Coevolution of Industries
The Case of Inland Transportation in the 19th Century

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Coevolution of Industries — The Case of Inland Transportation in the 19th Century[1]

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Introduction

The intellectual origin of this paper is the suggestion in Fogel's book on railroads and economic growth, that it would have been possible in the 19th century to develop the motor car instead of the railroad. "Consequently, one cannot foreclose the possibility that in the absence of railroads more capital and talent would have been devoted to the perfection of the horseless carriage, and that as a result the engineering knowledge and technical skills required to produce effective motor vehicles would have emerged decades sooner than it actually did."[2]

From a factual point of view it is of course simple to point out that the steam car preceded the steam locomotive and that the components of the modern internal combustion car were non-existing in 1830.[3] Down-stream markets were also undeveloped, as private transportation was a luxury and a discomfort in the age of stage-coaches and omnibuses. The challenge would be to prove that the imagined transition path to the modern car in Fogel's counterfactual world (stage coaches and steam boats as dominant means of inland transportation) was a swifter one than the transition path in the 19th century (railways dominating inland transportation). Fogel's own methodology didn't lend itself to an exploration of such a would be development as was pointed out in David (1967) and his discomforts of the first class: "The task of reckoning the direct social savings attributable to railroads in 1890 would seem to afford a splendid occasion for a thorough examination of the technical and economic aspects of late nineteenth-century transport and distribution arrangements in the US. An undertaking of that undoubtedly would shed much light upon elements of interrelatedness among methods of shipping, handling and storing goods. It would, moreover, be particularly germane to the thesis that the appearance of isolated 'great innovations' is less consequential for economic progress than the rate at which clusters of interlocking mutually supporting techniques can be brought into use. Regrettably, the opportunity to pursue such an inquiry has not been seized in Fogel's book."[4]

The possibilities to conduct an inquiry of the total effects of the railway today is much better, with the contributions of von Tunzelman (1976) on the impact of the steam

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[2] R.W. Fogel Railroads and American Economic Growth: Essays in Econometric History, (The John Hopkins Press, Baltimore, Maryland) 1964, p. 15.

[3] The following key technologies were not developed: the internal combustion engine, light weight chassies, and tires.

[4] David, P., 1969, Transport innovation and economic growth: Professor Fogel on and off the rails, Economic History Review, vol. 22, pp 506-525 reprinted in New Economic History. Selected Readings, P. Temin (ed.), Penguin Books, 1973, Harmondsworth, Middlesex, pp 267-68

engine on industrialization, Chandler (1977) on the impact of railroads on distribution of goods, Kindleberger () on the effects the railways had on the stock markets and other studies. Equally important for a treatment of such a waste topic is the development of models treating the interdependence between industry, technology and institutions.

My ambition is less far-reaching than the suggestion by David and I will limit this study to investigate if the railways rather helped than blocked the development of motor cars by an investigation of the direct and indirect linkages between the two technologies.

Coeval Technological Changes or Co-evolution of Technologies

When re-reading Fogel's texts on the social savings of railroads and other similar studies one of the most striking features is what is being omitted from the counterfactual comparison. Knowledge or other cumulative externalities are the principal facts missing. Fogel and others are of course aware of the fact that they are only telling part of the story when they measure the social savings of major innovations. What is beyond the pure measurement is speculation or extremely difficult to disentangle. Fogel (1966) writes: ìThe development of spacecraft, unlike the railroad, thus offers man access to knowledge that cannot be obtained in any other way. The knowledge gained from space exploration may have enormous consequences for the biological and physical sciences.î

The ìlateralî effects of Rostow where excluded by Fishlow (1965) in his study of railroads in the ante-bellum economy because the lateral effects ìare so general as to constitute the very process of industrialization and are a *consequence* of the other effects (the effects measured by Fislow) rather than an additional route of influence.î The exclusion of measuring the impact of the innovations induced by a major innovation was consequently not a mistake but a conscious decision to avoid measurement problems and other complications.

Von Tunzelman (1976) noted that it was unrealistic and problematic to assume that all other innovations would have developed in the same way as they actually did. The notion of a counterfactual world with coeval changes in the environment occurring in the hypothetical absence of a major invention is an extreme assumption as one might expect that the more significant the invention the greater the irreversible innovations might be.

In contrast with these studies in economic history a lot of the research on technological change measures in a micro-economic sense all the effects of an innovation. Probably could many of these studies be criticised not for excluding the impact of an invention but for being to generous in giving an invention credit where small effects are visible or measurable. However, more important from the point of view of the aim the paper, it is evident that this literature has provided us with methodologies and ways of interpretation that can help us comprehend all the paths of influence of one technology on another technology. The most complete and explicit way of treating the interrelation of technologies is found in the concept of coevolution which explicitly focus on how different entities (for example technologies) mutually shape each other.

Coevolution of technology, firms, and institutions

The concept coevolution is used in two different contexts in evolutionary economics. In the literature on the human economy and the natural world coevolution means the interdependence between nature and human culture (Gowdy, 1994 and Norgaard, R. B., 1994), while in the evolutionary models of technology induced economic change coevolution refers to the interdependence between technology, capital intensity and industry structure (Nelson, 1994b).

In a number of articles from 1994 and 1995 Nelson took up and reappraised a substantial part of the literature on economic growth, technology development and institutional change. He found that research on industrial change and technology development pointed at the coevolutionary character of what we earlier considered to be an evolutionary process. The point of departure in Nelson's perspective on coevolution of technology, firms, and institutions is that a new industry emerges as the result of a technological advance. Depending on the construction of an evolutionary model different sets of variables co-evolve. In more limited models the coevolution takes place between technology and industry structure (Nelson, 1995). He envisaged three development patterns for the selection process resulting in a dominant design within an industry: 1) one product design wins because it is simply better than the others, 2) one product design wins because it early on attracts resources producing improvements that make this design the only economic way to proceed, and 3) a product design becomes a dominant design because it benefits from system effects, for example the development of complementary products or users that develop skills that are difficult to transfer to other designs.[5]

Nelson (1995) also noted that in many studies a broader set of factors are coevolving. Beside technology and firms we can envisage that various supporting institutions evolve as a consequence of the evolution of the industry and the technology. McKelvey

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[5] Nelson (1994a) p 141 and Arthur (1994) p 118

(1994) gave a slightly different formulation of the factors that are coevolving. She wrote: "For technological innovation processes, co-evolution refers to significant relations 1) between different agents' innovative activities to generate and select technical alternatives, and 2) between agents' innovative activities leading to technical change and environmental conditions." In her model the coevolving entities in Nelson (1994a and 1994b) are represented as three environments - 1) the Public, 2) the Basic Scientific and 3) the Economic - to the coevolving innovation process. "Co-evolutionary innovation means an evolutionary pattern of technical change, where the incentives and informal institutions of the three specified environments mutually shape each other, innovative activities, and technical change over time."[6]

Nelson (1994b) also claimed that the coevolution within the setting of one industry potentially has impact on the competitive advantages of nations. "There clearly have been major national differences in how the institutions needed to support particular evolving technologies themselves evolved. Perhaps in the study of the coevolution of technology and institutions, we will begin to develop a serious theory of how national comparative advantage comes into being or is lost."[7] A similar idea was put forward in McKelvey (1997) where she suggested that different systems of innovation have different characteristics as regards the relationships in the technology, firm, and institutional set-up. A remark along the same lines is found in an article by Galli and Teubal (1997) on paradigmatic shifts in national innovation systems: "Along with market forces and endogenous coevolution between industry, technology, and institutions a predominantly endogenous transition trajectory may include a smattering of government-sponsored enabling changes in institutions."

The position I take in this paper is slightly different from Nelson and McKelvey. In my mind coevolutionary economics can also be about technologies and institutions that as they develop create externalities that impinge on the evolution of more than one industry. The path of an industry or a technology is linked to developments elsewhere in the economy and changes that seem to be independent of the technology may affect its development. Thus, the path-dependence of a particular technology is path-interdependent with economic, technical and political developments generated by other technologies. This interpretation of economic-technical linkages between industries has been highlighted in DahmÈn's development block concept. A development block is a set of interrelated complementarities that connect firms from different industries into a

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[6] McKelvey (1994) p 34

[7] Nelson (1994c)

network.[8] The complementarities appear sequentially as inventors and innovators solve economic-technical problems that have blocked the realization of the economic benefits of earlier innovations. These problems have been labelled bottlenecks, reverse salients or structural tensions. The problem-solving involved in this development process is not confined within industrial boundaries.[9]

A model of coevolution of industries

In evolutionary biology we find many different concepts used to understand interactions/interdependence between organisms. Boucher (1992) identifies three central non-overlapping terms. Mutualism is a +/+ type of interaction, predation is a +/- interaction and competition is a -/- interaction. The plus and the minus signs indicate the direction of the effect one organism has on the other. Beside these three central concepts we find terms related to mutualism, for example cooperation, symbiosis, protocooperation, altruism etc. Sometimes the mutual interdependence between species can be interpreted as a coevolutionary process where the species adapt to each other through reciprocal selection without exchange of genetic information between the groups (Odum, 1975 and Gowdy, 1994). ìFor coevolutionary ideas to apply in a particular system, the populations in that system must interact, or have interacted in the past, and must have been together long enough in space and time for the interaction to have had a realistic opportunity to cause evolutionary changes."[10] The specificity of a coevolutionary process compared to a simple evolutionary process is the mutual adaptation of the entities. "In a coevolutionary process,..., the adaptive landscape of one actor heaves and deforms as the other actors make their own adaptive moves." (Kauffman, 1993)

If we translate this general formulation of coevolution to the problem of coevolution of industries we can note that the interaction of interdependent industries can take many forms. Industries that interact may support or destroy growth in each other and in surrounding industries. Over time the interaction result in positive or negative externalities.

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[8] E. Dahmén (1993, p. 24). "Such initiatives may be taken by existing, or new, actors without concerted activities, that is simply as a reaction to market 'price signals', or within the framework of network-relations outside what is traditionally called a 'market'."

[9] E. Dahmén (1950) and (1989). The concept structural tension is used by Dahmén and the concept reverse salient by T. Hughes. Other concepts that emphasize the interdependence between technical evolution in interrelated industries are for example: Pacey's technology movements, Schumpeter's new combination and Basalla's artifactual continuity.

[10] Roughgarden (1983) p 41

We can now note the principal characteristics as regards externalities in a coevolutionary process. Externalities evolve as the technologies evolve, coevolution of industries is about dynamic externalities that interlock industries in an evolutionary process of entities that mutually adapt. A dynamic externality is an externality that operates through time (Balassa, 1962). A dynamic externality exists if current actions lead to higher future costs or higher future revenues. During the last years a lot of attention has been given to negative dynamic externalities, see for example Mason and Phillips (1997) "Increases in current fish harvests, for one example, generally reduce the reproductive capacity of the cohort and so lower the size of future populations, making it more costly to locate and harvest fish in the future." The classical treatment of dynamic externalities was that they were closely connected with the development of the economy (Balassa, 1962 on Marshall's Principles of Economics). They comprised the "spreading of technological and organizational know-how and the development of a managerial class and a skilled labor force." Balassa (1962, p. 146f) stressed that it was of little use to adopt a static interpretation of this category of externalities as "… technology and skills are developed through use. We face a dynamic process in the growth and acquisition of skills and the development of technological and organizational knowledge;…"

In a complete listing of all possible time dependent externalities linking interrelated industries we should beside knowledge and skills also include changes in the costs of inputs due to economies of scale or competition for scarce resources and changes in consumers' demand.

To conclude: a focal industry can create positive static and dynamic externalities in upstream industries, in complementary industries and in downstream activities through: 1) the strengthening of economies of scale through demand for an input that is an input in other industries; 2) the development of technology and knowledge spill-over; 3) supporting infrastructures and institutions that are valuable to other industries; and 4) developing new types of demand that are attractive to other industries and can be satisfied by other technologies. In a similar manner the industry can generate negative static and dynamic externalities for other industries. 1) it can by competing for scarce input resources withdraw these inputs from other industries — Fogel suggested that the railway did this by withdrawing capital and talent from the emerging motor car industry; 2) the industry can promote standards that restrict the search for knowledge, for example by holding patents potentially useful for other industries, or by developing notions about technology that restricts other ways of doing research. Institutions, for example regulations, can act in a similar way by blocking the growth of emerging industries; and 3) the industry may effectively tap the market of all the attractive demand forcing competing industries to survive on the left-overs of demand.

A Coevolutionary Interpretation of 19th Century Inland Transportation

This chapter seeks to give an analytical answer to Fogel's thesis that the modern car would have benefited if the railway would never existed. This is of course a pure exercise in counterfactual history.[11] The analysis doesn't aim at recapitulating everything that occurred in the inland transportation systems, instead it is based on a deconstruction of the historical developments into a set of ìanecdotesì characterized by a significant degree of externalities. Each anecdote is interpreted in terms of the effects that it had on the transport sector as a whole. To be able to say something about Fogel's speculation, the 19th century is divided into three periods: 1800-30, 1830-60, and 1860-90. It seems reasonable to stop the exercise in 1890 because at that date the internal combustion car existed in the real world.

When the 19th century started the few railways that existed were feeding goods to the canals and river boats. Long distance travel by stage coach was becoming possible on certain destinations, but often was it more convenient to take a boat on the longest leg of a journey. At the end of the 19th century railways were used for all types of inland transport, and stage coaches, trams and boats were feeding the railway network with passengers and freight. Bicycles were used for private transportation on short distances, and the automobile was beginning to be used by the rich as a substitute to private coaches.

Fragmented Case Studies

In the period 1800-30 was a number of new transport technologies launched and old technologies were improved: The steam car appeared in 1801, the velicopede was invented in 1817, the first commercial steam boat started to operate in 1807, the steam locomotive came in 1804, on the road networks were introduced suspension bridges and better road surfaces, and fundamental internal combustion engine theory was codified in 1824.[12]

In the period 1830-60 was many systems developed that originated in 1800-30. The first modern railway line was inaugurated, and was followed by new railway lines resulting in railway manias in Great Britain and the US. The steam locomotive

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[11] See Cowan and Foray (1997) for a discussion of counterfactual history and evolutionary economics.

[12] Westwood (1977) for the dates on the steam car and steam locomotive, Pacey (1992) for the date on the steam boat, Bijker (1995) for the date on the velocipede, and Fogel (1967) for the date on internal combustion theory.

developed into a dominant design, and the first steam car service was launched and failed. Components were developed for the new transport vehicles, for example the first tires appeared in 1845. Bridge building technique advanced and the problem of building bridges strong enough to carry steam trains resulted in the development of the tube bridge in Great Britain and while Roebling in the US developed suspension bridges for railway use. New transport markets were developed and tourism emerged as an industry.[13]

In the period 1860-90 emerged a new set of novel transport technologies and the expansion of the railway networks in the most advanced countries slowed down. Electricity was beginning to replace steam on some railway networks, and to replace horses on inner city tram lines. The bicycle was improved first as the ìOrdinaryì high wheel bicycle and later as the ìSafetyì bicycle. The first generation of cars were built, a few used electric motors but internal combustion engines dominated. The steam railway technology moved towards perfection, average speeds increased and on certain lines could long distance services run at an average speed of close to 100 km/h. The steam car found two market niches - in the agricultural sector and to haul bulky equipment on the road network.

How influenced these developments the arrival of the internal combustion car?

The period 1800-30

The steam engine was an important antecedent of the internal combustion engine (Basalla, 1988). The Watt-Boulton steam engines blocked in many ways the development of knowledge about how steam engines could be used in transport. Watt and Boulton targeted mines and mills with their steam engines and to minimise the risk of explosions they blocked the development of high-pressure steam (von Tunzelman, 1976). After their patents expired inventors rapidly started experiments with high-pressure steam engines. When Trevithick built the first functioning steam car and the first steam locomotive he used high-pressure steam engines. When nobody bought the steam car he sold the engine to a mill. The first commercial steam boat started to operate in 1807. It is understandable that steam engines were successfully applied to drive boats before they could be regularly used in road or rail vehicles, because the engine occupied a large space in proportion to the power it produced. This was partly because the use of low-pressure steam meant that the engine's cylinder had to be relatively large, and partly also because of the method of driving the flywheel via a

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[13] Petroski (1996), Westwood (1977), Bijker (1995), Nicholson (1982),

heavy beam above the engine. The first experiments with high-pressure steam engines in steam boats took place some years before in 1803. The engine was constructed by Oliver Evans, when he started to supply high-pressure steam engines he sold them to industrial customers (Pacey, 1992).

The velicopede was invented in 1817. It remained for 50 years a toy. Some explorations were made to use it in commercial activities. A mail service used the velicopede but because it lacked cranks, the wear on the shoes resulting from pushing the vehicle forward, prompted a halt of the use of the machine (Bijker, 1995).

The improvement of the road networks had started already in the 17th and the 18th century. The state took on responsibilities directly by building roads or indirectly by legislation for the provision of roads. Suspension bridges spanning over large distances were one result of the increased attention given to roads as were improved road surfaces. The most famous road and bridge project was Telford’s reconstruction of the road from Shrewsbury-Holyhead including the new suspension bridge over Menai Straits.

Three factors had played an important role in increasing coaching speeds in the second half of the 18th century: turnpiking, sprung coaches and better organization of the coach services through a system of innkeepers providing relays of horses along the route making possible for the various teams to gallop at higher speeds over short distances of ten miles or so. This new system cut the London-Manchester run from four and a half days in the early 1750s to 28 hours in the later 1780s, further improvements, for example macadam, cut travel times to 24 hours in 1821, 20 hours in 1830 and 18 hours in 1832. "An average speed of ten miles per hour was perhaps the limit possible for vehicles drawn by horses."[14] Improvements like these and later on the growth of railways resulted in a remarkable expansion in the use of horses. "In 1814 there had been 23,000 private four-wheeled carriages licensed in Britain. The number grew to 49,000 in 1834 and 125,000 in 1874."[15]

The period 1830-60

The building of railway networks created an effective way to distribute goods and to offer a cheap and fast way of transportation. The first railway line built for passenger transportation between Manchester and Liverpool showed the capacity of the improved steam locomotive, "The Rocket" worked at a steam pressure of 50 pounds per square

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[14] T. C. Barker, 1989, p. 99

[15] T.R. Nicholson, The Birth of the British Motor Car, Volume 3 the Last Battle 1894-97 (Macmillan, London, 1982) p. 372 and 373.

inch. The train reduced the travel time from four to 1.5 hours. The fare on the railway was half the former fare of stage coaches. Within five months the number of stage coach services fell from 29 to four. The Rocket was the first version of the emerging dominant steam locomotive design. After the success of the Liverpool-Manchester line railways diffused allover the world but came to a halt for nearly a decade in Great Britain.

In the interval from 1830-1838 tried entrepreneurs to develop a steam carriage service. One problem facing the steam carriage entrepreneurs was the lack of continuity in developing a pool of experience. For instance fell Trevithick's and others' experiments into oblivion and later generations of inventors had to conduct similar experiments in the 1820s. At that time had there emerged a pool of publications that published material on the progress of engineering. The steam carriage business was also aided by the successes of horsedrawn vehicles that promoted the construction of better roads and resulted in improvements of road vehicle technology.[16] The steam carriage entrepreneurs that entered the business in the late 1820s could benefit from better roads, general technical advances, increasing demand for road transportation and improved diffusion and codification of advances in engineering.[17] The most prominent of the steam carriage inventors and entrepreneurs was Goldsworthy Gurney. He presented in 1827 a steamer that within a few years time come to attract a lot of commercial and political interest. The steamer was at this time backed by many powerful interests - private investors were willing to finance steam carriage development, the army was interested and the Prime Minister was supportive.[18]

Guerney's steamer was after a couple of years of preparation in February 1831 introduced in a steam carriage service on the Gloucester-Cheltenham road. Already after a couple of months started the turnpike trusts, that controlled the road, to threat the operator with legal actions and they also raised the road tolls to prohibitive levels. Similar reactions from the turnpike trusts rapidly spread over Great Britain. Within a couple of years special tolls penalising steamers were introduced on many turnpike roads. The steam carriages threatened the turnpike trusts in at least three ways: 1) By a probable higher wear and tear on the roads than stage coaches, 2) By reducing the

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[16] The most astonishing example of the lack of continuity in knowledge is the idea that "... if power were transmitted through wheels to a road - ... - the wheels would slip and spin when reaching a hill." T.R. Nicholson, The Birth of the British Motor Car, Volume 1 A New machine 1769-1842 (Macmillan, London, 1982), p. 21. More than 100 years later a similar idea developed in railway technology when engineers thought that steel wheels on rail never could run faster than 350 k.p.h..

[17] T.R. Nicholson, The Birth of the British Motor Car, Volume 1 A New machine 1769-1842 (Macmillan, London, 1982), pp. 20-27

[18] T.R. Nicholson, The Birth of the British Motor Car, Volume 1 A New machine 1769-1842 (Macmillan, London, 1982), p. 65

number of toll paying coaches due to more seats on a carriage than on a coach, and 3) By its environmental effects: sound, shedding of red hot coal and letting out steam. It was claimed that they frightened all but a few animals from the road. The market opportunity for steam carriages dwindled away in Great Britain with the breakthrough of the railways in 1838-1841. Most of the possible lucrative markets disappeared as the new railway lines opened.[19]

The railway manias that occurred in the mid 19th century in Great Britain and the US and the enormous capital flows they created prompted the development of new financial instruments in the American capital markets.

The first pneumatic tires appeared in 1845. They were in the patent application designated to be used on carriages, but the inventor Thomson suggested that they may be used on railway wheels running on timber rails. The enterprise failed after some years and it took another 40 years for the product to find a market in the developing bicycle market (Bijker, 1995). Thinner tires had been put on bicycles in the 1870's.

Bridge building technique advanced and the problem of building bridges strong enough to carry steam trains resulted in the development of the tube bridge in Great Britain and while Roebling in the US developed suspension bridges for railway use (Petroski, 1995). It was not uncomplicated to develop new bridge designs as noted by Rosenberg and Vincenti (1978): "... Stephenson conceived of a tubular bridge, to be constructed out of riveted wrought-iron plates, and large enough to allow trains to pass through its interior. To Stephenson, "it appeared evident that the tubular bridge was the only structure which combined the necessary strength and stability for a railway, with the conditions deemed essential for the protection of the navigation." Such a structure, however, was totally unlike anything that had been previously attempted. Wrought iron had never before been used on so large a scale. The novelty of both the materials and the design was so great that there was no reservoir of reliable knowledge or experience upon which to draw in determining feasibility and, above all, safety. (Rosenberg, N. and Vincenti, W. G., 1978, s. 6-7, the quotation in the quotation is from Edwin Clark, The Britannia and Conway Tubular Bridges, London, 1850).

Expensive bridge projects were much easier to carry out in the railway network than in the road network. The bridge constituted a part of the railway line and could be paid for by passenger fares and revenue from freight transport. In the road network the bridge was a single costly project that had to carry its own costs. Two of the most

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[19] T.R. Nicholson, The Birth of the British Motor Car, Volume 1 A New machine 1769-1842 (Macmillan, London, 1982) p. 65-133

daring and famous road bridges in the 19th century were blocked for many years because of lack of capital. The first was Brunel’s Clifton Suspension Bridge, completed to honour after he died, and Roeblilng’s Brooklyn Bridge (Rolt, 1957 and Petroski, 1996).

The period 1860-90

The bicycle was improved first as the ìOrdinaryì high wheel bicycle and later as the ìSafetyì bicycle. With the Ordinary bicycle the bicycle became a racing device and it was the fastest vehicle on the roads in the 1870’s.

The first generation of cars were built, a few used electric motors but internal combustion engines dominated. An important way of using cars in the years was to race with them. The number of motor vehicles could remained insignificant until the 1890’s.

The steam railway technology moved towards perfection, average speeds increased and on certain lines could long distance services run at an average speed of close to 100 km/h. Most nations had completed their railway networks. Electricity and was beginning to be tested on some lines and electric trams began to replace horses on tram lines.

When steam carriages reappeared in 1850-60 they resembled the then dominating steam locomotives and were used for heavy transports and in the farm sector. It was against this type of vehicles that the red flag law was directed. A car was only allowed to travel 6 km/h or less and a man with a red flag should walk in advance and warn people of the vehicle. Competitive steam cars didn't appear before the turn of the century. It was first then that pressures high enough (600 pounds per square inch) and chassis constructions light enough enabled the steam car to compete with the horse on the roads.

Analysis and Conclusion

In what direction acted the dynamic externalities that were created by the transport sectors in the 19th century? And in particular did the railway lock-out or pave the way for the internal combustion car?

Fogel pointed at two negative externalities produced by the railway hampering the motor car industry - capital and talent. These two negative externalities were probably not important. The capital needs of the internal combustion technology were not demanding before the industry started to grow in the early 20th century. In retrospect it is true that the railways engaged themselves in a refinement of the steam technology that was equal to what is going on in the motor car industry today. However, most of the R&D were conducted within the framework of the servicing and control of steam locomotives in the operation of the railways. But if we consider all the other external effects that we discussed above?

It is evident that some facts support Fogel’s case and that other facts refute it. Below is a list of items either giving support or contradicting the idea that the railway blocked the development of the motor car.

Anecdotal evidence supporting Fogel's thesis:

The railway effectively locked in carriage technology in a system that was blocking the development of a passenger car. The carriages were to heavy, and the engines to big due to low steam pressure. This type of machines were useful in farming and for hauling of equipment at low speed on the roads. They resulted in the red flag law hampering the growth of a motor car industry in Great Britain.

The bicycle, being a toy, which contributed extensively to the car industry developed independently from the other transport technologies. Had the bicycle at an earlier date been regarded as a means of passenger transport could mass manufacturing had started earlier of bicycles and as a result of that of cars. Many bicycle manufacturers became car manufacturers when the bicycle market was saturated in the 1890’s. Against this interpretation could be argued that the bicycle didn’t develop because of difficulties in solving very simple technical problems.

Anecdotal evidence contradicting Fogel's thesis:

The steam car being an oddity was never well documented due to lack of economic interest in it. Each new generation of inventors had to repeat basic research that was not codified. Something similar was true for the internal combustion engine, entrepreneurs sought supranormal profits and therefore avoided to report result of experiments.

Many inventions necessary for the development of the motor car took many years to develop despite that the railway had no connection to them. The first tires were developed for horse carriages but made small success. It was not until a bicycle design that could benefit from a pneumatic tire that the tire industry could develop. The same could also be stated about the long time it took to develop light weight iron structures in the bicycle industry that eventually became important for the motor car industry.

The steam boat put limited demand on the steam engine since space wasn't a restriction. Therefore the first steam boats made use of low pressure Watt-Boulton steam engines completely unsuitable even for steam locomotives. A complicating fact is that demand for high-pressure steam engines was not limited to the transport sector. Some early high-pressure steam engines were sold to mills after failing in a steam car or a steam boat.

The railway is still a faster and safer means of transport than road transport. Had the car developed earlier is it possible that societal aspects such as the fear of speed and the private costs of accidents, could have produced reactions against motor vehicles. The steam car was punished by the legislators for reasons of safety and the disturbance it caused other means of transport. Even the bicycle, most importantly the Ordinary bicycle, met opposition because of its relatively high speed.

The railways were much more apt to solve the problem of financing bulky investments than the road system. Imagine the consequences on knowledge growth if all major bridge projects would have been delayed because of problems of financing.

The railway by being able to rapidly transport many passengers to one location was instrumental in helping specific cities to specialise in tourism. Had people travelled by car had recreational trips been more evenly distributed and economies of scale at particular tourist locations had been lost. Similar arguments could be advanced for the creation of densely populated suburbs. One of the most important effects of the motor car system is the growth of family home suburbs. This means that through the construction of tramways and suburban railway lines could relatively little resources be directed towards transport system building and passenger transportation in the growing industrial economy.

Conclusion

In a counterfactual treatment of Fogel’s thesis it would be an advantage if we could separate the developments into coeval changes and coevolutionary externalities. However, it would be difficult to be able to do this for the railway in the 19th century. Railways were to be seen everywhere except (perhaps) in counterfactual GDP estimates.

The externalities created by the railways in the 19th century and the lack of economic strength of the other transport systems probably prove that Fogel’s counterfactual speculation is false. The motor car could benefit from substantial dynamic positive externalities created by the railway. Even if the motor car and the railway did not coevolve can we identify many positive externalities that facilitated the rapid growth of the motor car industry. The railways provided much impetus for all other means of transport in terms of creating complementary markets, changing habits and consumption patterns, advancing knowledge in bridge construction, blocking the development of the steam car etc that the motor car was better off with rather than without the railway.

References

Arthur, W. B., 1994, Increasing Returns and Path Dependence in the Economy, The University of Michigan Press, Ann Arbor

Barker, T. C., 1989, Transport: the Survival of the Old beside the New, in The First Industrial Revolution, Mathias, P. and Davis, J. A., Blackwell, Oxford

Balassa, B., 1962, The Theory of Economic Integration, George Allen & Unwin Ltd, London

Basalla, George, 1988. *The Evolution of Technology*, Cambridge University Press, Cambridge.

Cowan, R. and Foray, D., 1997, Counterfactual History and Evolutionary Economics, mimeo, MERIT, University of Maastricht

DahmÈn, E., 1950, *Svensk industriell fˆretagarverksamhet, Kausalanalys av den industriella utvecklingen 1919-39*, 2 vols., IUI, Stockholm. English edition of Vol. 1, 1970, *Entrepreneurial Activity and the Development of Swedish Industry 1919-39*, Irwin, Homewood, Ill.

DahmÈn, E., 1989, 'Development Blocks' in Industrial Economics, in B. Carlsson, ed., *Industrial Dynamics*, Kluwer, Boston

David, P., 1969, Transport innovation and economic growth: Professor Fogel on and off the rails, *Economic History Review*, vol. 22, pp 506-525 reprinted in New Economic History. Selected Readings, P. Temin (ed.), Penguin Books, 1973, Harmondsworth, Middlesex

England, R. W. (ed.), Evolutionary Concepts in Contemporary Economics, The University of Michigan Press, Ann Arbor

Fogel, R.W., 1964, *Railroads and American Economic Growth: Essays in Econometric History*, The John Hopkins Press, Baltimore, Maryland

Fogel, R.W., 1967, Railroads as an Analogy to the Space Effort: Some Economic Aspects, Economic Journal pp 16-43, reprinted in New Economic History. Selected Readings, P. Temin (ed.), Penguin Books, 1973, Harmondsworth, Middlesex

Galli, R and Teubal, M., 1997, in Edquist, C. (ed.), Systems of Innovation. Technologies, Institutions and Organizations, Pinter, London

Gowdy, J., 1994, Coevolutionary Economics: The Economy, Society and the Environment, Kluwer, Boston

Mason, C. F. and Philips, O. R., 1997, Mitigating the Tragedy of the Commons through Cooperation: An Experimental Evaluation, *Journal of Environmental Economics and Management*, 34, pp 148-172

McKelvey, M., 1994, Evolutionary Innovation. Early Industrial Uses of Genetic Engineering, Linkˆping Studies in Arts and Science, Motala

McKelvey, M., 1997, Using Evolutionary Theory to Define Systems of Innovation, in Edquist, C. (ed.), *Systems of Innovation. Technologies, Institutions and Organizations*, Pinter, London

Nelson, R. R., 1994a, The Coevolution of Technologies and Institutions, in England, R. W. (ed.), *Evolutionary Concepts in Contemporary Economics*, The University of Michigan Press, Ann Arbor

Nelson, R.R., 1994b, Evolutionary Theorizing about Economic Change, in Smelser, N. J. and Swedberg, R. (eds.), *The Handbook of Economic Sociology*, Princeton University Press, Princeton N.J.

Nelson, R.R., 1994c, The Role of Firm Difference in an Evolutionary Theory of Technical Advance, in Magnusson, L. (ed.) *Evolutionary and Neo-Schumpeterian Approaches to Economics*, Kluwer, Boston

Nelson, R.R., Recent Evolutionary Theorizing About Economic Change, *Journal of Economic Literature*, Vol. XXXIII, March 1995, pp. 48-90

T.R. Nicholson, 1982, *The Birth of the British Motor Car, Volume 1, A New Machine 1769-1842*, Macmillan, London

T.R. Nicholson, 1982, *The Birth of the British Motor Car, Volume 3, The Last Battle 1894-97*, Macmillan, London

Norgaard, R. B., 1994, The Coevolution of Economic and Environmental Systems and the Emergence of Unsustainability, in England, R. W. (ed.), *Evolutionary Concepts in Contemporary Economics*, The University of Michigan Press, Ann Arbor

Odum, E. P., 1983, *Ecology*, 2nd ed., Holt Rinehart and Winston, London

Pacey, A., 1992, *The Maze of Ingenuity*, 2nd ed., The MIT Press, Cambridge, Mass.

Petroski, H., 1992, *The Evolution of Useful Things*, Vintage Books, New York

Petroski, H., 1992, *Invention by Design*, Harvard University Press, Cambridge Mass.

Rolt, L.T.C., 1957, *Isambard Kingdom Brunel*, Penguin Books, 1989, Harmondsworth, Middlesex

Rosenberg, N. and Vincenti, W. G., 1978, *The Britannia Bridge: The Generation and Diffusion of Technological Knowledge*, The MIT Press, Cambridge Mass.

Roughgarden, J., 1983, The Theory of Coevolution, in *Coevolution*, Futuyma, D. J. and Slatkin, M., (eds.), Sinauer Associates Inc. Publishers, Sunderland, Mass.

Westwood, J. N., 1977, *Locomotive Designers in the Age of Steam*, Sidgwick & Jackson, London