150 Years of Boom and Bust:
What Drives Mineral Commodity Prices?

Macroeconomic Dynamics, 2016

- Online-Appendix*-

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*The views in this online-appendix are those of the author and do not necessarily reflect the views of the Federal Reserve Bank of Dallas or the Federal Reserve System. Data is available at https://sites.google.com/site/mstuermer1 or from the author upon request.

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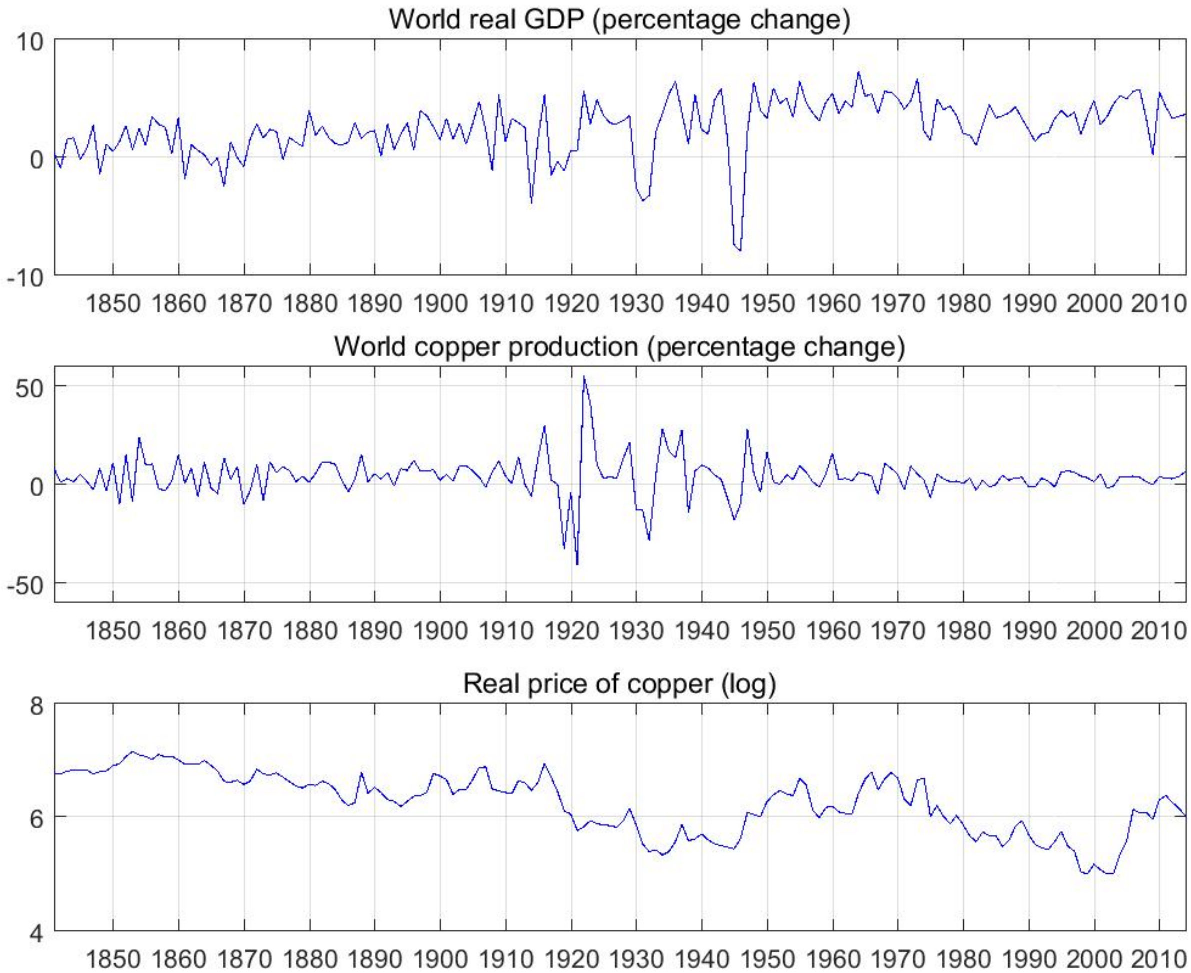


Figure 1: Historical evolution of world real GDP (percentage change), world copper production (percentage change), and the real price of copper (log) from 1841 to 2014.

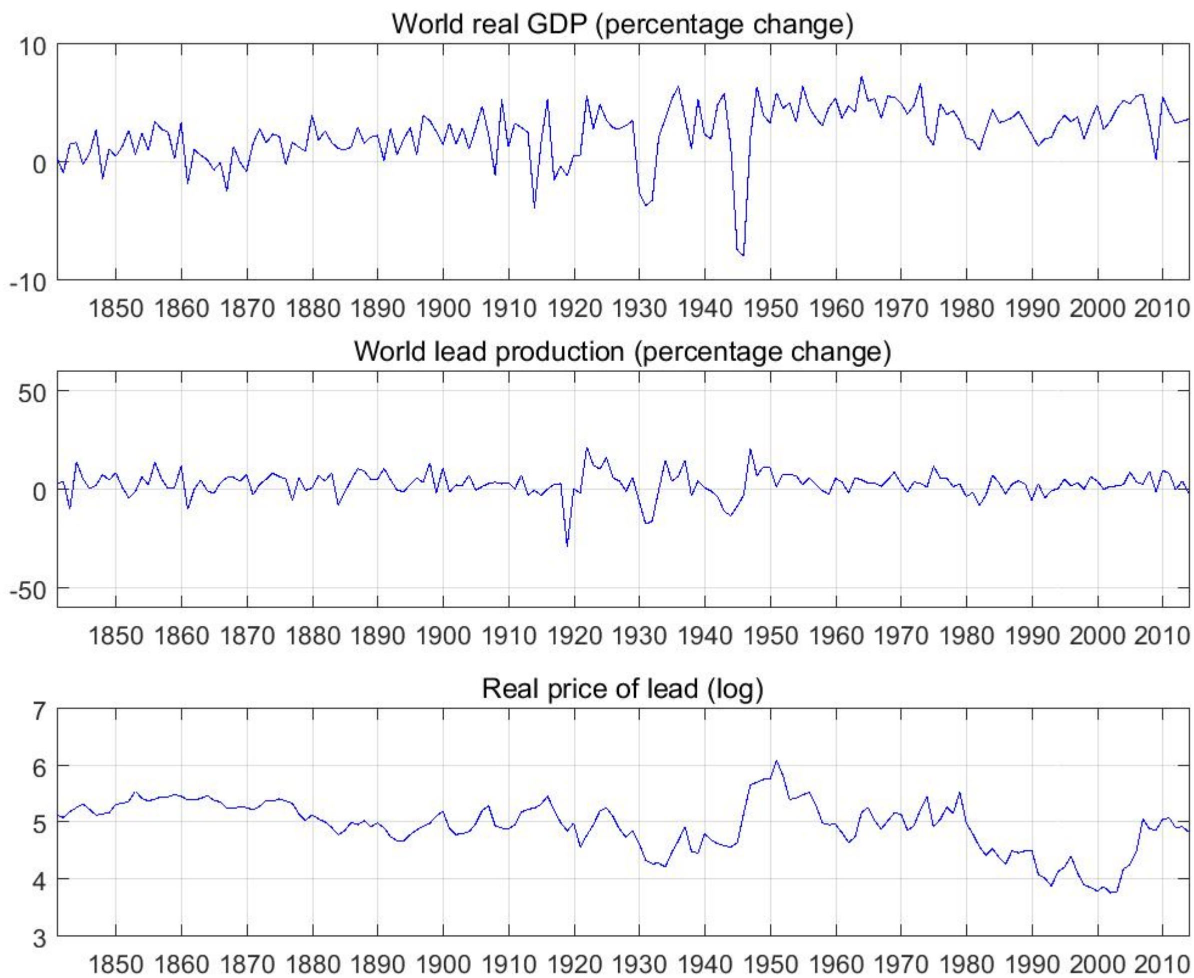


Figure 2: Historical evolution of world real GDP (percentage change), world lead production (percentage change), and the real price of lead (log) from 1841 to 2014.

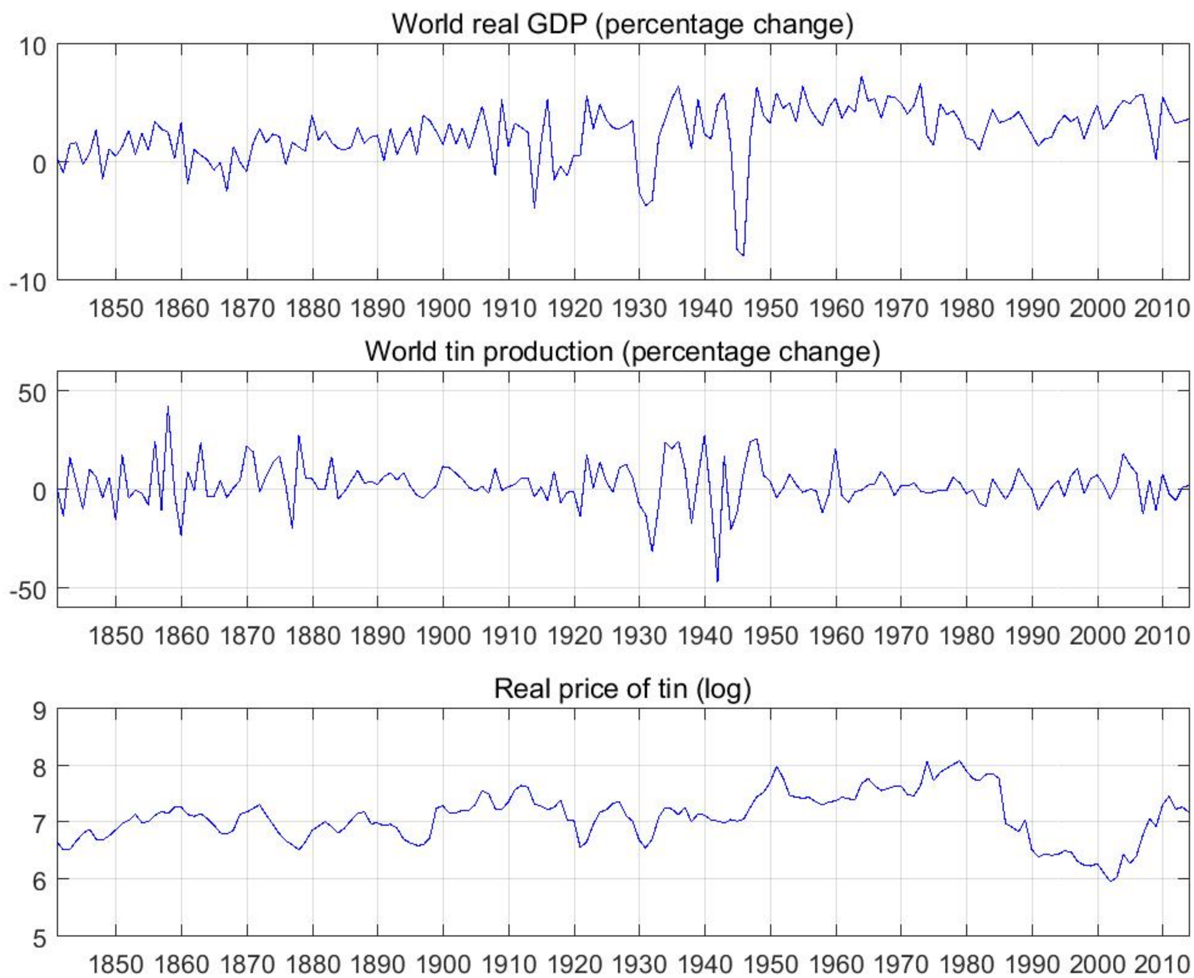


Figure 3: Historical evolution of world real GDP (percentage change), world tin production (percentage change), and the real price of tin (log) from 1841 to 2014.

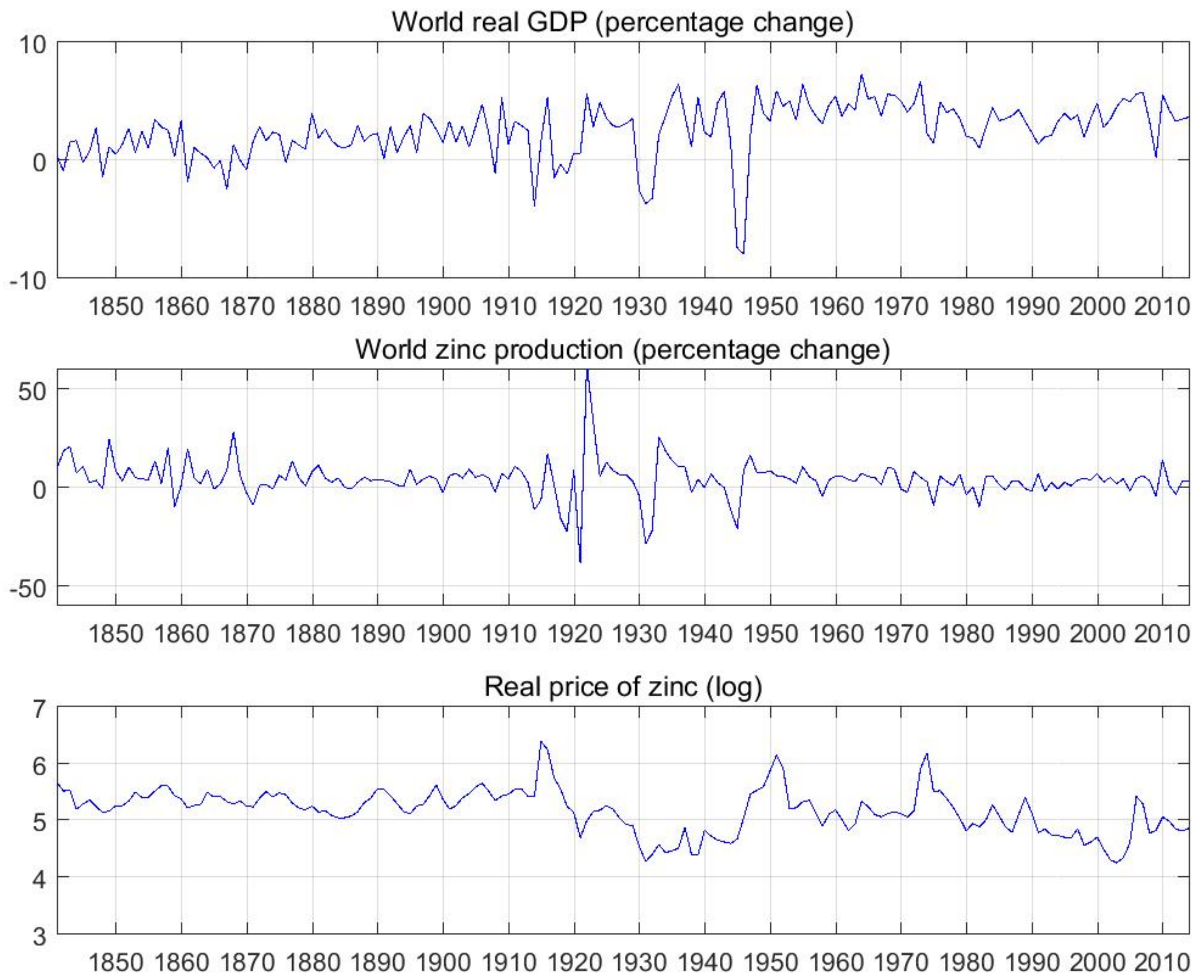
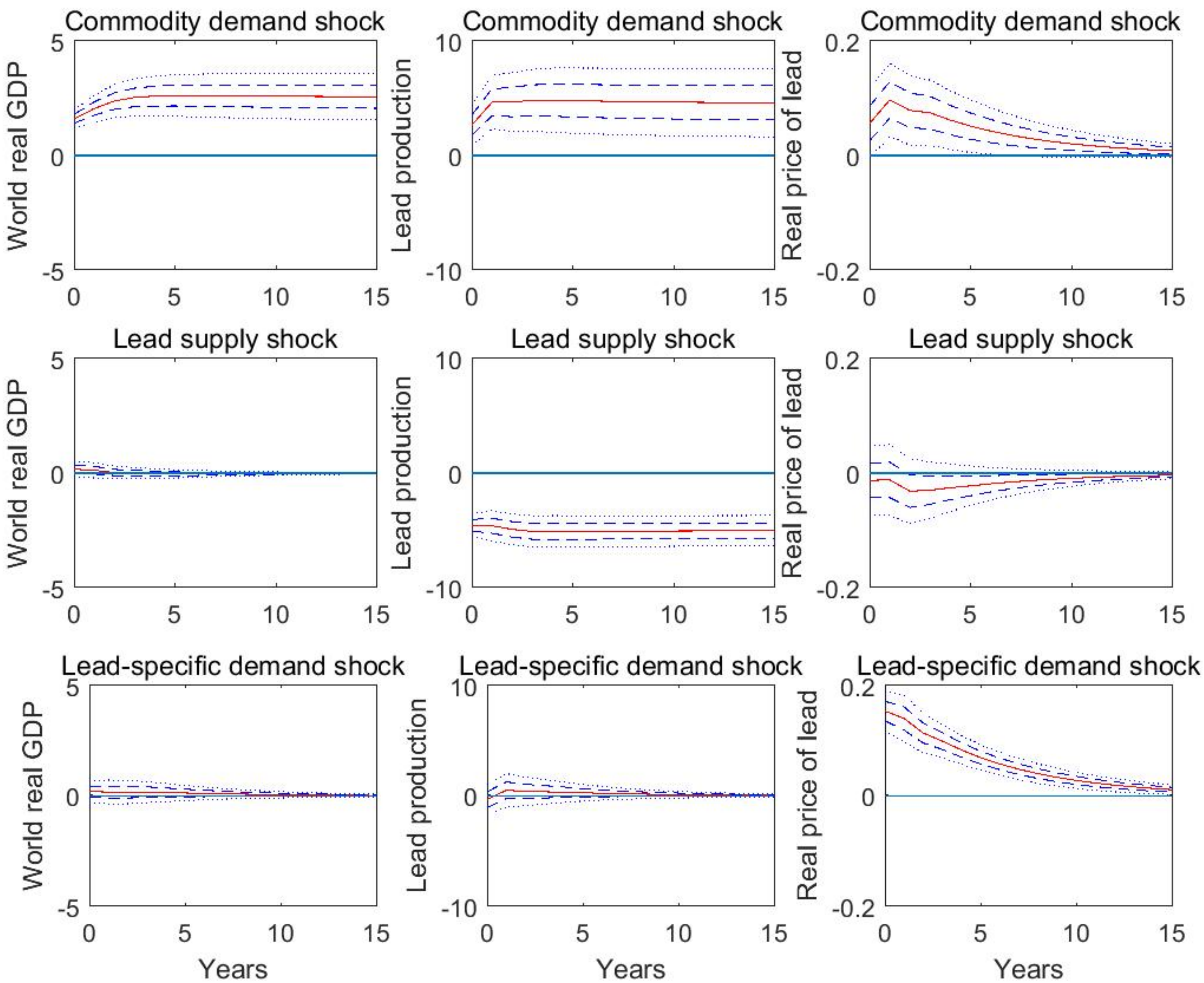
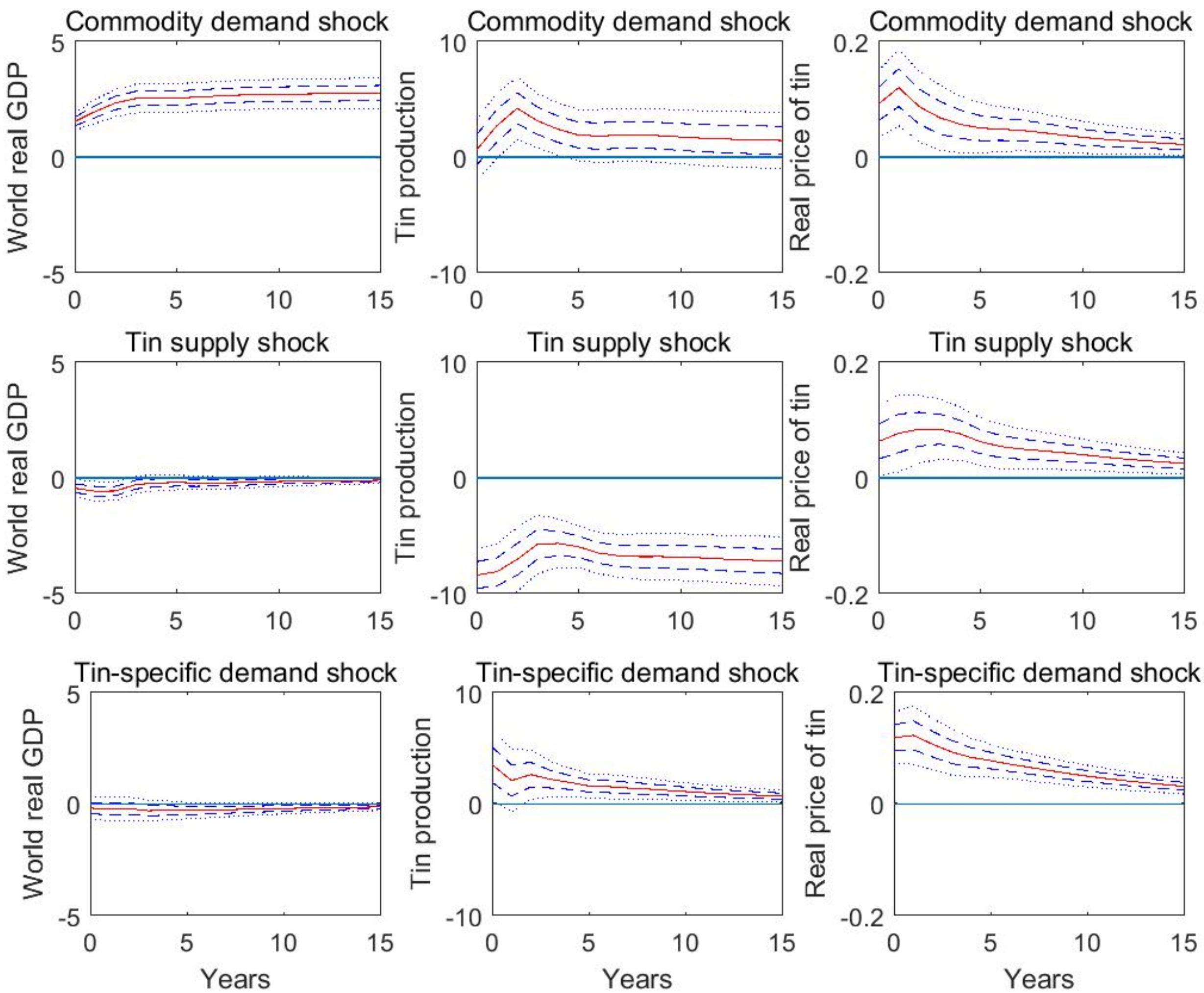


Figure 4: Historical evolution of world real GDP (percentage change), world zinc production (percentage change), and the real price of zinc (log) from 1841 to 2014.



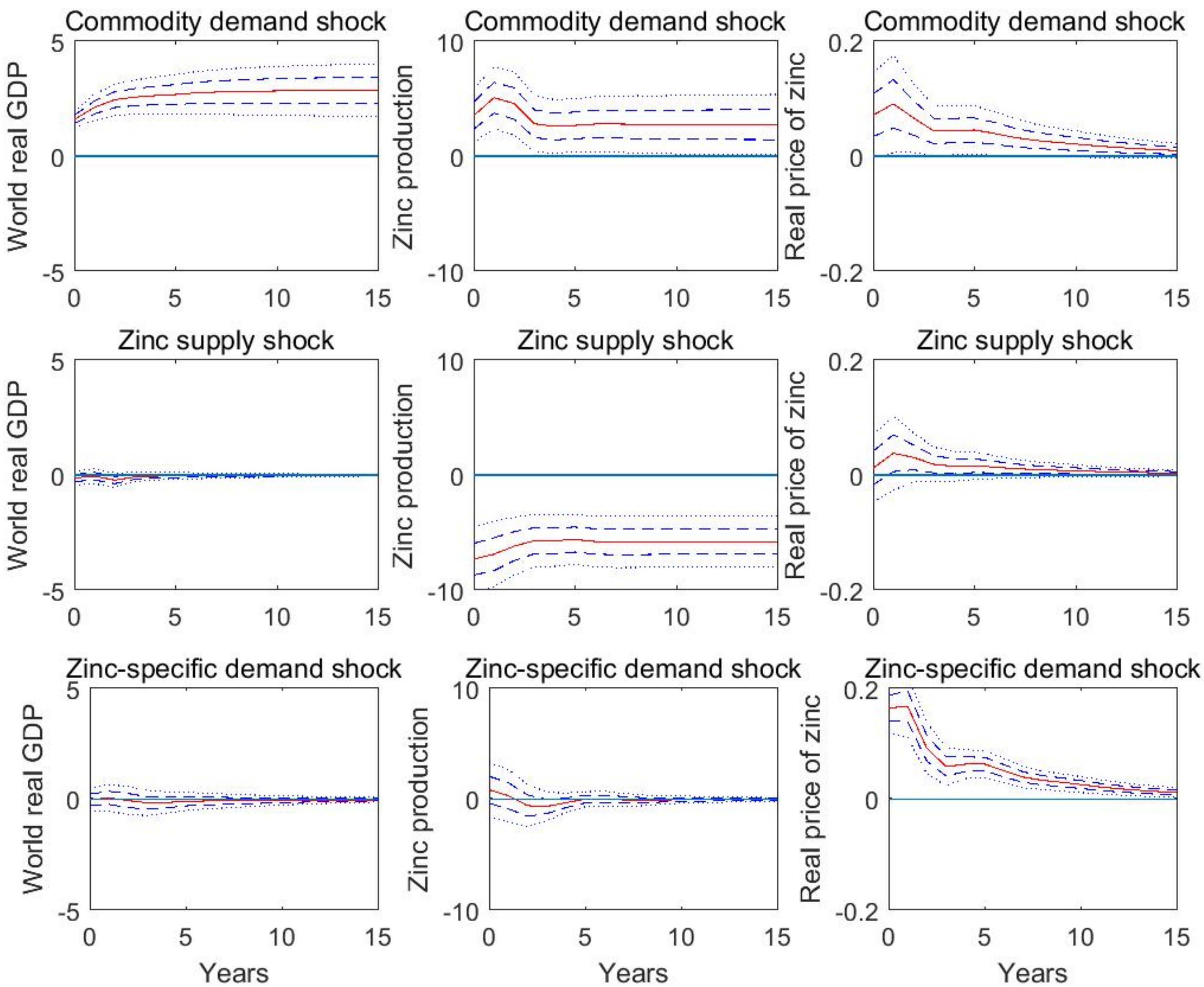
Notes: Notes: Point estimates with one- and two-standard error bands. All shocks have been normalized such that an innovation will tend to raise the price of the respective commodity. I use accumulated impulse response functions for the shocks to world mineral commodity production and world real GDP to trace the effects on the level of these variables.

Figure 5: Impulses to one-standard-deviation structural shocks for lead.



Notes: Point estimates with one- and two-standard error bands. All shocks have been normalized such that an innovation will tend to raise the price of the respective commodity. I use accumulated impulse response functions for the shocks to world mineral commodity production and world real GDP to trace the effects on the level of these variables.

Figure 6: Impulses to one-standard-deviation structural shocks for tin.



Notes: Point estimates with one- and two-standard error bands. All shocks have been normalized such that an innovation will tend to raise the price of the respective commodity. I use accumulated impulse response functions for the shocks to world mineral commodity production and world real GDP to trace the effects on the level of these variables.

Figure 7: Impulses to one-standard-deviation structural shocks for zinc.

2 Data Sources and Description

Mineral commodity	Time	Unit	Sources	Notes
Copper	1820-1878	mt	Schmitz 1979, pp. 64-9	Metal content of mined ores.
	1879-1928	mt	Schmitz 1979, pp. 209-13	Smelter production (primary but may also include secondary materials according to a personal communication with Doris Homberg-Heumann of the Federal Institute for Geosciences and Natural Resources).
	1929-1959	mt	Schmitz 1979, pp. 213-25	Refined production; according to a personal communication with Doris Homberg-Heumann from the Federal Institute for Geo-sciences and Natural Resource the data includes both primary and secondary sources. This is also the case when the data is compared with data from the International Copper Study Group (2010b) from 1960s onwards.
	1960-2005	mt	International Copper Study Group 2010b	Refined production from primary and secondary materials.
	2006-2007	mt	International Copper Study Group 2012b	Refined production from primary and secondary materials.
	2008	mt	International Lead and Zinc Study Group 2015	Refined production from primary and secondary materials.
	2009-2014	mt	International Copper Study Group 2016	Refined production from primary and secondary materials.
Lead	1840-1860	mt	Neumann 1904, p. 149-51	Metal content of mine production; missing data for Russia (1841-1844, 1846-1849, 1851-1854, 1856-1859), for Spain (1846-1850, 1853-1857), and for the United Kingdom (1839-1840, 1842-1844) has been completed by using geometric trends.

	1861-2008	mt	BGR, 2012	Metal content of refined production from primary and secondary materials; total production by smelters or refineries of refined lead, including the lead content of antimonial lead, ores, concentrates, lead bullion, lead alloys, mattes, residues, slag, or scrap. Pig lead and lead alloys recovered from secondary materials by remelting alone without undergoing further treatment before reuse are excluded. (See International Lead and Zinc Study Group, 2011)
	2009-2010	mt	International Lead and Zinc Study Group 2015	Metal content of refined production from primary and secondary materials; total production by smelters or refineries of refined lead, including the lead content of antimonial lead, ores, concentrates, lead bullion, lead alloys, mattes, residues, slag, or scrap. Pig lead and lead alloys recovered from secondary materials by remelting alone without undergoing further treatment before reuse are excluded.
	2011-2015	mt	International Lead and Zinc Study Group 2016	Metal content of refined production from primary and secondary materials; total production by smelters or refineries of refined lead, including the lead content of antimonial lead, ores, concentrates, lead bullion, lead alloys, mattes, residues, slag, or scrap. Pig lead and lead alloys recovered from secondary materials by remelting alone without undergoing further treatment before reuse are excluded.
Tin	1821-1883	mt	Neumann 1904, p. 251-3	Tin production.
	1884-2010	mt	BGR, 2012	Primary tin production (smelter)
	2011-2014	mt	International Tin Research Institute 2014	Primary tin production (smelter)
Zinc	1850-1879	mt	Schmitz 1979, p. 160-6	Mine production.
	1880-1888	mt	Metallgesellschaft 1889, p. 16	Raw zinc.
	1889-1894	mt	Metallgesellschaft 1901, p. 25,	Raw zinc.

	1900-2009	mt	BGR, 2012	Total production by smelters or refineries of zinc in marketable form or used directly for alloying regardless of the type of source material. Remelted zinc and zinc dust are excluded. (See International Lead and Zinc Study Group, 2011)
	2010	mt	International Lead and Zinc Study Group 2015,	Refined zinc.
	2011-2014	mt	International Copper Study Group 2016,	Refined zinc.
Oil	1961-1964	mt	Mitchell 2007	Crude petroleum (not from oil shales)
	1965-2014	mt	British Petroleum 2015	Includes crude oil, shale oil, oil sands and NGLs (the liquid content of natural gas where this is recovered separately). Excludes liquid fuels from other sources such as biomass and coal derivatives.

Table 1: Data sources and descriptions for the world production of the mineral commodities. Note: The differentiation between primary and secondary materials is not clear-cut, since so-called "new scrap" accrues across the different stages of the production process. "New" and "old" scrap are also fed back in the production process at different stages according to quality.

Mineral Comm.	**Market place**	**Time**	**Units**	**Sources**	**Notes**
Copper	London	1820-1976	£/mt	Schmitz 1979, p. 268-72	1820-1879: Tough copper, fire-refined, av. 99.25% metal cont.; 1880-1914: Best selected copper, fire-refined, av. 99.75% metal cont.; 1915-1976: Electrolytic wirebars, min. 99.9% metal cont.; 1939: Price average Jan-Aug only as LME dealings were suspended; Sep 1940-Aug 1953: controlled selling price of the Ministry of Supply.
	London	1977-2014	US-$/mt	World Bank 2015a	Grade A, cash, in LME warehouse, min. 99.99% metal cont.)
	U.S.	1850-1976	US-$/mt	Schmitz 1979, p. 268-72	1850-1899: Lake copper (fire-refined) New York; 1900-1976: electrolytic wire-bars, min. 99.9% metal cont., U.S. producer price; Sep 1967-Apr 1968: U.S. copper producer strike, so 1967 is the average of Jan-June and 1968 is the average of May-Dec.
	U.S.	1977-1990	U.S.-$/mt	U.S. Bureau of Mines 1981, 1987, 1993	Cathode, min. 99.99% metal cont., U.S. producer price
	U.S.	1991-2014	U.S.-$/mt	U.S. Geological Survey 1996, 2001, 2007, 2014a, 2016	Cathode, min. 99.99% metal cont., U.S. producer price
Lead	London	1820-1976	£/mt	Schmitz 1979, p. 226-37	1820-1886: English pig lead, mostly prices in provincial markets pre-1850, then mainly London prices; 1887-1945: Good soft pig lead; 1946-1976: refined pig, min. 99.97% metal cont.; 1914: Average Jan-July and Nov-Dec only; 1940-Sept 1952: Fixed selling price, Ministry of Supply
	London	1977-2014	U.S.-$/mt	World Bank 2015a	Min. 99.97% metal cont., cash, in LME warehouse
	New York	1820-1976	U.S.-$/mt	Schmitz 1979, p. 274-78	1820-1879: Pig lead; 1880-1976: Common grade lead, min. 99.73% metal cont.
	New York	1977-1990	U.S.-$/mt	U.S. Bureau of Mines 1981, 1987, 1993	Min. 99.97% metal cont., North American producer price, delivered.

	New York	1991-2013	U.S.-$/mt	U.S. Geological Survey 1996, 2001, 2007, 2014b	Min. 99.97% metal cont., North American producer price, delivered.
	New York	2014	U.S.-$/mt	U.S. Geological Survey 2016	Min. 99.97% metal cont., North American market price (Producer price suspended)
Tin	London	1820-1976	£/mt	Schmitz 1979, p. 240-1	1820-1837: Common refined tin, Cornwall; 1838-1872: Standard tin; 1873-1976: Standard tin, min. 99.75% metal cont.; 1914: Average price of Jan-July and Oct-Dec only; 1942-1949: controlled price, Ministry of Supply.
	London	1977-2014	U.S.-$/mt	World Bank 2015a	Min. 99.85% metal cont., in LME warehouse, cash.
	New York	1841-1850	U.S.-$/mt	House of Commons 1853,	Computed from quantities and values of imports of tin in blocks and pigs
	New York	1851-1855	U.S.-$/mt		Filled with a linear trend
	New York	1856-1962	U.S.-$/mt	Secretary of the Treasury 1864, p. 46-8	Computed from quantities and values of imports of tin in blocks and pigs.
	New York	1863	U.S.-$/mt	House of Commons 1866, p. 358	Computed from quantities and values of imports of tin in blocks and pigs.
	New York	1864-1865	U.S.-$/mt	House of Commons 1868, p. 378	Computed from quantities and values of imports of tin in blocks and pigs.
	New York	1866-1869	U.S.-$/mt		Filled with a linear trend.
	New York	1870-1976	U.S.-$/mt	Schmitz 1979, p. 293-8	1869-80: Block tin; 1881-1919: Ordinary brands, min. 99% metal cont.; 1920-76: Straits tin, Grade A, min. 99.85% metal cont.; 1918 = median price; 1976 = average January, July, and December only.
	New York	1977-1990	U.S.-$/mt	U.S. Bureau of Mines 1981, 1987, 1993	Contained tin, New York market price, average.
	New York	1991-2014	U.S.-$/mt	U.S. Geological Survey 1996, 2001, 2007, 2014b, 2016	Contained tin, New York market price, average.
Zinc	London	1823-1976	£/mt	Schmitz 1979, p. 299-303	1823-1951: Ordinary brands zinc; 1940-1944: controlled price, U.K. Ministry of Supply; 1952-1976: virgin zinc, min. 98% metal cont.
	London	1977-2014	U.S.-$/mt	World Bank 2015a	Special high grade, min. 99.995% metal cont., cash, LME

	New York	1872-1874	U.S.-$/mt	U.S. Bureau of Mines 1883	Import price of zinc in blocks or pigs.
	New York	1875-1976	U.S.-$/mt	Schmitz 1979, p. 300-3	1875-1899: Prime Western, min. 98% metal cont.; 1900-1976: Prime Western, Saint Louis, min. 98% metal cont.
	New York	1977-1990	U.S.-$/mt	U.S. Bureau of Mines 1981, 1987, 1993	1977-79: Prime Western, delivered, min. 98% metal cont.; 1980-90: High grade, min. 99.9% metal cont., delivered.
	New York	1991-2014	U.S.-$/mt	U.S. Geological Survey 1996, 2001, 2007, 2012, 2016	Special high grade, delivered, min. 99.99% metal cont.
Crude Oil	U.S./U.K.	1861-2014	U.S.-$/barrel	British Petroleum 2015	1861-1944: U.S. average; 1945-1983: Arabian Light posted at Ras-Tanura; 1984-2014: Brent dated.

Table 2: Data sources and descriptions for the world mineral commodity prices.

Currencies	**Time**	**Unit**	**Source**
U.S.-$ - British £	1820-2014	British £ per U.S.-$	Officer 2015

Table 3: Data sources and descriptions for U.S. $ to British £exchange rate.

Index	Country	Time	Unit	Source	Notes
PPI	U.K.	1820-1913	2005=100	Mitchell 1988, p. 722-4	Rousseaux price index constructed from wholesale prices and unit-value of imports of vegetable, animal, agricultural, and industrial products.
	U.K.	1914-1959	2005=100	Mitchell 1988, p. 725-7	Sauerbeck-Statist price index constructed from wholesale prices and unit-value of food (vegetable and animal) and raw materials (minerals, textile fibres, sundry).
	U.K.	1960-2014	2005=100	World Bank 2015b	Wholesale Price Index
	U.S.	1850-1859	1982=100	Mitchell 2003, p. 702	Wholesale Price Index
	U.S.	1860-1912	1982=100	Hanes 1998	Wholesale Price Index
	U.S.	1913-2014	1982=100	U.S. Bureau of Labor Statistics 2016b	Producer Price Index: All commodities
CPI	U.K.	1820-2014	Jan 1974=100	U.K. Office of Statistics 2016	Composite price index
	U.S.	1774-2010	1982-1984=100	Officer and Williamson 2011	Consumer price index, all urban consumers
	U.S.	2011-2014	1982-1984=100	U.S. Bureau of Labor Statistics 2016a	Consumer price index, all urban consumers

Table 4: Data sources and descriptions for price indices.

Time Period	Unit	Source	Notes
1820-1950	Million 1990 International Geary-Khamis dollars	Maddison 2010	Description of data in Maddison (2010)
1951-2014	Million 1990 International Geary-Khamis dollars	The Conference Board 2015	

Table 5: Data sources and descriptions for world real GDP.

3 Narrative Evidence

This chapter provides historical accounts for the four examined markets. I find that the evolution of the identified structural shocks is basically in line with this narrative evidence for the four examined markets. The text refers to the figures on the evolution of the identified structural shocks provided in this online-appendix and to the respective figures on the accumulated effects of the structural shocks in the main paper.

3.1 Copper Market

The historical account of events in the copper market for the period from 1840 to 2014 is basically in line with the evolution of the identified structural shocks in Figure 8 in this online-appendix and the accumulated effects of the structural shocks in Figure 1 in the paper. In the late 1840s the real price of copper was low owing to the British railway crisis from 1847 to 1848 (see Kindleberger and Aliber, 2011), which caused negative commodity demand shocks. In the 1850s the real price underwent a major upswing, driven mainly by positive commodity demand shocks due to the world economic boom at that time (see Kindleberger and Aliber, 2011). At the beginning of the 1850s, the price stopped rising even though commodity demand shocks still persisted. Large positive supply shocks due to the "copper mania" (Richter, 1927, p. 246), the opening of copper mines in the Southern Appalachians of the U.S., put downward pressure on the price of copper. As a result, the price experienced a long downturn during the 1860s, reaching a trough around 1870. This was due to negative commodity demand shocks triggered by the Panic of 1857, the U.S.-American Civil War from 1861 to 1865, and the Overend-Gurney Crisis in 1866 and their respective economic aftermaths (see Kindleberger and Aliber, 2011). At the same time, there was some downward pressure caused by positive copper supply shocks due to the opening of new mines in Arizona and Michigan - despite the problems posed by the Civil War - and a substantial increase in production in Chile and elsewhere in the world, especially in the late 1860s (Richter, 1927).

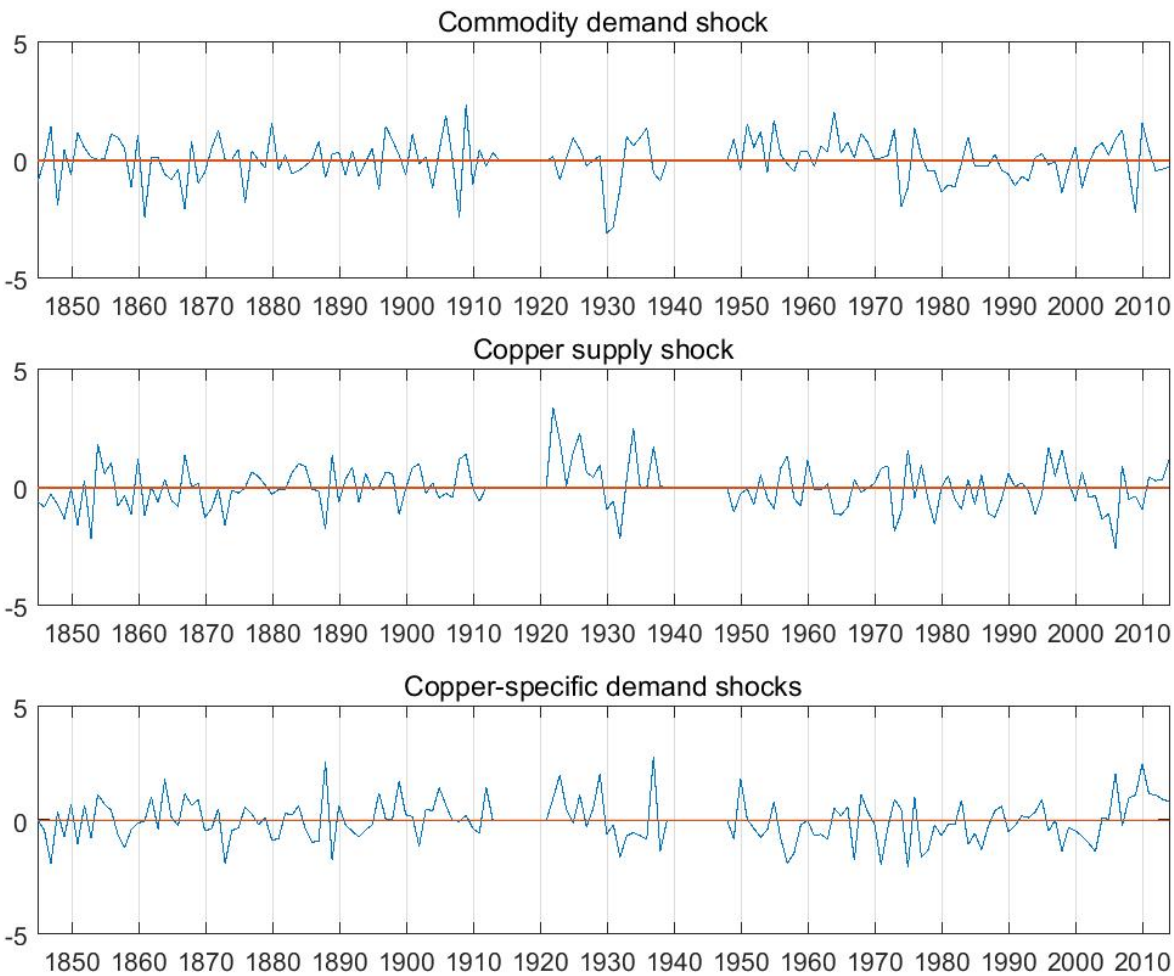


Figure 8: Historical evolution of structural shocks for copper.

After the price peaked at the end of the 1870s owing to positive commodity demand shocks, it fell until the mid 1880s. This was caused by two shocks. First, the Long Depression beginning in 1873 led to strong negative commodity demand shocks (Kindleberger and Aliber, 2011). Second, major, positive supply shocks drove prices down. Between 1875 and 1885, annual U.S. copper production rose by more than 500 percent. The Anaconda mine in Montana "proved fabulously rich and enormously productive" (Richter, 1927, p. 255), and several others mines opened in Arizona.

The mines in Michigan, which had already created a selling pool in the 1870s, reacted to the low prices with an aggressive rise in production and a sales policy aimed at driving out the new competitors (Richter, 1927, p. 256). This explains the major positive copper supply shock that drove prices down further in the first half of the 1880s. As many mines were unable to continue operating at a profit at these low prices, world production fell from 229,600 mt in 1885 to 220,500 mt in 1886 (Richter, 1927, p. 257). This explains the negative supply shock at that time.

In response, the Secrétan copper syndicate, which controlled up to eighty percent of world production, became active from 1887 to 1889 (Richter, 1927; Herfindahl, 1959), driving up the world market price to a high in 1887 by stockpiling copper (Richter, 1927; Herfindahl, 1959), as reflected in the strong copper-specific demand shocks at the time. However, the high prices led to increased production and oversupply, which the syndicate tried to compensate for by stockpiling even more (Richter, 1927; Herfindahl, 1959). This led to the syndicate's collapse in 1889. The Société Industrielle et Commerciale des Métaux, which handled the operations of the syndicate, and the main financing bank, Comptoir d'Escompte, were forced into bankruptcy, and the manager responsible committed suicide (Richter, 1927; Herfindahl, 1959). The copper from the inventories was sold over a period of three to four years, driving prices down until the mid 1890s (Richter, 1927, p. 259), as the accumulated effects of the copper-specific demand shocks show. Commodity demand shocks also had a waning impact on prices over this period.

Prices increased again at the end of the 1890s, then experienced a downturn reaching a low around 1904, followed by another boom in the mid 1900s and then a further downturn. These cycles of boom and bust were driven by all three kinds of shock. After gradual economic recovery in the 1890s, positive commodity demand shocks peaked at the beginning of the 20th century, followed by recessions in 1904 and 1907, which were triggered by financial crises in the U.S. as described by Kindleberger and Aliber (2011) (see also data provided by Crafts et al., 1989; National Bureau of Economic Research, 2010). Copper-specific demand shocks and supply shocks also affected prices over that period. In the late 19th century, the Amalgamated Copper Company, which controlled about one fifth of world copper production, and a number of other firms tried to stabilize the price of copper by withholding stocks from the markets and restricting output (Herfindahl, 1959, p. 81). This is also represented by spikes in the cumulative effects of both copper-specific demand shocks and supply shocks. In late 1901 the company changed course by releasing copper from its stocks in order to undersell its competitors, which resulted in negative copper-specific demand shocks to the market. Subsequently, there were renewed attempts at price manipulation through the withholding of stocks from 1904 to 1905, 1906 to 1907 and, finally, 1912 to 1913 (Herfindahl, 1959, pp. 83-91). These manipulations play a major role in explaining the fluctuations in the price of copper at the time, as the accumulated effects of copper-specific demand shocks show. Finally, from 1910 onwards the introduction of fine grinding methods and milling by flotation made large-scale mine production from low-grade ores possible (Richter, 1927, pp. 278-81). The consequent positive supply shocks helped to drive down prices, as copper production in Alaska and the South-West of the U.S. surged (Richter, 1927, pp. 278-81).

The real price of copper stayed relatively flat during the 1920s, with a small peak in 1929. According to my analysis, this was due to upward pressure by copper-specific demand shocks and downward pressure by copper supply shocks that roughly balanced each other out. On the one hand, strong positive copper supply shocks followed the sharp increases in production capacity during the First World War owing to improved mining technology (Radetzki, 2009) and war-time demand. The increased mining capacities were temporarily abandoned in the first few-years after the war in coordinated action by the Copper Export Association.[1] In 1917 world refined production totaled 1.4 million metric tons. It slumped to 0.5 million metric tons in 1921, but then rebounded to 1.3 million metric tons in 1923, after the cartel operation ceased. From 1927 to 1929 production leapt again (for the aforementioned data see U.S. Geological Survey, 2011a). On the other hand, there were strong positive copper-specific demand shocks that put upward pressure on the price of copper owing to the build-up of inventories and price manipulations by two cartels: the Copper Export Association in the early 1920s and later by the Copper Exporters Inc. (Herfindahl, 1959, pp. 93-4 and 100-6).

The Great Depression caused a major negative commodity demand shock that drove down the price of copper in 1929. In response, the Copper Exporters Inc. cartel, which controlled about 85 percent of world output, succeeded in firmly restricting copper production by taking collective action (Herfindahl, 1959, pp. 100-6). This resulted in strong accumulated effects of copper supply shocks that counterbalanced the commodity demand shocks to some extent. However, diverging interests and declining discipline among its members brought Copper Exporters Inc. to an end in 1932, and world copper production rebounded (Herfindahl, 1959, p. 105). In 1935 the International Copper Cartel emerged and succeeded in driving up the price of copper in the late 1930s (Herfindahl, 1959, p. 110), as the cumulative effects of copper-specific demand shocks reveal.

From the end of the Second World War until the mid 1970s, the real price of copper rose sharply, with peaks in 1955, 1966, 1969, and 1974. During this time post-war reconstruction and the economic rise of Japan generated strong, positive commodity demand shocks, which mainly determined price fluctuations. Interventions by the U.S. government in the form of price controls, import and export restrictions, and government stockpiling were quite common in this period (see Herfindahl, 1959; Sachs, 1999) and are largely reflected in copper-specific demand shocks. Their accumulated effect was, however, rather transient and insignificant. Voluntary production cutbacks in 1963 and strikes in the U.S.

[1] Please note that I have not included the three years after the First and Second World Wars in my regressions such that this period is not visible in the figures.

from 1959 to 1960 and 1967 to 1968 explain most of the supply shocks during this period (see Sachs, 1999). The nationalization of mines in Chile, Zambia, and elsewhere in the 1960s, and as well as the attempts by the Intergovernmental Council of Copper Exporting Countries (CIPEC) to limit production in 1975 aggravated the negative copper supply shocks (see Mardones et al., 1985; Sachs, 1999). Overall, the cumulative effects of copper supply shocks were rather limited compared to the commodity demand shocks during this period.

The price of copper reached its peak in 1974. This was due to several kinds of shocks. On the one hand, the CIPEC cartel reduced its exports by fifteen percent (Mikesell, 1979, p. 205), as is evident from the strong accumulative effects of copper supply shocks and copper-specific demand shocks. On the other hand, the recession in 1974 caused strong negative commodity demand shocks, which led to a serious decline in the price in 1975, since the CIPEC could not sustain its action. In the following three decades prices fell mainly because of the negative commodity demand shocks caused by the recession in 1981, the economic impact of the breakup of the U.S.S.R., and the Asian crisis. There were two small peaks in the late 1980s and the mid 1990s due to the interplay of positive commodity demand shocks and copper supply shocks.

The sharp rise in copper prices from 2003 to 2007 was basically driven by the cumulative effects of large commodity demand shocks due to the booming economy. Supply shocks also played a role. In 2005 and 2006 in particular, global copper mine production grew far less than expected owing to strikes, equipment shortages, and other production problems (U.S. Geological Survey, 2007, 2008).

Since the onset of the Great Recession in 2008 commodity demand shocks have had a negative effect on the real price of copper, except for the year 2010. This has been offset by strong copper-specific demand shocks, which have had a positive effect on price since 2005. These shocks reflect changes in inventories (see data provided by the International Copper Study Group, 2010a, 2012a). However, while consumers' and producers' inventories have stayed roughtly constant, inventories at exchanges grew more then fourfold between 2004 and 2010. At the same time, Chinese firms imported significant quantities in 2009 and 2010, but their inventories are not transparent (see U.S. Geological Survey, 2010, 2011b).

3.2 Lead Market

The price of lead rose strongly in the early 1850s reaching a peak in 1853. This increase was driven by a strong positive lead-specific demand shock and by positive commodity demand shocks as the world economy boomed in the 1850s (see Kindleberger and Aliber, 2011). The prices remained at this level for the next decade. Even though commodity demand shocks continued to put pressure on the lead price, strong positive lead-specific demand shocks supported them in the mid-1860s. Unfortunately, I have not been able to find a conclusive explanation for these shocks. In the early 1870s there were strong positive commodity demand shocks, which kept the price on a high level.

From the mid 1870s commodity demand shocks due to the Long Depression as well as negative lead-specific demand shocks exerted downward pressure on the price of lead. The price rose sharply in the late 1890s owing to commodity demand shocks, reflecting the booming world economy, but also due to lead-specific demand shocks. The latter might reflect action by producer cartels that where quite common at the time in the lead and zinc mining industry, especially in Germany (Gibson-Jarvie, 1983, p. 73). In 1900 and 1901 the Lead Trust, a large cartel in the U.S., limited its production, and stocks increased so sharply that prices rose for some time (Metallgesellschaft, 1904, p. VIII). This is shown in the large positive lead-specific demand shock on the price at the time. In 1909 the Metallgesellschaft, which controlled most German and other non-U.S. output, led a successful attempt at market manipulation by creating the Lead Smelters' Association together with the main Belgian and Spanish lead-mining companies (Gibson-Jarvie, 1983). Instead of controlling production, the members agreed to leave the entire marketing of lead to Metallgesellschaft, which then used stocks to withhold lead from the market (Gibson-Jarvie, 1983). The lead-specific demand shocks show that the association was relatively successful in driving up prices from 1910 to 1913 (Gibson-Jarvie, 1983). Overall, these ups

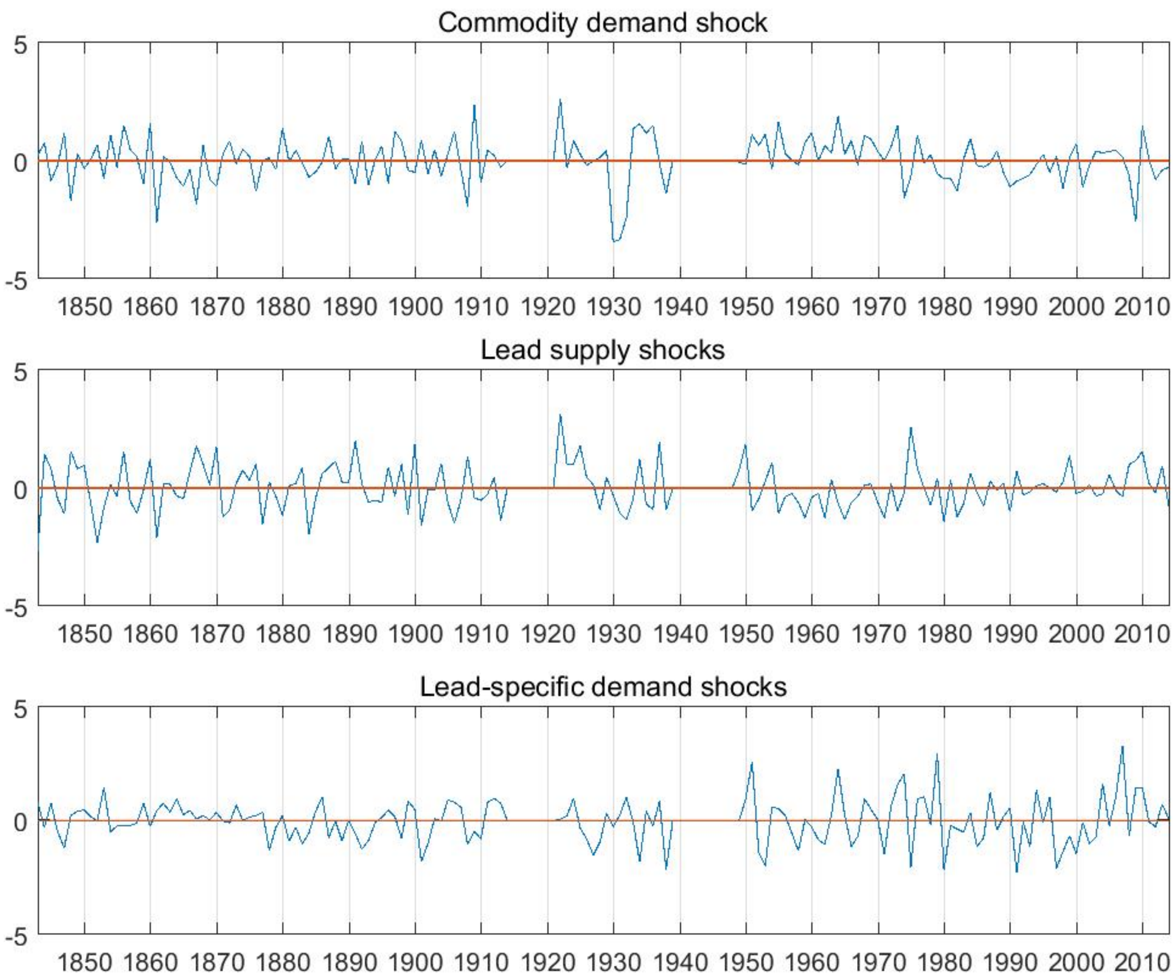


Figure 9: Historical evolution of structural shocks for lead.

and downs in cartel action explain the lead-specific demand shocks before the First World War.

In the inter-war period, prices rose, peaking in 1924 owing to the accumulated effects of commodity demand shocks. However, they came under pressure from strong negative lead-specific demand shocks, probably caused by extensive stockpiling (Gibson-Jarvie, 1983). As a reaction to stocks that "had amassed to an alarming degree" (Gibson-Jarvie, 1983, p. 79), non-U.S. producers established the Lead Producers' Reporting Association in 1931. It attempted to raise prices by both restricting production and stockpiling (Gibson-Jarvie, 1983). As the accumulated effects of lead-specific demand shocks show, stockpiling had a considerable positive impact in the first year, when it partly compensated for the strong negative commodity demand shocks caused by the Great Depression, but it collapsed when Britain imposed import tariffs in 1932 (Gibson-Jarvie, 1983). This put downward pressure on the price as stocks were dissolved (Gibson-Jarvie, 1983). Besides positive commodity demand shocks, lead-specific demand shocks drove the market in following years. The latter shocks include actions by goverments to protect their zinc producers with import tariffs and other measures and "speculation" on the London Metal Exchange (Hughes, 1938; Gibson-Jarvie, 1983).

After the Second World War prices rose sharply, reaching a peak in 1951 due to commodity demand shocks triggered by postwar reconstruction and due to lead-specific demand shocks. These lead-specific demand shocks were caused by a number of factors. First, after the Second World War the U.S. Strategic and Critical Materials Stock Piling Act led to heavy stockpiling, as can be seen from the sharp rise in the accumulative effects of lead-specific demand shocks, especially during the Korean War (see Mote and den Hartog, 1953, p. 684). In 1951 the U.S. government set a price ceiling (see Bishop and den Hartog, 1954, p. 752). As foreign importers were unwilling to sell their lead at the low mandatory U.S. price and foreign consumers could not absorb the quantities concerned, non-U.S. producers' stocks accumulated, as evident from the positive lead-specific demand shocks. As these stocks were sold on the market in the following two years, they exerted downward pressure on the real price of lead.

From 1961 to 1969 the U.S. government introduced the Lead and Zinc Mining Stabilization Program, which paid subsidies to mining companies when prices dropped below a certain threshold (Smith, 1999). This kept prices fairly stable over this period (Smith, 1999). From 1971 to 1973 the U.S. government imposed price limits, which were lifted in 1973 and then sharply increased the price of lead (Smith, 1999), which was followed by a strong negative lead-specific demand shock due to de-stocking. The price peak in 1979 was mainly attributable to a worldwide shortage of lead concentrates and heavy demand from centrally planned economies countries (Smith, 1999). However, my analysis suggests that it was this heavy demand from centrally planned economies and lead-specific demand shocks that drove the price up rather than supply shortages. There were major increases in consumers' and producers' stocks of refined lead (see data provided by U.S. Geological Survey, 2011a) that may have been captured by lead-specific demand shocks.

The 1980s saw strong downward pressure on the price of lead owing to the recession in 1981, as evident from the accumulated effects of commodity demand shocks, and due to the phasing out of lead from many appliances, which caused strong negative lead-specific demand shocks (see Smith, 1999). However, demand picked up again in the late 1980s with the growth of the battery industry (Smith, 1999).

From 2003 prices recovered, owing partly to positive commodity demand shocks until 2007, but largely to positive lead-specific demand shocks in 2005, 2007, 2009, and 2010. While the positive lead-specific demand shocks in 2009 and 2010 are attributable to a quadrupling of stocks at commercial exchanges, mainly reflecting demand from institutional investors (see data provided by International Lead and Zinc Study Group, 2011), the strong lead-specific demand shocks from 2005 to 2007 probably reflect the lead intensive growth in such rapidly industrializing countries as China (Guberman, 2009).

3.3 Tin Market

The rise in the prices from the 1840s until the late 1850s was due to positive commodity demand shocks, as the world economy boomed in the 1850s (Kindleberger and Aliber, 2011). At the same time, there were unexpected negative supply shocks due to partly simultaneous production shortfalls in the main mining areas of Cornwall and Banka, which drove up prices (see data provided by Neumann, 1904, pp. 251-2). tin-specific demand shocks also exerted downward pressure on the price, but their sources are not identifiable from the literature.

The price of tin slumped in the following years, reaching a trough in 1867. Britain, whose industry was the main user of tin at that time, lifted the restrictive import policies it had adopted to protect tin producers in Cornwall (Thoburn, 1994), which opened the market to tin from South-East Asia and led to positive supply shocks that drove prices down as the structural shocks in Figure 10 show. At the same time, several negative commodity demand shocks triggered by the Panic of 1857, the American Civil War and the Overend-Gurney crisis exerted downward pressure on the price (see Kindleberger and Aliber, 2011).

In the late 1860s and early 1870s, conflicts between Chinese clans that controlled mining production on the Malayan peninsula turned into war (Thoburn, 1994). Great Britain intervened and took control of important parts of the Malayan peninsula by 1874 (Thoburn, 1994). My analysis suggests that this event triggered major tin-specific demand shocks, since it increased uncertainty in the tin market, which led to a rise in pre-cautionary stock-holding by consumers. The resulting high price resulted in greater production elsewhere. Tin production in Cornwall reached a high in 1871, and Australian production rose significantly in the early 1870s (Thoburn, 1994). This caused positive supply shocks that put downward pressure on the price, which rose even higher after the British consolidated their control of the Malayan peninsula. The result was a significant increase in production and the Malayan peninsula became the most important producer in the world by the late 1870s (Thoburn, 1994). Moreover, the Long Depression in the industrializing world began

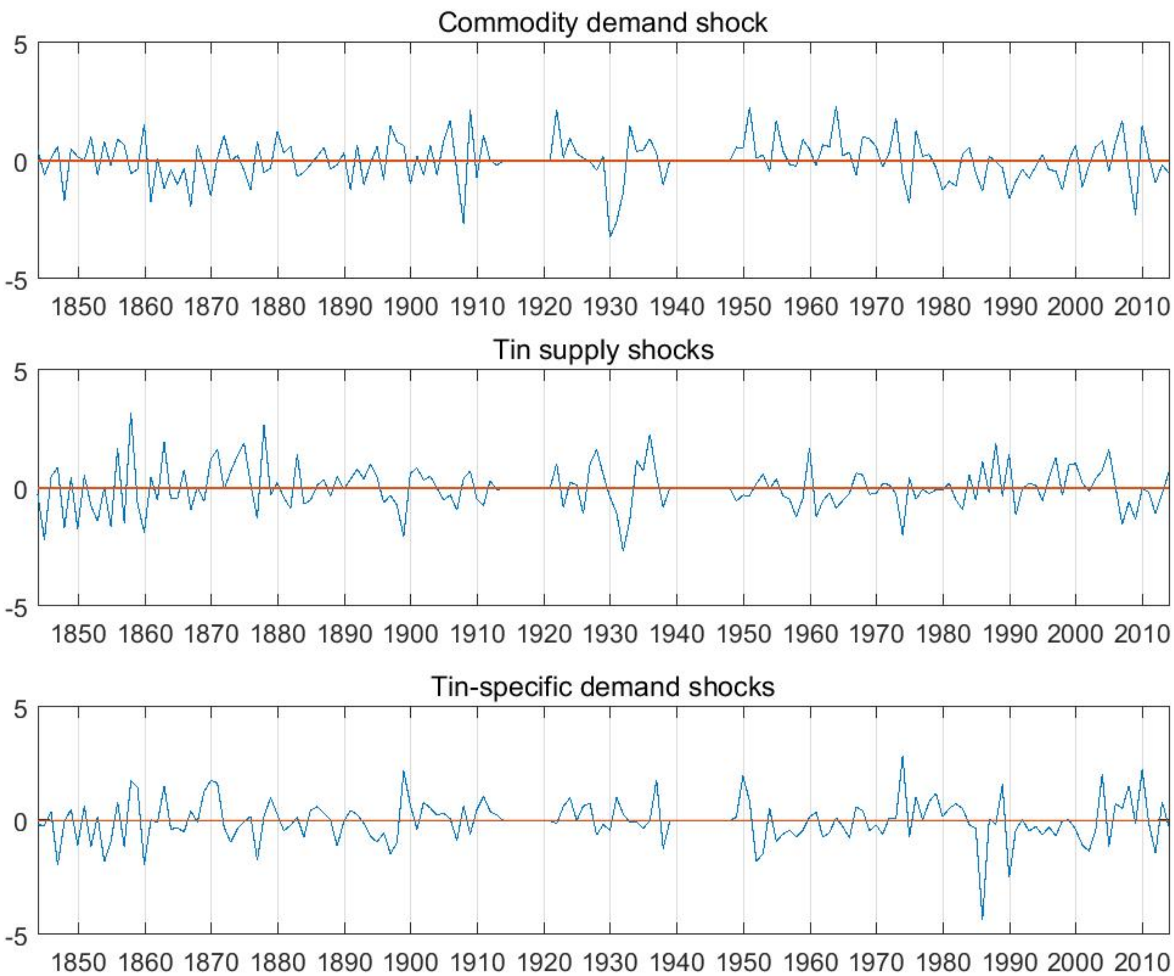


Figure 10: Historical evolution of structural shocks for tin.

in 1873 and exerted further downward pressure on the price of tin. Prices recovered from their low levels, reaching a peak in the late 1880s owing to the economic recovery after the Long Depression, which triggered positive commodity demand shocks. From 1889 to the late 1890s prices fell again because of sluggish economic growth and further positive supply shocks.

At the end of the 1890s prices rose dramatically. This was due to several factors. First, positive accumulative effects of commodity demand shocks peaked at the beginning of the 20th century (see also data provided by Crafts et al., 1989; National Bureau of Economic Research, 2010), which led to unexpectedly high rises in the demand for tin. Second, labor shortages and equipment problems caused negative supply shocks. These problems were also linked to the need to produce tin from deposits of lower ore grades and of greater depths (Thoburn, 1994) and were exacerbated by the decision of local authorities to stop the exploration for new deposits in Kinta Valley, the most important tin-mining area (Thoburn, 1994).

Until the outbreak of the First World War, the price of tin was essentially driven by positive and negative commodity demand shocks due to the business cycles of the two major economies at the time, the U.S. and the U.K. (see data provided by Crafts et al., 1989; National Bureau of Economic Research, 2010).

Price fluctuations in the inter-war period were mainly influenced by the economic recovery after the First World War, the effects of the Great Depression, and attempts to form cartels. In 1921 the governments of the Federated Malay States and the Dutch East Indies established the Bandoeng Pool and agreed to stabilize the price of tin by jointly managing inventories (Thoburn, 1994). The Bandoeng Pool controlled more than fifty percent of world production at the time (Thoburn, 1994, p. 77). From 1921 to 1923 it withheld some fifteen percent of world tin production from the market and sold it gradually when prices rose in the mid of the 1920s owing to positive commodity demand shocks (Thoburn, 1994). The action taken by the cartel is evident form the tin-specific demand shocks. The Bandoeng Pool reaped a "substantial profit from the operation"

(Thoburn, 1994, p. 77) and was dissolved in 1924 with its stocks exhausted (Baldwin, 1983).

The Great Depression caused strong negative commodity demand shocks to the price of tin, which coincided with a major expansion of world production (Thoburn, 1994). In response, a number of tin producers tried to withhold tin from the markets by stockpiling it, which explains the positive tin-specific demand shocks at the time. However, as these attempts were unsuccessful, the International Tin Agreement was drawn up. It encompassed the major producers and introduced formal restrictions on output (Thoburn, 1994). This caused a large negative supply shock in 1932, evident from the accumulative effects of the supply shocks, which drove the price up again. In 1938 a buffer stock was formed under the International Tin Agreement to stabilize prices (Thoburn, 1994). While the International Tin Agreement inventories were increased in the first year, causing prices to rise, it was soon exhausted in the run-up to the Second World War (Thoburn, 1994).

The high price from the end of the Second World War until the early 1970s was driven mainly by upward pressure from strong commodity demand shocks and mild supply shocks. The commodity demand shocks reflected post-war reconstruction, followed by South-Korea's and Japan's industrial expansion. Downward pressure at that time resulted from tin-specific demand shocks due to the U.S. stockpiling program. After the Second World War the U.S. passed the Strategic and Critical Minerals Stock Piling Act and bought tin into government inventories because of fears about supplies due to the spread of communism in South-East Asia (Thoburn, 1994). After the Korean War it stopped buying and gradually reduced its inventories during a period of high prices (Smith and Schink, 1976). Purchases from government stocks help to explain the downward pressure on prices by tin-specific demand shocks until the mid 1950s.

In 1956 the main producing and consuming countries, with the exception of the U.S., concluded a new International Tin Agreement with a view to stabilizing prices. It provided for both export restrictions and an international buffer stock (Thoburn, 1994). It imposed export restrictions, which are visible in the accumulative effects of supply shocks until they were lifted in 1960 (Thoburn, 1994). The resulting oversupply is clear from the structural shocks. The buffer stock formed under the International Tin Agreement also exerted some influence on the market in this period (see Thoburn, 1994; Smith and Schink, 1976). From an examination of tin-specific demand shocks it seems that the downward pressure of subsequent releases from the U.S. stockpiling program was offset by the upward pressure of action under the International Tin Agreement during the 1960s.

The recessions of 1974 and the early 1980s caused large negative commodity demand shocks to the price of tin (Thoburn, 1994). However, the price rose sharply in 1974 and continued at this high level because of action taken under the International Tin Agreement. Export restrictions were imposed, and the buffer stock was increased (Thoburn, 1994). This strategy worked until the famous collapse of the buffer stock and the suspension of the trade of tin on the London Metal Exchange (see Kestenbaum, 1991, for a detailed account). The collapse and dissolution of the buffer stock caused a serious slump in the price of tin, which leveled-off slowly in the 1990s. During this time, the Association of Tin Producing Countries was established and tried to restrict supplies (Thoburn, 1994).

From the beginning of the new millennium until 2007 the price of tin rose sharply as a result of positive commodity demand shocks caused by the rise of China and, to a far larger extent, by tin-specific demand shocks. This accords with data on inventories at the London Metal Exchange, which more than doubled from 2008 to 2010, according to data released by the BGR, 2013. This reveals the strong part played by inventory changes in the current price hike, and especially in compensating for the negative commodity demand shock in 2009. These changes have not only been been due to restocking at producers' and consumers' sites, but also, according to industry observers, due to stockpiling by investment funds as attribute (U.S. Geological Survey, 2011b).

3.4 Zinc Market

Prices rose sharply in the 1850s and peaked in 1857, driven by the accumulative effects of positive commodity demand shocks as the world economy boomed in the 1850s (see

Kindleberger and Aliber, 2011). Prices then slumped due to the accumulative effects of negative commodity demand shocks caused by the Panic of 1857 and the American Civil War (see Kindleberger and Aliber, 2011). Even though commodity demand shocks continued to put pressure on zinc prices, strong positive zinc-specific demand shocks supported them in the mid-1860s as the structural shocks in Figure 11 show. Unfortunately, I have not been able to find a conclusive explanation for these shocks. A possible explanation is the Austro-Prussian War of 1866, which may have affected the trade in zinc from the main mining area in Silesia and so caused "precautionary demand" for inventories. I leave it to future research to delve deeper into the history of the zinc market around that time.

Prices recovered in the early 1870s owing to commodity demand shocks and then reached a peak in 1875. This peak was mainly driven by market manipulations of U.S. producers, which are evident from the strong positive zinc-specific demand shocks at the time (Jolly, 1997). The high price caused production increases elsewhere, which sent prices down again (Jolly, 1997). The falling prices led to attempts by German producers in 1979 and by a number of other European producers in 1882 to form cartels and to put upwards pressure on prices by limiting production (Jolly, 1997; Cocks and Walters, 1968). These attempts failed, since local production decreases were offset by production elsewhere (Jolly, 1997; Cocks and Walters, 1968). As a result, negative zinc-specific demand shocks in combination with commodity demand shocks due to the Long Depression exerted downward pressure on prices, which reached their lowest level in the mid-1880s.

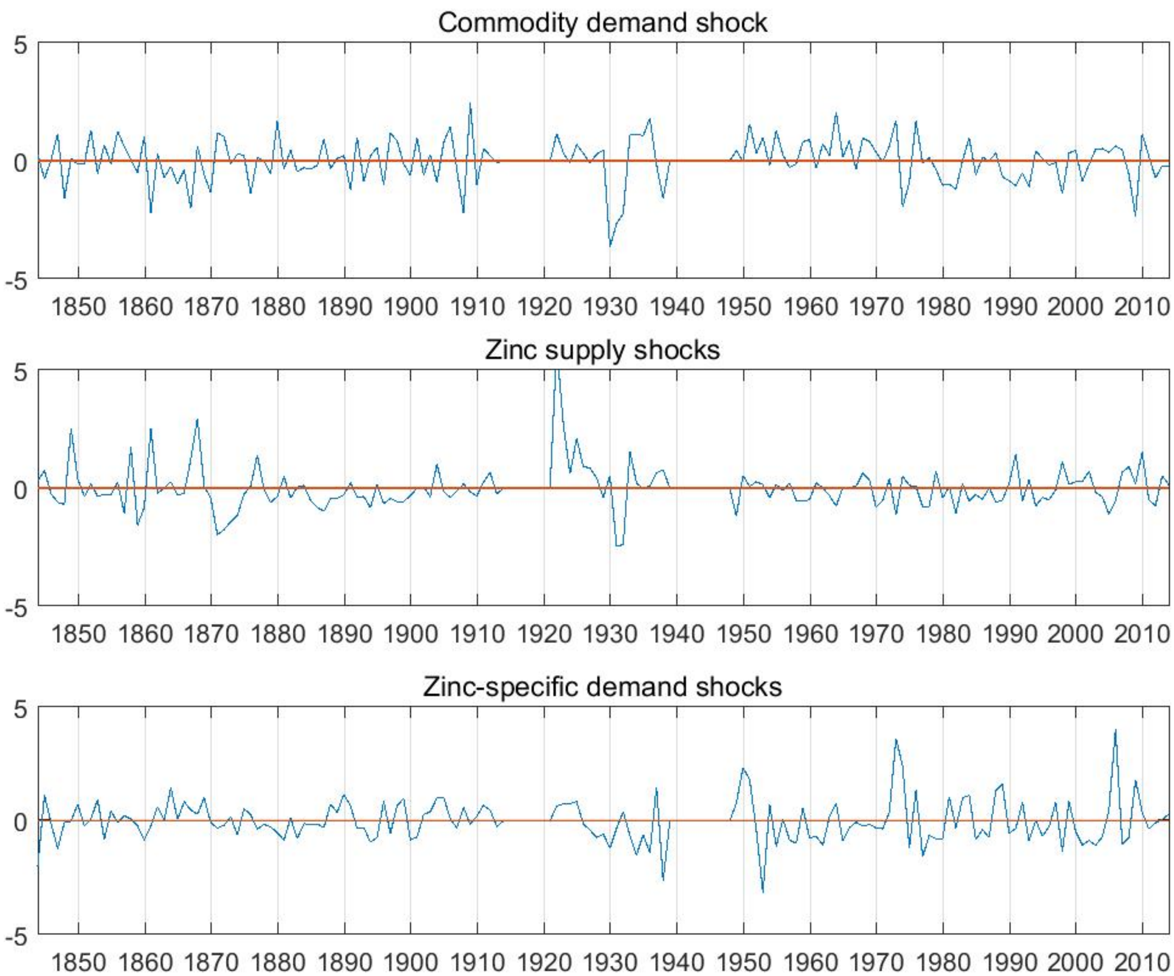


Figure 11: Historical evolution of structural shocks for zinc.

As a reaction to the low prices in the 1880s, major European producers joined the “first significant international zinc cartel” (Jolly, 1997, p. 116), which accounted for about 85 percent of world production (Jolly, 1997). The accumulative effects of zinc-specific demand shocks show that it succeeded in temporarily increasing the price, which reached a peak in 1890. There were also supply cuts, which are evident from the structural supply shocks, but did not have a major impact on prices, as can be seen from the accumulative effects. However, the cartel lost its power when new production came on to the market in reaction to the high prices (Jolly, 1997). Subsequent destocking inhibited strong negative zinc-specific demand shocks and exerted additional downward pressure on the price.

The price rose sharply in the late 1890s owing to commodity demand shocks, reflecting the booming world economy, but also to zinc-specific demand shocks, which may reflect not only growing stocks at smelters but also attempts by U.S. producers to form a trust (Metallgesellschaft, 1904). In the following years, the price was driven mainly by zinc-specific demand shocks, possibly reflecting the “cartel mentality” (Cocks and Walters, 1968, p. 16) of the German metal industry at the time. In 1909 another major attempt was made by European producers to form a cartel, known as the Spelter Convention, which drove up prices in the period until the outbreak of the First World War, as can be seen from the accumulated effects of the zinc-specific demand shocks (Jolly, 1997).

In the inter-war period, prices began by falling, then rose to a peak in the mid-1920s, slumped sharply during the Great Depression and did not recover from this low level until the end of the Second World War. My analysis shows the peak in the mid-1920s to be the result of positive commodity demand shocks due to the booming world economy and zinc-specific demand shocks probably due to industry stockpiling (see data provided by U.S. Geological Survey, 2011a). Positive supply shocks also exerted significant downward pressure on prices. I attribute these to the widespread introduction of flotation extraction and the electrolytic smelting technique, which made zinc production from complex sulphide ores possible (Gupta, 1982). These new techniques increased output especially in such areas outside Europe as Canada, Australia, Mexico, Rhodesia, and Indochina (Gupta, 1982). As a result, the production of flotation concentrate in the U.S., for example, rose from 34,000 tons in 1921 to 500,000 tons in 1928 (Jolly, 1997, p. 39).

The new competition from outside Europe triggered the formation of the European zinc cartel in 1928, but it was dissolved again in 1929 because of its members' disparate interests (Jolly, 1997; Gupta, 1982). The Great Depression caused a major negative commodity demand shock in 1930 and sent the price down. In response, the European zinc cartel was revived and imposed a 45 percent cut in production in 1931, raised to 55 percent in the following year (Jolly, 1997). This explains the negative supply shocks in these two years. However, the cartel dissolved in 1934, after some participants were found to have produced and sold more than agreed. Problems associated with the treatment of inventories, which began to be released on to the market as zinc-specific demand shocks show, were also not solved (Jolly, 1997; Gupta, 1982). Several attempts to revive the cartel failed, until one known as the International Sheet Zinc Cartel was founded at the end of the 1930s. It had a brief impact on the market, as the zinc-specific demand shocks suggest, but was dissolved as a result of the outbreak of the Second World War (Jolly, 1997).

The high price level from the end of the Second World War until the early 1970s was driven mainly by upward pressure due to strong commodity demand shocks fueled by post-war reconstruction and South Korea's and Japan's subsequent industrial expansion. After the Second World War the U.S. passed the Strategic and Critical Minerals Stock Piling Act, which led to heavy government stockpiling, evident from the sharp rise of accumulated zinc-specific demand shocks, and drove prices up very sharply (Gupta, 1982, p. 32). The following years were characterized by price controls and by selling from and buying into the U.S. government stockpile. This economic policy had a strong influence on the price in the rest of the world and a rather destabilizing effect (Gupta, 1982, p. 32). It is also apparent from the zinc-specific demand shocks. Furthermore, a new informal cartel was founded in 1964, known as the "Zinc Club" (Jolly, 1997, p. 117). The aim of its members, mainly European, Canadian, and Australian zinc companies, was to support the newly introduced European Producer Price and to restrict the influence of the London Metal

Exchange (Jolly, 1997). They used inventories as a tool to set the European Producer Price (Jolly, 1997).

In the early 1970s the price of zinc rose dramatically. My analysis shows that this was mainly due to zinc-specific demand shocks. The U.S. government imposed a stabilization program in 1971, under which prices were fixed at a low level (Jolly, 1997). After the fixed price was abandoned in 1973, both U.S. producers and the "Zinc Club" raised their prices by more than 225 percent (Gupta, 1982, p. 30). As producers withheld stocks, evident from the strong, accumulated response of the zinc-specific demand shocks, the price on the London Metal Exchange also rose sharply. The recession in 1974 had a major negative effect on the price, and as producers were no longer able to support prices, they fell again (Gupta, 1982). The governments of the U.S., Japan, and France helped zinc companies to reduce inventories while the price was low by increasing government stocks in 1975 and 1976 (Gupta, 1982). After investigations by the U.S. Department of Justice, the informal "Zinc Club" collapsed in 1976 (Jolly, 1997).

The price of zinc peaked in the mid and late 1980s. Both peaks can be ascribed to a combination of positive commodity demand shocks due to unexpected expansions in the world economy (U.S. Geological Survey, 2011a) and zinc-specific demand shocks. I attribute these zinc-specific demand shocks to the introduction of the zinc penny by the U.S. government (Jolly, 1997). This led to irregular purchases of zinc by the U.S. mint, which influenced its price throughout the decade (see Jolly, 1984, 1986, 1989).

In the 1990s the real price of zinc was driven by negative commodity demand shocks due to the breakup of the U.S.S.R. and the subsequent Asian crisis. The price rise in the early 2000s was fueled by positive commodity demand shocks until the Great Recession caused a very strong negative commodity demand shocks. However, strong positive zinc-specific demand shocks partly compensated for these negative shocks. They reflect a major change in warehouse inventories on the London Metal Exchange and the Shanghai Futures Exchange, which increased eightfold and sixfold respectively in the period from 2007 to 2010 (International Lead and Zinc Study Group, 2011). Interestingly, data on inventories held by consumers' and producers' sites did not increase in the same period (International Lead and Zinc Study Group, 2011), which is an indication of the role of institutional investors in the purchase of inventories.

4 An Alternative Identification

As a robustness check and to ease comparison, I provide an identification scheme using a structural VAR model with short-run restrictions following Kilian (2009). He identifies three different types shocks to the real price of crude oil, namely oil supply shocks, aggregate demand shocks and oil market-specific demand shocks.

The vector of endogenous variables is $z_t = (\Delta Q_t, \Delta Y_t, P_t)^T$, where ΔQ_t denotes the percentage change in world production of the respective mineral commodity, ΔY_t refers to the percentage change in world real GDP, and P_t is the log of the real price of the respective commodity. D_t denotes the deterministic term D_t consists of a constant, a linear trend, and annual dummies during the World War I and II periods and the three consecutive years. The structural VAR representation is

$$Az_t = \Gamma_1 z_{t-1} + ... + \Gamma_p z_{t-p} + \Pi D_t + \epsilon_t \ . \tag{1}$$

Assuming that A^{-1} has a recursive structure, I decompose the reduced-form structural errors e_t according to $e_t = A^{-1}\epsilon_t$, where ϵ_t is a vector of serially and mutually uncorrelated structural shocks:

$$e_t \equiv \begin{bmatrix} e_t^Q \\ e_t^Y \\ e_t^P \end{bmatrix} = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix} \begin{bmatrix} \epsilon_t^Q \\ \epsilon_t^Y \\ \epsilon_t^P \end{bmatrix}.$$

I employ the same restrictions on the short-term relations as Kilian (2009). Since he uses monthly and I use annual data, I discuss the plausibility of the identifying assumptions in the following:

Following Kilian (2009) I define supply shocks as unpredictable changes to the global production of the respective mineral commodity. The underlying assumption is a vertical short-run supply curve such that aggregate demand shocks and market-specific demand shocks lead to instantaneous changes in the real price (Kilian, 2009). According to this assumption neither innovations due to aggregate demand shocks nor due to market-specific demand shocks affect supply within the same year (Kilian, 2009).

Using annual data this assumption is plausible to the extent that firms are rather slow in responding to demand shocks by expanding production capacities. Expanding extraction and first stage processing capacities is highly capital intensive and it takes five or more years before new capacities become operational (Radetzki, 2008; Wellmer, 1992, see). It is contestable whether this assumption is also reasonable with respect to firms responding to demand shocks by increasing capacity utilization. However, like Kilian (2008) in the case oil, I find utilization rates of close to ninety percent in U.S.-data for the oil extraction, mining, and primary metals industries from 1967 to 2011 (U.S. Federal Reserve, 2011). In the case of the mining and primary metals industries, maintenance, and repairs make a capacity utilization rate higher than ninety percent also unlikely. I acknowledge the shortcomings of the assumption of a vertical supply curve in the short-run but believe that it is at least to some extent reasonable to use it as a robustness check.

I define aggregate demand shocks following Kilian (2009) as shocks to world real GDP that cannot be explained by supply shocks. Hence, I impose the restriction that real price changes driven by zinc-specific demand shocks do not affect world real GDP within a year. This assumption is plausible given that Kilian (2009) shows that real price increases due to oil market-specific demand shocks do not result in a statistically significant decline in the level of U.S. real GDP. Furthermore, on a global scale a price increase is only a redistribution of income from importing to exporting countries such that global output should not be affected.

5 Sensitivity Analysis

Comm.	Model	Time	Market Place	Deflator	Lag length	Percentage Shares (%)		
						Commodity Demand Shock	Commodity Supply Shock	Commodity Spec. Demand Shock
Copper	LR	1841-2014	London	CPI	4	40	31	29
Lead	LR	1841-2014	London	CPI	2	36	12	53
Tin	LR	1841-2014	London	CPI	3	34	28	38
Zinc	LR	1841-2014	London	CPI	3	32	13	55
Cr. Oil	LR	1862-2014	Internat.	CPI	2	44	5	51

Notes: LR = Long-run restrictions, CPI = Consumer Price Index, Internat. = International. I have chosen the lag lengths according to the Akaike Information Criterion

Table 6: Contribution of the different types of shocks to price fluctuations in the baseline scenario.

Comm.	**Model**	**Time**	**Market Place**	**Deflator**	**Lag length**	**Percentage Shares (%)**		
						Commodity Demand Shock	**Commodity Supply Shock**	**Commodity Spec. Demand Shock**
Copper	SR	1841-2014	London	CPI	4	46	11	43
Lead	SR	1841-2014	London	CPI	2	33	18	47
Tin	SR	1841-2014	London	CPI	3	27	12	61
Zinc	SR	1841-2014	London	CPI	3	33	10	57
Cr. Oil	SR	1862-2014	Internat.	CPI	2	38	21	41

Notes: SR = Short-run restrictions, CPI = Consumer Price Index, Internat. = International. I have chosen the lag lengths according to the Akaike Information Criterion

Table 7: Contribution of the different types of shocks to price fluctuations in the baseline specification using the alternative identification scheme based on short-run restrictions.

Comm.	**Model**	**Time**	**Market Place**	**Deflator**	**Lag length**	**Percentage Shares (%)**		
						Commodity Demand Shock	**Commodity Supply Shock**	**Commodity Spec. Demand Shock**
Copper	LR	1841-2014	London	CPI	3	34	34	33
Lead	LR	1841-2014	London	CPI	3	41	12	47
Tin	LR	1841-2014	London	CPI	3	34	28	38
Zinc	LR	1841-2014	London	CPI	3	32	13	55
Cr. Oil	LR	1862-2014	Internat.	CPI	3	50	3	47
Copper	LR	1841-2014	London	CPI	6	44	26	31
Lead	LR	1841-2014	London	CPI	6	45	13	43
Tin	LR	1841-2014	London	CPI	6	37	30	33
Zinc	LR	1841-2014	London	CPI	6	31	17	52
Cr. Oil	LR	1862-2014	Internat.	CPI	6	46	18	36

Notes: LR = Long-run restrictions, CPI = Consumer Price Index, Internat. = International. I have chosen the lag lengths according to the Akaike Information Criterion

Table 8: Contribution of the different types of shocks to price fluctuations in the baseline specification using lag lengths of 3 and 6.

Comm.	**Model**	**Time**	**Market Place**	**Deflator**	**Lag length**	**Percentage Shares (%)**		
						Commodity Demand Shock	**Commodity Supply Shock**	**Commodity Spec. Demand Shock**
Copper	LR	1841-2014	London	PPI	4	38	26	36
Lead	LR	1841-2014	London	PPI	2	30	15	55
Tin	LR	1841-2014	London	PPI	3	26	31	43
Zinc	LR	1841-2014	London	PPI	3	26	13	61
Cr. Oil	LR	1862-2014	Internat.	PPI	2	49	6	46

Notes: PPI = Producer Price Index, Internat. = International. I have chosen the lag lengths according to the Akaike Information Criterion

Table 9: Contribution of the different types of shocks to price fluctuations in the baseline specification using the producer price index instead of the consumer price index to deflate prices.

Comm.	**Model**	**Time**	**Market Place**	**Deflator**	**Lag length**	**Percentage Shares (%)**		
						Commodity Demand Shock	**Commodity Supply Shock**	**Commodity Spec. Demand Shock**
Copper	LR	1850-2014	New York	CPI	4	18	40	42
Lead	LR	1841-2014	New York	CPI	2	35	11	53
Tin	LR	1841-2014	New York	CPI	3	34	28	38
Zinc	LR	1872-2014	New York	CPI	3	32	13	55
Cr. Oil	LR	1862-2014	Internat.	CPI	2	44	5	51

Notes: PPI = Producer Price Index, Internat. = International. I have chosen the lag lengths according to the Akaike Information Criterion

Table 10: Contribution of the different types of shocks to price fluctuations in the baseline specification using New York instead of London prices.

Comm.	Model	Time	Market Place	Deflator	Lag length	Percentage Shares (%) Commodity Demand Shock	Commodity Supply Shock	Commodity Spec. Demand Shock
Copper	LR	1900-2014	London	CPI	4	45	24	31
Lead	LR	1900-2014	London	CPI	2	43	13	43
Tin	LR	1900-2014	London	CPI	3	37	34	29
Zinc	LR	1900-2014	London	CPI	3	35	23	42
Cr. Oil	LR	1900-2014	Internat.	CPI	2	39	32	28
Copper	LR	1925-2014	London	CPI	4	56	10	33
Lead	LR	1925-2014	London	CPI	2	48	19	33
Tin	LR	1925-2014	London	CPI	3	42	33	25
Zinc	LR	1925-2014	London	CPI	3	47	18	35
Cr. Oil	LR	1925-2014	Internat.	CPI	2	39	33	14

Notes: CPI = Consumer Price Index, Internat. = International. I have chosen the lag lengths according to the Akaike Information Criterion

Table 11: Contribution of the different types of shocks to price fluctuations in the baseline specification over the periods from 1900 to 2014 and from 1925 to 2014.

6 The Case of Crude Oil

The real price of crude is primarily driven by commodity demand shocks and oil-specific demand shocks. However, while the empirical results are quite robust for the four mineral commodities examined above, the results for the crude oil market are less compelling due to structural breaks in the time series.

There are several sources for structural changes. First, Alquist et al. (2011); Dvir and Rogoff (2010); Hamilton (2011) point to strong changes in access to supply and the changing role of the its active management, in particular by the Texan Railway Commission and later by OPEC. Second, crude oil was mainly used for the production of kerosene for lighting during the 19th and beginning 20th century, and then rapidly as a source of energy for automobiles (Yergin, 2009). Finally, there is to my knowledge also no empirical evidence regarding the historical integration of the oil market, which is another potential source of structural change.

I have collected annual data for the price and production of crude oil from different sources including British Petroleum (2015) and Mitchell (2007). The data is available only from 1861 onwards and I present the sources in Tables 1 to 4 in this online-appendix.

Figure 13 shows the evolution of the identified structural shocks. Commodity demand shocks do not develop in a similar fashion as for the other examined mineral commodities. Oil supply shocks are quite pronounced in the time before the First World War and in the interwar period, but have somewhat decreased in amplitude after the Second World War.

The impulse response functions in Figure 14 show that a commodity demand shock has strong negative effects on the real price. This is an anomaly, since it should feature a positive effect. An explanation for this behavior is strong structural changes in the oil market. All other impulse response functions behave as expected. Like in Kilian (2009) an oil supply shock does not have a significant impact on the real price of crude oil.

The historical decomposition in Figure 15 reveals again the problem with regard to commodity demand shocks. As expected from the impulse response function, their contribution is turned on its head with a large accumulation of effects of positive commodity demand shocks during the Great Depression and a large accumulation of the effects of negative shocks during the 1950s and 1960s. Over the entire period examined, the accumulative effects of oil supply shocks are not important and the accumulative effects of oil-specific demand shocks make a strong contribution to the real price of crude oil especially during the 1970s as in Kilian (2009). This is in line with the argumentation of Kilian (2009) that the political uncertainty in the Middle East caused a strong increase in the precautionary demand for oil. Overall, the evolution of the accumulative effects of oil supply and oil-specific demand shocks is plausible over the entire time period examined and in line with the empirical evidence presented by Kilian (2009) for the period from 1973 to 2007.

The results for crude oil are not robust with respect to different sub-periods due to the familiar structural changes in the oil market. To study this phenomenon a structural VAR with time varying coefficients would be necessary and I leave this to future research.

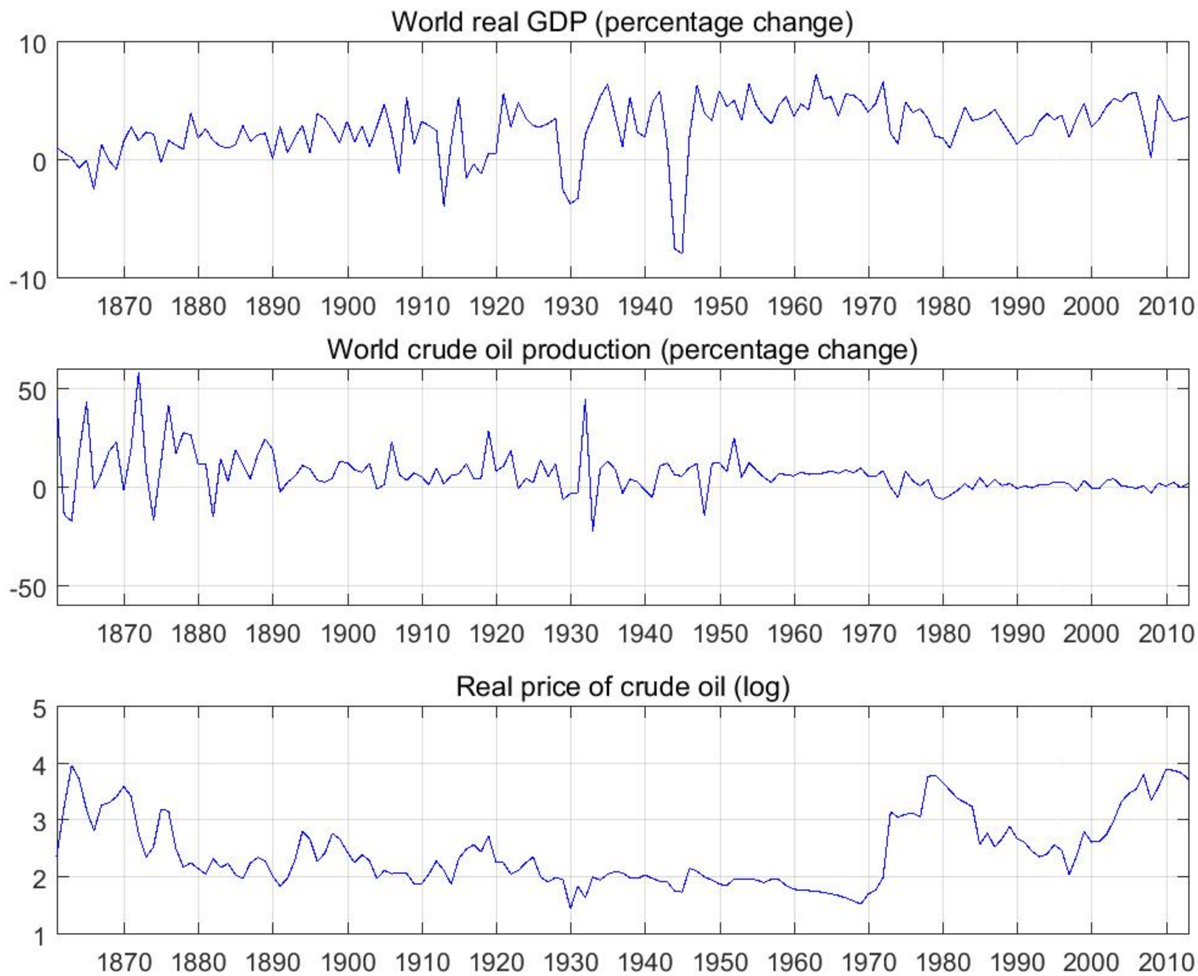


Figure 12: Historical evolution of world real GDP, world crude oil production, and the real price of oil from 1862 to 2014.

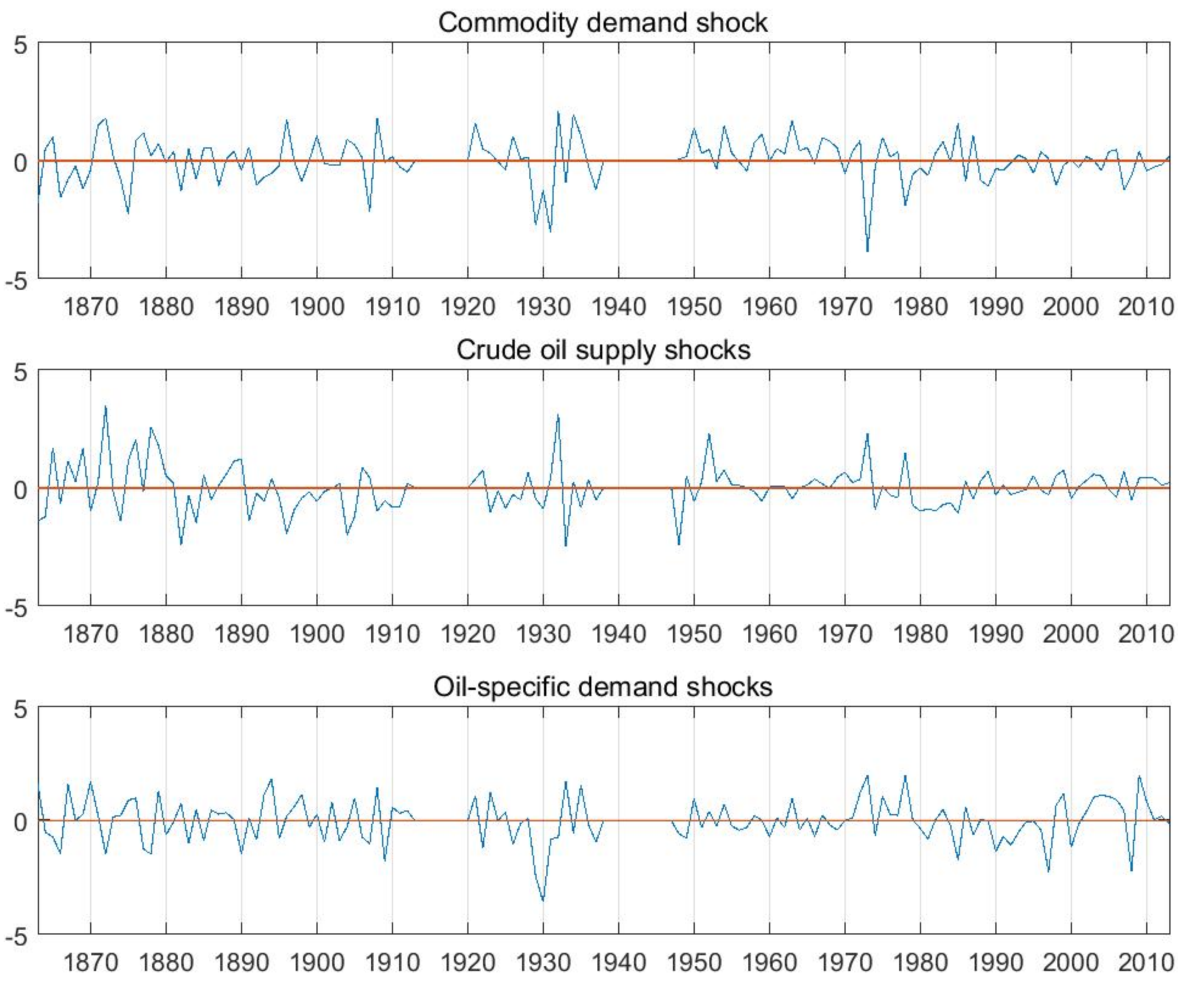
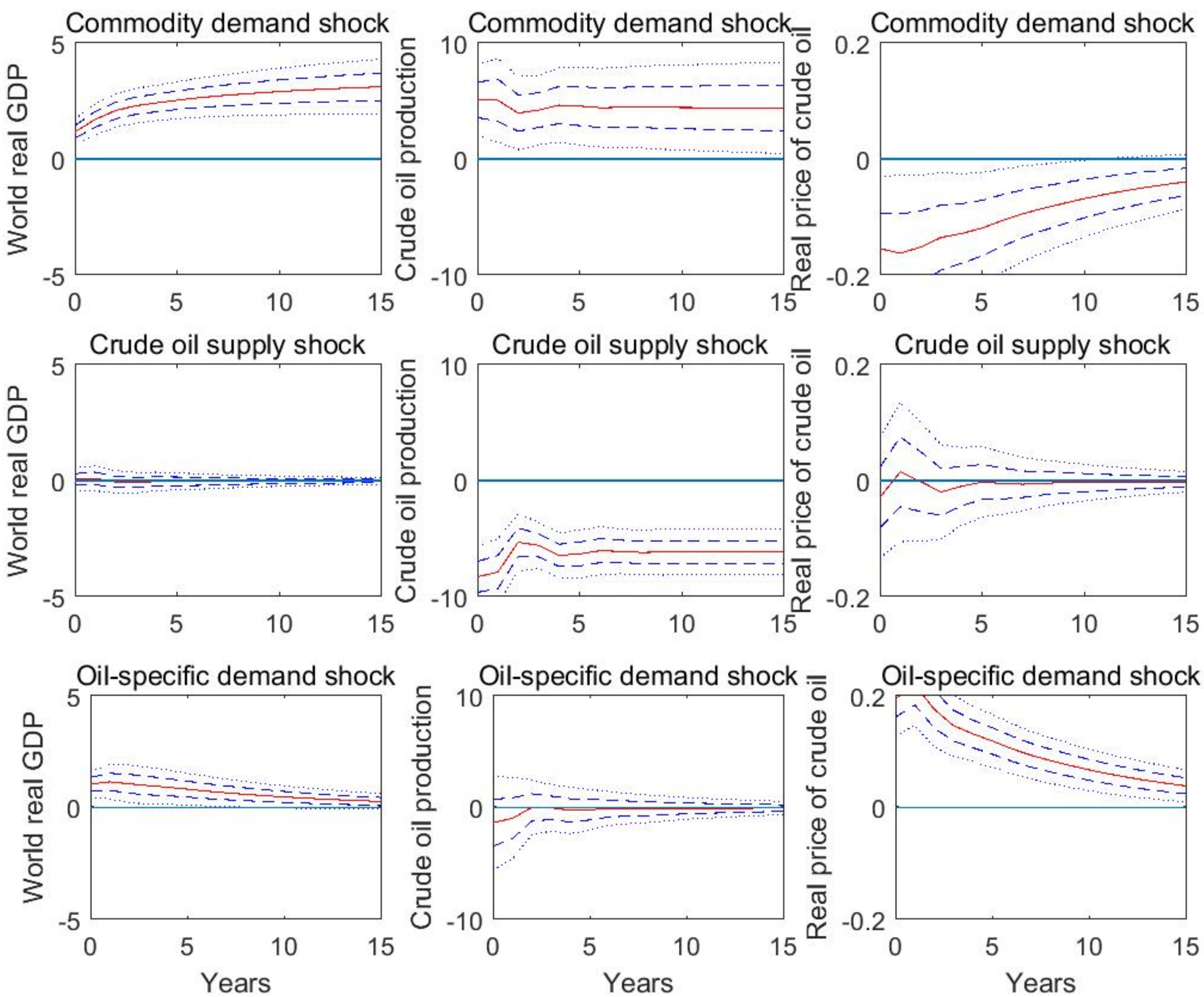


Figure 13: Historical evolution of the structural shocks for crude oil.



Notes: Point estimates with one- and two-standard error bands . I use accumulated impulse response functions for the shocks on world oil production and world real GDP to trace out the effects on the level of these variables.

Figure 14: Impulses to one-standard-deviation structural shocks for crude oil.

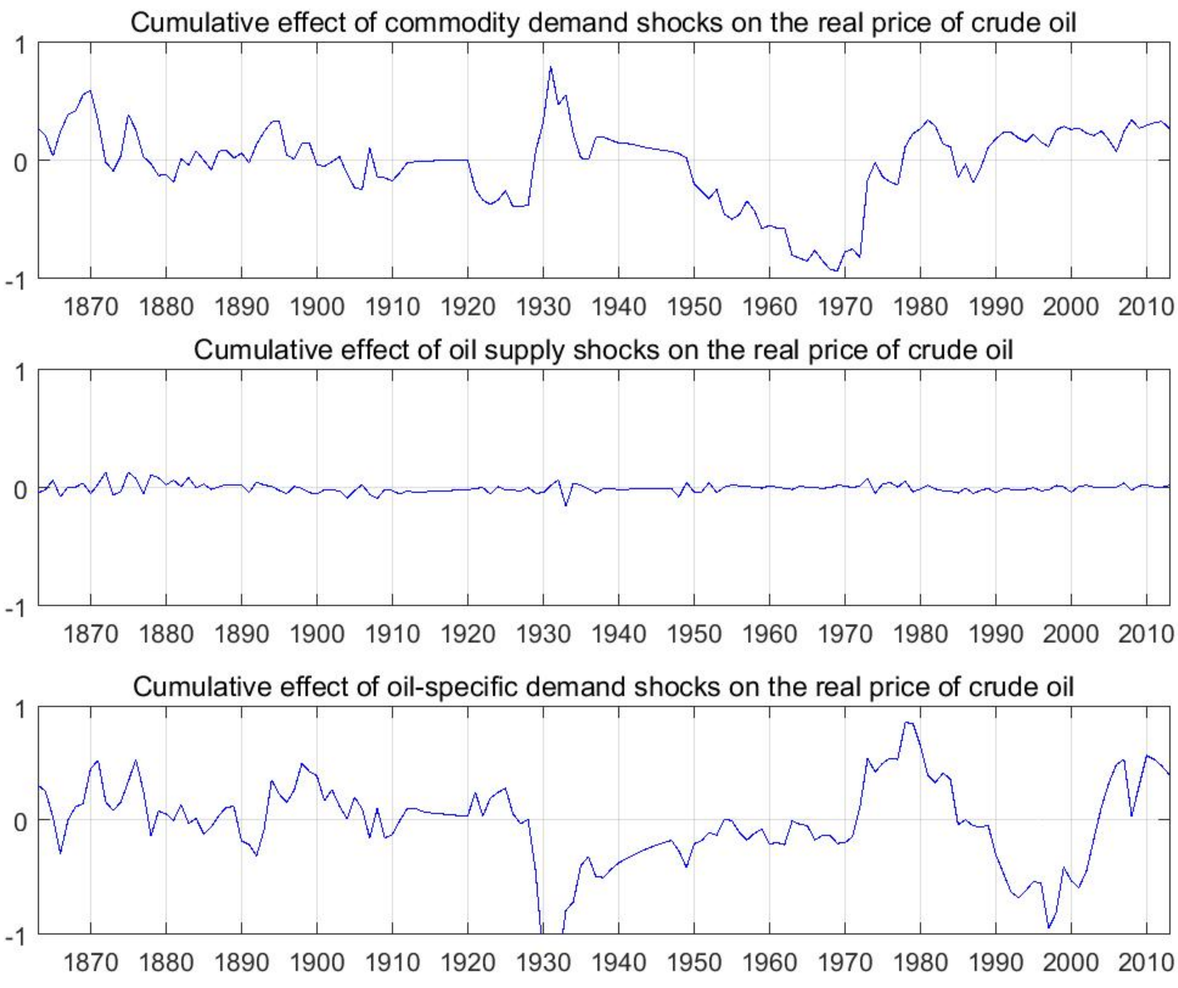


Figure 15: Historical decomposition of the real price of crude oil.

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