

WAR FINANCE AND AUSTRIAN BUSINESS CYCLE THEORY: THE NETHERLANDS' WISSELBANK IN THE WAR OF THE AUSTRIAN SUCCESSION AND THE FOURTH ANGLO-DUTCH WAR

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Resumen: La teoría austriaca del ciclo económico atribuye las recesiones a la creación inflacionaria de crédito facilitada por el sistema bancario de reserva fraccionaria. En un estudio previo, pusimos a prueba esta hipótesis de la reserva fraccionaria, examinando específicamente el balance y la creación monetaria del Banco de Ámsterdam (Wisselbank) entre 1609 y 1819. Para distinguir los efectos de la guerra de los del bajo nivel de reservas fraccionarias en la economía de Ámsterdam del siglo XVIII, el presente estudio analiza la Guerra de Sucesión Austriaca (1740-1748), durante la cual el Wisselbank mantuvo altos niveles de reservas, en comparación con la Cuarta Guerra Anglo-Holandesa (1781-1784), periodo en el que la posición de reservas del banco se deterioró progresivamente. Encontramos que el carácter fractal de la volatilidad de precios fue consistente con la teoría austriaca del ciclo económico durante este episodio de expansión monetaria mediante reservas fraccionarias, lo que resultó en inflación de precios y burbujas especulativas. Es altamente probable que la banca de reserva fraccionaria haya contribuido y agravado los ciclos de auge y caída en los Países Bajos durante el periodo examinado.

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Professor Guzelian conceptualized this article and procured data, Professor Mulligan provided methodology and computations, and Dr. Zelmanovitz provided insights into Austrian theory. All contributed to its drafting.

Palabras clave: Banca de reserva fraccionaria; expansión monetaria; estabilidad de precios.

Clasificación JEL: E42; E44; N13; N23; N83.

Abstract: Austrian business cycle theory attributes recessionary downturns to inflationary credit creation made possible by fractional-reserve banking. We tested this fractional-reserve hypothesis in a previous paper, specifically by examining the 1609-1819 Bank of Amsterdam's (Wisselbank) balance sheet and money creation. To separate the effects of war and low fractional-reserve banking on the 18th century Amsterdam economy the present study examines the 1740-1748 War of the Austrian Succession during which the Wisselbank maintained high reserves, compared with the 1781-1784 Fourth Anglo-Dutch War during which the bank's reserve position progressively deteriorated. We find that the fractal character of price volatility was consistent with Austrian business cycle theory during this expansionary fractional-reserve episode resulting in price inflation and speculative bubbles. It is highly likely that fractional-reserve banking contributed to and aggravated Dutch boom-bust cycles in the period examined.

Keywords: Fractional reserve banking; monetary expansion; price stability.

JEL Classification: E42; E44; N13; N23; N83.

Introduction

A full reserve bank's deposits never exceed actual assets. A bank maintains fractional reserves when it «grants credit to an amount exceeding this [amount] in deposits,» (Hayek 2008, p. 82), or in other words, «re-lends several times the amount deposited» (Hayek 2008, p. 86). Guzelian and Mulligan (2015) previously examined the Wisselbank's shift from full-reserve to fractional-reserve banking in 1780 at the start of the Fourth Anglo-Dutch War. Together with Wainhouse (1982, 1984), these seem to be the only empirical demonstrations that fractional-reserve banking impairs economic growth and stability. The Austrian concern with fractional-reserve banking—particularly when coordinated by central banks—is that prices,

employment, investment, and output all become more volatile, less sustainable, and subject to more frequent and severe fluctuations (Allais 1993; Hayek 2008; Mises 1998; Rothbard 1994, 2000, 2009; Haberler 1996; Huerta de Soto 2009, 2011). The fractional-reserve hypothesis condemns core practices of contemporary central banking, because after the British 1844 Peel Act, the world's banking systems almost universally adopted fractional reserves (Huerta de Soto 2011). The absence of any counter-examples make it difficult to evaluate the impact of fractional-reserve banking (Selgin & White 1996). While we are mindful of the challenges in examining a praxeological theorem's causal relevance (Guzelian 2016), empirical studies informed by Austrian business cycle (ABC) theory offer an opportunity to engage with and hopefully persuade empirically oriented mainstream economists. Our results support the Austrian praxeological claim of real-world relevance when applied to data that are ideally suited for examining such a claim.

Guzelian and Mulligan (2015) focused on the Bank of Amsterdam ("Wisselbank," 1609-1819), which practiced full- or high-reserve banking for nearly a century. In 1779, the Wisselbank abandoned full reserve lending and allowed its reserve ratio fall to approximately 20% by 1788 (Quinn & Roberds 2014b, pp. 26-27)—still very conservative by modern standards. More leveraged reserves accompanied significant price and output instability¹. Accordingly, we measured Amsterdam commodity price and interest rate volatility with fractal Hurst exponents, a measure of persistent price fluctuations and long-term volatility, finding that volatility generally increased compared to the Wisselbank's previous full-reserve era.

However, statistical tests in Guzelian and Mulligan (2015) potentially suffer from identification problems and endogeneity bias because the price volatility and boom-bust cycles caused by the war can be difficult to distinguish from the excessive lending permitted by fractional reserve banking (Hazlitt 2008, pp. 13-16).

¹ Austrian economists have praised the Wisselbank as an exemplary full-reserve bank «from its opening in 1609 until it yielded to the temptation of financing Dutch wars in the late eighteenth century» (Rothbard 1994, p. 44; see also Huerta de Soto 2009; Andrews 2010).

War procurement may distort prices even in the absence of credit expansion. However, without the inflationary credit expansion which nearly always accompanies a state of hostilities, the result is a real business cycle (Kydland & Prescott 1982; Long & Plosser 1983; Plosser 1989; Romer 2011), not an Austrian business cycle.

The present article seeks to distinguish potentially confounding war effects from the Wisselbank's low fractional-reserve lending. The approach is to compare two different wars: the War of the Austrian Succession (1745-1749) where the Wisselbank maintained high reserve ratios, and the Fourth Anglo-Dutch War (1781-1784) when reserves fell to around 35% by the war's end in 1783 and fell further to about 20% by the end of the subsequent civil unrest of the Dutch Patriot Period in 1788.

We find that Amsterdam commodity prices and interest rates show lower kurtosis and greater variability during the low-reserve period of the Fourth Anglo-Dutch War and Patriot Period than during the high-reserve period of the War of the Austrian Succession. This suggests the Wisselbank's low reserve ratio in the 1780s was likely a factor in leveraging credit and price volatility throughout the Dutch economy. Even during wartime, high-reserve banking seemed to suppress inflation and price volatility, suppressing commodity price bubbles and the unsustainable real expansion that makes a downturn inevitable.

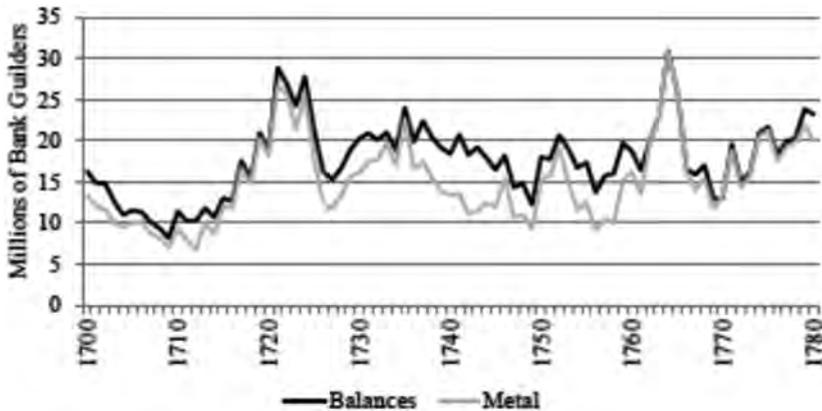
The rest of the paper is organized as follows—Section 2 gives a brief historical account of Dutch history and the conduct of the Wisselbank during the War of the Austrian Succession; Section 3 outlines the military and financial history of the Fourth Anglo-Dutch War and the following Dutch Patriot Period of civil disorder; Section 4 describes the data; Section 5 justifies our choice of the Hurst exponent as a measure of the fractal volatility; Section 6 discusses the results and their implications; Section 7 presents concluding comments.

2. The Wisselbank & the War of the Austrian Succession

The Amsterdamsche Wisselbank, literally the Exchange Bank of Amsterdam, was chartered by the city government in 1609 and

operated out of the city hall. From its earliest days, the Wisselbank frequently engaged in lending and fractional-reserve banking, but only on a limited scale, generally maintaining high or full reserves (Quinn & Roberds 2010, 2014a, 2014b). Figure 1 displays the Wisselbank's deposit liabilities and specie reserves over the 1700s. Reserves were always a high percentage of liabilities, often 100%. The Wisselbank assigned a book value to deposited specie and coinage based on its metallic content, not on the specie's official value. By the 1600s this practice led to a stable, fractional agio (exchange rate) between bank guilders (book currency) and circulating metal specie, although the bank charged a penalty for conversion and withdrawal of specie (Quinn & Roberds 2006, 2009).

FIGURE 1.
WISSELBANK BOOK BALANCES AND METAL RESERVES, 1700-1780



Source: Quinn & Roberds (2014a), van Dillen (1934).

Of special note in Figure 1 is that the reserve ratio during the War of the Austrian Succession (1740-1749) did fall below full reserves, but never below 75%. And over the war and immediate post-war years, the bank often held nearly 100% reserves (e.g., 1747 and 1750).

The War of the Austrian Succession began shortly after the death of Holy Roman Emperor Charles VI. His daughter Maria Theresa assumed the throne as Queen of Hungary, Croatia, and Bohemia, Archduchess of Austria, and Duchess of Parma, but as a female was not eligible for election as emperor. The imperial crown went to her cousin Charles VII of Bavaria who enjoyed French and Prussian support. Maria Theresa then contrived to share sovereignty with her husband the Grand Duke of Tuscany Francis Stephen I, enabling him to serve as an imperial prince-elector, which neither could do in their own right (Beales 1987, p. 183). Charles VI had left government finances severely depleted and Maria Theresa was initially perceived as a weak and ineffectual ruler.

Ironically, Charles VI's financial overextension was largely due to his efforts to ensure Maria Theresa's succession through the Pragmatic Sanction, a 1713 treaty obliging most of the German states to recognize her as heir to his hereditary lands and titles. Frederick II of Prussia violated the Pragmatic Sanction by invading Silesia on December 16, 1740 initiating the War of the Austrian Succession, with Prussia, France, and Bavaria allied against Maria Theresa (Browning 1995). Austria was supported by the Dutch Republic, Great Britain, Russia, Saxony, Sardinia, and Sweden. Spain, governed by a competing branch of Hapsburgs and already at war with Great Britain, hoped to force the Austrian Hapsburgs from northern Italy. Maria Theresa's husband Francis Stephen I was elected Holy Roman Emperor in 1745, making her Empress. They reigned jointly until his death in 1765, after which Maria Theresa reigned jointly with their son Joseph I. Francis Stephen took no active role in politics, deferring entirely to his wife as the more senior co-sovereign.

Although the imperial couple had sixteen legitimate children, Francis was also an infamous serial philanderer. Nevertheless, Maria Theresa remained devoted to him. Although she delegated financial affairs to her husband, a fairly significant concession, she did not otherwise allow him to participate in government. Fortunately, the emperor possessed extraordinary financial discipline and imposed more frugal and sustainable management on state expenditures than Maria Theresa might have managed alone (Bled 1994).

The war raged for four years before reaching the Netherlands. On May 17, 1744, Louis XV of France invaded the Austrian Netherlands

with 87,000 men, initially taking Menin and Ypres. He faced an allied British, Dutch, German, and Austrian army but the better organized French troops outmanned the defenders by a ratio of 4:3. Louis' advance was so rapid that the Dutch sent envoys to sue for peace but Louis rejected their entreaties (Browning 1995, pp. 172-174).

Prince Charles of Lorraine crossed the Rhine on June 30, 1744, with an allied army of 70,000, threatening to outflank Louis and cut off his supply. Louis responded by withdrawing to Alsace and Lorraine by July 20 (Browning 1995, p. 174). After regrouping, Louis reinvaded the Netherlands the following Spring on March 31, 1745 with an army of 95,000, the largest force of the entire war, besieging Tournay which held a Dutch garrison of only 7,000 men. Allied Anglo-Austrian-Dutch troops marched furiously to relieve them, and on May 11, 1745, fought the Battle of Fontenoy. Despite gallant efforts, British forces were deserted by their Dutch allies and surrounded by the French. This loss created shock waves across Europe, as British forces had previously been considered all but invincible. Moreover, because of a simultaneous Jacobite uprising in Scotland, British troops had to divide their forces between the continental conflict and homeland defense (Browning 1995, pp. 206-213, 220-221, & 243).

Great Britain's weakened position left its allies largely to their own devices, rendering the Dutch Republic's situation especially precarious. By the end of 1745, the French had taken Tournay, Ghent, Bruges, Oudenarde, Termonde, Ostend, Nieuport, and Ath (Browning 1995, pp. 219-220). Brussels capitulated on February 19, 1746. After two further major victories—Rocoux (October 11, 1746) and Laffeld near Maastricht (July 2, 1747)—the French had conquered the entire Austrian Netherlands and captured significant portions of the United Provinces. On September 16, 1747, the French took the important fortress of Bergen op Zoom in Zeeland. On May 7, 1748, the French Army took the fortress city of Maastricht, previously considered impregnable (Browning 1995, pp. 281-286, 304-306, 313-318, & 352-353).

Threatened with outright conquest and with even Amsterdam threatened, Prince William IV of Orange and the Dutch government sought to finance new Dutch troops and armaments by selling war bonds. While they raised the appreciable sum of 50,000,000 florins (Edmundson 1922), it was insufficient. William had to write

the British informing them of the Dutch Republic's precarious financial and military situation, telling them he could not continue without a loan. As Edmundson concludes, «[t]his pitiful revelation of the condition of their [Dutch] ally decided Great Britain to respond to the overtures for peace on the part of France» (Edmundson 1922, p. 313).

The exhausted major powers signed a general armistice, the Peace of Aix-la-Chapelle, on October 18, 1748, followed by a first implementation treaty signed by the French on December 6, 1748. King Louis XV, wishing to appear magnanimous, agreed to relinquish his Dutch conquests. On January 28, 1749, the French withdrew from Brussels and the Netherlands (Browning 1995, p. 362). Still, the French army had left the Dutch Republic in cultural, political, and economic turmoil.

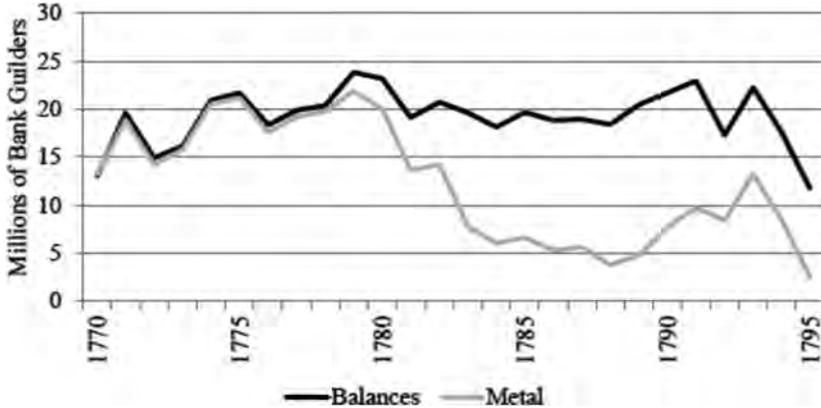
3. The Fourth Anglo-Dutch War and the Patriot Period

From 1779 even before the start of the Fourth Anglo-Dutch War, pressure was mounting on the Wisselbank's directors to underwrite massive loans to the Dutch East India Company. To support the war effort the Wisselbank made additional loans to the Amsterdam city government, to private parties through a new lending facility, the Municipal Loan Chamber, and to provincial governments across the Netherlands (Quinn & Roberds 2014a). After 1780 loans made to the municipal government and the Dutch East India Company were nominally interest-free (Quinn & Roberds 2014b). The City of Amsterdam, which sponsored and owned the Wisselbank, retained all the bank's profits (Quinn & Roberds 2014b).

This new war lending was not backed by specie and as the war dragged on the Wisselbank's balance sheet progressively deteriorated. Simultaneous specie flight from the Dutch Republic led to a precipitous decline from the bank's near-full reserve ratio in 1779, to 28% by summer 1783, falling to approximately 20% by 1788 (Figure 2)².

² The Netherlands were spared hyperinflation only because the Wisselbank's issues of unbacked paper notes to finance the war effort were limited, though many of

FIGURE 2.
WISSELBANK BOOK BALANCES AND METAL RESERVES, 1770-1795



Source: Quinn & Roberds (2014a), reprinting van Dillen (1934).

Wisselbank historians Quinn and Roberds (2014b, p. 21) concluded that «the Bank [was] insolvent by 1784.» This was true despite the City repaying of some of its loans with interest in 1783, even though they were not obliged to do so. Today this attempt to shore up the Bank's balance sheet would be characterized as a bailout. Quinn and Roberds ascribe the Wisselbank's eventual demise to three concurrent errors after 1780:

“The Bank's first policy error was its decision to support a large, bankrupt government-sponsored enterprise (the Dutch East India Company) while trying to maintain an indefensible policy target (the agio peg of 4-5 percent). Negative impacts on the Bank's net worth were amplified by a second policy error, which was the City of Amsterdam's practice of keeping Bank profits to itself and allocating losses to the Bank. The first two policies eroded the net worth of the Bank until a fiscal bailout offered the only feasible way to restore the Bank's reputation. A third policy error, of inadequate fiscal backup, was manifested in the City's botched recapitalization of 1791-92. Applied in isolation, any of these policies

the Wisselbank's specie deposits were withdrawn without a simultaneous reduction in bank guilder notes outstanding.

would have worked to undermine the Bank. The key lesson seems to be that a combination of all three was particularly toxic" (Quinn & Roberds 2014b, pp. 26-27).

Just as the Wisselbank's reserve ratio started to decline, Great Britain declared war on the Dutch Republic on December 20, 1780. While many causes contributed to this war the most relevant were Anglo-Dutch trade competition in the East Indies and Africa, Dutch support for American independence from Britain, and British fears that the Dutch might enter alliances with Russia, Sweden, and Denmark (Scott 1988).

Within mere weeks of the war's beginning, the British had captured more than 200 Dutch merchantmen carrying 15 million guilders in cargo. 300 more Dutch merchantmen were trapped in foreign ports (Dirks 1871, p. 291). Furthermore, Britain was not content to choke off the Netherlands' foreign trade, but blockaded Dutch ports to strangle the Dutch domestic economy. Syrett (1998, p. 129), aptly describes the situation and effects:

"When Britain declared war, units of the Royal Navy were dispatched to blockade the Dutch coast. Day after day they patrolled the coast of the Netherlands and the eastern approaches of the English Channel, searching for intelligence and for ships attempting to carry goods to Dutch, French, and Spanish ports. ... The British blockade of the coast of the Netherlands destroyed the national economy as well as Dutch seaborne trade. On 24 August 1781, an intelligence report reached the [British] Admiralty stating that "the Harbour of Amsterdam was like a desert..."³

Given the collapse in import tonnage⁴, it should be little surprise that many commodity prices skyrocketed and became

³ However, the British were not able to eliminate all seaborne trade. Goods imported through Hamburg were able to avoid the blockade because low-draft vessels could use a coastal route to the Netherlands that was protected by the Frisian Islands up to the Zuiderzee. British blockaders' deeper draft limited their ability to interdict this route. Thanks are due to Joost P.B. Jonker for making us aware of this situation.

⁴ Welling (1998) provides import data for hundreds of Dutch goods for the years in question. They are available at: <http://www.let.rug.nl/welling/paalgeld/>, transcribed from the Portbooks of the Levy of the Paalgeld.

progressively more volatile as the war went on, especially colonial goods like coffee, sugar, and black pepper (Guzelian & Mulligan 2015).

Although the British captured Dutch ports abroad in Asia and Africa, the Netherlands were never invaded as they had been by the French. Nevertheless, the blockade kept an ironclad grip on the Dutch economy until an armistice was reached in January 1783. In an attempt to shore up Dutch finances, the Wisselbank's directors decreased the Bank's reserve ratio to 28% by Summer 1783, down from 97% just four years earlier (Quinn & Roberds 2014b, p. 20). The British and Dutch signed preliminary articles of peace on September 2, 1783, with the final treaty being ratified on May 20, 1784.

However, the 1783 armistice's conclusion to the blockade did not end the Dutch Republic's political trials. As soon as the war was over an internal rebellion broke out in the Netherlands known as the *Patriottentijd* or Patriot Period (1780-1787), inspired by Enlightenment ideals and the American Revolution, seeking to forcibly overthrow the House of Orange⁵. The Patriots controlled large territories by 1785 but the Prussian Army drove them out in 1787 and most fled to France (Schama 2005; Scott 1988). The war and subsequent Patriot occupation led to the fall of the Dutch Republic, which ultimately collapsed in the Batavian Revolution of 1795.

4. Data

To compare price volatilities for the two war periods, we employed the same data set as in Guzelian and Mulligan (2015),

⁵ The princes of Orange had been hereditary stadholders in Friesland since the revolt against Spanish rule in 1572. William the Silent had been stadholder of Friesland and was appointed stadholder of Holland, the first province to revolt. Although each of the seven provinces could appoint their own stadholder, in practice they most often selected the head of the House of Orange. The stadholder of Holland and Zeeland would also generally assume the role of Captain-General of the Dutch Army. The office was effectively hereditary and became formally so in 1747, but William V, the last stadholder, fled in 1795. After the Napoleonic Wars, the Congress of Vienna invited Prince William Frederick, William V's heir, to assume the throne of the new kingdom of the Netherlands as William I.

available online at www.iisg.nl/hpw/. Professor Mikołaj Malinowski of the Rijksuniversiteit Groningen assembled it electronically from a manuscript stored at Harvard University's Kress Library and reproduced at the Netherlands Economic History Association (NEHA). The dataset provides weekly maximum and minimum prices for fifteen Amsterdam-traded commodities and international bills of exchange, mostly staple grains and colonial trade goods, as well as the official bank agio, the annualized discount rate the Wisselbank charged on specie deposits.

The Kress manuscript includes price series for sixty-six commodities and bills of exchange. However, Malinowski included only the sixteen price series most representative of the era's market activity. We excluded black pepper maximum prices, East Indies coffee price maxima, and Gdansk and Königsberg bills of exchange due to post-1780 gaps in these data. In the case of the two bills of exchange price series, no data were reported after 1780. We also excluded Königsberg wheat, black pepper maxima, Hamburg Bills of Exchange maxima, and agio maxima because no observations were provided for nearly two-thirds of the duration of the War of the Austrian Succession. Among the remaining commodities a few had minor gaps, while others were complete sets (Malinowski 2013, Table 1). The data were examined and compared for the War of the Austrian Succession (1740-1748) and the Fourth Anglo-Dutch War (1780-1784). The start and end dates for the two periods examined were April 5, 1745 marking the start of siege of Tourney when the French reinvaded the lower Netherlands, to February 3, 1749 when French troops withdrew from Brussels and the Netherlands for the War of the Austrian Succession, and December 25, 1780 five days after Britain's declaration of war to February 11, 1788 after the Prussian army had driven most of the Patriots out of the Netherlands for the Fourth Anglo-Dutch War. Hurst exponents were computed for each price or interest series as if there were no missing observations. Although the Kress weekly price data are largely intact over the periods in question, sparsely observed data are not problematic for estimating the Hurst exponent for such self-similar series.

5. Methodology

Conventionally, price distributions with greater variance around a constant mean are considered more volatile. The traditional test of variance ratios is an F-test of the hypothesis that the variance of a given set of normally distributed populations, where each has the same mean, are equal (Lomax 2007). Deferring to convention, we compute F-distributions for each war's commodity prices. These results are presented in Table 1 below.

However, it is not necessarily valid to assume that commodity price series are normally distributed. Mandelbrot (1963b) showed that commodity price series are non-Gaussian. We employ the Hurst exponent as a measure of price volatility, because it better reflects historical price movements and as a more powerful, modern, and non-parametric test, supersedes F-tests and other tests that assume either a stable mean or underlying Gaussian distribution (Mandelbrot 1963b; Mandelbrot & Hudson 2004; Mulligan 2010).

The Hurst exponent H was introduced as a measure of fractal volatility in the hydrological study of the Nile valley (Hurst 1951) and is the reciprocal of the characteristic exponent α of the probability distribution. Mandelbrot's (1963a, 1963b, 1972a, 1975, 1977) and Mandelbrot and Wallis's (1969) R/S or rescaled range analysis characterizes time series as one of four types:

- 1) platykurtic anti-persistent or mean-reverting series, also called biased random walks, random walks with drift, or fractional Brownian motion for which $0 < H < \frac{1}{2}$,
- 2) mesokurtic Gaussian or normal processes, also called Brownian noise or random walks for which $H \approx \frac{1}{2}$,
- 3) leptokurtic persistent or trend-reinforcing processes for which $\frac{1}{2} < H < 1$, or
- 4) autocorrelated or dependent series for which $H > 1$.

Mandelbrot-Lévy distributions are derived from the generalized central limit theorem and include the normal or Gaussian ($H \approx \frac{1}{2}$) and Cauchy ($H \approx 1$) as limiting cases (Lévy 1925; Gnedenko & Kolmogorov 1954). They are also referred to as stable,

Lévy-stable, L-stable, stable-Paretian, and Pareto-Lévy. The Hurst exponent is $H = 1/\alpha = 1/2$ for normally-distributed Gaussian processes. $H = 1$ for Cauchy processes, the most extreme leptokurtic fat-tailed member of the family. H is also related to the fractal dimension D by $D = 2 - H$.

Rescaled-range or R/S analysis is the conventional method introduced by Mandelbrot (1963a, 1963b, 1972a). R/S represents the range of a sample divided by the sample standard deviation, with R/S computed for various sample sizes. R/S varies systematically as a function of the sample size n , and the Hurst exponent H is defined from the relationship

$$R/S = an^H$$

where R is the average range of all subsamples of size n , S is the average standard deviation for all samples of size n , a is a scaling variable, and n is the size of the subsamples, which is allowed to range from an arbitrarily small value to the largest subsample the data will allow. Putting this expression into logarithms yields

$$\log(R/S) = \log(a) + H \log(n),$$

which allows H to be estimated as a regression slope. H ranges from zero to $1/2$ for anti-persistent platykurtic series, equals $1/2$ for normal, Gaussian, or random walk series, ranges from $1/2$ to one for persistent leptokurtic series, and is greater than one for a persistent or autocorrelated series. Mandelbrot, Fisher, and Calvet (1997) refer to H as the self-affinity index or scaling exponent.

Difficulties in applying and interpreting the R/S estimate of H led to the development of more robust approaches. The variogram method used in this paper is similar to Mandelbrot's original R/S rescaled range method, substituting the variance of subsamples of varying sizes drawn from a series (Kulatilake & Pan 1998; Stratakos & Sakellariou 2006; Wawszczak 2007; López et al 2009). The variogram or variance of the increments is defined as the expected value of the squared difference between two x values in a series separated by a distance h , where h is permitted to increase from the smallest to the largest values for which the

variogram can be computed. The variogram of a series $x(n)$ is measured by the equation

$$2\gamma(n, h) = (1/M) \sum_{i=1, M} [x(n_i) - x(n_i + h)]^2 = Kh^{2H}$$

where M is the number of pairs of roughness heights spaced h observations apart, for each given lag distance h . The Hurst exponent H is estimated by least-squares regression from the logarithmic form of the relationship $2\gamma(n, h) = Kh^{2H}$, analogous to $R/S = an^H$:

$$\log [2\gamma(n, h)] = \log K + 2H[\log (h)].$$

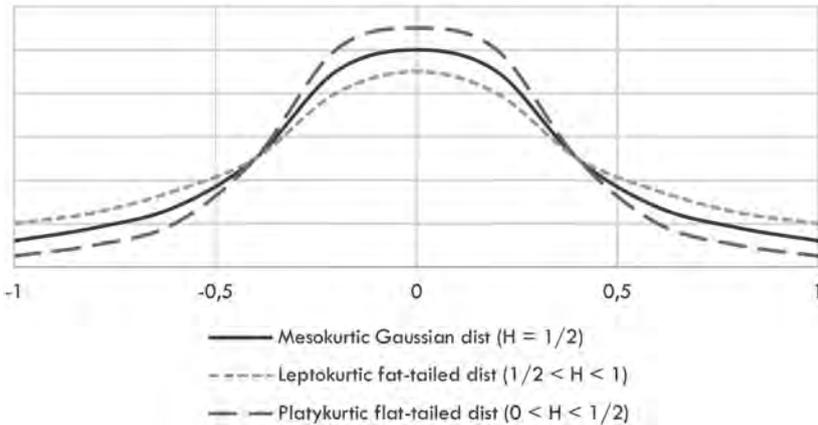
One advantage of this approach is that it does not assume a constant population variance for price or interest rate changes and thus will be robust to switching across regimes with different means, variances, or kurtoses.

When the series kurtosis is Gaussian or mesokurtic, price changes are merely a succession of unremarkably fluctuating white swans likely to result from the routine entrepreneurial experimentation of market process, where market participants are bidding and offering to uncover a price that will clear the market. Platykurtic flat-tailed series exhibit relatively frequent grey swans, that is, outliers are relatively common but also less extreme and may not be perceived as outliers at all. The more platykurtic a time series, the more common grey swans are in it. In eras of moderate price destabilization, whether attributable to war, fractional-reserve credit expansion, or some other cause, grey swan outlier price changes are as common as the white swans of a Gaussian regime. This might be characterized by moderate inflation that is relatively easy for agents to anticipate and incorporate into their bids and offers.

In contrast, a leptokurtic fat-tailed distribution, with the Cauchy distribution as the most extreme case, means that black swans are very rare but catastrophic. These are almost invariably extremely large price changes that accompany economic collapses and cannot be anticipated. Hyperinflation that results in monetary and economic collapse would be an example of a leptokurtic event. The

three basic forms of multifractal distributions can be represented graphically as in Figure 3.

FIGURE 3.
RELATIONSHIP BETWEEN HURST EXPONENT AND KURTOSIS



Note: the horizontal axis is the dimensionless scale of the observed variable standardized by subtracting the population mean and divided by the standard deviation.

To compare traditional variance and fractal price volatilities for the two war eras, we split the Malinowski data into prices for the War of the Austrian Succession (March 31, 1745 — December 4, 1748), and the Fourth Anglo-Dutch War and Patriot Period (December 20, 1780 — September 1787). We could have chosen from several dates for the start period for the War of the Austrian Succession. Admittedly, the selection of start and end dates of our data runs is somewhat arbitrary. For example, the French had already invaded the Netherlands in 1744 before withdrawing, only to return with a larger force in 1745. We could have also chosen multiple dates as the endpoint for the War of the Austrian Succession, such as the Peace of Aix-la-Chapelle signed on October 18, 1748, the first implementation treaty signed by France on December 6, 1748, the second implementation treaty signed by the remaining belligerents on January 21, 1749, the actual withdrawal of French troops on

January 28, 1749, etc. This endpoint vagueness also exists for the Fourth Anglo-Dutch War, the end of which could be dated to the armistice and the end of the blockade in January 1783, the preliminary agreement of September 2, 1783, or the final treaty of May 20, 1784. Since the actual withdrawal of French troops (January 28, 1749) and cessation of Dutch hostilities of the Patriot Period (late 1787/early 1788) would be the most psychologically significant dates to the populaces, we chose these these breakpoints to indicate that the conflicts had ceased and conditions had reverted to some semblance of normalcy⁶. We compared Hurst exponents for each subset to identify statistically significant differences with confidence intervals $\leq 95\%$.

6. Results

Guzelian and Mulligan (2015) demonstrated that after sixty years of high reserves the Wisselbank's rapid descent into low fractional-reserve banking in the 1780s coincided with dramatically higher commodity price volatility. The present study's *ex ante* hypothesis is that that volatility was primarily due to the Wisselbank's low fractional-reserve banking rather than the Fourth Anglo-Dutch War⁷.

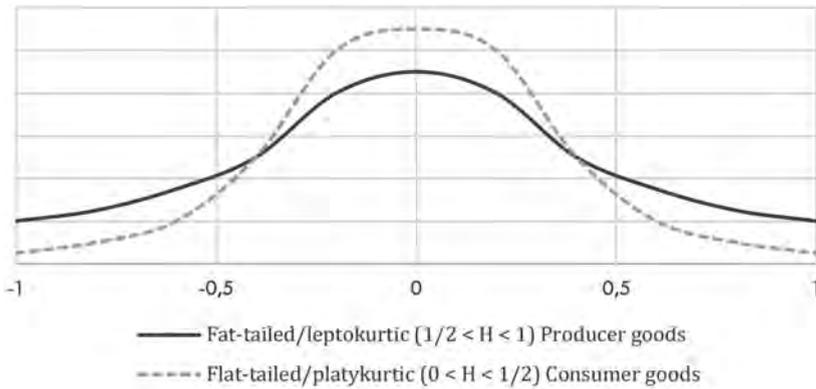
Huerta de Soto (2011) suggests that during any boom-bust cycle attributable to overleveraged fractional-reserve banking, price fluctuations have distinctly different characters for consumer and producer goods. Demand for consumer goods is less volatile than for producer goods facing derived demand. Once credit expansion sufficiently distorts relative prices, either by lowering interest rates making investment artificially cheap or by allocating credit to politically

⁶ The lead-up to a war could also create price volatility, and the formal end of hostilities does not necessarily end wartime economic effects.

⁷ Fractional-reserves only explain endogenous money expansion to the extent banks' profit motive incentivizes them to expand lending only for low-risk loans that are expected to be profitable. The problem arises when the same fractional-reserve arrangement leads to exogenous credit creation, without regard for credit risk or loan profitability. This is generally the case when loans are made for political reasons like war finance.

favorable activities like war procurement, these changes in the production structure lead to further misallocation which may ultimately result in capital losses as some investments become unprofitable and need to be reallocated to more sustainable uses [Figure 4].

FIGURE 4.
DISTRIBUTION OF PRICE CHANGES
FOR CONSUMER GOODS V. PRODUCER GOODS



Note that figure 4 does not depict the distribution of *baseline* price changes to which to compare *bubble* prices. When overleverage from fractional-reserve banking causes bubbles in consumer and capital goods prices, what would the time trend of prices have looked like, *ceteris paribus*, if bank lending had been disciplined by full-reserve banking? Entrepreneurial innovation guarantees dynamic prices (Huerta de Soto 2008). ABC theory posits that easy-money, low-interest policies create a bubble economy with price volatility beyond what would have occurred with full-reserve banking. Austrians do not believe the magnitude of the additional price movements can be predicted but assert *a priori* that *some* additional price movement will occur⁸. Though the magnitude of

⁸ Price stability can be achieved under fractional-reserve banking such as in the U.S. under the 1870-1914 gold standard, despite increases in the money supply whether

additional price volatility cannot be predicted, for our purposes, we need not concern ourselves with relative magnitudes of price fluctuations between full- and fractional-reserve economies. Whether black swans or grey, it is enough to say that ABC theory suggests *some* additional price volatility from credit expansion and overleverage, *until the bubble collapses*.

In terms of probability distributions, we focus on the relative frequencies of leptokurtic black swan or platykurtic grey swan events. While Austrians would suggest that historical price distributions cannot forecast future price movements (Howden 2009), a logical consequence of ABC theory is that the probability distributions of both consumer and producer goods prices under fractional-reserve banking should be either more leptokurtic black swans with exceptional, extreme volatility, or more platykurtic grey swans with moderate volatility, compared with prices in a full-reserve era, *ceteris paribus*. Furthermore, ABC theory leads to the expectation that capital goods in a fractional-reserve era should experience more atypical volatility overall than consumer goods.

To summarize, ABC theory combined with fractal analysis of time series suggests two likely outcomes will be observed:

- 1) both consumer and producer goods price distributions during a fractional-reserve period should be either more platykurtic resulting in moderate bubbles, or more leptokurtic resulting in more extreme bubbles, compared with a relatively Gaussian era of full-reserve banking.
- 2) under fractional-reserve banking producer goods prices should be less normal or Gaussian than consumer prices. In other words, producer goods prices should be either more leptokurtic or more platykurtic.

To examine proposition (2.) we use the two capital goods in our dataset, the *Wisselbank* agio and the Hamburg bills of exchange.

due to increases in the monetary base or increases in the supply of credit money by banks. This was because those increases were endogenous, that is, the increases in the monetary base were justified by profits from gold mining and increases in credit were justified by profitable lending opportunities.

These are forms of financial capital equally likely to finance consumer purchases or speculative stocks as well as capital investment, so they may not be ideal for comparing the distributional tails of consumer and capital goods. Furthermore both series are for more liquid financial or putty capital than the installed or clay capital (Bischoff 1971) to which proposition 2 applies.

First we examine proposition (1.) Austrian expectations about how goods prices behave during fractional-reserve eras and full-reserve economies amount to a testable hypothesis. Restating proposition (1.), we expect *a priori* that if fractional-reserve banking that began during an interwar period contributed to unsustainable expansion, commodity prices should become relatively either more leptokurtic (black swans) or platykurtic (grey swans), depending on the magnitude of the fractional-reserve induced bubble. If instead the relative change in fractional-reserve era prices were statistically indeterminate (i.e., fractal character unchanged from the full-reserve period of the War of the Austrian Succession), those results would suggest that fractional reserve banking did not contribute to speculative bubbles. As will be seen below, empirical findings support ABC theory.

Before estimating Hurst exponents, we computed conventional variance ratio/F-tests (Table 1). The null of constant variances is rejected, indicating a change in variance from the first war to the second, for colorful wheat, Prussian rye, Königsberg rye, dried rye, and for imported indigo and sugar (min), but not for Polish wheat, Frisian barley, fodder oats, coffee from the Dutch East-Indies (Java, Indonesia), and imported sugar (max) and black pepper. Nor was the variance significantly different for the two financial series—short-term Hamburg bills of exchange, and, perhaps most implausibly, the *Wisselbank* agio⁹. As mentioned above and in Guzelian and Mulligan (2015), traditional measures of commodity price volatilities are inappropriate and standard F-tests may be misleading, which Table 1 confirms.

⁹ Because the agio was so directly linked to the *Wisselbank*'s lending practices, it could be predicted to fluctuate more dramatically than other variables as the bank began engaging in fractional-reserve lending. Credit expansion may have suppressed short-run interest-rate volatility during the war at the cost of increasing it later.

...	<i>s.d. (P1)</i>	<i>var (P1)</i>	<i>n1</i>	<i>s.d. (P2)</i>	<i>var (P2)</i>	<i>n2</i>	<i>F</i>	<i>prob(F)</i>	<i>Result</i>
Black pepper	min 0.0286	0.0008	196	0.1367	0.0187	180	0.0438	1.0000	Fail to reject-no sig change
Indigo St Domingo	min 0.2720	0.0740	197	0.3019	0.0911	367	0.8118	0.9487	Fail to reject-no sig change
	max 0.3037	0.0923	197	0.1194	0.0143	367	6.4665	0.0000	Reject null
Sugar St Domingo	min 0.0255	0.0007	199	0.1206	0.0145	370	0.0447	1.0000	Reject null
	max 0.0255	0.0007	199	0.1194	0.0143	369	0.0456	1.0000	Fail to reject-no sig change
Hamburg, stvers for 1 thaler of 32 sols of Lütbeck, "kort zicht"	min 0.3960	0.1568	197	0.5964	0.3556	368	0.4409	1.0000	Fail to reject-no sig change
	Weekly bank agio in %	min 0.2892	0.0836	194	0.9196	0.8457	349	0.0989	1.0000

Notes:

1. The null hypothesis is that the two subsamples are drawn from the same population, i.e. that the population mean and variance are unchanged across the two subsamples.
2. The test statistic is F-distributed with numerator and denominator degrees of freedom equal to one less than the number of observations in each subsample.
3. "Kort zicht" or "short date" indicates short-term bills of exchange.

Table 2 subjects the same data to fractal analysis, reporting Hurst exponents computed by variogram with their standard errors for each price series for the two war periods. This enables us to construct hypothesis tests for non-normality, i.e., for significantly non-Gaussian character. Normal or Gaussian variables have Hurst exponents of $\frac{1}{2}$ and a characteristic exponent α of 2. These hypothesis tests indicate many of our price series have Hurst exponents either significantly above or below $\frac{1}{2}$, and that this fractal non-Gaussian behavior is not always the same during the two wars. The Hurst exponent of these prices during the War of the Austrian Succession (Table 2) establishes a baseline distribution for each commodity or bill, allowing us to analyze changes in fractal behavior of each price series.

Note particularly that $H > \frac{1}{2}$ indicates persistent long memory, where price trends persist over long periods, though punctuated by sharp but infrequent corrections, such as speculative bubbles. These data have a leptokurtic or black swan distribution. During the War of the Austrian Succession, this is observed for Prussian and Königsberg rye, and for all colonial goods except coffee. Later, during the Fourth Anglo-Dutch War, $H > \frac{1}{2}$ for colorful wheat (min), Frisian barley (min), pepper (min), indigo (min), and sugar.

$H < \frac{1}{2}$ indicates antipersistent long memory, where prices fluctuate back-and-forth more erratically without sustained trends showing a platykurtic or grey swan distribution. During the War of the Austrian Succession, we observe this for Polish wheat (max), dried rye (min), Frisian barley, and the Hamburg bill of exchange, and during the Fourth Anglo-Dutch War, for Polish wheat, Prussian rye (min), Königsberg and dried rye, coffee, indigo (max), and bank agio. During both wars, many price volatilities display statistically-significant non-Gaussian tendencies.

Table 3 presents two further hypothesis tests based on the Hurst exponent—one for an increase in the Hurst exponent from the War of the Austrian Succession to the Fourth Anglo-Dutch War, and one for a decrease. An increase in H indicates that the price series became more leptokurtic from one war to the next, exhibiting more black swans during the Fourth Anglo-Dutch War. A decrease indicates the series became more platykurtic, exhibiting more grey swans. As we have mentioned, analysis of Table 3, *ceteris paribus*, allows the fractional-reserve effects on the price series to be isolated from the war effects.

TABLE 2.
HURST EXPONENTS AND TESTS OF NORMALITY

	War of the Austrian Succession 1745-1748				Fourth Anglo-Dutch War 1780-1787						
	H_1 (1745- 1748)	s.d. (H_1)	95% conf int lower bound	95% conf int upper bound	Reject H_0 : $H_1=0.5$	H_2 (1780- 1787)	s.d. (H_2)	95% conf int lower bound	95% conf int upper bound	Reject H_0 : $H_2=0.5$	
Polish wheat	min	0.464	0.0331	0.3978	0.5302	$H_1=0.5$	0.403	0.0361	0.3308	0.4752	$H_2<0.5$
	max	0.387	0.0246	0.3378	0.4362	$H_1<0.5$	0.478	0.0272	0.4236	0.5324	$H_2<0.5$
Colorful wheat	min	0.532	0.0477	0.4366	0.6274	$H_1=0.5$	0.531	0.0105	0.5099	0.5521	$H_2>0.5$
	max	0.533	0.0234	0.4863	0.5797	$H_1=0.5$	0.467	0.0243	0.4184	0.5156	$H_2=0.5$
Prussian rye	min	0.600	0.0083	0.5835	0.6165	$H_1>0.5$	0.388	0.0550	0.2780	0.4980	$H_2<0.5$
	max	0.594	0.0161	0.5619	0.6261	$H_1>0.5$	0.401	0.0815	0.2381	0.5639	$H_2=0.5$
Königsberg rye	min	0.610	0.0136	0.5828	0.6372	$H_1>0.5$	0.377	0.0198	0.3374	0.4166	$H_2<0.5$
	max	0.605	0.0280	0.5490	0.6610	$H_1>0.5$	0.361	0.0394	0.2822	0.4398	$H_2<0.5$
Dried rye	min	0.453	0.0214	0.4102	0.4958	$H_1<0.5$	0.344	0.0243	0.2954	0.3926	$H_2<0.5$
	max	0.506	0.0421	0.4218	0.5902	$H_1=0.5$	0.468	0.0120	0.4441	0.4919	$H_2<0.5$
Frisian barley	min	0.412	0.0236	0.3649	0.4591	$H_1<0.5$	0.453	0.0273	0.3983	0.5077	$H_2>0.5$
	max	0.480	0.0118	0.4564	0.5036	$H_1<0.5$	0.465	0.0337	0.3976	0.5324	$H_2=0.5$

.../...

	War of the Austrian Succession 1745-1748				Fourth Anglo-Dutch War 1780-1787						
	H_1 (1745- 1748)	s.d. (H_1)	95% conf int lower bound	95% conf int upper bound	Reject H_0 : $H_1=0.5$	H_2 (1780- 1787)	s.d. (H_2)	95% conf int lower bound	95% conf int upper bound	Reject H_0 : $H_2=0.5$	
Fodder oats	min	0.391	0.0811	0.2287	0.5533	$H_1=0.5$	0.390	0.3155	-0.2410	1.0210	$H_2=0.5$
	max	0.445	0.0716	0.3018	0.5882	$H_1=0.5$	0.405	0.1754	0.0542	0.7558	$H_2=0.5$
Coffee East-Indies	min	0.479	0.0181	0.4427	0.5153	$H_1=0.5$	0.486	0.0035	0.4790	0.4930	$H_2<0.5$
Black pepper	min	0.532	0.0043	0.5235	0.5405	$H_1>0.5$	0.555	0.0021	0.5508	0.5592	$H_2>0.5$
Indigo St Domingo	min	0.543	0.0152	0.5126	0.5734	$H_1>0.5$	0.602	0.0250	0.5521	0.6519	$H_2>0.5$
	max	0.644	0.0085	0.6271	0.6609	$H_1>0.5$	0.383	0.0209	0.3412	0.4248	$H_2<0.5$
Sugar St Domingo	min	0.567	0.0013	0.5645	0.5695	$H_1>0.5$	0.583	0.0269	0.5293	0.6367	$H_2>0.5$
	max	0.563	0.0056	0.5519	0.5741	$H_1>0.5$	0.597	0.0334	0.5301	0.6639	$H_2>0.5$
Hamburg, stvers for 1 thaler of 32 sols of Lübeck, "kort zicht"	min	0.102	0.0086	0.0849	0.1191	$H_1<0.5$	0.381	0.1181	0.1448	0.6172	$H_2=0.5$
Weekly bank agio in Amsterdam in %	min	0.309	0.1197	0.0696	0.5484	$H_1=0.5$	0.351	0.0104	0.3302	0.3718	$H_2<0.5$

.../...

	H_1 (1745- 1748)	s.d. (H_1)	95% confint lower bound	95% confint upper bound	H_2 (1780- 1787)	s.d. (H_2)	95% confint lower bound	95% confint upper bound	Reject H_0 : $H_1 < H_2$	Reject H_0 : $H_1 > H_2$	Result	
	min	0.453	0.0214	0.4102	0.4958	0.344	0.0243	0.2954	0.3926	-0.2004	-0.0176	Indeterminate
Dried rye	max	0.506	0.0421	0.4218	0.5902	0.468	0.0120	0.4441	0.4919	-0.1462	0.0702	Becomes more antipersistent/ less persistent
Frisian barley	min	0.412	0.0236	0.3649	0.4591	0.453	0.0273	0.3983	0.5077	-0.0608	0.1428	Becomes more antipersistent/ less persistent
	max	0.480	0.0118	0.4564	0.5036	0.465	0.0337	0.3976	0.5324	-0.1060	0.0760	Becomes more antipersistent/ less persistent
Fodder oats	min	0.391	0.0811	0.2287	0.5533	0.390	0.3155	-0.2410	1.0210	-0.7943	0.7923	Becomes more antipersistent/ less persistent
	max	0.445	0.0716	0.3018	0.5882	0.405	0.1754	0.0542	0.7558	-0.5340	0.4540	Becomes more antipersistent/ less persistent
Coffee East-Indies	min	0.479	0.0181	0.4427	0.5153	0.486	0.0035	0.4790	0.4930	-0.0363	0.0503	Becomes more antipersistent/ less persistent

.../...

...	H_1 (1745- 1748)	s.d. (H_1)	95% confint lower bound	95% confint upper bound	H_2 (1780- 1787)	s.d. (H_2)	95% confint lower bound	95% confint upper bound	Reject H_0 : $H_1 < H_2$	Reject H_0 : $H_1 > H_2$	Result
Black pepper	min	0.532	0.0043	0.5235	0.5405	0.0021	0.5508	0.5592	0.0103	0.0357	Indeterminate
Indigo St Domingo	min	0.543	0.0152	0.5126	0.5734	0.0250	0.5521	0.6519	-0.0213	0.1393	Becomes more persistent/less antipersistent
	max	0.644	0.0085	0.6271	0.6609	0.383	0.3412	0.4248	-0.3197	-0.2023	Indeterminate
Sugar St Domingo	min	0.567	0.0013	0.5645	0.5695	0.583	0.5293	0.6367	-0.0402	0.0722	Becomes more persistent/less antipersistent
	max	0.563	0.0056	0.5519	0.5741	0.597	0.5301	0.6639	-0.0440	0.1120	Becomes more persistent/less antipersistent
Hamburg, stvers for 1 thaler of 32 sols of Lütbeck, "kort zicht"	min	0.102	0.0086	0.0849	0.1191	0.381	0.1448	0.6172	0.0257	0.5323	Indeterminate
Weekly bank agio in %	min	0.309	0.1197	0.0696	0.5484	0.351	0.3302	0.3718	-0.2181	0.3021	Becomes more persistent/less antipersistent

In Table 3, the decisive majority of consumer good price series became either more platykurtic (Polish wheat, colorful wheat, Prussian rye (max), dried rye (max), Frisian barley, fodder oats, and coffee) or more leptokurtic (indigo (min), sugar, and bank agio¹⁰). Said differently, there were a great deal many more grey swans, and a few more black swans, in the 1780s not attributable to the Fourth Anglo-Dutch War and the Patriot Period. This suggests price bubbles due to credit expansion.

Only for fewer than a third of the price series (totaling 7 out of 22), was our analysis unable to confirm any change in relative volatility, namely for pepper, indigo (max), the Hamburg bill of exchange, and, significantly, the min/max or both of *all* rye series. The fact that the rye series were stable may not be an accident. Guzelian and Mulligan (2015) did not control for war, and most price series in the 1780s became more leptokurtic black swans compared with the preceding 60 years of high-reserve banking *except for* bread grains (wheat and rye), which only experienced a platykurtic price destabilization (grey swans). Wheat and rye were used almost exclusively as bread grains, and the ordinary Dutch diet consisted primarily of rye bread (de Vries 2012). Bread grain prices, particularly rye, were more stable than other consumer goods:

“Some unique, offsetting, and prevailing cause(s) of wheat and rye price *stabilization* must have arisen at the same time the bank’s destabilizing fractional-reserve lending practices began in 1780. A change in tax policy was certainly not the culprit. Although bread was taxed far more heavily than other Dutch commodities, the grain mill rate remained unchanged for the entirety of the eighteenth century (de Vries 2012). One might conjecture that Amsterdam government officials established official market prices for grains at the outbreak of the war in 1780. Our research has failed to yield evidence of this. ... [But p]robably the most relevant finding for addressing the mystery of grain price stabilization, is that Amsterdam had a municipal granary that dispensed grain in

¹⁰ As mentioned previously, combining Austrian and fractal theory suggests relatively more leptokurtic price behavior of capital goods like the bank agio than for consumer goods, which indeed was the case here.

times of market scarcity to bakers, who “had to sell bread to the poor at a fixed price” (van Tielhof 2002, p. 109). By maintaining a relatively stable supply, the municipal government would have prevented market prices from fluctuating as severely, although there still may have been extreme—though less frequent—price swings if the city granary was ever fully depleted. Having consulted several prominent Dutch economic historians who uniformly lack specific knowledge about the granary’s operations during the 1780s, we can only conjecture that the granary logically would have been in significant operation during the war to fill the import shortfall and to avoid riots or famine (of which there is also no historical evidence). If the granary sensitively adjusted its daily market supply to maintain stable market prices and the government mandated a maximum price for bread sales to the poor, this could readily explain the post-1780 [stability] of wheat and rye prices, even in the face of destabilizing credit expansion by the Wisslebank” (Guzelian & Mulligan 2015).

Disregarding these government-stabilized grain prices, only 3 of the 16 remaining price series did *not* show an increase in black or grey swans, that is a greater divergence from Gaussian behavior during the Fourth Anglo-Dutch War. Thus what seems apparent from Table 3 is that fractional-reserve banking during and after the Fourth Anglo-Dutch War resulted in price inflation, commodity bubbles, and a business cycle across a variety of consumer goods and financial assets.

Next we consider our second proposition, that under fractional-reserve banking producer goods prices are expected to become more leptokurtic or less normal than consumer prices. This would mean that the Hurst exponent for the two financial assets (Wisslebank agio and Hamburg bills of exchange) should be farther from normality ($H \approx 1/2$) than for the commodity series. This can be examined by computing the absolute differences of deviations from normality, $D_H = (|H_F - 1/2| - |H_C - 1/2|)$, for each commodity series and each of the two financial series.

Figures 5 and 6 show the absolute differences D_H between Hurst exponents of the commodity prices and the financial series. Figure 5, which shows the difference for Hamburg bills of exchange is particularly striking. A high absolute difference between the

FIGURE 5.
HURTS EXP: BILLS OF EXCHANGE V. COMMODITY PRICES

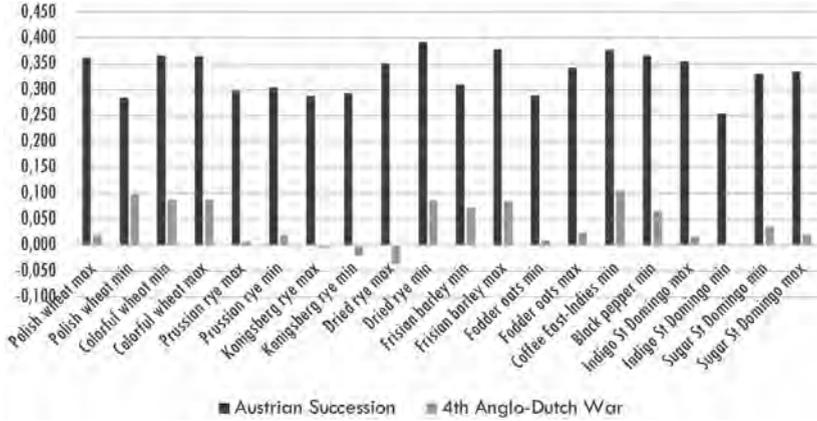
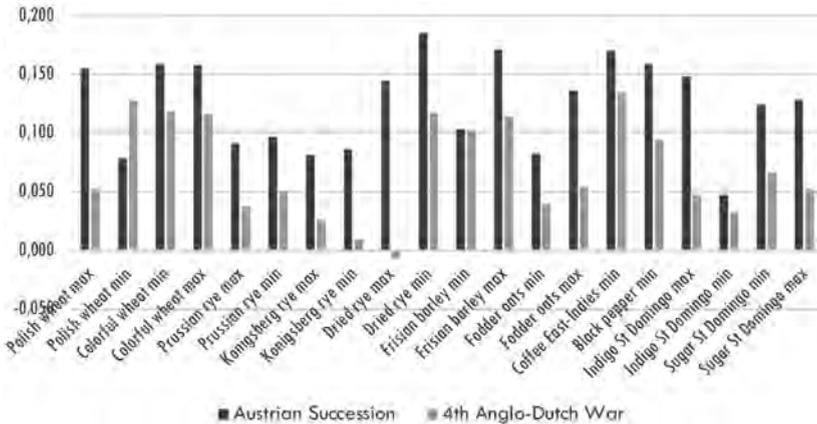


FIGURE 6.
HURTS EXPONENTS: BANK AGIO V. COMMODITY PRICES



commodity price H_s and the bills of exchange H indicates that commodity prices systematically diverge farther from normality. However, these divergences are much greater during the War of the Austrian Succession when reserve ratios were high, compared with the Fourth Anglo-Dutch War when they were lower. In the more leveraged environment of the Fourth Anglo-Dutch War

commodity prices and financial assets/capital goods behaved similarly. For a few commodities, Königsberg rye and dried rye maximum prices, the price series was more nearly normal than the bills of exchange, indicated by a negative difference.

Figure 6 compares the commodity prices with the agio. Commodity prices are predominantly either more extremely leptokurtic or platykurtic than the agio, and this divergence is much lower during the Fourth Anglo-Dutch War, when the Wisselbank abandoned high reserves, than during the War of the Austrian Succession. The only exception is the Polish wheat minimum price which was closer to normality during the Fourth Anglo-Dutch War than during the War of the Austrian Succession. Another anomaly is that the dried rye maximum price was closer to normality than the agio during the Fourth Anglo-Dutch War, as indicated by a negative absolute difference.

To better examine differences in kurtosis and Gaussian character for consumer and producer goods over the two war periods, we construct Welch's (1947) unequal variances t-test. This test has the advantage of not relying on an assumption of either equal means or equal variances of the populations being compared (Ruxton 2006; Derrick, Toher, & White 2016). We construct the t-statistic from the difference between the estimated Hurst exponent for one of the commodity price series minus that for each of the two financial asset price series, divided by a sample-size adjusted standard error estimate:

$$t = (H_C - H_F) / \{[(s(H_C))^2 + (s(H_F))^2] / (n - 1)\}^{1/2},$$

where H_C and H_F are the Hurst exponents for the commodity and financial assets price series, $s(H_C)$ and $s(H_F)$ are their standard errors, and n is the sample size, which in this case is the duration of each war period in years.

TABLE 4.
WELCH T-TESTS FOR GREATER LEPTOKURTOSIS IN FINANCIAL CAPITAL SERIES

		War of the Austrian Succession d.f. = 4				Fourth Anglo-Dutch War d.f. = 8								
		$H_C - H_B$	s_1	s_2	s_X	t	$p(t)$	$H_C - H_B$	s_1	s_2	s_X	t	$p(t)$	
1. Commodity series compared w/ Hamburg bills of exchange														
Polish wheat		min	-0.362	0.0148	0.0038	0.0153	-23.660	0.000***	-0.0220	0.0120	0.0394	0.0412	-0.535	0.608
		max	-0.285	0.0110	0.0038	0.0117	-24.457	0.000***	-0.0970	0.0091	0.0394	0.0404	-2.402	0.043**
Colorful wheat		min	-0.430	0.0213	0.0038	0.0217	-19.850	0.000***	-0.1500	0.0035	0.0394	0.0395	-3.796	0.005***
		max	-0.431	0.0104	0.0038	0.0111	-38.739	0.000***	-0.0860	0.0081	0.0394	0.0402	-2.140	0.065*
Prussian rye		min	-0.498	0.0037	0.0038	0.0053	-93.605	0.000***	-0.0070	0.0183	0.0394	0.0434	-0.161	0.876
		max	-0.492	0.0072	0.0038	0.0081	-60.409	0.000***	-0.0200	0.0272	0.0394	0.0478	-0.418	0.687
Königs-berg rye		min	-0.508	0.0061	0.0038	0.0072	-70.674	0.000***	0.0040	0.0066	0.0394	0.0399	0.100	0.923
		max	-0.503	0.0125	0.0038	0.0131	-38.438	0.000***	0.0200	0.0131	0.0394	0.0415	0.482	0.643
Dried rye		min	-0.351	0.0096	0.0038	0.0103	-34.045	0.000***	0.0370	0.0081	0.0394	0.0402	0.921	0.384
		max	-0.404	0.0188	0.0038	0.0192	-21.017	0.000***	-0.0870	0.0040	0.0394	0.0396	-2.199	0.059*
Frisian barley		min	-0.310	0.0105	0.0038	0.0112	-27.650	0.000***	-0.0720	0.0091	0.0394	0.0404	-1.782	0.113
		max	-0.378	0.0053	0.0038	0.0065	-58.007	0.000***	-0.0840	0.0112	0.0394	0.0409	-2.052	0.074*
Fodder oats		min	-0.289	0.0363	0.0038	0.0365	-7.920	0.001***	-0.0090	0.1052	0.0394	0.1123	-0.080	0.938
		max	-0.343	0.0320	0.0038	0.0322	-10.637	0.000***	-0.0240	0.0585	0.0394	0.0705	-0.341	0.742
.../...														

		War of the Austrian Succession <i>d.f.</i> = 4						Fourth Anglo-Dutch War <i>d.f.</i> = 8					
		$H_C - H_B$	s_1	s_2	s_X	t	$p(t)$	$H_C - H_B$	s_1	s_2	s_X	t	$p(t)$
Coffee East-Indies	min	-0.377	0.0081	0.0038	0.0090	-42.007	0.000***	-0.1050	0.0012	0.0394	0.0394	-2.667	0.029**
	min	-0.430	0.0019	0.0038	0.0043	-100.516	0.000***	-0.1740	0.0007	0.0394	0.0394	-4.420	0.002***
Black pepper	min	-0.441	0.0068	0.0038	0.0078	-56.515	0.000***	-0.2210	0.0083	0.0394	0.0402	-5.494	0.001***
	max	-0.542	0.0038	0.0038	0.0054	-100.612	0.000***	-0.0020	0.0070	0.0394	0.0400	-0.050	0.961
Indigo St Domingo	min	-0.465	0.0006	0.0038	0.0039	-120.125	0.000***	-0.2020	0.0090	0.0394	0.0404	-5.004	0.001***
	max	-0.461	0.0025	0.0038	0.0046	-101.007	0.000***	-0.2160	0.0111	0.0394	0.0409	-5.280	0.001***
2. Commodity series compared w/ <i>Wisselbank agio</i>													
		min	-0.1550	0.0166	0.0043	0.0171	-9.061	0.001***	0.0110	0.0029	0.0114	-4.560	0.002***
		max	-0.0780	0.0123	0.0043	0.0130	-5.987	0.004**	0.0082	0.0029	0.0087	-14.622	0.000***
Polish wheat	min	-0.2230	0.0238	0.0043	0.0242	-9.207	0.001***	-0.1800	0.0159	0.0029	0.0161	-11.148	0.000***
	max	-0.2240	0.0117	0.0043	0.0124	-18.008	0.000***	-0.1160	0.0078	0.0029	0.0083	-13.988	0.000***
Colorful wheat	min	-0.2910	0.0041	0.0043	0.0059	-48.923	0.000***	-0.0370	0.0028	0.0029	0.0040	-9.331	0.000***
	max	-0.2850	0.0080	0.0043	0.0091	-31.299	0.000***	-0.0500	0.0054	0.0029	0.0061	-8.237	0.000***
Prussian rye	min	-0.3010	0.0068	0.0043	0.0080	-37.455	0.000***	-0.0260	0.0045	0.0029	0.0054	-4.853	0.001***
	max	-0.2960	0.0140	0.0043	0.0146	-20.231	0.000***	-0.0100	0.0093	0.0029	0.0098	-1.025	0.335
.../...													

.../...

		War of the Austrian Succession <i>d.f.</i> = 4					Fourth Anglo-Dutch War <i>d.f.</i> = 8						
		$H_C - H_B$	s_1	s_2	s_X	t	$p(t)$	$H_C - H_B$	s_1	s_2	s_X	t	$p(t)$
Dried rye	min	-0.1440	0.0107	0.0043	0.0115	-12.493	0.000***	0.0070	0.0071	0.0029	0.0077	0.911	0.389
	max	-0.1970	0.0211	0.0043	0.0215	-9.166	0.001***	-0.1170	0.0140	0.0029	0.0143	-8.166	0.000***
Frisian barley	min	-0.1030	0.0118	0.0043	0.0125	-8.217	0.001***	-0.1020	0.0079	0.0029	0.0084	-12.206	0.000***
	max	-0.1710	0.0059	0.0043	0.0073	-23.471	0.000***	-0.1140	0.0039	0.0029	0.0049	-23.471	0.000***
Fodder oats	min	-0.0820	0.0406	0.0043	0.0408	-2.010	0.115	-0.0390	0.0270	0.0029	0.0272	-1.434	0.190
	max	-0.1360	0.0358	0.0043	0.0361	-3.772	0.020	-0.0540	0.0239	0.0029	0.0240	-2.247	0.055*
Coffee East-Indies	min	-0.1700	0.0091	0.0043	0.0100	-16.942	0.000***	-0.1350	0.0060	0.0029	0.0067	-20.181	0.000***
Black pepper	min	-0.2230	0.0021	0.0043	0.0048	-46.625	0.000***	-0.2040	0.0014	0.0029	0.0032	-63.978	0.000***
Indigo St Domingo	min	-0.2340	0.0076	0.0043	0.0087	-26.822	0.000***	-0.2510	0.0051	0.0029	0.0058	-43.156	0.000***
	max	-0.3350	0.0042	0.0043	0.0060	-55.621	0.000***	-0.0320	0.0028	0.0029	0.0040	-7.970	0.000***
Sugar St Domingo	min	-0.2580	0.0006	0.0043	0.0043	-59.613	0.000***	-0.2320	0.0004	0.0029	0.0029	-80.409	0.000***
	max	-0.2540	0.0028	0.0043	0.0051	-49.777	0.000***	-0.2460	0.0019	0.0029	0.0034	-72.314	0.000***

Results clearly demonstrate that virtually all commodity prices are more leptokurtic than bills of exchange or agio during the full-reserve period of the War of the Spanish Succession, and that this tendency becomes less, not more pronounced during the fractional-reserve credit expansion of the Fourth Anglo-Dutch War. This is consistent with Huerta de Soto's (2011) observation and confirms our second proposition. These empirical results are more impressive given the Welch t-test's high power and robustness against Type I error (Derrick, Toher, & White 2016).

Finally, we must acknowledge the methodological limitations of any attempt to control for war. Just as no two recessions are identical, no two wars are perfectly alike. The War of the Austrian Succession was a continental dynastic conflict where the Dutch Republic was allied with Great Britain. This conflict resulted in little disruption to the Netherlands' overseas trade, so price disruptions to colonial trade goods came primarily from the demand side, but generally not from the supply side. The Fourth Anglo-Dutch War saw overseas trade largely cut off by the British blockade, disrupting the supply of colonial trade goods, but grain prices stayed stable despite the embargo, probably because of emergency wartime provision from the Amsterdam granary (Guzelian & Mulligan 2015), and the fact that grain was both produced domestically and imported overland. The British embargo should have introduced price volatility from both the supply and demand sides, particularly for colonial trade goods. The Fourth Anglo-Dutch War was also accompanied by the internal revolts and civil unrest of the *Patriottentijd*, which was not the case for the War of the Austrian Succession.

7. Conclusion

The present article provides further empirical examination of low fractional-reserve banking practices by the Bank of Amsterdam and the possibility that those practices caused or contributed to substantial business cycle volatility in the 1780s. Indeed, there are few other empirical studies for any historical era regarding the oft-cited Austrian business cycle theory claim of a causal linkage between fractional-reserve banking and business cycles.

Guzelian and Mulligan (2015) found an increase in atypical price volatility for many prices once the Wisselbank began fractional-reserve banking in 1780, departing permanently from a centuries-old tradition of high- or full-reserve banking. The relative increase in atypical volatility that we found, either leptokurtic, fat tailed, or black swan distributions, or platykurtic, flat-tailed, or grey swan distributions, is consistent with the *a priori* ABC expectation that progressively overleveraged fractional-reserve banking causes economic cycles. This study controls for the identification problem introduced by the fact that fractional-reserve banking was introduced simultaneously with the outset of the Fourth Anglo-Dutch War, which the Wisselbank financed through fractional-reserve lending.

The present study compares Amsterdam commodity and financial price data during the War of the Austrian Succession (1744-1749) with the Fourth Anglo-Dutch War combined with the Patriot Period (1780-1788) that followed. During the former era, the Wisselbank limited itself to high- or full-reserve lending practices, whereas during the latter, reserves plummeted from full-reserves to about 20%. If fractional-reserve banking causes economic cycles, then we should have found price distributions in the wartime fractional-reserve economy of the 1780s either more leptokurtic, fat-tailed, or subject to less frequent but catastrophic black swans and extreme bubbles, or platykurtic, flat-tailed, or subject to more frequent but moderate grey swans and moderate bubbles, than during the full-reserve economy of the War of the Austrian Succession.

This is what we observe. Using Hurst exponents to measure volatility, for the clear majority of price series, the comparison of a high-reserve war banking to a low-reserve predominantly indicated either more pronounced leptokurtic or platykurtic behavior. This is consistent with ABC theory especially if fractional-reserve banking in the 1780s distorted prices apart from the destabilizing effects of the Fourth Anglo-Dutch War. The study therefore also offers evidence that non-inflationary war finance, such as practiced during the War of the Austrian Succession, has less impact on price levels and volatility, although it may still have significant impact on relative prices. Inflationary credit expansion during the

Fourth Anglo-Dutch War not only distorted relative prices but raised the price level as well.

These results confirm the Austrian praxeological claim's real-world relevance applied to economic circumstances ideally suited to test such a claim. The Bank of Amsterdam's sustained low fractional-reserve lending in the 1780s probably caused at least a modest economic bubble. However, one should heed Ludwig von Mises' admonition about difficulties in objectively and empirically determining a praxeological theorem's general historical and future causal relevance¹¹ (Guzelian 2016).

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¹¹ Mises (1998, pp. 57-58) writes: «[T]here necessarily enters into [factual] understanding an element of subjectivity. ... Two historians ... may fully agree in establishing that the factors *a*, *b*, and *c* worked together in producing the effect *P*; nonetheless they can widely disagree with regard to the relevance of the respective contributions of *a*, *b*, and *c* to the final outcome. ... [T]hese are not judgments of value, they do not express preferences of the historian. They are judgments of relevance. ... [A]s far as historians disagree with regard to judgments of relevance it is impossible to find a solution which all sane men must accept.»

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