LUND UNIVERSITY
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Master in Economic Development and Growth

Traditional Versus Revisionist:
The Case of the Industrial Revolution in Sweden, 1830-1980

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Abstract: This empirical paper uses modern methodology and techniques to analyze old and ongoing scholarly disagreements about the nature of Industrial Revolution. It analyzes the Industrial Revolution in Sweden and to find out whether it supports the traditional or revisionist view of the Industrial Revolution through quantitative time-series methodology and techniques such as cointegration analysis, Vector Error Correction Model, which isolates short-run from long-run relationships between variables under study, and Vector Autoregressive Model. Using data on labor productivity in Manufacturing and Building and Construction Industries as well as data on real product wage – nominal wage deflated by the price of the product – in Manufacturing Industry and Handicrafts, the results in this paper suggest that the "revolution" was not immediately widespread as many of the short-run effects in productivity in one sector on the productivity in other sectors are economically and statistically insignificant. The evidences presented in this paper support the revisionist rather than the traditional view of the Industrial Revolution.

Keywords: Industrial Revolution, Labor Productivity, Real Product Wage, Cointegration Analysis, Vector Error Correction Model

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1 Introduction

What is the nature of the Industrial Revolution in Sweden?

There are basically two views that could describe the nature of the Industrial Revolution, namely the traditional and revisionist views. On the one hand, proponents of the traditional view hold that the technological innovations during the Industrial Revolution have high impact on productivity and economic output growth not only in certain industrial sectors but also in other industrial sectors and the whole economy as well. In other words, the growths in productivity and economic output were fast and widespread during the Industrial Revolution. On the other hand, advocates of the revisionist view argue that these technological innovations have a rather modest impact on productivity and economic output growth. That is, the growths in productivity and economic output were rather slow and concentrated in some but not all industrial sectors during the period.

There are ongoing scholarly disagreements among economic historians about the two dissenting views on the Industrial Revolution as discussed in many research studies and position papers, including Crafts and Harley (1992) and Landes (1999). Crafts and Harley (1992) perhaps are the staunchest critique, while Landes (1999) as cited in Findlay and O'Rourke (2007, p. 312) is the "strongest defense" of the traditional view.

Take for example the case of Industrial Revolution in Britain as discussed in Crafts (1985). The traditional view is that the "factory system" or "steam-powered mechanization" of industrial production spreading from the cotton textile industry and iron metallurgy to other industries during the period have "spectacular" effects on the economy, often measured by macroeconomic variables such as growth in total and industrial outputs, capital, and total factor productivity. However, the revisionist view is less optimistic than the traditional one in that such technological innovations not only have slower but also less widespread effects in these macroeconomic variables than what was previously presented (Crafts 1985, pp. 7-8).

Interestingly, this empirical paper contributes to the literature about the two dissenting views of the Industrial Revolution by analyzing the nature of Industrial Revolution in Sweden during the period from 1830 to 1980 through the lens of a quantitative, time-series econometric methodology and techniques, using data drawn from various sources, such as the recently released data from the *Swedish Historical National Accounts 1560-2010* by Schön and Krantz (2012), *Long-term Trends in Real Wages of Labourers* by Söderberg (2010), and *Historiska Nationalräkenskaper för Sverige: Industri och Hantverk 1800-1980* by Schön (1988), among others.

While many in the literature looks into the pattern of total output growth, industrial product growth, or total factor productivity growth, this paper zeroes in on productivity as measured by labor productivity, and real product wage, or nominal wage deflated by the price of the product, over time and across different industrial sectors in the economy during the Industrial Revolution in Sweden. Moreover, the real product wage is shown to be a viable proxy measure for productivity. Hence, the robustness of the results using the data on the labor productivity can be checked using the data on the real product wage.

In particular, this paper uses a combination of cointegration analysis and vector models, specifically the Vector Error Correction Model that isolates the short-run – the main interest of this paper – from the long-run effects of one variable on the other variables under study, which is productivity in this case, in order to find out the nature of the Industrial Revolution in Sweden. The argument is that if the traditional view – where the Industrial Revolution in characterized by fast and widespread improvements in productivity owing to technological innovations not only in certain industrial sectors but also in other industrial sectors as well – is to be supported, then one should observe economically and statistically significant short-run effects of productivity in a "revolutionized" industrial sector on the productivity of other industrial sectors. Otherwise, the revisionist view of slow and concentrated effects of technological innovations on productivity of industrial sectors is to be supported instead.

It is important to emphasize that this paper does not explain why Industrial Revolution occurred Sweden, but rather analyze in hindsight how it proceeded over time. Does the case of the Industrial Revolution in Sweden support the traditional or revisionist view? What are the short-run effects – if any – of productivity in certain sectors on the productivity of other industrial sectors during the Industrial Revolution in Sweden? These are the questions that this paper seeks to answer.

This paper consists of ten sections. Section 2 reviews the two dissenting views about the nature of Industrial Revolution. Section 3 presents the Industrial Revolution in Sweden. Section 4 provides a theoretical framework of the nature of Industrial Revolution in Sweden. Section 5 formulates hypotheses about the two views on the Industrial Revolution that can be empirically tested. Section 6 describes the data on labor productivity and real product wage – a plausible proxy variable for labor productivity. Section 7 tackles the methodology used in the study, particularly the properties of time-series data and the econometric model. Section 8 shows the results from estimating the econometric model, while Section 9 discusses the results in more depth. Finally, Section 10 concludes.

2 Two Dissenting Views on the Industrial Revolution

2.1 Traditional and Revisionist View

Industrial Revolution is basically viewed in two different ways. On the one hand, those who adhere to the traditional view maintain that the Industrial Revolution, as in the case of Britain particularly in the period between the last half of eighteenth century and first half of the nineteenth century, was something fast and widespread. That is, high productivity and rapid output growth were not only confined to certain industrial sectors but to other industrial sectors as well. Landes (1969) describes this view:

> "In the eighteenth century, a series of inventions transformed the manufacture of cotton in England and gave rise to a new mode of production – the factory system. During these years, other branches of industry effected comparable advances, and these together, mutually reinforcing one another, made possible further gains on an ever-widening front" (Landes 1969, p. 41).

Moreover, the innovations that affected mutually reinforcing industrial sectors were so immense in variety that it is almost impossible to mention them one-by-one. These innovations are nevertheless subsumed into three principles, namely (i) "the substitution of machines – rapid, regular, precise, tireless – for human skill effort," (ii) "the substitution of inanimate for animate sources of power, in particular, the introduction of engines for converting heat into work, thereby opening to man a new and almost unlimited supply of energy," and (iii) "the use of new and far more abundant raw materials, in particular, the substitution of mineral for vegetable or animal substances" (Ibid).

Ashton (1934) expresses a similar view, saying that the Industrial Revolution was about massive expansion of technical change across industrial sectors. In fact, he describes the discoveries during the period not as "isolated miracles," but rather as "continuous growth," where changes of technical sort in one industry affected the others. "Technical changes in mining influenced those in engineering, in spinning those in weaving; the use of rollers in the textile trades was not unconnected with their use in the iron industry," he says, asserting that much remain to be done in giving many other illustrations of such "cross-fertilization" and suggesting that the technical change was indeed far-reaching (Ashton 1934, pp. 107-108).

On the other hand, those who challenge the traditional view – notably Crafts (1985) and Crafts and Harley (1992) – argues that productivity and economic output growth during the Industrial Revolution were rather slow and localized only in certain but not all industrial sectors. Providing empirical support for their "revisionist" and supposedly the new orthodox view of the British Industrial Revolution, Crafts and Harley (1992) vehemently refute and challenge the traditional view, saying:

> "We do, of course, reiterate that industry overall grew much more slowly than was once thought. Revolutionary changes in industrial technology were not widespread and productivity improvements contributed only modestly to the growth of GDP before the second quarter of the nineteenth century, probably causing a growth of national income of about one-third of one percent annually (table 5). To be sure, industrial change helped to alter social structure, demographic behavior, and savings habits, all of which may have stimulated growth. Nevertheless, it seems impossible to sustain the view that British growth leapt spectacularly in one generation as a result of innovations in manufacturing" (Crafts and Harley 1992, pp. 704-705).

Table 1 from Crafts and Harley (1992) presents the estimates of growth rates of output, capital, labor and total factor productivity (TFP) in Britain in two periods: one from 1760 to 1801 and the other from 1801 to 1831. In the period from 1760 to 1801, the estimates of output growth, capital growth, labor growth, and TFP are almost the same between the "old" and "new" estimates, with the old estimates of output growth and TFP just 0.1 percentage points above the new estimates.

However, the differences between the old and the new estimates are stark in all but labor growth for the period from 1801 to 1831. Note that, the old estimate of TFP is around one-half (1.3/2.7) of the output growth, while the new estimate of TFP is only around one-fifth (0.35/1.9) of the output growth. However note that the old estimate of capital growth is only around one-half (1.4/2.7) of the output growth, while the new estimate of capital growth is overwhelmingly around nine-tenth (1.7/1.9) of the output growth. Thus, the new estimates actually downgrade the importance of TFP in explaining output growth, but underscore the importance of capital growth in explaining output growth during the period. Overall, the output and TFP grew much slower in the revisionist view than in the traditional one, as the new estimates of output growth and TFP in this period are 0.8 and 0.95 percentage points lower than the old ones, respectively.

Table 1. Estimates of Total Factor Productivity Growth in Britain, 1760-1831 (per cent per year)

Old Estimates (Feinstein)	1760-1801	1801-1831	New Estimates (Crafts and Harley)	1760-1801	1801-1831
ΔY/Y	1.1	2.7	ΔY/Y	1.0	1.9
ΔK/K	1.0	1.4	ΔK/K	1.0	1.7
ΔL/L	0.8	1.4	ΔL/L	0.8	1.4
TFP	0.2	1.3	TFP	0.1	0.35

Note: ΔY/Y=Output Growth; ΔK/K=Capital Growth; ΔL/L=Labor Growth; TFP=Total Factor Productivity; Both capital and labor growth are given a weight of 0.5 by Crafts and Harley (1992).
Source: Crafts and Harley (1992, Table 5, p. 718)

By dint of these new estimates, Crafts and Harley (1992) emphasize that while it is widely acknowledged that changes in certain industrial sectors have altered so many things, as quoted above, the spectacular leap of British output growth in one generation because of the technological innovations during the period may seem impossible (Crafts and Harley 1992, p. 705).

2.2 *Scholarly Disagreements*

These contrasting views on Industrial Revolution produced interesting – and ongoing – debates among scholars, particularly between the "old" and the "new" economic historians. Table 2 from Mokyr (2009) provides a nice summary of the contrasting views about the nature of the British Industrial Revolution in quantitative terms. Column 1 presents the periods, Columns 2 and 3 the different estimates of national income per capita, and Columns 4 to 8 the different estimates of industrial product.

Note that estimates of growth in national income per capita by Deane and Cole (DC) in Column 2 is always higher than the estimates of growth in national income per capita by Crafts in Column 3, except for the period from 1830 to 1870 when the two are actually the same. In particular, the estimates by DC are 0.14, 0.35, and 1.09 percentage points higher than the estimates by Crafts in the periods from 1700 to 1760, from 1760 to 1800, and from 1800 to 1830, respectively. Another mark difference between the two sets of estimates of growth in national income per capita is the observation that estimates of DC show that the growth in national income per capita has always been increasing from one period to another period, while the estimates by Crafts show in contrast that growth in national income per capita has actually slowed down from 0.3 in the period from 1700 to 1760 to 0.17 in the period from 1760 to 1800, then increased in the following periods from 0.17 in the period from 1760 to 1800 to 0.52 in the period from 1800 to 1830, and then finally to 1.98 in the period from 1830 to 1870.

Moreover, the estimates of growth in industrial product by DC are again higher than the estimates by Crafts of the same particularly in the period from 1800 to 1830 when estimates by DC are 1.4 percentage points higher than estimates by Crafts. This difference may be high especially from the point of view of "modern eyes" accustomed to growth rates close to 2 per cent per year (Mokyr 2009, p. 256).

Indeed, the new estimates of the national income per capita and industrial output underscore the claim by revisionists that growth in economic output were "fairly slow" during the Industrial Revolution. "In contrast to Deane and Cole (1969) and Hartwell (1971), who viewed the Industrial Revolution as a period of accelerated economic growth," as Mokyr (2009) puts it, "Nicholas Crafts and C. Knick Harley (1992) have shown that aggregate growth was fairly slow during the Industrial Revolution and that even industrial output grew at a slower rate than what was implied by anything truly discontinuous (like a 'revolution')" Mokyr 2009, p. 255).

Table 2. Estimates of Real Output Growth in Britain, 1700-1871 (per cent per year)

Period	National income per capita (DC)	National income per capita (Crafts)	Industrial product (DC)	Industrial product (Crafts)
1700-1760	0.44	0.3	0.74	0.62
1760-1800	0.52	0.17	1.24	1.96
1800-1830	1.61	0.52	4.4	3.0
1830-1870	1.98	1.98	2.9	n.a.

Note: DC=Deane and Cole; [a]1770-1815; [b]1815-1841.
Source: Mokyr (2009, Table 12.1, p. 256)

Looking at trade during the Industrial Revolution, Temin (1997) argues that traditional view implies that Britain must have exported not only goods that were apparently produced with comparative advantage, such as cotton textile and iron bars, but also other manufactures during the relevant period of time. That is, technical change during the Industrial Revolution was "hardly uniform." It was not confined to cotton and iron industries during the early half of nineteenth century, but rather became widespread across many other industrial sectors. The assertion that "Britian became the workshop of the world, not just cotton factory of the world," is apparent with this argument (Temin 1997, p. 80).

Yet Harley and Crafts (2000) reject the claims made by Temin (1997) as in above. Simulating a computable general equilibrium model with according to them "realistic" assumptions about consumer demand and agricultural sector that exhibits diminishing returns to inputs, they conclude that their modern view about the Industrial Revolution is consistent with the industrial trade data. At the same time, this exercise actually solidifies their claim that the "exceptional feature of British Industrial Revolution" was rapid structural change, and not fast growth during the period (Harley and Crafts 2000, p. 839).

According to Crafts (1985), structural change – referring among many other things to the redeployment of resources away from agriculture towards other sectors of the economy or the movement of population from rural to urban areas – is one of the two types of economic changes that could explain "revolution" during the British Industrial Revolution. He argues that such structural change occurred "at a stage when income had still not risen very much" and "even though the overall economic growth had never been very fast" (Crafts 1985, p. 7).

The other change is technological, most especially referring to changes in the factory system. However, Crafts (1985) maintains that the important feature of the British Industrial Revolution was the revolution "in the sense of structural change" rather than the revolution "in the sense of the beginnings of the factory system," as majority of the workers during this period were still counted as "traditional craftsmen or labourer or domestic servant," not as "revolutionized industrial workers" such as machine operators. Apart from this, there was still no widespread use of "steam-powered mechanization and the factory system" at that time (Crafts 1985, p. 8).

In the midst of intense debate between the traditionalists and revisionists, there are those who believe that the gradual increase in the economic output during the Industrial Revolution is no "real mystery." Mokyr (2009), being one of them, argues that the relatively slower aggregate output growth during the Industrial Revolution than what a "revolutionary" growth would suggest is not inconsistent with the kind of structural transformation that happened in Britain during the early nineteenth century. "The Industrial Revolution," he says, "was above all a period of transition, in which technological change both deepened and widened until the sectors that resisted rapid change became more and more isolated enclaves, and we can speak with confidence of a 'modern economy'" (Mokyr 2009, pp. 255-256). He believes that all these happened through the useful application of "codified" and "tacit" knowledge in an environment with institutions conducive to such, providing his best definition of Industrial Revolution as "the set of events that placed technology in the position of the main engine of economic change" (Mokyr 2009, p. 5).

In summary, disagreements on the nature of British Industrial Revolution abound. On one end of the spectrum are the proponents of the traditional view who uphold that technological innovations in manufacturing during the Industrial Revolution have resulted in rapid and high productivity and output growth rates not only in certain industrial sectors but also in other sectors.

On the other end of the spectrum, however, are the critiques of this view who put forward the alternative view that the "revolution" happened during the Industrial Revolution is characterized not by a rapid, widespread increase in productivity and economic output, but rather by a rapid structural change that helped maintain an increasing income per capita even amidst a burgeoning population. This therefore aided the economy to find its way out of the so called "Malthusian trap." Such critiques argued that productivity and economic output growth rates were high in the culmination of and not during the period of Industrial Revolution.

The debate between groups of economic historian has been enriched by empirical studies. The literature is replete with quantitative evidences in support of one and against the other view of the nature of Industrial Revolution, and some of the most influential papers were discussed above. This paper meticulously tries to determine in the following sections which of these views – traditional or revisionist – is appropriate to describe the nature of the Swedish Industrial Revolution.

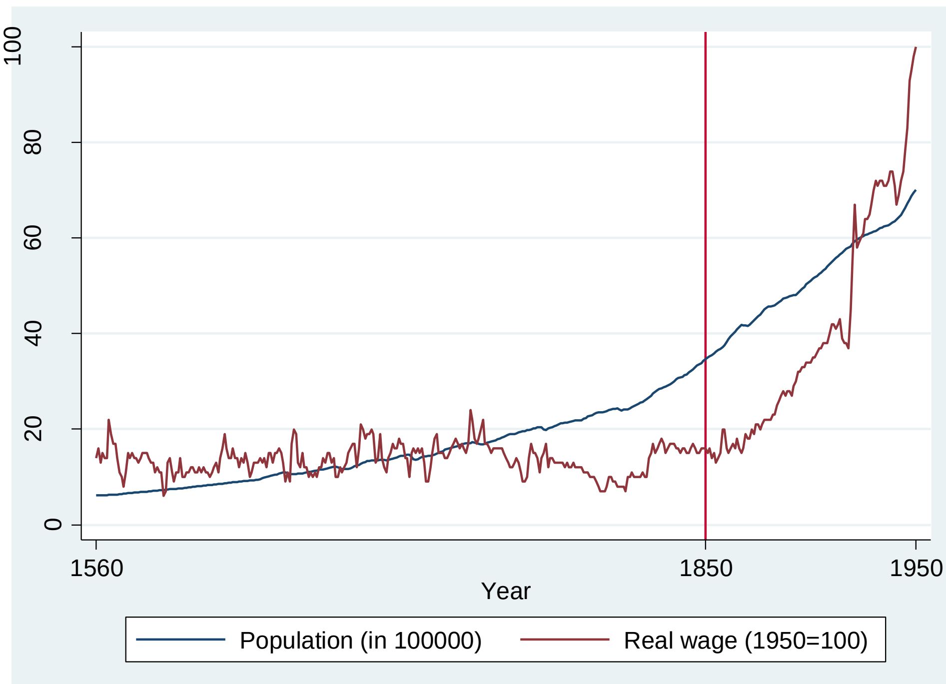
3 The Swedish Industrial Revolution

There is a rich literature about the Industrial Revolution in Sweden and the exact timing of its occurrence in the nineteenth century. To begin with, Gustafsson (1996) mentions several prominent economic historians and scholars in his discussion of the debate on the timing and causes of Industrial Revolution in Sweden, like Eli F. Heckscher – who regards 1870s as the beginning of the great divide with respect to legislation, technology and organization, Arthur Montgomery – who marks 1860s as a period of "something of a landmark in Swedish economic history" owing to four reasons: first, "the dwindling of agricultural supremacy;" second, "the rapid growth of the sawmill industry playing 'somewhat the same role in the industrial revolution in Sweden as the cotton trade in England';" third, "the incipient disappearance of surplus labor caused by overpopulation;" and fourth, "the spread of the factory organization in new branches of industry," Torsten Gårdlund – who supports Heckscher in regarding 1870s as the "watershed," but at the same time argues that the actual breakthrough occurred from the 1890s because only then "took place 'within a short period of time a transition to production of material goods based on machine technology causing fundamental change in the conditions of work and life habits of the people'," Lennart Jörberg – who, while taking note of the "rapid industrial growth" prior to 1850, believes 1870s as the "crucial period" in Swedish Industrial Revolution as it was the period when rapid structural change occurred with seemingly reference to the "rapid change taking place in industrial growth, investments and railway building," and Lennart Schön – who refers to the early industrialization before 1850s underscoring the role of agricultural revolution especially in widening the domestic market for industrial goods while at the same time downplaying the role of export demand (Gustafsson 1996, pp. 202-204).

Interestingly, Gustafsson (1996) categorizes the Industrial Revolution in Sweden into two phases. The first phase was dominated by the Textile (1830-1850) and Wood (1850-1880) industries, while the second phase (1880-1910) was distinctively characterized by a rapid parallel growth of several industrial sectors, such as Mining and Metal, Textile, Paper and Printing, and Food industries (Gustafsson 1996, pp. 207-215). Such rapid parallel growth of several industrial sectors, which may have happened during the epoch of the "Second Industrial Revolution in Sweden" in the late nineteenth century and continued until late twentieth century (Schön 1997, p. 219), is consistent with the formation of a "development block" or long-run interrelationships between complementary industrial sectors investigated upon by Enflo et al. (2008).

Focusing on the cotton textile industry, Schön (1980) describes the industrialization that occurred in Sweden during the period from 1820 to 1870. He analyzes the connections between technology, production types, and qualities of cloths, as well as market for cloth. The process of cotton weaving in the Rydboholm factory was first mechanized in 1834, supposedly to produce better quality of cloths and at the same time to challenge the British-made imported cloths (Schön 1980, p. 67). However, it was in 1850s when major breakthroughs in mechanization of production of marketed cloth occurred. The number of mechanized cotton weaving factories at this period in time increased from one to twelve, owing to the growing markets for "coarser" cloths – the supply being greatly affected by the increase in household production of cloths for market sale and the demand by the increase in wages of households – and to the "falling relative price of machinery in the wake of the evolving British machine industry and free trade treaties" (Schön 1980, p. 69).

Figure 1. Population and Real Wage in Sweden, 1560-1950

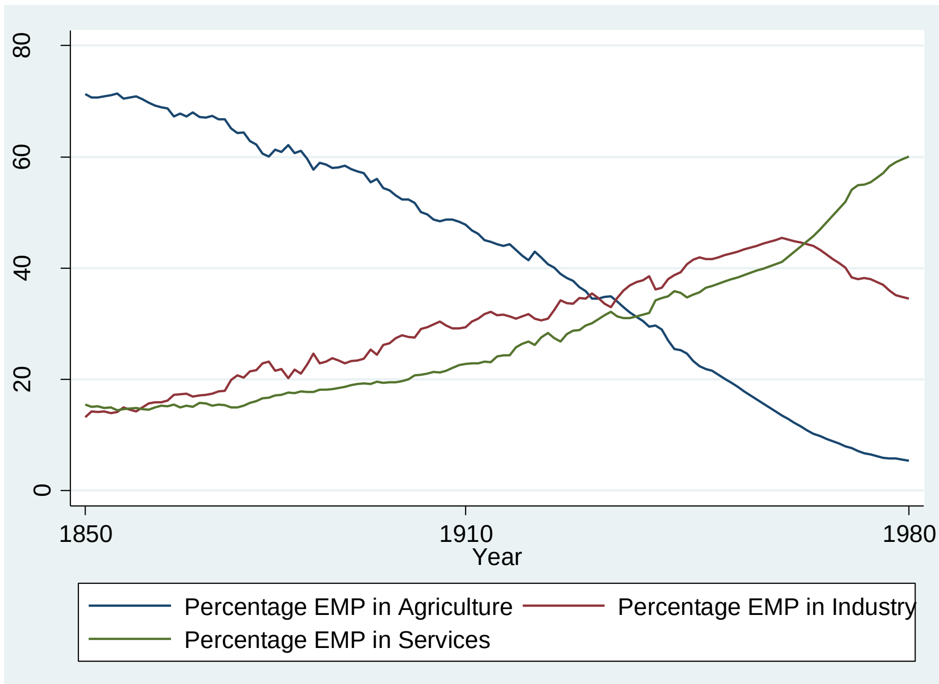


Note: Population is in the unit of hundred thousand; The vertical line supposedly marks the beginning of modern economic growth era in Sweden, as the increase in population is matched by the increase in real wage.
Source: Schön and Krantz (2012); Söderberg (2010, Table A9.1, pp. 472-475)

Figure 1 presents the population and real wage of "unskilled laborers" in Sweden from 1560 to 1950. Notice that while the population trend has been increasing over time, albeit nonlinearly, the real wage has not been increasing until the middle of nineteenth century. This supports the view that modern economic growth may have started in the middle of nineteenth century because it was the period when an increase in population was accompanied by an increase in real wage – a basic measure of standard of living according for instance to Söderberg (2010, p. 254) – allowing the country to break away from the infamous Malthusian trap. Put simply, the experience enabled the country to increase its population without a concomitant decay in its standard of living.

Moreover, the share of labor employment in the agricultural sector to total employment declined from 1850 to 1980, as shown in Figure 2. The agricultural share was 71.30 per cent in 1850, but it was down to only 5.40 per cent in 1980 – a precipitous decline as expected in the case of industrialized country. In stark contrast, the share of labor employment in the industrial sector increased from 1850 to 1960, then declined from 1960 to 1980 but not reaching back to its share in 1850. The industrial share was only 13.35 per cent in 1850, but it was up to 45.39 per cent in 1960, then down to 34.54 per cent in 1980. Lastly, the share of labor employment in the service sector continually increased from 15.45 per cent in 1850 to 60.05 per cent in 1980.

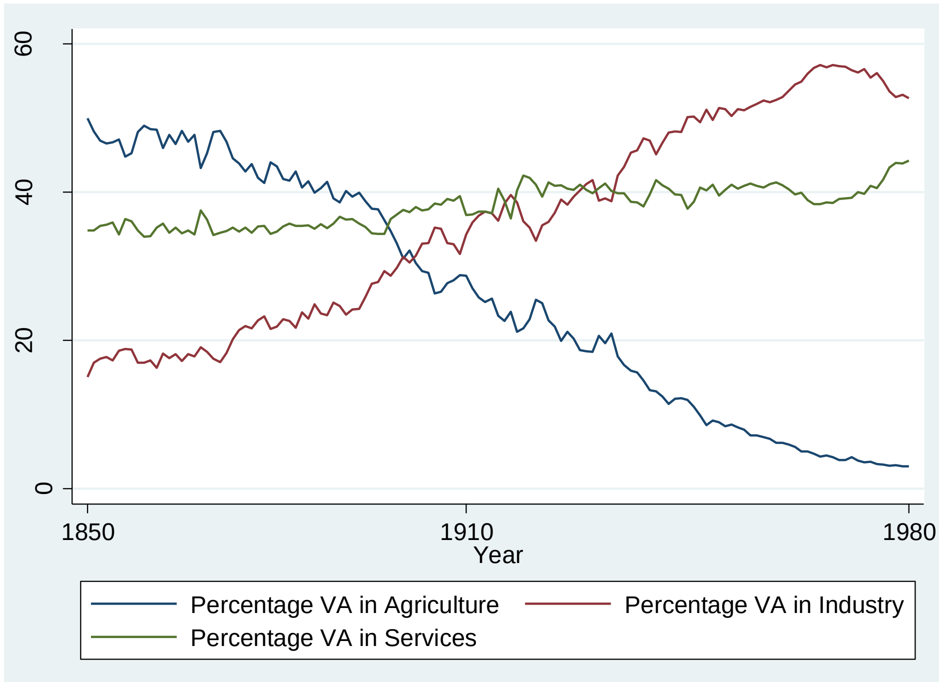
Figure 2. Percentages of Labor Employment in Main Sectors in Sweden, 1850-1980



Note: EMP=Labor Employment.
Source: Schön and Krantz (2012)

Such historical phenomenon in the employment of labor coincided with the decline in the importance of agricultural sector in terms of its contribution to the total value added, a measure of total output produced in the country, and at the same time increase in the importance of industrial sector in terms of its contribution to the total value added. Figure 3 shows that the agricultural sector share of value added in total value added was more than 41 per cent in 1850, but it was only less than three per cent in 1980. However, the share of industrial sector to total value added increased from 1850 until in the 1960s. Recall that the share of industrial sector in total labor employment increased in the same period. It is of course quite interesting to know what might have occurred in the 1960s that caused the decline in the industrial shares. Nevertheless, it is suffice to say for the purposes of this paper that the general trends in terms of labor employment and value added between agricultural and industrial sectors were different during the period. In the middle of the nineteenth century, the decline in the importance of agricultural sector coincided with the increase in the importance of industrial sector both in employment and output. Finally, a caveat on interpreting the real valued added. The shares in value added depend on the base year which in this case is the year 1910/12 following Schön and Krantz (2012). The primary reason for using value added in real rather than in nominal terms is to avoid the infamous index number problem.

Figure 3. Percentages of Real Value Added in Main Sectors in Sweden, 1850-1980



Note: VA=Value Added.
Source: Schön and Krantz (2012)

There were of course indispensable developments prior to 1850 – internal and external factors alike – that in many ways have contributed to the modern economic growth in Sweden (Schön 1980, 1997; Gustafsson 1996). For the purposes of this paper, the transition of Sweden from the traditional – usually characterized by agricultural-led economy – to the modern economic growth in the middle of the nineteenth century is taken as a hint for the choice of relevant time period covering the Swedish Industrial Revolution. By dint of this, the period from 1850 to 1980 is considered in this paper as the relevant period of study.

Furthermore, Schön (1988) itemizes in the *Historika Nationalräkenskaper för Sverige: Industri och Hantverk* 1800-1980 nine sectors of the Manufacturing Industry and Handicrafts, namely Mining and Metal (I), Mineral (II), Wood (III), Pulp, Paper and Printing (IV), Food Products (V), Textile and Clothing (VI), Leather, Hair, and Rubber (VII), Chemical (VIII), and Utilities, such as Power, Gas, and Waterworks, (IX). The importance of each of the nine sectors in terms of its contribution to the total value added or total output of the economy did change over time.

Table 3 shows the value added of each sector in real terms in different periods of time. Again, as in Figure 3 above, the purpose of using value added in real rather than in nominal term is to avoid the index number problem. Moreover, one has to be aware that using real value added may reflect price developments over time with reference to the base year which in this case is 1910/12 following Schön and Krantz (2012).

Table 3. Real Value Added in Manufacturing Industry and Handicrafts in Sweden, 1800-1980

Sector	1800	%	1830	%	1850	%	1880	%	1910	%	1980	%
I	6.9	*23*	8.70	*22*	13.5	*20*	41.1	*21*	248.1	*28*	7933	*53*
II	0.7	*2*	1.21	*3*	2.4	*4*	10.0	*5*	70.7	*8*	393	*3*
III	4.2	*14*	5.34	*14*	11.2	*17*	64.4	*33*	124.8	*14*	458	*3*
IV	0.1	*0*	0.37	*1*	0.5	*1*	3.8	*2*	79.6	*9*	1176	*8*
V	11.6	*40*	15.12	*38*	19.3	*29*	34.0	*17*	139.5	*16*	626	*4*
VI	4.1	*14*	6.24	*16*	17.2	*26*	32.4	*17*	107.9	*12*	323	*2*
VII	6.3	*21*	8.82	*22*	10.6	*16*	20.4	*10*	52.7	*6*	315	*2*
VIII	2.4	*8*	2.32	*6*	3.3	*5*	13.4	*7*	48.6	*5*	2563	*17*
IX	0.0	*0*	0.00	*0*	0.0	*0*	1.0	*1*	23.1	*3*	4499	*30*
Total	29.5	*100*	39.32	*100*	66.9	*100*	195.8	*100*	895.2	*100*	14967	*100*

Note: The figures are in the unit of million in constant 1910/12 SEK prices, except of course for figures in percentages; Note that the sum of value added in all nine sectors may not add up to total value added copied directly from the source; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks).
Source: Schön (1988, Table 114, pp. 301-310)

In the table it can be seen that in 1800, the three most important sectors relative to real output of others were Food Products (V), Mining and Metal (I), and Leather, Hair, and Rubber (VII), which comprised 40, 23, and 21 per cent of the total value added in Manufacturing and Handicrafts, respectively. The relative importance of these three sectors hardly changed in 1830.

However, the composition of the most important sectors in terms of share in the total value added interestingly changed in 1850, with Textile and Clothing (VI) joining Food Products (V) and Mining and Metal (I) in the top three sectors. Food Products (V) remained the highest in terms of its share in total value added until 1850, but its relative importance declined over time. In fact, in a span of half a century, its share decreased from 40 per cent in 1800 to only 29 per cent half a century in 1850. The share of Textile and Clothing (VI), however, sharply increased from 14 per cent in 1800 to 26 per cent in 1850. It was undoubtedly one of the fast growing sectors in this period in time. Moreover, the three leading sectors in 1880 were Wood (III), Mining and Metal (I), and Food Products (V), which were 33, 21, and 17 per cent of the total value added, respectively. Notice that the share of Wood (III) in 1880 was 16 percentage points higher than in 1850, while the share of Food Products (V) in 1880 was 12 percentage points lower in 1850. The importance of Food and Products (V) decreased from 29 per cent in 1850 to just 17 per cent of total value added in

1880, although its absolute value more than doubled in a span of three decades from 1850[1]. Furthermore, Mining and Metal (I) was ahead Wood (III) in 1910. This leading role of Mining and Metal (I) continued in 1980, constituting more than half of the total value added in 1980. At the same time, two other sectors – Chemical (VIII) and Power, Gas, and Waterworks (IX) – undoubtedly became more important sectors than others, having 17 and 30 per cent shares, respectively[2].

Indeed, the changing importance of each subsector in terms of its real output in comparison with others over time is a testament to the dynamic changes occurred during the Industrial Revolution in Sweden as discussed in Section 2. The leading sector in 1800 was Food and Products (V). In 1850, Textile and Clothing (VI) increased its share to the total output, while the share of Food and Products (V) decreased. Wood (III) overtook Textile and Clothing (VI) as the leading sector in 1880. Mining and Metal (I) became the dominant subsector in 1910 and retained its leading position until 1980, dwarfing the contribution of other sectors to the total value added.

Moreover, Chemical (VIII) and Utilities (IX) increased their shares in total output from virtually nothing – or nothing at all – in 1800 to almost one-fifth and one-third, respectively, of total output in the late twentieth century. Needless to say that analysis of the Industrial Revolution in Sweden should take these dynamic changes into account.

4 Theoretical Framework

The main implication of the traditional view of Industrial Revolution is that one sector could affect the other sectors in the economy relatively faster than what is suggested by the revisionist view. Say, for instance, improvements in labor productivity in one industrial sector, owing to product or process of production or technological innovations, may result in improvements in labor productivity in other industrial sectors that, in one way or another, "quickly" adapt to – or modify the organization of – its production process to take advantage of these new developments in technology.

A Sketch of the Traditional View of Industrial Revolution

Technological Innovation/Change → Impact on One Industry → Impact on Other Industries → Impact on Overall Output

However, the ramifications of such improvements in labor productivity in one industry may not immediately lead to improvements in labor productivity in other industrial sectors because of the substantial amount of time and efforts needed for the structural change to complete its process, such as for example the reallocation of resources from one sector to

[1] In fact, each sector on average grew in absolute terms from 1850 to 1980.

[2] Note that data for (IX) Utilities only became available from 1846 onwards. Also, these three sectors – Mining and Metal (I), Chemical (VIII), and Power, Gas, and Waterworks (IX) – comprise already 100 per cent of the total value added if copied directly from the source. In other words, the sum of value added in all nine sectors does not tally with the published total value added. Nevertheless, the observed discrepancy does not alter the fact that these three sectors comprise overwhelming shares of the total value added.

another with relatively higher productivity. In addition, the learning process necessary for effective transfer of technology from certain "revolutionized" industrial sectors to other industrial sectors of the economy may take more time than what the traditional view suggests. There is therefore a considerable time lag before the effects of the "revolution" in certain industrial sectors be experienced in other sectors and ultimately in the whole economy.

A Sketch of the Revisionist View of Industrial Revolution

Technological Innovation/Change → Impact on One Industry → Structural Change/Learning Process → Impact on Other Industries → Impact on Overall Output

5 Hypotheses

Whether the effects of the technological innovations and other developments in one sector on other sectors were immediate – short rather than long-run – is the main concern of the paper. Hence, an interesting case is when labor productivity in one industrial sector affects the labor productivity in other industrial sectors. As it does, finding out the speed, either short-run or long-run, and the magnitude of such effects provide straightforward answers to the first two questions posed in Section 1.

In particular, the null hypothesis that will be tested is that improvements in labor productivity in one industrial sector have no short-run significant effects – economically and statistically – on the other industrial sectors of the economy, against the alternative hypothesis that such improvements in the former sector have in fact significant short-run effects on the latter sectors. Consequently, the rejection of the null hypothesis in favor of the alternative one will lend credence to the traditional view of the Industrial Revolution. Otherwise, the revisionist view is supported instead.

The main focus of this paper is on the short-run effects of labor productivity in one sector to the others, as both traditional and revisionist views have common expected long-run effects. The necessary condition for the traditional view to hold is to observe significant short-run effects. If this necessary condition is not even satisfied, then the traditional view should be rejected. The decision rule that this paper imposes therefore is to reject traditional view if the short-run effects are economically and statistically not different from zero. Otherwise, the revisionist view should be rejected.

Summary of Expectations on Traditional and Revisionist Views

Effect	Traditional View	Revisionist View
Short-run	+	0
Long-run	+	+

It is highly likely to find long-run relationships between the industrial sectors in study, especially since many of these sectors are complementary (Enflo et al. 2008). In such case, it is important for estimating the short-run effects to control for any cointegration relationships – or systematic co-movements – between these sectors in the long-run, as failing to do so may lead to misspecification of the model and erroneous regression results. The analysis will thus be adjusted to reflect this case through a model that controls for cointegration relationships, particularly the Vector Error Correction Model, but the hypotheses generally remains the same. Section 7 discusses this in more detail.

6 Data

6.1 Labor Productivity

This paper utilizes two sets of data drawn from various sources to analyze the nature of the Industrial Revolution in Sweden. The first set is the data on labor productivity in two industrial sectors, namely Manufacturing (MFG), consisting of metal and food industries, and Building and Construction (BLDG) industrial sectors from 1850 to 1980. Labor productivity in this paper is defined as the ratio between output and labor input, where output is measured in terms of real value added in Swedish Kronor (SEK) in 1910/12 constant prices, while labor input is measured in terms of labor employment. Therefore labor productivity in each sector is provided as value added in SEK in 1910/12 constant prices per labor employment. It is computed from the *Swedish Historical National Accounts 1560-2010* (SHNA) by Schön and Krantz (2012).

However, the data is available only for two industrial sectors. Ideally, the sample of industrial sectors should at least include those sectors that experienced dramatic technological changes, referred to as "revolutionized" sectors, during the Industrial Revolution in Sweden. Industrial sectors such as Mining and Metal, Wood, Paper and Printing, and Textile and Clothing, and others industries discussed in Section 3, are possible candidates in this regard. Moreover, the series of labor employment – the denominator needed to compute for labor productivity – is available only from 1850, and therefore labor productivity in the two sectors are computed only from this year. Nevertheless, in spite of the inherent difficulties with estimation, the data on labor productivity in industrial sectors that can be computed from SHNA is by far the most recent available known to date for the study.

Table 4. Labor Productivity Growth in MFG and BLDG in Sweden, 1850-1980 (per cent per year)

Sector	1850-1980	1850-1880	1880-1910	1910-1980
Manufacturing Industry (MFG)	2.39	1.03	2.42	2.84
Building and Construction Industry (BLDG)	1.40	0.04	2.12	1.65

Note: MFG=Manufacturing; BLDG=Building and Construction.
Source: Schön and Krantz (2012)

Table 4 shows the rates of growth in labor productivity in MFG and BLDG in Sweden over the period from 1850 to 1980 with reference to 1910/12 base year. Notice that growth in labor productivity in both sectors increased over the period from 1850 to 1980. In particular, the growth rate of labor productivity in MFG was 2.39 per cent per year, while the growth rate of labor productivity in BLDG was only 1.40 per cent per year over the entire period. Note also that the labor productivity in MFG grew only by 1.03 per cent per year over the period from 1850 to 1880, while labor productivity in BLDG barely grew over the same period. However, the growth rates in labor productivity in MFG and BLDG accelerated in the following periods, so that these were 2.42 and 2.12 per cent per year, respectively, over the period from 1880 to 1910, and were 2.84 and 1.65 per cent per year, respectively, over the period from 1910 to 1980.

6.2 Real Product Wage

The second set is the data on real product wage defined as the ratio between nominal wage and the price of product. Note that this is different from the real wage defined as the ratio between nominal wage and price of consumption goods usually measured by the consumer price index. The nominal wage obtained from Söderberg (2010) is expressed in nominal wage in terms of gram of silver, while the price of product derived from Schön (1988) is computed implicitly as the ratio between nominal value added and real value added based on 1910/12 constant prices, hence the price of product is expressed as the implicit price deflator.

While the data on labor productivity runs from 1850 to 1980, the data on real product wage covers the period from 1830 to 1914. The start date 1830 is motivated by the discussion about the Industrial Revolution in Sweden discussed in Section 3. In particular, Gustafsson (1996) maintains that the first phase of the Industrial Revolution in Sweden over the period from 1830 to 1880 was dominated by textile and wood industries. Moreover, it was in 1834 when the process of cotton weaving in Sweden was mechanized for the first time (Schön 1988). The end date 1914 is determined based on the latest possible observation of data on nominal wage in gram of silver by Söderberg (2010).

However, the time series data on nominal wage in gram of silver by Söderberg (2010) is available only for unskilled laborers based on "daily summer rates of male unskilled laborers in Stockholm" for the period from 1365 to 1864 and "wages for industrial and mining workers in Sweden" for the period from 1864 onwards (Söderberg 2010, p. 453-454). In this paper, such long series of nominal wage is taken to envelop the general developments in the industrial sector as a whole. The rationale for this is that in principle nominal wages in different industrial sectors tend to move closely together in the long run owing to the process of integration in the labor market. Hence, the variations in the real product wage in different industrial sectors arise because of the variations in the implicit price deflator, while at the same time taking into account the overall trend in the nominal wage of the whole industrial sector.

It is worth to emphasize the strong empirical relationship between real product wage and productivity. Ljungberg (2004) argues that wage (plus social cost for example payroll tax) when deflated by output prices – the real product wage – should "parallel developments in productivity" by showing the close correlation between real product wage and productivity in the case of several industrial sectors in Sweden from 1913 to 1980, namely Metal-working Industry, Stone and Earthware Industry, Woodworking Industry, Pulp, Paper and Printing Industry, Food Industry, Textile and Clothing Industry, and Chemical Industry. In fact, there were "few cases" in which the growth in real product wage had "almost perfect coincidence" with the growth in productivity. In addition, it was also shown that there were indications of "far reaching" integration in the labor market among the so-called "blue collars" owing to factors such as "smooth market processes" or "national collective contracts" (Ljungberg 2004, pp. 249-250). To be sure, such empirical findings attest to the suitability of real product wage as proxy measure for productivity.

Therefore, this paper utilizes the data on real product wage for three main reasons. First, the data on real product wage, which under certain assumptions was shown to be mathematically[3] and empirically correlated to average productivity, is more comprehensive than the data on labor productivity because the data on real product wage can be computed for nine sectors of the Manufacturing Industry and Handicrafts, while the data on labor productivity can be computed only for two sectors MFG and BLDG. Second, observations earlier than 1850 are available in real product wage, but not in labor productivity, and therefore observations from years earlier than 1850 can now be included in the study using the data on real product wage. Finally, the robustness of results can be checked by comparing the results obtained from using the data on labor productivity with the results obtained from using the data on real product wage.

Table 5. Real Product Wage Growth in Manufacturing Industry and Handicrafts in Sweden, 1830-1914 (per cent per year)

Period	I	II	III	IV	V	VI	VII	VIII	IX
1830-1914	3.35	3.02	1.83	3.58	2.42	3.12	1.45	2.72	4.28[a]
1830-1880	1.87	2.41	0.38	1.51	0.87	2.21	0.39	0.93	2.25[b]
1880-1910	5.60	4.07	4.46	7.02	5.13	4.49	3.70	5.85	6.92

Note: [a]=1846-1914; [b]=1850-1880; Real product wage is computed as the ratio between nominal wage in gram of silver (Söderberg 2010) and implicit price deflator with 1910/12 as the base year (Schön 1988); I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks).
Source: Schön (1988, Table 12, pp. 218-227; Table 114, pp. 301-310); Söderberg (2010, Table A9.1, pp. 472-475)

Table 5 presents the growth in real product wage in nine sectors of Manufacturing and Industry and Handicrafts. Over the entire period from 1830 to 1914 with reference to the 1910/12 base year, the productivity as measured by real product wage in Mining and Metal (I) grew by 3.35 per cent per year; Mineral (II) by 3.02; Wood (III) by 1.83; Pulp, Paper, and Printing (IV) by 3.58; Food Products (V) by 2.42; Textile and Clothing (VI) by 3.12; Leather, Hair, and Rubber (VII) by 1.45; and Chemical (VIII) by 2.72. Utilities (IX) grew by 4.28 over the period from 1846 – the earliest possible data one could obtain from Söderberg (2010) – to 1914. Notice that real product wage in all nine industrial sectors grew during the first phase of Industrial Revolution in Sweden over the period from 1830 to 1880. The highest growth during this period was that of Mineral (II) which grew by 2.41 per cent per year, followed by that of Textile and Clothing (VI) which grew by 2.21 per cent per year. Utilities (IX) grew by 2.25 per cent per year over the period from 1850 to 1880. Furthermore, the real product wage in all nine industrial sectors also grew during the period of the second phase of Industrial

[3] The optimal level of average product of labor, $\frac{Q}{L}$, is determined by solving the first-order necessary condition, $\frac{d(\frac{Q}{L})}{dL} = 0$, where Q is output and L labor. Moreover, it can be shown that $\frac{d(\frac{Q}{L})}{dL} = \frac{L\frac{dQ}{dL} - Q}{L^2} = \frac{\frac{dQ}{dL} - \frac{Q}{L}}{L} = 0.$ Hence, the marginal product of labor, $\frac{dQ}{dL}$, which is equal to wage under perfect competition, is equal to the average product labor, $\frac{Q}{L}$.

Revolution in Sweden over the period from 1880 to 1910. The growth rates during this period range from 3.70 to about 7.02 per cent per year.

7 Methodology

7.1 Testing for Unit Root, Integration, and Cointegration

The results of Phillips-Perron Test for Unit Root[4] presented in Table 6 suggest that labor productivity in sectors MFG and BLDG and real product wage in nine sectors of Manufacturing Industry and Handicrafts are all nonstationary, as in each case the null hypothesis that there is unit root is not rejected in any conventional significance levels of ten, five, and one per cent. By visual inspection of Figures 4 and 5, one may argue that each series has mean that does not seem to revert to any constant over time, a violation of one of the conditions for stationarity of time-series variables (Asterious and Hall 2011, p. 267)

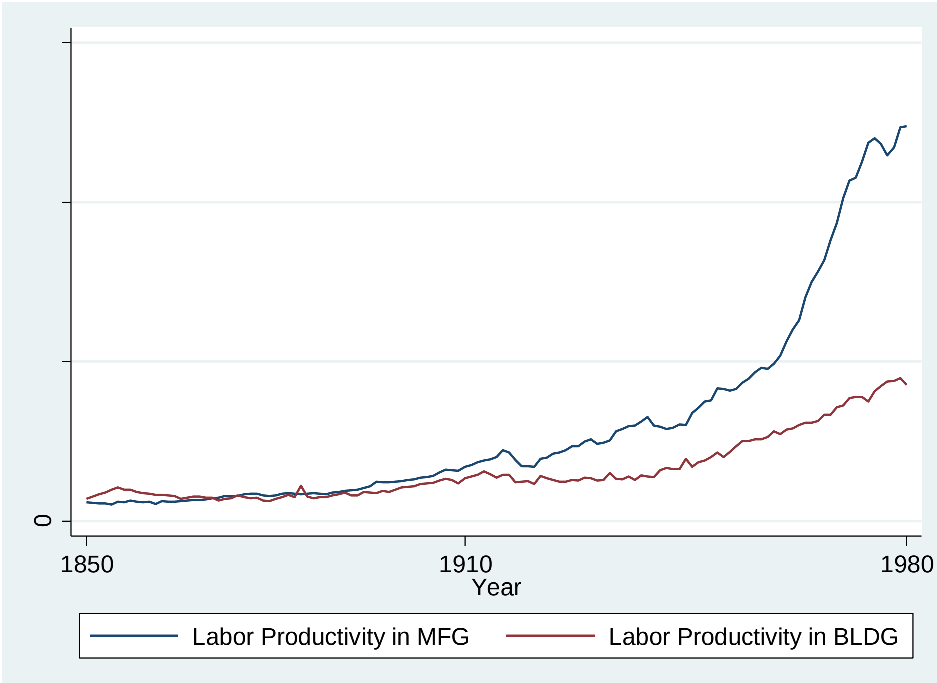
Table 6. Phillips-Perron Test for Unit Root in Labor Productivity (1850-1980) and Real Product Wage (1830-1914)

Variable	Lag(s)	Specification	Z(t)-Stat	5% CV	Conclusion	Obs.
Level Scale						
LP^{MFG}	4	Constant, Trend	1.602	-3.446	Nonstationary	130
LP^{BLDG}	4	Constant, Trend	0.231	-3.446	Nonstationary	130
RPW^{I}	3	Constant, Trend	1.033	-3.466	Nonstationary	84
RPW^{II}	3	Constant, Trend	-0.477	-3.466	Nonstationary	84
RPW^{III}	3	Constant, Trend	-2.041	-3.466	Nonstationary	84
RPW^{IV}	3	Constant, Trend	0.811	-3.466	Nonstationary	84
RPW^{V}	3	Constant, Trend	-0.729	-3.466	Nonstationary	84
RPW^{VI}	3	Constant, Trend	0.190	-3.466	Nonstationary	84
RPW^{VII}	3	Constant, Trend	-1.619	-3.466	Nonstationary	84
RPW^{VIII}	3	Constant, Trend	-0.220	-3.466	Nonstationary	84
RPW^{IX}	3	Constant, Trend	-0.747	-3.482	Nonstationary	68
Natural Logarithmic Scale						
$\ln(LP^{MFG})$	4	Constant, Trend	-1.886	-3.446	Nonstationary	130
$\ln(LP^{BLDG})$	4	Constant, Trend	-1.793	-3.446	Nonstationary	130
$\ln(RPW^{I})$	3	Constant, Trend	-1.785	-3.466	Nonstationary	84
$\ln(RPW^{II})$	3	Constant, Trend	-2.182	-3.466	Nonstationary	84
$\ln(RPW^{III})$	3	Constant, Trend	-2.653	-3.466	Nonstationary	84
$\ln(RPW^{IV})$	3	Constant, Trend	-1.806	-3.466	Nonstationary	84
$\ln(RPW^{V})$	3	Constant, Trend	-2.704	-3.466	Nonstationary	84
$\ln(RPW^{VI})$	3	Constant, Trend	-2.637	-3.466	Nonstationary	84
$\ln(RPW^{VII})$	3	Constant, Trend	-1.996	-3.466	Nonstationary	84
$\ln(RPW^{VIII})$	3	Constant, Trend	-1.648	-3.466	Nonstationary	84
$\ln(RPW^{IX})$	3	Constant, Trend	-2.068	-3.482	Nonstationary	68

Note: ln=Natural Logarithm; LP=Labor Productivity; MFG=Manufacturing; BLDG=Building and Construction; RPW=Real Product Wage; I=Mining and Metal; II=Mineral; III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities.
Source: Author's calculation using STATA

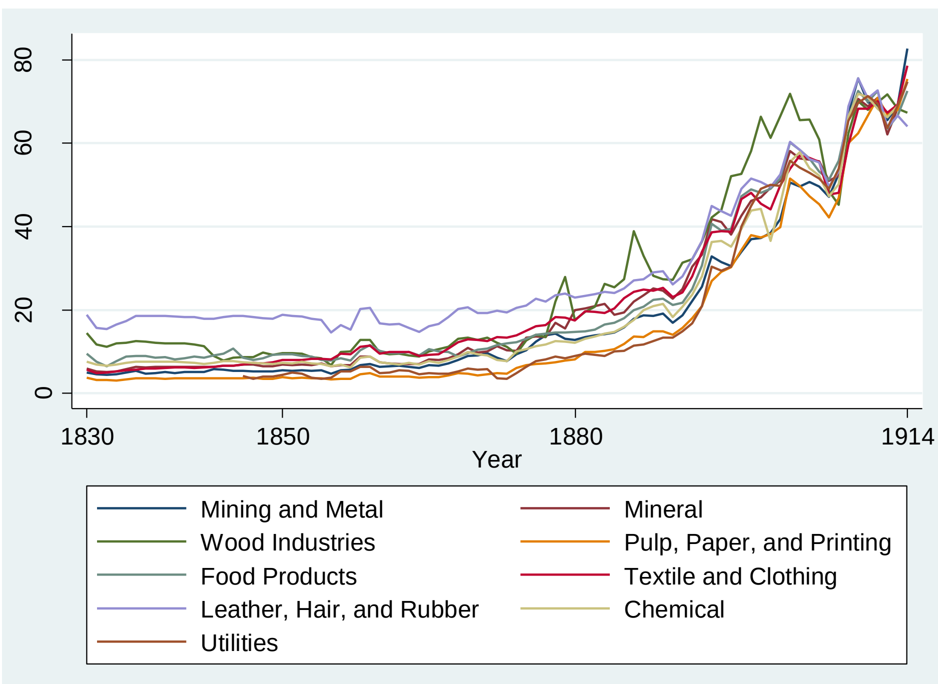
[4] The Phillips-Perron Test for Unit Root takes into account any serial correlation in the computation of standard error called the Newey-West standard error which in turn is used in constructing test statistics.

Figure 4. Labor Productivity in MFG and BLDG in Sweden, 1850-1980



Note: MFG=Manufacturing; BLDG=Building and Construction.
Source: Schön and Krantz (2012)

Figure 5. Real Product Wage in Manufacturing Industry and Handicrafts in Sweden, 1830-1914



Source: Schön (1988); Söderberg (2010)

The immediate implication of having nonstationary variables is that running any regression using these variables may yield "spurious" results. One way to avoid such problem is to perform regression using the first difference of variables, provided that the variables are integrated of the first order, denoted I(1). If the order of integration is two, then the second difference of variable is used instead, so on and forth. Table 7 shows that all variables are thus far shown to be integrated of the first order. In other words, while performing a traditional regression on non-stationary variables may yield spurious results, performing the same on the first difference of variables should lead to proper results, of course with the assumption that all other necessary conditions hold.

Table 7. Test for Integration in Labor Productivity (1850-1980) and Real Product Wage (1830-1914)

Variable	Lag(s)	Specification	Z(t)-Stat	5% CV	Conclusion	Obs.
			Level Scale			
ΔLP^{MFG}	4	Constant, No Trend	-5.795	-2.888	I(1)	129
ΔLP^{BLDG}	4	Constant, No Trend	-13.816	-2.888	I(1)	129
ΔRPW^{I}	3	Constant, No Trend	-5.080	-2.904	I(1)	83
ΔRPW^{II}	3	Constant, No Trend	-8.328	-2.904	I(1)	83
ΔRPW^{III}	3	Constant, No Trend	-8.338	-2.904	I(1)	83
ΔRPW^{IV}	3	Constant, No Trend	-6.685	-2.904	I(1)	83
ΔRPW^{V}	3	Constant, No Trend	-7.297	-2.904	I(1)	83
ΔRPW^{VI}	3	Constant, No Trend	-5.598	-2.904	I(1)	83
ΔRPW^{VII}	3	Constant, No Trend	-7.939	-2.904	I(1)	83
ΔRPW^{VIII}	3	Constant, No Trend	-6.381	-2.904	I(1)	83
ΔRPW^{IX}	3	Constant, No Trend	-5.609	-2.916	I(1)	67
			Natural Logarithmic Scale			
$\Delta\ln(LP^{MFG})$	4	Constant, No Trend	-11.260	-2.888	I(1)	129
$\Delta\ln(LP^{BLDG})$	4	Constant, No Trend	-15.508	-2.888	I(1)	129
$\Delta\ln(RPW^{I})$	3	Constant, No Trend	-7.683	-2.904	I(1)	83
$\Delta\ln(RPW^{II})$	3	Constant, No Trend	-9.952	-2.904	I(1)	83
$\Delta\ln(RPW^{III})$	3	Constant, No Trend	-9.265	-2.904	I(1)	83
$\Delta\ln(RPW^{IV})$	3	Constant, No Trend	-7.892	-2.904	I(1)	83
$\Delta\ln(RPW^{V})$	3	Constant, No Trend	-8.344	-2.904	I(1)	83
$\Delta\ln(RPW^{VI})$	3	Constant, No Trend	-8.312	-2.904	I(1)	83
$\Delta\ln(RPW^{VII})$	3	Constant, No Trend	-8.878	-2.904	I(1)	83
$\Delta\ln(RPW^{VIII})$	3	Constant, No Trend	-8.188	-2.904	I(1)	83
$\Delta\ln(RPW^{IX})$	3	Constant, No Trend	-6.709	-2.916	I(1)	67

Note: ln=natural logarithm; Δ=First Difference; LP=Labor Productivity; MFG=Manufacturing; BLDG=Building and Construction; RPW=Real Product Wage; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks).
Source: Author's calculation using STATA

However, as noted earlier, proceeding with the regression using the first-difference variables without taking into consideration the possible long-run relationships between these variables may lead to misspecification problems. The existence of such long-run relationships and systematic co-movements between the variables is tested using the Johansen Test for

Cointegration[5]. Industrial sectors that are complementary with each other are expected to be cointegrated (Enflo et al. 2008, p. 58). By dint of this, one should consider the possible cointegration relationships that may be observed in productivity between one and other sectors. For example, labor productivity in MFG and BLDG are expected to be cointegrated because the former supplies important inputs – specifically metal – to the latter while at the same time the latter creates demands for outputs of the former.

Table 8 reports the results of the Johansen Test for Cointegration in labor productivity in MFG and BLDG from 1850 to 1980 both in level and natural logarithmic scale. Following the Pantula Principle, the null hypothesis that there is no cointegration relationship between the two variables is first tested in the model with no deterministic trend in both Vector Autoregressive (VAR) and Cointegration Equation (CE), but with constant only in the CE, denoted RCONS. The corresponding alternative hypothesis is that there is at least one cointegration relationship. If the null hypothesis is rejected, then the test proceeds to the next model with constant in both VAR and CE, but no deterministic trend in both, denoted CONS. If still the null hypothesis is rejected, then the test continues to the next model with constant in both VAR and CE, but with deterministic trend only in CE, denoted RTREND. The test reverts to the first model with the new null hypothesis that there is at most one cointegration relationship between the two variables. The process repeats until the case when the null hypothesis is not rejected for the first time, which is marked with an asterisk (*) in Table 8.

Table 8. Johansen Test for Cointegration in Labor Productivity, 1850-1980

Pair	Lags	Specification	Max Rank	T-Stat	5% CV	Obs.
Level Scale						
$LP^{MFG} - LP^{BLDG}$	2	RCONS	0	40.53	19.96	129
$LP^{MFG} - LP^{BLDG}$	2	CONS	0	29.97	15.41	129
$LP^{MFG} - LP^{BLDG}$	2	RTREND	0	32.93	25.32	129
$LP^{MFG} - LP^{BLDG}$	2	RCONS	1	8.82*	9.42	129
$LP^{MFG} - LP^{BLDG}$	2	CONS	1	7.60	3.76	129
$LP^{MFG} - LP^{BLDG}$	2	RTREND	1	9.93	12.25	129
Natural Logarithmic Scale						
$\ln(LP^{MFG}) - \ln(LP^{BLDG})$	2	RCONS	0	34.10	19.96	129
$\ln(LP^{MFG}) - \ln(LP^{BLDG})$	2	CONS	0	10.16*	15.41	129
$\ln(LP^{MFG}) - \ln(LP^{BLDG})$	2	RTREND	0	19.24	25.32	129
$\ln(LP^{MFG}) - \ln(LP^{BLDG})$	2	RCONS	1	6.68	9.42	129
$\ln(LP^{MFG}) - \ln(LP^{BLDG})$	2	CONS	1	3.46	3.76	129
$\ln(LP^{MFG}) - \ln(LP^{BLDG})$	2	RTREND	1	5.80	12.25	129

Note: *=Null hypothesis not rejected for the first time; ln=Natural Logarithm; LP=Labor Productivity; MFG=Manufacturing; BLDG=Building and Construction; Number of lags is determined using information criteria.
Source: Author's calculation using STATA

[5] Asteriou and Hall (2011) provide a requirement for long-run relationship or cointegration between two variables to exist. "The key point here is that if there really is a genuine long-run relationship between Y_t and X_t, then despite the variables rising over time (because they are trended), there will be common trend that links them together. For an equilibrium or long-run relationship to exist, what we require, then, is a linear combination of Y_t and X_t that is a stationary variable (Asteriou and Hall 2011, pp. 356-357)."

Note that labor productivity between MFG and BLDG are cointegrated in level but not in natural logarithmic scale. To wit, the two variables are expected to be cointegrated, especially since these two industrial sectors are complementary with each other, and the conclusion that these two industrial sectors are cointegrated – at least in level scale – supports such expectation. In this exercise therefore one may think that the Johansen Test is not only sensitive to the number of lags included in the vector model but also to the scale form of the variables.

Moreover, a pairwise test for cointegration in real product wage both in level and natural logarithmic scale in each nine industrial sectors of Manufacturing Industry and Handicrafts is performed using the same Johansen Test and Pantula Principle. For example, a pairwise cointegration is tested on the real product wage between Mining and Metal (I) and Mineral (II), between Mining and Metal (I) and Wood (II), between Mining and Metal (I) and Pulp, Paper and Printing (IV), and so on. The same is done for each nine sectors from Mining and Metal (I) up to Utilities (IX). As there are nine sectors, the highest possible total number of pairwise cointegration relationship for each sector is eight.

Table 9 reports the total number of pairwise cointegration relationships in real product wage in each nine industrial sectors expressed in level scale. The sectors with the highest number of pairwise cointegration relationships are Mining and Metal (I), Textile and Clothing (VI), and Leather, Hair, and Rubber (VII), each of these sectors is cointegrated with seven other sectors. Recall in Table 3 that these sectors figure prominently in the top three sectors in terms of share in total value added with reference to 1910/12 base year. The next highest sector is the Pulp, Paper, and Printing (IV), which is cointegrated with five other sectors. The rest – Mineral (II), Wood (III), Food Products (V), Chemical (VIII), and Utilities (IX) – are cointegrated with four other sectors.

Table 9. Number of Cointegration Relationships in Real Product Wage, 1830-1914 (Level Scale)

	I	II	III	IV	V	VI	VII	VIII	IX
I	-	✓	✓	✓	✓	✓	✓		✓
II	✓	-				✓	✓	✓	
III	✓		-	✓		✓		✓	
IV	✓		✓	-	✓	✓	✓		
V	✓			✓	-		✓		✓
VI	✓	✓	✓	✓		-	✓	✓	✓
VII	✓	✓		✓	✓	✓	-	✓	✓
VIII		✓	✓			✓	✓	-	
IX	✓				✓	✓	✓		-
Total	7	4	4	5	4	7	7	4	4

Note: ✓=Cointegrated; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks)
Source: Author's calculation using STATA

Table 10 presents the total number of pairwise cointegration relationships in real product wage in the same set of industrial sectors but this time expressed in natural logarithm.

As in the case of labor productivity in MFG and BLDG, the Johansen Test yields different results when real product wage is expressed in natural logarithm from those results obtained from when real product wage is expressed in level scale. For example, in mark contrast with the previous results, Mining and Metal (I) and Textile and Clothing (VI) have zero pairwise cointegrated relationships. Moreover, although Pulp, Paper, and Printing (IV), Chemical (VIII), and Utilities (IX) have the same total number of pairwise cointegration relationships as in Table 9, the composition of relationships in Table 10 is different from the previous one. For instance, Pulp, Paper, and Printing (IV) is found to be pairwise cointegrated with Mining and Metal (I), Textile and Clothing (VI), and Leather, Hair, and Rubber (VII) in Table 9, but not in Table 10. The bottom line is Tables 9 and 10 are strikingly different from each other owing to the different scales used – level in Table 9 while natural logarithm in Table 10.

Table 10. Number of Cointegration Relationships in Real Product Wage, 1830-1914 (Natural Logarithmic Scale)

	I	II	III	IV	V	VI	VII	VIII	IX
I	-								
II		-	✓						
III		✓	-	✓					
IV			✓	-	✓		✓	✓	✓
V				✓	-			✓	✓
VI						-			
VII				✓			-	✓	✓
VIII				✓	✓		✓	-	✓
IX				✓	✓		✓	✓	-
Total	0	1	2	5	3	0	3	4	4

Note: ✓=Cointegrated; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks)
Source: Author's calculation using STATA

7.2 Econometric Model

The analysis and statistical tests so far reveals that labor productivity in MFG and BLDG and the real product wage in nine sectors of Manufacturing Industry and Handicrafts all have nonstationary time-series properties, as shown in Table 6. Furthermore, Table 7 shows that these variables are all integrated of the first order. Such results are robust to whether the variables are in level or in natural logarithmic scale.

However, the cointegration analysis yields results that are sensitive to the use of scales. One should therefore take this caveat about using different scales most especially in cointegration analysis. Tables 8 to 10 nevertheless provide guidance as to the choice of model between Vector Error Correction Model (VECM) and Vector Autoregressive Model (VAR) for estimating the short-run effects in each pair of equations. On the one hand, equations involving cointegrated variables constitute VECM, which takes into account long-run relationships through a Cointegrating Equation (CE), as expressed in the following equation:

$$\Delta y_{it} = \gamma_{i0} + \boldsymbol{\gamma_{i1}} \sum_{i=1}^{2} \sum_{j=1}^{J} \Delta y_{it-j} - \alpha_i \left(y_{it} - \beta_{i0} - \boldsymbol{\beta_{i1}} \sum_{j=1}^{J} y_{-it-j} - \varepsilon_{it} \right) + v_{it}$$

where Δy_{it} is the first difference of variable y_{it}; $\boldsymbol{\gamma_{i1}}$ the vector of short-run coefficients; $\boldsymbol{\beta_{i1}}$ vector of long-run coefficients; α_i the error-correction coefficient; $(y_{it} - \beta_{i0} - \boldsymbol{\beta_{i1}} \sum_{j=1}^{J} y_{-it-j} - \varepsilon_{it})$ the CE; and ε_{it} and v_{it} by assumption the well-behaved error terms for all sector $i = 1{,}2$, lag length $j = 1, \dots, J$, and time $t = 1, \dots, T$.

On the other hand, equations that do not involve cointegrated variables follow VAR, which is basically similar to VECM only that VAR does not contain the CE term. The equation in this case is given by the following:

$$\Delta y_{it}^{'} = \gamma_{i0}^{'} + \boldsymbol{\gamma_{i1}^{'}} \sum_{i=1}^{2} \sum_{j=1}^{J} \Delta y_{it-j}^{'} + v_{it}^{'}$$

where the prime notation $(')$ underscores the difference from the previous equation; $\Delta y_{it}^{'}$ the first difference of the variable $y_{it}^{'}$; $\boldsymbol{\gamma_{i1}^{'}}$ the short-run effects; and $v_{it}^{'}$ by assumption well-behaved error term for all sector $i = 1{,}2$, lag length $j = 1, \dots, J$, and time $t = 1, \dots, T$.

The short-run coefficients $\boldsymbol{\gamma_{i1}}$ and $\boldsymbol{\gamma_{i1}^{'}}$ are the main focus in this paper. These short-run coefficients are expected to be either zero or positive, as stipulated in Section 5. Note that these expectations about the short-run effects are the same for VECM and VAR. The main difference is that the long-run relationship between variables is taken into account in VECM, but not in VAR. Furthermore, both models involve variables that are I(1) in order to avoid spurious results. Even the term CE in VECM is I(1) because the linear combination of nonstationary variables in CE is I(1) by definition of cointegration.

Table 11. Model to Estimate Short-run Effects in Real Product Wage, 1830-1914 (Level Scale)

	I	II	III	IV	V	VI	VII	VIII	IX
I	-	VECM	VECM	VECM	VECM	VECM	VECM	VAR	VECM
II	VECM	-	VAR	VAR	VAR	VECM	VECM	VECM	VAR
III	VECM	VAR	-	VECM	VAR	VECM	VAR	VECM	VAR
IV	VECM	VAR	VECM	-	VECM	VECM	VECM	VAR	VAR
V	VECM	VAR	VAR	VECM	-	VAR	VECM	VAR	VECM
VI	VECM	VECM	VECM	VECM	VAR	-	VECM	VECM	VECM
VII	VECM	VECM	VAR	VECM	VECM	VECM	-	VECM	VECM
VIII	VAR	VECM	VECM	VAR	VAR	VECM	VECM	-	VAR
IX	VECM	VAR	VAR	VAR	VECM	VECM	VECM	VAR	-

Note: VECM=Vector Error Correction Model; VAR=Vector Autoregressive Model; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks)
Source: Author on the basis of Table 9

Consequently, the appropriate model to use in estimating the short-run effects in labor productivity between MFG and BLDG is VECM when labor productivity is expressed in level and VAR when it is expressed in natural logarithmic scale. The same logic applies in the case of real product wage in nine industrial sectors of Manufacturing Industry and Handicrafts. The appropriate model to use in estimating the short-effects in real product wage for each pair of industrial sectors is summarized in Tables 11 (above) and 12 (below). Table 11 is constructed based on Table 9, while Table 12 is based on Table 10. In particular, the short-run relationships in real product wage between a pair of industrial sectors which are cointegrated, particularly those pairs with tick mark (✓), should be estimated using VECM. Otherwise, the model to be used is VAR, and these are the pairs without the tick mark. Those pairs marked with hyphen (-) are not estimated since the focus in this paper is on the short-run effects of productivity in one to the productivity in other industrial sectors, and not the short-run effects of one to itself, which of course may also be interesting depending on one's research purposes.

Table 12. Model to Estimate Short-run Effects in Real Product Wage, 1830-1914 (Natural Logarithmic Scale)

	I	II	III	IV	V	VI	VII	VIII	IX
I	-	VAR	VAR	VAR	VAR	VAR	VAR	VAR	VAR
II	VAR	-	VECM	VAR	VAR	VAR	VAR	VAR	VAR
III	VAR	VECM	-	VECM	VAR	VAR	VAR	VAR	VAR
IV	VAR	VAR	VECM	-	VECM	VAR	VECM	VECM	VECM
V	VAR	VAR	VAR	VECM	-	VAR	VAR	VECM	VECM
VI	VAR	VAR	VAR	VAR	VAR	-	VAR	VAR	VAR
VII	VAR	VAR	VAR	VECM	VAR	VAR	-	VECM	VECM
VIII	VAR	VAR	VAR	VECM	VECM	VAR	VECM	-	VECM
IX	VAR	VAR	VAR	VECM	VECM	VAR	VECM	VECM	-

Note: VECM=Vector Error Correction Model; VAR=Vector Autoregressive Model; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks)
Source: Author on the basis of Table 10

8 Results

8.1 Labor Productivity

Table 13 presents the results from estimating the short-run effects in the case of labor productivity expressed both in level and natural logarithmic scale in MFG and BLDG. Note that the number of lags to include in the model is determined using the conventional information criteria AIC and SBIC, a practice that is strictly followed in all estimation procedures in this paper.

It is worth to emphasize that none of the estimated short-run effects is significant either in economic or in statistical sense. Recall that labor productivity is expressed as the ratio between real value added in SEK in 1910/12 constant prices and labor employment. However, the estimates of short-run effects in this scale are not even close to one, and hence not economically significant. Moreover, the estimate of the short-run effect of the labor productivity in MFG on the labor productivity in BLDG, denoted MFG→BLDG, is negative and is inconsistent with any of the expected signs stipulated in Section 5, but neither economically nor statistically significant at any conventional levels. Likewise the estimate of the short-run effect of the labor productivity in BLDG on the labor productivity in MFG, denoted BLDG→MFG, is negative, but again insignificant. The R^2 for the equations MFG→BLDG and BLDG→MFG are 0.152 and 0.537, respectively. This means that 15.2

(53.7) per cent of the variations in the labor productivity in BLDG (MFG) are explained by the equation model.

Using variables in natural logarithmic scale, the estimate of the short-run effect of the labor productivity in MFG on the labor productivity in BLDG is again negative and is inconsistent with any of the expected signs, but neither economically nor statistically significant at any conventional levels. However, the estimate of the short-run effect of the labor productivity in BLDG on the labor productivity in MFG is positive, as expected but again insignificant. So far, these evidences support the revisionist view hypothesis posited in Section 5, as the short-run effects are neither economically nor statistically different from zero. Notice that the R^2 in this case are lower than those obtained in the previous case. This means that only 8.3 (0.5) per cent of the variations in the labor productivity in BLDG (MFG) are explained by the equation model.

Finally, diagnostics for normality of residuals, autocorrelation, and stability of the estimates are performed after the regressions. In both cases, although there is no problem of autocorrelation up to the fifth order as shown in Breusch-Godfrey Test for Autocorrelation in Appendix 1, the residuals are found to be nonnormally distributed, according to the Jarque-Bera Test for Normality of Residuals in Appendix 2. As regards the stability of the estimates in the case of VECM, two roots are stable as they are found inside the unit root modulus as shown in Appendix 3.

Table 13. Estimates of Short-run Effects in Labor Productivity, 1850-1980 (Level and Natural Logarithmic Scale)

Equation	R^2	Number of Lag(s)	Short-run Coefficient	Number of Observations
		Level Scale		
MFG→BLDG	0.152	2	-0.009 (0.060)	129
BLDG→MFG	0.537	2	-0.037 (0.127)	129
		Natural Logarithmic Scale		
MFG→BLDG	0.083	1	-0.074 (0.142)	129
BLDG→MFG	0.005	1	0.042 (0.053)	129

Note: Number in parentheses is standard error; Number of lags is determined using information criteria.
Source: Author's calculation using STATA

8.2 Real Product Wage

Either VECM or VAR, summarized in Tables 11 and Table 12, is used to estimate the short-run effects in Tables 14 and 15, respectively, depending on whether the involved variables are cointegrated or not. That is, VECM is used to estimate the short-run relationships between cointegrated variables, while VAR to estimate the short-run relationships between noncointegrated variables. The main point is to be able to control for the cointegrating relationships in order to avoid problems that may arise because of misspecification, and to ensure that the estimates of short-run effects are "well behave."

Table 14. Estimates of Short-run Effects of Real Product Wage, 1830-1914 (Level Scale)

	I	II	III	IV	V	VI	VII	VIII	IX
I	-	*L1:* -0.309 (0.180) *L2:* -0.591* (0.191) *L3:* 0.250 (0.209)	*L1:* -0.075 (0.075) *L2:* -0.156* (0.076) *L3:* 0.146 (0.081)	*L1:* -0.080 (0.189) *L2:* -0.625* (0.182) *L3:* -0.028 (0.196)	*L1:* 0.172 (0.217) *L2:* -0.452* (0.189) *L3:* -0.002 (0.219)	*L1:* -0.032 (0.158) *L2:* -0.894* (0.158) *L3:* -0.330 (0.190)	*L1:* -0.144 (0.210) *L2:* -0.626* (0.203) *L3:* 0.374 (0.215)	*L1:* 0.053 (0.177) *L2:* -0.672* (0.184) *L3:* 0.141 (0.197)	*L1:* 0.384 (0.200) *L2:* -0.581* (0.202) *L3:* 0.251 (0.218)
II	**L1: 0.667*** (0.219) *L2:* 0.262 (0.220) *L3:* -0.683* (0.225)	-	**L1: 0.177*** (0.083) *L2:* -0.052 (0.083) *L3:* 0.090 (0.086)…	**L1: 0.630*** (0.197) *L2:* 0.061 (0.199) *L3:* 0.370 (0.195)…		*L1:* 0.131 (0.191) *L2:* -0.617* (0.185) *L3:* -0.792* (0.188)	*L1:* 0.371 (0.249) *L2:* 0.018 (0.256)	**L1: 0.657*** (0.153) *L2:* -0.221 (0.166) *L3:* 0.030 (0.165)	**L1: 0.804*** (0.199) *L2:* -0.240 (0.229) *L3:* 0.397 (0.225)…
III	**L1: 0.622*** (0.226) *L2:* 0.245 (0.217) *L3:* -0.250 (0.233)	**L1: 0.420*** (0.174) *L2:* 0.029 (0.191) *L3:* 0.149 (0.209)…	-	**L1: 0.773*** (0.219) *L2:* 0.444 (0.234)	**L1: 0.518*** (0.165) **L2: 0.481*** (0.174)	**L1: 0.606*** (0.257) *L2:* -0.313 (0.240) *L3:* -0.284 (0.273)	**L1: 0.466*** (0.171) *L2:* 0.187 (0.180) *L3:* -0.075 (0.196)…	**L1: 0.471*** (0.210) *L2:* 0.003 (0.199) *L3:* 0.045 (0.220)	**L1: 0.548*** (0.193) **L2: 0.726*** (0.209)
IV	*L1:* 0.310 (0.176) *L2:* 0.302 (0.168) *L3:* 0.000 (0.171)	*L1:* -0.086 (0.168) *L2:* -0.128 (0.173) *L3:* 0.093 (0.180)…	*L1:* -0.012 (0.077) *L2:* -0.022 (0.074)	-	**L1: 0.568*** (0.160) *L2:* 0.323 (0.169)	*L1:* 0.162 (0.168) *L2:* -0.429* (0.163) *L3:* -0.305* (0.156)	*L1:* 0.296 (0.166) *L2:* 0.232 (0.170) *L3:* 0.166 (0.162)	*L1:* 0.081 (0.147) **L2: 0.852*** (0.151)… **L4: 0.408*** (0.146)	**L1: 0.436*** (0.184)
V	*L1:* -0.120 (0.282) *L2:* 0.365 (0.238) *L3:* -0.385 (0.268)		*L1:* 0.045 (0.081) *L2:* -0.080 (0.080)	*L1:* -0.063 (0.246) *L2:* -0.543* (0.245)	-	*L1:* 0.126 (0.197) *L2:* -0.545* (0.194) *L3:* -0.335 (0.198)	*L1:* -0.033 (0.273) *L2:* -0.153 (0.263)	*L1:* 0.225 (0.158) *L2:* -0.737* (0.177)… *L4:* -0.611* (0.165)	**L1: 0.695*** (0.235) *L2:* -0.333 (0.258) **L3: 0.992*** (0.244)
VI	*L1:* 0.297 (0.166) *L2:* 0.185 (0.149) **L3: 0.377*** (0.155)	**L1: 0.244*** (0.121) *L2:* 0.206 (0.130) **L3: 0.795*** (0.134)	**L1: 0.169*** (0.072) **L2: 0.190*** (0.072) **L3: 0.230*** (0.073)	**L1: 0.589*** (0.126) **L2: 0.353*** (0.146) **L3: 0.788*** (0.146)	**L1: 0.280*** (0.134) *L2:* 0.152 (0.139) **L3: 0.599*** (0.158)	-	*L1:* 0.124 (0.142) *L2:* 0.267 (0.141) **L3: 0.749*** (0.150)	**L1: 0.382*** (0.160) **L2: 0.363*** (0.140) **L3: 0.325*** (0.157)	**L1: 0.405*** (0.135) *L2:* -0.112 (0.148) **L3: 0.610*** (0.152)
VII	*L1:* 0.634 (0.365) *L2:* 0.292 (0.344) *L3:* -0.136 (0.345)	*L1:* -0.579* (0.289) *L2:* -0.309 (0.297)	*L1:* 0.126 (0.098) *L2:* -0.194* (0.096)… *L4:* -0.206* (0.103)	*L1:* 0.484 (0.284) *L2:* -0.372 (0.296) *L3:* 0.057 (0.295)	*L1:* 0.191 (0.305) *L2:* 0.336 (0.298)	*L1:* 0.043 (0.245) *L2:* -1.122* (0.243) *L3:* -1.061* (0.256)	-	**L1: 0.454*** (0.215) *L2:* -0.627* (0.235) *L3:* 0.112 (0.236)	**L1: 0.664*** (0.263) *L2:* -0.230 (0.285) **L3: 0.752*** (0.277)
VIII	**L1: 1.029*** (0.194)… **L3: 0.442*** (0.220) **L4: 0.469*** (0.210)	*L1:* -0.071 (0.183) *L2:* -0.020 (0.197) *L3:* 0.135 (0.198)	*L1:* -0.069 (0.088) *L2:* -0.031 (0.087) *L3:* 0.083 (0.090)	**L1: 1.045*** (0.191) **L2: 0.693*** (0.199) **L3: 0.680*** (0.192)	**L1: 0.723*** (0.168) *L2:* 0.328 (0.201) *L3:* 0.222 (0.236)	*L1:* 0.074 (0.214) *L2:* -0.520* (0.191) *L3:* -0.730* (0.213)	*L1:* 0.080 (0.196) *L2:* 0.044 (0.212) *L3:* 0.024 (0.221)	-	**L1: 0.350*** (0.178) *L2:* 0.046 (0.187)… **L4: 0.425*** (0.200)
IX	*L1:* -0.082 (0.203) *L2:* 0.155 (0.186) *L3:* -0.709* (0.186)	*L1:* -0.542* (0.168) *L2:* -0.018 (0.186) *L3:* -0.491* (0.180)…	*L1:* 0.003 (0.081) *L2:* -0.105 (0.082)	*L1:* -0.277 (0.197)	*L1:* -0.524* (0.213) *L2:* -0.219 (0.213) *L3:* -0.869* (0.219)	*L1:* -0.247 (0.167) *L2:* -0.428* (0.154) *L3:* -0.679* (0.164)	*L1:* -0.496* (0.184) *L2:* -0.105 (0.170) *L3:* -0.616* (0.171)	*L1:* 0.042 (0.140) *L2:* -0.474* (0.140)… *L4:* -0.325* (0.143)	-
Total	6/25	3/23	4/23	8/21	6/18	1/24	2/23	8/27	12/23

Note: *=Statistically significant at 5 per cent level; L1=First Lag; L2=Second Lag; L3=Third Lag; L4=Fourth Lag; Total=Number of positive and statistically significant estimates of short-run effects (in bold)/Total of estimates of short-run effects; Number in parentheses is standard error; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks).

Source: Author's calculation using STATA

Table 14 is read "the short-run effects of column on row." For example, on average, an increase in the real product wage in Mining and Metal (I) by a gram of silver expressed in 1910/12 prices in the short-run leads to a 0.667 gram of silver in 1910/12 prices increase in the real product wage in Mineral (II) in first lag, 0.622 gram of silver in 1910/12 prices increase in Wood (III) in first lag, 0.377 gram of silver in 1910/12 prices increase in Textile and Clothing (VI) in third lag, and 1.029 gram of silver in 1910/12 prices increase in Chemicals (VIII) in first lag, 0.442 in third lag, and 0.469 in fourth lag, ceteris paribus.

It shows the estimates of short-run effects in real product wage expressed in level scale in nine industrial sectors of Manufacturing Industry and Handicrafts. Notice that the total number of positive and statistically significant estimates of short-run effects are only six out of 25 (6/25) in Metal and Mining (I); three out of 23 (3/23) in Mineral (II); four out of 23 (4/23) in Wood (III); eight out of 21 (8/21) in Pulp, Paper and Printing (IV); six out of 18 (6/18) in Food Products (V); one out of 24 (1/24) in Textile and Clothing (VI); two out of 23 (2/23) in Leather, Hair, and Rubber (VII); eight out of 27 (8/27) in Chemicals (VIII); and 12 out of 23 in Utilities (IX). Overall, the total number of positive and statistically significant estimates of short-run effects – as implied by the traditional view – in real product wage is only 50 out of 207, or a little less than one-fourth of the total of number of estimates of short-run effects. This number is rather less impressive than what the traditional view implies.

Apparently, there are also negative and statistically significant effects in Table 14. The industrial sector that has the most number of negative short-run effects on other industrial sectors is Textile and Clothing (VI). This industrial sector negatively affects Mining and Metal (I) in second lag; Mineral (II) in second and third lags; Pulp, Paper, and Printing (IV) in second and third lags; Food Products (V) in second lag; Leather, Hair, and Rubber (VII) in second and third lags; Chemicals (VIII) in second and third lags; and Utilities (IX) in second and third lags. It is therefore interesting to ask whether these negative and statistically significant estimates of short-run effects are evidence for what the literature calls "creative destruction," in the sense that an improvement in the productivity in one industrial sector may actually displace the obsolete practices or technology in other industrial sectors, referring to the ways of doings things, resulting in decline in productivity in these sectors in the short-run. This case warrants further research indeed.

Table 15, similarly read as how Table 14 is read, presents the estimates of short-run effects in real product wage expressed in natural logarithmic scale in the same set of industrial sectors. There are in this case a total of 46 "estimable" short-run effects, and only five of these are statistically significant. It is not possible to estimate the short-run effects in cases when information criteria suggest in the model either only one lag in the case of VECM or zero lag in the case of VAR. By dint of these technical reasons, one cannot really say much about the short-run relationships between variables in these cases. Nevertheless, only five out of 46, or just a little over one-tenth of the total estimable short effects "on hand" are positive and statistically significant, and the implication of which is the same as the one above. The number of positive and statistically significant estimates of short-run effects is too few to support the traditional view of the Industrial Revolution.

Table 15. Estimates of Short-run Effects of Real Product Wage, 1830-1914 (Natural Logarithmic Scale)

	I	II	III	IV	V	VI	VII	VIII	IX
I	-	*L1:* -0.146 (0.135) *L2:* -0.018 (0.139) *L3:* 0.098 (0.140) *L4:* 0.047 (0.136)							*L1:* 0.201 (0.111)
II	***L1:* 0.358*** (0.140) *L2:* 0.149 (0.145) *L3:* -0.279 (0.146) *L4:* 0.169 (0.150)	-		***L1:* 0.474*** (0.143)		*L1:* 0.317 (0.178) *L2:* 0.137 (0.172)		***L1:* 0.358*** (0.129) *L2:* -0.025 (0.132)	*L1:* 0.174 (0.096) *L2:* 0.136 (0.097)
III			-			***L1:* 0.525*** (0.259) *L2:* -0.002 (0.258)			*L1:* 0.268 (0.140) ***L2:* 0.439*** (0.141)
IV		*L1:* -0.082 (0.133)		-					*L1:* 0.189 (0.107)
V					-				*L1:* 0.090 (0.102)
VI		*L1:* 0.026 (0.106) *L2:* -0.160 (0.107)	*L1:* -0.034 (0.060) *L2:* 0.112 (0.060)			-		*L1:* 0.046 (0.124) *L2:* 0.029 (0.117) *L3:* 0.084 (0.120)	
VII							-		*L1:* 0.114 (0.158)
VIII		*L1:* 0.117 (0.151) *L2:* 0.093 (0.150)				*L1:* 0.111 (0.218) *L2:* 0.192 (0.206) *L3:* -0.392 (0.214)		-	*L1:* 0.028 (0.176)
IX	*L1:* -0.370 (0.250)	*L1:* -0.175 (0.176) *L2:* 0.097 (0.177)	*L1:* -0.120 (0.110) *L2:* 0.003 (0.110)	*L1:* -0.307 (0.201)	*L1:* -0.395 (0.228)		*L1:* -0.319 (0.251)	*L1:* -0.246 (0.208)	-
Total	1/5	0/11	0/4	1/2	0/1	1/7	0/1	1/6	1/9

Note: *=Statistically significant at 5 per cent level; L1=First Lag; L2=Second Lag; L3=Third Lag; L4=Fourth Lag; Total=Number of positive and statistically significant estimates of short-run effects (in bold)/Total of estimates of short-run effects; Number in parentheses is standard error; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks).

Source: Author's calculation using STATA

It is worth to interpret what is meant by the five positive and statistically significant estimates of short-run effects. To begin with, on average, a one per cent increase in the productivity in Mining and Metal (I) leads to a 0.358 per cent increase in the productivity in Mineral (II) in the following year; a one per cent increase in productivity in Pulp, Paper, and Printing (IV) leads to a 0.474 per cent increase in the productivity in Mineral (II) in the following year; a one per cent increase in the productivity in Textile and Clothing (VI) leads to a 0.525 per cent increase in the productivity in Wood (III) in the following year; a one per cent increase in the productivity in Chemical (VIII) leads to a 0.358 per cent increase in the productivity in Mineral (II) in the following year; and a one per cent increase in the productivity in Utilities (IX) leads to a 0.439 per cent increase in the productivity in Wood (III) in the following two years, ceteris paribus. It is possible that the improvement in productivity in Chemical (VIII) improves the productivity in Mineral (II) in the short-run because the former is an important input to the latter. This may very well be the case with Utilities (IX) and Wood (III). However, the short-run estimates with regard to Utilities (IX) should be interpreted with caution since its data became available from the source only from 1846 onwards, and may not be comparable with that of Wood (III). In the case of other three pairs – Metal and Mining (I) on Mineral (II); Pulp, Paper, and Printing (IV) on Mineral (II); and Textile and Clothing (VI) on Wood (III) – the improvements in productivity may imply improvement in terms of technological know-how, or ways of doing things, and spillover effects.

Furthermore, these particular five short-run effects are statistically significant, but determining whether these are in fact economically significant is a little bit tricky as each are expressed in percentages. However, even if one assumes that these estimates are economically significant, it cannot be denied that these are only one-tenth of the total short-run estimates. With this evidence on hand, one is therefore inclined to believe the revisionist view that the "revolution" was concentrated only in some sectors during the Industrial Revolution.

The results in Table 14 and Table 15 are diagnosed for normality of residuals and autocorrelation as shown in Appendices 4 and 5. There are more cases of autocorrelation when variables in level are used than when the variables in natural logarithmic scale are used instead. As in the labor productivity, the residuals are found to be non-normally distributed. This problem may be solved by adding more lags or controlling for different phases in the Industrial Revolution, for example first and second phases. Such undertaking can be done in future research.

9 Discussion

The results as discussed in the previous section tend to support the revisionist rather than the traditional view. If the traditional view is to be supported, then improvements in the productivity of one sector would have immediate effects on the productivity of other sectors, which meant that estimates of short-run effects would have been substantial in most cases. However, the estimates of the short-run effects both in the case of labor productivity and real product wage are economically and statistically insignificant except in very few cases.

To reiterate, the estimated short-run effects in the case of labor productivity is neither economically nor statistically significant. The estimates of the short-run effect of both the labor productivity in MFG on the labor productivity in BLDG and vice versa are not only inconsistent with any of the expected signs in most cases but also economically and statistically insignificant at any conventional levels. The results are robust to whether labor productivity is expressed in level or in natural logarithmic scale.

Moreover, this paper utilizes the data on real product wage. Not only that real product wage is a viable proxy measure for labor productivity, but it is also at the same time more comprehensive than the data on labor productivity since the former represents nine sectors of the Manufacturing Industry and Handicrafts while the latter represents only two industrial sectors MFG and BLDG. Using either VECM or VAR, the results imply that the "revolution" in productivity, if any, was concentrated only in some industrial sectors. There are positive and statistically significant short-run effects, but these are only a small percentage of the whole sample of estimates of short-run effects. Also, the evidences tend to emphasize the role of structural change in industrialization depicted in Section 4. One great implication of this is that there exists a substantial time lag before the innovations and technological improvement in one industrial sector can affect productivity in other industrial sectors. In other words, the full potential an innovation or technological improvement may be realized only after a long period of time – longer than what the proponents of traditional view have once implied.

Yet the results both using labor productivity and real product wage are to be interpreted with caution. First, the diagnostics on in both cases show that there may be problems of autocorrelation in some cases and non-normality of residuals in most cases. In particular, the problem remains even if more number of lags is included into the underlying vector model than what is suggested by information criteria. One possible solution for this problem is to reflect the different phases of Industrial Revolution in Sweden possibly by controlling for structural changes. Perhaps a dummy variable for each phase should be included into the model in a future research.

Second, estimates of short-run effects in the case of real product wage are not available for all nine industrial sectors owing to some technical reasons. For example, the analysis in the case of real product wage in natural logarithmic scale is limited to a sample of 46 estimates of short-run effects because of constraints imposed by the information criteria. This may therefore invite speculations about the other short-run effects that were not estimated. Other econometric methodology and techniques such as Panel Data Methods may solve the technical problem. In addition, this method may also be used to study the dynamic phases of Industrial Revolution, that may require dividing the long period of Industrial Revolution into different shorter periods, for example first period from 1830 to 1850, second period from 1850 to 1880, and third period from 1880 to 1910. In panel data, the degree of freedom is not compromised even if the number of time periods is less because the total number of observations is determined by multiplying the number of time periods with the number of cross-section units. This is again an endeavor that is suggested for future research.

10 Conclusion

So what is the nature of the Industrial Revolution in Sweden? The quantitative time-series analysis in this paper finds the nature of Industrial Revolution in Sweden during the period from 1850 to 1990 as characterized by sectors that gradually – not immediately – affected the productivity of each other, resembling the picture of revolution in structural change painted by revisionists who argue against the traditional view.

Furthermore, the analysis in this paper offers straightforward answers to the first two specific questions posed in Section 1. On the first questions: Does the case of Sweden support the traditional view of Industrial Revolution? The results in this paper affirm the revisionist view, but negate the traditional view of Industrial Revolution.

On the second question: What are the immediate effects – if any – of such "revolution" in certain sectors on the other industrial sectors of the economy? The immediate effects of an improvement in productivity in one sector on the productivity in other sectors are negligible in the sense that most of the estimated short-run effects are economically and statistically insignificant.

Finally, one might asks, "What historical lessons – or perhaps policy for recommendation – can developing or 'industrializing' countries in the present day glean from this quantitative analysis of the nature of Industrial Revolution in Sweden?" Admittedly, it is a lot more challenging to provide a straightforward answer to this question than the first two questions, especially since different countries may have unique experiences that may result in different paths of industrialization. Yet the quantitative analysis suggests that structural change is imperative for industrialization. Perhaps with the continuous improvements in the quality and availability of historical data on different industrial sectors, it is interesting to find out whether expediting structural change can lead to faster industrialization.

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Appendix 1. Breusch-Godfrey Test for Autocorrelation in Labor Productivity, 1850-1980 (Level and Natural Logarithmic Scale)

Lag	Chi2	DF	Prob
Level Scale			
1	6.7022	4	0.15249
2	5.7506	4	0.21857
3	5.4604	4	0.24323
4	8.8819	4	0.06412
5	6.693	4	0.15303
Natural Logarithmic Scale			
1	7.5933	4	0.10766
2	4.6349	4	0.32685
3	2.8309	4	0.58651
4	4.1124	4	0.39101
5	6.6469	4	0.15576

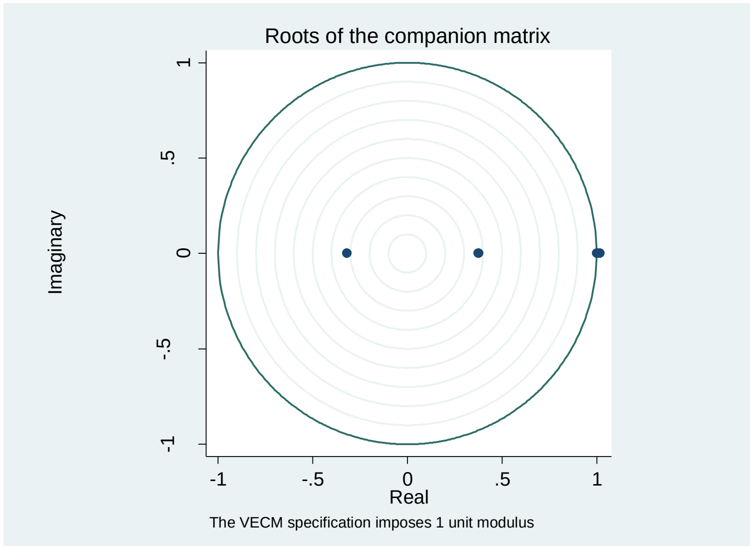
Note: Null hypothesis is no autocorrelation.
Source: Author's calculation using STATA

Appendix 2. Jarque-Bera Test for Normality of Residuals in Labor Productivity, 1850-1980 (Level and Natural Logarithmic Scale)

Test	Chi2	DF	Prob
Level Scale			
Jarque-Bera	52.911	4	0.000
Skewness	3.107	2	0.212
Kurtosis	49.804	2	0.000
Natural Logarithmic Scale			
Jarque-Bera	0.167	4	0.000
Skewness	14.128	2	0.920
Kurtosis	59.094	2	0.000

Note: Null hypothesis is normal distribution of residuals.
Source: Author's calculation using STATA

Appendix 3. Test for Stability of Estimated Roots in Labor Productivity, 1850-1980 (Level Scale)



Source: Author's calculation using STATA

Appendix 4. Summary of Tests for Normality of Residuals and Autocorrelation in Real Product Wage, 1830-1914 (Level Scale)

	I	II	III	IV	V	VI	VII	VIII	IX
I	-	a,b	a,b	a,b	a,b	a,b	a,b	a,b	a,b
II	a,b	-	a	a	-	a,b	a	a,b	a,b
III	a,b	a	-	a	a	a,b	a	a,b	a
IV	a,b	a	a	-	a	a,b	a,b	a,b	a
V	a,b	-	a	a	-	a	a	a,b	b
VI	a,b	a,b	a,b	a,b	a	-	a,b	a,b	a,b
VII	a,b	a,b	a	a,b	a	a,b	-	a,b	a,b
VIII	a,b	a,b	a,b	a	a,b	a,b	a,b	-	a,b
IX	a,b	a,b	a	a	a,b	a,b	a,b	a,b	-

Note: a=nonnormally distributed residuals; b=autocorrelated; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks)
Source: Author's calculation using STATA

Appendix 5. Summary of Tests for Normality of Residuals and Autocorrelation in Real Product Wage, 1830-1914 (Natural Logarithm Scale)

	I	II	III	IV	V	VI	VII	VIII	IX
I	-	a	-	-	-	-	-	-	a
II	a	-	-	a	-	a	-	a	a
III	-	-	-	-	-	a	-	-	a
IV	-	a	-	-	-	-	-	-	a
V	-	-	-	-	-	-	-	-	a
VI	-	a	a	-	-	-	-	*	-
VII	-	-	-	-	-	-	-	-	a
VIII	-	a	-	-	-	*	-	-	a
IX	a	a	a	a	a	-	a	a	-

Note: *=No problem of nonnormality of residuals and not autocorrelated; a=nonnormally distributed residuals; b=autocorrelated; I=Mining and Metal; II=Mineral (Stone, Clay, and Glass); III=Wood; IV=Pulp, Paper, and Printing; V=Food Products; VI=Textile and Clothing; VII=Leather, Hair, and Rubber; VIII=Chemical; and IX=Utilities (Power, Gas, and Waterworks)

Source: Author's calculation using STATA