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Industrial Revolutions and Environmental Problems

The current environmental problems have been created by the development of industrial society since the industrial revolution. Successive industrial revolutions have since increased man's capacity to transform nature. Technological change has interacted with socio-economic change in the core countries of the world economy. In this paper, I look at the relationships between macro-level technological change and environmental problems. Freeman & Louca (2001) suggest that the Western world has lived through four industrial revolutions since the late 18th century and is currently moving into a fifth. Table 1 provides details about these revolutions, which tend to emerge in 50-year cycles. I also include three extra columns related to environmental problems. First, as environmental problems are often related to energy use, there is a column demonstrating the main energy source during different periods.

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Second, there is a column suggesting main environmental problems (both problems for ecosystems and human health). Third, I have added a column that demonstrates how each industrial revolution has contributed to the amelioration of pre-existing environmental problems. While I do not make claims about the importance of these paradigms for the long waves of the world economy, I still find this periodization of technology history to be interesting as a background for understanding the evolution of environmental problems in the capitalist core.

1780–1930: The environmental problems of the industrial revolution in Britain and the US/German catch-up

The industrial breakthrough in Britain both created new environmental problems and resolved some of the existing problems. Urbanization and the increasing use of coal relieved the pressure on land in the UK. Pomerantz (2000) describes how less demand for fuelwood in the wake of increasing coal consumption reduced land constraints and contributed to increasing agricultural production. Combined with new crop rotation techniques and expanding food imports, this alleviated old Malthusian constraints. However, unconstrained exploitation of workers in factories and mines, abysmal housing and hygienic standards, as well as thickening black smog and soot from burning coal aggravated socio-environmental problems (infections, respiratory problems, poisoning, workplace accidents) in the expanding urban slums and factories of the industrial revolution in the UK, portrayed by Dickens as *Coketown* in his 1854 novel "Hard Times". While black smog from coal burning came predominantly from

Upswing/ downswing	Constellation of technical and organizational innovations	Core input and other key inputs	Carrier branch and other leading branches	Main energy source	Environmental problems	Solutions to previous problems
1780-1815 **1815-1848**	Water-powered mechanization of industry	Iron, raw cotton, coal	Cotton spinning Iron products Water wheels Bleach	Waterpower/ Coal	Socio-environmental (slums), smog	Forest depletion, hunger
1848-1873 **1873-1895**	Steam-powered mechanization of industry and transport	Iron, coal	Railways and rail equipment, steam engines, machine tools, alkali industry	Coal	Socio-environmental (slums), smog	
1895-1918 **1918-1940**	Electrification of industry, transport and households	Steel, copper, metal alloys	Electrical equipment, heavy engineering, heavy chemicals, steel products	Electricity (mostly based on coal)	Water pollution (mainly from chemical industry)	Fewer work hazards, improved housing, reduced urban air pollution
1941-1973 **1973-??**	Motorization of transport, civil economy and war	Oil, gas, synthetic materials	Autos, trucks, tractors, tanks, diesel engines, aircraft, refineries	As above, but also nuclear	Smog, acid rain, climate change and its effects, radiation	Mass-consumption reduces poverty
??	Computerization of entire economy	Computers, software, telecom equipment, biotech	Telecommunications	As above		Emerging decoupling of energy use and production/consumption

Table 1. Five industrial revolutions and their environmental problems

Source for the 4 columns to the left: Freeman & Louca (2001, p. 141).

steam engines and metal smelting in many industrial towns, emissions from the pollutive burning of coal in open hearths in homes was important everywhere and dominated as a source of the notorious London smog.

On the factory floor, transmission belts from steam engines caused work accidents. The alleviation of socio-environmental problems linked to the livelihoods of the working classes was slow in spite of pressure from emerging trade unions, medical doctors, and new laws and authorities trying to curb smoke and soot emissions and bad sanitary conditions. The bad health of British soldiers fighting in the Crimean, Boer and First World War illustrated the slowness of the progress (Mjøset & Kasa, 1994).

With the demise of British textile and railway production, industrial hegemony was passed on to the US and Germany. These states dominated the next industrial revolution, led by organic chemicals, electricity and steel. While the chemical revolution was driven by consumption of items such as synthetic dyestuffs for clothing and medicines became important applications of newly developed chemical compounds from coal tar, steel production found its main markets in investment goods such as infrastructure, buildings and armaments.

Electricity reduced many of the problems linked to urban smoke and dangerous working environments, as emission sources became concen-

trated on fewer power stations often located outside the cities, and electrical machines replaced steam engines. Better housing conditions for factory workers improved the livelihoods of workers, as seen, for example, in Berlin´s famous *Siemensstadt*.

Soda production, a key input for other industries, was also made less pollutive in the 1860s with the introduction of the Solvay process, which reduced hydrochlorine gas emissions, sulphur emissions and toxic waste, compared with the existing Leblanc process. While the Solvay process diffused rapidly in Germany, less innovative UK industrialists stuck to more polluting processes until almost 1920, being part of a wider process in which British industrial hegemony was eclipsed by Germany and the US.

For the environment, however, the new industries also led to problems: Increasing consumption of chemicals led to the poisoning of European rivers, climaxing in the 1971 pollution scandal in the Rhine which finally led to massive efforts to clean up the river. While industries did not use coal as a key factor during this period, energy supply was still dominated by coal and coal consumption for steel production increased steeply in the most dynamic industrial regions such as the Ruhr and Pittsburgh. Here, the use of coal for steelworks produced serious smog problems. In addition, the smog problems characterizing Britain in the 19th century were not sufficiently ameliorated. Extension of electricity networks lagged behind here, and coal burnt in ineffective open hearths was still common. The adequate regulation of smoke only emerged after the smog disaster of 1952, when 4 000 people died within a few days in London.

Fordism, cars and oil producing acid rain and climate change

Following the emergence of mass-produced cars and the further extension of electricity to consumers, the US saw a middle class-based boom of consumer durables during the 1920s. Car consumption was based on the discovery and use of oil, particularly from Texas, for gasoline. The Great Depression and WW II postponed the surge of consumption of consumer durables assisted by collective wage agreements characterizing post-war US 'Fordism'. During the Cold War, this fourth industrial revolution became generalized in the Western world. For socio-environmental problems, this led to progress. Mass consumption linked to productivity-indexed wage formation in combination with decreasing inequality reduced poverty in OECD countries.

Through its dependence on oil, this match between technologies and consumption patterns led to environmental problems. Locally, increasing car density produced new kinds of smog. This was first noted in car-dominated, sunny Southern California. The California smog was created by sunlight-assisted reactions between exhaust fumes producing particles and ozone that were hazardous for humans, animals and plants. Catalytic converters introduced during the 1970s reduced, but failed to eliminate this problem.

However, Fordism was above all characterized by the emergence of transnational and global environmental problems. The main problems are acid rain stemming both from industries and road transportation – and most importantly – climate change. In its 2007 report (IPCC, 2007), the UN IPCC concludes with virtual certainty that anthropogenic climate change mostly due to emissions from fossil fuels is taking place. Future

temperature increases will probably cause the sea level to rise, cause more intense tropical storms and disappearing Arctic summer sea ice, as well as more heat waves, aggravating problems such as hunger and poverty.

Increases in carbon emissions leading to today's problems accelerated as Fordism became generalized in the Western world. Figure 1 below shows a dramatic increase in emissions from the consumption of oil prior to the 1973 OPEC oil shock.

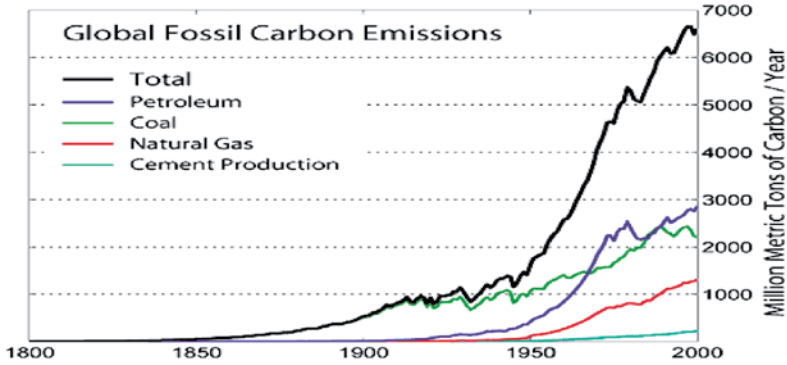

Figure 1: Global Fossil Carbon Emissions 1800–2000.

Source: Marland *et al*. (2005).

Previous work (Perez 1985, Mjøset & Kasa, 1994) suggested that the fifth industrial revolution that began to build up in the late 1970s offered an exit opportunity from the environmental and resource constraints of Fordism. From the OPEC shock until the 1990s, Japan was a case in which energy demand and pollution were rapidly decoupled from economic growth. Growth was fuelled primarily by *information* and not *energy* intensive production. This industrial model was combined with heavy investments in extraordinarily energy efficient and widely used railways. Social and cultural barriers to expanding mass consumption peculiar to Japan, as well as a very high level of dependence on imported energy, were also important factors behind this energy extensive social model. Japan has remained heavily dependent on exports to spendthrift US consumers, and Japanese savings have directly assisted US consumption through purchases of US treasuries and currency.

The re-emergence of the US as a leader in the ICT economy also, combined with the demise of Japan and the rise of China as a chief supplier of consumer durables to the US market, appears to have blocked the generalization of the opportunities emerging in the Japanese model. The current US model is a hybrid in which leadership in ICT and biotech is combined with the path-dependent maintenance of some of the world's most oil- and energy-intensive consumption patterns. The "Fordist-like" (mass consumption financed by consumer debt, cf. Boyer 2000) component of this hybrid is undermined by two sets of environmental and resource constraints (besides the financial constraints emerging from the current global crisis which has its origin in the combination of excessive financial liberalization and a mismatch between US wages and consumption levels) . *First*, the expansion of energy intensive *consumption* patterns in the US partly supported by the rise of energy intensive *production* patterns in China, threatens to outstrip global oil supplies. *Second*, climatic constraints: While recent years have seen brisk growth in global emis-

sions, these have to be cut by more than 80% by 2050 to limit exceedingly serious global problems linked to global warming of more than 2 degrees (Rive *et al.*, 2007). As the top emitters, China and the US may face the greatest challenges, but none of these states are currently willing to commit to emission cuts (Kasa *et. al*, 2008).

A failure to implement cuts may lead to the re-emergence of Malthusian constraints on food production. The dampening of these constraints by the first industrial revolution and their removal by inventions in fertilizer production during the third (Smil, 2001, Cline, 2007) are essential, but often overlooked elements of modern technological and environmental history. It is as yet unclear whether these constraints can be ameliorated by new biotechnologies, and even more uncertain if the current global institutional framework can facilitate the diffusion of such technologies (IAASTD, 2008). This reminds us about a main point in this paper: As new industrial revolutions often supplied technologies that eased existing environmental problems, this relief was often only partial. Exploiting the benefits of new technologies for environmental improvements has always been dependent on complimentary socio-political changes.

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