The Price of Nails since 1700: Even Simple Products Experienced Large Price Declines

Daniel E. Sichel*
Wellesley College and NBER

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ABSTRACT

Many products—such as lighting and computing—have undergone revolutionary changes since the beginning of the industrial revolution. This paper considers the opposite end of the spectrum of product change, focusing on nails. Nails are a simple, everyday product whose form has changed relatively little over the last three centuries, and this paper constructs a continuous, constant-quality price index for nails since 1695. These data indicate that the price of nails fell significantly relative to an overall basket of consumption goods as reflected in the CPI, with the preferred index falling by a factor of about 15 times from the mid 1700s to the mid 1900s. While these declines were nowhere near as rapid as those for lighting and computing, they were still quite sizable and large enough to enable the development of other products and processes and contribute to downstream changes in patterns of economic activity. Moreover, with the relative price of nails having been so much higher in an earlier period, nails played a much more important role in economic activity in an earlier period than they do now. [A not yet completed section of the paper will use a growth accounting framework to assess the proximate sources of the change in the price of nails.]

Introduction

The first and second industrial revolutions brought forth an amazing array of new products and production processes, with dramatic changes to almost every dimension of everyday life and work. More recently, the digital revolution has brought further extraordinary changes. Commentary on these developments often has focused on products undergoing the most significant changes. For example, Nordhaus (1997 and 2007) developed long-span price indexes for lighting and computing, products that he described as undergoing "tectonic shifts."[1] His work showed that these products experienced spectacular declines in relative prices, with the real price of lighting falling by a factor of about 3400 from 1800 to 1992 and the real cost of computing dropping by a factor of about 3 trillion times from 1850 to the early 2000s.

While these changes are remarkable, what about simple, everyday products that did not undergo dramatic transformations? To explore this question, this paper looks at the price of nails since 1695. Nails are an ideal product to consider because their form has changed relatively little over the past three centuries so it largely is possible to make direct comparisons across the centuries without the complication of the product itself changing. Indeed, nails produced in the 1700s would be quite recognizable today, and early-style nails are still produced for some specialty applications.

The data assembled show that nails experienced sizable declines in relative prices, fueled by huge changes in the process for producing them. Using the preferred price index developed in this paper, the real price of nails on a quality adjusted basis fell—relative to a broad bundle of consumption goods as measured by the overall CPI—by a factor of about 15 from its peak in the

[1] Nordhaus contrasts products undergoing these tectonic shifts to products that experienced "run-of-the-mill" changes (such as basic food items) and to products that were "seismically active" (undergoing significant changes but remaining similar enough to their form in the early 1800s so as to still be recognizable such as housing). Nails would be in his "run-of-the-mill" category.

mid-1700s to the middle of the 20th century, averaging a decline of 1.3 percent a year. (Prices have risen some in the past several decades during which time imports became much more important.)

These large price declines reflected radical changes in the production process for nails—mirroring many key milestones of the industrial revolution—as well as dramatic improvements in the quality of the iron and steel used as inputs. For example, prior to the industrial revolution nails were produced one at a time by a blacksmith, and according to Rybczynski (2000, p. 70-71), it took about a minute to produce a single hand-forged nail. Currently, a nail-making machine with a footprint of about three square feet can produce 300 to 450 wire nails in a minute.

While the real price declines for nails are not on the scale of lighting or computing, they are consequential nonetheless, and highlight that even some everyday products experienced substantial price declines. These changes had important implications for patterns of economic activity, especially in the construction sector. Moreover, the rapid real price declines imply that the relative price of nails was much higher in the mid-1700s than it is today and that difference in relative prices made nails both more precious and a more important component of economic activity.

In terms of being more precious, the dome of the Maryland State Capitol, completed in 1788 and made largely of wood, was joined together with no nails but rather with wooden pegs and iron straps. Presumably, this choice was made, at least in part, because of the high cost and limited availability of nails at the time.[2] And, nearly a century later, nails were still highly valued (and preferred to wood pegs), as can be seen from the following quote from *Little House*

[2] See Maryland State Archives (2011). The high value of nails during the 1700s is highlighted by the practice of burning down abandoned buildings to facilitate recovery of the nails (see Temin (1964, p. 42)).

on the Prairie (Wilder, 1935, p. 124). The quote describes attaching a roof to a log home on the frontier during about the 1870s (after the price of nails had already fallen significantly from the late 1700s):

> Now Pa carefully took the nails one by one from his mouth, and with ringing blows of the hammer he drove them into the slab. It was much quicker than drilling holes and whittling pegs and driving them into the holes. But every now and then a nail sprang away from the tough oak when the hammer hit it, and if Pa was not holding it firmly, it went sailing through the air.
>
> Then Mary and Laura watched it fall and they searched in the grass till the found it. Sometimes it was bent. Then Pa carefully pounded it straight again. It would never do to lose or waste a nail.

Regarding the importance of nails in overall economic activity, this paper also reports domestic absorption of nails, going back to 1810. At that time—more than 20 years after the Maryland State Capitol was completed—nails are estimated to have amounted to about 0.4 percent of nominal GNP. In today's terms, this share is similar to that of today's household purchases of personal computers and peripherals or of airfares. As prices plunged during the 1800s, domestic absorption rose dramatically. But, as a share of nominal GDP, domestic absorption of nails, which once were quite important, became de minimus. So, while nails appear commonplace today, that perception reflects some centuries of significant declines in their relative price.

This paper is organized as follows. To provide some context, the next section reviews a timeline of key milestones in the development of nails. Section 3 discusses the construction of the price indexes for nails. Section 4 focuses on the implications and interpretation of the long-span time series for nail prices. Section 5 provides an accounting for the sources of the decline in relative prices (this section is not complete). Section 6 concludes.

2. A Brief History of Nails

Table 1 presents a brief historical time line for nails.[3] Nails fall into three broad types—hand forged, machine cut, and wire—with each of these types dominant in each of three overlapping periods. Hand-forged nails have been made at least since Roman times and continued to be made in relevant quantities through about 1820. Forged nails are made by a blacksmith (or nailsmith), hammering the nail from a rod of iron and hammering a head on the top. According to Rybczynski (2000, p. 70-71), an experienced nailsmith could produce a nail from a blank in about one minute.

Cut nails are made by a bladed machine that cuts nails from thin strips of iron or steel. The first patents for cut nails in the United States were granted in the 1770s and 1780s, and a flood of patents followed in subsequent years. The manufacturing technology for cut nails improved dramatically during the 1800s, mirroring many of the developments of the broader industrial revolution. The power source shifted from water to steam and later electricity, and the machinery became increasingly automated requiring less and less operator intervention.[4] In the 1880s, production shifted from iron to steel nails.

By the 1880s wire nails became more prevalent, with the first U.S. patent for wire nails granted in 1877. Initially, wire nails were made from iron wire. By the late 1880s and early 1890s, wire nails were being produced from steel wire in sizable quantities. Wire nails are made by cutting each nail from a coil of drawn wire, sharpening a tip, and adding a head. Wire nails remain the dominant type used for most purposes today, though cut nails are still used for some

[3] A number of authors have described the history of nails. For example, see Adams (2002), Lewis (1998), and Wells (1998). The description here summarizes key points from that literature. The particular facts coming from different sources are noted in table 1, and for expositional simplicity, the source notes are not repeated in the text.
[4] Wells (p. 85) notes that the iron sheets used to make nails were rolled by water-powered equipment in 1810 in a Philadelphia factory and that steam power was used in a Pittsburgh rolling mill a year later.

specialty applications. For wire nails, the manufacturing technology also has improved considerably in the decades after the 1880s.

Figure 1 illustrates each of these three types of nails. The top nail is a hand-forged nail; the middle one is a cut nail, and the bottom one is a wire nail. The hand-forged and cut nails look rather similar and, indeed, they have similar holding power (or resistance to being withdrawn after being pounded in). One advantage of hand-forged nails over early machine cut nails is that forged nails could be "clinched": that is, the tip of the nail that extended through the pieces of material being joined could be bent over, or clinched, thereby increasing the holding power of the nail. Early machine cut nails had the grain of the metal running perpendicular to the length of the nail, and cut nails would break if an effort were made to clinch them. Later, cut nails were made with the grain of the metal running parallel to the length of the nail, and these cut nails could be clinched. Wire nails have considerably less holding power than forged or cut nails, but, because each nail is lighter, shipping costs per nail were less. The basic wire nail has changed relatively little since the 1890s, with the graphic in early Sears catalogues depicting a nail that looks much like one that could be purchased at Home Depot today.

From the mid 1700s—when it took, perhaps, a minute to make a single nail—to today, the changes in nail manufacturing technology are rather stunning. As noted, today, a nail-making machine with a footprint of about three square feet can produce 300 to 450 nails per minute.[5] If we assume that one worker can operate 4 machines at once and that each machine produces 350 nails a minute, then labor productivity of nail production has increased by a factor of 1400 times since the era of hand-forged nails when it took a worker about a minute to produce a nail. With most of this change occurring over the period from 1790 to 1940, the annual rate of

[5] Machinetools.com (2011).

increase in labor productivity was nearly 5 percent a year; much slower than the pace of productivity advance in the production of computers in recent decades, but still significant.[6]

Beyond improvements in the manufacturing technology, the number of varieties of nails produced has expanded significantly over the years, including nails with coatings to prevent rust and with rings around the nail's shank to increase holding power. Indeed, the online catalog of a current American nail manufacturer lists 107 distinct varieties of nails, not counting different sizes of the same type of nail.[7] In addition, the advent of nail guns has dramatically changed the way that nails are installed. The implications of nail guns for the measurement of nail prices are discussed in section 3.

3. Price Indexes for Nails

Raw Nominal Data and Conversion to Real Prices

Figure 2a plots the raw data on the nominal price of nails in cents per pound; all the price quotes I found for nails were on a price per pound basis. In the figure, different colors capture the different "regimes" of data. (The data are also reported in an available Appendix.) Table 2 provides details on the sources from which these prices were drawn. The green segment refers to prices from Beveridge (1939) for nails in the United Kingdom from 1695 to 1792.[8] Given the time period, these quotes must have been for hand-forged nails. The quotes cover a wide range of sizes, with prices provided in U.K. shillings per 12 pounds of nails. I converted these prices to cents using an exchange rate from U.K. pounds to U.S. dollars for 1792.[9] Thus, before 1792,

[6] Based on $1400^{(1/150)}$

[7] Catalog available at www.mazenails.com. The list of nail varieties is on page 4 of the 2010 catalog.

[8] The original source of Beveridge's price quotes for nails is fascinating. In particular, he obtained logs of purchases made by the Greenwich hospital. This hospital entered prices and quantities of pretty much everything it purchased into a logbook, providing a rich data source.

[9] The exchange rate used for 1792 is $4.47 per U.K. pound sterling. The exchange rate is from the Measuring Worth website at www.measuringworth.com.

these prices are capturing movements in prices in the United Kingdom, indexed to the 1792 value in cents per pound.

The blue segment in figure 2a captures prices from Cole (1938) for the period from 1784 to 1813. The type of nail is not specified; given the time period, these quotes probably cover a mix of hand-forged and cut nails, and I refer to this stretch of data as "mixed." The quotes in Cole are for various size lots, and they were all converted to cents per pound of nails.

The red segment covers machine-cut nails from 1814 to 1890. From 1814 to 1828 the prices are from Cole (1939), while the quotes for the later period through 1890 are from various sources and, like Cole's data, were reproduced in *Historical Statistics of the United States.* The quotes are for dollars per hundred pounds and were converted to cents per pound.

The black segment in figure 2a covers the period from 1890 to the present and refers to wire nails. This segment incorporates data from the Bureau of Labor Statistics, reflecting a number of different reports for the earlier periods and producer price indexes (PPIs) in the more recent periods. The quotes are for different varieties of nails and are quoted for lots of various sizes. All of these quotes were converted to cents per pound.[10] The orange dot reports a price quote for 2011 from Amazon.com for 50 pounds of nails converted to cents per pound.

In a perfect world, an index of nail prices would be constructed by using shipment or consumption weights to aggregate prices of each type of nail. Data limitations make that impossible, and the choice of breakpoints in price quotes across the different types of nails is largely driven by data availability. That said, the switchovers to cut nails in1814 and to wire

[10] Starting in 1992, the PPI provides index numbers—rather than prices in natural terms—and these PPIs are used to extend the price series on a cents per pound basis.

nails in 1890 are consistent with what archaeologists characterize as the eras in which each type of nail was prominent.[11]

At the switchover points, as can be seen in figure 2a, there are some discontinuities. In the late 1700s, the series for forged nails the United Kingdom (shown in green) is below the series for "mixed" nails (shown in blue) in the United States. This gap could reflect any of a number of factors. Perhaps nails were produced more cheaply in the United Kingdom in this period. But, shipping nails was expensive so if shipping charges were added to the U.K. prices, they might look more like the higher U.S. prices during this period. In addition, the descriptions of the nails for which quotes were collected are pretty sketchy so there likely are differences in what is being priced. The other interesting overlap is that between the series for cut nails and wire nails. It appears that wire nails were more expensive, raising the question of why buyers shifted to wire nails, particularly given their less impressive holding power. This issue is discussed further in the next section on quality adjustment.

I also collected a parallel time series of prices from Sears catalogs.[12] These quotes extend from 1897 to 1960, the last year the Sears catalog included steel wire nails in a variety of sizes. As noted, this analysis relies primarily on the BLS prices for nails in this period, though below I compare the BLS prices to the Sears prices and discuss the differences.

To calculate real prices, I constructed a CPI back to 1695 by linking together series for the U.K retail price index (RPI) from 1695-1784 and various measures of the U.S. CPI from 1784-2011.[13] This CPI series is shown in figure 2b. The base year for the CPI series is 2010 so

[11] See figure 8 in Wells (1998).
[12] Economists have a long tradition of using Sears catalogs (and those from other retailers), including work by Albert Rees (1961) and Robert Gordon (2008).
[13] For 1784-1800, U.S. CPI data are from Officer (2011); for 1800-2010, CPI data are from the Minneapolis Federal Reserve's website; and for 2011 the figure used is the 12-month change in the CPI for April 2011. [Will switch to measuringworth.com for earlier period and PCE chain price index starting in 1929.]

the real price measures shown are in terms of 2010 dollars. Of course, as Gordon (2008) and many others have noted, comparisons of CPIs over very long spans of time raise a host of difficult issues. Nonetheless, it seems more relevant to focus on real prices—despite the inherent limitations—rather than nominal prices, particularly given the central interest in the prices of nails and screws relative to prices of other goods and services.

Real prices of nails, relative to the CPI, are shown in figure 3a on a cents per pound basis from 1695-2011. The real price on this basis was relatively stable from 1695 through the early 1800s (at least compared with the large decline that followed), and the real price exhibited a peak in the mid 1700s. Over most of this period, the prices refer to hand forged nails. Then, during the 1800s, the price fell dramatically, dropping from about 160 cents per pound around 1800 to a little less than 30 cents per pound by 1930. Since then, prices on this basis jumped in the late 1940s and 1950s and then fluctuated in a fairly wide range through 2011.

Quality Adjustment

One important difficulty with the prices on a cents per pound basis is that cents per pound does not price a homogenous product but rather is conflating prices of nails of many different sizes. When nails are purchased, buyers likely are thinking of a particular project for which they need a certain number of nails of a certain size. So, to standardize the size of nails in the index, I convert everything to be as equivalent as possible to a 2", size 6d nail.[14] For the earlier periods before nails sizes were standardized, I standardize on 2" nails.

Table 3 shows the counts of nails per pound used for this conversion and the sources from which these counts were drawn. Forged and cut nails are pretty similar in general shape (as can be seen in figure 1), and I use a count of 85 per pound for both forged and wire nails. Wire

[14] The "d" in 6d refers to the size of the nail. A 6d nail often is referred to as a 6-penny nail.

nails are considerably thinner, and as the quotes switch to wire nails in 1890, the count jumps to 150 for size 6d 2" nails. This jump in the count of nails per pound helps to explain why, on a cents *per pound* basis, the price of wire nails was initially higher than the price of cut nails. The count briefly jumps to 181 during the second World War when nails available to the public became thinner, presumably to conserve essential war materials. After the war, the count dropped back to 168, where it has remained since.

Using these count estimates, figure 3b puts real prices on a cents per nail basis. One key difference is evident between the upper and lower panels. On a *per nail* basis prices fell by a larger multiple than on a per *pound* basis. In particular, note what happened around the period of transition in price quotes in 1890 from cut nails to wire nails. On a *per pound* basis, wire nails look more expensive than cut nails, but on a *per nail* basis wire nails look less expensive than cut nails. The reason for this difference is the higher count of wire nails per pound than of forged or cut nails. Temin (1964) pointed out that wire nails' lighter weight per nail meant lower shipping costs per nail, and this factor also enhanced the attractiveness of wire nails. This discussion highlights the importance, for the purposes of price measurement, of being as precise as possible about the product being priced.

But, wire nails are not the same in every aspect as cut or forged nails. In particular, wire nails have less holding power than cut or forged nails. This outcome occurs primarily because the cross section of a cut or forged nails is rectangular and tapered compared with the round and untapered cross section of a wire nail. The greater holding power comes from the wedging action arising from the shape of the cut nails. In the world of wood engineering, these differences in holding power have been measured, and the literature suggests that cut nails have

about twice the holding power of wire nail.[15] Figure 4a repeats the plot of real prices on a cents per nail basis from figure 3b and adds a sequence of dashed lines showing real prices in terms of cents per nails *with prices for the period before 1890 adjusted for the greater holding power of cut and forged nails.* This adjustment was done by dividing prices in the earlier period by two to account for the roughly double holding power of cut and forged nails relative to wire nails.

One could interpret this adjustment as a simple hedonic correction for a one-time change in quality. And, to the extent that holding power is the only relevant characteristic, this adjustment puts prices in the earlier period on constant-quality basis, relative to the period with wire nails since 1890. Of course, holding power is not the only relevant characteristic. For many applications, the smaller holding power of wire nails is perfectly sufficient so that the greater holding power of cut nails would be unnecessary. (Note the analogy to the discussion of how much users value increases in the speed of personal computers beyond a certain point.) Moreover, in many applications using wire nails it is possible to use additional nails to gain holding power. [16]

As noted, shipping costs are another characteristic that would be important to some buyers. For example, the 1897 Sears catalog indicates that shipping costs for a 100-pound keg of nails from Chicago to Boston amounted to about 20 percent of the price of the nails. Given the greater number of wire nails that would be in a keg compared with the number of cut nails, shipping costs per nail would have been considerably lower for wire nails than for cut nails.

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[15] Stern (1952) finds that 2½" plain shank brads (wire nails) have 140 pounds of holding power immediately after being pounded into wood and about the same amount after a year. He finds that 2½" cut flooring nails have about 360 pounds of holding power immediately after being pounded in and about 235 pounds after a year. The ratio for the immediate holding power of cut to wire nails is 2.6, and the ratio after one year is 1.7. Similarly, the *Woodworking Newsletter* (2009) from Lee Valley reports that "Academic studies of [cut and wire nails] show that cut nails have somewhere between 65 percent and 135 percent more holding power than wire nails." (Lee Valley is a popular seller of woodworking tools and hardware.) I take this information as being consistent with cut nails having about twice the holding power of wire nails.

[16] In a perfect world, I could run a hedonic regression on a panel of prices in the period when cut and wire nails were both prevalence to see how the market priced holding power. Data limitations make that a tough thing to do.

Some simple calculations suggest that these differences would close a chunk of the discontinuity in 1890 between the prices shown in figure 4a for cut and wire nails on a constant holding power basis.[17] In particular, if shipping costs were to be added in, the dashed lines in figure 4a would shift up by more than would the black solid line. I do not explicitly adjust for shipping costs, though the matched model index described below does implicitly control for these differences in shipping costs.

Finally, to construct a single index for the full time span that holds quality constant as well as possible with the available data, I construct a matched-model index, linking prices across the switchover points. While the matched-model approach surely misses some important differences, it seems the best way available to construct a single price index that, as much as possible, holds quality constant. Specifically, I use the prices shown by the solid segments in figure 4a: the U.K prices (converted to U.S. currency) from 1695-1784, the series labeled "mixed" from 1784-1814, the series labeled "cut" from 1814-1890, and the series labeled "wire" from 1890-2011. I start with the prices for the most recent period (the black segment for wire nails), and then link backwards. In each of the crossover years (1890, 1814, and 1784), I use the price from the more recent type of nail and link backwards from that year using price changes for the earlier type of nails in the earlier years. This series is plotted in figure 4b and shows that real prices of nails fell by a factor of about 15 times from its peak in the mid 1700s to its low point in the middle of the 20th century.

[17] For example, in 1897, a 100-pound keg of 2", 6d wire nails was listed in the Sears catalog for $1.85; a keg of cut nails was listed for $1.80. Fourth-class freight for 100 pounds from Chicago to Boston was 39 cents. With 85 nails per pound in the keg of cut nails and 150 nails per pound in the keg of wire nails, shipping costs would have amounted to 0.0026 cents per nail for wire nails and 0.0046 cents per nail for cut nails. And, with a CPI in 1897 of 3.81 (2010=100) the real cost per nail for shipping was 0.068 cents per nail for wire and 0.12 cents per nail for cut.

An additional important innovation is nail guns, with pneumatic guns appearing in the Sears catalog in the early 1980s. Nail guns raise the question of what is the nail-related product being priced? If it's an individual nail, then nail guns can be regarded as a distinct piece of capital equipment; however, if the product to be priced is an *installed* nail, then nail guns should be considered an integral part of the process of installing nails. An all-in price for installed nails would include materials (the nails), capital costs (hammer v. nail gun), labor costs, shipping, and everything else. Although I have not calculated an all-in price across all years, the following illustrative example highlights that nail guns are a big deal.

Today on Amazon.com, a high-quality nail gun that shoots 2" nails can be purchased for $175, and a small compressor and air hose costs $214. Packs of nails for the gun are about $41 per 5000 nails. In contrast, a hammer costs about $9.[18] Assume that a nail gun and compressor lasts 6 years in commercial applications and experiences straight-line depreciation over that period (assume the same for the hammer). Further, assume that the hourly wage for a construction worker is $20 per hour.[19] Finally, assume that a worker with a hammer can install 6 nails per minute and that worker with a nail gun can install 20 nails per minute.[20] With these assumptions, the cost per *installed* nail for a worker using a hammer is 6.2 cents per nail (including the cost of the nail, the cost of capital per nail, and the wage per nail). The cost per installed nail for a worker using a nail gun is 2.5 cents per nail, about 60 percent below the cost using a hammer.[21] If we were to port this difference over to the matched-model price index for

[18] Prices were pulled from Amazon in July 2011 for a Porter-Cable FR350A framing nailer ($174.55), a Makita MAC700 compressor ($194), a 50' air hose ($19.99), and a standard claw hammer.
[19] The BLS' employment report for June 2011 reported average hourly earnings in construction of $25.36. I assume that a construction worker who primarily installs nails is somewhat less skilled than an average construction worker and is paid a bit less.
[20] Based on personal experimentation for nails per minute with a hammer and an assumption that a worker with a nail gun could position and fire a nail about every three seconds.
[21] Additional assumptions are that a full time worker is employed for 2000 hours a year and that the worker spends 500 hours installing nails and 1500 hours arranging materials and undertaking other tasks; accordingly, the labor

nails shown in figure 4b, then the advent of nails guns can be seen to be a pretty big deal. For example, the price of a nail in for 2011 is just over 0.5 cents per nail. If this price were lowered by 60 percent, it would be about 0.2 cents per nail, which would pull the price back down close to its all-time low.

Parallel Price Series

As noted earlier, I also collected prices for nails from Sears catalogs from 1897 to 1960, though quotes are not available in all years.[22] The appeal of these prices is that it is straightforward to hold quality constant. For example, it is possible to track the price of 2", size 6d nails over this period. The Sears prices for steel wire nails that are 2" long and size 6d (converted to real prices) are plotted in figure 5a on a cents per pound basis and in figure 5b on a cents per nail basis. The quote from Amazon for nails of this size also is plotted in the figure.

As can be seen the Sears prices track the prices from the PPIs pretty closely through about 1940. This suggests that the PPIs, converted to a cents/nail basis, are doing a reasonable job of capturing constant-quality price changes for the 2" long, size 6d nails that the Sears series is tracking. Starting after 1940, the Sears price rises considerably more rapidly than does the series based on PPI indexes. I am unsure of the source of this difference, but it could reflect a shifting wholesale/retail margin at Sears. The PPI quotes (and the quotes for the earlier periods) are producer prices. The Sears price is, technically, a retail price, though in the late 1800s and the first part of the 1900s, Sears sold nails in large volumes (100 pound kegs) and sold them directly to homebuilders (inferred from the advertising copy in the catalogs). In the later period,

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cost allocated to installing nails is $10,000 (=$20x500). On these assumptions, the worker would install 600,000 nails in a year with a nail gun (=20x60x500) and 180,000 nails with a hammer (=6x60x500).

[22] In some years around 1900, the Sears catalog noted that nail prices (which were sold in 100 pound kegs) were volatile and that buyers should request an up to date price list. I have not been able to track down these price lists. For shorter periods in which I could not or did not collect quotes, I interpolated between years in which quotes were collected.

it appears that the Sears catalog was catering exclusively to retail purchasers of nails. In particular, starting in the mid 1930s, Sears began quoting prices for 1 pound packages and in the early 1940s began quoting prices for 5 pound packages; by this time Sears no longer quoted prices for 100 pound kegs in their catalog. These changes support the view that Sears shifted from being more of a wholesaler to more of a retailer in the market for nails. Such a shift could be consistent with the more rapid increase in Sears' prices relative to the PPIs over the same period.

Another possible explanation for the differences between the Sears prices and the PPIs is that the Sears prices are more precisely controlling for quality change by tracking prices of nails of the same size and quality—though, as noted, sold in different lot sizes in different periods—while, perhaps, the PPIs were missing changes in the mix of products included in the index. One data point that argues against this interpretation is the price quote for 2011 from Amazon.com. As noted, this quote is for a 50 pound lot of 2", size 6d, wire nails without shipping. This price is fairly close to that generated from the PPIs and suggests that the PPI was reasonably on track with wholesale prices for 2", 6d nails in 2011.

4. Downstream Effects of Declines in the Price of Nails

Changes in Domestic Absorption

Looking again at figure 4b, the real price of nails fell by about 1/3 from the mid 1700s to about 1800. Presumably, these price declines reflected many of the types of process improvements that Adam Smith (1776) noted for pins as well as the beginning of the machine-cut nail era.[23] During the 1800s, prices plunged, with the sharp drop continuing through to the 1940s. All told, prices fell by a factor of 15 from their mid-1700s peak to their mid 1900s

[23] For a discussion of the pin trade, see Pratten (1980).

trough. Then, prices rose in the 1950s and 1960s, dropped back some through the early 2000s and then rose somewhat again.

Focusing on the period of rapid declines in real prices of nails, these rapid declines contributed to a huge increase in demand. Figure 6a shows domestic absorption of nails for selected years (the data points are shown as red dots that are connected by line segments).[24] As can be seen, domestic absorption rose dramatically, from about 16,000 tons of nails (including spikes, tacks, and staples) in 1810 to over 200,000 tons in 1872 and more than 1.6 million tons in 2002. [Need to scale domestic absorption by population.] This pattern, of falling prices and rising quantities, suggests that the supply curve was shifting outward as production technology improved, leading to falling prices along the demand curve. No doubt, the demand curve also was shifting out as the U.S. economy expanded. As noted above, changes in production technology for nails was quite dramatic from the late 1700s through the latter part of the 1800s. In addition, innovation in upstream industries (iron and steel) surely played an important role in falling prices for nails.[25]

Although domestic absorption of nails may seem small in 1810, nails actually were an important part of the economy at that time. For 1810, I estimate that domestic absorption of nails amounted to over 0.4 percent of GDP on a current-dollar basis. To put this into perspective, 0.4 percent of GDP in 2010 amounted to $58.6 billion (=.004 x $14660.4).

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[24] I calculate absorption as production plus imports less exports. From 1872 forward, the data are mostly from *Annual Statistical Reports* of the American Iron and Steel Institute (AISI and known as the American Iron and Steel Association in earlier years). For 1810, I could only find data on production (French (1858, p. 18)), and based on his description that imports of nails were significant until the War of 1812, I arbitrarily doubled the production figure to get a figure for domestic absorption. For the 1992 and 2002 observations, I pulled numbers on the value of production from the Census of Manufactures and used numbers on exports and imports from the AISI reports. The AISI numbers and the Census of Manufactures numbers for production may not be comparable. Finally, the numbers for value of production from the American Iron and Steel Institute covering the latter part of the 1800s and the early part of the 1900s are larger than the numbers from Shaw (1947). I have not yet tracked down the source of that difference.

[25] See Temin (1964) for a discussion of developments in the broader iron and steel industry during the 19th century.

Moreover, by way of comparison, household purchases of personal computers and peripheral equipment amounted to 0.4 percent and household purchases of air travel amounted to 0.34 percent. So, nails were a big deal in the 1700s and early 1800s.[26]

Despite the huge increase in quantities, with the drop in price, domestic absorption of nails as a share of GDP (GNP in earlier years) fell very substantially. The blue dots in figure 6a show domestic absorption of nails as a share of GDP, showing the decline in share from an estimated 0.4 percent in 1810 to just over 0.01 percent in 2002. [The right-axis should have decimal places in front of the labels.] The drop shown in the figure highlights the transformation of nails from an important product in the U.S. economy to a commonplace product that is, largely, taken for granted, and whose consumption is a trivial fraction of GDP. Put another way, with dramatic changes in relative prices, the role of nails in the economy changes significantly, as did our perception of them.

In addition to turning nails into an everyday, nearly disposable product, the decline in relative price also affected patterns of economic activity. The construction industry (including railroad beds and fences) benefited from the decline in the price of nails, and that sector was relatively more important in the U.S. economy in that earlier period than it is today.[27] One important transformation within construction is that, according to Jackson (1987), the drop in prices of nails enabled balloon-frame construction. Balloon-frame buildings use many nails (in contrast with post and beam construction that could use no or few nails) and only became

[26] Nails often were included in measures of industrial production and price indexes for the 1800s. For example, Hansen (1916) included nails in his wholesale price index for 1801-1840.

[27] According to Gallman (1966) gross investment in construction (including farm improvements) amounted to about 16 percent of nominal GNP in 1839, compared with 7½ percent in 2008 (and about 5 percent in 2010)Gallman reports gross capital formation for new construction (including both residential and nonresidential) of $137 million in 1839 in current dollars. This figure excludes $133 million of the value of improvements to farmland made with farm construction materials. If the farm figure is added in, gross investment in construction amounts to $270 million, which is about 16 percent of Gallman's estimate of GNP (plus the value of farm improvements) for 1839. The calculation is 0.27/(1.54+.133), with the figures coming from tables A-1, A-3, and A-4.

feasible once the relative price of nails had fallen far enough. Outside of construction, other downstream sectors benefitting from price declines for nails and screws include furniture, wooden containers and boxes, and many other products made from wood).

Imports of Nails

The evolution of nails in the United States highlights another common development in manufacturing; namely, the rise of serious foreign competition in the second half of the 20th century.[28] As shown in figure 6b, the import share for nails (imports/domestic absorption) began a steady uptrend in the 1950s, rising to about 70 percent by the 1980s. The share appears to drop back in the 1990, though this shift could reflect, at least in part, a non-comparability between the data for 1992 and 2002 and the data for earlier years.[29] This rise in import shares is quite dramatic. Moreover, it came earlier than for many other manufactured goods likely reflecting that by 1950 the technology for producing nails was well understood and had become rather pedestrian.

The sharp rise in import shares raises an interesting question about the price series. If imports were rising so rapidly, what was happening to import prices and how does that compare to domestic prices? [This section is incomplete. So far, I only have the BLS series for import prices of nails and screws (and other fasteners) back to 1974. I should be able to track down unit values for imported nails and screws at a finer level of detail from other sources for earlier periods.] The rapid increase in imports starting in the 1950s coincides with a rapid increase in the matched-model index for the real price of nails. It seems a little puzzling that prices of

[28] I've only started to track down the early trade and tariff information. I infer from other sources that tariff policy was an important issue for the iron/nail/screw industry in the first part of the 1800s. The AISA data indicate that by the 1870s, imports were pretty inconsequential and did not become important until after the second World War.
[29] The data in figure 6b generally are calculated from the AISI data on imports, exports, and production. But, I use the Census of Manufactures figures for the value of production for 1992 and 2002, possibly introducing a non-comparability.

domestically produced nails should rise so rapidly at a time that import competition was increasing.

For the period since 1974, I have measures of import prices, and figure 7a shows the matched-model index for real prices of nails (based on PPIs in this period) and "real" import prices calculated as the import price divided by the CPI.[30] Over this period, import prices fell quite a bit relative to the PPIs. Indeed, from 1974 to 2011, real import prices fell about 60 percent. The matched-model index moved down some through the early 2000s but then moved back above its 1974 level. This comparison of PPIs to import prices raises the question of possible mis-measurement in either the PPIs or the import price measure. In particular, why were domestic prices rising during a period of further competition from imports and what products was the PPI pricing as domestic production dropped back rather dramatically? Along these lines, the BLS shift in 2005, to a very broad category of all hardware raises the possibility that the BLS had trouble pricing domestically-produced basic nails and screws.[31]

Finally, the rising import share raises the question of what price index to use to gauge prices faced by domestic *purchasers*? If the PPIs and official measures of import prices are taken as correct, then perhaps the appropriate price index would be a weighted average of the PPI-based prices and import prices, using domestic and imported shares as weights.

5. Accounting for the Sources of Price Change

This section describes a plan for work to be done. The basic idea is to use the dual representation of a production function, along with company reports going back to the early

[30] The narrowest BLS import price series covers "Nails, screws, nuts, bolts, rivets of iron, steel, copper, or aluminum" from 1974 to 2005 and "Hardware manufacturing" thereafter. The series codes are EIUIM694 and EIUIZ3325, respectively.

[31] Indeed, Michael Mandel (2011) noted in a 2011 blog post that the U.S. military had difficulty finding domestic sources of some basic screws and other simple hardware.

1800s to decompose price changes in nails over time into the portion coming from changes in the costs of energy, materials, labor, capital, and technology. This decomposition would not be causal in any sense but would provide some guidance to proximate sources of price declines. Here's the basic setup.

Conventional growth accounting decomposes growth in output into contributions from labor, capital, materials, energy, and total factor productivity (TFP).

$$\dot{y} = \alpha_1 \dot{l} + \alpha_2 \dot{k} + \alpha_3 \dot{m} + (1 - \alpha_1 - \alpha_2 - \alpha_3)\dot{e} + t\dot{f}p$$

where lower case variables with dots indicate growth rates and Y = output, L = labor input, K = capital, M = materials, E = energy input, and TFP = total factor prod. In principle, such a production function could be applied to nail manufacturers; if data were available, either in aggregate or to data from individual companies.

This representation of the production function has a dual in prices that can be expressed as:

$$\dot{p} = \alpha_1 \dot{w} + \alpha_2 \dot{r} + \alpha_3 \dot{p_m} + (1 - \alpha_1 - \alpha_2 - \alpha_3)\dot{p_e} - t\dot{f}p$$

where p=price of nails, w=wages, r=cost of capital, p_m = price of materials, and p_e = price of energy.

The plan is to identify and use data from reports from companies producing nails back to about 1800. I believe that these data would make it possible to construct snapshots of the price decomposition for different time periods for a collection of individual companies so as to evaluate changes over time in the contribution of different factors to the change in the price of nails.

The goal would be to fill in as many cells as possible in a table like the following:

Sources of Price Decline for Nails, 1695-2011
(percent change)

	1695-1776	1776-1810	1810-1850	1850-1915	1915-1940	1940-2011
Price	+ 5.2	-16.0	-29.4	-74.0	+4.0	+103.8
contribution from (pct point):						
Wages						
Cost of capital						
Cost of materials						
Cost of energy						
Total factor productivity						

My sense at this point is that it may be difficult to separate out the effects of capital and technology so those categories might, by necessity, be grouped together.

6. Conclusion

Many products—such as lighting and computing—have undergone revolutionary changes since the beginning of the industrial revolution. This paper considers the opposite end of the spectrum of product change, focusing on nails. Nails are a simple, everyday product whose form has changed relatively little over the last three centuries, and this paper constructs a continuous, constant-quality price index for nails since about 1700. These data indicate that the price of nails fell significantly relative to an overall basket of consumption goods as captured in the CPI. Using the preferred index in this paper, the relative price of nails fell by a factor of about 15 times from the mid 1700s to about 1950. While these declines were nowhere near as rapid as those for lighting and computing, they were still large enough to enable the development of other products and processes and contribute to downstream changes in patterns of economic activity. quite sizable. Moreover, with the relative price of nails having been so much higher in an earlier

period, nails played a much more important role in economic activity in an earlier period than they do now.

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Table 1
Historical Time Line for Nails*

Roman era to 1820	Hand forged nails • Slitting equipment in Saugus, MA in 1645. (Lewis, p. 8.06.03) • From drawn iron rods up to about 1805 • Often made at home. • From machine rolled and cut iron rods starting in 1600s to about 1820 • Took a nailsmith about 1 minute to make a nail from a prepared blank (Rybczynski, p. 71)
1790s – early 1890s	Cut nails from sheets of iron or steel • First patents for cut nails in 1770s and 1780s. Flood of patents in following years. (Lewis, p. 8.06.09) • Cutting and heading machines in operation near Boston in 1794. (Lewis, p. 8.06.09) • Cut nails became dominant by early 1800s • Machine heading starting around 1800 (Lewis, p. 8.06.09-8.06.10) • Improved rolling of iron and inline grain starting in 1820s, prevalent by 1830s • Increasing sophistication and automation of machinery (first water power and then steam power) • In 1880s, shift from iron to steel
1850s	Wire nails developed
1877	First American patent for wire nails (Adams, p. 69)
1880	Iron wire nails began to be manufactured in U.S. on large-scale
Late 1880s, early 1890s	Steel wire nails produced in sizable quantities
1920	Wire nails dominate (only 8 percent of produced nails were cut)
Early 1980s	Pneumatic nail guns appear in Sears catalogue for first time
Today	Fully automated machine makes 300-450 nails per minute (machinetools.com)

*Except where noted, source is Wells (1998).

Table 2
Nails: Data Sources for Prices

Dates	Nail Description	Quote	Source
1695 - 1792	Various, hand forged	Shillings/12 pounds, based on purchase records of Greenwich hospital. Converted to U.S. cents/lb using 1792 exchange rate of £1 = $4.47 from www.measuringworth.com	Beveridge (1939). No data are reported for selected years and values for these years are interpolated.
1784 - 1828	1814-1827 quotes for "cut nails," all sizes"; for other years, "assorted sizes." Earlier years may include forged nails.	Philadelphia market, quotes for various size lots,	Cole (1938)*
1828 - 1834	Nails, cut	New York market, $/100 lbs	1881 Report of the Director of the mint, p. 54*
1835 - 1849	Cut nails	$/100 lbs	Report of the Secretary of the Treasury, 1849.*
1850 - 1859	Cut nails	$/100 lbs	American Iron and Steel Association*
1860 -1890	Cut nails	$/100 lbs	American Iron and Steel Association*
1890 - 1947	Wire, 8d, fence and common	$/100 lbs	BLS reports*
1947 - 1960	Wire, common	$/100 lbs	BLS reports*
1962 - 1997	Wire, common, quoted at $/50 lbs. From 1992-98 "bright nails."	$/50 lbs	BLS reports For 1992-98, from PPI WPU10880211

1997-2009	Steel nails, staples, tacks, and spikes, made in plant that draw wire,	Index number	PPI, WPU108812012
2009 – 2011	Steel nails, staples, tacks, spikes, and brads, WPU10881201	Index number. 2011 value is average of January-May.	PPI, WPU10881201
Parallel Data			
1897- 1960	Wire, 6d, 2", iron and steel, roughly for every 2nd or 3rd year.	$/100 lbs for 1897- 1932 $/lb for 1936 – 1940 $/5 lbs for 1942-1960	Sears Catalogues
2011	Wire, 6d common	$/50 lbs	www.amazon.com

*Prices reprinted in *Historical Statistics of the United States.*

Table 3
Count per Pound for 2" Nails

Period	Count	Source
1695 – 1889	85	Average from multiple sources*
1890 – 1941	150	Counts from various Sears catalogs for 2", 6d wire nails
1942 – 1944	181	Sears catalogs, 2", 6d wire nails
1945 – 2011	168	Sears catalogs and Grainger.com, 2", 6d wire nails

*****The Tremont Nail company currently advertises 2" 6d cut nails described as common, standard, at 85 per pound (see tremontnail.com). Lee Valley currently advertises 2" cut nails with wrought heads at 68 per pound and with rose heads at 97 per pound. A document from the early 1800s [*A List of Nails and Spikes Required for the Service of the Office of Ordnance* (1813), reprinted in the *Bulletin of the Association for Preservation Technology*] lists clasp-headed 2" cut nails at 100 per pound and clout 2" cut nails at 83 per pound. I took 85 as a reasonable value capturing this range.

Figure 1
Hand Forged, Machine Cut, and Wire Nails

Note: Forged nail at top, machine cut nail in middle, and wire nail at bottom.
Source: www.glasgowsteelnail.com/nailmaking.htm

Figure 2a

Nominal Price of Nails

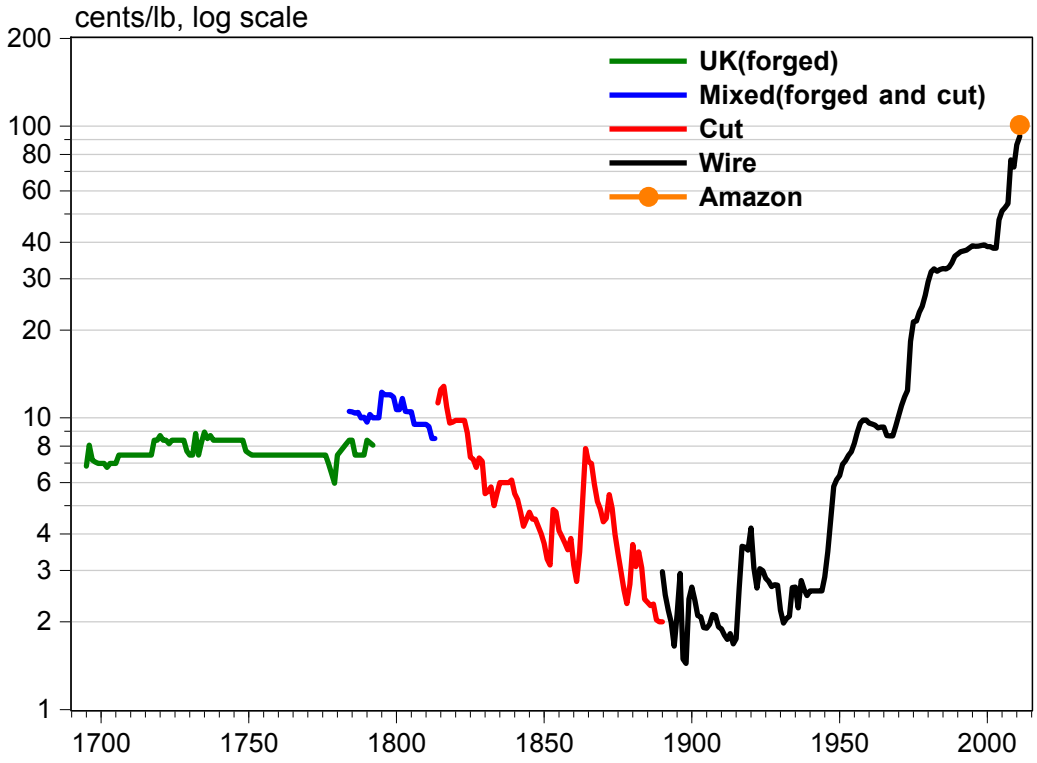

Figure 2b

CPI w/RPI splice

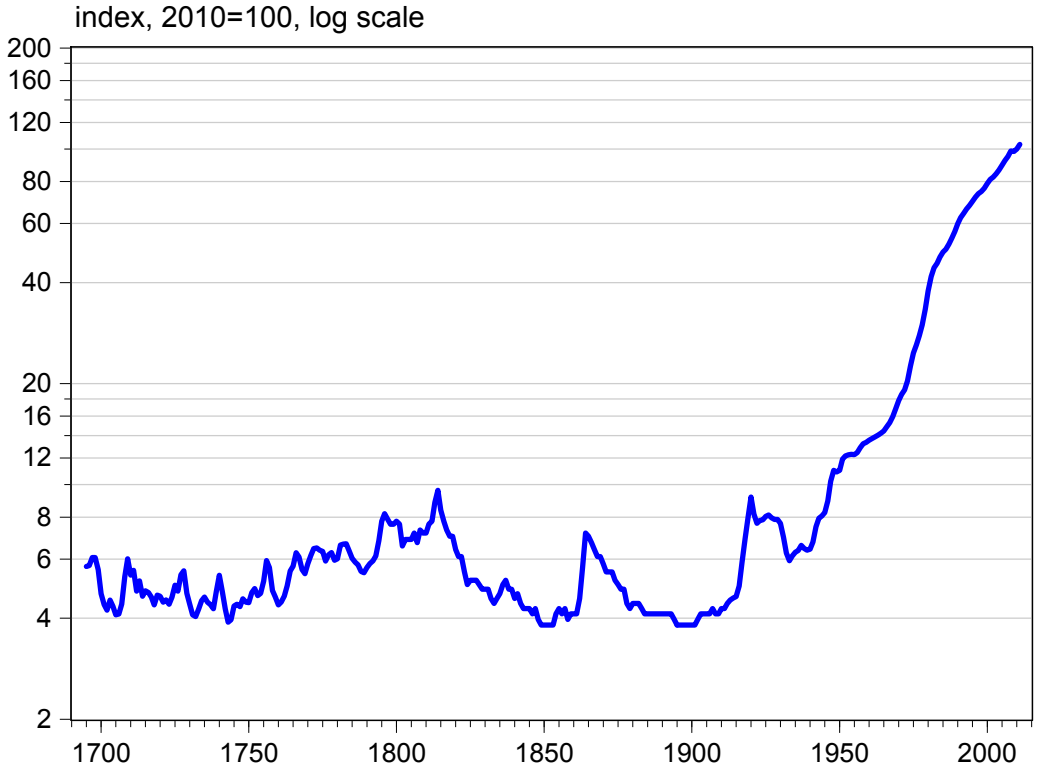

Figure 3a

Real Price of Nails (cents/lb)

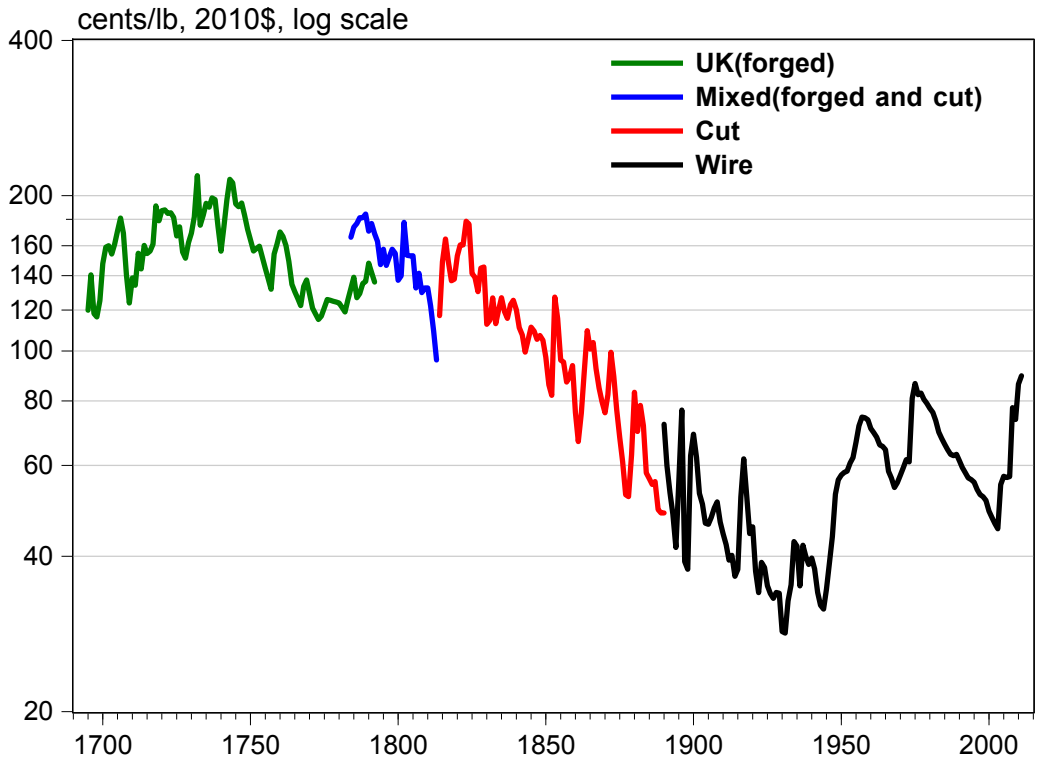

Figure 3b

Real Price of Nails (cents/nail)

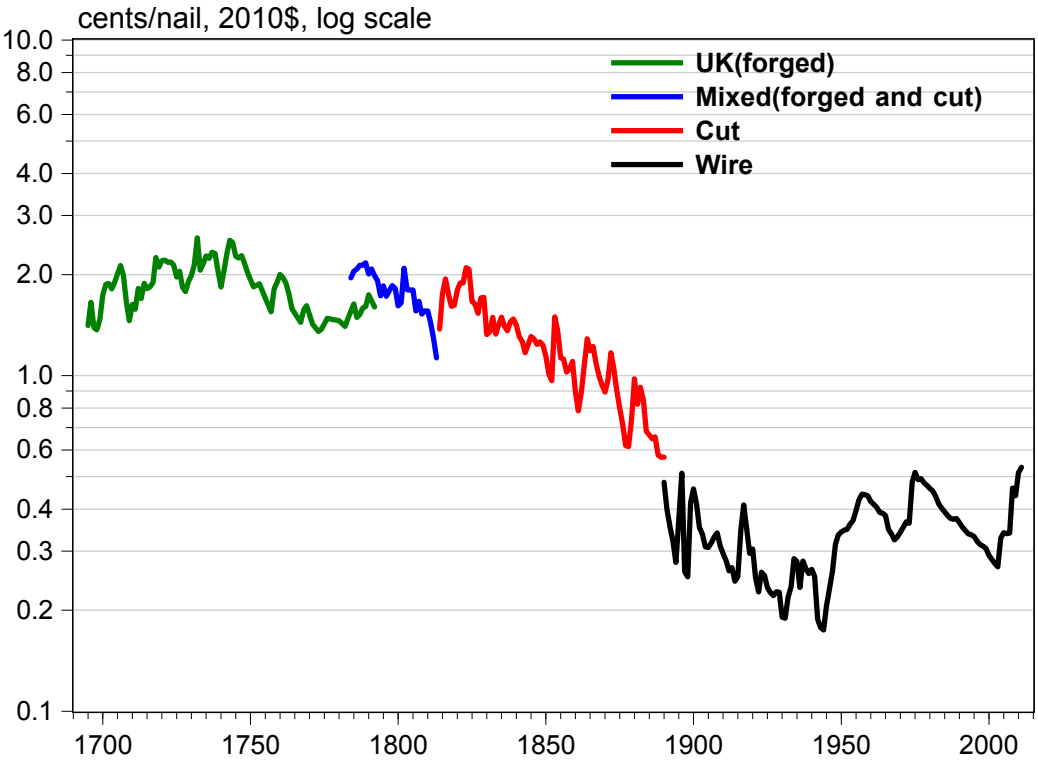

Figure 4a

Real Price of Nails
(dashed lines - constant holding power)

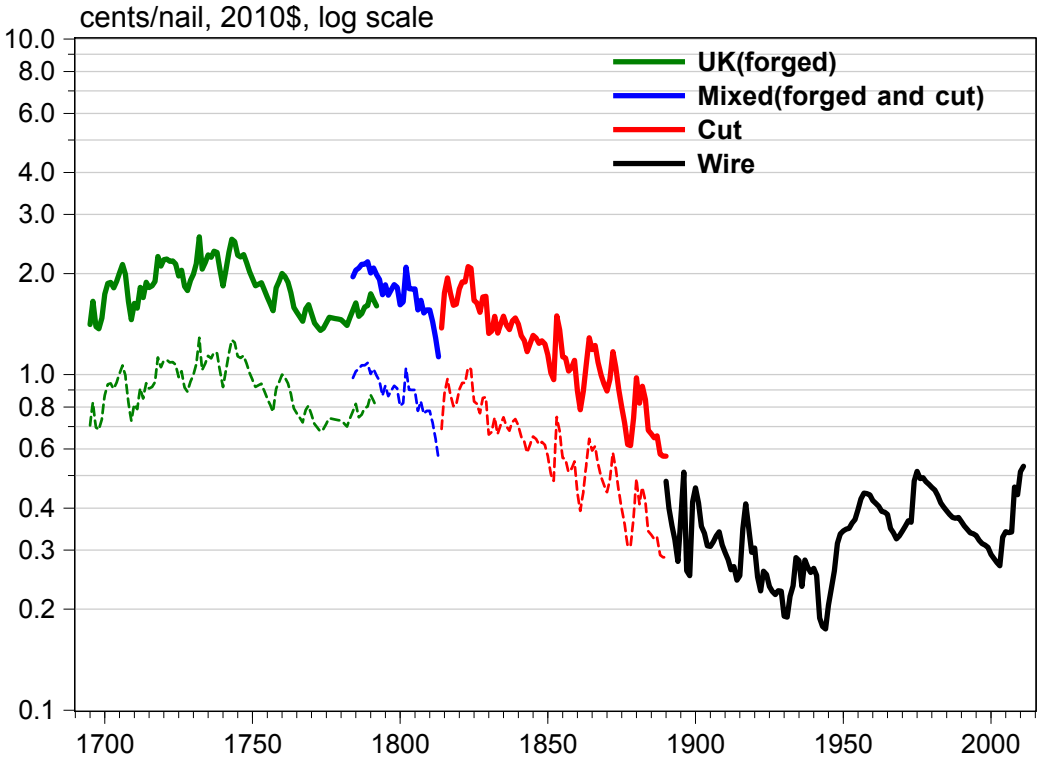

Figure 4b

Real Price of Nails: Matched-Model

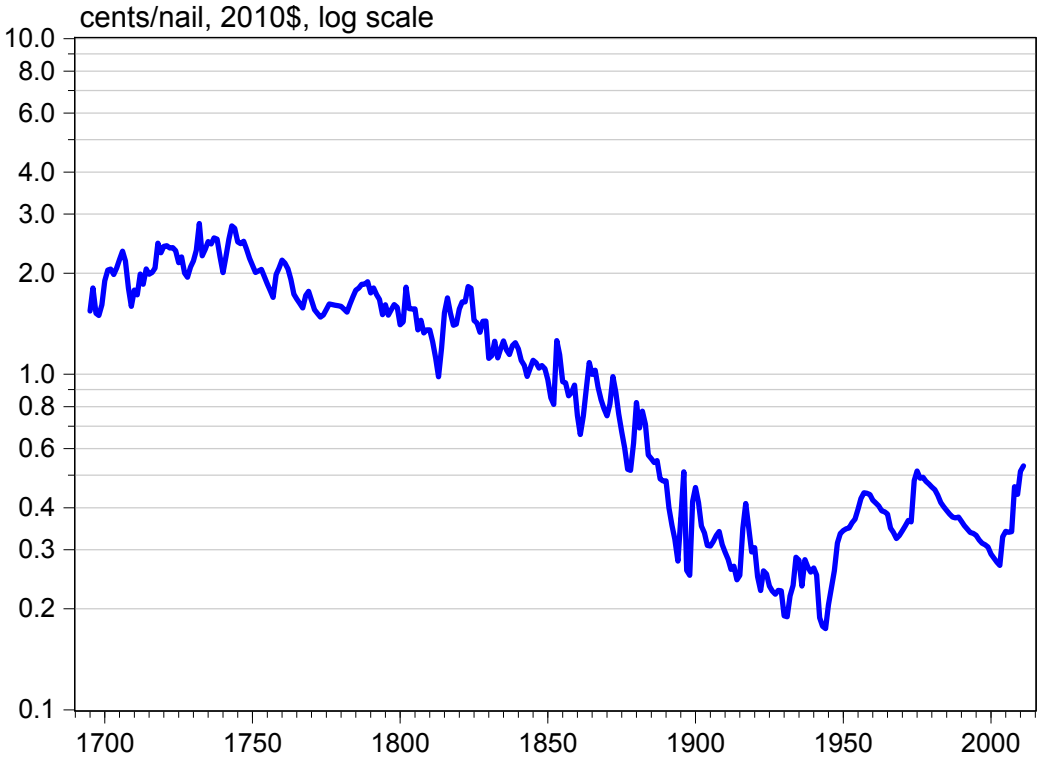

Figure 5a

Real Price of Nails (cents/lb)

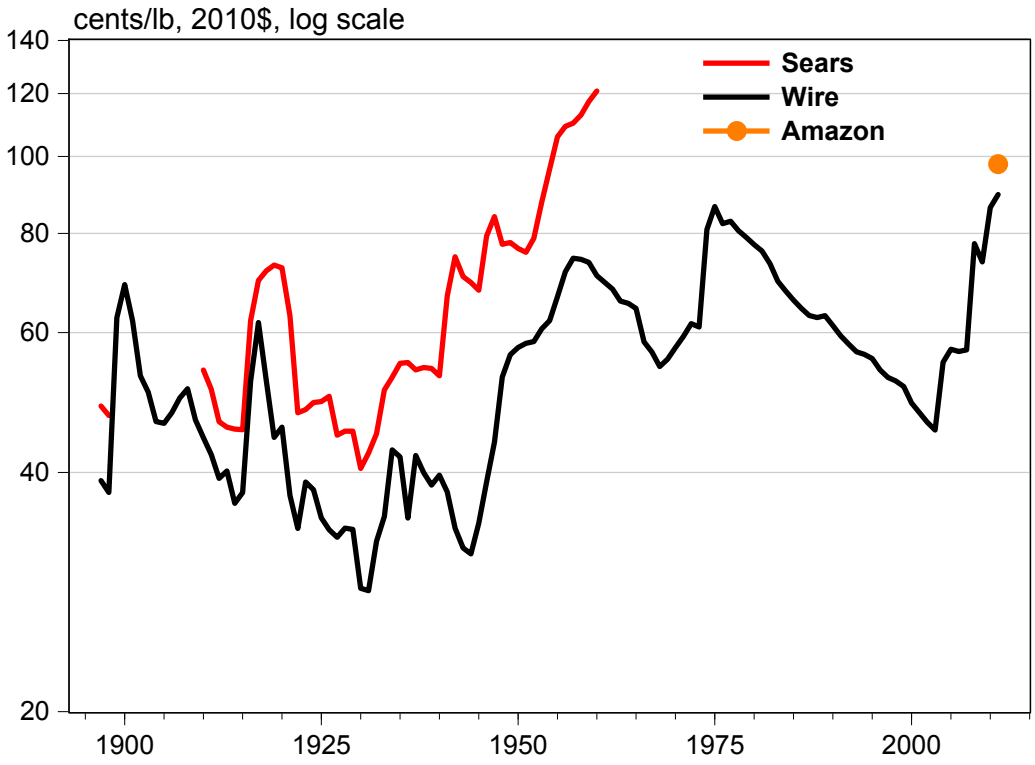

Figure 5b

Real Price of Nails (cents/nail)

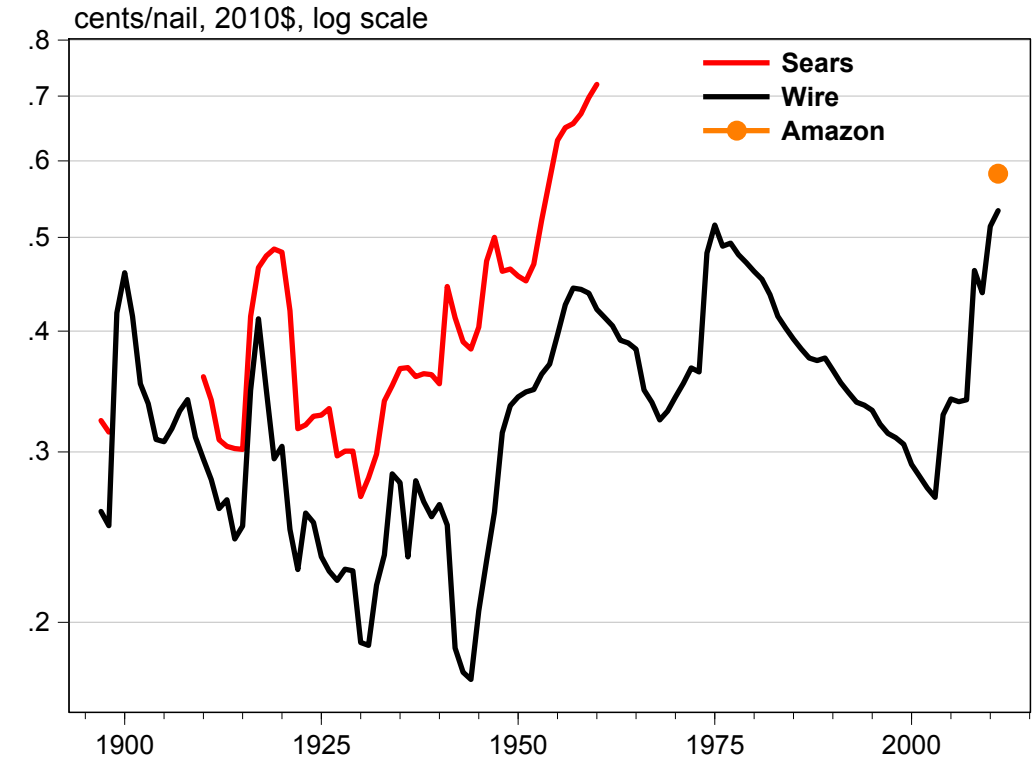

Figure 6a

Domestic Absorption of Nails in Thousands of Tons and Value as Share of Nominal GDP

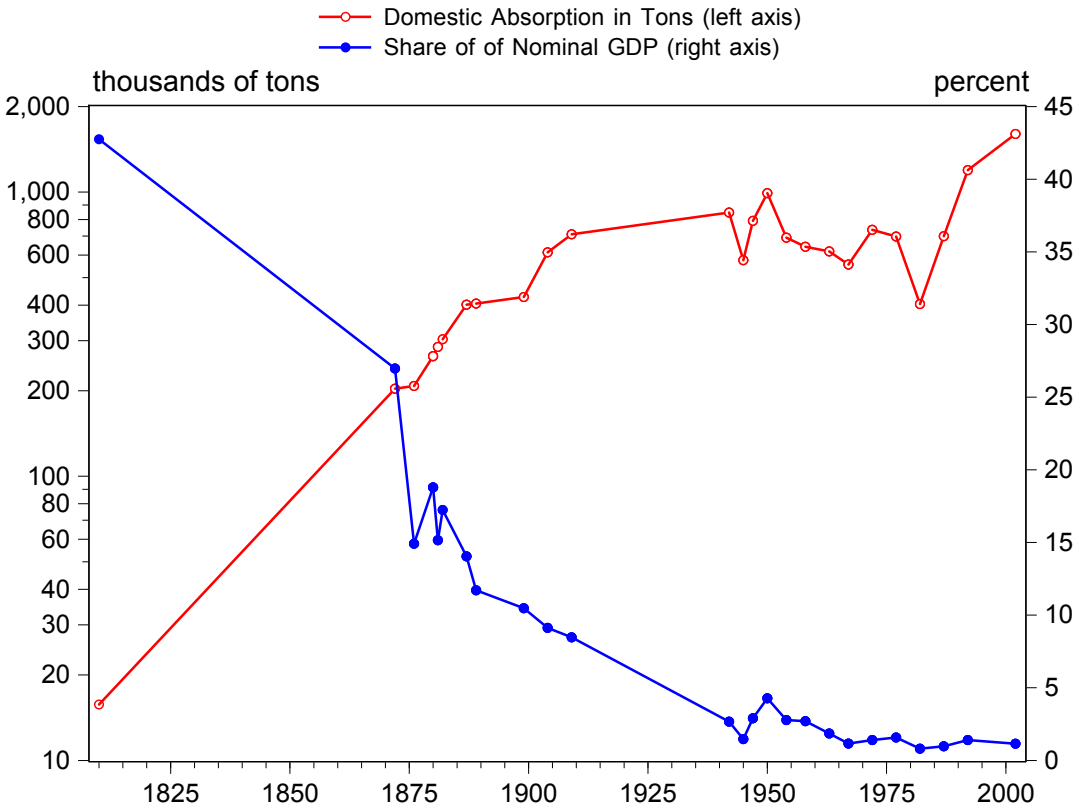

Figure 6b

Nail Imports as Share of Domestic Absorption

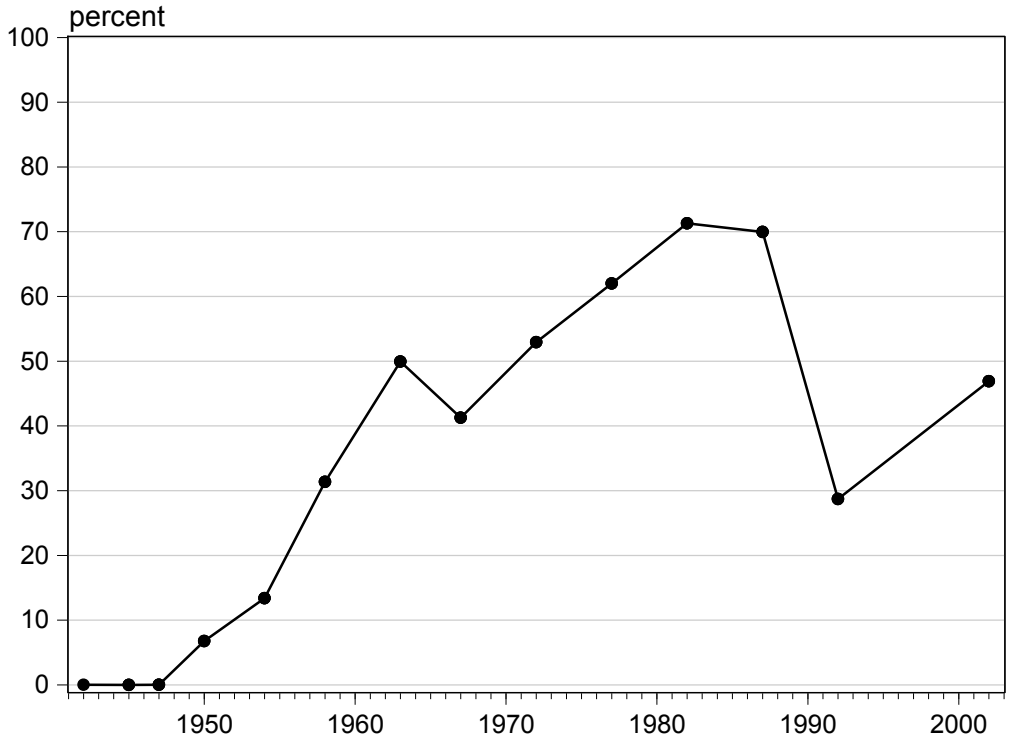

Figure 7a

Real Price of Nails and Imported Nails and Screws