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Machinery and horsepower prices. 1850 - 1913*

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Abstract

The debate on the industrial revolution (IR) has been focused on the incentives behind investment decisions and how the preliminary conditions for it appeared in England / Great Britain. One of the most famous theories to explain the IR is the one developed by Allen (2012, 2009b,a), who argues that the IR was British due to a unique combination of expensive labour and cheap energy, producing incentives to invest in labour-saving machinery. His theory takes into account a vast literature on organic fuels and the transition to fossil fuels (WRIGLEY, 1962; Wrigley, 2013).

Several works have proved the existence of cheap fossil fuels during the 19th century, determined by the introduction of coal. Even though the figures on wages and energy are broadly accepted, machinery price indices are challenged. The most widely used index is based almost completely on the price of iron (Feinstein, 1972, 1988). To prove Allen's hypothesis we require a better index of machinery prices, measuring horsepower prices, relative costs and international changes in their trade. This article presents such a series, using novel data from merchants' catalogues, international trade statistics plus all the price indices previously available. The new series corresponds to the UK in the period 1850 - 1913; given the influence of British Machinery & Equipment in the world market until 1913, this price index could be useful to understand the transformation of relative costs in several regions.

JEL Codes: N13, N63, N70, O13, O14, O33.

Keywords: Machinery prices, Industrial Revolution, Technological change.

*Ongoing research, please do not quote.

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1 Introduction

Computer prices have been decreasing without interruption since the 1990's. If we consider the services given by these machines, the classic accounting methods become useless. Microchips' capacity has been increasing year by year, converting the extremely expensive PC of the 1980's in a quite common consumer good in our days. This and other contemporaneous examples compel us to review and question our capital stock measures, basis of the Total Factor Productivity (TFP) figures and some of the wealth components that are key to understanding income differences between countries.

A similar problem arises when we try to measure machinery prices in the long run. In this article we will test the reliability of current price indices of machinery and how their revision could affect estimations about the industrial revolution's pace and diffusion. Machinery and equipment is one of the main components of technological change and probably, the "easiest" way to measure structural changes in the economy. The current debate on robotization and jobless growth derived from automation is an inheritor from luddism, unemployment lead by technological changes and labour saving technology.

Despite the current importance of these phenomena and the newest theories on the industrial revolution, our current knowledge about machinery prices during the crucial period of 1850- 1913 is limited. Currently, for the UK, the main index was elaborated by Feinstein (1972). As we are going to see later in the text, this index is strongly correlated with iron and steel prices, dismissing the complexity and quality changes of M&E.

One of the main problems to estimate a reliable price index for machinery are the quality changes through the years. Uses, functions and models change constantly and the services displayed by machinery and equipment were not the same in 1870 than in 1913. In order to solve these problems, we propose an index with more elements, taking into account the most important indicator of machinery and equipment in the first and second industrial revolution: horsepower prices. Focusing our attention on the relative price instead of an isolated machinery price, we could improve our knowledge of price incentives in a crucial time of modern economic history.

This article is organized as follows: in the second section, we do a critical review of the main literature on machinery price indices and how important these figures have been to understand the diffusion of the industrial revolution. In the third section we describe the main sources used to improve the current machinery price index. Our methodology is described and explained in the fourth section. The fifth section presents preliminary results and a comparison with previous indices, while the sixt, concludes with the discussion and further research.

2 Literature review

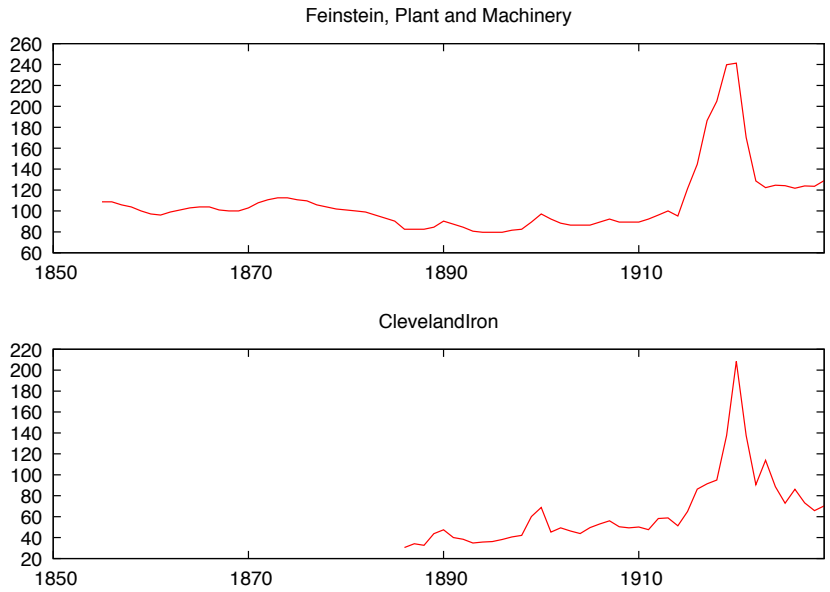
There have been several studies dealing with machinery and equipment in the UK, highlighting the dissertation by Floud (1976). In the case of Sweden, there are works worth mentioning, such as *"Priser och marknadskrafter i Sverige 1885-1969: en prishistorisk studie"* (Ljungberg, 1990). The figures presented in these books are relevant for our research, but do not resolve the main questions that we have proposed.

Machinery prices have been analysed from tangential perspectives, and not as playing a key role. **Technological changes in the past centuries (19th-20th) are so huge that** we have to continue re-estimating relative prices of capital goods. This problem is even bigger if we want to elaborate long run series and compare the prices of a good in the 1870's with that of a "similar" item in the 1930's. Current debates in computers and software prices are dealing with similar problems. Several attempts have been made to understand the role of technology and relative prices changes in historical perspective (Collins and Williamson, 2001), but the majority of these works are estimations based on proxies of capital prices such as interest rates or import/export figures. In Collins and Williamson (2001), for example, M&E price indices are proxies of investment figures, which do not take into account the enormous differences within the several non-residential investment items.

Jones, for example, uses data underlying the PWT to argue that "an increase in the relative price of machinery reduces capital accumulation and therefore reduces the growth rate of the economy. Moreover, the use of almost the same indices for the period 1850 - 1913 could be considered a noticeable mistake. However, as we will see in this section, the construction of M&E indices taking into account quality changes are absent. If we observe the last developments in economic history research, it could be possible to sort the literature on M&E prices between technological change studies, historical national accounts and industrial revolution debate.

Albers (2002) and Allen (2012) observed, analysing a national experience and in a comparative framework respectively, the influence of machinery in economic growth and how the available horsepower in the economy could impulse productivity and the transition from organic to mineral fuels.

Figure 1: Price indices for Machinery and Equipment and Iron. 1850 - 1913



If the studies people as Abramovitz and Solow are even approximately correct with respect to orders of magnitude, the contribution of technological change to rising per capita incomes absolutely dwarfs the

contribution from a rising but qualitatively unchanging stock of capital

"Several studies have collected data on prices paid by buyers, but few of these series refer to capital goods. While a seller can provide price information on a given model of a complicated piece of machinery over a period of time, most buyers purchase capital goods only occasionally and thus cannot provide a continuous price series (Gordon, 1971)

> The relative price of capital goods, an important component of the user cost of capital, has rarely been incorporated into comparative studies of long-run capital accumulation. This article constructs and explores a data set for capital-goods and equipment prices covering the 1870–1950 period for 11 OECD countries. We document substantial differences across countries in the relative prices of capital goods, but also find convergence in those prices over time. Finally, we show that relative capital- goods prices are strongly negatively correlated with investment rates.

Collins and Williamson (2001)

2.1 Feinstein

Feinstein (1972) elaborated an impressive amount of data to estimate the main macroeconomic variables of the UK during the period 1855-1965. To estimate the capital stock during these years, he utilized the Perpetual Inventory Method (PIM) developed by Goldstein a few years before. In the case of "Plant and Machinery", the decision to estimate the prices in the long run could be criticized from a contemporary point of view, but absolutely understandable within the main objective of his work (the broad picture of the British economy). His work took the principal raw material to build machinery during the second half of the 19th century and the first half of the 20th: iron. Using iron prices plus an arbitrary "quality index", corresponding to eight per cent of the aforementioned price, he calculated a machinery price index until 1913. We can see in graph 1 and table 2.1 an extremely high correlation between both variables, measured as indices and growth rates.

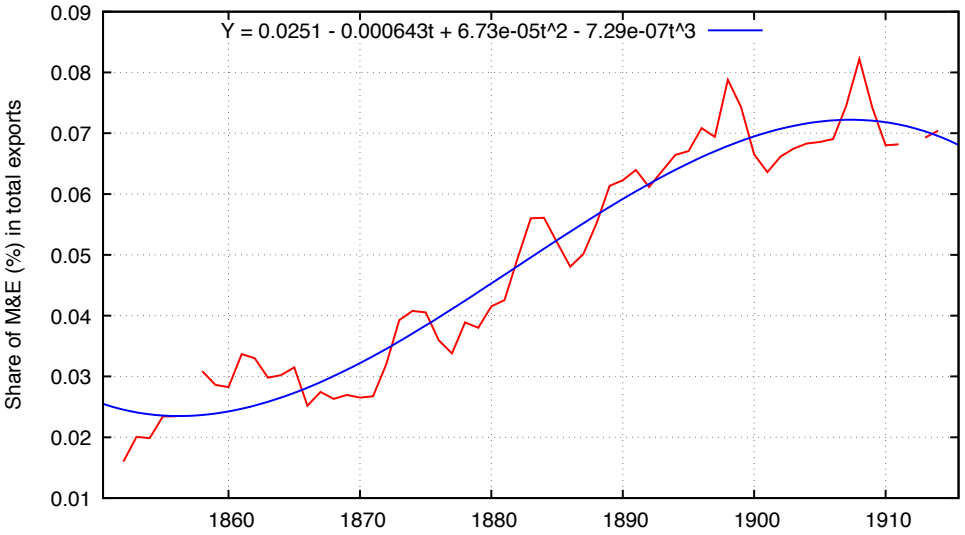
Model 2: OLS, using observations 1886–1933 (T = 48)
Dependent variable: l_PlantMchFeinstein

	Coefficient	Std. Error	t-ratio	p-value
const	2.05186	0.169255	12.12	0.0000
l_ClevelandIron	0.640738	0.0414515	15.46	0.0000

Mean dependent var	4.655194	S.D. dependent var	0.286761
Sum squared resid	0.623949	S.E. of regression	0.116465
R^2	0.838559	Adjusted R^2	0.835050
$F(1, 46)$	238.9346	P-value(F)	7.74e–20
Log-likelihood	36.12025	Akaike criterion	−68.24049
Schwarz criterion	−64.49809	Hannan–Quinn	−66.82623
$\hat{\rho}$	0.640256	Durbin–Watson	0.675412

One of the main reasons to have a reasonable doubt about the current machinery price indices are international trade figures. If we consider the literature on the "British decline" and how the UK begun to be replaced in the main international markets, a noticeable growth in British machinery exports would be difficult to explain (Broadberry and Burhop, 2007; Ljungberg, 2012). Nevertheless, a reconstruction of the UK exports share on M&E has shown how steadily this sector was gaining weight in the exports basket. Moreover, several works on Latin American M&E markets have discovered a slower decline of the British share in the market Tafunell and Ducoing (2016); Ducoing and Tafunell (2013). Criticism of these figures is not new. Some years after Nicholas (1980) pointed out that the indices developed by Feinstein (1972) were not totally reliable.

Figure 2: Share of M&E exports on total UK exports. 1850 - 1913



Source: Annual Stament of the trade, several years

As we can appreciate in the figure 2, the share of machinery was growing constantly since 1860, increasing its participation in the exports basket from 2% until 7% circa 1910.

Besides the price explanation, there are others factor underrated by the literature, such as international business networks, branding and path dependence. For example *Engineering*, a magazine specialized in Machinery and Tools industries, reported during the boom of the 1890's that quick delivery was becoming more important than price in determining engineering orders (Nicholas, 1980). There is little evidence of price competition for agricultural implements in the Victorian market, **remarked** that non price factors such as differences in size, accessories, style and draft were heavily emphasized. To include these factors a different approach is necessary, but such lies beyond the scope of this research.

3 Methodology

As we have noted, one of the biggest problems of current machinery price indices is the lack of "quality" embodied in these figures. A machinery price index should include some proxy of efficiency or at least a related indicator. To improve our knowledge on this matter, we have developed a new index which includes information from several sources and considers the relative price of M&E.

3.1 Sources

> The grounds for contention in discriminating between the models which emphasize supply, particularly Floud's revised model, as opposed to demand, centers in the first instance on the movement of American and British machinery prices. Unfortunately no definitive answer is possible since the price indices for American and British machinery are unreliable....
>
> Nicholas (1980)

Appleby's Catalogue During the period 1863 - 1905, Appleby Brothers was one of the main machinery retailers in UK, with a noticeable presence in the market. To promote their products, the company published with random frequency the famous *Illustrated Handbook and price of current of Machinery and Iron Work*, a detailed sample or their products, sorted by type of machinery.[1] Figure 3 shows a typical advertisement by Appleby's circa 1878. At the top of the page there is a detailed drawing of the machine, in this case a compound beam engine. Below this image, there is a description of the machine in terms of efficiency and fuel consumption, and finally, the most important information for our research: nominal horsepower (in its several models), price, coal consumption, etc.

There are eight Appleby catalogues available: 1863, 1869, 1873, 1878, 1879, 1885, 1895 and 1897. The last one was re-edited several times, with a new price estimation in the first page. In the 1904's re edition, the text said: *"NOTICE. Owing to the increased cost of labour and materials since the publication of this book (1897), the printed prices are no longer reliable, and about ten per cent. should be added to cover this increase"*. Every year is going to be used as a benchmark to interpolate it with the rest of variables. Let's see an example of these benchmarks: taking the year 1895, we search for a similar engine from the items gathered from previous handbooks. In this case an interesting product are the "compound condensing engines", because the information presented in the catalogue allows to estimate the average fuel consumption.

Table 1: Prices of Tandem Compound Condensing Engines

Indicated horse power	100	150	200	250	300	350
Price of engine	525 £	£650	£780	£910	£1000	£1130

Source: Appleby's Handbook, 1895, pag. 9

Taking into account all the elements presented previously, the new relative price index is constructed as follows

[1] One of the largest catalogue has five volumes, sorted in prime movers, mining, pump machinery, agriculture and tools.

Figure 3: Steam engine offered by Appleby's circa 1878

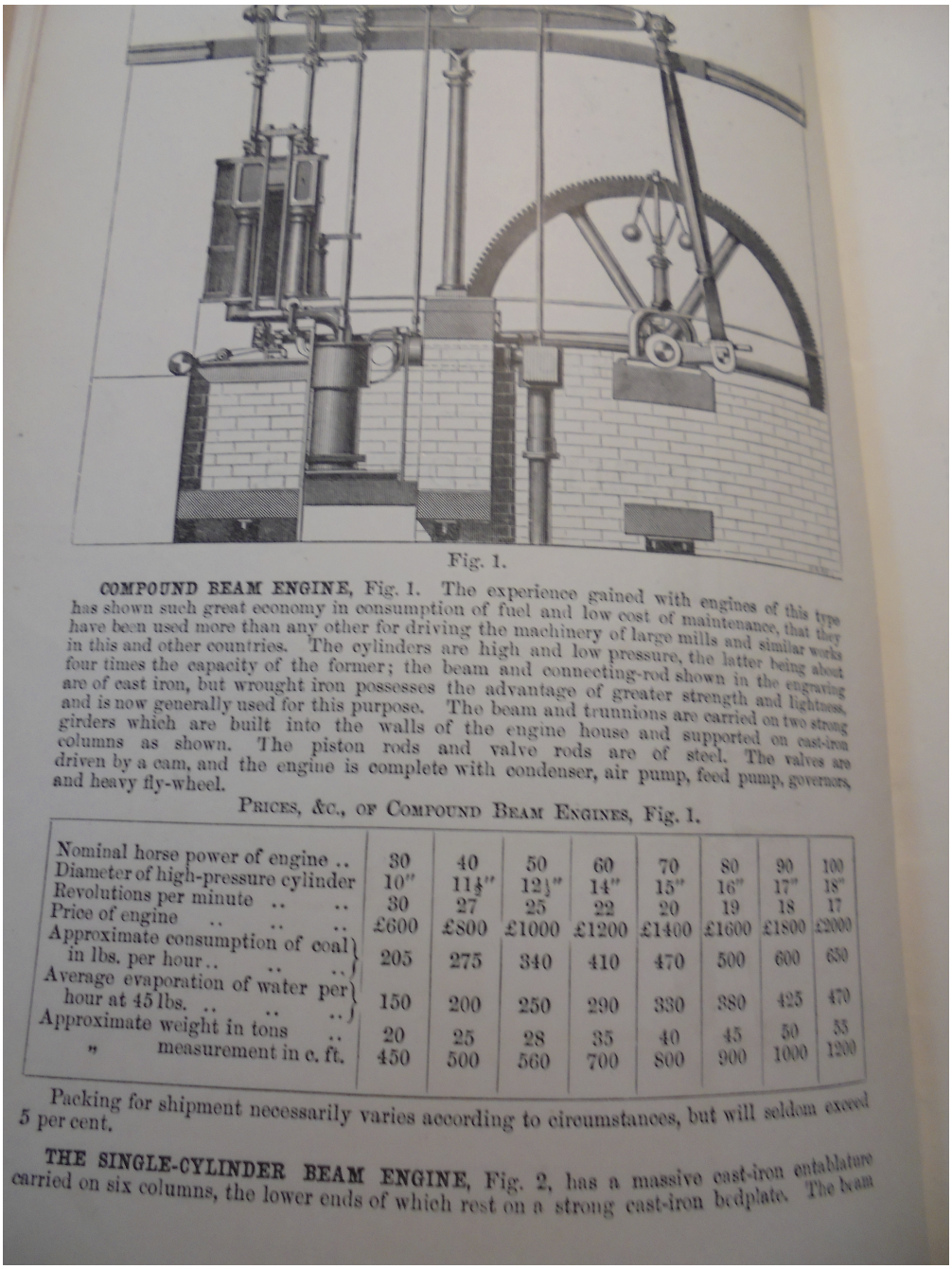


Fig. 1.

COMPOUND BEAM ENGINE, Fig. 1. The experience gained with engines of this type has shown such great economy in consumption of fuel and low cost of maintenance, that they have been used more than any other for driving the machinery of large mills and similar works in this and other countries. The cylinders are high and low pressure, the latter being about four times the capacity of the former; the beam and connecting-rod shown in the engraving are of cast iron, but wrought iron possesses the advantage of greater strength and lightness, and is now generally used for this purpose. The beam and trunnions are carried on two strong girders which are built into the walls of the engine house and supported on cast-iron columns as shown. The piston rods and valve rods are of steel. The valves are driven by a cam, and the engine is complete with condenser, air pump, feed pump, governors, and heavy fly-wheel.

PRICES, &c., OF COMPOUND BEAM ENGINES, Fig. 1.

Nominal horse power of engine ..	30	40	50	60	70	80	90	100
Diameter of high-pressure cylinder	10"	11½"	12½"	14"	15"	16"	17"	18"
Revolutions per minute	30	27	25	22	20	19	18	17
Price of engine	£600	£800	£1000	£1200	£1400	£1600	£1800	£2000
Approximate consumption of coal in lbs. per hour	205	275	340	410	470	500	600	650
Average evaporation of water per hour at 45 lbs.	150	200	250	290	330	380	425	470
Approximate weight in tons ..	20	25	28	35	40	45	50	55
" measurement in c. ft.	450	500	560	700	800	900	1000	1200

Packing for shipment necessarily varies according to circumstances, but will seldom exceed 5 per cent.

THE SINGLE-CYLINDER BEAM ENGINE, Fig. 2, has a massive cast-iron entablature carried on six columns, the lower ends of which rest on a strong cast-iron bedplate. The beam

Source: Appleby's catalogue, 1878.

- 1850 - 1913
- Machines using modern energy carriers (steam power, internal combustion, electricity)
- IWe use the 8 benchmarks from Appleby's catalogues to estimate HP levels:
  - iron prices
  - energy
  - coal
  - wages
  - Previous indices (Floud, 1976)
- With these inputs, we have the trend between benchmarks, and also, a quite fair approximation to horse power prices.
- Simple econometric model $Mch_t = \alpha + \beta_{t-1} + \gamma_{t-1} + r_t + e$ where β is energy prices in the previous period and r is the interest rate in period t

4 Results

Previous machinery price indices point to mixed conclusions. In the case of Feinstein (1972, 1988), his index doesn't show a clear trend until the First World Ward and an upward trend after 1914. For the period we are interested on here, the yearly annual growth rate is -0.37%, starting from high prices in the 1850's.

4.1 New Price index in Machinery and Equipment

Our new price index has been constructed with the methodology described above. The items presented in this preliminary index are mainly steam boilers (prime movers). The upward trend observed in the years before First World War graph (see figure 4) in the figures elaborated by Floud (1976) and Feinstein (1972, 1988).

Figure 4: Price index for Machinery and Equipment. UK 1850 - 1913. 1900 = 100

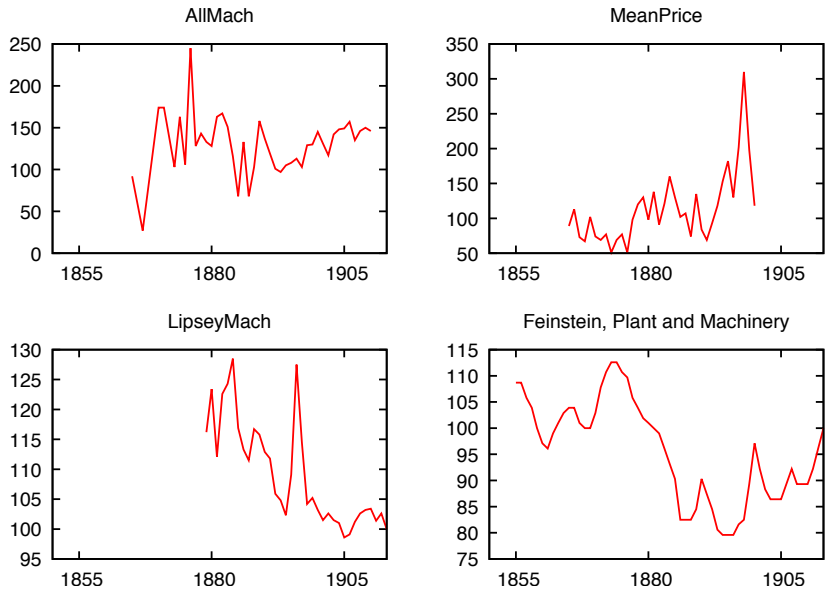
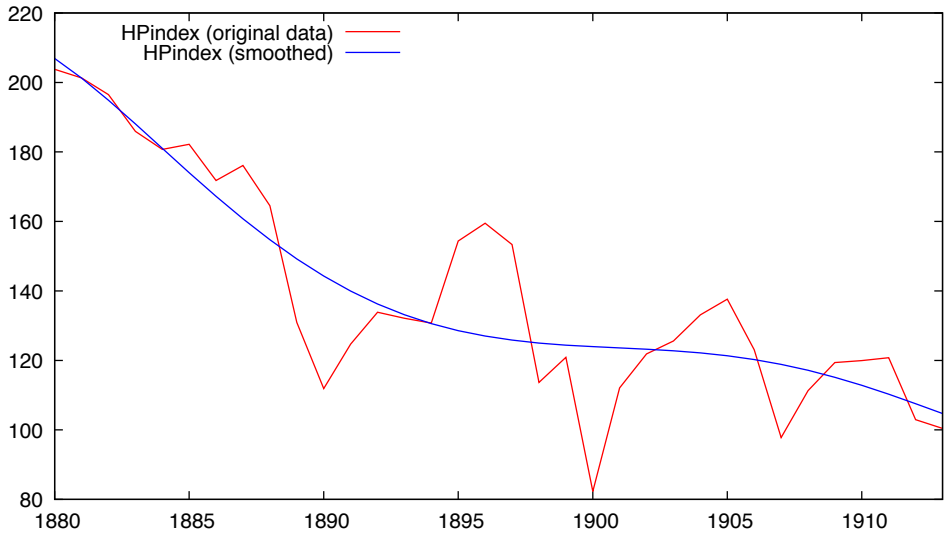


Figure 5: HP index, 1880 - 1913 (1913 = 100). Original series and filtered



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