The Price of Nails since 1695: What Can We Learn from Prices of a Simple Manufactured Product?

Daniel E. Sichel*
Wellesley College and NBER

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ABSTRACT

This paper focuses on the price of nails over the past 300+ years and the proximate source of changes in those prices. Why nails? They are a basic, non-revolutionary manufactured product whose form and quality have changed relatively little over the last three centuries, yet the process for producing them has changed dramatically. Accordingly, nail prices provide a useful prism for examining effects of changes in manufacturing over the last 300+ years. Several conclusions emerge. First, the price of nails fell significantly relative to the prices of an overall basket of consumer goods and services from the late 1700s to the mid 20th century, with real prices falling by a factor of about 10. These price declines had important effects on downstream industries, most notably construction. Second, while declining materials prices contribute to reductions in nail prices, the largest proximate source of the decline in real prices during this period was multifactor productivity growth in nail manufacturing, highlighting the likely role of the specialization of labor and re-organization of production processes. Third, with these price declines, the share of nails in GDP dropped back from 0.4 percent of GDP in 1810—comparable to today's share of household purchases of personal computers—to a *de minimis* share more recently; consistent with that change, nails played a more important role in earlier days in American life. Finally, real nail prices have increased since the mid 20th century, reflecting an upturn in materials prices and other factors.

1. Introduction

Almost every dimension of economic life in the United States was dramatically transformed by the first and second industrial revolutions. More recently, the digital revolution has brought further extraordinary changes. Commentary on these developments often has focused on the most dramatic developments. For example, Nordhaus (1997 and 2007) showed that the real cost of computing dropped by a factor of at least 2 trillion times from 1850 to the early 2000s and that the real cost of lighting fell by a factor of about 3400 from 1800 to 1992.

This type of evidence, while providing important insights, does not particularly shed light on the many important developments and changes that affected more pedestrian products. We need to look elsewhere for that, and one product that hits the nail on the head is, wait for it, nails. Nails are a basic manufactured product whose form and quality has changed relatively little since the late 1600s, and nails produced then would be quite recognizable today (as would nails produced in ancient Rome). Yet, the manufacturing process for nails has changed dramatically, with a shift from artisanal to factory production, a change in power source from hand to water to steam to electricity, and a shift in materials from iron to steel.

Coincident with those changes, the price of nails fell significantly, as evidenced by the price index for nails that is constructed back to 1695 and that is the focus of this paper. Indeed, the real price of nails (relative to an index of overall consumer prices) fell by a factor of about 10 from the late-1700s to the middle of the 20^{th} century, averaging a decline of about 1-1/2 percent a year. While these declines are paltry compared with those for lighting or computation, even basic manufactured products experienced large price declines, and an individual nail today seems cheap and disposable.

These declines in the price of nails provide a useful entry point for deepening our understanding of changes in manufacturing processes, key sources of those changes, and the evolving role of nails in the U.S. economy. Moreover, nails are ideal for this analysis because there has been so little change in the product itself, thereby avoiding the need to account for any such changes as is the case for so many other products.

Even for a run-of-the-mill item like nails, the changes in manufacturing processes were a big deal. 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. Adam Smith (1776) highlighted early process improvements for pin manufacturing, and many of the same developments would have been applied to nail manufacturing as well. Changes since then have been more dramatic. Currently, a typical nail-making machine with a footprint of about three square feet can produce 300 to 450 wire nails in a minute while the newest machines can produce 2000 nails per minute. Assume 500 nails per minute, on average, and that a worker can operate seven machines at once.[1] Then, the number of nails produced per minute of worker time has increased by a factor of 3500 times since the era of hand-forged nails.

Over the same span of 300-plus years during which these transformations occurred, the place of nails in the economy (and in popular accounts) also underwent a huge shift. In 1810 (the earliest year for which I could assemble necessary data), domestic absorption of nails in the U.S. (their use measured as production plus imports minus exports) was 0.4 percent of GDP on a current-dollar basis as shown in figure 1. To put this share into perspective, in 2019 household purchases of personal computers and peripheral equipment amounted to roughly 0.3 percent of GDP and household purchases of air travel amounted to about 0.5 percent. That is, back in the

[1]Roelif Loveland, President of Maze Nails, reported in a January 2020 email provided information on the number of nails per minute made by a typical nail-making machine as well as the number made by the latest machines. In addition, he reported that a worker can operate seven machines at once.

1700s and early 1800s, nails were about as important in the economy as computers and air travel purchased by consumers are today.

Not only were nails a consequential component of GDP in earlier times, they also were considered far more precious, as reflected in common practice and literature. The high value of nails during earlier periods is reflected in the practice of recovering used nails. According to Temin (1964 p. 42), during the 1700s abandoned buildings were sometimes burned down to facilitate the recovery of nails. Even a century later, nails were still highly valued as can be seen from the following quote from *Little House on the Prairie* (Wilder, 1935, p. 124). The quote describes attaching a roof to a log home on the frontier during the 1870s (after the price of nails had already fallen significantly from the late 1700s) and highlights the value placed on nails:[2]

> 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.
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> Then Mary and Laura watched it fall and they searched in the grass till they found it. Sometimes it was bent. Then Pa carefully pounded it straight again. It would never do to lose or waste a nail.

Today, 150 years after the period depicted in *Little House,* the importance of nails in the economy has fallen way off as prices have declined and alternative means of fastening objects together have been developed. Indeed, the share of nails in GDP (figure 1) dropped to a *de minimis* value of less than 0.01 percent by 2017.

The rapid price declines for nails documented in this paper also affected economic activity more broadly in the 19th and early 20th centuries. Those effects were especially

[2] Despite the very substantial declines in the relative price of nails documented in this paper, some builders still recover them from construction sites though this now largely is seen as a sign of frugality. For example, the *New York Times* (1999) reported in the obituary of Fred Trump (Donald's father) that the senior Trump at one of his construction sites "would walk through the studs and across the plywood floors, picking up unused nails to hand back to his carpenters the next day."

pronounced in the construction industry (including railroad beds and fences) during a time when construction represented a larger share of economic activity than it does today.[3] One particularly important transformation within construction is that, according to Jackson (1987), the drop in prices of nails enabled balloon-frame construction to develop in the 19th century as a considerably lower-cost style of construction than long-used post-and-beam. Balloon-frame construction—in which a building's walls are made up of dimensional-lumber studs (2x4s today) that carry the weight of the structure—use many nails and became feasible only after the relative price of nails had fallen far enough. Outside of construction, other downstream sectors benefitting from price declines for nails include furniture, wooden containers and boxes, and many other products made from wood.

The story told here of price declines and attendant changes, of course, raises the question of what accounted for the drop in nail prices. To more deeply understand the sources of changes in nail prices, this paper decomposes changes in nail prices since 1790 into their proximate sources by calculating contributions from changes in the prices of capital, labor, energy, materials, and purchased services as well as in multifactor productivity (MFP). While this decomposition should not be interpreted as causal, some interesting points emerge.

Declines in materials prices (iron in the earlier part of the period and steel later) contributed noticeably to the drop in nail prices during the 19th century and first part of the 20th. Perhaps more surprising is that MFP growth—a catchall category capturing technological advance and any other sources of changes in prices over and above changes in the cost of inputs—made the largest contribution to price declines for nails through 1930. The large role for MFP during the period of rapid price decline is consistent with the story told by Atack, Margo,

[3] Residential and nonresidential construction amounted to 16 percent of nominal GDP in 1839—according to Gallman (1966)—compared with about 6¾ percent in 2019.

and Rhode (2020) that factors such as the specialization of labor—which would be captured in MFP—accounted for the bulk of productivity advances in manufacturing in the 19th century rather than just mechanization that would show through in changes in the cost of capital and power. The large role for MFP also is consistent with the idea developed by David (1990) that reorganization of business processes—which also would be captured by MFP—is an essential ingredient in the realization of the full productivity benefits of new technologies.

The mid-20th century represented the end of what could be called the golden age of nail manufacturing that started in the late 18th century. Since then real prices of domestically produced nails have risen considerably. These increases reflect higher materials prices as well as, at least in part, a shift in U.S. production to more specialized and higher-priced products as more standard nails largely came to be imported and advances in the technology of producing basic nails dwindled. In addition, the introduction of nails guns in the 1980s offset a part of these price increases by significantly lowering the "all-in" price of an installed nail in construction and some other applications by reducing the amount of time needed to install a nail.

2. A Brief History of Nails

Nails fall into three broad types—hand forged, machine cut, and wire—with each of these types dominant in each of three overlapping periods as described in Adams (2002), Lewis (1998), and Wells (1998). (Additional details on the timeline and additional source citations are in Appendix Table A1.) 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), a skilled nailsmith could produce a nail from a blank in about one minute. This type of production coincides with Goldin and Katz's (1998) artisanal production done largely by hand by skilled workers.

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 as production shifted to factories, mirroring many of the developments of the broader industrial revolution. The power source shifted from water to steam and later electricity, and more and more of the individual tasks of nailmaking became mechanized. 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 specialty applications such as period architecture and furniture.[4] For wire nails, the manufacturing technology also improved considerably in the decades after the 1880s. Today, a significant part of nailmaking has become continuous-process manufacturing, with large wire rolls fed into a machine that automatically transforms that wire into finished nails.[5]

Figure 2 illustrates each of these three types of nails. The top nail is hand-forged; the middle one is a cut nail, and the bottom one is a wire nail. The hand-forged and cut nails look

[4] One manufacturer in the U.S. (Tremont Nail Company in Wareham, MA) still makes cut nails, in some cases using vintage machinery with some components dating back to the early 19th century. (Based on tour of factory and conversation with Gary Anderson in early 2020.)

[5] Goldin and Katz (1998) describe shifts from artisanal to factory to continuous-process production technologies, and how these shifts affected the complementarity of capital with skilled and unskilled labor.

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 late 19th century Sears catalogues depicting a nail that looks much like one that could be purchased at Home Depot today.

Beyond improvements in the manufacturing technology, the variety of nails produced has expanded significantly over the years, including nails made from specialized materials for particular applications, nails made with coatings to prevent rust, and nails made with rings around the shank to increase holding power. Indeed, the website of Maze nails, one of a handful of current American nail manufacturers, lists 110 distinct varieties of nails, not counting different sizes and colors of the same type of nail.[6]

3. Nail Prices

Raw Nominal Price Data

Figure 3a 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

[6] Catalog available at https://www.mazenails.com/assets/pdf/maze-nails-price-list-catalog.pdf. The list of nail varieties is on page 4 of the 2020 catalog.

different "regimes" of data, and the appendix 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. Beveridge collected these prices from log books and other records of hospitals, schools, and government departments. Given the time period, these quotes must have been for hand-forged nails, and 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 U.S. cents using an exchange rate from U.K. pounds to U.S. dollars for 1792.[7] Thus, before 1792, 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 3a captures prices from Cole (1938) for the period from 1784 to 1813. These data represent wholesale prices in the Philadelphia market.[8] The type of nail is not specified, but, given the time period, these quotes probably cover a mix of hand-forged and cut nails. I refer to this segment 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. These data are from Cole from 1814 to 1828 and from various other sources in the later part of the period. The price quotes cover wholesale prices for New York City through 1849 and prices posted by a Pennsylvania nail manufacturer through 1890. The quotes are for dollars per hundred pounds and were converted to cents per pound.

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

[8] As highlighted in the text, the price quotes from nails are taken from disparate sources, often reflecting prices in major cities that may or may not be representative of nail prices in other locations or purchased through other distribution channels. Overcoming this challenge would be difficult given available data. That said, Rothenberg (1979) found that movements in prices received by farmers for agricultural products in rural Massachusetts were similar to price movements for those products in Boston and New York City.

The black segment in figure 3a covers the period from 1890 to the present and refers to wire nails. This segment incorporates data from the Bureau of Labor Statistics (BLS), reflecting a number of different reports for the earlier periods and producer price indexes (PPIs) for more recent years. 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.

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 nails in 1890 are consistent with what historical archaeologists characterize as the eras in which each type of nail was prominent as described in Wells (1998, figure 8).

At these breakpoints, as can be seen in figure 3a, there are some discontinuities in prices. In the late 1700s, the series for forged nails in 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 prices were collected often are pretty limited so there likely are differences in what is being priced. The break after 1813 reflects the data source which began explicitly pricing cut nails starting 1814. The implied jump in price in that year is not so surprising given that it occurred during the War of 1812 when many commodity prices rose. The other interesting overlap is that between the series for cut nails (red) and wire nails (black). 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. The resolution of this puzzle is discussed in the section below on quality adjustment.

An Alternative Price Series since 1897

As a check on the BLS prices used since 1890 for nail prices, I also collected nail prices from Sears catalogs. These quotes extend from 1897 to 1960, the last year the Sears catalog included steel wire nails in a variety of sizes. One appeal of the Sears prices is that it is straightforward to compare like to like by pricing the same nail over time. For example, it is possible to track the price of 2", size 6d nails over this period, where a number followed by the letter d is a standard for nail sizing. Moreover, economists have a long tradition of using Sears catalogs (and those from other retailers) to track prices over time--including work by Rees (1961) and Gordon (2008)—so these catalogs are a natural source to use as a check on the BLS prices.

The Sears prices—plotted in Appendix figure A3—track the BLS prices on which I rely reasonably closely from 1897 through about 1940. However, starting after about 1940, the Sears price rises considerably more rapidly than does my preferred price series. While it is difficult to ascertain definitively the source of this difference, a likely factor is a shifting wholesale/retail margin at Sears. The PPI quotes forming the basis for my preferred price series 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 more recent period, it appears that the Sears catalog was catering almost 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 marketing changes support the view that Sears gradually shifted from being more of a wholesaler to more of a retailer in the market for nails after 1940 or so. Such a shift would be consistent with the more rapid increase in Sears' prices relative to the PPIs and would suggest that Sears prices since about 1940 may not be so useful for tracking producer or wholesale prices of nails. This gap also emphasizes the importance of care in choosing what price of a product to track over long spans of time.[9]

Real Prices

The real price of nails—relative to an overall index of consumer prices—is constructed by deflating the nominal nail price index with an index of consumer prices. I construct a consumer price index back to 1695 by using ratio splices to link together series for the United Kingdom retail price index (RPI) from 1695-1784, the U.S. Consumer Price Index (CPI) from measuringworth.com for 1784-1928, and the chain price index for personal consumption expenditures from the Bureau of Economic Analysis for 1929-2018. The overall consumer price series is shown in figure 3b. The base year for this index is 2012 so the real price measures shown are in terms of 2012 dollars. Of course, as Gordon (2008), Nordhaus (1997), and many others have noted, comparisons of price indexes 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 relative to those of other goods and services.

[9] More broadly, I suspect that this issue of shifting wholesale/retail margins could affect other products in the Sears Catalog as well. In addition, Gordon (2008) found evidence for a later period that prices for apparel in Sears catalog increased relative to the CPI as Sears was increasingly undercut on prices by new competitors such as Target and Walmart. My conjecture about margins, along with Gordon's results, suggest that researchers using catalog prices may need to be mindful of what catalog prices represent.

Real prices of nails, relative to the consumer prices, are shown in figure 4a on a cents per pound basis from 1695-2018. On this basis, without any adjustment for quality changes, the real price of nails was relatively stable from 1695 through the early 1800s (at least compared with the large decline that followed) with a peak in the mid 1700s. Then, during the 1800s, the real price fell substantially through the 1930s before rising, on balance, over subsequent decades.

Quality Adjustment

Ideally, price indexes are constructed on a quality adjusted basis, so that price comparisons over time are like-to-like. Directly comparing prices of a car today to a Model T in 1908 would be problematic because the quality of the vehicles is so different so that it would not represent, without some adjustments, a like-to-like comparison. Quality adjusting prices of nails is much easier because, as noted above, nails have change very little over the centuries. Indeed, just two adjustments are made to construct a quality-adjusted price index for nails.

First, nail prices are adjusted so as to, as well as possible, track the same size nail over time. The series on nail prices on a cents per pound basis does not price a homogenous product but rather is conflating prices of nails of many different sizes. 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. For the earlier periods before nails sizes were standardized, I standardize on 2" nails. To do this, I convert pounds of nails to the number of 2" nails using an estimate of the number of 2" nails per pound. As detailed in the appendix, I use a count of 85 nails per pound for both forged and cut nails for the period spanning 1695 to 1889 based on an average of counts from multiple sources. Wire nails are considerably thinner, and as the quotes switch to wire nails in 1890, the count jumps to 150 nails per pound for size 6d 2" nails in that year. The count briefly increases further 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. With these counts, I convert prices in real cents per pound to real cents per nail, and figure 4b shows these prices. One key difference is evident between figures 4a and 4b. 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, enhancing 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.

The second adjustment accounts for differences in other characteristics of hand-forged, cut, and wire nails. Key differences include holding power and shipping costs.

Regarding holding power, 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 when pounded into wood. In the world of wood engineering, these differences in holding power have been measured, and as discussed in the appendix the literature suggests that cut nails have about twice the holding power of wire nail. The prices plotted in figure 4b could be adjusted explicitly for differences in holding power. However, 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 and may not be valued as highly as would be suggested by an explicit adjustment holding power. (The Appendix provides some additional information on the holding power of cut and wire nails.)

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. Again, with some additional data and calculation, the prices in figure 3b could be explicitly adjusted for differences in shipping costs. (See the appendix for some additional analysis of shipping costs.)

How best to account for identifiable differences in holding power, shipping costs, and any other relevant characteristics of different types of nails? Ideally, a so-called hedonic price index would be constructed that would use statistical techniques to explicitly account for all relevant characteristics of nails and for how the marketplace valued those characteristics. Data limitations make that impossible, and so I use another technique, a matched-model procedure. This methodology links prices in figure 3b across the switchover points from one type of nail to another; this linking will accurately adjust for quality change to the extent that the price/performance ratio for nails was equalized by the market in periods when multiple types of nails were available. This approach is a sensible and widely used methodology to construct a consistent price index that, as much as possible, holds quality constant so that like can be compared to like given available data. Specifically, 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 and extend backwards from that year using percent changes in prices for the earlier type of nails in the earlier years.

The matched-model price series is plotted in figure 5. It shows that real prices of nails fell by a factor of about 10 from the late-1700s to its low point in the middle of the 20th century, amounting to a 1.6 percent annual average rate of decline from 1792 to 1930. Declines in real prices during this period were uneven, with especially rapid declines during two periods: from the early 1820s to 1860 and from the early 1880s through about 1930. Since the middle of the 20th century, real prices have risen considerably on balance.

4. What Accounted for Changes in the Real Price of Nails?

Over long spans of time, changes in nail prices, as for any product, should largely depend on changes in the cost of inputs and on advances in the production technology (very roughly captured through MFP). This relationship can be captured using the dual representation of a production function. While such a decomposition is not causal in any sense, it does provide guidance as to the proximate sources of price changes, for example, quantifying linkages between changes in prices of nails and changes in the prices of key inputs such as iron or steel.

Here's the basic setup for this decomposition. Conventional growth accounting decomposes growth in output (value added) into contributions of capital and labor based on a Cobb-Douglas production function in which growth rates of inputs (capital and labor) and factor shares are time-varying. The KLEMS variant of growth accounting—described in Jorgenson, Fukao, and Timmer (2016)—decomposes growth in gross output (Y) into contributions from capital (K), labor (L), energy (E), materials (M), purchased services (S), and MFP in a so-called KLEMS decomposition:

$$\dot{y} = \alpha_K \dot{k} + \alpha_L \dot{l} + \alpha_E \dot{e} + \alpha_M \dot{m} + (1 - \alpha_K - \alpha_L - \alpha_E - \alpha_M)\dot{s} + \dot{mfp} \qquad (1)$$

where lower case variables with dots over them represent growth rates (log differences) of inputs and the $\alpha's$ are the factor shares. In the typical setup, both the growth rates of inputs and the factor shares vary year-to-year. Because I am focusing on changes in prices rather than quantities, I turn to the dual representation of the production function:

$$\dot{p} = \alpha_K \dot{rc} + \alpha_L \dot{w} + \alpha_E \dot{p_E} + \alpha_M \dot{p_M} + (1 - \alpha_K - \alpha_L - \alpha_E - \alpha_M)\dot{p_S} - \dot{mfp} \quad (2)$$

where P is the price of nails and RC, W, P_E, P_M, and P_S are the rental cost of capital, wages, and prices of energy, materials, and services, respectively, with all prices measured in real terms. Notice that the growth of MFP enters the dual equation with a negative sign because improvements in MFP hold down prices relative to the contributions of factor costs. In short, equation 2 says that changes in the price of nails reflects a weighted average of changes in input (factor) prices using factor shares as weights with an adjustment for MFP growth. To implement equation 2 empirically, I compiled an annual dataset on factor prices and factor shares to supplement the annual data on quality adjusted nail prices that is plotted in figure 5.

Data on Factor Prices

For factor prices, I assembled annual data back to 1790 on the rental cost of capital, wages, the price of energy as likely used in manufacturing, the price of steel and iron for earlier years, and an estimate of the price of purchased services. 1790 was the initial year because that is when the wage series started. (Additional details on sources and data construction are described in the Appendix.) Briefly, I used data from various sources, including the BLS, Gallman and Rhode (2019), measuringworth.com, the MacroHistory database, Temin (1964), and Warren and Pearson (1933). Each factor price was converted to real (2012 $) using the index for consumer prices that was used to calculate real nail prices.

Figure 6 plots the resulting real factor prices for each input with each price indexed to 100 in 1790. As the figure indicates, real wages rose substantially from 1790-2018 as did the real price of purchased services. (No surprise on purchased services given that wages were used as an extrapolator prior to 1949.) The real rental price of capital was relatively flat from 1790 until about 1900, and then moved lower through 2018. The real price of energy followed a similar trajectory to that of capital, though it declined more rapidly during the 20th century until the early 1970s energy crisis after which it moved higher. The real price of materials fell through about 1950 and then began moving higher.

Discussion. These long spans of factor prices rely on solid research by statistical agencies and economic historians. That being said, they undoubtedly are measured with some error. As noted, linking together price statistics over long spans of time can miss the benefits of more revolutionary changes in inputs. For example, the benefits of the switch from water power to steam likely are missed in my methodology given that fuel prices were used to extend back into the period when water was a principal power source. And, the linking methodology also may miss benefits of the switch from steam to electric power. Moreover, I pulled data from many different sources, likely creating inconsistencies in the definitions and data collection procedures used.

Regarding the rental price of capital, the capital stock deflators that I rely on were not constructed with the attention to quality adjustment that is typical for many types of capital in a modern price measurement framework. Nonetheless, these factor prices capture important trends over time. In addition, the price decomposition I implement relies only on growth rates (log differences) in these factor prices so some inconsistencies in levels will be washed out. Finally, as will be evident from the sensitivity analysis described below, even substantial allowances for measurement error in the cost of capital would not alter the basic story that emerges from my analysis.

Data on Factor Shares

For factor shares for capital, labor, energy, materials, and purchased services, I also had to rely on a range of sources, including BLS' KLEMS decomposition for fabricated metal products that started in 1949, the *Hand and Machine Labor* study published in 1898 that compared machine production for many products in 1897 to hand production for the same products in 1813[10], and the Bateman, Weiss, and Atack extracts from the 1850 and 1870 Census of Manufactures as described in Atack and Bateman (1999). From these sources, I obtained annual factor shares from 1949-2018 and shares for 1813, 1850, 1870, and 1897. For the intervening years, I linearly interpolated shares. For the years prior to 1813, I used the 1813 shares. Because I am using a decomposition into five factors (plus multifactor productivity), the labor and capital shares will not be the familiar 2/3 and 1/3, although the five factor shares still sum to unity under the maintained assumption of constant returns to scale.

Details for data sources and the construction of factor shares are provided in the Appendix. That being said, estimating factor shares for 1850 and 1870 from the Bateman, Weiss, and Atack Census extracts has not been done often and is not entirely straightforward so a brief explanation here is warranted with details described in the Appendix.[11] For 1850 and 1870, the extracts provide firm-level accounting information for a sample of firms in those years. I identified the firms in the extracts for which nails were the dominant output: seven firms in 1850

[10] For background on the *Hand and Machine Labor* study, see Atack, Margo, and Rhode (2019 and 2020). They recently digitized the voluminous information in that study, making it much more widely accessible to researchers. Although not directly related to the measurement of factor shares, see Margo (2015) for a discussion of likely measurement error for the labor input of smaller firms relative to larger firms.
[11] One other paper that used these data to identify key aspects of production processes is Margo and Atack's (2019) paper on blacksmithing in the U.S. from 1850-1870.

(three hand powered, three water powered, and one steam powered) and four firms in 1870 (three steam powered and one water powered). For each firm, the extract provided figures for the value of output, the wage bill, the cost of energy inputs, and the cost of materials inputs. From these, I could calculate factor shares for labor, energy, and materials. The extract also provided an estimate of firm "capital" though it is not entirely clear what is included in that figure. Nonetheless, I used that number and the user cost of capital formula (along with some assumptions about components of the formula) to estimate the factor share for capital. The factor share of purchased services was estimated as a residual. The numbers used for my decomposition are the unweighted average factor shares across the seven firms in 1850 and across the four firms in 1870.

Figure 7 plots the estimates of factor shares from 1790-2018. Two observations fall out immediately from this figure. First, the capital intensity of nail production rises over the period, with capital's share rising steadily over time, from a low between 3 and 4 percent at the beginning of the sample to about 15 percent by 2018. Second, the energy share remains low throughout the sample, though it is lowest in the earliest years. Other observations are more subtle, given the ups and downs of factor shares. Labor intensity was relatively high early in the sample during the period of hand production (about 34 percent in 1790). As nail manufacturing began to become mechanized, the share fell to about 25 percent in 1850. The share then rose over the next 100 years to reach just above 40 percent in the early 1950s. Since then, my estimate of the labor share drops back to about 30 percent by 2018, likely owing to increased mechanization as reflected by the rise in the capital share during this period. The materials share generally increases and then falls back, rising from around 36 percent in 1790 to about 50 percent by 1870, drifting lower to about 40 percent by the late 1940s, and then fluctuating around that value through the end of the sample. Finally, the purchased services share generally declines and then increases part way back; specifically, it falls from around 25 percent early in the sample to around 10 percent in the 1980s before rising back up to about 15 percent by the end of the sample.

Discussion. In my view, the factor share estimates are the weakest element of the price decomposition, given the sparseness of years for which I obtained estimates, the range of very different sources and methodologies, and the incompleteness of data even for the years for which I obtained estimates. Indeed, one could argue that we just do not know enough about early factor shares to draw confident conclusions. However, the sensitivity check described below suggests that any measurement error in factor shares would not significantly affect the conclusions drawn from the decomposition of proximate sources of changes in real prices of nails. In addition, my estimates are not that different from those of other researchers using different sources, as described in the Appendix.

What Accounted for Price Changes?

With data on factor prices and shares in hand, I can calculate the price term on the left-hand side and each term on the right-hand side of equation 2 for each year, estimating MFP growth as a residual. For these annual estimates, I follow usual practice in the growth accounting literature in which the factor shares used in the decomposition are the average of shares for the two years covered by each annual percent change in a factor price; for example, the factor shares entering equation 2 for, say, 1872 are the averages of the annual factor shares for 1871 and 1872. Although I calculate the decomposition for each year, I only report averages over longer spans of time, given the short-run volatility in markups, tariffs, taxes, and other factors.

Table 1 and figure 8 report the price decomposition for nails, using equation 2. The selected periods shown correspond to eras I identified in trends for real prices of nails: the modest declines from the late 18th century through about 1820, the first wave of very rapid declines that came with increasing mechanization through 1860, the flattening out during the next two decades, the second wave of very rapid price declines between 1881 and 1930, and then the substantial increases in real prices from the 1930s through the end of the sample in 2018.

In figure 8, the solid black line plots the average annual percent change in real nail prices in each period, while the colored bar segments show the contribution of changes in the prices of each input. The exact numbers are reported in table 1. Looking across periods, the most interesting and important result in the decomposition is the large contribution of MFP (orange bars). In the early period (1791-1820) when real nail prices declined about 0.4 percent a year, rapid advances in MFP pulled down nail prices by an average of 1.5 percentage points per year. The improvement in MFP (and the downward pull on nail prices) was even more substantial during the first (1821-1860) and second (1881-1930) waves of rapid decline in real nail prices, with MFP growth holding down the annual average rate of change of real prices by 2.6 and 2.3 percentage points in these periods, respectively.[12] Then, in more recent decades, changes in MFP growth accounted for nearly 0.5 percentage point per year of the increase in real nail prices.

The very large role of MFP growth during the two waves of rapid price declines in real nail prices suggests that mechanization itself and changes in power sources, while important, were not the whole story for nail manufacturing. Other influences reflected in very rapid MFP growth in key periods also appear to have played an important role. For the 19th century, this pattern reflects the argument in Atack, Margo, and Rhode (2019 and 2020). They find, using their digitized version of the *Hand and Machine Labor* study, that mechanization per se

[12] The decomposition used here abstracts from shifts in the complementarity of capital to skilled and unskilled labor as the technology of nailmaking evolved, a factor highlighted by Goldin and Katz (1998). To the extent that such shifts are not accounted for by input prices or shares, they will be reflected in the MFP term in the decomposition.

accounted for only about one-third of the productivity advance in manufacturing between 1813 and 1897. In their analysis, the balance of 19th century productivity advance reflected other factors, such as the increasing specialization of labor. This pattern also reflects the story told by David (1999) for the transition from steam to electric power early in the 20th century. In particular, he highlights, the important role of reorganization of manufacturing processes in boosting labor productivity, a factor that would show up in the decomposition as MFP growth.

Materials prices (purple bars) also contribute importantly to declines in real nail prices, especially during the first and second wave of rapid price declines. Specifically, falling real materials prices pull down real nail prices by an average of about 0.75 and 1.3 percentage points per year in 1821-1860 and 1881-1930, respectively. These rapid price declines in materials prices—iron in the earlier period and steel in the latter period—likely reflect the dramatic advances in the manufacture of those inputs. This pattern of declining materials prices reversed more recently, consistent with the general upturn in commodity prices after 1950 documented by Jacks (2013). The upturn in materials prices in the decades after 1930 contributed about 0.3 percentage point per year to the average annual increase in real nail prices.

Among other factors, changes in the rental price of capital (dark blue bars) account for relatively little of the change in the real prices in any period, reflecting the modest changes in the price of capital and capital's relatively small factor share. On the one hand, this result is surprising. On the other hand, this observation fits with the story that there was more than just mechanization to the changes in nail manufacturing. Real wages (the price of labor shown as the red bars) make a consistent and noticeable positive contribution to nail prices of between about 0.3 and 0.8 percentage point per year on average, partially offsetting other sources that pushed down nail prices.

Interestingly, declines in the price of energy make only very modest contributions to declines in the real price of nails through 1930 and also very little contribution to the upturn in nail prices in more recent decades. The factor share of energy is sufficiently small so that even substantial swings in energy prices do not account for much of the movement in real nail prices.

Sensitivity Analysis and Measurement Error

Factor shares. As noted, the estimates of factor shares are based on incomplete source data and so could well be subject to measurement error, especially for periods prior to 1949 (the first year for which more detailed BLS data on shares are available). To assess the effect of possible measurement error in factor shares, I did a sensitivity analysis, holding factor shares prior to 1949 fixed at their 1949 levels and recalculating the decomposition of price changes. In this "fixed-share" scenario, the overall pattern of contributions is very similar to that in the decomposition reported above with my estimates of factor shares. This result suggests that measurement error in factor shares would likely have little effect on the conclusions drawn from the decomposition of price changes.

Capital prices. As noted, one could have concerns that the price deflator for capital in the earlier periods did not fully account for quality improvements. If quality-adjusted capital prices fell more rapidly than is reflected in the price deflators used to construct the rental price of capital, then improvements in the quality of nail-making machinery would become a more important factor contributing to the decline in real nail prices as compared with its negligible effect in the numbers reported above. And, if the capital contribution to price declines were larger in some periods (say during the two periods of very rapid declines in nail prices), then the contribution of MFP to price declines—which is calculated as a residual—would be smaller in those periods.

That being said, even significant measurement error in the price deflator for capital would not affect the overall story. Between 1790 and 1948, the real rental price of capital used in the decomposition declined at an average annual rate of 0.29 percent. (By comparison, the average rate of decline of this variable from 1949-2018 is 0.32 percent.) A simple sensitivity analysis provides an illustrative example of the possible role of mismeasurement in capital prices. Suppose that the true real rental price of capital declined 4 percentage points faster per year. (Such a change would represent a massive reassessment of deflators for capital in the 19th century.) With capital's factor share averaging in the neighborhood 10 percent, adopting this alternative cost of capital would make capital's contribution to declining real nail prices larger by 0.4 percentage point (=4 x 0.10) a year with an offsetting reduction in the amount by which MFP growth held down nail prices. While certainly noticeable, this shift is modest enough to suggest that possible measurement error in the price deflator for capital is unlikely to change the overall story dramatically.

What Accounted for the Increases in Real Prices Since the Mid-20th Century?

The decomposition of real price changes suggests that the increases since the 1930s relative to the sizable earlier drops primarily reflects two factors: the upturn in materials costs after decades of declines and a *decline* in MFP after sizable increases in earlier periods. (Recall that, as shown in equation 2, increases in MFP hold down prices while declines in MFP boost prices.) Real wages also rose in this period and made a positive contribution to the change in nail prices since the mid-20th century, although that positive contribution is not so different from that in earlier periods.

Undoubtedly, the story just described captures important elements of the story for the period since the 1930s. The increase in steel prices amid a more general rise in commodity prices is easy to understand. The decline in MFP, however, is more puzzling. Did the ability of manufacturers to organize production really go backwards? This question raises the possibility that other factors, not reflected in equation 2, may also have played a role. Possibilities along these lines include the rising import share of nails and the shifting product mix of domestic production.

Some straightforward calculations (detailed in the Appendix) show that the import share for nails (imports/domestic absorption) began a dramatic uptrend in the 1950s, rising to about 70 percent by the 1980s before dropping back somewhat. Moreover, the increase in imports came earlier than for many other manufactured goods likely reflecting that by 1950 the technology for producing basic wire nails was well understood and had become rather pedestrian.

Several pieces of evidence suggest that this increase in imports led domestic producers to shift to more specialized, higher-value products. First, the BLS discontinued specific series for prices of domestically-produced nails after 1998 and shifted to pricing a broader category of steel hardware presumably because the agency no longer could find enough price quotes for domestically produced basic nails. Second, a current U.S. nail manufacturer confirmed the shift in product mix. Specifically, Maze nails, one of the few remaining U.S. producers of nails, produces mostly specialized nails. In addition, by the 2000s the U.S. military was having difficulty finding domestically-produced basic hardware as noted in Mandel (2011).

The final evidence supporting the view that domestically-produced nails represented a different product mix than imported nails comes from a comparison of prices of imported and domestically-produced nails. Relevant import price data are available starting in 1974, though consistent with the earlier theme prices are available only for broader and broader categories over time. (From 1974-2005, the available series covers “nails, screws, nuts, bolts, and rivets of iron, steel, copper or aluminum," while though 2010, it reports prices for "hardware manufacturing," and since then it covers the even broader category of "fabricated metal products.") On this measure, real import prices fell nearly 60 percent from 1974 to 2018. During this time period, the matched-model index for prices of domestically-produced nails increased, on balance. This sharp divergence in the trajectory of prices suggests that the import price series and the PPI for domestically-produced items were tracking different products. (Additional information on import prices is provided in the Appendix.)

Taken together, this evidence suggests that starting in the late 1990s, my series on real "nail" prices was no longer tracking the 2-inch, size 6d nail that I standardized on in earlier periods. While I do not have access to the underlying detail for the relevant PPI series, it is easy to imagine scenarios in which prices of specialty nails would rise faster than those for basic nails that were now imported in significant quantities. To the extent that this shift in product mix is leading to more rapid increases in the PPIs in the matched-model index, then that shifting product mix also contributed to the runup in real nail prices in recent decades.

Nail Guns

Nail guns, which first became widely available in the early 1980s, are an important innovation in the construction industry. They had sizable effects on the all-in "installed" price of a nail, and, from the perspective of a user, offset some of the increase in the real price of nails in recent decades. Indeed, nail guns raise the question of what nail-related product should be priced? If it is an individual nail, then nail guns can be regarded as a distinct piece of complementary 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.

In mid-2020 on Amazon.com, a high-quality pneumatic nail gun that shoots 2” nails could be purchased for $247 and a small compressor and air hose for $170. Packs of nails for the gun are about $75 per 5000 nails—about 1.5 cents per nail and about twice the price of the same size nail not packed in in strips for a nail gun. In contrast, a standard claw hammer costs about $16.[13] For illustrative purposes, assume that a nail gun and compressor last 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 $25 per hour, somewhat below what the Bureau of Labor Statistics reported as the average hourly earnings of a construction worker in July of 2020 on the assumption that a nail installer is somewhat less skilled than an average construction worker and is paid a bit less. Finally, I assume (based on personal experimentation with a hammer and nail gun) 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. With these assumptions, a plausible estimate of the cost per *installed* nail for a worker using a hammer is 7.7 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 3.6 cents per nail, less than half the cost using a hammer.[14] This calculation indicates that the advent and diffusion of nail guns offset some of the rise in the price of an installed nail thereby mitigating the upward trajectory of nail prices in recent decades.

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[13] Prices were pulled from Amazon in August 2020 for a DeWalt DWF83PL framing nailer ($247), a Bostitch BTFP02012-WPK compressor and 50’ air hose ($170), and a standard fiberglass 16 oz. claw hammer.
[14] 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 cost allocated to installing nails is $12,500 (=$25x500). 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).

6. Conclusion

This paper focuses on nails—a basic, non-revolutionary manufactured product whose form has changed relatively little over the last three centuries—and constructs quality-adjusted price indexes for nails since 1695. The index indicates that the price of nails fell significantly relative to prices of an overall basket of consumption goods, with the real price of nails falling by a factor of about 10 from the late 1700s to the middle of the 20^{th} century.

What accounted for these rapid price declines? A growth-accounting type of decomposition into a weighted average of input costs and MFP highlights the proximate sources. Falling material prices for iron and steel were important during the two bursts of rapid price drops (1821-1860 and 1881-1930), while, perhaps surprisingly, the cost of capital and of energy played a relatively minor role during the full time span. The most important factor contributing to these rapid price declines was increases in MFP during the period, highlighting that factors other than automation were important, such as the specialization of labor and re-organization of production processes as emphasized by Atack, Margo and Rhode (2019 and 2020) and David (1990).

While the real price declines for nails documented in this paper are nowhere near as rapid as those that Nordhaus (1997 and 2007) documents 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 such as for housing. And, the decomposition into the proximate sources of the price declines highlights interesting features of the changes in production processes, especially during the first and second industrial revolutions. 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 that earlier period than they do now, a story reflected in the data as well as anecdotes about nails about that earlier time. All told, a focus on the price of nails provides a useful window into economic changes over the past 300 years.

References

Adams, William Hampton (2002), "Machine Cut Nails and Wire Nails: American Production and Use for Dating 19th-century and Early 20th-century Sites," *Historical Archaelogoy,* 36(4), p. 66-88.

American Iron and Steel Institute (various years), *Annual Statistical Reports,* Philadelphia in early years, New York in intermediate years, and Washington, D.C. in more recent years, previously the organization was the American Iron and Steel Association.

Atack, Jeremy and Fred Bateman (1999), "Nineteenth-Century U.S. Industrial Development through the Eyes of the Census of Manufactures," *Historical Methods,* Vol. 32, No. 4, Fall, p. 177-188.

Atack, Jeremy, Robert A. Margo, and Paul W. Rhode (2019), "'Automation' of Manufacturing in the Late Nineteenth Century: The Hand and Machine Labor Study," *Journal of Economic Perspectives,* Vol. 33, Number 2, Spring, p. 51-70.

Atack, Jeremay, Robert A. Margo, and Paul W. Rhode (2020), "Mechanization Takes Command: Inanimate Power and Labor Productivity in Late Nineteenth Century American Manufacturing," NBER working paper number 27436.

Bakker, Gerben, Nicholas Crafts, and Pieter Woltjer (2019), "The Sources of Growth in a Technologically Progressive Economy: The United States, 1899-1941," *Economic Journal,* Vol. 129, Issue 622 (August) pp. 2267-2294.

Beveridge, William (1939), *Prices and Wages in England from the Twelfth to the Nineteenth Century,* Vol. I, Price Tables: Mercantile Era, Longmans, Green, and Co., London.

Budd, Edward, "Factor Shares (1960), 1850-1910," in *Trends in the American Economy in the Nineteenth Century*, CRIW/NBER, Princeton University Press, p. 365-406.

Chamberlain, Joseph (1866), "Manufacture of Iron Wood Screws," in *Birmingham and the Midland Hardware District, A Series of Reports Edited Samuel Timmins,* Robert Hardwicke, London, reprinted by Frank Cass & Co. Ltd, Abingdon, UK, in 1967.

Cole, Arthur Harrison (1938), *Wholesale Commodity Prices in the United States 1700-1861,* Harvard University Press, Cambridge, MA.

David, Paul A (1990), "The Dynamo and the Computer: An Historical Perspective on the Modern Productivity Paradox," *American Economic Review,* Vol. 80, No. 2, pp. 355-361.

Dickinson, H.W. (1941-42), "Origin and Manufacture of Wood Screws," *Transactions of the Newcomen Society,* 22: 80.

Eichholtz, Piet M. A. (1997), "A Long Run House Price Index: The *Herengracht* Index, 1628-1973," *Real Estate Economics*, Vol. 25, No. 2, pp. 175-192.

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

Gallman, Robert E. (1966), "Gross National Product in the United States, 1834-1909," in *Output, Employment, and Productivity in the United States After 1800,* Studies in Income and Wealth, Volume 30 by the Conference on Research in Income and Wealth, National Bureau of Economic Research and Columbia University Press, p. 3-90.

Gallman, Robert E. and Paul W. Rhode (2019), *Capital in the Nineteenth Century,* National Bureau of Economic Research and the University of Chicago Press.

Goldin, Claudia and Lawrence F. Katz (1998), "The Origins of Technology-Skill Complementarity," *Quarterly Journal of Economics*, Vol. 113, No. 3 (August), pp. 693-732.

Gordon, Robert J. (2018), "Why has Economic Growth Slowed When Innovation Appears to be Accelerating?" NBER working paper number 24554 (April

Gordon, Robert J. (2008), "Apparel Prices 1914-93 and the Hulten/Bruegel Paradox," in *Price Index Concepts and Measurement,* edited by Erwin Diewert, John Greenlees, and Charles Hulten, NBER and University of Chicago Press, p. 85-128.

Jacks, David S. (2013), "From Boom to Bust: A Typology of Real Commodity Prices in the Long Run," NBER working paper number 18874.

Jorgenson, Dale W., Kyoji Fukao, and Marcel Timmer (2016), *The World Economy: Growth or Stagnation,* Cambridge University Press.

Jackson, Kenneth T. (1987), *Crabgrass Frontier,* Oxford University Press.

Kent, William (1903), *The Mechanical Engineer's Pocket Book,* John Wiley & Sons, New York.

Lee Valley (2020), data on counts per pound pulled from leevalley.com in October 2020.

Lee Valley (2009), "A Very Brief History of Nails," *Woodworking Newsletter*, Vol. 3, Issue 3, January, available at leevalley.com/newsletters/Woodworking/3/3/article1-2.htm.

Lewis, Miles (1998), *Australian Building: A Cultural Investigation,* Section 8: Metals, pulled on June 29, 2011 from www.mileslewis.com.

machinetools.com, spec sheets for Allied Machinery Wire Nail Making Machine AMC-2, AJIT Automatic Wire Nail Making Machine AWN-1, and ABHIJAT Automatic Screw Machines, single spindle, AL-25, pages pulled on April 10, 2011 and June 28, 2011.

Mandel, Michael (2011), "Mandel on Innovation and Growth: Air Force Certifies the Weakness of Domestic Manufacturing," available at innovationandgrowth.wordpress.com/2011/0418/air-force-certifies-the-weakness-of-domestic-manufacturing/.

Margo, Robert A. (2015), "Economies of Scale in Nineteenth Century American Manufacturing Revisited: A Resolution of the Entrepreneurial Labor Input Problem" in *Enterprising America: Businesses, Banks, and Credit Markets in Historical Perspective,* ed. by William J. Collins and Robert A. Margo, NBER and University of Chicago Press.

Margo, Robert A. (2000), *Wages & Labor Markets in the United States, 1820-1860,* National Bureau of Economic Research and the University of Chicago Press.

Margo, Robert A. and Jeremy Atack (2019), "Gallman revisited: blacksmithing and American manufacturing, 1850-1870," *Cliometrica* 13, pp. 1-23.

Maze Nails Company, online catalog, available at www.mazenails.com.

Measuring Worth (2011), historical exchange rates and price indexes pulled from measuringworth.com during May and June 2011.

New York Times, "Builder of Housing for Middle Class Dies at 93," June 26, 1999, p. B7.

Nordhaus, William D. (1997), "Do Real Output and Real Wage Measures Capture Reality? The History of Lighting Suggests Not," in Timothy F. Bresnahan and Robert J. Gordon, eds., *The Economics of New Goods*, Vol. 58, 1997, pp. 29-66.

Nordhaus, William D. (2007), "Two Centuries of Productivity Growth in Computing," *The Journal of Economic History*, vol. 67, issue 01, pages 128-159.

Officer, Lawrence H. (2009), *Two Centuries of Compensation for Production Workers in Manufacturing,* New York, Palgrave Macmillan.

Officer, Lawrence H. (2011), "The Annual Consumer Price Index for the United States, 1774-2010," MeasuringWorth, available at measuringworth.com/uscpi/.

Public Archives of Canada, *A Most Significant Reference Document: A List of Nails and Spikes Required for the Service of the Office of Ordnance, March 17, 1813,* Record Group 8, C series, volume 1433, reprinted in the *Bulletin of the Association for Preservation Technology, Vol. VIII, No. 3, 1976.*

Raff, Daniel and Susan M. Wachter (2013), "Real Estate Prices in Beijing, 1644-1840," *Explorations in Economic History* 50(30), pp. 368-386.

Rees, Albert (1961), *Real Wages in Manufacturing: 1890-1914,* NBER and Princeton University Press.

Rothenberg, Winifred (1979), "A Price Index for Rural Massachusetts, 1750-1855," *The Journal of Economic History,* Vol. 39, No. 4, December, pp. 975-1001.

Rybczynski, Witold (2000), *One Good Turn: A Natural History of the Screwdriver and the Screw,* Scribner, New York.

Shaw, William Howard (1947), *Value of Commodity Output,* National Bureau of Economic Research, New York.

Smith, Adam (1776), *The Wealth of Nations,*

Stern, George (1952), "Immediate Vs. Delayed Holding Power of Nails," Virginia Polytechnic Institute Wood Research Laboratory.

Temin, Peter (1964), *Iron and Steel in the Nineteenth Century America,* MIT Press, Cambridge, Massachusetts.

Tremont Nail Company (2011), price lists at tremontnail.com.

United States Bureau of Labor Statistics (1899), *Hand and Machine Labor, 13th Annual Report of the Commission of Labor 1898*, Volume 1 (*Introduction and Analysis)* and Volume 2 (*General Table)*.

Unites States Bureau of the Census (1975), *Historical Statistics of the United States: Colonial Times to the Present,* Washington, D.C.

United States Department of Agriculture Forest Service (2002), *Wood Handbook: Wood as an Engineering Material,* reprinted by Algrove Publishing, Almonte, Ontario, Canada.

US Department of Labor. 1899. Thirteenth Annual Report of the Commissioner of Labor, 1898: Hand and Machine Labor. Washington DC: GPO. Available from HathiTrust.org: http://hdl.handle. net/2027/nnc1.cu08593957.

United States Senate (1893), *Wholesale Prices, Wages, and Transportation, Report by Mr. Aldrich from the Committee on Finance,* March 3, Part II.

Warren, George F. and Frank A. Pearson (1933), *Prices*, New York, John Wiley and Sons.

Wells, Tom (1998), "Nail Chronology: The Use of Technologically Derived Features," *Historical Archaeology,* 32(2), p. 78-99.

White, Christopher (about 2005), "Observations on the Development of Wood Screws in North America," presentation to the Museum of Fine Arts in Boston.

Wilder, Laura Ingalls (1935), *Little House on the Prairie,* Harper Collins, New York.

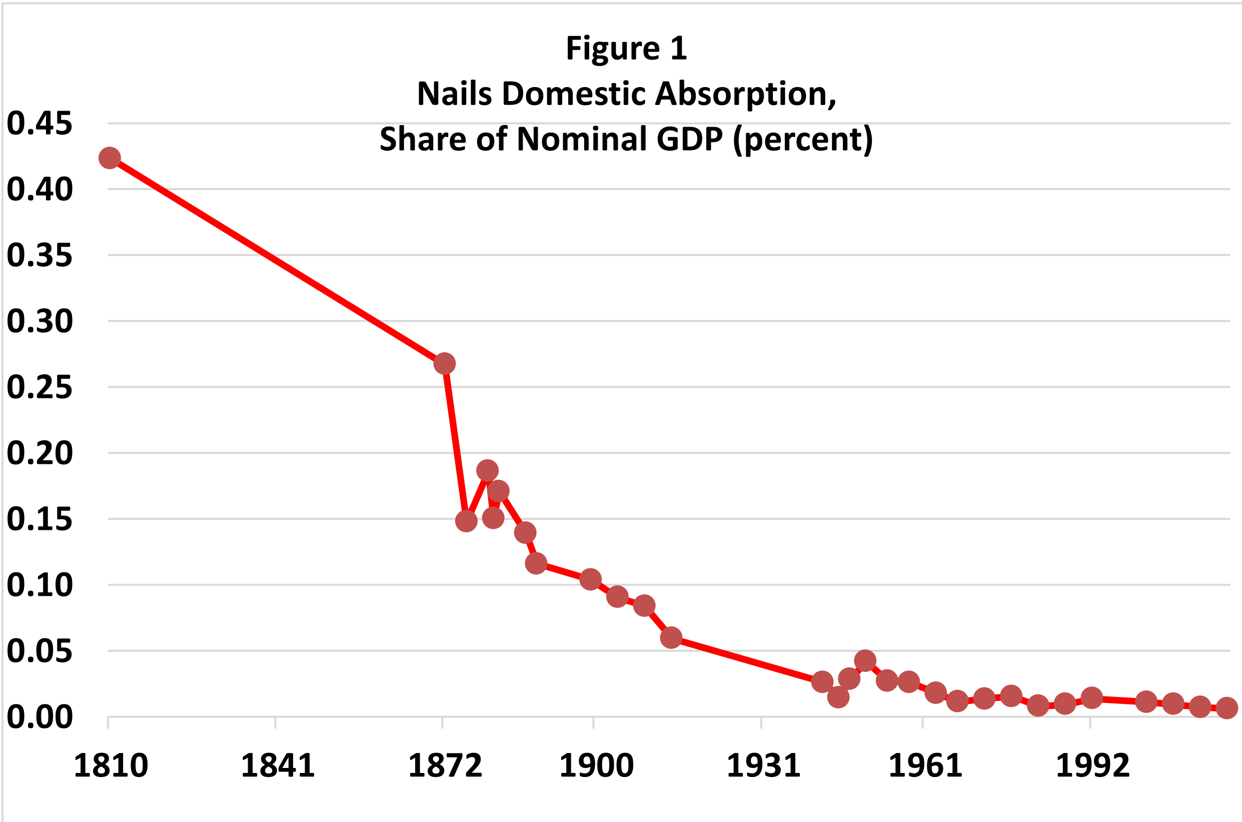
Table 1
Sources of Real Price Change for Nails, 1790-2018
(annual averages over periods shown)

	Percent change	Contribution of (in percentage points)					
Period	**Nails**	**Capital**	**Labor**	**Energy**	**Materials**	**Purchased Services**	**Multifactor Productivity**
1791-1820	-.37	.03	.66	.01	-.04	.49	-1.51
1821-1860	-1.89	.00	.84	.00	-.75	.62	-2.60
1861-1880	.45	.08	.30	-.02	-.11	.15	.06
1881-1930	-2.89	-.12	.62	-.02	-1.30	.23	-2.31
1931-2018	1.60	-.04	.75	-.01	.31	.10	.48
Memo:							
1791-2018	-.36	-.03	.69	-.01	-.31	.28	-.97

Notes:

Values in columns for inputs and multifactor productivity sum to the percent change in the price of nails for each period reported.

All prices are real prices, using the consumer price index described in the text to convert nominal prices.



Note: Data include nails, spikes, tacks, and staples. Data points are shown as dots connected by line segments.

Figure 2
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 3a
Nominal Price of Nails, 1695-2018
(cents/lb)

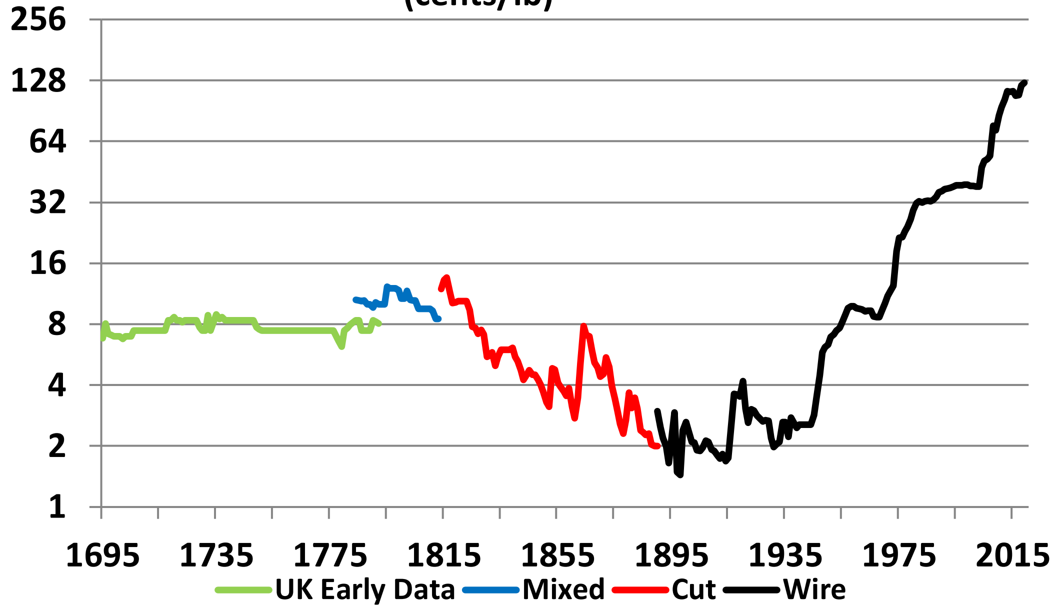
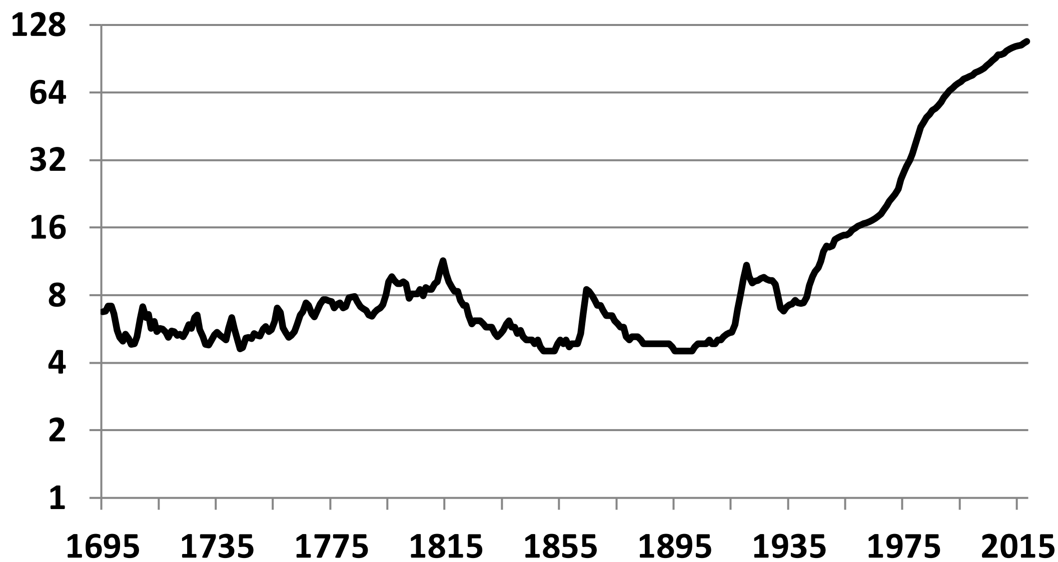


Figure 3b
Consumer Prices (PCE: 1929-2018, CPI: 1695-1928)
(2012=100)



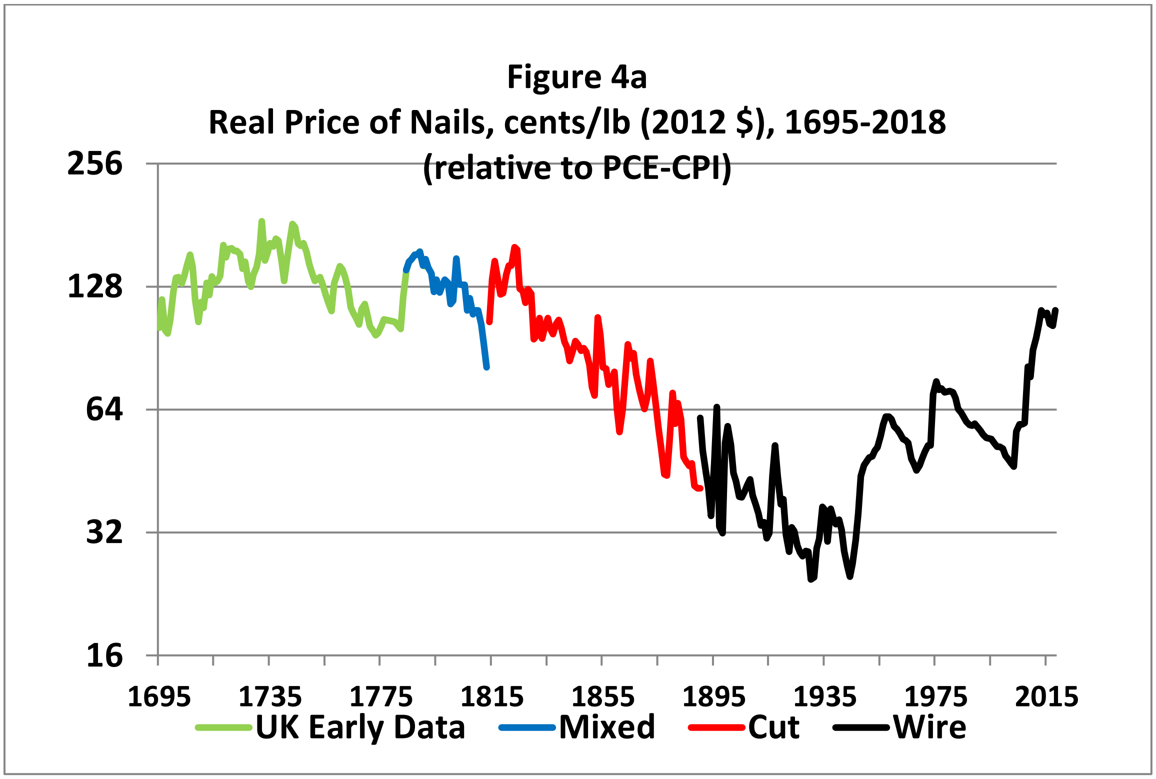


Figure 4a
Real Price of Nails, cents/lb (2012 $), 1695-2018
(relative to PCE-CPI)
256
128
64
32
16
1695
1735
1775
1815
1855
1895
1935
1975
2015
UK Early Data
Mixed
Cut
Wire

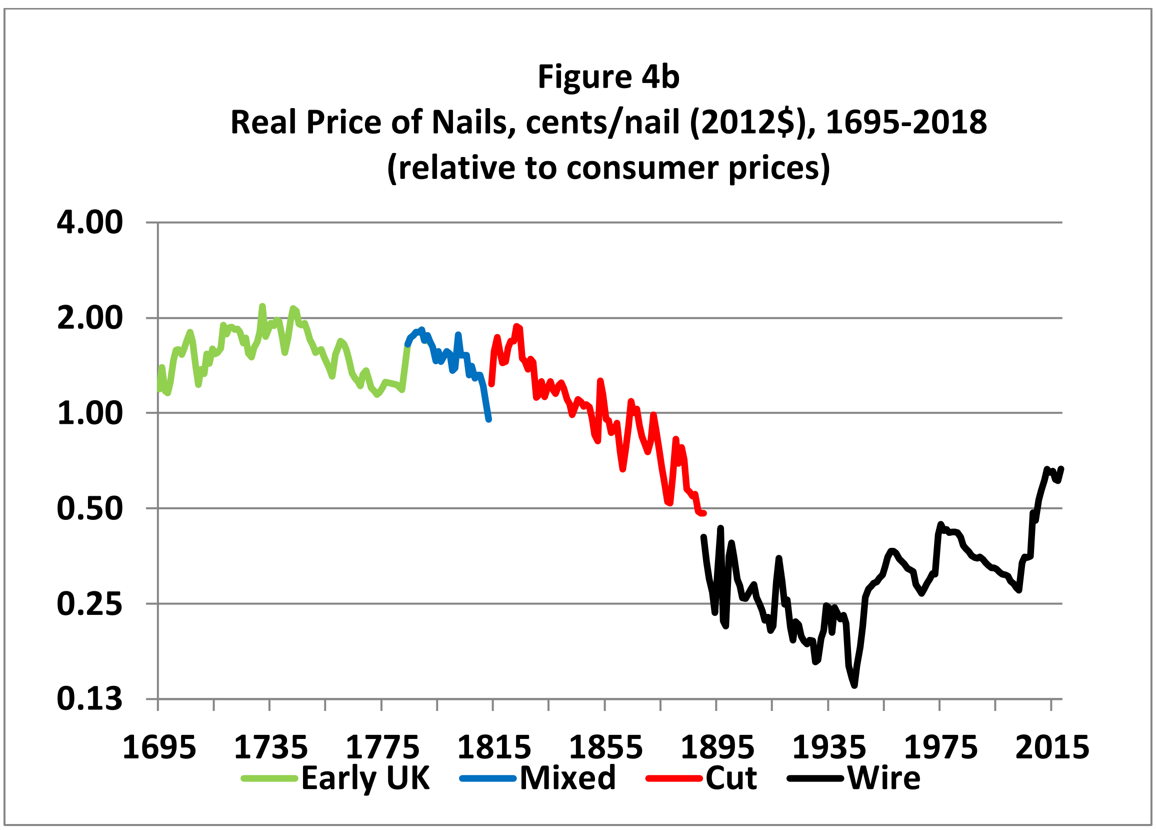
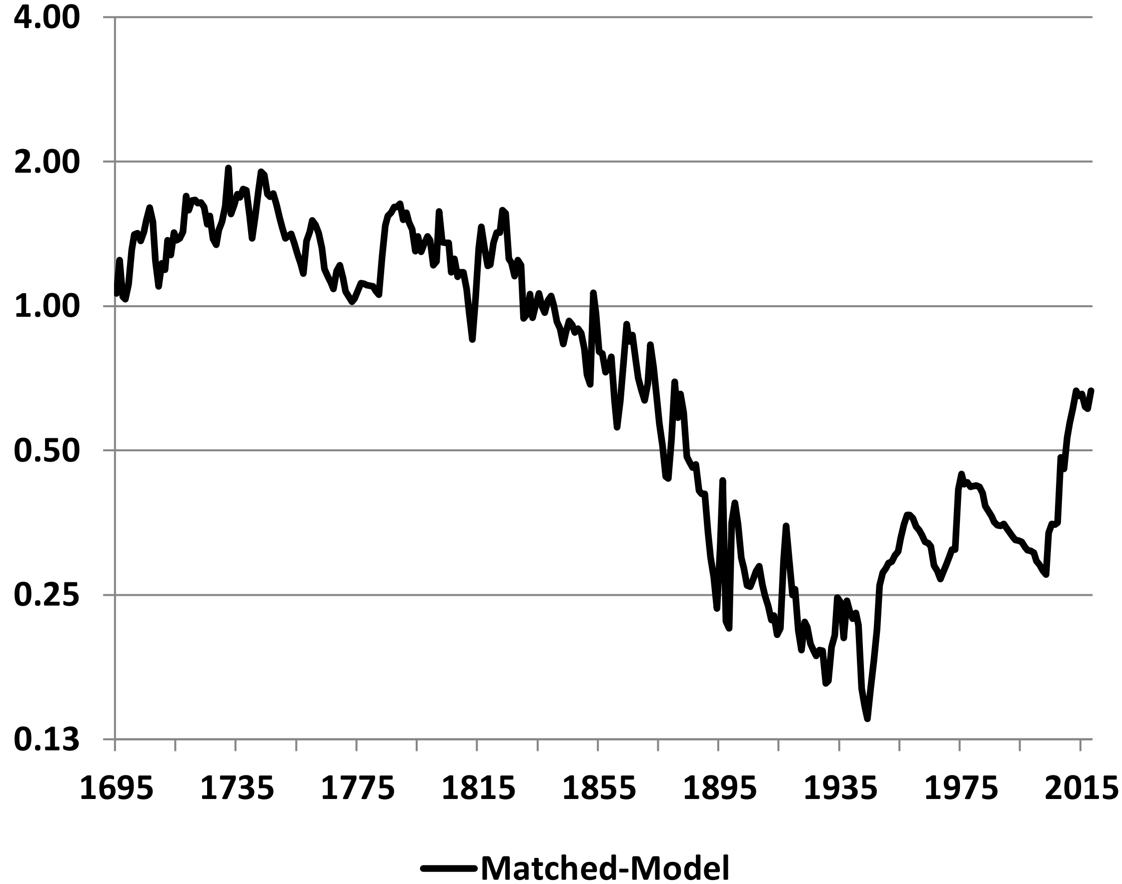


Figure 4b
Real Price of Nails, cents/nail (2012$), 1695-2018
(relative to consumer prices)
4.00
2.00
1.00
0.50
0.25
0.13
1695
1735
1775
1815
1855
1895
1935
1975
2015
Early UK
Mixed
Cut
Wire

Figure 5
Real Price of Nails: Matched-Model, 1695-2018
cents/nail 2012 $



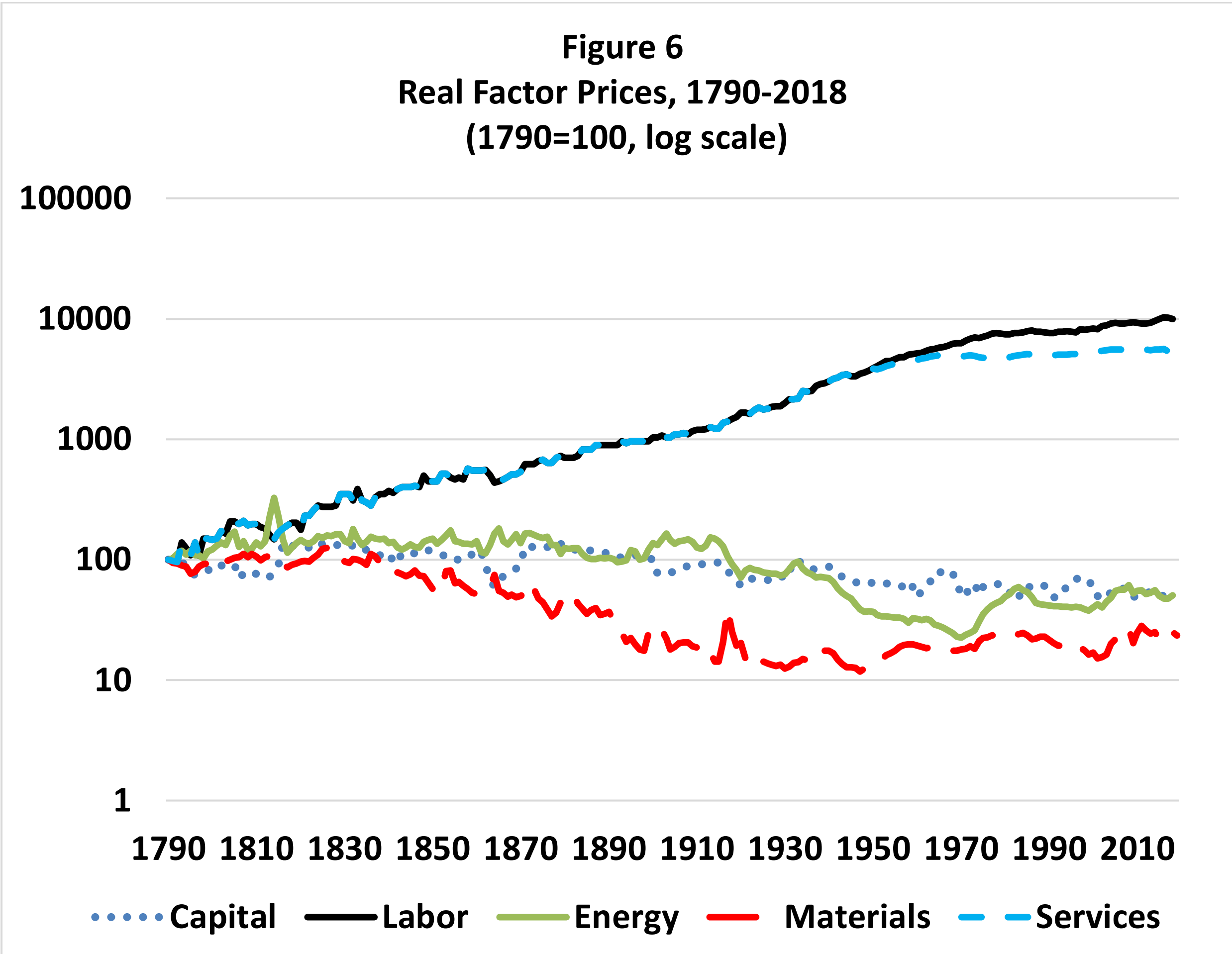
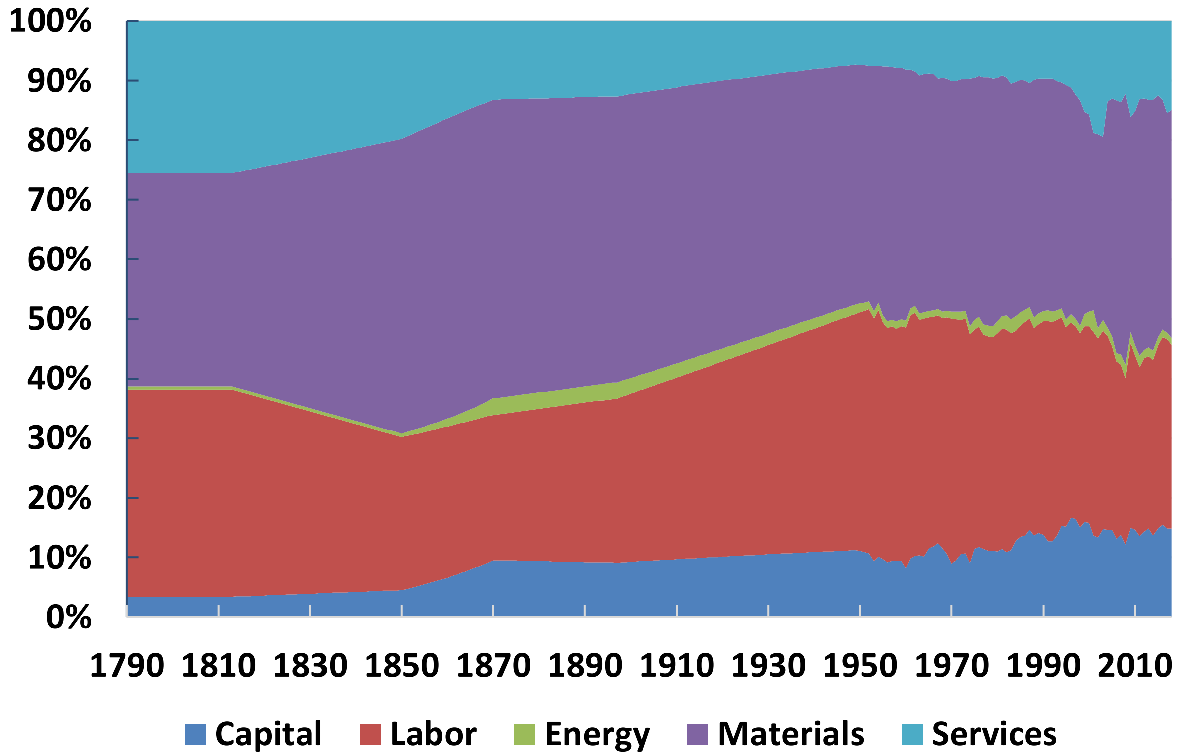


Figure 6
Real Factor Prices, 1790-2018
(1790=100, log scale)
100000
10000
1000
100
10
1
1790
1810
1830
1850
1870
1890
1910
1930
1950
1970
1990
2010
Capital
Labor
Energy
Materials
Services

Figure 7
Factor Shares, 1790-2018



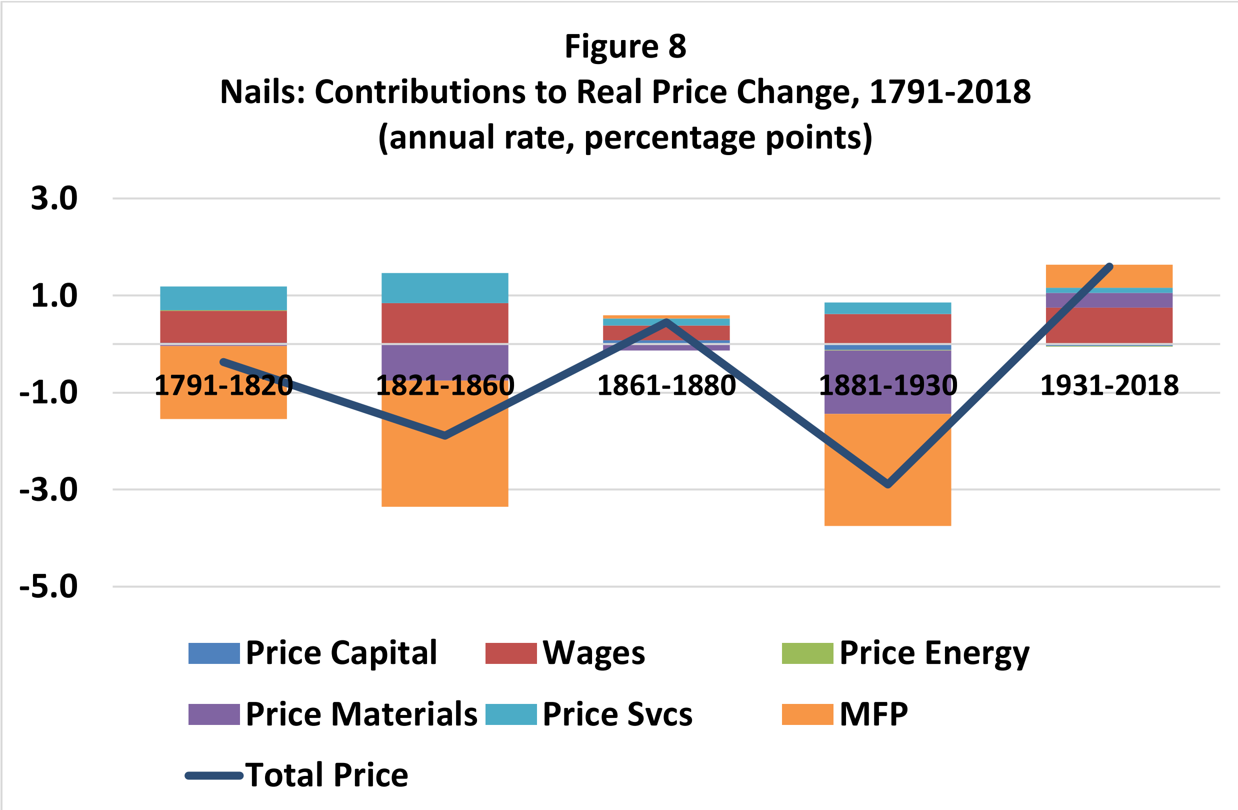


Figure 8
Nails: Contributions to Real Price Change, 1791-2018
(annual rate, percentage points)
3.0
1.0
-1.0
-3.0
-5.0
1791-1820
1821-1860
1861-1880
1881-1930
1931-2018
Price Capital
Wages
Price Energy
Price Materials
Price Svcs
MFP
Total Price