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THE ANTEBELLUM U.S. IRON INDUSTRY: DOMESTIC PRODUCTION AND FOREIGN COMPETITION

Joseph H. Davis
Douglas A. Irwin

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ABSTRACT

This paper presents new annual estimates of U.S. production of pig iron and imports of pig iron products dating back to 1827. These estimates are used to assess the vulnerability of the antebellum iron industry to foreign competition and the role of the tariff in fostering the industry's early development. Domestic pig iron production is found to be highly sensitive to changes in import prices. Although import price fluctuations had a much greater impact on U.S. production than changes in import duties, our estimates suggest that the tariff permitted domestic output to be about thirty to forty percent larger than it would have been without protection.

Joseph H. Davis
The Vanguard Group
P.O. Box 2600, MS V36
Valley Forge, PA 19482-2600
and NBER
joseph_davis@vanguard.com

Douglas A. Irwin
Department of Economics
Dartmouth College
Hanover, NH 03755
and NBER
douglas.irwin@dartmouth.edu

The Antebellum U.S. Iron Industry: Production Estimates and Import Competition

1. Introduction

The role of import tariffs in promoting the growth of U.S. manufacturing in the antebellum period remains a highly contested question. American manufacturers of the period are usually portrayed either as fledgling newcomers that could not have survived without protection from foreign competition, or as heartier enterprises whose success did not depend upon tariffs but on tailoring their products to the particular circumstances of the domestic market. Both contemporary observers and economic historians have debated which perspective is a more accurate portrait of early American manufacturing.[1]

The vulnerability of the antebellum iron industry to foreign competition has been particularly controversial. Writing in the late 1840s, Henry Carey (1872, p. 83) argued that should the United States have "perfect freedom of trade . . . the result would be the stoppage of every [iron] furnace in the Union." By contrast, Frank Taussig (1931, p. 135) believed that "there is no reason to doubt that, had there been no duty at all, there would yet have been a large production of anthracite pig- and rolled iron." When duties on imported iron were significantly reduced in the mid-1840s, Swank (1897, p. 86) noted the "paralyzing effect" it had on the industry. Alternatively, Grosvenor (1871, p. 25) concluded that "No one who attentively considers the record of our foreign trade will fail to observe that the influence of changes of tariff, either to check or to stimulate importations, has been much less than has commonly been supposed."

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[1] For example, Harley (1992), Irwin and Temin (2001), Harley (2001), and Rosenbloom (2004) have recently provided contrasting views on the degree to which tariff protection was important for the antebellum cotton textile industry.

How dependent on tariff protection were antebellum iron manufacturers? Answering this question has been hampered by the lack of production data for much of the antebellum period. The standard annual estimates of domestic pig iron output, based on Fogel's (1965) calculations, start in 1840, with a few scattered observations from the 1820s. The short span of production data prior to the Civil War makes it difficult to determine the impact of import competition and tariff protection on domestic production. In addition, the 1840s was a particularly volatile decade in which the industry was buffeted by large changes in import prices and in import duties, both of which contributed to a severe import shock between 1847 and 1853. During this period, imports soared while domestic production was sliced nearly in half.

This paper seeks to enhance our understanding the antebellum iron industry's vulnerability to foreign competition and remarkable volatility in the 1840s in two ways. First, we revise Fogel's (1964) existing production data from the 1840s and extend the series back to 1827. We supplement the new production data with new calculations of the volume of imports and the precise level of the tariff on pig-iron related products. These data give us a general picture of the state of the antebellum iron industry and allow us to examine a consistent set of figures on domestic production, imports, import prices, and the tariff during the period 1827 to 1859.

Second, we use these data to estimate a simple reduced-form partial equilibrium equation that explains movements in U.S. pig iron production. This allows us to disentangle the effect of import competition and tariff changes on domestic iron output, as well as general economic conditions in the United States. The results indicate that domestic production was highly sensitive to changes in import prices, implying that a substantial part of the industry's output would not have existed without the tariffs on imports. However, consistent with Engerman (1971), a significant decline in British export prices, rather than the U.S. tariff reduction, was mainly responsible for the sharp fall in domestic output in the late 1840s.

2. New Estimates of U.S. Iron Production, 1827-1843

This section reviews the existing estimates of early American pig iron production and describes the data and methods used to push these existing series back to 1827. Annual production data for the antebellum period date from the founding the American Iron and Steel Association (AISA) in 1854. From its start, the AISA conducted mail surveys of the nation's forges and foundries in order to determine the quantity of pig iron produced. While these AISA tabulations are viewed as comprehensive and credible, considerable contention surrounds the reliability of earlier national output estimates that the trade group adopted.[2] Motivated by the absence or shortcomings of contemporary census returns, various organizations periodically undertook the task of estimating national iron production before the AISA's formation. Unfortunately, the misinterpretation or intentional mishandling of survey data, perhaps because many of these groups had a vested interest in influencing the ongoing tariff data, resulted in vastly different accounts of output before 1854.[3]

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[2] In 1912, the AISA changed its name to the American Iron and Steel Institute (AISI). The historical pig iron production data are reproduced in the Census Bureau's *Historical Statistics* (1975, M-217). Today, the AISI continues to provide shipments data for the Federal Reserve Board's monthly industrial production index.

[3] As Paskoff (1983, p. 77) notes, "Attempts to ascertain the size of the domestically produced national supply of pig, bar, and rolled iron have not been particularly successful and are clouded with uncertainty. In part, this failure has been due to defects - deliberate and inadvertent - in the reports the iron produces made at various times, but especially in 1832 and 1849."

The first two columns of Table 1 illustrate the extent of the statistical discord. Column 1 is obtained from the AISA's *Annual Report* (AISI 1918, 9–10), U.S. Bureau of the Census (1975, series M-217), and *Historical Statistics* (2006, series Db74). Beginning in 1854 the AISA series represents actual production compiled from its industry-wide surveys and is commonly regarded as *de facto* benchmarks. The earlier figures were adopted from census returns and secondary sources. Figures from 1828 through 1830 were initially gathered by the 1831 Philadelphia free trade convention. The New York Friends of Domestic Industry (1832), a protectionist trade group, accepted the convention's estimates for 1828 and 1829, but provided revised figures thereafter to demonstrate the (positive) impact of the Tariff of 1828. The 1840s was also a period of intense controversy. The AISA adopted Carey's (1872, 11) subjective pro-tariff extrapolations for 1842 and from 1847–49, but dismissed his 1840 figure.

Column 2 reflect estimates that Temin (1964, 264–65, table C.1) deemed "reliable" based upon his discussion in appendix A (see especially pp. 233–45). Temin notes that the figures adopted by the AISA for 1828–30 are inaccurate in that they include the pig iron equivalent of wrought iron production; Pearse (1876, 278) reports the appropriate figures.[4] However, Temin rejects Pearse's estimates for 1831 and 1832: Pearse's 1831 figure is an erroneous compilation of Carey's 1830 estimate, while the 1832 figure is simply an extrapolation. He also disregards Carey's estimated range (215,000 – 230,000 gross tons) for 1842 since Carey extrapolated downward U.S. output from defective Sixth Census returns to conform to his belief that the iron industry was severely depressed. Similarly, Temin contends that an appropriate interpretation of

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[4] The correct 1830 estimate (180,000 gross tons) was amended in the Friends of Domestic Industry pamphlet and is superior to the plagued McLane Report (Paskoff 1989, xxix).

the 1846–49 AISA–Carey data lies between Carey's pro-tariff figures (upper bound) and Grosvenor's (1871) opposing pro-trade estimates (lower bound).[5]

Column 3 presents Fogel's (1964, 151-167, table 5.6) reconstructed annual estimates from 1840 through 1853, the period he considers most "wrapped in confusion." Fogel created these estimates by inflating Pennsylvania benchmarks to U.S. levels. Specifically, Fogel estimated the quantity of U.S. pig iron produced for years with missing or dubious figures by fitting a quadratic trend through known U.S.-to-Pennsylvania output ratios, i.e., the observed U.S.-to-Pennsylvania ratios reported for 1839/40 (Sixth Census), 1844 (Home League), 1849/50 (Seventh Census), and for 1854–1856 (AISA surveys, from Lesley (1859, 750)). Pennsylvania is an appropriate choice because the state was the century's largest producer of pig iron and trade groups periodically conducted surveys of the state's furnaces. Fogel's estimates are valuable in reassessing the controversial picture of national production during the 1840s and have been widely accepted. Many researchers, such as Paskoff (1983) and Calomiris and Hanes (1994), have merged the Fogel and AISA data to form a continuous U.S. pig iron series from 1840.

The revised production series presented here was also created by employing Fogel's intuitive procedure, with several important modifications.[6] First, because Fogel was only concerned with inflating post-1840 Pennsylvania data, his trend, as illustrated in Figure 1, turns out to be inaccurate in deriving earlier estimates. The Fogel curve would grossly overstate pre-1840 output since the trend implies a tenuously low Pennsylvania share in the early 1800s. (For

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[5] For a concise series comparison, see Fogel (1964, 154, table 5.1).

[6] This series was originally created as a component to a broader study of early U.S. industrial production in Davis (2004). However, Davis (2004) did not elaborate on the details of the construction of the early pig iron production series and it is presented here for the first time.

example, applying Fogel's trend to Pennsylvania benchmarks generates the counterintuitive result that American iron production in 1810, approximately 300,000 gross tons, roughly equaled that observed in 1840.) Indeed, the pre-1840 Fogel plot contradicts prevailing theories concerning the spatial and technological developments in the early iron industry.

Consequently, Fogel's inflation curve has been recalculated by incorporating pre-1840 Pennsylvania output shares.[7] The revised trend in Figure 1 displays a more consistent, muted U-

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[7] Bold figures refer to existing estimates from previous surveys or research. Quantities for 1841, 1844, 1845, 1846, 1847, 1849, and 1850 agree with Fogel (see Table 1, column 3). Pennsylvania's 1842 estimate is based on a furnace survey conducted by the state's Coal and Iron Association, which held a convention of iron masters in Harrisburg. Since the response rate to the Harrisburg circular was low (only 79 of the 210 known furnaces responded), estimates issued separately by two of the association's members vary, based on the productivity assumptions made for the excluded establishments. Both estimates assume that average productivity at unreturned furnaces was below average, contending that such establishments were of "inferior class" and were often operated on a part-time basis. Childs (1847, 587) placed 1842 output at 194,580 gross tons. Reeves (U.S. Congress, Senate 1849, 809) calculated production at 151,885 tons in a letter to William Meredith. The latter figure has been accepted based on the discussion in Temin (1964, 237–38) and Paskoff (1983, 75, table 20; note that Paskoff incorrectly assigns Childs's 1842 Harrisburg estimate to 1840) and should therefore be interpreted as a lower bound for total output. Fogel's implication for 1842 Pennsylvania output is untenable: returned firms alone produced 84,885 gross tons of pig iron that year, and Reeves's lower bound would imply Pennsylvania accounted for two-thirds of U.S. production as expressed by the Carey–Fogel estimate. Pennsylvania counts for 1828 and 1830 originate from surveys conducted by the 1831 Philadelphia convention. According to returned schedules, Pennsylvania pig iron production was 28,515 gross tons in 1828 (24,822 tons pig iron + 3,693 tons of direct castings) and 36,562 gross tons in 1830 (31,056 + 5,506), as summarized in Childs (1847, 584–85) and Paskoff (1983, 75, table 20; note Paskoff's 1830 figure erroneously omits castings). Philadelphia convention members arrived at national estimates (see Table 1, column 2) for these years by assigning mean output at the unreturned furnaces the average of those returned. This approach, however, significantly understates aggregate Pennsylvania output, as there was an obvious *regional bias* in completed schedules. Specifically, 44 of the 63 furnaces responding in 1828 and 45 of the 73 in 1830 were located in Pennsylvania, while a disproportionate number of unreturned circulars pertained to more distant establishments, who presumably did not make the longer trip to Philadelphia (Smith 1847; Paskoff 1983). This hypothesis is bolstered by the fact that the 19 out-of-state returns in 1828 were predominantly located in nearby states (11 in New Jersey; 5 in Maryland; 2 in Virginia; and 1 in Delaware). The convention noted that of the 129 furnaces unreturned in 1830, many were located in states completely un-represented in the survey,

shape, yet closely resembles Fogel's curve after 1840. There are compelling reasons why the revised (quadratic) trend shown in Figure 1 should be more accurate. While Pennsylvania accounted for roughly one-half of domestic output around 1810, American iron production was nevertheless decentralized insofar as most states had charcoal iron forges to meet local blacksmithing demand.[8] Scholars on the pre-Civil War iron industry, most notably Bruce

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including all of New England, Tennessee, New York and Ohio. These states possessed a significant number of charcoal furnaces. While the over-representation of Pennsylvania firms in the Philadelphia survey does not affect the national totals, it surely biases downward the share of output attributable to Pennsylvania (PA output was not inflated by the committee). Failing to account for this survey bias would lead to a spuriously low PA-to-US trend (see Figure 1) and would thus overstate U.S. iron output during the 1830s. An attempt to correct for this regional response bias is made by accessing additional data on furnace counts at the state level as a mechanism to properly inflate Pennsylvania output in 1828 and 1830. The number of operational furnaces was compiled from information in Lesley (1859), Smith (1851), "Documents" (1851), Swank (1878, 1892), Bining ([1938] 1973), and Paskoff (1983). Pennsylvania output was then imputed from the underlying weighted average of Pennsylvania and out-of-state returns, adjusted to reflect the number of additional unreturned Pennsylvania furnaces in the inflated totals. Pennsylvania's revised output share was checked against non-Pennsylvania furnace data from existing case studies and federal and state censuses. The procedure appropriately revises downward the survey's share of Pennsylvania furnaces in 1828 from 70 percent (*reported, unadjusted, non-inflated*) to 36 percent (*adjusted, inflated*). The latter share is more consistent with the ratio of Pennsylvania iron furnaces reported in the broader 1810, 1832, and 1840 national canvasses. The revised state furnace shares were subsequently used to arrive at Pennsylvania estimates in column 4 based on the 1828 and 1830 U.S. estimates discussed in column 2. Note that changes in Pennsylvania output between 1828 and 1830 accord well with increases in new charcoal furnace capacity constructed in the state over this period (Smith 1851). Non-bold state figures have been interpolated on pig iron shipments descending from the Lehigh and Schuylkill iron districts, home to the major anthracite coal deposits in eastern Pennsylvania.

[8] The deficiencies in the 1810 manufacturing survey have been well documented, most cogently by Fishbein (1963). While evidence exists that iron returns outside of Pennsylvania were erroneously tabulated, the Pennsylvania iron industry also voiced considerable dissatisfaction with the deficiencies in the reported state totals. By incorporating Pennsylvania's returned 1810 share (*49.9%*, see Coxe 1814) in the calculations, the census bias is assumed to be distributed symmetrically between Pennsylvania and all other iron–producing states. That said, the final results are resilient to changes in the 1810 observation because trend values before 1827 are discarded.

([1931] 1967), Warren (1973), Paskoff (1983), and Knowles and Healey (2006), have noted that iron production was spatially diversified in the 1820s and early 1830s on account of accentuated frontier development. The combination of high transportation costs and a reliance on blast-furnace technology, meanwhile, hampered Pennsylvania furnaces from reliably serving distant markets. Coupled with the frontier discoveries of iron-ore deposits and the widespread use of charcoal technologies, Temin (1964, 240–41) argues that Pennsylvania's iron industry lost market share throughout the 1820s to more rapidly growing states.[9]

Confidence in the revised curve in Figure 1 is bolstered by several factors. First, the new ratio curve implies that Pennsylvania began to regain market share by the mid-1830s with the emergence of anthracite coal as an alternative smelting fuel. The relationship between Pennsylvania's market share and the share of pig iron produced with non-conventional fuels is documented in Table 2. Following the development of the hot blast, anthracite rapidly replaced charcoal as the primary mineral fuel in eastern Pennsylvania blast furnaces. Since anthracite deposits were highly concentrated in eastern Pennsylvania, Temin (1964, 241) argues "the rising proportion of mineral fuel production can account for the change in the proportion of production made in Pennsylvania." Concomitant transportation improvements (canals, railroads) only further facilitated non-local consumption of Pennsylvania iron.

To arrive at pre-1840 totals, the revised Pennsylvania-to-national trend from Figure 1was multiplied to an extended annual series on Pennsylvania pig iron production (Table 1, column 4).

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[9] Auxiliary data in Lesley (1859), Grosvenor (1871, 192), and Paskoff (1983) support this claim. Records of charcoal-furnace construction indicate that new Pennsylvania iron capacity lagged additions elsewhere until the mid-1830s.

Pennsylvania output is based partially on existing state estimates.[10] Missing observations, however, have been interpolated using pig iron shipments from the Lehigh and Schuylkill iron districts.[11] While this approach undoubtedly introduces a degree of measurement error, Figure 2 shows that trends between the two series are highly correlated and display similar turning points. This should not be surprising, given that the regions' shipments accounted for the bulk of pig iron arriving in Philadelphia. The Schuylkill and Lehigh Canals opened in the early 1820s and forwarded pig iron from eastern Pennsylvania furnaces toward a legion of Philadelphia forgeries and wrought ironworks.

The Pennsylvania series, coupled with the revised ratio curve, provide the basis for the national estimates. The extended series is listed in column 6 of Table 1. Several features of the U.S. iron estimates should be noted. Most importantly, the series validates the despondent views held by furnace owners following the recessions in 1837 and 1839. While production slipped after the Panic of 1837, output fell 31 percent from 1839 to 1841 before rebounding sharply. The extended pig iron series also revises Fogel's earliest estimates from 1840 through 1843.

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[10] Fogel accepts Pennsylvania estimates for 1841 from the *Philadelphia Commercial List* and for 1844 from the Home League survey. Calendar-year figures for 1849 and 1850 were derived from Seventh Census returns and shared according to data collected by the Philadelphia convention of iron masters (Smith 1851, 576–77). Fogel provides new estimates of Pennsylvania output for the years 1845–47 based upon the Philadelphia convention data and his assumption of 50-percent utilization of new furnace construction (see p. 162, table 5.4 for the derivations). Fogel adopts the Home League's 1840 estimate to replace the understated census figure. Fogel ostensibly accepts the upper bound of Carey's 1842 figure to reflect depressed conditions in the iron industry, thereby effectively endorsing Carey's subjective method. Fogel linearly interpolated the remaining missing values (1843, 1848) on adjacent U.S. estimates.

[11] The shipments represent the sum of descending pig iron tonnage from the Lehigh and Schuylkill iron districts bound toward Philadelphia. Shipments data are transcribed from *Hunt's Merchants' Magazine* (various issues), *Annual Reports of the Board of Managers of the Lehigh Coal and Navigation Company* (1831-35), and Jones (1908).

Observations from 1844 through 1853 reflect the Fogel series since differences between column 3 and column 5 are negligible. However, the revised estimates from 1845–48 validate Fogel's (1964, 163) concern that his figures for those years "may be low." Differences in 1840 and 1843 reflect additional information from the Pennsylvania series in column 4 and slight discrepancies in the revised trend equation. The difference in 1841 is trivial and solely reflects revised trend values in Figure 1.

The most significant change from Fogel's series involves the quantity produced in 1842. The difference in 1842 results from discarding the Carey's pro-tariff (and subjective) estimate and instead inflating Reeves's 1842 Harrisburg tabulations in column (4) to national levels. The only logical explanation for why Fogel accepts the 1841 Pennsylvania figure but excludes the 1842 observation is that Fogel, like Carey, wished to illustrate the industry's depression in his post-1840 series. In straining to defend Carey's figure, Fogel argues that the 1842 protectionist Harrisburg convention is in itself evidence that production was depressed. This is a valid point, but depressed since when? Iron masters certainly must have been concerned that 1841 production had fallen more than one-third below the levels attained before the late 1830s. More compelling quantitative evidence points to a rebound in the iron industry by 1842 in lockstep with other broad sectors of the U.S. economy. More anecdotally, contemporary observers talked of forges increasing supply in anticipation of improved market conditions following the enactment of the tariff on imported iron (Grosvenor 1871; Paskoff 1989, xvii).

Yet perhaps the most convincing reason why the Fogel–Carey estimate is untenable is that it implies Pennsylvania accounted for nearly two-thirds of U.S output in 1842 but only *one-*

third the previous year.[12] This change is implausible.

3. Foreign Competition and the Antebellum U.S. Iron Industry

The development of the pre-Civil War iron industry and the role of foreign competition can best be understood by examining data on domestic production, imports, and tariff rates. While data on imports are readily available, compiling them is not a straightforward matter. The volume (by weight) of imports of iron products – encompassing pig iron and bar iron, either hammered or rolled – is available in the Secretary of the Treasury's annual *Report on Commerce and Navigation*. A broad definition of imports is required because a simple comparison of domestic- and foreign-produced pig iron would give a misleading view of foreign competition in the domestic market. Imported bar iron, either hammered or rolled, is a close substitute for domestically-produced pig iron; for example, if the United States imposed higher duties on imported pig iron, consumers could respond by purchasing more foreign-produced bar iron instead. All domestically-produced bar iron, however, originated either from domestic or imported pig iron.

Therefore, domestic pig iron production should be compared with effective imports of pig iron, consisting of both pig and bar iron. To do so, the import data have been adjusted in two ways. First, various sources suggest that 1.25 tons of pig iron were required to make one ton of bar iron (Engerman 1971, p. 15) . Therefore, the weight of bar iron imports is multiplied by 1.25

[12] Fogel also struggled to explain his increase in production for 1843. The revised series displays a slight drop in output that year.

and added to imports of pig iron to arrive at total effective imports of pig iron (what Engerman calls pig iron equivalents). Second, the import data are reported on a fiscal year basis (October to September), whereas domestic production is reported for the calendar year. Therefore, the import data are adjusted to match the production data more closely. Thus, imports in the calendar year 1830 are calculated as 0.75 times imports in fiscal year 1829-30 plus 0.25 times imports in fiscal year 1830-31.

Figure 3 presents domestic production and imports of pig iron from 1827 to 1859 and shows that fluctuations in production and imports after 1840 were particularly pronounced. Significant changes in tariff policy were also an important feature of this period. In 1842, import duties were raised significantly, and production of pig iron more than doubled between 1841 and 1847. Imports did not increase during this period, but rose rapidly after the 1846 Walker tariff reduced duties on imported iron. From this point, domestic production collapsed, falling 46 percent from 1847 to 1851, such that the volume of imports actually exceeded domestic production in 1851 and 1852. Production then rebounded with imports continuing to increase until 1853, after which they trailed off.

Because these fluctuations in production and imports are often associated with changes in the tariff, the average tariff on imported iron must be calculated. Table 3 (a) presents the statutory tariffs for the three classification of goods: pig iron and bar iron, hammered and rolled. Table 3 (b) presents the ad valorem equivalent tariff of the specific duties that were in effect from 1827 to 1845. The ad valorem equivalents of the specific duties are calculated by dividing the duty by the item’s average price, which is approximated by the unit value, i.e., by dividing the value of imports by their weight.[13] The table presents the average ad valorem tariff on effective pig iron imports, which is an import value-weighted average of the tariffs on the three import categories, as well as the volume of imports. By this measure, which is displayed in Figure 4, the average tariff moved between 30 percent and 60 percent in the 1830s, until lower import prices and the Tariff Act of 1842 briefly pushed it up to nearly 70 percent. After 1844, higher import prices eroded the ad valorem equivalent of the specific duties to such an extent that the Walker tariff of 1846 (effective in December of that year) reduced the effective tariff on pig iron from just 43 percent in 1846 to 30 percent in 1847.

However, tariffs appear to be much less important than import prices in influencing the cyclical pattern of U.S. output. As shown in Figure 5, the slight rise in the price of imported iron goods through the 1830s coincides with the expansion of U.S. production. In the early 1840s, however, import prices fell sharply and domestic producers suffered from the nationwide economic downturn as well.[14] The tariff of 1842 cushioned the fall in import prices, as Figure 5 illustrates, but did not prevent it. Sharply higher import prices after 1844 pushed domestic

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[13] One complication is that duties collected on imports of rolled iron for railroads – a component of rolled iron – were rebated between 1831 and 1843. The value of these rebates is presented in U.S. Treasury (1857, pp. 8-9) and is deducted from the total tariff revenue collected on rolled iron imports to arrive at the effective tariff. The domestic iron industry did not have, and did not seem interested in developing, the capacity to meet the growing demand for rails. Railroads lobbied strenuously to exempt rail imports from the tariff. The tariff of 1830 granted them a rebate on the duties paid and the tariff of 1832 made railroad iron duty free. This exemption was revoked with the tariff of 1842. See Fishlow (1965), pp. 133-134.

[14] Wallis (2001) notes that the Crisis of 1839 was a greater shock than the more famous Panic of 1837 because it ushered in a four year period of deflation and depression. As Temin (1964, p. 21) writes, output was initially flat and then declined output during the years 1837 to 1841 due to "the general depression in American business conditions that followed the boom years of the previous decade."

production to record high levels, but the collapse of those prices after 1847 completely erased the increase in output during the early 1840s and led to the subsequent dramatic surge in imports.

The tariff reduction in December 1846 had little immediate impact on producers because domestic prices rose through 1847 as demand continued to expand. The AISA reported that “the last half of 1847 and the first part of 1848” was the period of “greatest production” (Fogel 1964, p. 160). The collapse in prices was only slightly exacerbated by the Walker tariff reduction itself, although the shift to an ad valorem tariff, instead of a specific duty, as we shall see, deprived the industry of a great deal of protection. Domestic production did not recover until 1852 when import prices started rising again.

The factors affecting the U.S. iron industry after 1840 are intimately related to developments in Britain, the source of the overwhelming majority of U.S. imports of iron goods. Import prices were the key mechanism by which changes in the British iron market were transmitted to the United States and affected American production, a point is stressed by Engerman (1971). For example, the British railway investment boom in mid-1840s led to a significant increase in iron prices in both countries (Kenwood 1965). A commercial crisis at the end of 1847 in Britain ended the speculative boom and led to a four year decline in prices (Boot 1984, Gayer, Rostow, and Schwartz 1953). U.S. production surged during the British boom, but collapsed with the steep drop in British export prices. Specie flowed from the United States to Britain and U.S. interest rates soared: the rate on short-term commercial paper climbed from 4.7 percent in 1845 to 15.1 percent in 1848 (*Historical Statistics* 2006, Cj1223).

U.S. producers blamed British “dumping” of iron in the U.S. market and the Walker tariff reduction for the distress after 1847. A group of iron producers assembled in Pittsburgh in

August 1849 declared that “the present depressed state of the iron trade has its origin and is entirely caused by the low rate of duty at which English iron is admitted to this country” (Eiselen 1932, 221). But the “dumping” was due to the adverse demand shock in Britain rather than a targeted effort to harm American producers through price discrimination: the price of pig iron in Britain fell 39 percent between 1847 and 1851, while the U.S. import price of pig iron fell 37 percent over the same period (Mitchell 1988, p. 763; Figure 3).[15]

Although the U.S. economy recovered quickly from the British financial disturbance in 1847-48, the iron industry took much longer to rebound. Surveys published in contemporary periodicals revealed that capacity utilization in the Pennsylvania iron industry fell from 71 percent in 1847 to 46 percent in 1849, and then to 36 percent in 1850.[16] In addition, as of May 1850, 48 percent of the furnaces in the state were out of blast, a figure that rose to 56 percent by November of that year. Relief finally came in 1853 when the Crimean War diverted British iron production to domestic uses, thereby driving up British export prices and reducing exports to the United States.

These import price shocks force many adjustments upon the American iron industry, part of which was accomplished by the entry and exit of firms. As Table 4 shows, the pattern of firm entry and failure is closely related to the cyclical developments just discussed. From 1844 to

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[15] The domestic price of pig iron fell 29 percent between 1847 and 1851; U.S. Bureau of the Census (1975), series M 218.

[16] See, for example, Smith (1851). This figure is production in 1847 and 1849 divided by capacity in 1850. Utilization in 1850 was “obtained simply by deducting from the known make of 1849, the product of such furnaces as were at work in the former year and not in the latter. Nothing was allowed for any diminution consequent on a further decline in prices which took place in the latter part of the year, nor for stoppages or failures,” according to Smith (1851), p. 576.

1846, high prices triggered the construction of many new iron furnaces. When import prices reversed themselves starting in 1847, many firms ceased production, either temporarily or permanently, or were sold.

Thus, the presence of a substantial import tariff did not prevent U.S. iron producers from feeling the effects of a high degree of integration with the British market. Domestic pig iron producers came under severe stress in the late 1840s largely because of intensified foreign competition and tariff changes. The key issue is untangling these various factors to determine their relative contribution to changes in domestic production.

4. Explaining Fluctuations in American Iron Production

The availability of the longer series on U.S. pig iron production presented in section 2 enables us to disentangle the various factors - domestic economic activity, import competition, and tariff protection - in promoting or retarding the growth of the domestic industry. The relative contribution of these factors can be assessed in a simple reduced-form partial equilibrium model that can be estimated using the existing data for this period.[17]

The framework used here is largely based on Grossman (1986) and treats domestic and foreign pig iron as imperfect substitutes for one another, as is frequently assumed even in contemporary models of the iron and steel industry. Suppressing the time subscripts, the domestic supply of pig iron is specified as:

(1) $$\log (x_S) = \epsilon_0 + \epsilon_1 \log (p/p_{CPI}) + \epsilon_2 \log (p_C/p_{CPI}) + \epsilon_3 \text{(time)} + \xi,$$

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[17] Fogel and Engerman (1969) also examined the determinants of output growth of the antebellum iron industry, but as Joskow and McKelvey (1971) noted, their model is not clearly identified.

which states that the quantity supplied by domestic producers (x_S) depends upon the relative price of domestic pig iron (p/p_{CPI}, where p is the price of iron and p_{CPI} is the U.S. consumer price index), the relative price of coal (p_C/p_{CPI}), and a time trend. The coefficient ϵ_1 is the elasticity of domestic supply and ϵ_3 reflects trend factors, such as productivity growth, that can affect supply. The coefficient ϵ_2 captures the impact of cost shocks, in this case the price of anthracite coal, which was the most common source of fuel used by the end of sample.[18]

The demand for domestically-produced pig iron is specified as:

(2) $\log (x_D) = \eta_0 + \eta_1 \log (p/p_{CPI}) + \eta_2 \log (p^*[1+\tau]/p_{CPI}) + \eta_3 \log (IP) + \zeta,$

which indicates that the quantity demanded depends upon the relative price of domestic pig iron (p/p_{CPI}), the tariff-inclusive relative price of imported iron ($p^*[1+\tau]/p_{CPI}$, where p* is the foreign price and τ is the ad valorem tariff), and U.S. industrial production. Industrial production (excluding of iron itself) is the relevant demand-shifting variable, rather than a broader measure such as gross domestic product, because pig iron is not a final consumer good but a raw material used mainly in the production of other industrial goods. The coefficient η_1 is the own-price elasticity of demand, η_2 is the cross-price elasticity of demand, and η_3 is the elasticity of demand with respect to industrial production.

The key relationship of interest is the responsiveness of domestic supply to changes in the price of imported iron. Domestic supply is affected indirectly by the price of imported iron through its impact on the demand for domestic iron. The closer substitutes that domestic and foreign iron are in demand, the greater the sensitivity of supply to the price of imports. The price

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[18] Regrettably, data on other inputs, such as the price of iron ore, are not readily available. As discussed below, wage rates on common labor can be used as other cost shifters, but will not affect the results.

of imported iron alone is a sufficient measure of foreign competition because it is plausibly exogenous; see Grossman (1986) for a discussion of this point. For example, exports of iron products to the United States accounted for about 7 percent of British iron production, and thus U.S. demand was a relatively small part of total British iron output (Mitchell 1988, 281, 300). By contrast, the volume of imports is clearly endogenous and depends upon domestic supply and demand factors, as well as on foreign market conditions.

Therefore, solving the domestic demand equation for the relative price of domestic pig iron and substituting it into the domestic supply equation, while noting that $x_D = x_S$ in equilibrium, we obtain the following reduced-form equation:

(3) $\log (x_S) = \gamma_0 + \gamma_1 \log (p^*[1+\tau]/p_{CPI}) + \gamma_2 \log (IP) + \gamma_3 \log (p_C/p_{CPI}) + \gamma_4 (time) + \nu.$

The elasticity of domestic production with respect to the relative price of imports (γ_1) is a function of the elasticity of supply and the own- and cross-price elasticities of demand. This coefficient should be positive, implying that domestic production is positively related to the relative price of imported iron goods, because $\gamma_1 = -\epsilon_1\eta_2/(\eta_1 - \epsilon_1)$, and $\epsilon_1 > 0$, $\eta_2 > 0$, and $\eta_1 < 0$.

Table 5 presents the results from estimating this equation. (The data sources are described at the bottom of the table.) Estimates of the static version of equation (3) are presented in column (1), but this specification ignores all the dynamics in the data and consequently the results are marred by serial correlation. Column (2) presents a first difference version of this specification, which corrects for serial correlation but also eliminates any relationship between the levels of the variables. To address both issues, column (3) estimates a simple autoregressive distributed lag model (ARDL) of the same equation.[19] In comparison with the column (1) result, the column (2) ARDL results show a better fit, lower regression standard error, and the absence of serial correlation. The column (2) results indicate that the lagged relative price of imports has a strong effect on domestic production than the contemporaneous price. The long-run elasticity of domestic output with respect to relative import prices is 1.41.[20] The elasticity of output with respect to import prices is remarkably high, implying that a 10 percent increase in import prices will increase domestic production by about 14 percent.[21] The long-run impact of industrial production on pig iron output is 1.22, indicating that iron output was also quite responsive to the general expansion of industry.

These results are robust to two changes in the underlying data. First, although there are regrettably few cost-shifters in the supply equation due to the scarcity of data for the antebellum period, real wage rates for common laborers in the Northeast from Margo (2000, Table 3A.9) could included as a supply determinant. However, in results not reported, the log of the real wage rate is not statistically significant in the regression and does not alter the coefficients of interest. Second, real GDP from Johnston and Williamson (2006) could be used in place of

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[19] The ARDL approach has been revived recently in comparison to other dynamic specifications, such as error-correction mechanisms. See, for example, Gerrard and Godfrey (1998) and Pesaran and Shin (1998). Pesaran and Shin (p. 372) note that "the traditional ARDL approach justified in the case of trend-stationary regressors is in fact equally valid even if the regressors are first-difference stationary."

[20] In the simplest ARDL specification takes the form: $y_t = \beta_1 x_t + \beta_2 x_{t-1} + \alpha y_{t-1} + u_t$, where the long-run impact of x_t on y_t is given by $\theta = (\beta_1 + \beta_2)/(1-\alpha)$.

[21] This elasticity is remarkably close to the cross-price elasticity of demand with respect to import prices (-1.67) estimated by Fogel and Engerman (1969) using different data and different methods. Note, however, that we estimate a supply responsiveness while they are estimating a demand responsiveness parameter.

industrial production. If specification (3) on Table 5 uses real GDP instead of industrial production, the long-run elasticity of domestic output with respect to import prices is 1.86 (somewhat higher than the previous finding) and the long-run impact of GDP on domestic output is 2.87, a larger impact because industrial production grew faster than real GDP during this period. However, as we argued above, we believe industrial production is a more appropriate proxy for iron demand than GDP.

In sum, production in the antebellum U.S. iron industry appears to have been quite sensitive to the relative price of imports and domestic demand conditions. Not every antebellum industry is so sensitive to import competition. For example, Irwin and Temin (2001) found that domestic production of cotton textiles in the antebellum period was not very sensitive to changes in import prices. The importance of product differentiation in the textile industry may explain the lower degree of sensitivity to import competition in comparison to the pig iron industry, where the product is more homogeneous.

With the aid of these estimates, the impact of the Walker tariff and the import price decline on domestic production can be determined. According to Figure 4, by 1845 the specific duties in the tariff of 1842 had been eroded by higher import prices, so the Walker tariff act amounted to a reduction in the average applied tariff from 43 percent in 1846 to 30 percent in 1847. By itself, this would reduce the relative price of imports by 9 percent, calculated as $(1+\tau_{1847})/(1+\tau_{1846})-1$. A 9 percent reduction in the relative price of imports would reduce domestic production by about 13 percent, equivalent to nearly 100,000 tons of 1847 production. A contemporary estimate held that "had the tariff of 1842 remained unchanged, the produce of this year would have been greater than that of 1847 by at least 200,000 tons" ("The Tariff of

1846," 4). While this appears to be an exaggeration, the tariff reduction still brought about a significant loss of output by the industry.

By contrast, import prices (exclusive of the tariff) fell 39 percent between 1846 and 1851, which would translate into an output decline of about 55 percent, or 378,000 tons. Overall U.S. industrial production grew 4.5 percent over this period, providing a modest offset in the face of falling prices. Domestic production of pig iron actually fell 46 percent between 1847 and 1851, so it appears that much of this can be explained by the decline in the relative price of imports due to the lower tariff and lower import prices. (The measures above overstate their role in reducing output because they are not relative to changes in the consumer price index.) Nevertheless, the decline in import prices was roughly four times more important than the tariff reduction of 1846.

However, had the specific duties of the 1842 tariff remained in effect, the ad valorem equivalent would have risen from 43 percent in 1846 to 49 percent in 1847, instead of declining to 30 percent in that year. Furthermore, falling import prices would have pushed the ad valorem equivalent of the 1842 tariff as high as 82 percent by 1851. While import prices including the tariff fell by more than 40 percent between 1846 and 1851, they would have fallen only 21 percent had the specific duties remained in effect. Therefore, the shift from specific to ad valorem duties deprived the industry of a substantial degree of insulation from import price shocks. Retaining the specific duty would have substantially mitigated the fall in domestic production; instead of falling a projected 65 percent due to the decline in import prices (all other things equal), output would fall just 32 percent. The loss of insurance that the shift from specific to ad valorem duties entailed mattered much more than the amount by which the tariff rates were cut in 1846.

Another counterfactual experiment is the complete abolition of the tariff. Eliminating the tariff in 1846 would produce a fall in the relative price of imports of 30 percent, calculated as $1/(1+\tau_{1846})-1$, where τ_{1846} = 43 percent. This would reduce domestic production by 42 percent. Therefore, by this calculation, about two-fifths of domestic iron output was dependent upon the tariff for its existence. However, this conclusion is not independent of the tariff level. For example, the abolition of the 30 percent ad valorem tariff after 1847 and before 1857 would have reduced the relative price of imports by 23 percent, resulting in a 32 percent decline in domestic production. As a general statement, these results suggest that domestic production would have declined by about one-third to two-fifths - somewhere between 30 percent and 40 percent - in the absence of the tariff.

To summarize, domestic production of pig iron was highly sensitive to changes in import prices in the antebellum period. Import prices were subject to large swings as cyclical fluctuations in Britain were transmitted to the United States. The decline in domestic output during the late 1840s and early 1850s was more due to a fall in British export prices than to the Walker tariff reduction. Our conclusion about the tariff is very similar to Temin's (1964, p. 23), who thought it "doubtful" that changes in import duties was the major factor driving changes in domestic production. Still, even though the large reduction in domestic output would have taken place even if import duties had not been reduced in 1846, the tariff reduction in that year still constituted an extremely severe shock nonetheless.

We conclude with two related points, one relating to the relationship between the tariff and technological change in pig iron production, and the other to the relationship between pig iron producers and the broader iron and steel industry. Grosvenor (1871) and Taussig (1931) argued that an undesirable consequence of the tariff of 1842 was that it perpetuated the use of the less efficient charcoal furnaces, which were destined to be displaced by anthracite coal furnaces.[22] While there is evidence to support this claim, the tariff was just one factor at work. Because charcoal furnaces were smaller and less expensive to construct than anthracite furnaces, Paskoff (1983, p. 131) notes that their construction "entailed a level of capitalization well within reach of an individual or small partnership and did not require the formation of a company." As a result, higher iron prices in early 1840s – due only in part to the higher tariff – prompted the entry of many small charcoal furnaces that would be unable to survive if prices fell.

Table 4 confirms this pattern by showing that, between 1844 and 1846, 58 charcoal furnaces were constructed but just 29 coal furnaces. But the apparent failure of these entrants once prices declined was high as well: from 1847 to 1850, 80 charcoal furnaces failed but only 11 coal furnaces met a similar fate (although the number of coal burning furnaces was much small than charcoal furnaces at this time).[23] Yet in the aftermath of the 1840s import shock, the

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[22] As Taussig (1931, p. 133) put it, "Charcoal iron for general use was a thing of the past; the effect of the tariff of 1842 was to call into existence a number of furnaces which used antiquated methods, and before long must have been displaced in any even by anthracite furnaces." Hence, Taussig (p. 134) argued that tariffs "retarded for the United States that cheapening of iron which has been one of the most important factors in the march of improvement in this century, and maintained in existence costly charcoal furnaces long after that method had ceased in Great Britain to be in general use."

[23] Grosvenor (1871, pp. 219-220) argues: "Was it well for the country, then, that Pennsylvania was paid, at public cost, for erecting so large a number of furnaces destined surely to be closed and abandoned whenever the use of anthracite became more general? Pointing to the wrecks scattered over Pennsylvania, where millions of money were lost by men who were tempted by the tariff of 1842 into the making of iron at the public expense, the advocate of protection asks whether the country did not lose by the destruction of these works. It did lose, not by their destruction, but by their establishment. It lost by the investment of large sums of money and much energy and enterprise in a wasteful instead of profitable manner."

industry shifted from charcoal to anthracite coal as the primary fuel, with the share of anthracite iron production increasing from 17 percent in 1849 to 47 percent in 1854 (Warren 1973, p. 18). The import shock of the late 1840s may have accelerated this conversion: "the anthracite furnaces and rolling mills emerged from the 1840s in larger numbers and in robust health. . . .This was not true of the charcoal-pig-iron sector, in which the effects of the high mortality rate among existing firms -- 47 percent of the sixty three firms active in 1842 did not survive until 1850 -- were exacerbated by a sharp decline in the number of new firms formed after 1846, the year of the Walker Tariff. By 1850 virtually no one with capital and a desire to make money by producing pig iron was so foolish as to try it by building a charcoal furnace" (Paskoff 1983, pp. 106-107).[24]

Finally, although the focus of this paper has been on how import tariffs promoted greater production by domestic pig iron producers, there is no presumption that such a policy should have been the goal of government policy. This paper has not conducted a cost-benefit analysis of the protection given to pig iron producers, and in fact the domestic iron industry was sharply divided over the merits of high tariffs on imported iron. As Paskoff (1983, p. 76) notes, by the early 1820s the American iron industry had matured into two distinct branches: pig and bar iron producers who made the raw material for iron manufacturers, who made pots, stoves, beams and structures, rails, nails, and other products. Iron manufacturers had an interest in obtaining inexpensive pig iron, which led them to oppose protection for pig iron producers. As Paskoff (1983, p. 76) writes: "For producers, no amount of protection from imported British iron could

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[24] Of course, Knowles and Healey (2006) suggest that a richer set of geographic factors were responsible for the slow adaptation of mineral fuel technologies rather than factors such as the tariff.

ever be too much protection; for the manufacturers, who purchased foreign as well as domestic pig and bar iron, rates in excess of *pro forma* levels were an 'excessive burden.' In a series of memorials and petitions to Congress between 1820 and 1850 each of the two increasingly antagonistic branches of the industry attempted to persuade the House and Senate of the wisdom, justice, and public-spiritedness of its position and of the base and groundless character of its opposition, which had only its own interests, and not those of the nation, at heart."

5. Conclusions

This paper has sought to understand the vulnerability of the antebellum iron industry to foreign competition by presenting a new data series on early U.S. pig iron production that pushes back existing estimates to 1827. This series was then used with a new compilation of imports and import prices to determine the importance of foreign competition and the tariff in affecting domestic output. Domestic iron production is found to be highly sensitive to import price fluctuations. This sensitivity may account for the strong protectionist sentiment in Pennsylvania in the nineteenth century (Eiselen 1932), although existing import duties could not prevent price shocks originating in the British market from having severe repercussions for U.S. producers.

References

Bining, Arthur Cecil. 1938. *Pennsylvania Iron Manufacture in the Eighteenth Century*. Publications of Pennsylvania Historical Commission, vol. 4. Harrisburg, PA: Pennsylvania Historical Commission.

Boot, H. M. 1984. *The commercial crisis of 1847*. Hull, England: Hull University Press.

Bull, Marcus. 1882. Charcoal pig iron statistics. *Journal of the United States Charcoal Iron Workers* 3, no. 2.

Calomiris, Charles W. and Christopher Hanes. 1994. Consistent output series for the antebellum and postbellum periods: Issues and preliminary results. *Journal of Economic History* 54, 409–22.

Cary, Henry. 1872. "The Harmony of Interests," in *Miscellaneous Works*. Philadelphia: H. C. Baird.

Childs, C. G. 1847. The iron trade of Europe and the United States: With special reference to the iron trade of Pennsylvania. *Hunt's Merchants' Magazine* 16:574–93.

Coxe, Tench. 1814. *A Statement of the Arts and Manufactures of the United States of America, for the Year 1810*. Philadelphia: A. Cornman.

David, Paul, and Peter Solar. 1977. "A Bicentenary Contribution to the History of the Cost of Living in America," in *Research in Economic History*. Greenwich, CT: JAI Press.

Davis, Joseph H. 2004. "A Quantity Based Annual Index of U.S. Industrial Production, 1790-1915." *Quarterly Journal of Economics* 119 (November): 1177-1215

DeBow's Review. Title varies. New Orleans.

"Documents Relating to the Manufacture of Iron in Pennsylvania." 1851. *Journal of the Franklin Institute* 21 (January): tables following pp. 69-72.

Eiselen, Malcolm R. 1932. *The rise of Pennsylvania protectionism*. Philadelphia, University of Pennsylvania.

Engerman, Stanley. 1971. "The American tariff, British exports, and American iron production. 1840-1860." In Donald N. McCloskey (ed.), *Essays on a Mature Economy: Britain after 1840*. Princeton: Princeton University Press.

Fishbein, Meyer H. 1963. The censuses of manufactures: 1810–1890. *National Archives Accessions* 57:1–20.

Fishlow, Albert. 1965. *American Railroads and the Transformation of the Antebellum Economy*. Cambridge: Harvard University Press.

Fogel, Robert W. 1964. *Railroads and American Economic Growth*. Baltimore: Johns Hopkins University Press.

Fogel, Robert W., and Stanley Engerman. 1969. "A Model for the Explanation of Industrial Expansion during the Nineteenth Century: With an Application to the American Iron Industry." *Journal of Political Economy* 77 (May/June): 306-28.

French, B. F. 1858. *History of the Rise and Progress of the Iron Trade of the United States, from 1621 to 1857*. New York: Wiley & Halstead.

Gayer, Arthur D., W. W. Rostow, and Anna J. Schwartz. 1953. *The growth and fluctuation of the British economy, 1790-1850*. Oxford, Clarendon Press.

Gerrard, W. J., and L. G. Godfrey. 1998. "Diagnostic Checks for Single Equation Error-Correction and Autoregressive Distributed Lag Models." *Manchester School* 66 (March): 222-237.

Grossman, Gene M. 1986. "Imports as a Cause of Injury: The Case of the U.S. Steel Industry." *Journal of International Economics* 29 (1986): 201-223.

Grosvenor, W. M. 1871. *Does Protection Protect?* New York: D. Appleton & Co.

Harley, C. Knick. 1992. "International Competitiveness of the Antebellum American Cotton Textile Industry." *Journal of Economic History* 52: 559-584.

Harley, C. Knick. 2001. "The Antebellum Tariff: Different Products or Competing Sources? A Comment on Irwin and Temin." *Journal of Economic History* 61: 799-805.

Irwin, Douglas A., and Peter Temin. 2001. "The Antebellum Tariff on Cotton Textiles Revisited." *Journal of Economic History* 61: 777-798.

Johnston, Louis A., and Samuel H. Williamson. 2006. "The Annual Real and Nominal GDP for the United States, 1790 - Present." Economic History Services, July 27, 2007, URL : http://eh.net/hmit/gdp/

Joskow, Paul L., and Edward F. McKelvey. 1973. "The Fogel-Engerman Iron Model: A Clarifying Note." *Journal of Political Economy* 81: 1236-40.

Kenwood, A. G. 1965. "Railway Investment in Britain, 1825-1875." *Economica* 32 (August): 313-322.

Knowles, Anne Kelley, and Richard G. Healey. 2006. Geography, Timing, and Technology: A GIS-Based Analysis of Pennsylvania's Iron Industry, 1825–1875. *Journal of Economic History* 66 (September): 608-634.

Lesley, J. Peter. 1859. *The Iron Manufacturer's Guide to Furnaces, Forges and Rolling Mills of the United States, with Discussions of Iron as a Chemical Element, an American Ore, and a Manufactured Article, in Commerce and Industry*. New York: John Wiley.

Margo, Robert A. 2000. *Wages and Labor Markets in the United States, 1820-1860.* Chicago: University of Chicago Press.

Mitchell, Brian R. 1988. *Abstract of British Historical Statistics*. New York: Cambridge University Press.

Paskoff, Paul F. 1983. *Industrial Evolution: Organization, Structure, and Growth of the Pennsylvania Iron Industry, 1750-1860*. Baltimore: Johns Hopkins University Press.

———, ed. 1989. *Iron and Steel in the Nineteenth Century*. Encyclopedia of American Business History and Biography. New York: Facts on File.

Pearse, John B. 1876. *A Concise History of Iron Manufacture of the American Colonies up to the Revolution and of Pennsylvania until the Present Time*. Philadelphia: Allen, Lane, & Scott.

Pesaran, M. Hashem, and Yongcheol Shin. 1998. "An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis." In *Econometrics and Economic Theory in the 20th century: The Ragnar Frisch Centennial Symposium*, edited by Steinar Strøm. New York: Cambridge University Press.

Rosenbloom, Joshua. 2004. "Path Dependence and the Origins of the American Cotton Textile Industry." In David Jeremy and Douglas A. Farnie, eds. *The Fibre that Changed the World: Cotton Industry in International Perspective* (Oxford: Oxford University Press.

Schallenberg, Richard H. 1975. "Evolution, adaptation and survival: The very slow death of the American charcoal iron industry." *Annals of Science* 32:341–58.

Smith, Charles E. 1851. "The Manufacture of Iron in Pennsylvania." *Hunt's Merchants' Magazine* 25 (November): 574-581.

Swank, James. 1897. *Notes and Comments on Industrial, Economic, Political, and Historical Topics*. Philadelphia: American Iron and Steel Association.

Swank, James M. 1878. *Introduction to a History of Iron Making and Coal Mining in Pennsylvania*. Philadelphia: by the author.

Swank, James M. 1892. *History of the Manufacture of Iron in All Ages, and Particularly in the United States from Colonial Times to 1891*. 2d ed. Philadelphia: American Iron and Steel Association.

Taussig, Frank W. 1931. *Tariff History of the United States*. 8th Edition. New York: G. P. Putnam's Sons.

Temin, Peter. 1964. *Iron and Steel in Nineteenth Century America: An Economic Inquiry*. Cambridge: MIT Press.

"The Tariff of 1846, Considered in Regard to its Effects upon the Planters and Farmers of the Union," 1849. *The Plough, the Loom, and the Anvil*, 2 (July): 1-11.

U.S. Bureau of the Census. 1975. *Historical Statistics of the United States*. Washington, D.C.: Government Printing Office, 1975.

U.S. Congress. House of Representatives. 1833. *McLane Report on Manufacturers, Documents Relative to Manufactures in the United States*. [McLane Report]. 22nd Cong., 1st sess. H.R. Doc. 308. 2 vols. Washington, DC: Gales and Seaton.

U.S. Congress, Senate. 1849. *Report of the Secretary of the Treasury, on the State of Finances*. With letter from Samuel J. Reeves to William M. Meredith, November 21. 31st Cong., 1st sess. Exec. Doc. 552. Washington, DC: U.S. Government Printing Office.

U.S. Department of the Treasury. Various years. *Report on Commerce and Navigation*. Washington, D.C.: Government Printing Office.

U.S. Department of the Treasury. 1845. "Report from the Secretary of the Treasury, December 3, 1845." 29th Congress, 1st Session. House of Representatives Executive Document No. 6. (1844-45).

U.S. Department of the Treasury. 1857. "Report from the Secretary of the Treasury, Respecting Duties Remitted on Railroad Iron, February 18, 1857." 34th Congress, 3d Session. Senate Executive Document No. 55. (1844-45).

Wallis, John Joseph. 2001. "What Caused the Crisis of 1839?" NBER Historical Working Paper No. 133, April.

Warren, Kenneth. 1973. *The American Steel Industry, 1850-1970: A Geographical Interpretation*. Oxford: Clarendon Press.

Wickens, M. R., and T. S. Breusch. 1988. "Dynamic Specification, the Long-Run and the Estimation of Transformed Regression Models." *Economic Journal* 98 (Supplement): 189-205.

Young, Edward. 1873. *Special Report on the Customs Tariff Legislation of the United States*. Washington, D.C.: Government Printing Office.

Table 1: Estimates of U.S. Pig Iron Production, 1827-1854

Year	Existing U.S. pig iron production estimates: AISA	Temin	Fogel	Revised Pennsylvania estimates	*PA share of U.S., Fogel*	Extended/ revised U.S. series	*PA share of U.S., revised*	Difference *(ths. tons)*	Final U.S. series
	[1]	**[2]**	**[3]**	**[4]**	[4]/[3]	**[5]**	[4]/[5]	[5]-[3]	**[6]**
1827				47,023		129,183	*36.4*		*129,183*
1828	130,000	**123,404**		**44,028**		**123,404**	*35.7*		**123,404**
1829	142,000	**134,954**		47,039		**134,954**	*34.9*		**134,954**
1830	165,000	**180,598**		**61,941**		**180,598**	*34.3*		**180,598**
1831	191,000			76,399		223,641	*34.2*		*223,641*
1832	200,000			85,055		249,104	*34.1*		*249,104*
1833				87,170		255,762	*34.1*		*255,762*
1834				84,304		246,745	*34.2*		*246,745*
1835				101,161		294,099	*34.4*		*294,099*
1836				128,018		368,162	*34.8*		*368,162*
1837				138,623		392,821	*35.3*		*392,821*
1838				138,939		386,557	*35.9*		*386,557*
1839				142,475		387,938	*36.7*		*387,938*
1840	286,903	[317,306 - 347,000]	347,000	115,112	*33.2*	305,895	*37.6*	(41)	*305,895*
1841			278,136	**103,450**	*37.2*	267,676	*38.6*	(10)	*267,676*
1842	215,000		230,000	**151,885**	*66.0*	381,977	*39.8*	152	*381,977*
1843			358,000	145,967	40.8	348,667	*41.9*	(9)	*348,667*
1844		**486,000**	**486,000**	**211,488**	*43.5*	**486,000**	*43.5*	-	**486,000**
1845			**574,018**	**253,037**	*44.1*	580,921	*43.6*	7	**574,018**
1846	765,000	[551,000 - 765,000]	**686,865**	**314,071**	*45.7*	699,260	*44.9*	12	**686,865**
1847	800,000	[597,674 - 800,000]	**764,972**	**361,719**	*47.3*	781,514	*46.3*	17	**764,972**
1848	800,000	[570,000 - 800,000]	**696,153**	339,219	*48.7*	711,986	*47.6*	16	**696,153**
1849	650,000	[542,903 - 650,000]	**627,334**	**313,871**	50.0	**627,334**	*50.0*	-	**627,334**
1850	563,755	563,755	**481,381**	**246,265**	*51.2*	**481,381**	*51.2*	-	**481,381**
1851			**413,000**	207,825	*50.3*	404,238	*51.4*	(9)	**413,000**
1852	500,000		**540,755**	281,341	*52.0*	536,191	*52.5*	(5)	**540,755**
1853			**723,214**	387,631	*53.6*	726,175	*53.4*	3	**723,214**
1854	**657,337**	**657,337**	**657,337**	**327,685**	*49.9*	**657,337**	*49.9*	-	**657,337**

Table 2: Pennsylvania's Share of the U.S. Pig Iron Industry and Structural Change in Fuel Technology

			U.S. pig iron production, by fuel *(%)*		
Year	**PA % of U.S. pig iron output**		**Charcoal**	**Anthracite coal**	**Bituminous coal & coke**
	[1]		**[2]**	**[3]**	**[4]**
1830	34.3	*falls*	100.0	-	-
1831	34.2		100.0	-	-
1832	34.1		100.0	-	-
1833	34.1	** nadir*	100.0	-	-
1834	34.2		100.0	-	-
1835	34.4		100.0	-	-
1836	34.8	*rises*	98.2	1.5	0.3
1837	35.3	*sharply*	96.4	3.1	0.5
1838	35.9		94.6	4.6	0.8
1839	36.7		92.8	6.1	1.1
1840	37.6		91.0	7.6	1.4
1841	38.6		87.7	10.5	1.8
1842	39.8		84.3	13.4	2.2
1843	41.9		81.0	16.4	2.6
1844	43.5		77.7	19.4	2.9
1845	44.1		74.3	22.4	3.2
1846	45.7		71.0	25.4	3.6
1847	47.3		68.0	28.3	3.7
1848	48.7		65.0	30.7	4.3
1849	50.0		62.1	33.0	4.9
1850	51.2		59.1	35.3	5.6
1851	50.3		56.1	38.5	5.5
1852	52.0		53.0	41.2	5.8
1853	53.6		49.7	43.5	6.8
1854	49.9	*AISA*	46.5	46.1	7.4
1855	54.0	*AISA*	43.3	48.7	8.0
1856	55.2	*AISA*	41.9	50.2	7.9

Sources: [1] See Table 1. [2]-[4] From 1854, fuel-distribution statistics are provided in AISA, Annual Reports & Notes. Earlier values have been prorated on Eavenson's (1942) anthracite and bituminous coal output shares from charcoal data provided in Bull (1882), Debow (1854), French (1858), Paskoff (1989, xxxv, table A.1), Pearse (1876), Schallenberg (1975), Swank (1878, 1892), and Temin (1964, 266-7, table C.2). Missing observations have been linearly interpolated. The smelting of pig iron by mineral fuel commenced shortly after the successful adaptation of British puddling techniques to the hot-blast furnace. Anthracite smelting reportedly occurred at the Schuylkill (PA) Furnace in 1836; bituminous coke was employed shortly thereafter in Fayette County (Swank 1878, 1892).

Table 3: Customs Duties on Imported Iron

A. Statutory Duties

Year	Pig Iron	Bar Iron, Hammered	Bar Iron, Rolled
1825	50 cents per cwt	90 cents per cwt	$1.50 per cwt
1828	62.5 cents per cwt	1 cent per lb.	$37 per ton
1832	50 cents per cwt	90 cents per cwt	$30 per ton
1842	$9 per ton	$17 per ton	$25 per ton
1846	30 percent	30 percent	30 percent
1857	24 percent	24 percent	24 percent

Source: Young (1873).

Note: cwt stands for hundred weight.

B. Import Volume and Ad Valorem Equivalent Tariff, 1827-1859

Year	Volume of Pig-Iron Equivalent Imports ('000 gross tons)	Weighted Average Ad Valorem Tariff (percent)	Pig Iron (percent)	Bar Iron, Hammered (percent)	Bar Iron, Rolled (percent)
1827	45.7	44.2	37.5	32.8	78.3
1828	57.3	46.1	37.8	35.9	87.7
1829	50.0	48.0	50.6	40.5	107.1
1830	57.0	60.6	54.3	44.9	115.2
1831	70.9	70.8	55.0	47.5	114.7
1832	93.3	52.2	56.2	43.4	66.4
1833	92.0	55.8	42.4	38.9	80.4
1834	90.1	45.5	41.5	37.2	55.8
1835	95.7	44.2	37.7	37.7	52.3
1836	113.3	51.5	30.3	34.1	67.1
1837	109.5	43.1	32.1	32.2	52.6
1838	99.5	32.9	36.9	36.1	30.1
1839	124.2	42.2	38.1	34.8	47.6
1840	97.4	37.2	43.7	35.0	37.9
1841	130.6	57.2	43.7	37.1	68.1
1842	101.5	60.0	34.2	31.9	75.2
1843	85.3	69.5	72.7	33.2	81.9
1844	98.6	66.0	54.1	35.0	80.8
1845	100.5	53.0	46.7	33.0	66.8
1846	91.7	43.3	44.9	30.9	49.3
1847	142.0	30.0	30.0	30.0	30.0
1848	264.4	30.0	30.0	30.0	30.0
1849	380.6	30.0	30.0	30.0	30.0
1850	420.2	30.0	30.0	30.0	30.0
1851	476.1	30.0	30.0	30.0	30.0
1852	584.4	30.0	30.0	30.0	30.0

1853	622.9	30.0	30.0	30.0	30.0
1854	510.9	30.0	30.0	30.0	30.0
1855	409.2	30.0	30.0	30.0	30.0
1856	399.7	30.0	30.0	30.0	30.0
1857	311.7	24.0	24.0	24.0	24.0
1858	256.6	24.0	24.0	24.0	24.0
1859	327.6	24.0	24.0	24.0	24.0

Note: Calculated from annual the Treasury Department's annual *Commerce and Navigation of the United States*. Duties are adjusted for drawbacks as discussed in the text.

Table 4: The Entry and Failure of Blast Furnaces in Pennsylvania, 1840-1850

Year	Coal		Charcoal	
	Built	Sold or Failed	Built	Sold or Failed
1840	3	0	3	3
1841	1	0	3	1
1842	5	2	8	8
1843	0	1	5	4
1844	4	6	13	2
1845	14	0	15	2
1846	11	1	30	3
1847	8	1	12	15
1848	5	5	6	20
1849	3	5	2	30
1850*	3	0	0	15

* first four months.

Source: Smith (1851), pp. 580-581.

Table 5: Reduced-Form Estimates of Domestic Pig Iron Production

Dependent Variable: Log $(x_S)_t$ – Log of Domestic Production of Pig Iron

	(1) Static Levels	(2) First Difference	(3) Dynamic ARDL
Constant	6.64* (1.00)	--	3.84* (1.23)
$\log (p^*[1+\tau]/p_{CPI})_t$	0.77* (0.27)	0.30 (0.21)	0.27 (0.20)
$\log (p^*[1+\tau]/p_{CPI})_{t-1}$	--	--	0.45* (0.24)
$\log (p_c/p_{CPI})_t$	-0.66* (0.18)	-0.08 (0.14)	-0.19 (0.14)
$\log (p_c/p_{CPI})_{t-1}$	--	--	-0.09 (0.14)
$\log (IP)_t$	1.34* (0.26)	1.38* (0.30)	1.70* (0.30)
$\log (IP)_{t-1}$	--		-1.08* (0.28)
Time	-0.05* (0.02)	--	-0.02 (0.02)
$\log (x_S)_{t-1}$	--	--	0.49* (0.11)
Adj. R^2	0.91	0.32	0.95
Standard Error	0.169	0.138	0.113
LM χ^2 (p value)	7.00* (0.01)	0.53 (0.76)	2.59 (0.12)

Abbreviations: (x_S) is domestic output, $(p^*[1+\tau]/p_{CPI})$ is the relative price of imports, (IP) is industrial production, (p_C/p_{CPI}) is the relative price of coal.

Notes: Time period is 1827 to 1859 (N=33). Standard errors have been corrected for heteroscedasticity. * indicates significance at the 10 percent level.

Data Sources: Domestic production: see Table 1. Price of imports: unit value of imports, as described in the text. Average tariff: see Table 3. Industrial production: from Davis (2004); however, it has been purged of pig iron production, which receives a weight of 0.082 in the index. It was purged by calculating the index without pig iron, i.e., (1/0.918)*(IP - 0.082*Pig Iron). Price of coal: the U.S. Bureau of the Census (1975), series E-129. Consumer price index: David and Solar (1976).

Figure 1: Trends in Pennsylvania's Share of U.S. Iron Production

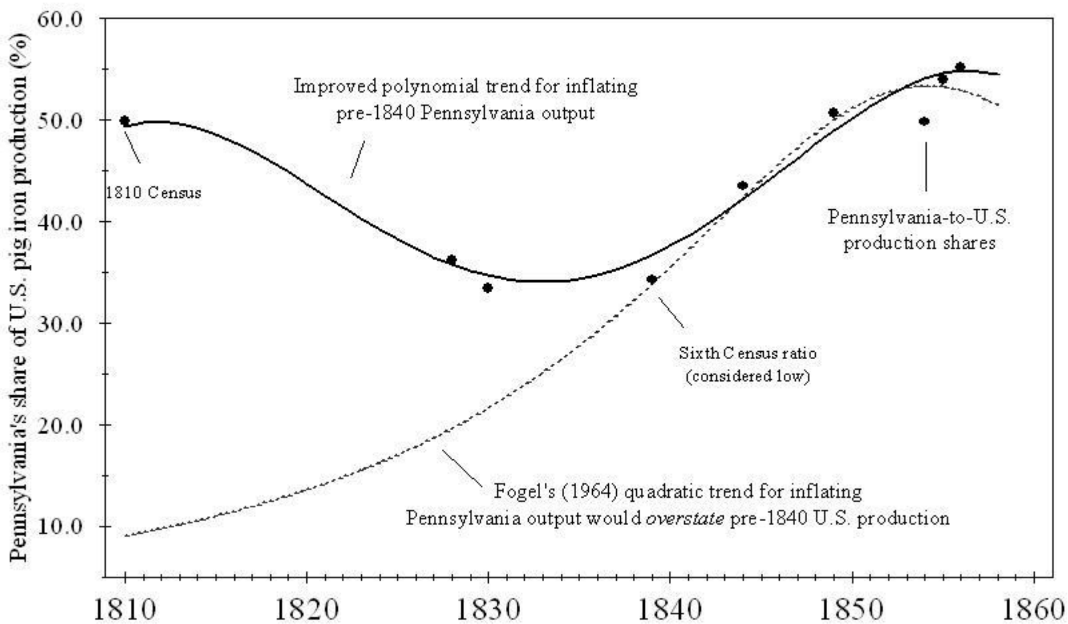
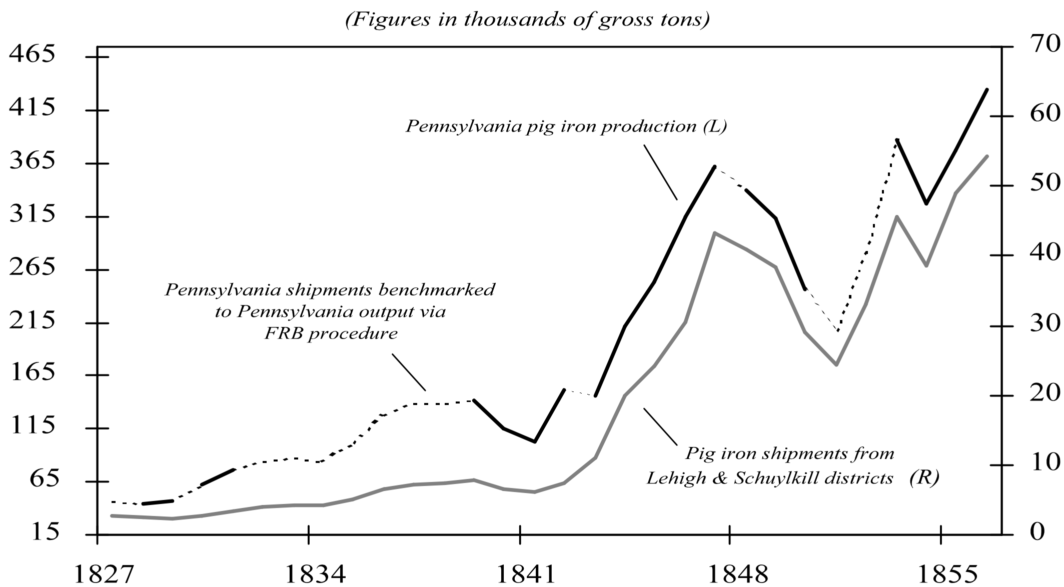
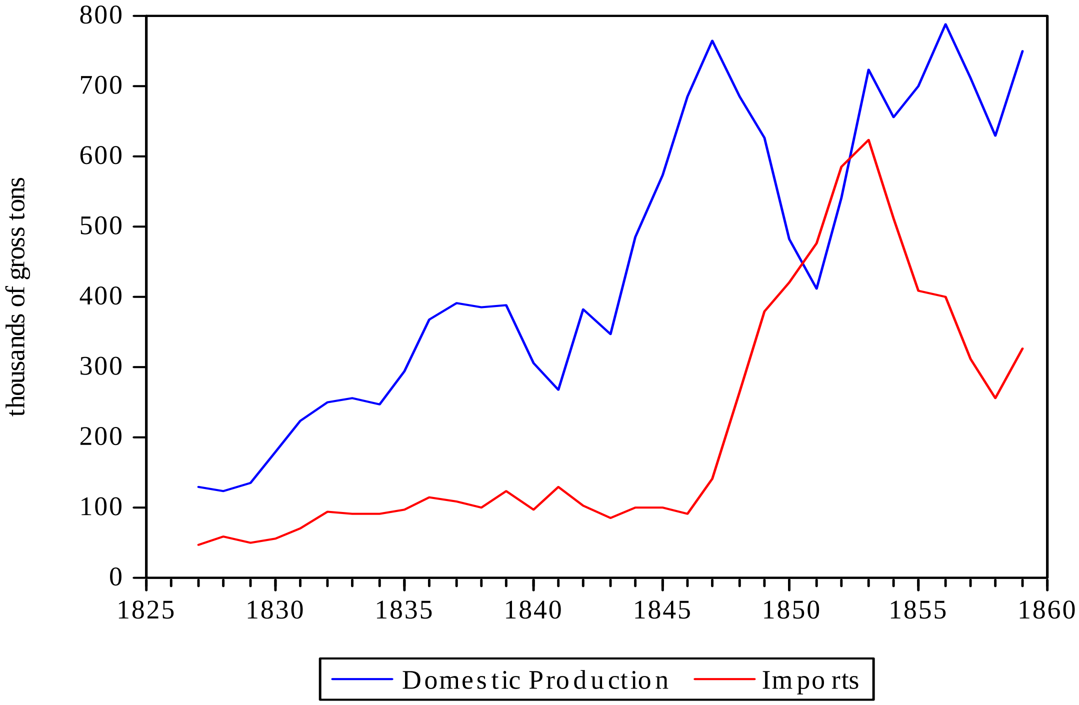


Figure 2: Pennsylvania Iron Shipments and Output Estimates



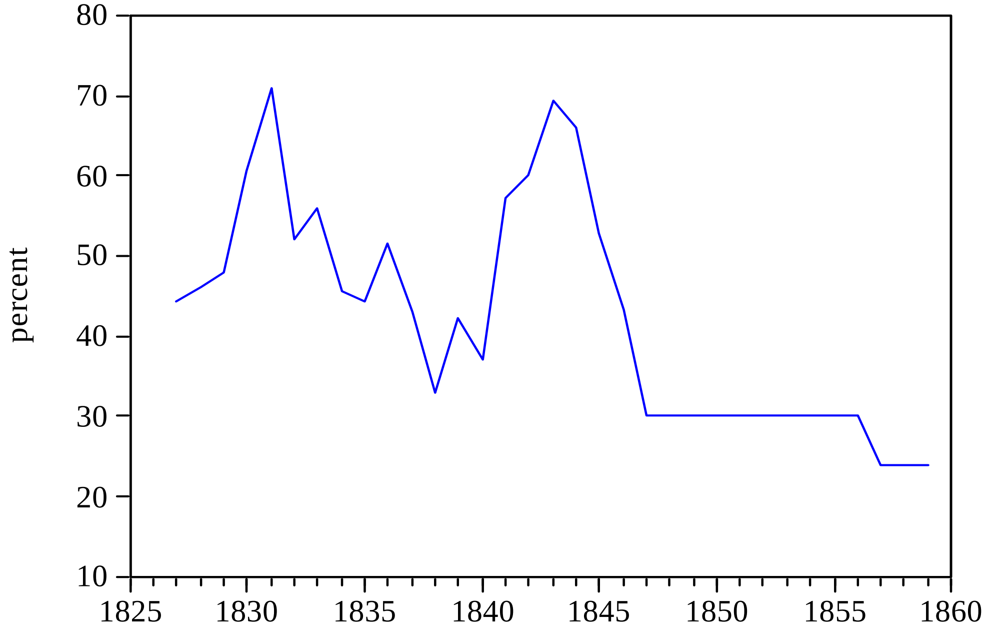
Sources and notes: See Technical Appendix Table D1 for Pennsylvania production series. Shipments represent the sum of descending pig iron tonnage from the Lehigh and Schuylkill iron districts (bound toward Philadelphia). Shipments data transcribed from Hunt's Merchants' Magazine (various issues), Annual Reports of the Board of Managers of the Lehigh Coal and Navigation Company (1831–1885), and Jones (1908).

Figure 3: Domestic Production and Imports of Pig Iron, 1827-1859



Sources: Domestic production from Table 1, column 6 for 1827-1854, 1855-1859 from Temin (1964), p. 264. Imports: see Table 3 (b).

Figure 4: Average Ad Valorem Tariff on Pig Iron Imports, 1827-1859



Source: Table 3 (b).

Figure 5: Relative Price of Iron Imports, 1827-1859

Note: Price of iron imports divided by U.S. consumer price index, as described in the text.