staff Report, *supra* note 43, at 169.
52. *See id.* at 195 ("The net impact for Metro was that, each day in which the front of the queue was occupied by a metal owner executing a merry-go-round deal, its warehouses lost virtually no metal.").
53. Aluminum Inventories, London Metal Exchange (retrieved from Bloomberg).
54. Staff Report, *supra* note 43, at 191.
55. *See id.* at 192 ("Goldman and Metro's use of the LME load-out rate as a maximum rather than minimum load-out rate has been targeted as an abusive practice in over a dozen class action suits.").
56. *Id*.

minimum load-out rate to as much as 3,000 tons per day in response to complaints about queue lengths at the Detroit warehouses.[57] That action, however, only partly lessened the problem because the load-out constraint was still so tight. Loosening the constraint would have required a much greater increase in the minimum load-out rate. In November 2013, LME adopted a rule that would have cut queues by requiring warehouses to load out metal as quickly they load it in.[58] The new rule, interestingly enough, was challenged in court by warehouse owners and was not implemented until February 2015.[59]

Thus, by restricting the flow of aluminum out of their warehouses, Goldman prevented LME participants from immediately selling their metal on the market or using it themselves. In economic terms, Goldman artificially created contractionary supply shocks in the aluminum market.

Goldman had multiple ways to profit off this scheme, even though it paid significant sums of money to store the aluminum.[60] First, Goldman made money because customers paid rent while waiting in line to withdraw their metal. Second, and most importantly, Goldman entered into derivative contracts that required aluminum owners to pay Goldman when the Midwest premium rose.[61] This meant that Goldman directly profited as queues at the Detroit warehouses caused the Midwest premium to rise. Although we do not have access to specific aluminum derivative positions, we can see from publicly available Y-9C data on holding companies that Goldman's transactions in over-the-counter written option contracts for commodities averaged over $90 billion per quarter from 2010 through 2014.[62] Since 2015, that average has dropped to slightly over $50 billion per quarter. We see a similar story in exchange-traded commodities option contracts. Goldman had an average of $86.6 billion in exchange-traded written option contracts per quarter from 2009 to 2010. That quarterly average increased to over $140 billion during 2014. This jump was not caused merely by a rebound from the financial crisis. In 2015, Goldman's exchange-traded written option contracts for commodities fell back to its former level. Since the last quarter of 2015, Goldman's transactions in exchange-traded option contracts

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57.   Pratima Desai, Clare Baldwin, Susan Thomas & Melanie Burton, *Goldman's New Money Machine: Warehouses*, REUTERS (July 29, 2011), https://www.reuters.com/article/us-lme-warehousing/goldmans-new-money-machine-warehouses-idUSTRE76R3YZ20110729 [https://perma.cc/7XXF-X253].

58.   Staff Report, *supra* note 43, at 191.

59.   *Id.*

60.   In certain schemes, the actor engages in seemingly "uneconomic behavior" at first in order to derive substantial profits later. See, for example, cases that involve "banging the close," which is defined as "[a] manipulative or disruptive trading practice whereby a trader buys or sells a large number of futures contracts during the closing period of a futures contract (that is, the period during which the futures settlement price is determined) in order to benefit an even larger position in an option, swap, or other derivative that is cash settled based on the futures settlement price on that day." *CFTC Glossary*, CFTC, https://www.cftc.gov/ConsumerProtection/EducationCenter/CFTCGlossary/glossary_b.html [https://perma.cc/9R8W-7RWA].

61.   Desai, Baldwin, Thomas & Burton, *supra* note 57.

62.   *See Holding Company Data*, FED. RSRV. BANK OF CHI., https://www.chicagofed.org/banking/financial-institution-reports/bhc-data.

have averaged $80 billion per quarter, which is in line with its average before the aluminum scheme began. [63]

To be sure, although Goldman was the financial institution that enabled this aluminum market distortion, it was not the only one to have participated in, or profited from, the market distortion. Other firms were involved in Goldman's "merry-go-round" scheme as well.[64]

This merry-go-round of metal caused the queue length to peak at nearly two years.[65] If an aluminum user purchased aluminum in the LME spot market in April 2014 and immediately filed the paperwork to remove the aluminum, that purchaser would not take physical possession of the metal until March 2016. The growing queue made LME inventories essentially inaccessible to aluminum users, which allowed aluminum producers to raise prices knowing that their customers no longer had a nearby supplier of last resort. Without a supply backstop, the Midwest aluminum premium more than tripled between 2010 and 2014, as shown in Figure 1.

One might wonder why aluminum users did not bypass the scheme. Why wouldn't an adversely affected industrial user just pay Goldman to skip the queue? The answer is that a payment for preferential treatment would have violated LME warehouse rules, exposing both parties to litigation from other metal owners in the queue.[66] Relatedly, one might wonder why aluminum users did not try to obtain aluminum inventories from another city, like Baltimore, instead of waiting for delivery from Goldman's Detroit warehouses. The answer is simple. By 2014, when the Midwest premium had spiked to its highest level, the vast majority of U.S. aluminum inventories were trapped in Detroit. It would have been difficult to obtain aluminum from somewhere else.

This case study exposes the shortcomings of LME's self-regulation. Its members interpreted warehousing rules to their benefit, stalled for years on providing relief to aluminum owners, and faced no consequences in the aftermath of the scheme. LME was unable to prevent this market distortion. If anything, LME's self-regulatory design made this scheme possible in the first place. The need for public supervision and regulation is clear. In the next Part, we address a question fundamental to this need: how can market regulators detect such schemes in the future?

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63. *Id.*

64. Staff Report, *supra* note 43, at 194.

65. Agnieszka de Sousa, *Detroit Aluminum Pile that Rattled Beer Makers Is Vanishing*, BLOOMBERG (May 22, 2016), https://www.bloomberg.com/news/articles/2016-05-22/detroit-s-aluminum -pile-that-rattled-beer-makers-is-vanishing [https://perma.cc/E8Q2-JWZM]; *see also* Staff Report, *supra* note 43, at 193.

66. Per the LME, a queue refers to "circumstances where load-out requests cannot be serviced immediately by a Warehouse, measured by the number of calendar days a metal owner cancelling a Warrant today must wait for a scheduled delivery slot." *Decision Notice on Amendments to the LME Warehouse Agreement in Respect of Charge-Capping*, LONDON METAL EXCH. (Sept. 28, 2016), https://www.lme.com/en/Physical-services/Warehousing/LME-warehouse-reform-2013-to-2016 [https:// perma.cc/DT32-BBTR]. An owner must wait if the load-out-request cannot be completed immediately. There is no option for side payments. *See id.*

II. The Regional Aluminum Market

To understand why existing methods failed to detect the market distortion caused by the unprecedented backlog of delivery from Detroit warehouses, one must understand how *regional* markets work. Our discussion begins with the U.S. regional price of aluminum, known as the Midwest premium. The Midwest premium measures the difference between the transaction prices paid by aluminum market participants and the aluminum cash settlement price on the LME.[67] This premium exists because commodity markets, unlike equity markets, involve physical goods, which cannot be immediately and freely dispatched from one regional market to other regional markets. When purchasers take delivery of a commodity, they must pay for transportation, and possibly storage, as the commodity is moved from an LME warehouse to the purchaser's storage facility.[68] The Midwest premium therefore reflects the cost of transporting aluminum out of LME warehouses as well as the variation in regional supply and demand for aluminum.[69]

The Midwest premium is constructed using a survey by S&P Global Platts of aluminum bids, offers, and transaction prices for delivery within a given month.[70] Similar regional premiums exist for all metals traded on the LME.[71] These metal premiums reflect regional determinants of price, because global factors that determine price are excluded from the premium.

Existing detection mechanisms detailed in the academic literature do not flag abnormalities in regional markets for two reasons. First, they do not focus on identifying aberrations in regional markets. Instead, most focus primarily on global spot and futures prices.[72] Global spot and futures prices are not necessarily tied to regional premiums in the short run. Second, existing detection mechanisms simply ignore transaction costs that are key factors in regional markets. A regional premium for a commodity could rise while spot and futures prices fall if, for example, high transportation costs prevent the commodity from flowing into the region.

Turning our attention to the global aluminum market, we can easily see why measurable indicators did not appear suspicious to existing algorithms. First, commodity markets crashed during the 2008-2009 global financial crisis, so metal prices on a global scale were already very low. Second, the spot and futures prices of aluminum trended *downward* between 2010 and 2014. There were no

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67.   *What Is the Aluminum Transaction Price?*, S&P GLOBAL PLATTS, https://www.spglobal
.com/platts/en/our-methodology/price-assessments/metals/us-aluminum-transaction [https://perma.cc/R9
5A-EQZL]; *see also* Staff Report, *supra* note 43, at 171-72.

68.   Staff Report, *supra* note 43, at 179.

69.   *Id.* at 171-72.

70.   *Id.* at 172.

71.   *Specifications Guide: Global Nonferrous Metals*, S&P GLOBAL PLATTS (Aug. 2021), https://
www.spglobal.com/platts/en/our-methodology/methodology-specifications/metals/nonferrous-
methodology [https://perma.cc/M5KT-LMT4].

72.   Pirrong, *supra* note 27.

sharp breaks similar to the breaks in the Midwest premium. The downward trend was caused by growing global supply and weakening global demand.

On the supply side, global aluminum production did not diverge from its long-term trend during this period. In fact, global production grew at an increasing rate, while production in North America was essentially flat (Figure 5a). The anti-dumping case that the United States brought against China in 2010 suggests that the U.S. aluminum market was not particularly tight when Goldman's scheme began.[73] Evidently, the U.S. aluminum market had enough supply to warrant an anti-dumping complaint. On the demand side, global real economic activity in industrial commodity markets—a measure of global commodity demand—trended downward from 2010 to 2014 after bouncing back from historic lows in 2008 and 2009 (Figure 5b). This decline in commodity demand was likely driven by weakening Chinese consumption.[74] Therefore, regulators would not have detected any abnormalities in the aluminum market by focusing solely on global supply and demand shocks.

Figure 5: Global Aluminum Market

(a) Primary Aluminum Production[75]

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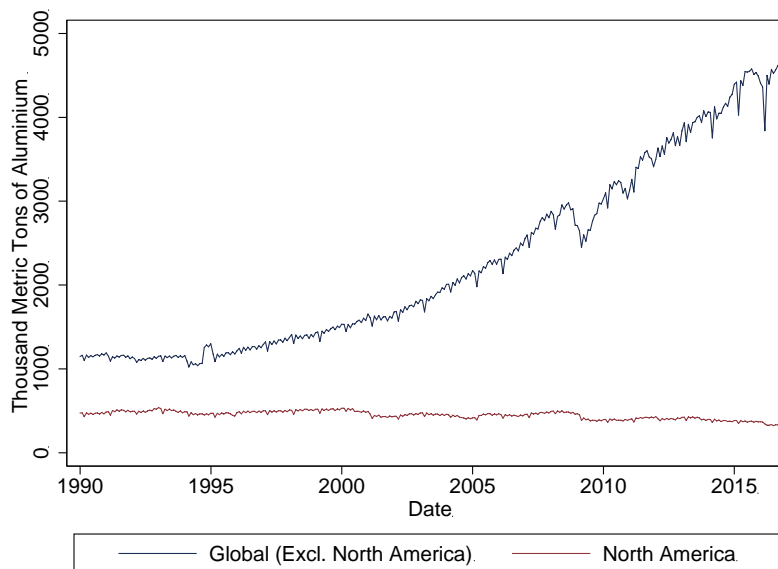
73. Aluminum Extrusions from the People's Republic of China: Initiation of Antidumping Duty Investigation, 75 Fed. Reg. 22,109 (Apr. 27, 2010).

74. See World Bank data for an indication of slowing Chinese consumption (not production) growth. *GDP Growth (Annual %) – China*, WORLD BANK (2020), https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG?locations=CN [https://perma.cc/GJ9G-6ZW7].

75. *Primary Aluminum Production*, INT'L ALUMINUM INST., https://international-aluminium.org/statistics/primary-aluminium-production/ [https://perma.cc/EUG3-KBTL].

(b) Economic Activity in Commodity Markets[76]
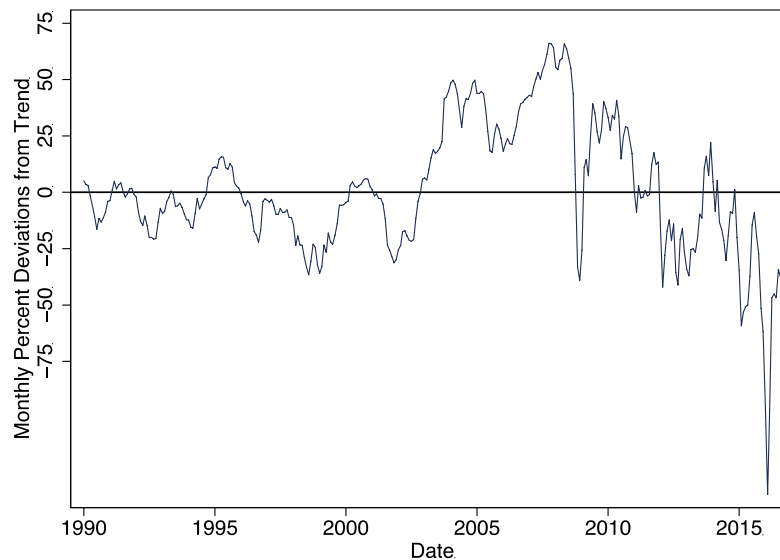
Due to the lack of global supply and demand shocks, regulators would not have detected any regional market distortion by analyzing only the spot and futures markets for aluminum. From 2011 to 2014, the aluminum spot price and the aluminum futures price fell along with the spot and futures price of the metal's main production complement, copper (Figure 6). Regulators would not have noticed anything odd by comparing global spot and futures prices across related commodities. Additionally, aluminum and copper prices rose in 2010, partially recovering from the trough reached during the Great Recession. This post-recession increase occurred in the early 2000s as well, following the 2001 recession. It is not surprising that commodity prices reverted back to their pre-recession levels.

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76.   *Kilian Index*, LUTZ KILIAN, https://sites.google.com/site/lkilian2019/research/data-sets; *see* Lutz Kilian, *Not All Oil Price Shocks Are Alike: Disentangling Demand and Supply Shocks in the Crude Oil Market*, 99 AM. ECON. REV. 1053 (2009).

Figure 6: LME Spot and Futures Prices[77]
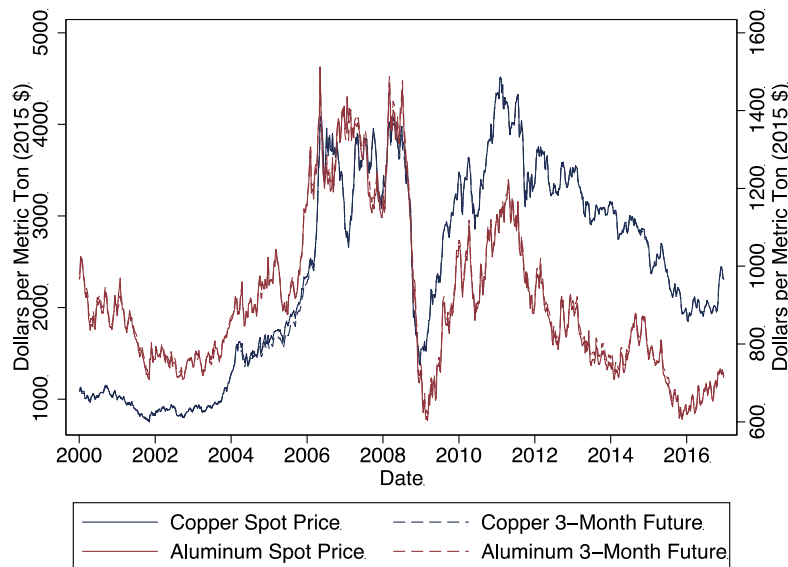
In past cases of alleged market distortions—for example, silver in 1980 and soybeans in 1989—regional premiums were unaffected, so it was sufficient to monitor only spot and futures prices.[78] The 2010-2014 aluminum scheme was successful because regulators did not monitor regional commodity markets as closely as they monitored the LME. The regional metals market slipped through the cracks.

III. Empirical Analysis of the Market Distortion

Parts II and III provided background on the U.S. aluminum market as well as financial institutions' involvement in that market from 2010 to 2014. With the set-up complete, we now pivot to the empirical analysis of our Article. In this Part, we use difference-in-differences regressions to demonstrate that the market distortion was caused by certain banking organizations and that the distortion harmed businesses and consumers. At a high level, in order to conduct a difference-in-differences regression analysis—one with causal inference—we need two time periods (before and after) and two groups (control and treatment).[79] The before and after comparison is simple, marked by the start of the rapid accumulation of aluminum inventory in 2010. The designation of the

77.   Copper and Aluminum Spot and Futures Prices, London Metal Exchange (retrieved from Bloomberg).

78.   *See* Scott Barnhart, Kandice Kahl & Cora Barnhart, *An Empirical Analysis of the Alleged Manipulation Attempt and Forced Liquidation of the July 1989 Soybean Futures Contract*, 16 J. FUTURES MKT. 781 (1996); Pirrong, *supra* note 27.

79.   *See* Marianne Bertrand, Esther Duflo & Sendhil Mullainathan, *How Much Should We Trust Differences-In-Differences Estimates?*, 119 Q. J. ECON. 249 (2004).

treatment group also is straightforward. It is the commodity that was targeted in the Detroit operation: aluminum. The challenge is to construct a control group that serves as the counterfactual. Having a credible control group allows us to answer the "what if" questions, such as: "What if the increase in the regional price was simply due to a natural increase in demand?" This is why we develop the concept of complementary commodities in Section III.A and identify strong complementary commodities in Section III.B. Using complementary commodities as the control group, we perform the difference-in-differences regression analysis in Section III.C. Finally, we conclude this empirical discussion in Section III.D with an assessment of the harm to industrial producers and household consumers.

A. Complementary Commodities

Based on the previous discussion, we know that regional markets require separate attention from regulators. It is not sufficient to scan for divergences in the global spot and futures prices of a commodity; regulators must separately investigate the regional price. But this is not the only adjustment that regulators need to make to their analysis. They also must compare the regional price of the target commodity to the regional price of its complementary commodities. If the regional price of aluminum increases, it could be due to either an *artificial* distortion or to *natural* shifts in regional supply and demand. By comparing the regional price of aluminum with the regional price of a commodity that is similarly affected by regional supply and demand, we can be more confident that the regional price spike is due to artificial shocks.

To qualify as complements, two commodities must react similarly if affected by the same market shock. For example, if the market demand for commodity x increases, then the demand for the complement of commodity x should also increase. In an ideal world, the demand shock would affect the two commodities in an identical manner, in both sign and magnitude. In the real world, however, regulators might have to live with spillover effects—a one-unit demand increase to commodity x results in less than a one-unit increase to its complement. This implies that the proposed method of comparing complementary commodities will be more effective if the complementary relationship is stronger.

As a highly stylized example, suppose peanut butter and jelly are always consumed together and suppose further that market investors expect a significant shortfall in next year's peanut harvest. Market investors should therefore expect a reduced supply of peanut butter next year and a higher price of peanut butter. In turn, market investors also should expect a dip in the price of jelly next year (assuming the supply of jelly were unchanged) due to reduced demand of jelly, because consumers would be making fewer peanut butter and jelly sandwiches. In other words, due to the complementary nature of peanut butter and jelly, a

natural decrease in supply of peanut butter should translate into a decrease in the price of jelly, all else equal.[80]

An artificial price—one that is not the result of natural changes in supply and demand—would therefore materialize if there is a sustained deviation between peanut butter prices and jelly prices that is inconsistent with the expected elasticity. For example, if the price of peanut butter suddenly increased threefold and the price of jelly remained flat, the price of peanut butter would be artificially high, assuming no idiosyncratic demand or supply shocks to jelly. (If the reader disapproves of this example due to preferences over peanut butter and jelly sandwiches, please consider left shoes and right shoes instead. The logic is the same.)

Market supervisors at agencies like the CFTC have several resources to identify complements and their expected co-movement behavior. They can look at elasticities provided by industry sources, academic studies, or government institutions like the United States Department of Agriculture. Supervisors also can use their own economic "demand model," like the one provided in Appendix C, or a more advanced model from the academic literature.[81]

B. Identifying Complements

Obtaining the best complement(s) for our empirical analysis requires digging into the details of the aluminum market. Aluminum is the second most commonly consumed metal on earth, behind only iron.[82] (An immediate implication is that the downstream impact of a distorted aluminum market on industrial producers and household consumers is not trivial.) Aluminum is rarely consumed in its pure form.[83] It is almost always alloyed—combined with other metals—to achieve the desired conductivity, density, strength, and corrosion resistance. The properties of aluminum alloys depend on the metals used, and aluminum industry guidelines mandate that each alloy include specific proportions of the component metals. The metals cannot be substituted without changing the properties of the alloy. This strict industry regulation of alloys

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80. For a highly stylized example going the opposite direction and involving pasta and pasta sauce, see *Complementary Goods*, EZY EDUCATION, https://www.ezyeducation.co.uk/ezyeconomics details/ezylexicon-economic-glossary/519-complementary-goods.html [https://perma.cc/U22K-UCC9] ("[A]n increase in supply of pasta leads to a fall in the price due to excess supply. If the price of pasta falls . . . this will also cause the demand for pasta sauce to increase as they are complementary goods."). In our peanut butter and jelly example, a decrease in the supply of peanut butter causes the demand for jelly to fall.

81. For a review of the literature on empirical models of consumer demand, see Aviv Nevo, *Empirical Models of Consumer Behavior*, 3 ANN. REV. ECON. 51 (2011).

82. *Aluminum Statistics and Information*, *supra* note 20.

83. *International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys*, ALUMINUM ASS'N (Aug. 2018), https://www.aluminum.org/sites/default /files/Teal%20Sheet.pdf [https://perma.cc/9US8-7B5U]; *see also* ALLOYING: UNDERSTANDING THE BASICS (J.R. Davis & Assocs. ed., 2013) (noting that even "pure" aluminum is not 100 percent aluminum, as it is either alloyed or has impurities).

enables aluminum users to purchase alloys from any producer, knowing that the alloy composition and properties are consistent.[84]

The metals that are combined with aluminum to produce alloys form an ideal control group for a standard difference-in-differences analysis.[85] In particular, copper, nickel, and zinc are used in aluminum alloys. Copper is the most common aluminum alloying element and is our primary metal of interest. Aluminum-copper alloys contain between 3 and 14 percent copper, and copper is also added in smaller amounts to other common alloys, including aluminum-silicon alloys (up to 5 percent copper) and aluminum-zinc alloys (up to 2.4 percent copper).[86] Nickel and zinc also are regularly added to aluminum alloys, and the U.S. premiums of those metals are included in robustness checks.[87]

In addition to using standard industry sources to search for complementarity, our own analysis confirms that copper, nickel, and zinc are complements of aluminum. We estimate the uncompensated demand elasticities using a linear-approximate-almost-ideal demand system. The results, detailed in Appendix C, show that aluminum and copper are net complements. Specifically, the cross-price elasticity of aluminum and copper (-0.29) is only somewhat smaller than the own-price aluminum elasticity (-0.33). The aluminum-nickel and aluminum-zinc cross-price elasticities (-0.11 and -0.01, respectively) are smaller, suggesting that the relationship between demand for these metals and aluminum is not as strong as the aluminum-copper relationship.

Figure 7 plots the Midwest premiums for aluminum and copper between November 1999 and December 2015. They are based on actual transaction prices in the physical metal spot markets. Prior to Goldman's purchase of aluminum warehouses in Detroit, the two premiums followed a parallel trend, as would be expected from production complements. Between 2000 and 2009, the average spread between the copper and aluminum premiums was only $0.02 per pound.

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84. The aluminum industry has a public register of all alloys. *E.g.*, *Understanding Alloys: Advancing Aluminum*, ALUMINUM ASS'N (2021), https://www.aluminum.org/understanding-alloys-adva ncing-aluminum [https://perma.cc/ZD26-UCZF] ("In order to make further advancements in these markets, new alloys, many of which are variations of earlier alloys, are being registered every year. The Aluminum Association, in collaboration with its membership, manages this process as an ANSI-accredited standards-setting body.").

85. A difference-in-differences model uses a control group (e.g., the regional premiums of metals regularly added to aluminum alloys) to estimate the effect of a treatment (e.g., the purchase of the Metro International warehouses) on an outcome variable (e.g., the Midwest aluminum premium). The key identifying assumption of this model is that the regional price of aluminum would have followed a similar trend to the regional prices of complement metals absent Goldman's entry into the aluminum market. For the canonical example of difference-in-differences, see David Card & Alan B. Krueger, *Minimum Wages and Employment: A Case Study of the Fast Food Industry in New Jersey and Pennsylvania*, 84 AM. ECON. REV. 772, 733-78 (1994). For a broader discussion of the method, see JOSHUA D. ANGRIST & JÖRN-STEFFEN PISCHKE, MOSTLY HARMLESS ECONOMETRICS: AN EMPIRICIST'S COMPANION (2009).

86. The Aluminum Association's four-digit numbering system categorizes alloys. Aluminum-copper alloys are in the 2xxx range; aluminum silicon alloys are in the 4xxx range; aluminum-zinc alloys are in the 7xxx range. *See* ALLOYING: UNDERSTANDING THE BASICS, *supra* note 83, at 354 tbl.1. Using that information, we search through the alloys registered in those ranges to pick out the maximum for each alloy category.

87. *See id.* at 353.

After the warehouse purchase in 2010, however, the regional price of aluminum spiked. The spread jumped to $0.18 per pound.

Figure 7: U.S. Regional Premiums[88]
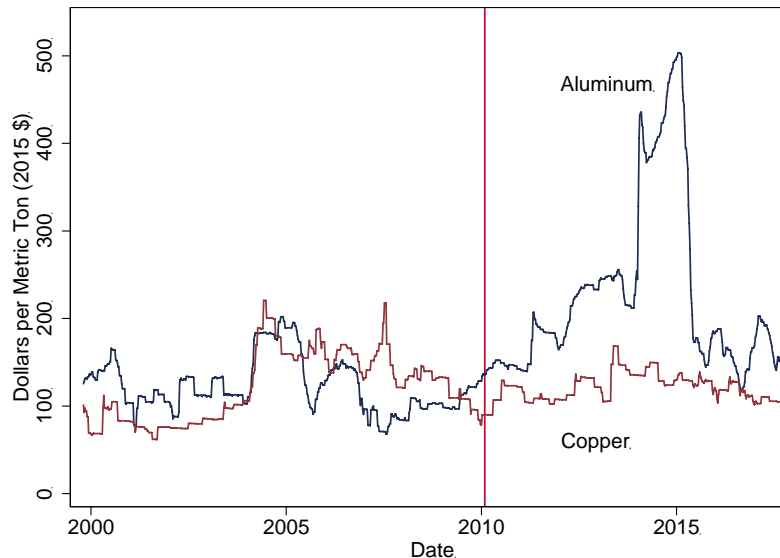
C. Regression Results of Market Entry and Exit

Our empirical approach compares the Midwest premium of aluminum to the Midwest premiums of its production complements. The econometric specification is:

$$P_{i,t} = \alpha + \beta_1 Alum_i + \beta_2 Post_t + \beta_3 Alum_i \times Post_t + \beta_4 X_{i,t} + \varepsilon_{i,t} \quad (1)$$

where i indexes metals and t indexes weeks. The *Alum* variable is an indicator for aluminum; $Alum = 1$ for aluminum and $Alum = 0$ for other metals. The *Post* variable is an indicator for the dates after Goldman Sachs purchased Metro International; $Post = 0$ prior to February 2010 and $Post = 1$ after. The explanatory variable of interest is the interaction between the aluminum indicator (*Alum*) and the warehouse purchase indicator (*Post*). To control for confounding time trends, the X_{it} vector contains month-of-sample fixed effects, a linear time trend and, in some specifications, metal-specific linear time trends. The coefficient of this variable (β_3) represents the effect of Goldman's entry into the aluminum market on the aluminum premium.

The key identifying assumption of this difference-in-differences model is that the regional price of aluminum would have followed a similar trend to the regional prices of complement metals absent Goldman's entry into the aluminum

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88.   S&P Global Platts (retrieved from Bloomberg).

market. The pre-2010 premiums of aluminum and copper are very similar and do not deviate by more than a couple of cents. To test this assumption more rigorously, we perform a means comparison test on the weekly growth rates of the aluminum and copper premiums before Goldman Sachs purchased the LME warehouses in Detroit (November 1999 through December 2009). We fail to reject the null hypothesis that there is no difference in the mean growth rates of the two price series, with a p-value of 0.66. Taken together, these data support our identifying assumption that the U.S. premiums for two metals commonly consumed together did not significantly diverge in a normally functioning market.

The results of this difference-in-differences model are presented in Table 1 and are robust to using Newey-West standard errors.[89] The first column presents least squares estimates of Equation 1. Using copper as a control, we find that the U.S. aluminum premium increased about $0.057 per pound post-2010, essentially doubling the average premium from 1999 through 2010. Adding metal-specific time trends and month-of-sample controls increases the estimated effect to $0.068 per pound post-2010 (Table 1, Column 2). To put this premium increase in perspective, the Midwest premium accounted for less than 10 percent of the total cost of aluminum for U.S. consumers prior to 2010, when Goldman entered the market. After 2010, the premium accounted for as much as 30 percent of the total aluminum price.

These results are robust to other, somewhat less common alloying metals—nickel and zinc—in addition to copper in the control group. With these three metals forming the control group, the estimated treatment effect is similar at about $0.052 per pound (Table 1, Column 3). Adding time trends for each metal and month-of-sample controls yields a slightly larger estimate, $0.06 per pound (Table 1, Column 4). In all cases, the estimated effect of Goldman Sachs's entry into the warehousing market is statistically significant.

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89.   *See* Whitney K. Newey & Kenneth D. West, *A Simple, Positive Semi-Definite, Heteroskedasticity and Autocorrelation Consistent Covariance Matrix*, 55 ECONOMETRICA 703 (1987); *Stata Manual: Newey*, STATA (2021), https://www.stata.com/manuals13/tsnewey.pdf [https://perma.cc/W8AD-HSUX].

The Costs of Banks Engaging in Non-Banking Activities

Table 1: Difference-in-Differences Model Estimates[90]

Dependent Variable: U.S. Regional Metal Premiums ($/pound, Real)

	(1)	(2)	(3)	(4)
Aluminum x Post	0.0571***	0.0682***	0.0518***	0.0601***
("Entry Effect")	(0.00329)	(0.00251)	(0.00333)	(0.00357)
Aluminum	0.000691	0.00834***	0.00706***	0.0127***
(Treatment)	(0.00107)	(0.00156)	(0.000940)	(0.00181)
Post	0.000599	-0.0324***	0.00582***	-0.0129
(Post-Feb 2010)	(0.00101)	(0.0123)	(0.00112)	(0.0175)
Observations	1,572	1,572	3,144	3,144
R-squared	0.430	0.774	0.282	0.562
Controls Included:				
Copper	YES	YES	YES	YES
Nickel & Zinc	NO	NO	YES	YES
Metal-Specific Time Trends	NO	YES	NO	YES
Month-of-Sample	NO	YES	NO	YES

Notes: Each column contains the results for a separate regression. The data are reported weekly by country. The parentheses contain standard errors that are clustered by county. *** denotes significance at the 1 percent level, ** denotes significance at the 5 percent level, * denotes significance at the 10 percent level.

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90. Each column contains the results for a separate regression. The unit of observation is week. *** denotes significance at the 1 percent level, ** denotes significance at the 5 percent level, and * denotes significance at the 10 percent level.

To put this $0.068 estimate in context using a back-of-the-envelope calculation, consider the effect of this price increase on a particular industrial aluminum consumer, General Motors Corporation. During this period, vehicles sold in the United States by General Motors contained approximately 370 pounds of aluminum.[91] The average all-in price per ton of aluminum in 2014 was $2,293, given the average spot price of $1,853 per metric ton and the average regional premium of $440 per metric ton. This means General Motors spent $369.74 for 370 pounds of aluminum at the market rate. If the regional premium were $0.068 lower without the market distortion, then General Motors would have spent $344.58 for the same amount of aluminum at the market rate, a decrease of 6.8 percent.

Our regression analysis using complementary commodities as a control group demonstrates that the aluminum market distortion was caused by the financial institutions' entry into the warehousing business, not by natural changes in regional supply and demand. To see the power of using the complementary commodity, consider the question: What if the increase in the regional premium was due to benign market speculation?

Suppose, for the purposes of contradiction, that participants in the aluminum market rationally anticipated that the price of aluminum would increase at some point in the future (due to a natural, positive demand shock, as opposed to an artificial, negative supply shock). If the expected price increase exceeded the storage cost of aluminum and the opportunity cost of investment, then those market participants would rationally decide to store more aluminum in the present in order to profit off the higher prices of aluminum in the future. This would lead to an increase of aluminum inventories in storage relative to copper inventories in storage, followed by an increase of the aluminum Midwest premium. There is nothing wrong thus far.

However, given that aluminum and copper are production complements, if aluminum prices are expected to increase in the future due to a positive demand shock, then copper prices should also be higher in the future. A positive demand shock to one will spill over to the other. (For example, if consumers demand more pasta, they also would demand more pasta sauce.) Thus, rational agents also should speculatively store more copper inventories at present. Yet this did not occur. The data show that copper inventories only increased slightly (Figure 8). Therefore, the data do not support the argument that the unprecedented increase in aluminum inventories was caused by benign speculative hoarding.

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91.   *2011 Minerals Yearbook: Aluminum*, U.S. GEOLOGICAL SURV. (Dec. 2013), https://s3-us-west-2.amazonaws.com/prd-wret/assets/palladium/production/mineral-pubs/aluminum/myb1-2011-alumi.pdf [https://perma.cc/QMS6-2RNN] ("Aluminum content in automobiles continued to increase as automakers substituted aluminum for steel in order to increase fuel efficiency. General Motors Corp. . . . expected that its vehicles sold in the United States in 2012 would contain an average of 168 kilograms (370 pounds) of aluminum.").

Figure 8: LME Metal Inventories[92]
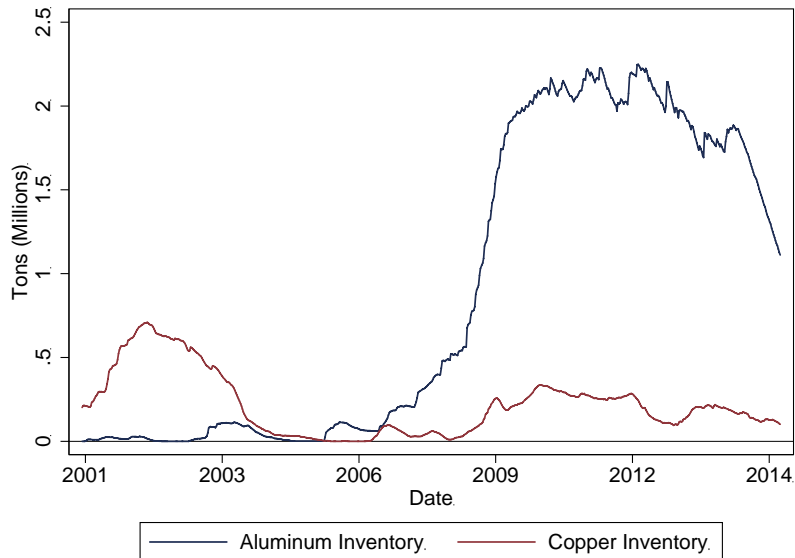
The logic in this thought experiment, as well as the corresponding data, also rules out other explanations that are consistent with the expected impact on aluminum prices but inconsistent with the expected impact on the prices of aluminum's complements. For example, some may argue that the abnormal aluminum price spike was due to market agents arbitraging the rates of LME versus non-LME warehouses.[93] This explanation would be plausible if the storage market consisted solely of aluminum. But it does not, and the argument fails to account for non-aluminum metals stored in the warehouses. LME and non-LME warehouses stored commodities other than aluminum. If this were merely a story of warehouse arbitrage, then we would expect to see price spikes in the other (complementary) commodities as well, but we do not.

In addition, some may correctly observe that the Midwest premium reflects the transaction prices paid by aluminum market participants *less* the aluminum cash settlement price on the LME. Thus, could it be the case that the Midwest premium spiked because the LME price cratered? The answer here is "no," and the proof is shown above in Figures 1 and 6. Figure 1 shows a jump in the Midwest premium that is clearly not linear.[94] Figure 6 shows the decline in LME prices that is much more linear (i.e., almost a straight line).[95] It is not possible for a linear decrease in LME prices to have caused the non-linear increase in the Midwest premium.

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92.   London Metal Exchange (retrieved from Bloomberg).

93.   *See* Matt Levine, *The Goldman Sachs Aluminum Conspiracy Was Pretty Silly*, BLOOMBERG (Nov. 20, 2014), https://www.bloomberg.com/opinion/articles/2014-11-20/the-goldman-sachs-aluminum -conspiracy-was-pretty-silly [https://perma.cc/AQA3-MBX5].

94.   *See supra* Introduction.

95.   *See supra* Part II.

If this is not enough to convince the reader, we point out that the financial institutions' exit from the aluminum storage business in Detroit further supports our position. If our arguments up to this point are correct, then we would expect to see the regional premium of aluminum decline significantly following Goldman's sale of Metro International in 2014.[96] This is precisely what occurred.

The merry-go-round transactions in the Detroit warehouses were widely publicized by an article in *The New York Times* on July 20, 2013.[97] That article brought unprecedented attention to the issue. Three days later—on July 23, 2013—these aluminum warehousing activities became the focus of the Senate Banking Subcommittee on Financial Institutions and Consumer Protection.[98] During the following month, large aluminum consumers, including Eastman Kodak and Mag Instrument, filed more than a dozen lawsuits.[99] The Senate's investigation continued through November 2014, when the committee released a detailed report on these activities.[100] This Senate report increased public scrutiny of the warehouse scheme, which only abated when Goldman sold its Metro International warehouses at the end of 2014. Aluminum premiums fell precipitously within four weeks of the sale.

Having shown that Goldman's entry into the market caused an increase in the aluminum Midwest premium, we next examine whether Goldman's exit from the market had the opposite effect, causing a decrease in the aluminum Midwest premium. We use the same difference-in-differences model described above with a few key changes. Specifically, we use a sample period that begins with Goldman's purchase of the Metro International warehouses in February 2010 and ends in September 2017, nearly three years after its sale of Metro International. (We find similar results using a sample beginning in 2013, when the queues at the Detroit warehouses were near their peak.) We also redefine the $Post$ variable as an indicator for Goldman's sale of Metro International; $Post = 0$ prior to December 2014 and $Post = 1$ after. In this specification, the coefficient on the $Alum_i \times Post_t$ interaction term (β_3) captures the causal effect of Goldman's exit on the Midwest premium.

As in the previous model, the key identifying assumption is that the regional aluminum and copper prices would have followed parallel trends absent Goldman's activities in the aluminum market. It is indeed the case that the regional premiums of aluminum and copper are similar after Goldman exited the

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96.   Christian Berthelsen & Ira Iosebashvili, *Goldman Sachs Sells Aluminum Business to Swiss Firm*, WALL ST. J. (Dec. 22, 2014), https://www.wsj.com/articles/goldman-sachs-sells-aluminum-busin ess-to-swiss-firm-1419279027 [https://perma.cc/5UHV-MHQ6].

97.   Kocieniewski, *supra* note 1.

98.   *Examining Financial Holding Companies: Should Banks Control Power Plants, Warehouses, and Oil Refineries?: Hearing Before the Subcomm. on Fin. Insts. and Consumer Prot. of the S. Comm. on Banking, Hous., and Urb. Affs.*, 113th Cong. (2013).

99.   *In re Aluminum Warehousing Antitrust Litig.*, 95 F. Supp. 3d 419, 427 (S.D.N.Y. 2015) ("In August 2013 plaintiffs filed the first of what would be a large number of lawsuits alleging anticompetitive conduct impacting aluminum pricing. Numerous actions were filed in various jurisdictions across the country and eventually brought together in this District pursuant to an order of the U.S. Judicial Panel on Multidistrict Litigation.").

100.   Staff Report, *supra* note 43.

market in late 2014. We examine this assumption using a means comparison test on the weekly growth rates of the aluminum and copper premiums after Goldman sold the LME warehouses in Detroit. If we perform a difference-in-means test using data after May 2015, we fail to reject the null hypothesis that there is no difference between the aluminum and copper mean growth rates, with a p-value of 0.99.

The results from this difference-in-differences model are presented in Table 2, and are robust to using Newey-West standard errors. The estimated effect varies across specifications, from -$0.02 to -$0.09, and is statistically significant in three of the four specifications. This variation in estimates is not surprising given that the backlog took time to unwind. The queues remained elevated for many months. These results suggest a change in the aluminum market following Goldman's sale of Metro International.

Table 2: "Exit" Model Estimates[101]

Dependent Variable: U.S. Regional Metal Premiums ($/pound, Real)

	(1)	(2)	(3)	(4)
Aluminum x Post	-0.0183***	-0.0917***	-0.00280	-0.0954***
("Exit Effect")	(0.00513)	(0.00836)	(0.00532)	(0.00909)
Aluminum	0.0586***	-0.183***	0.0596***	-0.227***
(Treatment)	(0.00317)	(0.0167)	(0.00325)	(0.0186)
Post	-0.00158**	0.0478	-0.0170***	0.0240
(Post-Feb 2014)	(0.000705)	(0.0435)	(0.00159)	(0.0250)
Observations	802	802	1,484	1,484
R-squared	0.369	0.799	0.395	0.720
Controls Included:				
Copper	YES	YES	YES	YES
Nickel & Zinc	NO	NO	YES	YES
Metal-Specific Time Trends	NO	YES	NO	YES
Month-of-Sample	NO	YES	NO	YES

Notes: Each column contains the results for a separate regression. The data are reported weekly by country. The parentheses contain standard errors that are clustered by county. *** denotes significance at the 1 percent level, ** denotes significance at the 5 percent level, * denotes significance at the 10 percent level.

To be sure, the Midwest premium did not immediately return to its pre-2010 level following the sale of Metro International, but that is because the

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101.   Each column contains the results for a separate regression. The unit of observation is week. *** denotes significance at the 1 percent level, ** denotes significance at the 5 percent level, and * denotes significance at the 10 percent level.

backlog inventory took time to unwind. Queues remained elevated for many months. By mid-2015, however, the aluminum premium had fallen approximately 75 percent from its peak and was nearly identical to the copper premium, as it was prior to 2010. As of November 2015, the only LME warehouses with aluminum queues over thirty days were the warehouses in Detroit, as they continued to suffer from the artificial backlog.[102]

D. Harm to Producers and Consumers

In addition to the impact of these non-traditional warehousing activities on regional market prices and the tremendous backlog in delivery queues, this lack of separation between banking and commerce had another important consequence, namely, the increased cost of aluminum to businesses and consumers.

The Midwest premium spike had a significant impact on the U.S. aluminum industry, which is composed of producers, processors, and manufacturers. Industrial aluminum processors stand between aluminum producers, which mine and refine raw material to produce primary aluminum,[103] and aluminum manufacturing firms, which use processed aluminum in products sold to consumers. As middlemen, industrial processors convert pure aluminum ingots into alloyed aluminum, extruded aluminum, or flat-rolled aluminum that is used in industrial applications and by manufacturers to produce consumer goods.

Industrial processors in the United States typically purchase aluminum from aluminum producers using contracts that tie the purchase price to the "all-in" aluminum price. The all-in price is the sum of the spot price and the Midwest premium at the time of purchase. From 2000 through 2010, the Midwest premium accounted for an average of 5.6 percent of the all-in price. At its peak during this period of market manipulation, the Midwest premium accounted for 22.3 percent of the all-in price.[104]

Aluminum processing takes place over the course of several weeks, after which the processors sell the processed aluminum to aluminum manufacturers at a markup to the all-in price at the time of sale. Because the industrial aluminum processors' purchase and sale contracts are based on the all-in aluminum price at different dates, these contracts leave firms vulnerable to changes in either the spot price or the Midwest premium that occur between the purchase of aluminum

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102. *Warehouse Company Stocks and Queue Date for November 2015*, LONDON METAL EXCH. (Nov. 2015), https://www.lme.com/en-GB/Market-Data/Reports-and-data/Warehouse-and-stocks-reports /Warehouse-and-queue-data [https://perma.cc/8TZR-MLVJ].

103. Primary aluminum is produced by a refining process that converts bauxite ore into alumina, which is smelted into pure aluminum. *See* IAN POLMEAR, DAVID ST. JOHN, JIAN-FENG NIE & MA QIAN, LIGHT ALLOYS: METALLURGY OF THE LIGHT METALS (2017). Secondary aluminum is produced by recycling existing aluminum scrap into pure aluminum. *See Secondary Production*, ALUMINUM ASS'N https://www.aluminum.org/industries/production/secondary-production [https://perma.cc/R4PK-656X]. The LME spot and futures prices, as well as the Midwest premium, are based on the price of primary aluminum.

104. Calculations based on London Metal Exchange and S&P Global Platts data retrieved from Bloomberg database.

and the sale of processed aluminum. While aluminum processors can hedge against changes in the aluminum spot price with aluminum futures contracts, changes in the Midwest premium are not usually hedged with exchange-traded financial contracts.[105]

As the Midwest premium rose, industrial aluminum processors began reporting gains in their SEC filings due to unhedged exposure to the Midwest premium. Note that a rising Midwest premium means the all-in price at the time industrial users purchase aluminum is below the all-in price at the time industrial users sell aluminum. Thus, all else equal, increases in the Midwest premium would benefit industrial processors by allowing them to sell at a price that is higher than the purchase price. However, declines in the Midwest premium would, all else equal, lower profits for them, because they would sell at a price that is lower than the purchase price. The net income attributed to the difference between the price of metal at the time of purchase and sale is labeled the "metal price lag" in their SEC filings.[106]

Because the Midwest premiums for other metals were relatively flat from 2010-2014, the metal price lag provides a reasonable measure of the effect of the aluminum premium on net income. As an example, the metal price lag for Alcoa Inc.—one of the largest firms in the aluminum industry—is plotted in Figure 9, along with the Midwest premium.[107] In 2013 and 2015, when the Midwest aluminum premium fell over the course of the year, Alcoa lost $45 million and $133 million, respectively, due to the metal price lag. In 2014, when the Midwest premium was rising, Alcoa gained $78 million due to the metal price lag. The net income attributable to the metal price lag was relatively small, but not trivial, representing 0.6 to 2.4 percent of annual total revenue from Alcoa's processed (flat-rolled) aluminum sales, which is about $7 billion per year.[108]

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105.   Exchange-traded Midwest premium futures contracts were not available until August 2013, when the Commodities Mercantile Exchange (CME) began offering futures contracts based on the aluminum premium. *See* Xan Rice, *New Contract to Hedge High Aluminum Premium*, FIN. TIMES (Feb. 5, 2014), https://www.ft.com/content/6a436782-8e90-11e3-b6f1-00144feab7de [https://perma.cc/6BNX-C3KY].

106.   The metal price lag captures the effect of unhedged exposure to all metals, not just aluminum. *See, e.g.*, Aleris Corp., Annual Report (Form 10-K) 12 (Mar. 27, 2015); Novelis, Inc., Annual Report (Form 10-K) 14 (May 8, 2019); Constelium SE, Annual Report (Form 20-F) 52 (Mar. 9, 2020).

107.   The metal price lag was not regularly listed as a line item in SEC filings prior to 2013 because there was relatively little net income attributable to changes in regional metal premiums prior to the 2010-2014 aluminum premium spike.

108.   *2015 Annual Report*, ALCOA INC. 72 (2016), https://www.arconic.com/global/en/invest ment/pdfs/2015_Annual_Report.pdf [https://perma.cc/Q4V3-3Q2L].

Figure 9: Alcoa Metal Price Lag Income[109]
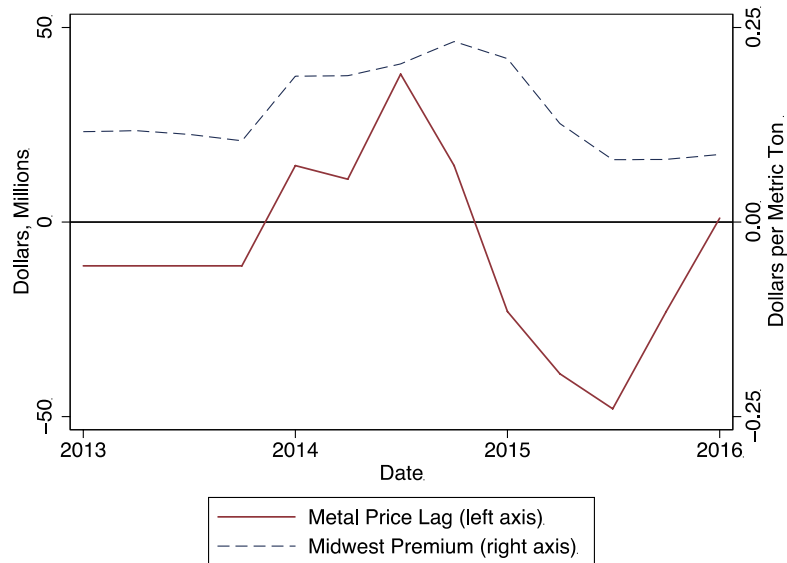
On the whole, aluminum processors, like Alcoa, appear to have passed on the increased aluminum cost to manufacturers, as is evident in the Producer Price Index (PPI) for aluminum sheet, plate, and foil manufacturing.[110] This price index, which reflects the input costs of aluminum manufacturers, typically tracks the LME aluminum spot price closely. Between 2010 and 2014, however, the two series diverged significantly as the aluminum spot price fell and the Midwest premium rose (Figure 10).

Given that research has consistently shown that increases in the PPI cause increases in the Consumer Price Index (CPI),[111] one would expect the prices paid by consumers for goods that contain aluminum to reflect the increased aluminum costs paid by manufacturers. While an estimate of the total impact of aluminum price manipulation on consumers is beyond the scope of this Article, we provide a detailed analysis of the carbonated beverage market in Appendix A. Our econometric estimates show that the distortion in the U.S. aluminum market increased the price of a can of Coca-Cola by roughly 1.6 percent. It is reasonable to assume that other consumer goods with aluminum components had similar increases.

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109.   *Id.* (metal price lag); S&P Global Platts (retrieved from Bloomberg) (Midwest premium).

110.   *Producer Price Indexes*, U.S. BUREAU OF LAB. STAT., https://www.bls.gov/ppi [https://perma.cc/BPK4-8JB3].

111.   Several articles demonstrate a causal relationship between PPI and CPI. *See, e.g.*, Guglielmo Maria Caporale, Margarita Katsimi & Nikitas Pittis, *Causality Links Between Consumer and Producer Prices: Some Empirical Evidence*, 68 SOUTHERN ECON. J. 703, 703 (2002); Aviral Kumar Tiwari, Suresh K.G., Mohamed Arouri & Frédéric Teulon, *Causality Between Consumer Price and Producer Price: Evidence from Mexico*, 36 ECON. MODELLING 432, 432 (2014).

Figure 10: Aluminum Manufacturing Price Index and Spot Price[112]
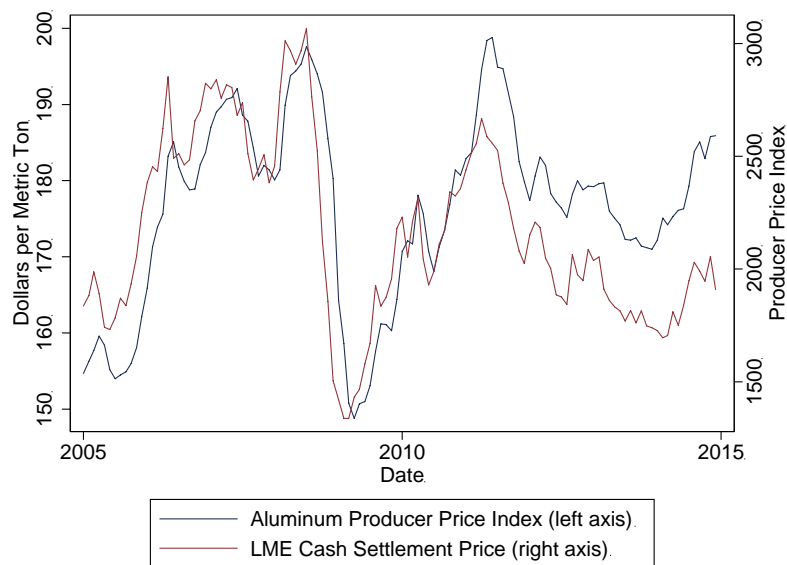
Statistical analysis aside, this section contains a crucial, high-level takeaway. Many policymakers assume that the actions undertaken by financial institutions have consequences only for financial markets. That is not true. The aluminum case study highlighted here had ramifications for the broader economy, and it does not take much creativity to imagine the impact of financial institutions artificially restricting the supply of commodities. Consider lumber, another physical commodity that can be traded on exchanges and stored in warehouses. Hoarding lumber would have a tremendous, negative impact on the ability of builders to construct new homes or manufacture other household durable goods like furniture. Thus, while the present analysis only shows the negative impact of the 2010-2014 aluminum scheme on producers and consumers, the analysis is easily generalizable.

IV. Mitigating Market Distortions by Banks and Non-Banks

Many cracks have emerged in the wall that separates commerce and banking. We have focused our empirical analysis on one such gap. From 2010 through 2014, certain financial institutions began amassing unprecedented levels of aluminum inventories in Detroit warehouses, which were approved to hold inventories traded on the London Metal Exchange. Over those four years, the queue length—that is, the time it takes to remove metal from the warehouse—in those warehouses increased from a few days to nearly two years, and the Midwest premium of aluminum rose threefold.

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112.   Producer price index for aluminum sheet, place, and foil manufacturing. U.S. Bureau of Lab. Statistics; London Metal Exchange (retrieved from Bloomberg).

Regional markets are particularly vulnerable to such distortions because they can be influenced with changes in relatively small inventories. Although the inventories accumulated in Detroit were likely insufficient to move the global market, they were large enough to increase load-out queues in the region, causing prices paid by industrial aluminum users to significantly diverge from spot prices. These operations continued without a perceptible impact on the global market, so supervisors who tracked only the LME spot and futures prices would not have noticed anything peculiar occurring in the aluminum market. If policymakers, supervisors, and regulators are not on guard, this episode might recur in the near future.

What is to be done? In this Part, we outline several options to address the problems identified in this Article. To be sure, the "right" path forward depends on the objective. The first set of options aims to prevent the sort of commodity market distortions caused by banking organizations that are documented in this Article. These proposals narrowly target U.S. banking law. Specifically, they call for repealing section 4(o) of the Bank Holding Company Act, recalibrating holding periods for merchant banking investments, and regulating the volume of these activities. Such changes would require action from Congress, the U.S. Treasury, or the Federal Reserve (or combinations of these three).

The second set of options aims to prevent general distortions in regional markets, which are characterized by high transaction costs,[113] regardless of whether the market participants are banking organizations or non-banks like hedge funds. The first option relates to capture and is tailored to situations in which there are extremely clear conflicts of interest between the organization engaging in the commodity operations and the exchange on which the commodities are traded. The next option involves a statistical detection algorithm, built using the insights developed in this Article. Having a screen to detect abnormal movements in regional markets would enable agencies like the CFTC to undertake more effective surveillance and enforcement measures. Finally, we note that our insights could be used to more easily prove or disprove two elements of market manipulation—price artificiality and causality—under the Commodity Exchange Act,[114] which may help the CFTC pursue any market participants involved in similar distortionary operations.

A. Section 4(o) of the Bank Holding Company Act

Section 4(o) of the Bank Holding Company Act exempts banking organizations from merchant banking restrictions.[115] Recall that merchant

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113. Transaction costs account for the costs of participating in a market. Much of the literature on transaction costs focuses on the relationship between firm structure, markets, and transaction costs. *See* Oliver E. Williamson, *The Economics of Organization: The Transaction Cost Approach*, 87 AM. J. SOCIO. 548 (1981). This literature shows that large changes in transaction costs, as were seen in U.S. regional markets between 2010 and 2014, have important impacts on all market participants.

114. 7 U.S.C. § 9 (2018).

115. 12 U.S.C. § 1843(o) (2018).

banking involves the investment in, and potential ownership of, non-financial companies and products.[116] Thus, the exemption provided under 4(o) means that a financial holding company could use its merchant banking powers to take non-financial risks and exert control over non-financial companies.

Why does this exemption matter for the analysis in this Article? Note that merchant banking authority, before section 4(o)'s exemption, is accompanied by two primary safeguards: (i) a maximum ten-year holding period for the investment and (ii) no routine management.[117] That is, a firm must dispose of a merchant banking investment within ten years, unless an extension is granted, and the firm may not routinely manage the investment.

The full definition of routine management is explicitly laid out in 12 C.F.R. 225.171, but for our present purposes, a financial holding company (like Goldman Sachs) is presumed to routinely manage or operate its merchant banking portfolio company (like Metro International) if "[a]ny director, officer, or employee of the financial holding company serves as or has the responsibilities of an officer or employee of the portfolio company."[118] The presumption is easily satisfied. During the lifespan of the Detroit warehousing operation, approximately a dozen Goldman employees, including Goldman executives, served on the Board of Directors of Metro International.[119] While the first merchant banking constraint on holding periods would not have mattered, the second merchant banking constraint would almost certainly have been binding. If Goldman were subject to regular merchant banking authority, it would not have been able to operationalize the Detroit warehousing scheme from 2010 through 2014. However, Goldman was able to take advantage of a loophole that allowed it to operate outside of the boundaries drawn by merchant banking: section 4(o) of the Bank Holding Company Act. Thus, one straightforward option to restrict financial institutions from engaging in market distorting operations, such as the one described in this Article, is for Congress to directly repeal section 4(o) of the Bank Holding Company Act.

Section 4(o) is effectively a grandfather provision. A company that was not a bank holding company prior to November 12, 1999, and that became a financial holding company after that date, can continue to engage in activities related to the trading, sale, or investment in commodities and underlying physical properties that were not permissible for bank holding companies as of September 30, 1997.[120] The more permissive range of activities is carried over into the new

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116.   To help orient the reader in this Section, think of merchant banking authority as a less egregious violation of the separation between banking and commerce than section 4(o) authority. Common examples of merchant banking investments include investments in energy companies, real estate, pipelines, and inventories of various physical commodities.

117.   12 C.F.R. §§ 225.171-72 (2021).

118.   *Id.* § 226.171(b)(2)(i).

119.   Staff Report, *supra* note 43, at 185. After Goldman's acquisition of Metro International, "many business decisions by Metro required review and approval by Metro's Board of Directors or a Board subcommittee, both of which were comprised entirely of Goldman employees." *Id.*

120.   12 U.S.C. § 1843(o) (2018). The company must have been engaged in those activities prior to September 30, 1997.

regime, without the need to consider impediments like routine management. Such activities include the Detroit warehousing scheme described in Part II of this Article.[121]

There are two other aspects of section 4(o) authority that are socially harmful. First, only Goldman Sachs and Morgan Stanley benefit under section 4(o), which puts their rivals at an awkward competitive disadvantage. Because this authority does not come with a sunset provision, the uneven playing field will continue into the foreseeable future. Second, this grandfather authority is automatic, meaning that Goldman Sachs and Morgan Stanley do not have to seek approval from the Federal Reserve to engage in more expansive activities in the physical commodity markets. Specifically, Goldman did not have to contact the Federal Reserve in 2009 or 2010, describe its proposed business plan in seeking to purchase Metro International, and then wait for the Federal Reserve's approval. Goldman just did it. Partly because of these downside risks, in 2016, the Federal Reserve advised Congress to repeal the grandfather authority under section 4(o) of the Bank Holding Company Act.[122]

In sum, if the grandfather authority under section 4(o) were not in place, Goldman would not have been able to engage in the warehousing operations in Detroit. Goldman could still have invested in aluminum warehouses inventories,[123] but it would have had to first seek approval from the Federal Reserve, and it would not have been able to routinely manage the merry-go-round transactions.

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121. As Saule Omarova points out:

This is a very curious provision that, to date, has remained largely unnoticed and rarely, if ever, invoked or discussed in public discourse or legal analysis. . . . The vague phrasing of this section seems to allow a qualifying new FHC to conduct not only virtually any kind of commodity trading but also any related commercial activities (for example, owning and operating oil terminals and metals warehouses), if it engaged in any commodities business-even if on a very limited basis and/or involving different kinds of commodities prior to the 1997 cut-off date.

Omarova, *supra* note 7, at 289-90. Moreover, according to the Federal Reserve:

This statutory grandfathering authority permits certain FHCs to engage in a potentially broader set of physical commodity activities than may be conducted under the complementary authority, such as storing, transporting, and extracting commodities, and without the conditions that the Board has placed on engaging in complementary commodities activities to protect safety and soundness.

Section 620 Report, *supra* note 11, at 27.

122. In its recommendation, the Federal Reserve also observed that:

Operation of facilities used for the storage, transportation, and extraction of physical commodities expose firms to substantial legal, operational, and environmental risks. In particular, catastrophic and environmental events related to the companies' physical commodities activities may impose losses in amounts that greatly exceed the companies' investments in the underlying physical assets, the market value of the physical commodities involved in the catastrophic event, committed capital, and insurance policies of the organization. A variety of catastrophic and environmental events in recent years have highlighted the danger of underappreciated tail risks associated with conducting physical commodities activities and shown that the actions firms may take to limit these risks are more limited.

Id. at 27.

123. For instance, JPMorgan Chase did not benefit from section 4(o) authority yet was able to purchase Henry Bath & Sons, which like Metro International, owned a global network of warehouses storing metals traded on the LME. *See* Staff Report, *supra* note 43, at 184 n.1089.

B. Merchant Banking

Merchant banking authority was implemented in section 4(k) of the Bank Holding Company Act by the Gramm-Leach-Bliley Act of 1999.[124] As discussed previously, the authority allows qualifying financial holding companies to make investments in companies engaged in non-financial activities as part of a bona fide securities underwriting, merchant, or investment banking activity.[125] This authority is what allows financial institutions to engage in activities that would typically be considered commercial in nature.

Eliminating merchant banking authority altogether and returning to the financial world order prior to the Gramm-Leach-Bliley Act is sensible. The downside risks posed by banks undertaking these commercial activities, especially in the realm of physical commodities, seem significant. Indeed, in the same 2016 report to Congress referenced above, the Federal Reserve also advised Congress to *fully repeal* the authority of financial holding companies to engage in merchant banking activities.[126]

While regulation of merchant banking is supported by the analysis in this Article, a flat-out prohibition might be too blunt of a response. The scope of this Article is more limited: it does not touch upon the potential diversification benefits of commingling banking and commerce that come with operating new business lines, but it does show that diversification may come at a steep price in terms of weakened market integrity and harm to consumers.[127] The proponents of eliminating the separation between banking and commerce may have a fair point in that financial theory teaches us that portfolio diversification smooths out idiosyncratic shocks. Permitting a banking organization to pursue diverse business opportunities therefore may be desirable—even if the business opportunities are divorced from what the average person would consider banking. And one might argue that the system would be safer if individual banks are safer.[128]

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124.   12 U.S.C § 1843(k) (2018).

125.   *Id.* § 1843(k)(4)(H).

126.   Section 620 Report, *supra* note 11, at 28. To support its recommendation, the Federal Reserve noted that, even under merchant banking authority, a financial holding company may narrowly manage a portfolio company "as may be necessary or required to obtain a reasonable return on the resale or disposition of the investment." *Id.* at 31. In other words, there is still legal risk involved for the financial holding company in potentially operating the company. "Thus, a repeal of merchant banking authority would help address potential safety and soundness concerns and maintain the basic tenet of separation of banking and commerce." *Id.*

127.   A key difference between this discussion and the previous discussion is that section 4(o) authority benefits only two firms, Goldman Sachs and Morgan Stanley. Moreover, it is evident that the benefits to Goldman were outweighed by the costs to the entire regional physical commodity market and to downstream businesses and consumers. In this case, the benefits of merchant banking authority might be nontrivial.

128.   Of course, this is not always the case. *See* Omarova, *supra* note 7, at 344. One also could argue that banks, like human beings, have finite abilities. There is only so much that a bank can be good at. Consider European banks. They employ a universal banking model, which means they can invest in anything, yet they are underperforming relative to U.S. banks. *See, e.g.*, Margot Patrick & Simon Clark, *Facing a Profitability Crisis, Europe's Banks Rush to Restructure*, WALL. ST. J. (Aug. 23, 2020),

However, this does not mean that the merchant banking regulation is perfect in its current state. In addition to the two merchant banking constraints of (i) a maximum ten-year holding period and (ii) no routine management, regulators can reduce the risks associated with merchant banking investments through imposing higher capital requirements on equity investments, which are described below in Section IV.C. In addition, it might be welfare enhancing to tighten the existing regulation on merchant banking holding periods in order to reduce the social harm highlighted in this Article, as well as the legal, operational, and environmental risks described by commentators.[129]

Allowing an eligible banking organization to hold a merchant banking investment for a decade is already a significant period of time, especially given the non-financial risks involved with such an investment, yet this holding period is often extended. Under the joint merchant banking regulation issued by the Federal Reserve and the U.S. Treasury, if a financial holding company surpasses the ten-year holding period for a merchant banking investment, it may petition the Federal Reserve for a one-year extension.[130] The agencies should make it more difficult to obtain approval for an extension.[131] For example, the agencies might consider whether the merchant banking investment has lost value over time or only recently, and be stricter on long-term losses because it is less likely that the investment will increase in value the next year. Relatedly, they might consider whether the forces affecting the investment's value are structural (e.g., fracking was invented) or idiosyncratic (e.g., a random weather event), and be stricter in the former case because idiosyncratic shocks may disappear, but structural shocks are unlikely to disappear. In addition, they might consider the success or failure rate of similar investments in the past, if possible, and be stricter when there is no track record. Agencies currently do not take these factors into account.

Besides being tougher on granting merchant banking extensions, the agencies could revisit the penalty on exceeding the ten-year holding period. The regulation currently has a 25-percent "capital deduction" for merchant banking investments that exceed the ten-year holding period.[132] Specifically, if the value of the investment is $50 million, a 25-percent capital deduction would lead to a loss on the equity-side of the balance sheet by $12.5 million. The idea is that this deduction acts as a penalty on firms for keeping their merchant banking

https://www.wsj.com/articles/facing-a-profitability-crisis-europes-banks-rush-to-restructure-1159818 4000 [https://perma.cc/8N43-RH7K]. Thus, trying to do too many things—especially if the activities are outside of the core area of expertise—may end up diluting performance.

129.   *See* Omarova, *supra* note 7, at 270 ("When financial institutions act as traders and dealers in physical commodities, they assume a variety of new financial and non-financial risks—including operational, environmental, and geo-political risks—that fundamentally alter their business and risk profiles.").

130.   12 C.F.R. § 225.172 (2021).

131.   Typically, a firm requests an extension of its merchant banking investment when it has trouble selling the investment. By having an extra year or two to sell the investment, the firm would not be forced into accepting a low price. The other side of this argument would point out that the firm did not have to wait until the last minute to attempt a sale—it had a decade to do so.

132.   12 C.F.R. § 225.172(b)(6)(i)(B) (2021).

investments for a longer period than is desirable. One could argue for a much higher capital deduction, even upward of 100 percent (i.e., dollar for dollar), in response to overshooting the ten-year holding period. By incentivizing firms to stay within the holding period, the agencies would mitigate the social harms highlighted in this Article as well as the legal, operational, and environmental risks described by commentators.

C. Inventory of Physical Commodities

As a complement to the previous two options discussed in Section IV.B, the Federal Reserve could independently constrain the level of inventories of physical commodities that any one bank holding company may possess. In 2016, the Federal Reserve actually proposed such a regulation. The Federal Reserve did not propose this rule to mitigate the risks of regional market distortions—which is understandable because the Federal Reserve, unlike the SEC or the CFTC, does not regulate markets—but rather to better address the potential legal, reputational, and financial risks posed by such activities, particularly those that can result from an environmental catastrophe.[133] The proposed regulation included:

> (1) tightening the limit (e.g., under 5 percent of tier 1 capital) placed on physical commodity holdings of financial holding companies by taking into account physical commodities held anywhere within the FHC under most other authorities; and
> (2) establishing new public reporting requirements for commodities holdings and activities of financial holding companies to increase transparency, allow better monitoring by the regulatory community, and improve firm management of these activities.

Consider what the first part of the regulation would have meant for Goldman Sachs. Goldman had $68.5 billion of tier 1 capital in the first quarter of 2010,[134] so it would have been able to devote only 5 percent of that—or $3.4 billion—to holdings of physical commodities. Goldman directly owned over $3 billion in aluminum alone. This does not include its ownership of other non-aluminum metals, or the amount of aluminum stored by Metro International.[135]

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133. *See* Risk-Based Capital and Other Regulatory Requirements for Activities of Financial Holding Companies Related to Physical Commodities and Risk-Based Capital Requirements for Merchant Banking Investments, 81 Fed. Reg. 67,220 (Sept. 30, 2016). This proposed rule does not appear to have advanced to the finalization stage of the notice-and-comment rulemaking process. Separately, limiting holdings as a function of capital is normal for safety-and-soundness reasons but, for the purposes of market integrity, one might imagine capital requirements for a commodity position that account for the size of the position relative to the size of the market.

134. *See Holding Company Data*, *supra* note 62.

135. It is possible that 5 percent of tier 1 capital is too generous, especially for larger organizations. Doing a back-of-the-envelope calculation, 5 percent of JPMorgan's tier 1 capital is roughly $10 billion. The entire world only produces roughly $20 billion worth of lead per year (assuming that 11 million tons of lead are produced annually, and one ton of lead is $1,800). It is mindboggling to think that JPMorgan could hold, in inventory, half the lead that is produced around the world in a given year.

Goldman's merry-go-round scheme never would have been able to get up and running if this regulation had been in effect in 2010.

The regulation also would provide a boost for market regulators (and participants) who could use the reporting data to monitor transactions. Imagine if, back in 2010, market regulators saw on Goldman's disclosed reporting form that the firm was amassing unprecedented levels of aluminum in its warehouses. That would have raised alarm bells even in the absence of a repeal of section 4(o) of the Bank Holding Company Act or the use of any econometric detection algorithm. That is no small matter, because under section 4(o)'s grandfather authority, financial holding companies do not even have to notify the Federal Reserve of their 4(o) activities and certainly do not have to provide data related to their size or scope.

The proposed regulation would not ban financial institutions from owning or trading in physical commodities.[136] It would, however, ensure that financial institutions cannot control so much of a single commodity that their actions can lead to an artificial market distortion.

D. (Self-)Regulatory Capture

As this Article documents, financial institutions, both banks and non-banks, can cause a large, sustained impact on regional prices while leaving global spot and futures prices untouched. The previous set of solutions relates to banking organizations but would not impact non-banks like hedge funds and private equity funds. We now pivot away from federal banking law and discuss other ways to mitigate the general problems identified in this Article.

Regulatory capture is traditionally defined as the process through which private firms influence interventions by regulators.[137] For example, private firms can influence regulators through monetary incentives such as campaign donations. Firms can also gain influence through a "revolving door" in which employees move back and forth between the firms and the regulators, first working at one and then the other. With the revolving door, firms are able to influence regulation by having former employees work for the regulator while also providing regulators with the opportunity for future employment at the firm.

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136. The first option described in this section restrains the permissible range of activities. Specifically, repealing section 4(o) of the Bank Holding Company Act would bring Goldman Sachs and Morgan Stanley in line with their peer organizations. The second and third options in this section do not restrain the extent of activities but rather the transaction volume of those activities.

137. In the academic literature, "capture" usually refers to the interaction between a private entity and the public sector. Early theoretical work on regulatory capture by George Stigler focused on firms that demand regulation from policymakers to protect the firm from competition. *See* George J. Stigler, *The Theory of Economic Regulation*, 2 BELL J. ECON. & MGMT. SCI. 3 (1971). Research on regulatory capture has broadened to cover any case in which special interests influence state intervention. *See* Ernesto Dal Bó, *Regulatory Capture: A Review*, 22 OXFORD REV. ECON. POL'Y 203 (2006). We use the term "capture" to refer to the process through which private firms influence the regulation of their firms.

The literature is filled with examples of regulated firms controlling the policymakers that should, in turn, be controlling the firms.[138]

No government actors were involved in Goldman's warehousing scheme. The warehousing rules were set by the LME, rather than by the public sector.[139] But the conflict-of-interest principles of regulatory capture still apply to self-regulated organizations. Indeed, financial institutions with obvious conflicts of interest were able to influence LME's interpretation of warehouse rules through the LME's Warehousing Committee, which provides recommendations to the LME board regarding warehouse governance.[140] For instance, Metro International's position on the committee enabled Goldman Sachs (the owner of Metro International) to directly influence LME's decisions regarding warehousing rules.

It is unlikely that the regional market distortion would have occurred if LME members had not been able to interpret LME's warehousing contracts. Recall that, in 2010, LME required warehouse owners to load out a minimum of 1,500 tons of aluminum per day. The minimum load-out amount had traditionally been applied to each individual warehouse, but after 2010, this requirement was applied at the city level, not at the warehouse level. This meant that a warehouse owner—such as one of the large financial institutions in this operation—only needed to load out a total of 1,500 tons each day across *all* of its warehouses in Detroit to meet the requirement.

It is perplexing that LME members with obvious conflicts of interest were allowed to decide the interpretation of warehousing rules. These institutions owned warehouses in Detroit with significant volumes of inventory. Shouldn't they have been conflicted out? Their participation in the decision-making process was a clear failure of governance. This suggests that there is a role for an independent body to review the organizational structure and voting procedures of private exchanges that are self-regulating, like the LME. To the extent that their procedures do not pass basic conflict-of-interest standards, supervisors and regulators should more actively monitor activities and transactions occurring on those exchanges.

E. Tailored Detection Algorithm

Because non-banks can also undermine market integrity,[141] another option is to create a detection screen based on financial metrics as opposed to the legal form of a market participant. Such a screen could be used to flag abnormal

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138.   *See, e.g.*, Jeffrey E. Cohen, *The Dynamics of the "Revolving Door" on the FCC*, 30 AM. J. POL. SCI. 689 (1986); William T. Gormley, Jr., *A Test of the Revolving Door Hypothesis at the FCC*, 23 AM. J. POL. SCI. 665 (1979).

139.   Many exchanges are self-regulated. Well-known examples include the New York Stock Exchange (NYSE), the Financial Industry Regulatory Authority (FINRA), and the Fixed Income Clearing Corporation (FICC).

140.   *Committees*, LONDON METAL EXCHANGE, https://www.lme.com/Company/About/Committees [https://perma.cc/4N7X-2Q7D].

141.   *See infra* Section V.F.

deviations in financial metrics that are proven to be highly correlated with artificial market distortions.

Supervisors and regulators have limited resources and cannot hunt down every lead. While newspapers can publicize alleged schemes, they may not do so in time to be able to stop them (Figure 11). Having an early warning signal would enable supervisors and regulators to thoroughly investigate any identified aberrations and intervene, if necessary, to limit the damage done to markets. Thus, a supervisory detection algorithm, along the lines of one outlined in this section, could help deter similar schemes in the future. (Here, the framework is applied to U.S. regional data. For the European case study, see Appendix B).

Figure 11: Midwest Premium and Timeline[142]
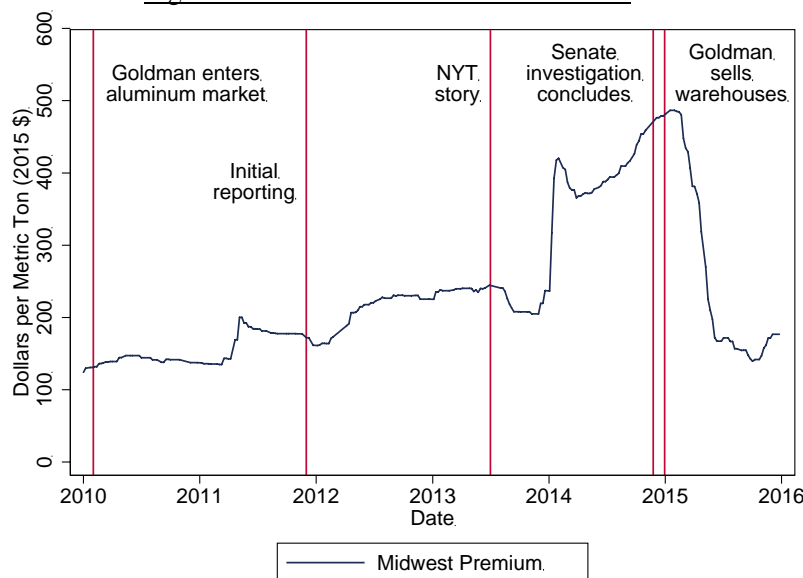
We do not claim that our algorithm is perfectly designed. Our goal is to outline the basic mechanisms of a framework and to demonstrate its great potential. Agencies should employ the insights developed here to create better statistical screens, leveraging more sophisticated quantitative techniques and their access to confidential data. Indeed, with recent advances in computing power, machine learning, and "Big Data," the field of supervisory technology is booming. The SEC, for instance, now uses statistical screens for market surveillance and suspicious trading detection; similarly, the Federal Reserve Bank of New York also uses powerful algorithms for market monitoring.[143]

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142.   S&P Global Platts (retrieved from Bloomberg).
143.   Fin. Stability Inst., *FSI Insights on Policy Implementation No. 9: Innovative Technology in Financial Supervision (Suptech) – the Experience of Early Users*, BANK INT'L SETTLEMENTS (July 2018), https://www.bis.org/fsi/publ/insights9.pdf [https://perma.cc/J3QH-KKVL].

Our framework, which incorporates the insights developed from the previous parts of this paper, is meant to detect artificial distortions in commodity markets. Specifically, the algorithm uses inventories, regional premiums, and warehouse load-out wait times as inputs. Unlike detection methods that rely on spot and futures market prices, our algorithm accounts for inventory delivery backlogs as well as regional supply and demand shocks, which raise transaction prices for industrial users but do not affect spot or futures prices.

In our model, the key to detecting a regional price distortion is identifying *structural breaks* in commodity inventories, queues, and premiums. There has to be a trend break in each of the three variables.[144] For example, the market participant must acquire an unusually large inventory of the commodity, which can be detected as a break in the inventory trend. Likewise, there has to be an abnormal spike in queue length and a subsequent increase in the regional price, which are captured by breaks in the cancelled-warrant and premium trends, respectively.

Following the intuition that underlies the complements logic in our differences-in-differences estimation, the relevant inventory, queue, and premium series are the differences between those of the commodity of interest (aluminum in our case) and those of its production complement (copper). These series are plotted in Figure 12. In other words, we are searching for a structural break in the differences between the inventory, queue, and premiums of aluminum and those of copper. The existence of a statistically significant break across these three series indicates the existence of a market distortion with high probability.

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144.   *See* Jushan Bai, Robin Lumsdaine & James H. Stock, *Testing for and Dating Common Breaks in Multivariate Time Series*, 65 REV. ECON. STUD. 395, 395-97 (1998).

Figure 12: U.S. Aluminum-Copper Inventory, Queue, and Premium Spreads[145]
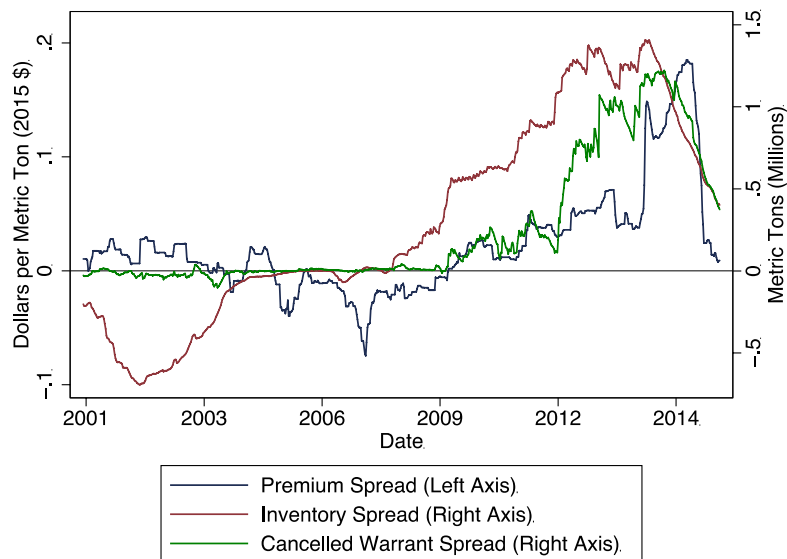
This approach has two primary advantages. First, testing for a simultaneous break across multiple series improves the econometric estimate by giving a tighter confidence interval around the estimated break date, relative to testing for a break with a single series.[146] The confidence interval of a break estimate decreases with the number of variables, not the sample size. The confidence interval is helpful for regulators who are interested in both the date of the break and the uncertainty. Second, using the difference between a commodity and its complement eliminates the effect of natural supply and demand shocks. A detection algorithm is better if it generates a relatively small number of false positives. Because the differenced variables will not vary with common shocks, the model should detect fewer spurious breaks.

We use the model developed by Bai, Lumsdaine, and Stock[147]—and employed by Hansen[148] and by Bekaert, Harvey, and Lumsdaine[149]—to test for and date a structural break across multiple time series. Specifically, we estimate a vector autoregression (VAR) of the form:[150]

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145.   London Metal Exchange (retrieved from Bloomberg); S&P Global Platts (retrieved from Bloomberg).

146.   *See* Bai, Lumsdaine & Stock, *supra* note 144, at 395-97.

147.   *Id.*

148.   Bruce E. Hansen, *The New Econometrics of Structural Change: Dating Breaks in U.S. Labor Productivity*, 15 J. ECON. PERSP. 117, 122-23 (2001).

149.   Geert Bekaert, Campbell R. Harvey & Robin Lumsdaine, *Dating the Integration of World Equity Markets*, 65 J. FIN. ECON. 203, 205 (2002).

150.   A univariate autoregression is a single-equation, single-variable linear model in which the current value of a variable is explained by its own lagged values. (Here, "lagged" means in the past.) A VAR is an *n*-equation, *n*-variable linear model in which each variable is in turn explained by its own

$$y_t = \alpha + \sum_{i=1}^{4} A_i y_{t-i} + \varepsilon_t \ (2)$$

where y_t is a $3 \times t$ vector containing the premium, inventory, and queue length variables. To estimate the model, we use weekly data on inventories, cancelled warrants, and premiums from November 1999 through December 2015. The model has four weekly lags. (The lag length was determined by the Akaike Information Criterion, which is a lag selection procedure that tends to produce the most accurate models using small time series data sets.[151]) The model tests whether there exists a date, γ, such that:

$$\alpha + A_j = \begin{cases} \alpha_1 + A_{j,1} \ for \ t < \gamma \\ \alpha_2 + A_{j,2} \ for \ t \geq \gamma \end{cases} \ (3)$$

In other words, for every week in the data set, we split the data into two sample periods: the sample period before the selected week and the sample period after the selected week. We then estimate the coefficients in the VAR model in Equation 2 using each sample period and test whether there is a statistically significant difference between the coefficients estimated using the two different samples. The week for which the difference in model parameters is most statistically significant is the structural break date.[152]

Over the full sample period, November 1999 through December 2015, the model estimates a break date on of January 8, 2012, with the 90 percent confidence interval beginning on January 1, 2012, and ending on January 15, 2012 (Figure 13). In reality, regulators do not have the luxury of looking for structural breaks using the full sample period because they do not know when a scheme like Goldman's warehousing operation is occurring. To better simulate a real scenario, we run our algorithm using only the data available to regulators while the scheme was ongoing. For instance, if we only use data available up until December 2012, we estimate the same break date, January 8, 2013, and confidence interval. This means that a regulator using our algorithm in late 2012 or early 2013 would have seen a statistically significant break in the physical aluminum market in late 2012, more than six months before the operation was publicized by *The New York Times*.

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lagged values, plus current and past values of the remaining *n-1* variables. For a general discussion, see, for example, JAMES H. STOCK & MARK W. WATSON, INTRODUCTION TO ECONOMETRICS (2011).

151.   *See* Joseph E. Cavanaugh & Andrew A. Neath, *The Akaike Information Criterion: Background, Derivation, Properties, Application, Interpretation, and Refinements*, 11 WIRES COMPUTATIONAL STAT. 1460 (2019).

152.   Break dates too close to the beginning or end of the selected sample cannot be identified, because there are too few observations at the end points to identify the model parameters. We use a trimming value of 5 percent to get around the problem. For example, if there are 100 days in the sample, the model only tests for possible structural breaks dates between day 5 and day 95.

Figure 13: Test for Common Break in the U.S. Aluminum Market, Estimate and 90 Percent Confidence Interval[153]
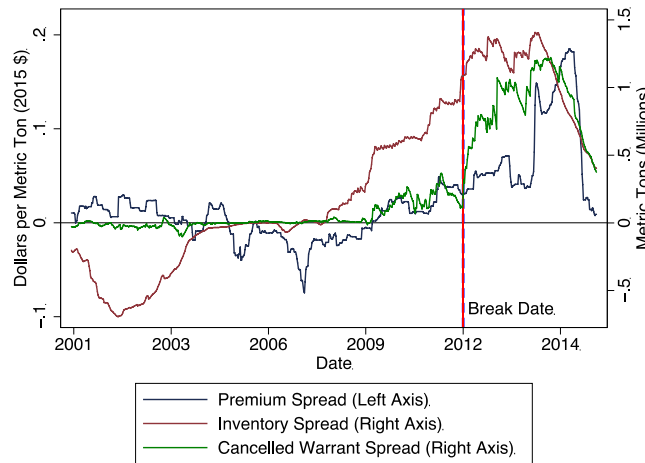
There is no such thing as a one-size-fits all detection algorithm. This is why existing detection methods allowed the regional market distortion to slip between the cracks. Those detection methods were focused on spot and futures prices, which change only due to global determinants of supply and demand. Regional factors, particularly changes in regional transaction costs, are not accurately reflected in those global prices. Regulators should utilize the lessons from various case studies and tailor the detection algorithms accordingly. Ours is particularly well suited to raising the alarm when there is an anomaly in regional commodity markets.

To be sure, detection algorithms, just like other methods used by regulators to monitor financial markets, can be "gamed" by the regulated parties. In the context of regional physical commodity markets, if a firm wishes to artificially inflate the price of a commodity, and if it knows the complements used by regulators in the structural break test, then that firm could avoid detection by artificially inflating the price of both commodities. While inflating the prices of multiple commodities simultaneously is possible, it would be much more expensive and much more operationally difficult than inflating the price of a single commodity. Moreover, regulators could make this prohibitively expensive by expanding the range of complements used in the detection algorithm. At the very least, this algorithm can help regulators combat market malfeasance by significantly increasing the costs of it.

F. Market Manipulation

Throughout this Article, we have been careful to not use the word "manipulation" in the sense of "market manipulation." There is a reason we toe

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153. London Metal Exchange (retrieved from Bloomberg); S&P Global Platts (retrieved from Bloomberg).

the line between market manipulation and market distortion—proving market manipulation under the existing statutory law and case law is very difficult. The approach described in the previous Section has the added virtue of making it more provable because at least two elements of it can be subject to empirical analysis.

The Commodity Exchange Act prohibits the manipulation or attempted manipulation of the price of any commodity.[154] Proving a case of alleged manipulation in commodity markets requires proving four elements: (i) an act or omission, (ii) an artificial price, (iii) causation, and (iv) specific intent.[155] The discussion and analysis around market manipulation has always been murky because "no statute, regulation, or case defines manipulation for the purposes of the Commodity Exchange Act," which has resulted in a non-systematic approach to analyzing allegations of manipulation.[156] An artificial price has been described as one that does not "reflect basic forces of supply and demand."[157] But how does one know when a price fails to reflect that? What are the basic forces of supply and demand? Some scholars have therefore described manipulation in commodity markets as an unprosecutable crime.[158] Others even question whether manipulation exists.[159]

That might be a stretch. Our analysis has the added virtue of showing that two of the elements—price artificiality and causality—lend themselves to identification via empirical methods. We present an intuitive method to prove price artificiality and causality in regional commodity markets. Our approach compares the regional price of the commodity in question to the regional price of its strongest complement, where two commodities are complements if they react similarly to a shock. Because our method uses a difference-in-differences regression model, it has the added benefit of being able to prove both artificial prices and causation.

Conclusion

The separation of banking and commerce has a long history in the United States. Cracks in the wall have emerged in recent decades, however, and they are only widening. While greater cross-pollination between the two may provide efficiency gains from diversification, it may also weaken market integrity and lead to an excessive concentration of economic power.

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154.   7 U.S.C. § 9 (2018).

155.   *See* Jerry W. Markham, *Manipulation of Commodity Futures Prices—The Unprosecutable Crime*, 8 YALE J. ON REGUL. 281, 349 (1991).

156.   Rosa M. Abrantes-Metz, Gabriel Rauterberg & Andrew Verstein, *Revolution in Manipulation Law: The New CFTC Rules and the Urgent Need for Economic and Empirical Analyses*, 15 PENN. J. BUS. L. 357, 362 (2013).

157.   Cargill, Inc. v. Hardin, 452 F.2d 1154, 1163 (8th Cir. 1971).

158.   Markham, *supra* note 155.

159.   *See* Daniel R. Fischel & David J. Ross, *Should the Law Prohibit "Manipulation" in Financial Markets?*, 105 HARV. L. REV. 503 (1991).

This Article presents an empirical study of an episode in the U.S. regional metals market during the early 2010s, when financial institutions sought to take advantage of depressed commodity markets in the aftermath of the 2008-2009 financial crisis. Our analysis does not disprove the potential diversification benefits that come with operating new business lines that may bridge banking and commerce. But our analysis does show that such diversification is not costless. Part III details the economic impact to market integrity (in our case, a threefold increase in the Midwest premium) and the harm to industrial producers and household consumers (here, higher prices of goods that are manufactured using aluminum). The latter impact, in particular, is worth emphasizing, because the actions undertaken by financial institutions in commodity markets have significant consequences outside of financial markets. Given the fragility of global supply chains highlighted by the COVID-19 pandemic, it would seem highly desirable for policymakers to enact straightforward guardrails to prevent the potential of further harm to industrial producers and household consumers.

Indeed, policymakers should internalize the lesson that weakening the existing separation is not merely a theoretical debate. A slow brick-by-brick erosion may have unintended, undesired consequences on markets, businesses, and consumers. Notably, the 2010-2014 market distortion described in this Article may recur. The legal framework remains unchanged, and financial institutions respond to incentives. With respect to incentives, commodities are still relatively cheap compared to assets like equities.[160] In addition, commodity markets have become incredibly volatile following the COVID-19 pandemic: for example, in 2021, the price of lumber more than doubled from January to May and then fell to below its January level in the subsequent two months.[161] Taken together, these facts suggest that commodity markets remain vulnerable to schemes similar to ones describes in this Article.[162] Solving this problem will require action from Congress as well as coordination among the Treasury, Federal Reserve, and CFTC.

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160. Ryan Dezember, Georgi Kantchev & Chuin-Wei Yap, *Commodities Remain a Popular Bet Despite Recent Declines*, WALL ST. J. (Jun. 27, 2021), https://www.wsj.com/articles/commodities-remain-a-popular-bet-despite-recent-declines-11624753695 [https://perma.cc/6L42-LA2J] (showing that commodity indexes have underperformed the S&P 500 in recent years).

161. *Lumber (LBS)*, NASDAQ (Aug. 2, 2021), https://www.nasdaq.com/market-activity/commodities/lbs; *see also* Dezember, Kantchev & Yap, *supra* note 160 (describing the turnaround in commodity prices); Ryan Dezember, Joe Wallace & Andrew Barnett, *What Commodity Prices Are Saying About Inflation*, WALL ST. J. (May 20, 2021), https://www.wsj.com/articles/what-commodities-prices-are-saying-about-inflation-11621485045 [https://perma.cc/CHZ4-PU2X] (describing soaring commodity prices).

162. *See* Joe Wallace & Hardika Singh, *Aluminum Notches Decade Highs on Soaring Demand, Snarled Supplies*, WALL ST. J. (Aug. 30, 2021), https://www.wsj.com/articles/aluminum-notches-decade-highs-on-soaring-demand-snarled-supplies-11630311034 [https://perma.cc/XM5S-A6HB] ("A chunk of aluminum is still locked up in financing deals that investors, banks and trading firms struck last year, said Wenyu Yao, a strategist at ING Groep, further limiting available supplies. The deals involved buying aluminum, placing it in storage and selling the metal forward. . . . The trade's popularity prompted smelters to produce metal in shapes that could be sold to banks, crimping output of other varieties whose prices have now shot up, Ms. Yao added.").

Appendix A: Estimated Impact on Consumers

Consumers typically purchase carbonated beverages at retail stores in either aluminum or plastic containers.[163] For a beverage like Coca-Cola, the contents inside the aluminum and plastic containers are identical. The only difference is the container size and number of containers in a package. Two-liter plastic bottles (67.6 ounces) are almost always sold in single units, while aluminum cans (12 ounces) are most commonly sold in packages of 12, 20, or 24.

Carbonated beverages provide an ideal setting to estimate the effect of aluminum price manipulation on consumer goods, because we can compare the prices of goods that are nearly identical except for the packaging: one set of goods uses aluminum packaging, and another set of goods uses plastic packaging. If the prices of bottled and canned carbonated beverages move in parallel, and the differences in price are time invariant, a difference-in-differences model will allow us to estimate the effect of manipulation on the price of carbonated beverages sold in aluminum cans.

We use carbonated beverage price data from the Nielson Retail Scanner database.[164] This database consists of weekly consumer goods prices from point-of sale systems at retail stores across the United States. In this analysis, we use prices scanned at the register for about 56 million Coca-Cola beverage purchases. The Coca-Cola Company was among the first to complain to the LME in the summer of 2011 about increased aluminum costs caused by queue lengths at the Detroit LME warehouses.[165] We narrow the focus of this case study to a single brand for computational ease. Including other brands in the analysis, like Pepsi, yields similar results.

The average prices of Coca-Cola in cans and Coca-Cola in bottles from 2006 to 2010 are plotted in Figure 14, with the 30-day moving averages plotted in the solid lines. Though there is more volatility in the aluminum can price, the long-term trends appear similar prior to Goldman Sachs's entry into the aluminum market in February 2010. To confirm this visual evidence, we use a means comparison test on the weekly growth rates of the price of Coca-Cola in aluminum cans and the price of Coca-Cola in plastic bottles. Using data from January 2006 through January 2010, we fail to reject the null hypothesis—that the mean difference in growth rates in Coca-Cola in aluminum cans and plastic bottles is zero—with a p-value of 0.96. Despite the short-run volatility in prices, the long-term price trends are nearly identical. After February 2010, the price of aluminum cans appears to increase somewhat more than plastic bottles, but the difference between the trends after February 2010 is subtle. Given that the container cost represents only a fraction of the total beverage cost, which

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163.   Consumers also can purchase carbonated beverages in glass bottles, though glass bottles are significantly more expensive than either plastic or aluminum and represent a small fraction of the market. Using glass bottles instead of plastic bottles as the control group in the difference-in-difference regression does not have a significant effect on the results presented in Table 1.

164.   Nielson Retail Scanner data retrieved from NielsenIQ database.

165.   Kocieniewski, *supra* note 1.

includes ingredients, marketing, distribution, etc., we would not expect a large price response to an aluminum price increase.

Figure 14: Coca-Cola Prices: Plastic Bottle and Aluminum Cans[166]
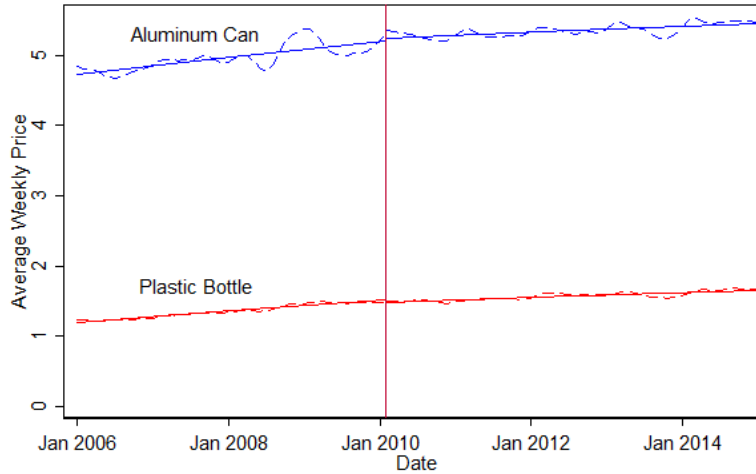
We use a difference-in-differences model, similar to the model used in analyzing the Midwest premium, to estimate whether there was a price increase in aluminum cans of Coca-Cola relative to plastic bottles of Coca-Cola after February 2010:

$$P_{i,t} = \alpha + \beta_1 Can_i + \beta_2 Post_t + \beta_3 Can_i \times Post_t + \beta_4 X_{i,t} + \varepsilon_{it} \text{ (4)}$$

where *i* indexes beverage container and *t* indexes the date. The *Can* variable is an indicator for aluminum cans; *Can* = 1 for aluminum cans and *Can* = 0 for plastic bottles. The *Post* variable is an indicator for the dates after Goldman Sachs purchased Metro International; *Post* = 0 prior to February 2010 and *Post* =1 after. Additional controls are contained in $X_{i,t}$, including week by year fixed effects, month fixed effects, year fixed effects, and state fixed effects.

The results of this difference-in-differences model are presented in Table 3. The first column presents least squares estimates of equation above with no time or location fixed effects. Using Coca-Cola in plastic bottles as a control, we find that the average price of Coca-Cola in aluminum cans increased $0.09 per multi-can package. Adding week of sample, month, year, and state fixed effects increases the estimated effect slightly to $0.11 per multi-can package, which translates into about a half-cent increase per can (Column 2).

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166.   Nielsen Retail Scanner database. The aluminum can price reflects the average weekly price of 12 ounce cans in 12, 20, and 24 unit packages. The plastic two-liter bottle (67.6 ounces) reflects the average price of a single unit package.

Table 3: Coca-Cola Regression Results

Dependent Variable: Coca-Cola Price

	(1)	(2)
Aluminum Can x Post	0.0933*** (0.00683)	0.107*** (0.00691)
R^2	0.979	0.984
Controls Included:		
State FE	NO	YES
Month and Year FE	NO	YES
Week-of-Sample	NO	YES
Sample Period:		
Jan. 2006 – Dec. 2014	X	X

Notes: Each column contains the results for a separate regression. The data are reported weekly by country. The parentheses contain standard errors that are clustered by county. *** denotes significance at the 1 percent level.

The distortion in the U.S. aluminum market increased the price of a can of Coca-Cola by 1.6 percent. It is reasonable to assume that other consumer goods with aluminum packaging had similar increases. In 2015, aluminum packaging made up only 20 percent of domestic aluminum consumption.[167] Other categories, including automotive and consumer durables, accounted for a much greater share of domestic aluminum consumption. They may have experienced larger price increases. This points to a significant welfare loss caused by the manipulative scheme.

167.   *Mineral Commodity Summary 2016*, U.S. GEOLOGICAL SURV. 20 (2016), https://s3-us-west-2.amazonaws.com/prd-wret/assets/palladium/production/mineral-pubs/mcs/mcs2016.pdf [https://perma.cc/B7NB-MLQN].

Appendix B: European Case Study

In late 2011, as the Midwest aluminum premium rose in response to record levels of cancelled-warrant inventories in the Detroit LME warehouses, a similar trend emerged in the European aluminum market. Prior to December 19, 2011, the cancelled-warrant inventory levels for aluminum were extremely low at the LME warehouses in the port city of Vlissingen, Netherlands. Over the previous twelve months, only 0.008 percent of the total LME aluminum inventory in Vlissingen were cancelled-warrant inventories. In fact, during the first week of December 2011, the cancelled-warrant inventory level was zero for aluminum in the Vlissigen LME warehouses. That changed between December 19, 2011, and December 31, 2011, when the cancelled-warrant level for aluminum exploded from five tons to 500,000 tons (Figure 15). Aluminum warrant cancellations continued to grow throughout 2012, and the cancelled-warrant inventory represented an average of 49 percent of the total aluminum stock in the Vlissingen LME warehouses during that year.[168]

Figure 15: Cancelled-Warrant Inventories in Vlissingen LME Warehouses[169]
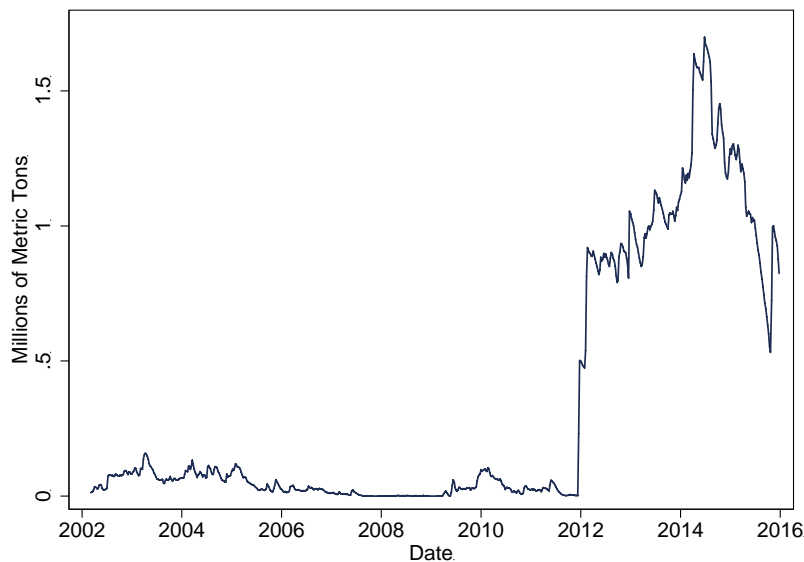
In August 2011, six months before the enormous wave of warrant cancellations, twenty-seven of the twenty-nine LME warehouses in Vlissingen were purchased by Glencore,[170] a commodity trading firm that was involved in

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168. Authors' calculation based on London Metal Exchange data retrieved from Bloomberg.

169. London Metal Exchange (retrieved from Bloomberg).

170. *See Glencore Completes Deal for Pacorini Metals*, REUTERS (Sept. 14, 2010), https://www.reuters.com/article/pacorini-metals-idUSLDE68D0RR20100914 [https://perma.cc/W2NR-

cancelled-warrant transactions in the Detroit warehouses. In Vlissingen, Glencore appeared to follow the same scheme employed by Goldman in Detroit. First, Glencore attracted record levels of aluminum to the Vlissingen warehouses by paying incentives to aluminum stockholders. These rebates more than doubled the aluminum in Glencore's warehouses, which eventually held as much as 93 percent of the total European LME aluminum inventory (Figure 16).

Figure 16: European Aluminum Inventories (LME)[171]
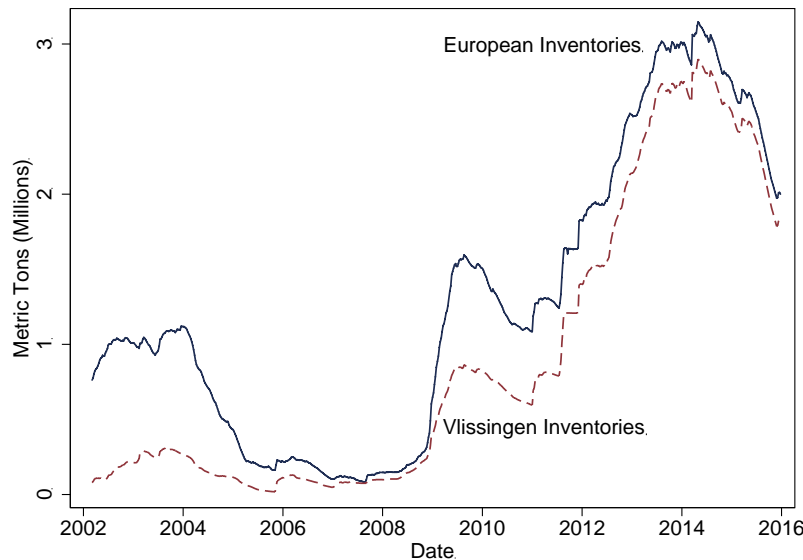
Following a substantial buildup of aluminum inventory in the Vlissingen warehouses, aluminum warrants were cancelled at a record level. Glencore responded to the cancelled warrants by only loading out the daily minimum tonnage required by LME. [172] This caused the load-out queue at the Vlissingen warehouses to rise with the level of cancelled warrants. The queue length at Vlissingen peaked in June 2014 at 774 days, over three months longer than the queue at Goldman's Detroit LME warehouses at the time. During this disruption of the local aluminum market, the European aluminum premium rose as the queue length restricted access to LME aluminum inventories, which act as a backstop option for industrial aluminum consumers (Figure 17).

Unlike the U.S. Senate's investigation of Goldman Sachs, there has been no public investigation of Glencore's purchase and management of the Vlissingen warehouses. Without the data revealed by a public investigation, we

D6YB]; Maytaal Angel & Melanie Burton, *Glencore Profits from Metals Backlog in Dutch Port*, REUTERS (Apr. 27, 2012), https://www.reuters.com/article/us-glencore-metals-warehousing/glencore-profits-from-metals-backlog-in-dutch-port-idUSBRE83Q0JZ20120427 [https://perma.cc/HJ87-92S7].

171.   London Metal Exchange (data retrieved from Bloomberg).

172.   *See* Staff Report, *supra* note 43, at 184 n.1088; *id.* at 198 n.1181.

do not know which firm(s) cancelled the aluminum warrants. Therefore, we do not address whether the practices at Glencore's Vlissingen warehouses caused the European aluminum premium to rise, though we suspect that is the case. Rather, we investigate whether our detection algorithm would have indicated the probable existence of a market distortion. Our answer is yes. Notably, this answer is supported by reporting at the time by the *Financial Times* and *Reuters*, which raised concerns about Glencore's practices. [173]

Figure 17: European Aluminum Premium[174]
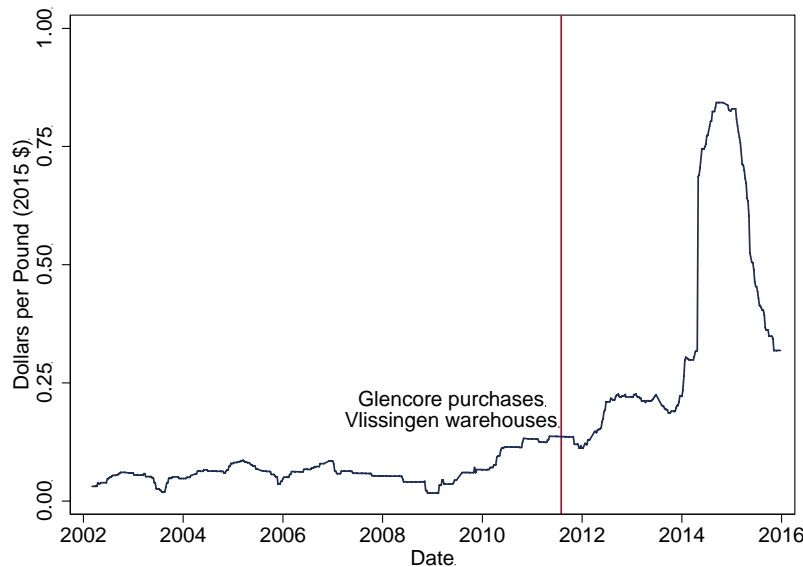
In order to perform the empirical analysis, we once again use copper as a complement for aluminum and estimate whether there was a statistically significant structural break in the aluminum-copper European premium spread, the aluminum-copper European LME inventories, and the aluminum-copper European cancelled-warrant levels (a proxy for warehouse queues). Over the full sample period, March 2002 through December 2015, our model estimates a break occurred on December 15, 2011, with the 90 percent confidence interval beginning two weeks prior to the break and ending two weeks after the break (Figure 18). Not surprisingly, this break coincides with the jump in cancelled warrants that occurred six months after Glencore purchased the warehouses. To better approximate the problem facing regulators, we again run our algorithm using only data available to regulators in real time to determine whether the scheme could have been detected earlier. If we use only data through December

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173.   Angel & Burton, *supra* note 170; Jack Farchy, *Warehousing Problem Hangs Over LME*, FIN. TIMES (Jan. 19, 2012), https://www.ft.com/content/2cfdc5ec-4280-11e1-97b1-00144feab49a [https://perma.cc/7TV4-7E62].

174.   London Metal Exchange (retrieved from Bloomberg)

2012, we estimate the same break date and an almost identical confidence interval. A regulator using our algorithm in late 2012 would have found that a statistically significant break occurred in the European aluminum market in late 2012.

Figure 18: Test for Common Break in the European Aluminum Market, Estimate and 90 Percent Confidence Interval[175]
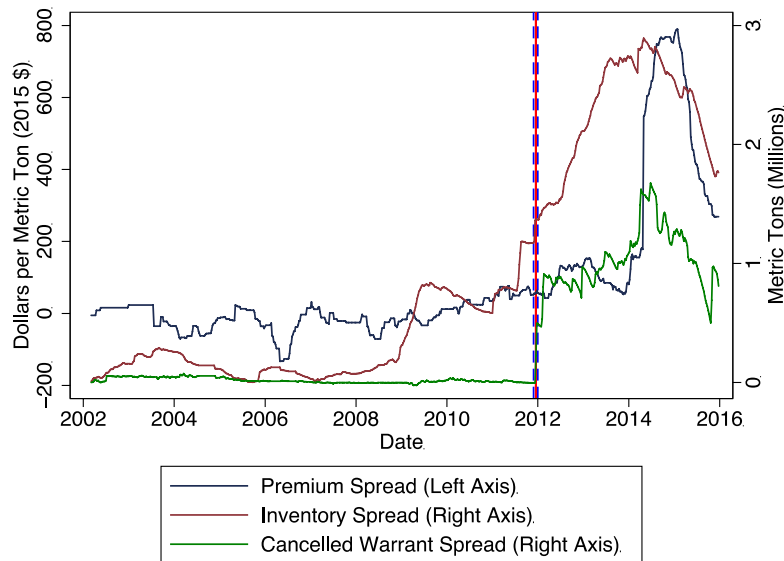
Because our detection algorithm estimates a statistically significant break in both the U.S. and European regional aluminum markets in late 2011, an objection could be that our algorithm is detecting shifts in a global aluminum market and not a unique market distortion. However, this phenomenon of skyrocketing cancelled warrants and extraordinary queue lengths did not occur throughout the global aluminum market. Of the 139 LME warehouses operating in June 2014, only the warehouses owned by Goldman Sachs in Detroit (which had a 681 day queue) and Glencore in Vlissingen (which had a 774 day queue) had non-zero load-out queues.[176] At every other warehouse in the world, there was a zero-day wait time for aluminum.[177] This was also true for every other metal traded on the LME.[178] Given that about half of global LME inventories were not stored at warehouses owned by Goldman Sachs and Glencore, we would expect to see cancelled warrants and queues rising at other locations if our algorithm were merely detecting a global shift in the aluminum market.

175.   London Metal Exchange (retrieved from Bloomberg).
176.   Authors' calculation based on London Metal Exchange data retrieved from Bloomberg.
177.   Authors' calculation based on London Metal Exchange data retrieved from Bloomberg.
178.   Authors' calculation based on London Metal Exchange data retrieved from Bloomberg.

Appendix C: Simple Demand Model

Market supervisors have multiple resources to identify complements and their expected co-movement behavior. They can look at elasticities provided by industry sources, academic studies, or government institutions like the United States Department of Agriculture. Supervisors also can use their own economic "demand model," like the one provided in this appendix, or a more advanced model from the academic literature

To measure the extent to which industrial metals traded on the LME are production complements of aluminum and, therefore, subject to the same demand shocks, we estimate the cross-price elasticities for each pair of industrial metals using a simple demand model. This demand model is based on Deaton and Muellbauer's almost ideal demand system (AIDS),[179] which has been used to estimate demand models for publicly traded commodities, including agricultural commodities[180] and energy commodities.[181] These demand models estimate total demand, as well as relationships between commodities. In particular, a demand model for industrials metals provides cross-price elasticity estimates, which show whether aluminum and copper are net complements or net substitutes. We follow the usual AIDS approach by modeling the expenditure share for each metal i as:

$$w_i = \alpha_i + \sum_i \gamma_{ij} \ln(p_j) + \beta_i \ln\left(\frac{m}{P^*}\right) + \varepsilon_i \ (5)$$

where w_i is the share of total expenditure for the metal i, p_j is the real price of each of the j metals, m is the total expenditures on metals in the demand system, ε_i is the model residual for metal i, and P^* is the Stone price index, $P^* = \sum_k \frac{w_k}{\ln(p_k)}$. Because we use the Stone price index, as opposed to the translog price index, this model estimates the linear approximate AIDS (LA/AIDS). These expenditures shares are estimated for aluminum, copper, lead, nickel, tin, and zinc, which are all traded on the LME.

Green and Alston show that the uncompensated demand elasticities for metal i can be written as[182]:

$$\eta_{ij} = -\delta_{ij} + \frac{\gamma_{ij}}{w_i} - \frac{\beta_i}{w_i}\left[w_j + \sum_k w_k \ln(P_k^*)\left(\eta_{kj} + \delta_{kj}\right)\right] \ (6)$$

where η_{ij} is the uncompensated elasticity of demand for metals i and j, and δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ if $i = j$ and $\delta_{ij} = 0$ if $i \neq j$). These uncompensated demand elasticities capture allocations between two metals,

179.   Angus Deaton & John Muellbauer, *An Almost Ideal Demand System*, 70 AM. ECON. REV. 312 (1980).

180.   Laura Blanciforti & Richard Green, *An Almost Ideal Demand System Incorporating Habits: An Analysis of Expenditures on Food and Aggregate Commodity Groups*, 65 REV. ECON. & STAT. 511 (1983).

181.   Apostolos Serletis & Asghar Shahmoradi, *Semi-Nonparametric Estimates of Interfuel Substitution in U.S. Energy Demand*, 30 ENERGY ECON. 2123 (2008); Apostolos Serletis, Govina R. Timilsina & Olexandr Vasetsky, *Interfuel Substitution in the United States*, 32 ENERGY ECON. 737 (2010).

182.   Richard Green & Julian M. Alston, *Elasticities in AIDS Models*, 72 AM. J. AGRIC. ECON. 442, 443 (1990).

holding total metal expenditures constant. This demand system with the five industrial metals traded on the LME (aluminum, copper, nickel, tin, and zinc) has twenty-five simultaneous uncompensated demand elasticity equations. Estimation of this system of equations is complicated by endogeneity.[183] We assume price is exogenous, and assume quantity and total expenditures on metals, m, which is a product of the price and quantity variables, are endogenous. If total expenditures are correlated with the error term in Equation 5, then the estimated total expenditure coefficients, β_i, will be biased.

In the economics literature, instrumental variables are typically used to address the endogeneity of m.[184] We use a popular method that Capps Jr. et al.[185] and Dharmasena and Capps Jr. have justified.[186] Following this research, we instrument for total expenditures using a set of variables that includes the log of all real metals prices, which are assumed to be exogenous and capture supply-side influences, and the log of a measure of income (real gross domestic product), which is, to a first-order approximation, exogenous with respect to metal expenditures and captures demand-side influences:

$$\ln(m_t) = c_0 + \sum_{j=1}^{5} c_j \ln(p_{jt}) + c_{11} \ln(GDP_t) + u_t \quad (7)$$

The predicted values for total expenditures by metals type, $\widehat{m}$, are then used as an instrument in the demand system estimation, replacing actual total expenditure in Equation 5. The estimates for these regressions are not displayed and are available by request.

Using this instrument for total expenditures, we estimate an iterated seemingly unrelated regression. This model is fit using annual data from the U.S. Geological Survey on aluminum, copper, lead, nickel, tin, and zinc consumption and prices for the United States from 1970 through 2009.[187] We also use GDP estimates from the Bureau of Economic Analysis.[188] The estimated own-price and cross-price elasticities are presented for each metal in Table 4.

183.   *See* Clifford Attfield, *Homogeneity and Endogeneity in Systems of Demand Equations*, 27 J. ECONOMETRICS 197 (1985).

184.   James S. Eales & Laurian J. Unnevehr, *Simultaneity and Structural Change in U.S. Meat Demand*, 75 AM. J. AGRIC. ECON. 259 (1993); Henry W. Kinnucan, Hui Xiao, Chung-Jen Hsia & John D. Jackson, *Effects of Health Information and Generic Advertising on U.S. Meat Demand*, 79 AM. J. AGRIC. ECON. 13 (1997).

185.   Oral Capps, Jr., Reyfong Tsai, Raymond Kirby & Gary W. Williams, *A Comparison of Demands for Meat Products in the Pacific Rim Region*, 19 J. AGRIC. & RES. ECON. 210 (1994).

186.   Senarath Dharmasena & Oral Capps, Jr., *Intended and Unintended Consequences of a Proposed National Tax on Sugar-Sweetened Beverages to Combat the U.S. Obesity Problem*, 21 HEALTH ECON. 669 (2012).

187.   *See Aluminum Statistics, supra* note 42.

188.   *See Gross Domestic Product*, U.S. BUREAU ECON. ANALYSIS (May 25, 2021), https://www.bea.gov/data/gdp/gross-domestic-product [https://perma.cc/UA9H-VVQJ].

Table 4: Metal Demand Model[189]

	Aluminum	Copper	Lead	Nickel	Tin	Zinc
Aluminum	-0.33378*** (0.0451)					
Copper	-0.28669*** (0.0237)	-0.49639*** (0.0409)				
Lead	-0.09068*** (0.0203)	0.018098 (0.0264)	-0.22092** (0.0965)			
Nickel	-0.11126*** (0.00994)	-0.03816** (0.0169)	-0.13873** (0.0521)	-0.05148*** (0.0457)		
Tin	-0.09764*** (0.00338)	0.042204*** (0.00443)	-0.03417*** (0.0122)	0.010796 (0.00696)	0.022292*** (0.00227)	-0.28427*** (0.0175)
Zinc	-0.01118 (0.0126)	-0.12822*** (0.0180)	-0.1502*** (0.0453)	-0.17775*** (0.0301)	-0.28427*** (0.0175)	0.197535*** (0.0560)

The cross-price elasticity for aluminum and copper, -0.29, is similar in magnitude to the own-price elasticity for aluminum, -0.33, and both are statistically significant, indicating the two goods are strong production complements. The cross-price elasticities for aluminum and the other metals traded on the LME (lead, nickel, tin, and zinc) are all negative, though smaller in magnitude. In other words, those metals are complements of aluminum, but the relationships are not strong as the copper-aluminum relationship. Overall, the demand model confirms that copper is a strong production complement of aluminum.

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189.   * is p value of 0.1, ** is p value of 0.05, *** is p value of 0.01.