THE GUN-SLAVE HYPOTHESIS AND THE 18TH CENTURY BRITISH SLAVE TRADE

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THE GUN-SLAVE HYPOTHESIS AND THE 18TH CENTURY BRITISH SLAVE TRADE*

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ABSTRACT

The Gun-Slave Hypothesis is the long-standing idea that European gunpowder technology played a key role in growing the transatlantic slave trade. I combine annual data from the Transatlantic Slave Trade Database and the Anglo-African Trade Statistics to estimate a Vector Error Correction Model of the 18th century British slave trade that captures four versions of the Gun-Slave Hypothesis: guns-for-slaves-in-exchange, guns-for-slaves-in-production, slaves-for-guns-derived and the gun-slave cycle. Three econometric results emerge. (1) Gunpowder imports and slave exports were co-integrated in a long-run equilibrium relationship. (2) Positive deviations from equilibrium gunpowder "produced" additional slave exports. This guns-for-slaves-in-production result survives 17 placebo tests that replace gunpowder with non-lethal commodities imports. It is also confirmed by an instrumental variables estimation that uses excess capacity in the British gunpowder industry as an instrument for gunpowder. (3) Additional slave exports attracted additional gunpowder imports for 2-3 more years. Together these dynamics formed a gun-slave cycle. Impulse-response functions generate large increases in slave export in response to increases in gunpowder imports. I use these results to explain the growth of slave exports along the Guinea Coast of Africa in the 18th century.

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"…it was not the war which was the cause of the Slave Trade, but the Slave Trade which was the cause of the war."

Thomas Clarkson (1839, p. 167).

"Previous to my being in this employ, I entertained a belief that the kings and principal men [in Africa] breed Negroes for sale as we do cattle. All the information I could procure confirms me in the belief that to kidnapping, the trade owes its key support. "

Alexander Falconbridge (1788, p. 15).

1 INTRODUCTION

According to the *Transatlantic Slave Trade Database* (2009), the trans-Atlantic slave trade carried more than 13 million enslaved Africans from the coast of Africa destined for the Americas. What social factors lay behind this human traffic? For Thomas Clarkson, the intellectual leader of the British Abolition Movement, this question went to the heart of the matter – to the legitimacy or illegitimacy of the trade itself. According to the dominant Natural Rights philosophy of the time, if African slaves were captured in "justified" wars among African peoples who were caught in the "natural" struggles of nation building, then the victors had every right to enslave the vanquished because they had justly chosen to spare their lives. On the other hand, if "it was the slave trade which was the cause of the wars" then nobody had a right to the victims, not the African captors nor their British trading partners.[1] Alexander Falconbridge's admission, while less philosophical than Clarkson's, is probably closer to the typical layman's query: did African societies produce human slaves in their normal course of affairs, or did the international slave trade cause the enslavement?

There is still no scholarly consensus on this important issue. Was the Abolitionist's view just propaganda or was it the truth (to which Britons agreed in 1807)? Did British traders encourage enslavement or were the slaves there for the taking? A number of important

[1] For a full elaboration of this critique see Clarkson (1786), his award-winning Oxford essay that launched his career as a major figure in the British abolition movement. Also see Patterson (1982) who calls the process of enslavement "social death" regardless of justification.

debates could benefit from a clearer answer to this question, not least the debate about why Britain abolished its slave trade in 1807.

Historical studies of the transatlantic slave trade also line up on one side of this issue or the other. Were the major determinants of growth in the international slave trade internal to Africa or external to Africa? One school emphasizes external shocks and how they increased the supply of slave exports. Shocks include the American demand for plantation labor and the introduction of gunpowder technology into the African context. This view is most forcefully argued by Walter Rodney in *How Europe Underdeveloped Africa* (1972, chapter 4), but it is also found in the writings of Basil Davidson (1961), Kwame Daaku (1970), A. G. Hopkins (1973), Joseph Inikori (1982), Robin Law (1991), Nathan Nunn (2008), Acemoglu and Robinson (2010) and others.[2] A second approach emphasizes the contributions of pre-existing African conditions like low labor productivity, drought, and the ancient tradition of slavery and slave trading in Africa. The strongest modern proponent of this view is John Thornton in *Africa and Africans in the Making of the Atlantic World, 1400-1800* (1998, chs. 3 and 4), but similar emphases can be found in John Fage (1969), Philip Curtin (1975a), David Eltis (1987), Fenske and Kala (2015), Gareth Austin (2008a, 2008b) and Sean Stillwell (2014).[3] Finally, a third approach tends to be more theoretical in nature and seeks to understand the dynamic interaction between external shocks like gunpowder imports and internal conditions like the structure of African polities. Examples include Jack Goody's *Technology, Tradition and the State in Africa* (1971), Stefano Fenoaltea (1999) and Gemery and Hogendorn (1997).[4]

[2] Rodney (1972, p. 135): "It is clearly ridiculous to assert that contacts with Europe built or benefited Africa in the precolonial era… The truth is that a developing Africa went into slave trading and European commercial relations as into a gale-force wind, which shipwrecked a few societies, set many others off course, and generally slowed down the rate of advance."

[3] Thornton (1998, p. 73): "When Rodney presented his conclusions on the negative impact and hence special status of the slave trade as a branch of trade, it was quickly contested by J. D. Fage, and more recently the transformation thesis has been attacked by David Eltis. As these scholars see it, slavery was wide-spread and indigenous in African society, as was, naturally enough, a commerce in slaves. Europeans simply tapped this existing market, and Africans responded to the increased demand over the centuries by providing more slaves."

[4] Goody (1971, p. 39): "It is necessary to remind the reader that, in talking of pre-colonial states, I do not imply that such states were uninfluenced by the advent of Europeans to the coastal areas of Africa. The import of guns and the external demand for slaves encouraged the war-like proclivities of centralized government and consequently the nature of their interaction with other people."

This paper falls into the third group, but it is an empirical study rather than a theoretical one. It contributes to the debate by documenting the dynamic interactions between imported European gunpowder technology and exported African slaves -- what has been called the *Gun-Slave Hypothesis*. Existing evidence for-or-against this hypothesis is far from conclusive, consisting of a few observations on the growth of firearms imports, better data on slave exports, and the writings of contemporary observers stationed along the coast of Africa.

I find at least four (4) versions, or pieces, of the gun-slave hypothesis mentioned throughout the literature on the transatlantic slave trade. Each lines up with a particular side of the debate concerning external vs. internal contributions to growth. One version of the hypothesis, what I call *guns-for-slaves-in-production*, argues that the imported gunpowder technology increased "productivity" in capturing slaves and marching them to the coast.[5] Here, an external factor (European gunpowder technology) increases slave exports by increasing the productivity of African resources devoted to slaving. Running in the opposite direction is a version of the hypothesis I call *slaves-for-guns-derived*, which claims that it was African-induced increases in slave exports that attracted the European gunpowder technology to Africa. A third version of the hypothesis claims that the two processes reinforced each other and accelerated into a self-perpetuating *gun-slave cycle* which neither side could escape. A fourth version of the hypothesis, *guns-for-slaves-in-exchange*, claims that the productivity advantage of guns shows up as a preference for the gunpowder technology among African slave traders.

I test these claims by documenting the dynamic interaction between gunpowder imports and slave exports in the 18th century British slave trade. The data come from the *Transatlantic Slave Trade Database* and the heretofore-underutilized *Anglo-African Trade Statistics* (1990).[6] I combine these data to build a time-series of annual observations on commodity flows and slave flows between 1699 and 1807. The time-series allow me to estimate within-

[5] The term "production" should be interpreted to mean the allocation of resources to institutions that facilitate the capture and transport of people as slaves. For a discussions of the dialectical relationship between slave capture and slave trading in the African context, see Meillassoux (1991).
[6] I am aware of two other studies that have used this data: Richardson (1991) and Gemery and Hogendorn (1990).

year and between-year correlations between British gunpowder shipment to Africa and British slave purchases on the African coast. For our purposes, gunpowder is a better measure than guns because it is a continuous and homogeneous measure of the capacity of the gunpowder technology.

I specify a vector error-correction model (VEC) that estimates the intertemporal relationships among three endogenous variables: CARGO, which measures the annual value of British goods exchanged for slaves; SLAVES, which measures the annual number of slaves that CARGO purchased; and GUNPOWDER, which measures the annual value of British gunpowder exported to Africa. Three results emerge. First, the three endogenous variables are found to be co-integrated in a long-run equilibrium relationship that spanned the 18th century. In other words, GUNPOWDER and slave price (CARGO/SLAVES) were systematically related to each other. Second, deviations from long-run equilibrium set in motion adjustments among the variables that returned the system toward equilibrium. When gunpowder imports were above their equilibrium level, next years' slave exports increased. This is taken to be evidence of guns-for-slaves-in-production (which takes time) as opposed to guns-for-slaves-in-exchange (which is a cotemporaneous transaction). Similar results are produced by an instrumental variables estimation of the slave export equation that uses excess capacity in the British gunpowder industry as an instrument for British gunpowder exports. This guns-for-slaves-in-production result also survives 17 placebo tests that replace gunpowder with non-lethal British imports. Third, slaves-for-guns-derived shows up in the coefficients on lagged slave exports. Increases in slave exports attracted additional gunpowder imports for 2-3 more years.

Together, the estimated coefficients of the VEC model document a gun-slave cycle as a general dynamic feature of the 18th century British slave trade. Assuming that the flow of information from Africa to Britain followed shipping routes in the North Atlantic, impulse-response functions estimate large increases in African slave exports in response to exogenous increases in British gunpowder imports. A one percent increase in gunpowder set in motion a 5-year gun-slave cycle that increased slave exports by an average of 50%, and the impact continued to grow over time

These results have implications for a variety of issues in African economic history. The shock to African economies was large and widespread, not small or localized. The corresponding re-allocation of resources towards slaving and away from other economic activities must have been large as well. A cross-section of cases would tend to under-estimate the significance of guns in the production of slaves because snapshots limit the notion of productivity to technical productivity in specific battles or raids. A virtue of the aggregate time series data is its ability to trace the broader and longer-term impact of gunpowder as it worked its way through African social relations over time.

The study also provides important historical and empirical context for recent econometric research that document long-term negative consequences of the slave trade for Africa. [7] The primary evidence reported in those studies is a negative statistical relationship between regional slave exports in the past and social and economic outcomes centuries later. This line of research has been criticized for "compressing" history because it glosses over historical detail, like whether or not the shock of the slave trade was large enough to leave indelible marks on African societies for so long (Austin, 2008a). This study provides empirical evidence that the 18th century shock was large.

The rest of the paper is organized as follows. Section 2 discusses the major literature that addresses the four (4) versions of the gun-slave hypothesis. Section 3 describes the data used in the econometric analysis. Section 4 discusses econometric issues and presents the econometric results. Section 5 discusses implications for the economic history of West Africa and for future research on the slave trade in Africa. Section 6 offers concluding remarks.

2. THE GUN-SLAVE HYPOTHESIS

European shipments of firearms to Africa accelerated in the late 17th and early 18th centuries.[8] This is also when African slave exports began to increase. Before then, the older

[7] For examples of this growing literature, see Nunn (2008), Nunn and Wantchekon (2011), Obikili (2016), Whatley (2014), Whatley and Gillzeau (2011a, 2011b) and Dalton and Leung (2014)

[8] Curtin (1975b, pp. 320-25); Inikori (1977); and Richards (1980).

matchlock musket proved ineffective in tropical climates and the Catholic Church prohibited their sale to non-Christians. The sale of large numbers of guns and gunpowder to Africans began with Protestant slave traders not bound by Catholic prohibitions. [9] The Dutch were the first to sell large numbers, followed by the English as their participation in the slave trade grew. Fearful of losing their competitive position, the Portuguese quickly followed suit. By the 1680s, the more-reliable flintlock technology was replacing the matchlock technology and firearms became a staple outbound cargo on most slave ships destined for Africa. By the 1690s, the new flintlock technology was influencing military formations and military strategies along the Lower Guinea Coast, precisely when slave exports from that region began to increase. [10]

Thus began a period of sustained growth in both firearms shipments to Africa and slave exports out of Africa. Between 1680 and 1685, the British Royal African Company shipped only 2,615 firearms per year to Africa (Davies, 1975, p. 356). By the end of the 18th century, Inikori (1977) estimates that the British were shipping 150,000 to 200,000 guns per year, and the total for all Europe was 300,000-400,000 guns per year. Eltis and Jennings (1988), estimate a tenfold increase in firearms between the 1680s and the 1780s, increasing from 20,000 to 200,000 guns per year. Figure 3 reports the natural log of annual British gunpowder exports to Africa for the 18th century (from the *Anglo-African Trade Statistics*). The figure also reports the natural log of annual British slave purchases for the 18th century (from the *Transatlantic Slave Trade Database*). The correlation coefficient is 0.80.

The core claim of the Gun-Slave Hypothesis is that the imported gunpowder technology increased the productivity of resources devoted to capturing slaves and marching them to the coast. If one thinks of the violent process of enslaving people and marching them to the coast against their will, one can imagine how firearms might give captors an advantage. The question is how much of an advantage? In Europe, the strategic advantage was the projectile's ability to pierce armor, something that was seldom worn in and around the rainforests of Africa. In Africa, the advantage was the projectile's ability to cut through

[9] Kea (1971, p. 186), Wilks (1993, p. 23) and Northrup (2002, pp. 90 – 98).
[10] Kea (1971, pp. 207-213), Thornton (1999. pp. 61-64),

arrow-proofed shields and the thicket and overgrowth of forest that often served as cover for troops and escapees (Thornton, 1999, pp. 58-59, 62-63, 105). Kea (1971) describes how the flintlock revolutionized military formations and strategies in the forests kingdoms of the Lower Guinea Coast. Thornton (1999, pp.31-32) describes how the flintlock allowed marksmen to cover wider gaps in infantry formations to slow the advance of cavalry.[11] “Travel outside the homeland was dangerous” and those who ventured too far were subject to kidnap (Hair 1965, p. 198). Bandits, warlords and kidnappers carried guns. Merchants and caravans carried guns.

But firearms were also effective defensive weapons, especially behind walls (Thornton 1999, 50-51). They were used extensively to hunt elephants for ivory, to hunt for food, and to defend against predatory animals and people (White, 1971). The net advantage of firearms in the capture and transport of slaves is not a forgone conclusion. It is an empirical question that this study addresses by subjecting the gun-slave hypothesis to empirical scrutiny.

In the historical literature one finds four versions of the gun-slave hypothesis, each emphasizing a different aspect of the gun-slave connection. I call them guns-for-slaves-in-exchange, guns-for-slaves-in-production, slaves-for-guns-derived and the gun-slave cycle. Guns-for-slaves-in-exchange highlights the preference for firearms among African slave exporters. The preference is taken to be evidence of the advantage of guns in the capture and transport of slaves. Inikori (1977):

> "These imports (guns) were due very largely to the strong preference for firearms by slave sellers and gatherers. The preference of ivory sellers for guns came a distant second to that of slave sellers. Sellers of other commodities, particularly foodstuffs, do not seem to have had any stronger demand for firearms (p. 361)."

[11] The “shock-and-awe” advantage was also a tactic learned early and often from encounters with Europeans. The early Portuguese traders were quick to display the power of their weaponry, and when British ships arrived on the coast of Africa to purchase slaves, they announced their arrival by firing rounds of canons (St. Clair, 2007, chapter 1).

Johnson (1966) reports the details of a number of contracts showing the exchange of cargo for slaves. Almost every contract included guns or gunpowder. Richardson (1979, pp. 312-315) reports data on the cargoes of a sample of slave ships out of Bristol and Liverpool between 1758 and 1806. Almost every ship carried a substantial cargo of guns and gunpowder. During the Seven Years War British traders claimed that guns and gunpowder "greased the trade" and that ships could not depart for Africa until the government granted British slave traders exemptions from the wartime prohibition on private gunpowder exports (West 1991, pp. 124-126).

A second version of the gun-slave hypothesis is guns-for-slaves-in-production. This version highlights the use of firearms in the production of slaves. In 1730, the Dutch Director General at Elmina Castle described what he saw along the Gold Coast of Africa as guns-for-slaves-in-production:

> "The great quantity of guns and gunpowder which the Europeans have brought have *caused* terrible wars between the Kings and Princes and Caboceers of these lands, who made their prisoners of war slaves; these slaves were immediately bought up by Europeans at steadily increasing prices… (quoted in Richards, 1980, 46, emphasis added)."

In his study of the 18th century Bambara Kingdom of Segu, located in the Middle Niger valley, Richard Roberts (1987) states:

> "Making war not only gave slave warriors their specialized occupation; it gave them the means to renew their *tools of production*. Warriors needed a constant supply of weapons, including lances, horses, and after the mid-eighteenth century, steady supplies of firearms, flints, lead shot, sulfur, and gunpowder (p. 35, emphasis added)."

A third version of the hypothesis is slaves-for-guns-derived. This version emphasizes how African elites sought the latest military technology to fight nation-building wars for reasons that had little to do with the international slave trade. Any slaves who happened to be captured and exported were by-products of these politically-motivated wars.[12] This view was fully developed by Curtin (1975a, pp. 156-168) in his discussion of the distinction between "political" and "economic" motivations for slave production. According to Curtin, politically-motivated slave exports were by-products of political campaigns of nation-building.[13] The proclamation of King Ose Bonsu of Asante is often enlisted in support of this view:

> "I cannot make war to catch slaves in the Bush, like a thief. My ancestors never did so. But if I fight a king, and kill him when he is insolent, then certainly I must have his gold, and his slaves, and the people are mine too (quoted in DuPuis, 1824, p. 163)."

Lastly, guns-for-slaves and slaves-for-guns are combined in a self-perpetuating gun-slave cycle.[14] This is the version of the hypothesis described by Gemery and Hogendorn (1974) as a prisoners' dilemma arms race of "raid or be raided:"

> "States playing no role in the slave trade, and therefore not receiving muskets in payment for slaves, found themselves on the losing side of an arms race. Their dilemma: without firearms defense was precarious. To get muskets, there must be something to export. The only item in great demand was slaves. Thus, it is not surprising that slave trading spread rapidly, especially in the eighteenth century when the flintlock replaced the cumbersome matchlock (p. 242)." [15]

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[12] See Northrup (2002, pp. 90-98) for an extensive discussion of the gun-slave hypothesis that emphasized this version. Also see Thornton (1998, p. 123).

[13] Under these conditions, slave exports will have zero or very low price elasticities of supply. A few estimates of supply elasticity exist, but these are average time-series correlations between quantity and price over long periods of time, and each estimate identifies the supply function by *assuming* it is stable over time. Estimates range from a low of one (Curtin, 1975, ch. 4; LeVeen, 1975; Grubb and Stitt, 1994) to a high of thirty-five (Gemery and Hogendorn, 1977).

[14] What Acemoglu and Robinson (2012, ch. 12) call a "vicious cycle."

[15] Examples of raid-or-be-raided dynamics can be found in Davidson (1961, pp. 142-43), Hawthorn (2003, pp. 96-98) and Klein (2001, pp. 56, 58, 61).

The Dutch Director General at El Mina who was quoted earlier does not describe what he saw in 1730 as a prisoners' dilemma arms race, but his quote continues along similar lines. The guns produced the slaves export:

> "…, which in its turn, animates again and again these people to renew their hostilities, and their hope of big and easy profits makes them forget all labor, using all sorts of pretexts to attack each other or revive old disputes (quoted in Richards, 1980, 46)."

The gun-slave cycle essentially endogenizes the slaves-for-guns-derived channel by recognizing how the external slave trade influenced the economic, political and military motivations of Africans.[16]

One of these four versions of the gun-slave hypothesis is mentioned in almost every major study of West Africa in the 18th century, but it is often dismissed as "too simple" an idea. Miller (1988), for example, refers to firearms as the "very soul of commerce" in the Angolan slave trade, but concludes that "[t]he 'gun-slaves cycle' in Western Central Africa was a much more complicated affair then the sheer unbridled violence sometimes inferred from the data on imports (pp. 93-94)." Curtin (1975a), after documenting a dramatic increase in gun imports into the Senegambia region in the 18th century (p. 321), nonetheless concludes that the "arms for slaves stereotype does not hold in the 18th century… (p. 325)." After a long review of the historiography of the gun-slave hypothesis, Northrup (2002) concludes that, "... while imports of firearms closely tracked exports of slaves, a guns for slaves equation is too simple to describe the complexities of political transformations (p. 97)." Eltis and Jennings (1988), after documenting a tenfold increase in firearms imports between 1680 and 1780, conclude that "[t]hose claiming a major impact from arms will have to build their arguments on some basis other than just the volume of imports (p. 954)." Thornton (1998), who notes correctly that "…the simple correlation between imports of firearms and exports

[16] Roberts (1980, pp. 397-99) uses this feedback loop to criticize Curtin's distinction between political and economic motivations for slaving in Africa: "In contrast to the arguments offered by… Curtin, I will present one that involves a more dynamic view… Instead, I will try to demonstrate the exact amount of *productive* activity which was central to the organization of warfare in the Middle Niger valley (p. 399)."

of slaves is not a causal relationship," then, without proof, makes the following causal claim: "It is more likely that African demands for guns increased simply because they were creating larger armies, which itself had complicated internal social causes. The availability of European weapons did not provoke an increase in warfare (p. 123)." And as a final example, take Reid (2012). While acknowledging that "something approaching an arms race emerged in the seventeenth and, especially, the eighteenth centuries (p. 103)," he nonetheless concludes that "even though much of the political and military development in Atlantic Africa has been explained in terms of a gun-slave cycle, it is an oversimplification to do so… (p. 89)."

Being a simple idea does not mean it is an unimportant idea. The gun-slave hypothesis is the simple claim that imported gunpowder technology (or any imported weaponry) was the source of improvements in the productivity of African resources devoted to capturing people and marching them to the coast. As the technology diffused across the African landscape it disrupted the balance of power among nations, cities and villages in a way that increased the kinds of social conflict that produced slaves. To quote Walter Rodney: "When one tries to measure the effect of European slave trading on the African continent, it is essential to realize that one is measuring the effect of social violence rather than trade in the normal sense of the word (1972, p. 95)." By the end of the 18th century the British gunpowder technology was absorbing 20 percent of the African revenues generated by the British slave trade (see Figure 1).[17] Any productivity advantage would have appreciably increased the kinds of conflict and violence that produced slaves.

3. THE DATA

This study uses time-series data to test the four versions of the gun-slave hypothesis. Production takes time, and time series data can track the intertemporal relationship between gunpowder imports and slave exports. The data come from the aggregate 18th century British slave trade, so the analysis abstracts from local and regional histories. Instead, the analysis

[17] There is no evidence of firearms manufacture in West Africa in the 18th century. Mungo Park (2000, pp 143-144) encountered the manufacture of low-quality gunpowder among the Moors on his way to Bambara country in March of 1796. Blacksmith repair of guns were more common (Kea 1971, pp. 205-206; White 1971, pp. 174-175).

focuses on documenting broader, inter-temporal dynamics between guns and slaves. What follows is a discussion of the three primary data series used in the empirical analysis: GUNPOWDER imports and SLAVES exports (to test the gun-slave hypotheses); and CARGO imports, to control for price dynamics (CARGO/SLAVES=average annual slave price).

British Cargo. The British demand for slaves arrived on the coast of Africa as ships laden with cargo looking for slaves to buy. The gunpowder technology arrived as cargo items on these ships. African destinations were determined before ships left Britain, and cargos were carefully selected to meet the anticipated preferences of intended African consumers.[18] The most popular items were textiles of various kinds, iron bars, firearms and other weapons, rum, cowrie shells and an array of manufactured goods. On the coast of Africa these commodities (*CARGO*) were traded for slaves who had been captured by Africans in wars and raids in the interior.

Annual estimates of the value of *CARGO* come from the *Anglo-African Trade Statistics.* Observations run from 1699-1807.[19] The data were recorded in the 18th century British Customs Office and later digitized by Marion Johnson et al (1990).[20] *The Anglo-African Trade Statistics* do not record British slave purchases. Slaves were shipped to the Americas and never entered Britain. *CARGO* is calculates by taking the value of total British commodity exports to Africa and subtracting the value of total African commodity exports to Britain. What is left is the value of *CARGO* that was used to purchase the slaves that were shipped to the Americas.

The *Anglo-African Trade Statistics* are annual estimates of the *real* value of British *CARGO*.

[18] The *Anglo-African Trade Statistics* do not report trade by region, but several studies have analyzed trade books and ships' ledgers that document the regional variation in African preferences. See Metcalf (1987a, 1987b) and Eltis (2000, p. 168) for a sample.
[19] Data are missing for 1705 and 1712. These years are estimated by taking the average of the bracketing years.
[20] See Richardson (1991) for a discussion of countervailing biases in the Anglo-African Trade Statistics. On the one hand, Customs Office records underestimate British exports to Africa. Ships took on additional goods at non-British ports, at Channel Island and the Isle of Man; and between 1713 and 1730 many ships outbound for Madeira eventually sailed on to Africa. On the other hand, the Customs Office did not record imports of gold from Africa. No official British record of gold imports exists. No attempt has been made to correct for these omissions. After careful assessment, Richardson concluded that the two omissions probably cancelled each other out.

The British Customs Office set the value of trade goods at "official prices." These were primarily 1699 prices that did not change over the sample period. Changes in *CARGO*, therefore, measure changes in the quantities of items shipped to Africa, not changes in their prices. It is the appropriate measure for our purposes because we want to investigate the responses of African slave exporters to changes in the number of cargo items they received, especially weapons.

British gunpowder. The *Anglo-Africa Trade Statistics* do not record data on guns separately as a category of *CARGO*.[21] *CARGO* does contain an annual time-series on gunpowder. For our purposes gunpowder is a better measure than guns. There were so many kinds of guns that it would prove difficult to construct a reliable annual index. Also, firearms are durable goods. Converting trade flows into annual stocks available for slave production would require estimates of depreciation rates, and ideally a different depreciation rate for each type of gun. Even if the stock of guns could be estimated, their capacity as weaponry was still largely determined by the amount of gunpowder available to activate the guns.

Gunpowder, on the other hand, is a more homogeneous product and easier to handle quantitatively. While there were different grades of gunpowder, a poor grade was always shipped to Africa to match the poor quality of the firearms shipped to Africa.[22] Gunpowder is measured in standardized pounds or barrels, something we could not do for guns. And gunpowder does not last nearly as long as guns, especially in the humid tropics.[23] The analysis that follows assumes that the flow of gunpowder largely determines the productive capacity of the gunpowder technology.

Figure 1 shows the importance of the British gunpowder technology in the assortment of

[21] We still do not know why. Marion Johnson et al. (1990), the scholars who digitized the *Anglo-African Trade Statistics*, believed guns were recorded in the category "wrought iron (p. 9)." Inikori (1977, p. 347) finds, in the *British Parliamentary Papers,* data on the value of firearm shipment between 1796 and 1805, so the data exist for that period. Other than this, a time series on British firearms shipments to Africa does not seem to exist.
[22] See Inikori (1977), West (1991, pp. 122-33) and Richards (1980)
[23] West (1991, p. 14) describes 18th century British-made gunpowder. "Not only might the gunpowder explode in transit but it was also highly susceptible to both damp, which would cause the grains to clog and become ineffective, and to damage due to violent movement which could break the grain." Kea (1971) notes that "traders of the Gold Coast carefully examined gunpowder for dampness (p. 205)."

British goods shipped to Africa. As a share of British *CARGO*, gunpowder imports increased steadily during the first half of the 18th century, peaked at about 10 percent of *CARGO* in the 1760s and held steady or declined thereafter. If we add the available data on British firearms between 1792-1805, the share of British gunpowder technology in British *CARGO* increases by approximately ten percentage points.[24] Adding knives and swords would increase the share of weaponry even further. A reasonable range for British weaponry exports to Africa in the late 18th century appears to be 20-25 percent of British *CARGO*. This is in line with other estimates. For the period 1758-1806, Richardson (1979, p. 312) estimates guns and gunpowder to be 25-33 percent of the British cargo into the New Calabar and Windward Coast slave trades, and about 20 percent of British cargo into the Gambia and Bonny slave trades.

African slaves. Annual estimates of British slave purchases (*SLAVES*) come from the *Transatlantic Slave Trade Database*.[25] The variable $SLAVES_t$ measures the annual number of slaves boarding the same British ships that carried $CARGO_t$ to Africa.[26] Figure 2 presents the data on annual British slave purchases, along with numbers for other nations. The British trade was largely confined to the 18th century, but it quickly became one of the largest slave trade in the world. The British trade mimics the trade of other nations, with rapid growth over the 18th century and sharp contractions in the 1740s, 1770s and 1790s. These contractions correspond to European military conflicts like the War of Austrian Succession, the American War for Independence and the Napoleonic Wars. These wars disrupted Atlantic trade generally, including the slave trade.

4. ECONOMETRIC ISSUES AND ESTIMATES

The vector-error-correction model. I use the three time series to test the four versions of the Gun-Slave Hypothesis. Figure 3, panel (a) displays the natural logs of CARGO, SLAVES and GUNPOWDER. Panel (b) displays annual changes in the natural logs. These

[24] These are values reported by Inikori (1977, p. 347).

[25] All data on slave export quantities are taken from the Transatlantic Slave Trade Database at www.slavevoyages.org. Downloaded 5/7/2013.

[26] For cut-off dates, the British Customs Office used Christmas-to-Christmas for 1699-1771 and January 5-to-January 5 for 1772-1807 (Johnson, 1990, p. 13). If $CARGO_t$ measures the cargo leaving Britain in 1750, then $SLAVES_t$ measures the number of slaves leaving Africa on the ships that left Britain between Christmas 1749 and Christmas Eve 1750.

two panels show that the data are non-stationary I(1) time-series. Each series increases over time while the annual changes in the series do not increase. Co-integration is also an issue. Price theory predicts co-integration between CARGO and SLAVES because CARGO/SLAVES equals the average annual price of slave (the real value of cargo per slave). Panel (c) displays the natural log of CARGO/SLAVES, and shows that CARGO and SLAVES were indeed co-integrated. Increases in CARGO could not proceed indefinitely without an eventual increase in SLAVES, and vise-versa.

The co-integration of CARGO and SLAVES is evidence that there existed an international market for African slaves, one where demand and supply tended to equilibrate on price. The Gun-Slave Hypothesis claims that the imported gunpowder technology was also an integral part of this market and how it equilibrated over time. A natural first-order test, therefore, is to see if GUNPOWDER, SLAVES and CARGO form a long-run co-integrated system.

The vector-error-correction model (VECM) searches the 18th century British data for a co-integrating vector $(\beta_c, \beta_s, \beta_g)$ such that

$$\beta_c \Delta lnCARGO_t - \beta_s \Delta lnSLAVES_t - \beta_g \Delta lnGUNPOWDER_t$$

is stationary. If such a co-integrating vector exists, then CARGO, SLAVES AND GUNPOWDER formed a long-run equilibrium process that spanned the 18th century and around which the variables of the system fluctuated. This co-integrating vector could be $(\beta_c, \beta_s, \beta_g)$ or a linear combination of vectors like $(0, \beta_{s1}, \beta_{g1})$ and $(\beta_{c2}, 0, \beta_{g2})$. There are three variables in the system, so there can be at most two independent co-integrating vectors. Deviations from equilibrium are equilibrium errors, or e_t. e_t is stationary because the system tends to return to equilibrium when the error is not equal to zero. e_t has mean zero and constant variance.

The full VEC model adds to the error correction term a reduced-form vector auto-regression model (VAR). The resulting first-order VEC model looks like this:

$$\Delta lnS_t = \gamma + \delta t + \alpha_s(\beta_c lnC_{t-1} - \beta_s lnS_{t-1} - \beta_g lnG_{t-1} + v + \rho t) + \theta_{sc}\Delta lnC_{t-1} + \theta_{ss}\,\Delta lnS_{t-1} + \theta_{sg}\Delta lnG_{t-1} + \varepsilon_{st}$$
$$\Delta lnC_t = \gamma + \delta t + \alpha_c(\beta_c lnC_{t-1} - \beta_s lnS_{t-1} - \beta_g lnG_{t-1} + v + \rho t) + \theta_{cc}\Delta lnC_{t-1} + \theta_{cs}\,\Delta lnS_{t-1} + \theta_{sc}\Delta lnG_{t-1} + \varepsilon_{ct}$$
$$\Delta lnG_t = \gamma + \delta t + \alpha_g(\beta_c lnC_{t-1} - \beta_s lnS_{t-1} - \beta_g lnG_{t-1} + v + \rho t) + \theta_{gc}\Delta lnC_{t-1} + \theta_{gs}\,\Delta lnS_{t-1} + \theta_{gg}\Delta lnG_{t-1} + \varepsilon_{gt}$$

The expression in parentheses is the equilibrium error, or the size of the annual deviations from long-run equilibrium. The $\alpha_j s$ estimate the speed at which the variables adjust to deviations from long-run equilibrium. The θ_{ij}s are estimates of past-dependence, or the effects of changes in the past on changes in the current period. For the sake of brevity, I have displayed a first-order VEC with one-period lags of the endogenous variables. The actual number of lags remains to be specified. $\gamma, \delta t, v\ and\ \rho t$ are linear and quadratic deterministic trends that also need to be specified. The ε_{ij} error terms are assumed to be individually serially uncorrelated white noise processes with zero mean and constant variance.[27]

The model is flexible enough to capture all four versions of the Gun-Slave Hypothesis. Guns-for-slaves-in-exchange is captured by β_g, the estimate of co-integration between gunpowder and slave price over the long-term. Guns-for-slaves-in-production is captured by a slave response to either excess gunpowder imports (α_s) or past increases in gunpowder imports (θ_{sg}). Slaves-for-guns-derived is captured by a gunpowder response to either excess slave exports (α_g) or past increases in slave exports (θ_{gs}). A gun-slave cycle would be a pair of significant coefficients. One pair is (α_s, θ_{gs}), where a history of increases in slave exports attracts additional gunpowder that Africans use to produce and export more slaves. The other pair is (α_g, θ_{sg}), where a history of increases in gunpowder imports produces additional slave exports that attract additional gunpowder.

Specification Tests. Specification tests proceed as follows. First I test the model for optimal lag-length using a variety of methods. Once the lag-length is chosen, I test for co-integration among the three dependent variables under different specifications of the deterministic trend. Third, I check to see if the preferred specifications exhibit any auto-correlation in the

[27] The ε_{ij} are composites of the three error terms of a structural VAR. Since those are white noise processes, their composites are individually white noise processes. But since they are each composites of each other then they are correlated with each other. This becomes an issue when we estimate impulse-response models. The solution will be a Choleski decomposition.

errors. I remove autocorrelation by increasing the lag length. Finally, I check to see if the estimated long-run equilibrium relationship is stable over time.

Table 1 reports five statistical tests for lag order. Four of the tests identify one-period as the optimal lag length. Table 2 reports Johansen rank test for co-integration among CARGO, SLAVES and GUNPOWDER under different constraints on the deterministic trends and with one-period lags. The rank of the coefficient matrix determines the number of independent co-integration relationships. The Johansen tests identify two cases of co-integration.[28] The first, Model 1, has rank=1, lag=1 and no trend. The second, Model 2, has rank=2, lag=1 and a restricted constant trend ($\upsilon \neq 0$).

Table 3 checks for autocorrelation in the errors of these two models. The first panel checks for autocorrelation when the dependent variables are lagged one period. Both models exhibit some autocorrelation. I then check for autocorrelation in second-order models. These also show autocorrelation. The 3-period and 4-period models also show autocorrelation. The autocorrelation disappears when I lag the dependent variables for 5 periods. The preferred specifications, therefore, are: Model 1 with rank=1, lag=5 and no trends; and Model 2 with rank=2, lag=5 and a restricted constant trend on the equilibrium path ($\upsilon \neq 0$).

Equilibrium dynamics. Table 4 reports the estimated co-integrating equations (the βs). Since Model 1 has rank=1, it can have at most one co-integrating equations. Model 2 has rank=2 and can have two co-integrating equations. Each co-integration vector is unique up to a scalar, so the estimation procedure normalizes the equations by setting one of the coefficients equal to one.[29] Models 1 and 2 impose the Johansen normalization restrictions.[30]

[28] Ender (2010, pp. 401-405). The Johansen rank test is a nested test. If the trace statistic for rank=0 is less than the 5% critical value, then the test fails to reject rank=0 for the matrix. If this is the case, then the variables are I(1), not co-integrated and OLS in differences can be applied. If the trace statistic for rank=0 is greater than the 5% critical value, then the Johansen test proceeds to test for rank=1. If the test fails to reject rank=1 then the matrix of coefficients has rank=1 and the variables are I(1) and co-integrated. If the test rejects rank=1 then the Johansen test proceeds to test for rank=2. If the Johansen test rejects all possible ranks, then the variables are I(0) and OLS in levels can be apply.

[29] Enders (2010, pp. 359-360 and 371-373).

[30] These are the default normalization restriction imposed by STATA 13.1.

All of the coefficients are highly significant. The estimated equation for Model 1 is $\ln(C^{2.21}/S) = \ln G^{1.82}$. CARGO and SLAVES are co-integrated through the price of slaves. Gunpowder is co-integrated with the price of slaves, some, but not all, through its co-integration with cargo. Model 2 reveals similar patterns.

Table 5 reports the estimated speed of adjustment parameters (α). The top panel reports estimated speed-of-adjustment parameters when *slave exports* are above long-run equilibrium. The second panel reports speed-of-adjustment parameters when *gunpowder imports* are above long-run equilibrium. Model 1 performs poorly. None of the variables adjust to deviations from long-run equilibrium, indicating that the model is not really one of co-integration. Model 2 performs better. In Equation 1, when the equilibrium error is positive, slaves are above their equilibrium level with cargo (meaning cargo/slaves=slave price is below its long-run equilibrium). The speed of adjustment parameters predict that all three variables will adjusted downward, with slave exports declining faster than cargo to restore long-run equilibrium price.

Equation 2 of Model 2 tells us what happens when gunpowder is above its long-run equilibrium level. When this happens, none of the variable adjust with any degree of statistical significance. One adjustment, however, is close to statistical significance. When gunpowder is above its long-run equilibrium, slave exports increase: α_s =.12 with a p-value of .204. This is evidence of guns-for-slaves-in-production, although the standard error of the estimate is large.

The standard error is large in part because British traders were not the only slave traders operating on the coast of Africa. Some British gunpowder was used to capture slaves who were eventually sold to French or Portuguese merchants. And some British purchases were captured by Africans slavers who used French or Portuguese gunpowder. Model W2 is designed to reduce these leakages and injections in the estimated relationship between *British* gunpowder imports and *British* slave purchases. Model W2 weights British gunpowder imports by the degree of British dominance in their major slave trading ports. The weight (W) is the British share of trade in the 18 ports where British traders purchased 25,000 or more slaves over the course of the 18th century. This represents approximately 90 percent of all British slave purchases from known ports.[31] As W approaches one, British trade in these ports approaches monopoly, and leakages and injections from competitors approach zero. At smaller W, leakages and injections are larger, so the weighting scheme treats British gunpowder as less effective at producing the slaves that British merchants ultimately purchase. Similarly, the weighted variable can now account for changes in the observed British gun-slave relationship that emanate from changes in W, holding GUNPOWDER constant.

Column (3) of Tables 4 and 5 report the results for Model W2. The co-integrating equations change very little but the estimated speed of adjustment to excess gunpowder imports changes considerably. Now British slave exports increase significantly when British gunpowder is above long-run equilibrium: α_s =.15 with a p-value of .053. Cargo also now responds positively to excess gunpowder: α_c = .32 with a p-value of .007.

A remaining issue with Model 2 and Model W2 is instability in co-integrating Equation 2. The first column of Figure 4 displays the predicted values of the co-integrating equations for Model W2. Stationarity requires that the predicted values fluctuate around zero. Equation 2, however, has an inverted U-shape that overestimates gunpowder's share of cargo in the middle of the century. This could reflect changes in the nature of the gunpowder-cargo relationship sometime in the middle of the 18th century.[32] The estimates of Models 2 and W2 imposed the Johansen constraints on the co-integrating equations. Under these constraints, Equation 2 estimates the relationship between gunpowder and cargo. For our purposes we might want to impose constraints that explicitly capture the dynamics between gunpowder and slaves.[33]

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[31] The ports are Gambia and St. Louis in Senegambia; Ilse de Los and the Sierra Leone Estuary in Sierra Leone; Bassa and Cape Mount on the Windward Coast; Anombu and Cape Coast Castle on the Gold Coast; Benin and Whydah in the Bight of Benin; Bonny, Calabar, Cameroons and New Calabar in the Bight of Biafra; and Cabina, Congo River, Loango and Malembo in West Central Africa

[32] West (1991, pp. 119-135) documents how British slave traders successfully petitioned Parliament for exemptions to the national prohibition on private gunpowder exports during the Seven-Years War (1756-62). This might explains the mid-century hump in the gunpowder share of cargo.

[33] "When there are multiple cointegrating vectors, any linear combination of those vectors is also a cointegrating vector… For example, if there are two cointegrating vectors in a three-variable system, there is a cointegrating vector for each bilateral pair of the variables. (Enders 2010, pp. 397-398)."

Those constraints are imposed in Model W2.1 and are reported in column (4) of Tables 4 and 5. Equation 1 still captures the long-run equilibrium relationship between slaves and cargo (slave price). Equation 2 now captures the long-run equilibrium relationship between gunpowder imports and slave exports. The second column of Figure 4 graphs the corresponding equilibrium errors for Model W2.1 and shows that both equilibrium equations are now stable over time. The estimate of guns-for-slaves-in-production is unchanged, but the estimated price dynamics change considerably. Now, when slave exports are above their equilibrium levels (and the slave price is low) the model predicts that British cargo exports will increase in the next year to take advantage of the lower slave price on the coast of Africa. This is a simpler and more reasonable market adjustment process than the one estimated by Model 2 and Model W2. Model W2.1, therefore, is taken to be the preferred specification.

Past dependence. Table 6 reports the estimated coefficients on the lagged endogenous variables. The first panel reports the influences of *past slave exports* on the current values of each of the three endogenous variables. The second panel reports the influences of *past gunpowder imports* on the current endogenous variable, and the third panel reports the influences of *past cargo imports* on current values. There is significant evidence of slaves-for-guns-derived in the first panel. In Models 2 and 2.1 the influence of past slave exports on current gunpowder imports dates back three years. In Model W2 and W2.1 slaves-for-guns dates back two years. The coefficients are large and statistically significant. When African slave exports increased, British gunpowder imports grew for another 2-3 years.

Sensitivity test. In this section I look to see if the estimate of α_s (guns-for-slaves-in-production) is sensitive to the way CARGO is measured. The original measure of cargo = British exports - African imports. Alternative measures are these: cargo1 = cargo - indirect African imports; cargo_nog = cargo – gunpowder; cargo1_nog = cargo1 – gunpowder. Exports = British exports, and the other Export measures follow the same pattern as the corresponding cargo measures. None of these alternative measures of cargo change the result on α_s (see Table 7).

Placebo tests. I interpret α_s to be an estimate of guns-for-slaves-in-production, as if excess gunpowder increased the production of African slaves for export. It could be the case that all excess commodity imports, not just gunpowder, produced additional slave exports, through a kind of commodity-for-slaves link. Slave exports were the dominant exchange earner in 18th century West Africa. Excess commodity imports of any kind could have produced additional slave exports because African slave-exporters (elites, polities or trade networks) were also the dominant commodity-importers. Was there anything unique about excess gunpowder and its intertemporal link to additional slave exports?

Substituting non-lethal commodity imports for gunpowder imports can help address this issue. All cargo items exchanged for slaves but only guns, gunpowder and other weapons helped produce slaves in the sense that we are trying to identify. I substitute other commodities for gunpowder and re-estimate the system. I then look to see if any of the other imports display a commodity-for-slave relationship like the gunpowder-for-slaves relationship.

The *Anglo-African Trade Statistics* divide *CARGO* into 18 classes of commodities that together sum to the value of *CARGO*.[34] I use 16 of these commodity classes in the placebo tests.[35] The *Anglo-African Trade Statistics* also single out wrought-iron as a special sub-class "because it is thought to contain firearms, a commodity conspicuously absent elsewhere in the statistics (Johnson, et al 1990, p. 24)." Call these 17 commodities *PLACEBO*s. The 17 PLACEBOs are substituted one-at-a-time for GUNPOWDER and the models are re-estimated.

Table 8 reports the resulting estimates of α_s (commodities-for-slaves-in-production). The first entry reproduces the gunpowder-for-slaves result. The estimate for wrought iron (which the authors of the dataset thought contains firearms) is statistically significant and similar in

[34] These are listed and described in Johnson, et al (1990), Table 2, page 24. "A product category is an agglomeration of related commodities with a single range broad enough to enhance clarity but narrow enough to retain interesting differences in development (p. 23)."
[35] I do not use Coins (which has only five non-zero entries) and Military Stores (because it includes *GUNPOWDER*).

magnitude to the gunpowder estimate. The only other commodities that exhibit statistically significant coefficients are misc. manufactures, glass, and other textiles.[36] The category iron and steel is almost significant with a p-value of 0.11 and includes shackles, chains, swords and the raw materials to produce shackles, chains and swords.[37]

The magnitude of the effect. The VEC model identified and estimated three gun-slave dynamics in the 18th century British slave trade. First, gunpowder, slaves and cargo were co-integrated in a long-term equilibrium relationship that characterized the 18th century British slave trade. In this sense, gunpowder was an integral part of the 18th century British slave trade and how the international market adjusted to shocks. Second, positive deviations from equilibrium levels of gunpowder produced additional slave exports. Third, increases in African slave exports attracted additional gunpowder imports for 2-3 years. Together, these gun-slave dynamics formed a gun-slave cycle.

What was the effect on slave exports of a one percent increase in gunpowder imports? The increase in gunpowder would have to work its way through the gun-slave cycle. To answer this question we need to place some restrictions on the error terms in our model. The VEC errors (ε_{it}) are linear combinations of the pure errors from the structural VAR (ϵ_{it}). The structural VAR allows cotemporaneous interactions among the endogenous variables which preclude the use of OLS in estimating coefficients. The reduced-form VAR (which is the one estimated here with an error correction term) is derived from the structural VAR by dumping all of the cotemporaneous interactions into the error term. The resulting errors of the reduced-form VAR (ε_{it}) are therefore linear combinations of the structural errors (ϵ_{it}) weighted by the coefficients of cotemporaneous interactions from the structural VAR ($\emptyset_{ij}s$). Each ε_{it} is a white noise process because the underlying pure innovations are white noise processes. The ε_{it} however are not independent of each other. In order to trace the impact

[36] Some of these results may provide clues to the kinds of economic development taking place within slave trading networks. Iron, steel and wrought iron could have been intermediate imports for blacksmiths (see Hawthorne 2003, pp. 96-98; Bocoum 2004). Glass could have been an intermediate import for bead makers (see Christopher R. DeCorse 1989). Both had established occupations and markets in West Africa.

[37] In his discussion of an "iron-slave cycle" in coastal Guinea-Bissau, Walter Hawthorne (2003) writes "In sum, the need to obtain European weapons for defensive purposes may not have compelled Africans to conduct slave raids, but the need to obtain iron from which to forge practical defensive or offensive weapons – as well as cutting edges for digging tools – did compelled *coastal* Africans in Guinea-Bissau to produce and market captives (p. 97)."

of a pure innovation in gunpowder (ϵ_{gt}) on slave exports we need to order the cotemporaneous interactions among the variables by setting some of the $\emptyset_{ij}$ equal to zero. This is the Choleski decomposition.[38]

What is the order of the cotemporaneous interactions among $CARGO_t$, $GUNPOWDER_t$ *and* $SLAVES_t$? The observations in our system are annual observations from the 18th century British Triangular Trade. A key question is this: could the level of *SLAVE* exports in year *t* influence the amount of *GUNPOWDER* shipped to Africa in year *t*? The answer depends on the length of time it took for information about market conditions on the coast of Africa ($SLAVES_t$) to return to Britain and influence $GUNPOWDER_t$.

Figure 5 plots the number of days it took for the ships in the British sample to travel from Britain-to-Africa-to-America. The average duration approached 300 days. From there, the ventures had to sell their slaves in the Americas, restock provisions, secure a British-bound cargo of sugar and sail back to Britain. In Britain, they had to unload the American cargo, secure a new commission and crew, restock *GUNPOWDER* and set sail for Africa. In order for reliable information about supply conditions on the coast of Africa in year *t* to influence, in this way, the amounts of gunpowder shipped to Africa in year *t*, ships had to complete the cycle from Britain to Africa to America to Britain and then outbound to Africa again all within the calendar year *t*.[39] Some of the first ships leaving in January might complete the triangle before the end of the calendar year, but the vast majority will not. The same applies to $CARGO_t$.[40]

This suggests two possible Choleski orderings: $GUNPOWDER_t \rightarrow CARGO_t \rightarrow SLAVES_t$ and $CARGO_t \rightarrow GUNPOWDER_t \rightarrow SLAVES_t$.[41] The first ordering traces system responses to pure increases in gunpowder ($\varepsilon_{gt} = \epsilon_{gt}$). The second ordering traces system responses to a

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[38] Enders (2010, pp 305-311 and 405-407). In a system of n variables, the Choleski decomposition requires parameterization of $(n^2 - n)/2$ restrictions. In our case the number is three (3).
[39] This was the nature of the Triangular Trade. Because of ocean currents and prevailing winds, information in the northern hemisphere of the Atlantic Ocean tended to flow in a clockwise direction.
[40] This ordering finds support in the estimates of past-dependence reported in Table 6. There, changes in *SLAVES* have a lagged effect on changes in *GUNPOWDER* and *CARGO*.
[41] The first ordering sets $\emptyset_{gs} = \emptyset_{gc} = \emptyset_{cs} = 0$. The second ordering sets $\emptyset_{cs} = \emptyset_{cg} = \emptyset_{gs} = 0$.

derived increase in gunpowder ($\varepsilon_{gt} = F(\epsilon_{ct}, \epsilon_{gt})$). The resulting cumulative impulse-response functions are graphed in Figure 6. The estimated response of slave exports to increases in gunpowder never dies out, even after 20 years. This is the case for both Choleski orderings and for both the weighted and unweighted models. The size of the response is larger for the $GUNPOWDER_t \rightarrow CARGO_t \rightarrow SLAVES_t$ ordering. This ordering simulates situations like the Seven Years War, when British slave traders sat in London Harbor waiting for government permission to export gunpowder to Africa.[42] This ordering probably also held during transitions from war to peace, when excess capacity in the British gunpowder industry was used to produce cheap and abundant gunpowder for Africa (as will be discussed later). The average impulse-response was probably somewhere between the first and second orderings. A one percent increase in gunpowder set in motion a 5 year gun-slave cycle that increased slave exports by an average of 50%, and the impact continued to grow over time.

Instrumental variables estimates. In this section I develop an instrumental variables estimation of guns-for-slaves-in-production building on the specification tests already performed. Column 1 of Table 9 reports the results of a simple regression of ΔlnSLAVESt on ΔlnCARGOt and ΔlnGUNPOWDERt with a 5-period lag of the error term. The coefficient on cargo shows that the estimated elasticity of slave exports with respect to £1 worth of the average cargo basket (which includes gunpowder) is 0.44. The coefficient on gunpowder shows that £1 worth of gunpowder secured 13 percent more slaves than £1 worth of the average cargo basket. This is evidence of a preference for gunpowder among African slave traders.[43] Column (2) lags the three variables for four periods. This matches the VEC

[42] Prohibition on the private export of gunpowder and guns was established by Parliamentary Act in April of 1756. According to West (1991), "Liverpool merchants told the Privy Council in May of 1756 that it was impossible to undertake trade to Africa without gunpowder and arms.... [T]hey requested that the Liverpool Customs officers be given power to inspect and permit movement of shipments without license…. On 5 October the Privy Council reported to the Board that… the merchants of Liverpool would be permitted to export such quantities of gunpowder, arms and ammunition as necessary for trade and the defense of ships… agreement for general license also given to the Society of Merchant Adventurers of Bristol. (pp. 124-5)." London merchants "stressed that the legislation had resulted in ships lying in the Thames with valuable assorted cargoes, manned at great expense yet unable to proceed for want of powder. (p. 126)"

[43] Cargo items are valued in 1699 prices, so these are the real British values per slave paid by African slave traders on the coast of Africa. The coefficient on gunpowder says that British merchants received 13% more slaves on the coast of Africa for a £ of gunpowder than for a £ worth of the average cargo bundle. As Inikori (1977, p. 340) states: "The very high demand for guns which prevailed in West Africa in the 18th century is reflected in the fact that £1 sterling of guns had a much higher purchasing power in West Africa than £1 sterling of other goods." Presumably,

specification. The estimate of guns-for-slaves-in-exchange is now 21 percent. The lags reveals how additional gunpowder imports and slave exports were correlated over a four year period. The immediate impact multiplier of gunpowder on slaves is 21 percent. The 5-year multiplier is 36 percent.[44] Column (3) reports estimates using weighted gunpowder. The immediate impact multiplier drops to 17 percent and the 5-year multiplier increase to 40 percent. The 5-year multipliers are similar in magnitude to the cumulative impulse-response multipliers 5-years out.

The VEC estimates revealed significant interactions among the three variables, so it is best to perform an instrumental variables estimation of guns-for-slaves-in-production. As in the VEC specification, guns-for-slaves is taken to be the impact of last year's gunpowder on this year's slave exports. Table 10 reports the results of a search for an instrument for gunpowder. I regress gunpowder on a number of variables that might capture variations in gunpowder but be independent of variations in slaves and cargo. The first potential IV is a measure of excess capacity in the British gunpowder industry. The index is constructed from data found in Mitchell's *British Historical Statistics* (1988, pages 578-580). The index, called EXCESS_CAPACITY, is the previous peak level of central government spending on ordnances minus the current level of central government spending on ordnances.[45] The British Ordnance Office was the major purchaser of gunpowder in Britain. Wartime demands always expanded industry capacity, but demand always collapsed at the end of hostilities, leaving excess industrial capacity to produce a commodity that was costly to store.[46] Under these conditions, the excess capacity could be used to produce gunpowder for Africa at very low opportunity cost. The first column of Table 10 shows that current gunpowder exports to Africa were highly correlated with current and future excess-capacity in the gunpowder industry. It was as if cheap gunpowder was available for private export to

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African slave traders were willing to pay a coastal premium of 13 percent because they knew the internal consumers who would cover it – namely, interior slave producers and slave traders.

[44] In Auto Regressive Distributed Lag models like this one, the long-run multiplier is $\sum_{i=0}^{n} b_i/(1-\sum_{j=1}^{n} a_j)$, where a is the coefficient on the independent variable and b is the coefficient on the dependent variable

[45] EXCESS_CAPACITY is sometimes negative during war years (nine observations). The natural log is not defined for those years. To handle this, the negative years are set to .01.

[46] Volatility in both government purchases and industry demand is clearly documented in West (1991): "The period of peace demonstrates severe problems for gunpowder makers. They had no government employment, due to the inability of the Ordnance Office to agree contracts prematurely for a substance which could not be stored indefinitely. They were therefore dependent entirely on private trade (p. 5)."

Africa once a permanent peace in the European theater had been secured.

The second column reports regressions of gunpowder on a dummy variable called WAR, which take the value 1 during years of hostility, zero otherwise.[47] The regression shows that war depressed gunpowder exports, but only weakly. War is also likely to depress cargo and slaves, which makes it an unlikely instrument for gunpowder in this context. The third column regress gunpowder on British war casualties, and shows no significant correlation between the two.[48]

Table 11 reports IV results using the statistically significant EXCESS_CAPACITY measures from Table 10 as instruments for last year's gunpowder. Results are reported for unweighted and weighted gunpowder. The bottom panel reports first-stage results. In the first stage, EXCESS_CAPACITY performs well as an instrument for last year's gunpowder imports. For the unweighted model, the Shea partial R-square is 0.16 and the Kleibergen-Paap F-statistic is 7.22. For the weighted model the partial R-square is 0.12 and the F-statistic is 3.79. The weaker performance of the weighted model is due to the fact that EXCESS_CAPACITY is not a good predictor of the British share of trade in African ports (W).

The top panel of Table 11 reports second stage results. Both models estimate guns-for-slaves-in-production to be 18-19 percent, similar in magnitude to the 12-15 percent estimated by the VEC model. The differences make sense. The IV model captures average slave responses to exogenous changes in gunpowder imports. The VEC model captures average slave responses to exogenous deviations of gunpowder from its long-run equilibrium level. This difference probably explain why the VEC estimates are smaller than the IV estimates. The F-statistic for the unweighted IV model exceeds the Stock-Yogo critical value for 20% maximal IV relative bias. Both models pass the Hansen test for over-

[47] The wars are the War of Spanish Succession (1701-1711), the War of Quadruple Alliance (1718-1719), the War with Spain (1727-29), the War of Austrian Succession (1743-1748), the Seven Years War (1756-1762), the American Revolutionary War (1775-1782), and the Great French Wars (1793-1801 and 1803-1807). The variable WAR=1 for years of British involvement in these conflicts, zero otherwise.

[48] The measure of war casualties is the annual UK war casualty data found in Clodfelter (2002). I thank Mark Dincecco for sharing this data with me.

identification restriction.

5. IMPLICATIONS FOR 18th CENTURY WEST AFRICAN HISTORY

The estimated parameters of the VEC model reveal a dynamic relationship between gunpowder and slaves in the 18th century British slave trade. Increases in slave exports attracted British gunpowder to Africa, which Africans used to produce more slaves, and the cycle repeats. This is the gun-slave cycle. Impulse-response functions predict that once this dynamic is established, increases in gunpowder will have explosive effects on the future time-path of slave exports. These findings suggest a new direction for research on the slave trade in Africa: look for times and places of explosive growth in slave exports, identify what Jack Goody calls "the means of destruction (1971, ch. 3)," and document how the relationship between the two gets reproduced.

Such an exercise is well beyond the scope of this paper. The 18th century African landscape was dotted with literally hundreds of small polities, each engaged in their own local and regional geo-political struggles. [49] A few examples, however, might help convince the reader that this approach merits further consideration.

Figure 7 reports time-trends of British slave exports and total slave exports for broad regions of the Guinea Coast of Africa. The bold lines are 6-degree polynomials that reflect changes in trends. The first two panels show explosive growth in trends in the first half of the 18th century along the Gold Coast and the Bight of Benin. Is there evidence in the historical record of a gun-slave cycle operating here at this time?

Most historians believe a gun-slave cycle operated here. Thornton (1999) states that "[h]ere it has been possible to speak of a 'gunpowder revolution' (p. 61)." According to Daaku (1970, 144-155), in the late 17th century the state of Denkyira was expanding territorially behind the Gold Coast, selling war captives and gold for guns and gunpowder.

[49] All of the econometric studies cited in footnote 7 use the ethno-linguistic diversity in Africa recorded in Murdock (1967). A key issue is whether or not the observed ethnic diversity was influenced by the slave trade. See Whatley and Gillezeau (2011a, 2011b).

In the early 18th century several interior Akan clans joined forces to form the Asante Confederation to protect themselves from coastal powers like Denkyira. In 1701 Asante fought for and won its independence from Denkyira. The victory was closely tied to Asante gaining access to firearms and blocking Denkyira access the firearms. Once secured, Asante embarked on an aggressive campaign of territorial expansion, such that by 1750 it claimed the majority of what is now the state of Ghana. Asante controlled its northern territories by prohibiting the flow of armaments northward (Wilks 1975, pp. 18-25). The Dutch Director General at El Mina who was quoted earlier in this paper was describing the gun-slave cycle along the Gold Coast in 1730 (Richards, 1980, p. 46).

Behind the Bight of Benin, a similar dynamic unfolded in the geo-political struggles between Alladah, Whydah, Dahomey and Oyo. According to Law (1991), by 1730 these geo-political struggles culminated in the regional dominance of Dahomey, a militarized state boasting a large standing army of riflemen. While the details differ, both nation-building efforts relied heavily on the import of firearms, the export of slaves and the control of the flow of guns (Kea, 1971, p. 201). These are the proto-typical "slave-states" of West Africa, born in the era of the transatlantic slave trade and built on the import of guns and the export of slaves.

But these are *not* the gun-slave cycles that the British data identify. British traders participated in the expansion along the Gold Coast, but they did not dominate the region. In the Bight of Benin they were never major players. The British data point to other possible gun-slave cycles. Candidates include the Bight of Biafra, the Windward Coast and Sierra Leone. Before mid-century these regions exported very few slaves, but beginning around 1740 each experienced explosive growth, with British traders leading the way. Senegambia shows a similar increase after 1740, but with major leakages and injections in the British gun-slave relationship coming from other nations.

Developments behind the Bight of Biafra are well-documented. Long before 1740, a trading diaspora called the Aro came to dominate the Atlantic trade into and out of the hinterland. Around 1740 the structure of this trading network underwent some changes.

For our purposes, the most significant change was the use of force to expand into the densely-populated Igbo heartland to the west. According to G. Ugo Nwokeji (2010):

> "Aro incursion into the densely populated Igbo heartland and the establishment there of their most important settlements in about the mid-18th century coincided with the steady increase observed in the Biafra trade during this time (p. 19)."[50]

The Aro trade diaspora dates back to at least the mid-17th century, with its origin tied to the "introduction of firearms into the equation (Nwokeji 2010, p. 26)." Unlike other trade diasporas, "the Aro almost always had access to military resources, which was often a decisive factor in their dealings with hinterland groups (p. 55)." The push into the Igbo heartland "manifested by the mid-eighteenth century in Bonny's supersession of Old Calabar as the Biafra's principal port just as the Aro expanded westward (p. 45)." The firearms coming into Bonny in exchange for these slaves were British-made firearms, known as Bonny rifles.[51]

The export trends for Sierra Leone, Windward and Senegambia are more difficult to interpret because the inland geography behind the coast is complicated by a vast highland plateau. Transportation waterways fan out in all directions from these highlands, making it difficult to assign coastal slave exports to any particular region or conflict.[52] In addition, on the northern slope and down into the Middle Niger Valley,

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[50] "In spite of the ties, strategies, and practices that facilitated the establishment of Aro settlements among the non-Aro hosts, the Aro deemed force to be particularly effective in the Igbo heartland… Their massive and consistent application of force in this region is widely recognized as a-typical of Aro methods (Nwokeji 2010, p. 68)."

[51] Northrup (1978) does not see this as a gun-slave cycle, primarily because the region's history is void of state-sponsored war: "Rather than being used by armies in warfare, most of the weapons imported by this region must have gone into the hands of common people, who used them for hunting, for self-defense, and for firing at funerals and other ceremonial occasions, rather than for war (p. 97)." The research by G. Ugo Nwokeji (2010) appears to call this view into question.

[52] The Highland Plateau serves as the source of three major rivers: the Niger, the Senegal and the Gambia rivers. The Niger flows northeastward into the Middle Niger valley. The Senegal and Gambia flow to the northwest and into the Atlantic Ocean along the Senegambia coast. Since the Middle Ages these waterways have integrated the trade and politics in the Western Sudan, producing the classic Sudanese Empires of Ghana, Mali and Songhai. Falling southward from the highlands, towards the Sierra Leone coast, is a dense system of lesser rivers and streams that flow through forest.

the trans-Atlantic trade competed with the trans-Saharan trade. Still, the post-1740 increases in slave exports from these Atlantic coasts coincide with a number of interior conflicts that expanded trade toward the Atlantic coast in order to secure the latest gunpowder technology.[53]

Thornton (1999) in his book *Warfare in Atlantic Africa, 1500-1800*, discusses Senegambia and Sierra Leone together in chapter two entitled "War in the Rivers." The major political development of the 18th century was the 1726-27 formation of Futa Jallon in the highlands.[54] Thornton reports that "…firearms were desired everywhere, and it was probably inability to obtain them rather than a rejection of their military utility that caused them to be scarce in inland areas like Futa Jallon in the 18th century (pp. 46)" The King of Futa Jallon "…appreciated guns, for he sold slaves to obtain guns and gunpowder whenever possible (p. 46)." As late as 1794 "… guns were still rare…, but Susus, near neighbors who had better coastal access, were almost all equipped with guns. The leaders of Futa Jallon were anxious to obtain more supplies of Muskets and artillery, and prepared to sell slaves in large numbers to acquire them to protect themselves against their enemies (p. 46)."

Curtin et al. (1995, p. 197) claim that the slaves exported from the 18th century Senegambia coast were largely Mande victims of the rise and expansion of Bambara states in the interior, one of which was Segu.[55] Richard Roberts (1987, pp. 58-62) describes Segu as a warrior state based on a steady influx of firearms, especially after the mid-18th century (p. 35). He also describes how trade shifting towards the Atlantic coast to obtain adequate supplies.

[53] Guns tended to come across the Atlantic, while horses (as military technology) tended to come across the Sahara. The tse-tse fly of the forest regions effectively limited horses to the drier Sahel. See Law (1980). The case of Senegambia is further complicated by the possibility of complementarity or substitutability between gun-slave cycles and horse-slave cycles. See Thornton (1999) and Goody (1971) for discussions of the comparative impacts of the two military technologies.
[54] Lovejoy (2016, pp. 36-66) describes how Futa Jallon was the result of Islamic Jihad against non-believers like the *Ceddi* and the emerging Bambara states who were threatening Muslims with enslavement. Backed by scholar clerics, merchants and elites, the expressed ideology was the protection of Muslims and the purification of Islamic practices. Once successful, the ideology was re-deployed to justify the capture and export of non-Muslim slaves.
[55] "To be 'Bambara' in West Africa meant that a person could be enslaved as far as Muslims were concerned (Lovejoy 2016, p. 60)."

> "The Middle Niger valley was surrounded by three export regions. Trade with the Maghrib, Senegambia and the southern forest zone followed different routes…. At least some of the slaves produced by the warriors of Segu found their way into the Atlantic economies. Even more-direct, however, was the dependence of the Segu political economy on firearms, gunpowder, and other European manufactures, which could best be supplied through the Atlantic coast trade. Demand for these commodities increased the importance of the westerly and southwesterly direction of trade (pp. 59-60)."

These are just a few examples, but they highlight the importance of imported gunpowder technology in growing the transatlantic slave trade.[56] Many examples can also be found among the decentralized societies of West Africa. In fact, most slaves may have originated in skirmishes and kidnappings involving decentralized groups who were trying to defend against being enslaved by more-centralized societies, warlords and bandits. They deployed a variety of defensive strategies like building walls (Thornton 1999), moving to rugged terrain (Nunn and Puga 2012), paying tribute (Wilks 1975, pp. 19-23) and securing guns and other imported weapons to defend themselves (Hawthorne 2003, ch. 3; Klein 2001). The latter strategy, and sometimes paying tribute in slaves, pulled these decentralized societies into the orbit of the gun-slave cycle.

6. CONCLUDING REMARKS

This econometric study has documented a gun-slave cycle in the 18th century British slave trade. One must ask, then, why historical studies tend to down-play the importance of the gun-slave hypothesis. One possible answer is that modern Africanist sought, self-

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[56] The British were only marginal players in West Central Africa. The Portuguese/Brazilian trade dominated the southern hemisphere. Slave exports from West Central Africa averaged approximately 10,000 per year for the second half of the 17th century. After 1720 exports exploded to 40,000 per year by the end of the 18th century. Concerning the role of gunpowder technology in this region, Miller (1988, p. 104) notes that "[t]he stories circulating about the bones of the vanished yielding the gunpowder of the new trade thus expressed the essence of the fatal and tragic exchange of people for power in a strikingly accurate metaphor."

consciously, to critique what Joseph Miller calls the "Hamitic myth" that African state-formations had been imposed by outsiders (1976, pp. 1-10).[57] The gun-slave hypothesis is sometimes taken to imply that Europeans "forced" African societies against their will to capture and export others. This interpretation is argued forcefully by Thornton (1998, p. 113-125, 305; 1999, pp. 5, 150-151) who turns a hypothesis about productivity into a European conspiracy.

In a sense, the gun-slave cycle can be seen to contain an element of force, if one chooses to see it that way (in addition to enslavement). On the African side, people are forced (or must choose) to raid-or-be-raided. On the European side, traders are forced (or must choose) to sell guns to compete with other traders. But this is not a conspiracy. It is the way competition works, and the way competitive markets are sustained over the long-term.[58] The co-integration equations reported in this paper show that gunpowder was integral to the reproduction of the 18th century international market for slave. The gun-slave cycle reveals some of the ways Europeans and Africans sustained that market, what Davidson (1961, p. 241) calls the "inner-dynamic of the slaving connection with Europe." The impulse-response estimates show how increases in gunpowder influenced African agency.

Another possible reason why the gun-slave hypothesis has not gained traction is because the intertemporal links between weapon imports and slave exports are difficult to track. Exchange contracts document cotemporaneous links, but exchange contracts

[57] (Miller, 1976, p. 1): "As modern African nations drove towards political independence during the late 1950s and early 1960s, historians did their part by searching the African past for precedents which justified the capacity and right of Africans to enter Kwame Nkrumah's long-awaited political kingdom." Fenoaltea (1999, p.142) uses this new emphasis on African agency to defend the "extreme" interpretation of his model of the slave trade: "The prime movers of the Atlantic trade are thus seen to be the African elites themselves, as their wealth created the demand for imported luxuries and their power the supply of exported slaves. *Not long ago, such a view would have been anathematized as an attempt to shift the white man's burden of guilt; but now it seems reasonable enough, as it recognizes that Africa controlled her own destiny* (emphasis added)."

[58] Lovejoy (2000) rejects the simple formulation of the gun-slave cycle as a conspiracy and adopts the more-complex formulation advanced in this study: "The simple formulation of this theory holds that guns were sold to Africans in order to *encourage* enslavement. While some Europeans may have understood the connection between guns sales and slaves, it would be wrong to attribute the slave trade to such *manipulations*. The correlation between the quantity of imported guns and the volume of the slave trade more accurately reflect the economic and political *choices* of African rulers and merchants who acted in their own best interests (p. 110, emphasis added)."

do not prove the case, as many historians have pointed out. Intertemporal production links, by contrast, are mediated by social processes that take time to unfold. This study has shown that it took time for increases in British gunpowder imports to work their way through African social relations and increase slave exports. And it took time for British traders to read the situation on the coast of Africa and respond with additional gunpowder shipments. In the final analysis, the British time-series reveal how the interactions between these two processes locked the slave trade into a self-perpetuating gun-slave cycle, a cycle that generated explosive growth in both slave exports and conflict among Africans.

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Figure 1. Gunpowder Technology in the 18th Century British Slave Trade

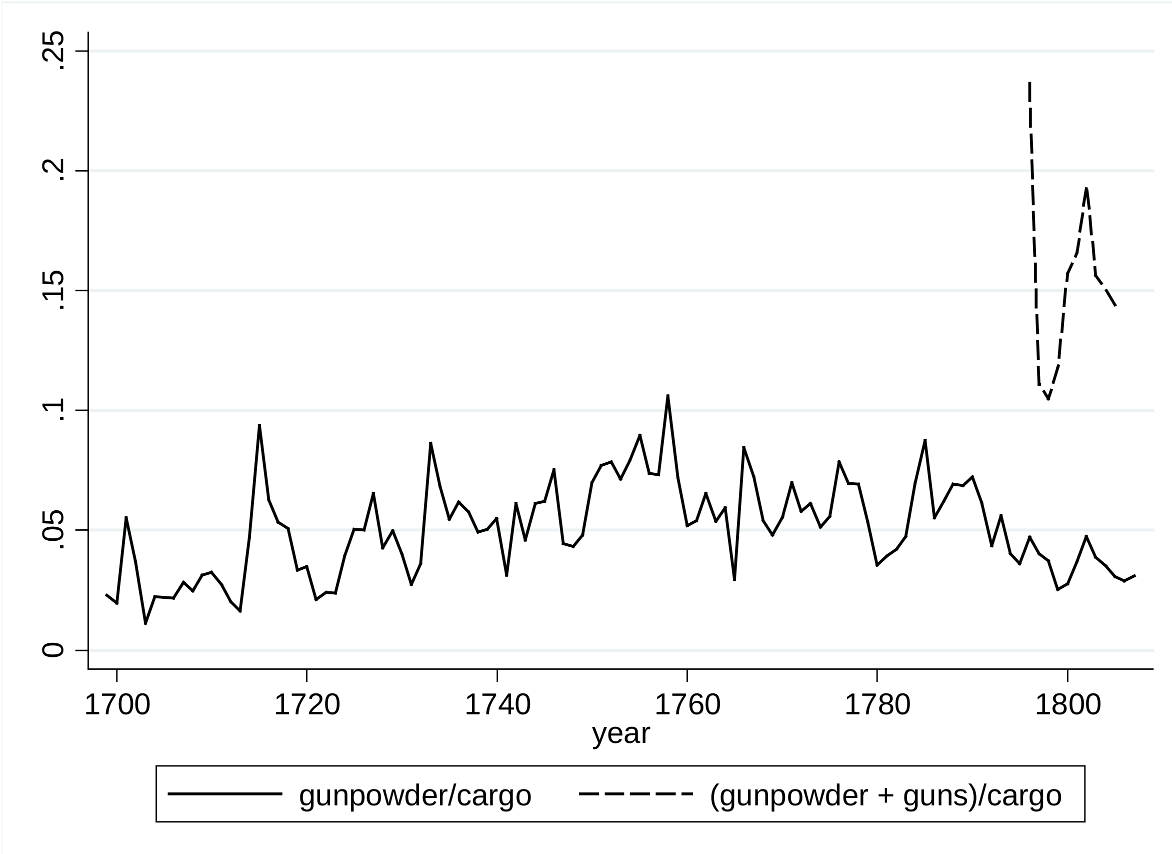


Figure 2. Transatlantic Slave Trade by National Carrier

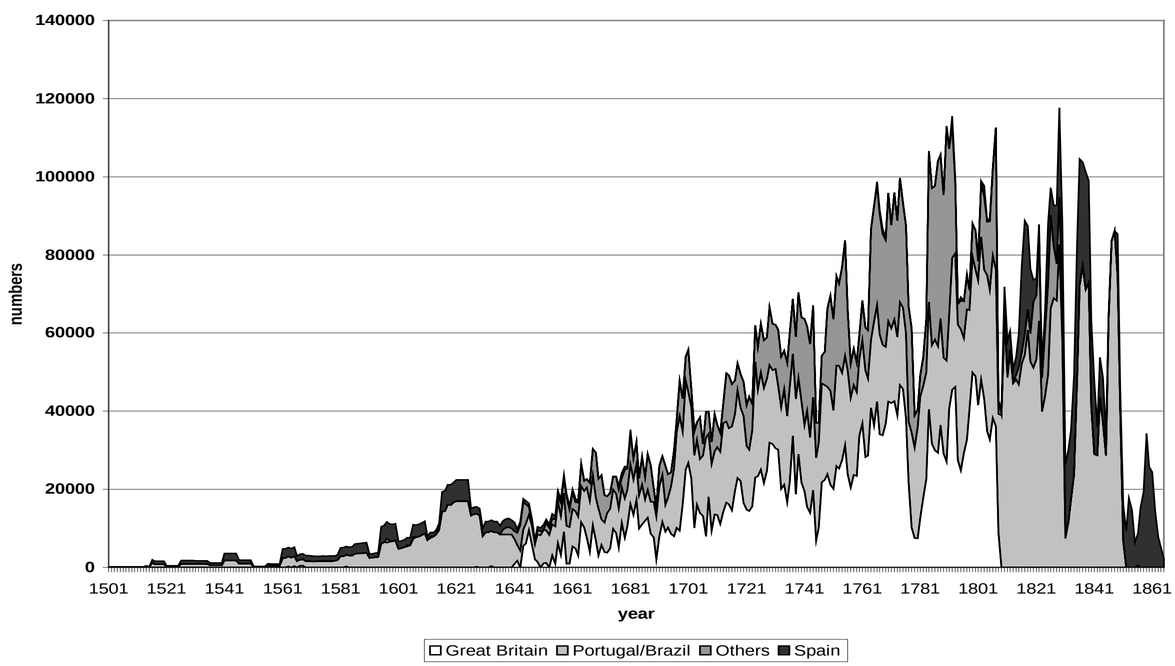
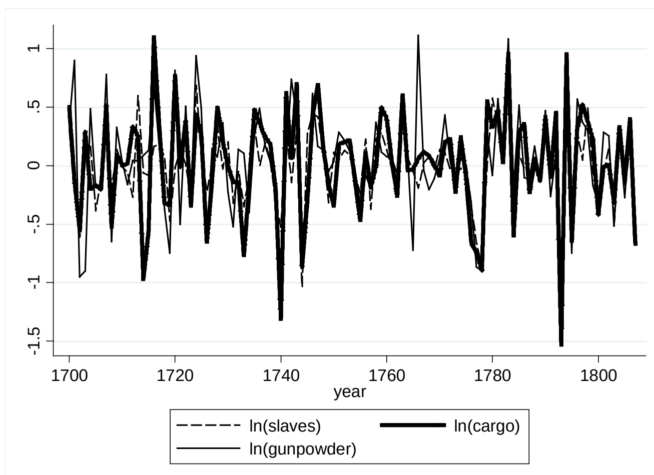


Figure 3. Time series properties

(a) Natural logs

(b) Annual changes in natural logs



(c) Natural log of slave price

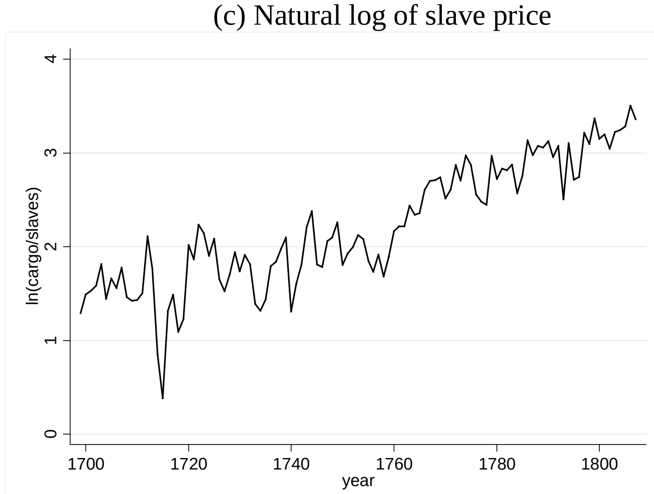
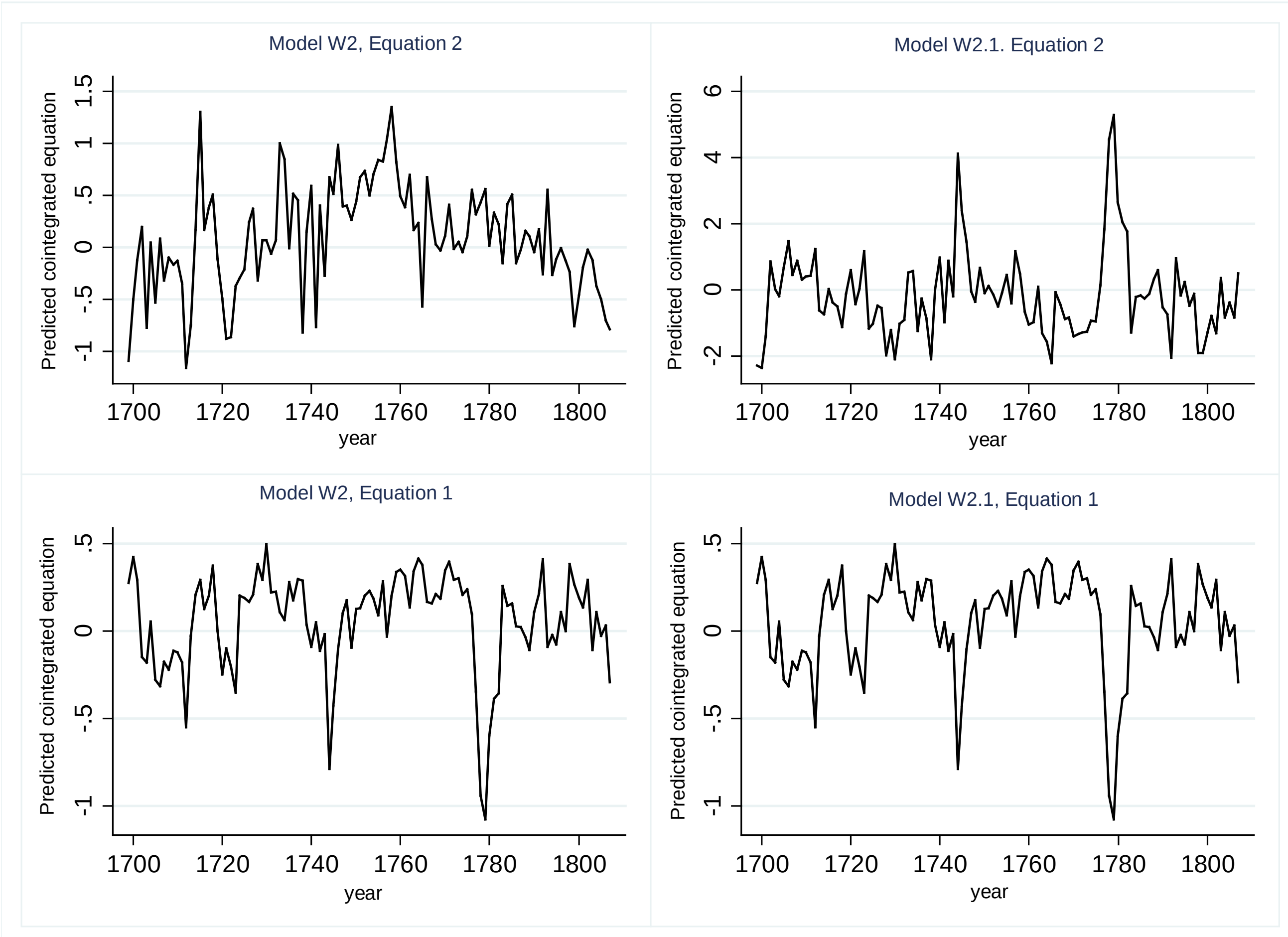


Figure 4. Co-integration equations



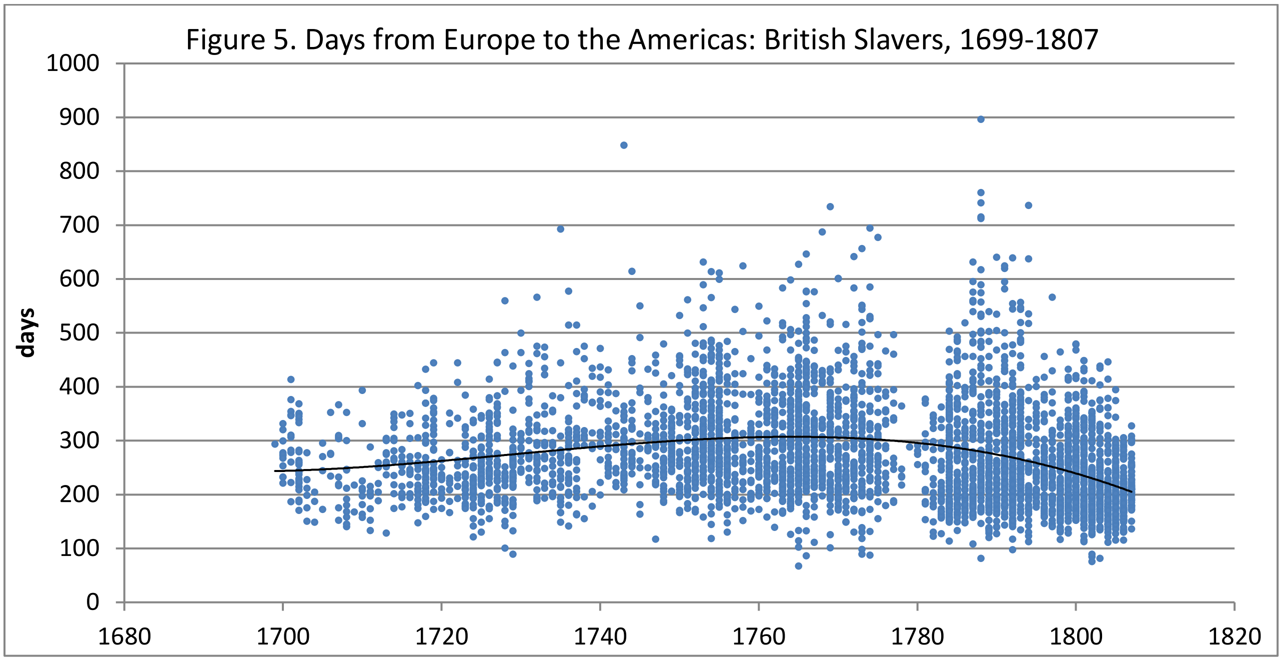
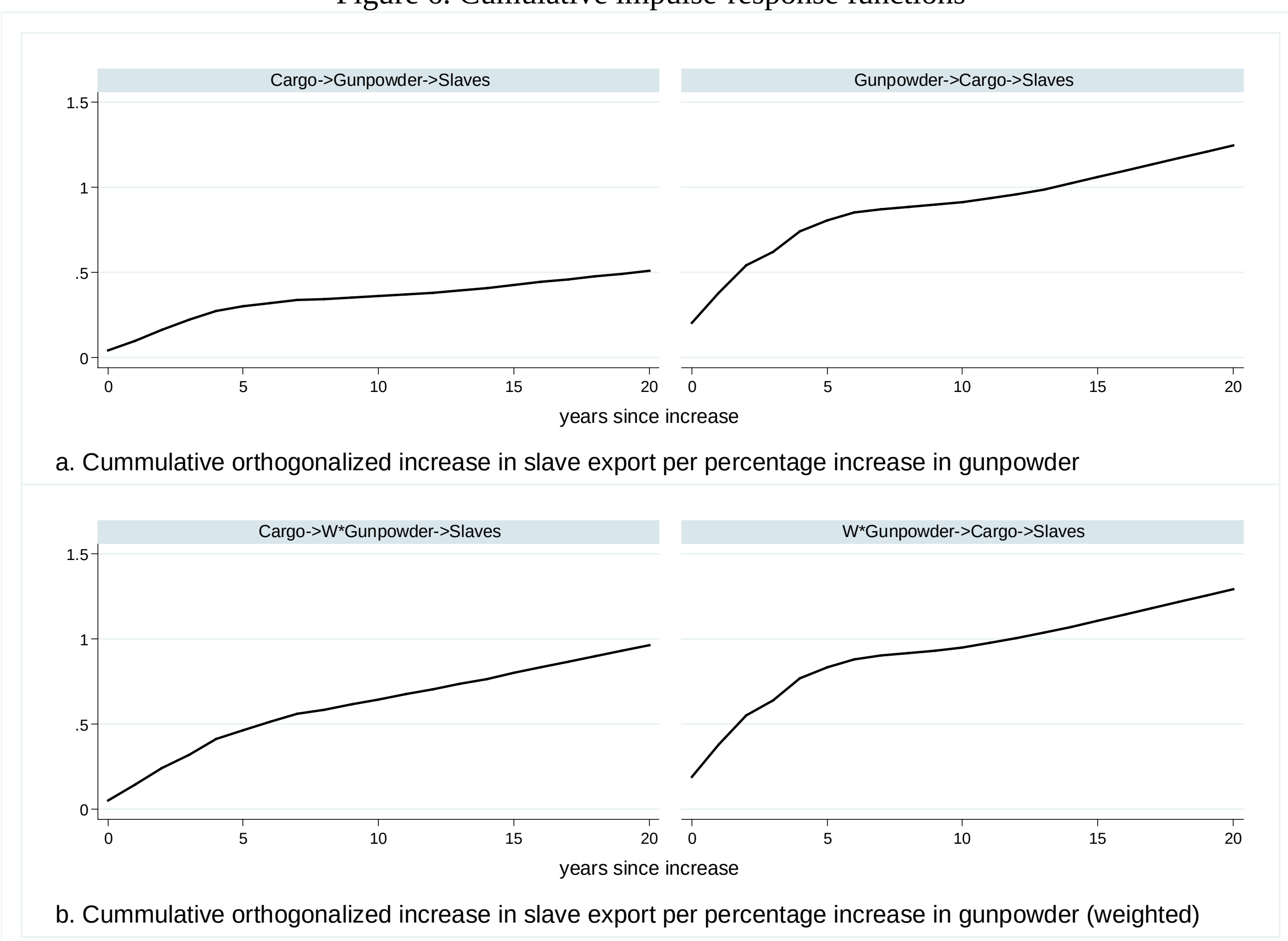


Figure 5. Days from Europe to the Americas: British Slavers, 1699-1807

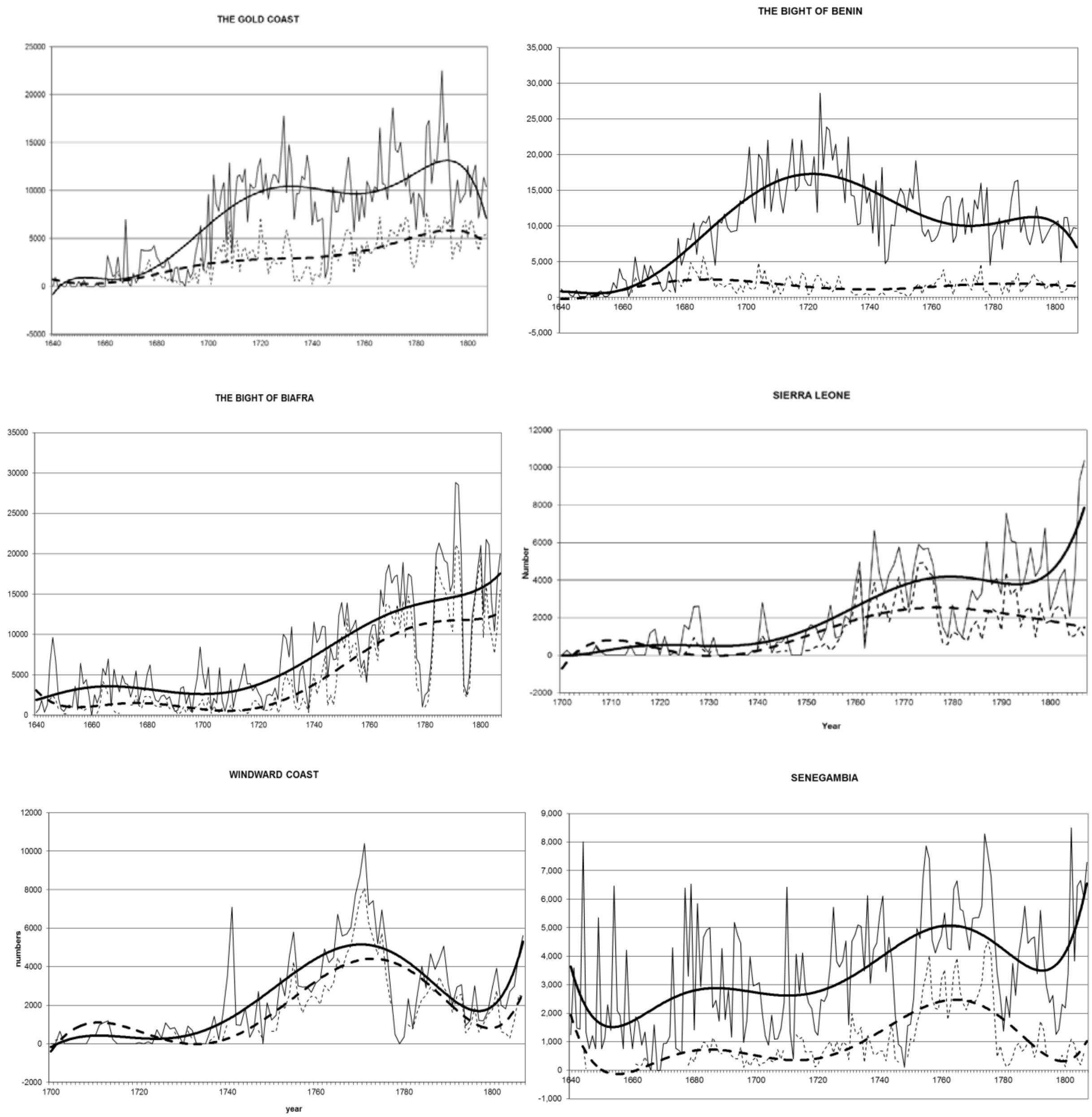
Figure 6. Cumulative impulse-response functions



a. Cummulative orthogonalized increase in slave export per percentage increase in gunpowder

b. Cummulative orthogonalized increase in slave export per percentage increase in gunpowder (weighted)

Fig. 7. Annual volume of the transatlantic slave exports by region, 1640-1807 (with 6-degree polynomial trend line)



_____ Total slave exports

-------- British slave exports

Table 1. Lag order selection statistics

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-200.91				0.0105	3.96	3.99	4.04
1	-38.07	325.68	9	0.00	0.0005*	0.97*	1.10*	1.28*
2	-32.30	11.55	9	0.24	0.0006	1.03	1.25	1.57
3	-26.34	11.92	9	0.22	0.0006	1.09	1.40	1.86
4	-19.29	14.10	9	0.12	0.0006	1.13	1.54	2.13
5	-9.86	18.871*	9	0.03	0.0006	1.12	1.62	2.35
6	-7.96	3.79	9	0.93	0.0007	1.26	1.85	2.72

Notes: 103 observations. Tests are run using the STATA *varsoc* command. *Varsoc* reports the final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC) lag-order selection statistics for a series of vector autoregressions of order, in this case, 1,..,maxlag(6). A sequence of likelihood-ratio (LR) test statistics for all the full VARs of order less than or equal to the highest lag order is also reported. The preestimation version of *varsoc* can also be used to select the lag order for a vector error-correction model (VECM). As shown by Nielsen (2001), the lag-order selection statistics discussed here can be used in the presence of I(1) variables. * denotes $p<0.05$.

Table 2. Johansen tests for cointegration

maximum rank	parms	LL	eigenvalue	trace statistic	5% critical value
No trend ($\gamma = \tau = \nu = \rho = 0$)					
0	0	-75.79	.	24.40	24.31
1	5	-66.80	0.15	6.4282*	12.53
2	8	-63.59	0.06	0.01	3.84
3	9	-63.59	0.00		
Unrestricted constant ($\tau = \rho = 0$)					
0	3	-75.47	.	48.73	29.68
1	8	-61.43	0.23	20.65	15.41
2	11	-53.45	0.14	4.70	3.76
3	12	-51.11	0.04		
Restricted constant ($\gamma = \tau = \rho = 0$)					
0	0	-75.79	.	49.36	34.91
1	6	-61.73	0.23	21.25	19.96
2	10	-53.69	0.14	5.1785*	9.42
3	12	-51.11	0.05		
Unrestricted trend (γ, τ, ν and ρ are estimated)					
0	6	-75.31	.	82.03	34.55
1	11	-54.45	0.32	40.30	18.17
2	14	-41.82	0.21	15.05	3.74
3	15	-34.30	0.13		
Restricted trend ($\tau = 0$)					
0	3	-75.47	.	82.34	42.44
1	9	-54.56	0.32	40.52	25.32
2	13	-41.89	0.21	15.18	12.25
3	15	-34.30	0.13		

Notes: 108 observations. * denotes p<.05. The Johansen rank test is a nested test. If the trace statistic for rank=0 is less than the 5% critical value, then the test fails to reject rank=0 for the matrix. If this is the case, then the variables are I(1), not co-integrated and OLS in differences can be applied. If the trace statistic for rank=0 is greater than the 5% critical value, then the Johansen test proceeds to test for rank=1. If the test fails to reject rank=1 then the matrix of coefficients has rank=1 and the variables are I(1) and co-integrated. If the test rejects rank=1 then the Johansen test proceeds to test for rank=2. If the Johansen test rejects all possible ranks, then the variables are I(0) and OLS in levels can be apply.

Table 3. Lagrange multiplier tests for autocorrelation

	Model 1: r(1), t(n)		Model 2: r(2), t(rc)	
	variable lag order (1); 108 obs.			
error lag order	chi2	Prob>chi2	chi2	Prob>chi2
1	20.35	0.016	12.56	0.183
2	12.29	0.198	10.97	0.277
3	19.57	0.021	14.37	0.110
4	13.58	0.138	16.53	0.057
5	9.57	0.386	7.43	0.593
	variable lag order (2); 107 obs.			
1	20.86	0.013	19.06	0.025
2	16.49	0.057	15.84	0.070
3	11.13	0.267	7.25	0.611
4	12.47	0.188	13.66	0.135
5	9.13	0.425	6.98	0.639
	variable lag order (3); 106 obs.			
1	20.20	0.017	12.46	0.189
2	11.95	0.216	11.50	0.243
3	19.58	0.021	13.73	0.132
4	13.69	0.134	16.75	0.053
5	9.36	0.405	7.49	0.586
	variable lag order (4); 105 obs.			
1	21.39	0.011	22.91	0.006
2	8.48	0.486	8.44	0.490
3	15.59	0.076	15.20	0.086
4	15.11	0.088	16.61	0.055
5	8.74	0.462	5.14	0.822
	variable lag order (5); 104 obs.			
1	2.93	0.967	3.746	0.927
2	6.01	0.739	8.861	0.450
3	7.70	0.565	5.665	0.773
4	7.55	0.580	4.488	0.876
5	9.68	0.377	8.366	0.498

Notes. The STATA command *veclmar* implements a Lagrange- multiplier (LM) test for autocorrelation in the residuals of the vector error-correction models (VECMs) Model1 and Model 2. The Null Hypothesis is no autocorrelation at the specified lag order. The residual autocorrelation tests are run for models with variable lag orders of 1-5 periods.

Table 4. Long-run equilibrium relationships

		(1)	(2)	(3)	(4)
	Variables	Model 1	Model 2	Model W2	Model W2.1
Equation 1					
	$\Delta lnSLAVES_{t-1}$ (β_s)	1	1	1	1
	$\Delta lnGUNPOWDER_{t-1}$ (β_g)	1.86***	(omitted)	(omitted)	(omitted)
		(0.45)	(omitted)	(omitted)	(omitted)
	$\Delta lnCARGO_{t-1}$ (β_c)	-2.21***	-0.28***	-0.30***	-0.30***
		(0.34)	(0.06)	(0.06)	(0.05)
	CONSTANT		-6.58***	-6.30***	-6.30***
			(0.69)	(0.70)	(0.56)
Equation 2					
	$\Delta lnSLAVES_{t-1}$ (β_s)		(omitted)	(omitted)	-4.39***
			(omitted)	(omitted)	(0.45)
	$\Delta lnGUNPOWDER_{t-1}$ (β_g)		1	1	1
	$\Delta lnCARGO_{t-1}$ (β_c)		-1.01***	-1.33***	(omitted)
			(0.12)	(0.14)	(omitted)
	CONSTANT		3.20**	7.65***	35.29***
			(1.48)	(1.71)	(4.49)

Notes: 104 observations. Equations are estimated using Johansen's maximum likelihood method with 5-period lags. The top panel (Equation 1) reports estimated long-run equilibrium relationships when slave exports are set equal to one. The second panel (Equation 2) reports estimated long-run equilibrium relationships when gunpowder imports are set equal to one. Model 1 and Model 2 use unweighted gunpowder imports. Model W2 and W2.1 use gunpowder imports weighted by the share of British trade in its 18 major trading ports. *** p<0.01, ** p<0.05, * p<0.1.

Table 5. Speed of adjustments parameters

		(1)	(2)	(3)	(4)
		Model 1	Model 2	Model W2	Model W2.1
Equation 1	Adjustments when $\Delta \ln SLAVES_{t-1}$ is above long-run equilibrium				
	$\Delta \ln SLAVES_t$ (α_s)	-0.04	-0.56***	-0.53***	0.14
		(0.04)	(0.14)	(0.14)	(0.34)
	$\Delta \ln GUNPOWDER_t$ (α_g)	-0.09	-0.46**	-0.54**	-0.07
		(0.06)	(0.20)	(0.24)	(0.59)
	$\Delta \ln CARGO_t$ (α_c)	0.03	-0.47**	-0.44**	0.98*
		(0.07)	(0.22)	(0.21)	(0.52)
Equation 2	Adjustments when $\Delta \ln GUNPOWDER_{t-1}$ is above long-run equilibrium				
	$\Delta \ln SLAVES_t$ (α_s)		0.12	0.15*	0.15*
			(0.09)	(0.08)	(0.08)
	$\Delta \ln GUNPOWDER_t$ (α_g)		-0.04	0.11	0.11
			(0.13)	(0.14)	(0.14)
	$\Delta \ln CARGO_t$ (α_c)		0.23	0.32***	0.32***
			(0.14)	(0.12)	(0.12)

Notes: 104 observations. The top panel (Equation 1) reports estimated speed-of-adjustment parameters when slave exports are above long-run equilibrium. The second panel (Equation 2) reports speed-of-adjustment parameters when gunpowder imports are above long-run equilibrium. Model 1 and Model 2 use unweighted gunpowder imports. Model W2 and W2.1 use gunpowder imports weighted by the share of British trade in its 18 major trading ports. Equations are estimated using Johansen's maximum likelihood method. *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 6. Past-dependence

	Model 2 and 2.1			Model W2 and W2.1		
	$\Delta lnSLAVES_t$	$\Delta lnGUNPOWDER_t$	$\Delta lnCARGO_t$	$\Delta lnSLAVES_t$	$\Delta lnGUNPOWDER_t$	$\Delta lnCARGO_t$
$\Delta lnSLAVES_{t-1}$	0.25	0.86***	0.52*	0.17	0.88***	0.46
	(0.19)	(0.27)	(0.29)	(0.19)	(0.32)	(0.28)
$\Delta lnSLAVES_{t-2}$	0.11	0.56**	0.48*	0.06	0.73**	0.45
	(0.19)	(0.27)	(0.29)	(0.18)	(0.32)	(0.28)
$\Delta lnSLAVES_{t-3}$	0.18	0.64**	0.47*	0.12	0.42	0.50*
	(0.18)	(0.26)	(0.27)	(0.17)	(0.30)	(0.27)
$\Delta lnSLAVES_{t-4}$	-0.05	0.02	0.05	-0.06	-0.05	0.04
	(0.17)	(0.25)	(0.26)	(0.16)	(0.28)	(0.25)
$\Delta lnGUNPOWDER_{t-1}$	-0.02	-0.38**	-0.20	0.02	-0.68***	-0.25
	(0.13)	(0.18)	(0.19)	(0.11)	(0.19)	(0.17)
$\Delta lnGUNPOWDER_{t-2}$	0.03	-0.20	-0.07	0.06	-0.33	-0.14
	(0.12)	(0.18)	(0.19)	(0.12)	(0.20)	(0.18)
$\Delta lnGUNPOWDER_{t-3}$	0.02	-0.13	-0.09	0.00	-0.15	-0.18
	(0.11)	(0.16)	(0.17)	(0.11)	(0.18)	(0.16)
$\Delta lnGUNPOWDER_{t-4}$	0.04	-0.14	-0.12	0.07	-0.07	-0.16
	(0.10)	(0.14)	(0.15)	(0.08)	(0.14)	(0.12)
$\Delta lnCARGO_{t-1}$	-0.06	-0.27	-0.24	-0.02	0.14	-0.08
	(0.13)	(0.19)	(0.20)	(0.13)	(0.23)	(0.20)
$\Delta lnCARGO_{t-2}$	0.02	-0.15	-0.25	0.02	-0.11	-0.14
	(0.13)	(0.19)	(0.20)	(0.13)	(0.22)	(0.20)
$\Delta lnCARGO_{t-3}$	-0.20	-0.38**	-0.40**	-0.15	-0.30	-0.31*
	(0.12)	(0.18)	(0.19)	(0.12)	(0.21)	(0.19)
$\Delta lnCARGO_{t-4}$	0.16	0.26	0.11	0.16	0.17	0.17
	(0.12)	(0.18)	(0.19)	(0.12)	(0.20)	(0.18)

Notes: *** $p<0.01$, ** $p<0.05$, * $p<0.1$. 104 observations. Equations are estimated using Johansen's maximum likelihood method. The maximum lag order is 5 periods. Model 1 and Model 2 use unweighted gunpowder imports. Model W2 and W2.1 use gunpowder imports weighted by the share of British trade in its 18 major trading ports.

Table 7. Sensitivity tests of alternative measure of CARGO

	Models 2 and 2.1	**Model W2 and W2.1**
	Est. of α_s	Est. of α_s
ln(cargo)	0.117	0.151*
	(0.092)	(0.078)
ln(cargo1)	0.117	0.146*
	(0.089)	(0.077)
ln(cargo_nog)	0.119	0.150**
	(0.088)	(0.075)
ln(cargo1_nog)	0.120	0.144**
	(0.085)	(0.073)
ln(exports)	0.098	0.134*
	(0.090)	(0.075)
ln(exports1)	0.108	0.133*
	(0.084)	(0.072)
ln(exports_nog)	0.101	0.132*
	(0.086)	(0.070)
ln(exports1_nog)	0.111	0.131*
	(0.080)	(0.068)

Notes: 104 observations. Alternative measures of CARGO are substituted for CARGO and the VECM is re-estimated. The table reports the resulting speed of adjustment parameter α_s. The original measure of cargo = British exports - African imports. Alternative measures are these: cargo1 = cargo - indirect African imports; cargo_nog = cargo – gunpowder; cargo1_nog = cargo1 – gunpowder. Exports = British exports, and the other Export measures follow the same pattern as the corresponding cargo measures. Model 2 use unweighted gunpowder imports. Model W2 and W2.1 use gunpowder imports weighted by the share of British trade in its 18 major trading ports.*** p<0.01, ** p<0.05, * p<0.1.

Table 8. Placebo tests on guns-for-slaves-in-production (α_s)

	Models 2 and 2.1	**Models W2 and W2.1**
	Est. of α	Est. of α
ln(gunpowder)	0.117	0.151*
	(0.092)	(0.078)
ln(salt)	0.014	0.013
	(0.017)	(0.016)
ln(british cottons)	0.030	0.035
	(0.033)	(0.031)
ln(woolens)	-0.148*	-0.121
	(0.076)	(0.080)
ln(linen)	-0.007	0.042
	(0.040)	(0.061)
ln(Indian piece goods)	0.053	0.082
	(0.064)	(0.062)
ln(other textiles)	0.119	0.221*
	(0.122)	(0.123)
ln(iron and steel)	0.133	0.175
	(0.120)	(0.108)
ln(copper and brass)	-0.015	0.012
	(0.072)	(0.073)
ln(other metals)	0.008	0.088
	(0.105)	(0.115)
ln(alcoholic beverages)	-0.076	0.000
	(0.098)	(0.087)
ln(tobacco products)	0.064	0.090
	(0.099)	(0.081)
ln(cowries)	-0.044*	-0.044
	(0.025)	(0.027)
ln(beads)	-0.024	0.008
	(0.060)	(0.065)
ln(glass)	0.127**	0.128**
	(0.059)	(0.052)
ln(wooden products)	0.027	0.041
	(0.055)	(0.048)
ln(misc. mfr.)	0.107**	0.099**
	(0.043)	(0.038)
ln(wrought iron)	0.157*	0.179**
	(0.083)	(0.078)

Notes: 104 observations. Alternative imports are substituted for GUNPOWDER and the VECM is re-estimated. The table reports the resulting speed of adjustment parameter, α_s. See text for a discussion of the placebo products. Model 2 and 2.1 use unweighted placebo imports. Models W2 and W2.1 use placebo imports weighted by the share of British trade in its 18 major trading ports. *** p<0.01, ** p<0.05, * p<0.1.

Table 9. OLS estimates of the slave export equation

	(1)	(2)	(3)
VARIABLES	$\Delta lnSLAVES_t$	$\Delta lnSLAVES_t$	$\Delta lnSLAVES_t$
	(unweighted)	(unweighted)	(weighted)
$\Delta lnSLAVES_{t-1}$		-0.33***	-0.36***
		(0.10)	(0.10)
$\Delta lnSLAVES_{t-2}$		-0.36***	-0.42***
		(0.08)	(0.07)
$\Delta lnSLAVES_{t-3}$		-0.27**	-0.30***
		(0.11)	(0.08)
$\Delta lnSLAVES_{t-4}$		-0.18*	-0.18**
		(0.10)	(0.08)
$\Delta lnGUNPOWDER_t$	0.13**	0.21*	0.17**
	(0.07)	(0.10)	(0.08)
$\Delta lnGUNPOWDER_{t-1}$		0.18**	0.26***
		(0.08)	(0.07)
$\Delta lnGUNPOWDER_{t-2}$		0.14*	0.20***
		(0.07)	(0.06)
$\Delta lnGUNPOWDER_{t-3}$		0.11	0.12**
		(0.07)	(0.06)
$\Delta lnGUNPOWDER_{t-4}$		0.12*	0.15***
		(0.06)	(0.04)
$\Delta lnCARGO_t$	0.44***	0.40***	0.42***
	(0.08)	(0.11)	(0.09)
$\Delta lnCARGO_{t-1}$		0.12	0.05
		(0.10)	(0.07)
$\Delta lnCARGO_{t-2}$		0.18**	0.14*
		(0.08)	(0.07)
$\Delta lnCARGO_{t-3}$		0.05	0.06
		(0.10)	(0.09)
$\Delta lnCARGO_{t-4}$		0.10	0.10
		(0.10)	(0.08)
Constant	-0.01	-0.03	-0.03*
	(0.01)	(0.02)	(0.02)
F-statistic	54.54	33.25	53.27
Observations	108	104	104

Notes: *** p<0.01, ** p<0.05, * p<0.1. Newey-West standard errors are reported in the parentheses. The maximum lag order is 5 periods. Columns 1 and 2 use unweighted gunpowder imports. Column 3 uses gunpowder imports weighted by the share of British trade in its 18 major trading ports.

Table 10. Potential instrumental variable for gunpowder imports
(Dependent variable = ΔlnGUNPOWDERt)

Time period	OLS Coefficients on lagged potential IVs		
	Δln(EXCESS CAPACITY)	ΔWARS	Δln(WAR CASUALTIES)
t+3	0.02	0.02	0.00
	(0.03)	(0.11)	(0.02)
t+2,	0.05***	0.04	0.02
	(0.02)	(0.09)	(0.02)
t+1	0.07***	-0.18	-0.02
	(0.03)	(0.15)	(0.02)
t	0.08**	-0.23*	-0.02
	(0.03)	(0.12)	(0.03)
t-1	0.01	0.03	-0.03
	(0.02)	(0.11)	(0.04)
t-2	-0.01	-0.12	-0.01
	(0.02)	(0.13)	(0.03)
t-3	-0.00	-0.20	-0.02
	(0.02)	(0.14)	(0.02)
Constant	0.03	0.03	0.03
	(0.02)	(0.03)	(0.03)
F-stat	4.57***	2.05**	2.66*
Observations	94	102	102

Notes: Newey-West standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. EXCESS_CAPACITY is the previous maximum level of British central government's expenditure on ordnances minus the current level of central government spending on ordnances. WARS is a dummy variable that take the value 1 during war years, zero otherwise. WAR CASUALTIES are the annual UK war casualties found in Michael Clodfelter (2002).

Table 11. Instrumental variable estimate of guns-for-slaves

(a) Second stage: Dep. var. = $\Delta lnSLAVES_t$		
Variables	(1)	(2)
	Unweighted	Weighted
$\Delta lnGUNPOWDER_{t-1}$	0.19**	0.18**
	(0.08)	(0.07)
$\Delta lnGUNPOWDER_t$	0.17***	0.14
	(0.06)	(0.10)
$\Delta lnCARGO_t$	0.43***	0.45***
	(0.09)	(0.11)
Constant	-0.01	-0.02*
	(0.01)	(0.01)
R-squared	0.55	0.58
Hanson J-statistic for over-identification. Chi-sq(2) p-value	0.62	0.56
Stock-Yogo critical F-stat for 20% maximal relative bias	6.46	6.46
(b) First stage: Dep. var. = $\Delta lnGUNPOWDER_{t-1}$		
	(1)	(2)
	Unweighted	Weighted
$\Delta lnGUNPOWDER_t$	-0.25*	-0.29***
	(0.13)	(0.08)
$\Delta lnCARGO_t$	-0.05	-0.01
	(0.13)	(0.12)
$\Delta lnEXCESS\_CAPACITY_{t+1}$	0.07***	0.07**
	(0.02)	(0.03)
$\Delta lnEXCESS\_CAPACITY_t$	0.10***	0.10***
	(0.02)	(0.03)
$\Delta lnEXCESS\_CAPACITY_{t-1}$	0.07**	0.06
	(0.03)	(0.04)
Constant	0.04**	0.05**
	(0.02)	(0.02)
Kleibergen-Paap F-statistic	7.22	3.79
Shea Partial R-squared	0.16	0.12
Observations	98	98

Notes: Estimated by GMM. Newey-West standard errors are reported in parentheses. The number of lags is 5 years. *** p<0.01, ** p<0.05, * p<0.1.