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Technological Determination and Determinism: Industrial Growth and Location

RICHARD A. WALKER

With the breakdown of neoclassical hegemony in location theory, interest has shifted from the realm of exchange to the realm of production and, thence, to technology. This has dovetailed with a revival of interest in Schumpeter's ideas about technical innovation as the prime mover of economic growth and business cycles. Meanwhile, technology has come to be viewed by the public as the key to the magic kingdom of regional development and national competitiveness. As substantial technological changes and regional shifts are unquestionably in progress, it is salutary that economic geographers are looking seriously into the subject of technology in the spatial patterning of economic growth (for a review, see Malecki, 1983). This process has only begun. It is not surprising, therefore, that various kinds of technological determinism have found their way into the regional debate, such as the notion that high tech industries have a unique locational pattern, that R&D centers are crucial to local growth because of their innovative function, or that the product cycle dooms older industrial regions to imminent stagnation.

I wish to drive a wedge into the cracks in some common ideas about technology and location in order to open up further room for debate. I do not do this as an antagonist of the idea of technological determination, pushing a putative 'Marxist' line about the monocausal force of social relations. Quite the contrary, I see technology as an essential structuring factor in industrial development and location. Nonetheless, it is necessary to frame the limits of technological determination. Technology must be set against other, equally fundamental aspects of the capitalist economy and capitalist growth, particularly capital-capital (competitive) and capital-labor (class) relations. The collision—or, rather, tension—between the relations and forces of production shapes the course of industrial development. Second, historical outcomes are not mere results of impersonal forces, like the ricocheting of billiard balls. Therefore, determinism must be replaced by a structural-realistic view of cause and effect that comprehends the gap between underlying causes and actual outcomes, given the infinite possibility of intervening contingencies, which in history (unlike in a laboratory) can never be controlled. To this must be added the necessary intervention of human consciousness and human agency, of choice and struggle. These render all social history an open system, in which results never may be read off from technology or any other determinist force, no matter how tight the bonds of social structure may appear (Giddens, 1979; Sayer, 1982a; Walker, 1985).

The first part of this chapter dessects industry cross-sectionally, looking at four technological dimensions of production: product, process, linkage, and division of labor. It lays a groundwork for the rest of the discussion in the specificity of industries along these several dimensions. The second part looks at the patterns of technical change and how they further distinguish the developmental paths of industries and their rhythms of growth. The third section uses these insights about technical structuring of industry and growth to critique deterministic models of the technical imperative in the location of industry and regional development patterns, in terms of the spatial division of labor; spatial linkages and agglomeration; technical change and relocation; and innovation and regional growth.

TECHNOLOGY AND THE ANATOMY OF PRODUCTION

Technology casts industries in different molds and sets them down different paths of development. Non technological factors augment these differences. Of course, certain technical and social factors lead commonality to the fates of industries—most obviously, their organ-
The division of labor has far-reaching implications for the development and organization of industries. The classic example is the automobile, where the division of labor is so fine that each worker performs a specific task, such as assembling a specific part or performing a specific inspection. This division of labor has led to increased efficiency and productivity, as each worker becomes highly specialized in their task.

Technical considerations often decide which parts of the production process are best suited for automation. For example, in the automobile industry, the assembly line is highly automated, while research and development is still done manually.

However, some parts of the production process are still done manually, such as painting and finishing. This is because automation can be expensive and the parts of the production process that are automated can be expensive to change. In addition, some parts of the production process are not suited for automation, such as the assembly of complex parts.

The division of labor has also led to the development of subcontracting, where parts of the production process are done by other companies. This can be seen in the automobile industry, where parts are produced by subcontractors who are then assembled by the main company.

In conclusion, the division of labor has had a significant impact on the development and organization of industries. It has led to increased efficiency and productivity, but also to increased specialization and automation. The division of labor is a powerful force that continues to shape the development of industries.
THE PROTONIZATION PROCESS

In a protonization process, the proton is removed from the Be solution by...

...the following:...

The distinction between the two sides of production also addresses the riddle of bias in process change (see, again, David, 1975; Uselding, 1974; Kennedy & Thrulwall, 1972). From the materials side, technical change will be neutral as there is no incentive to save on one input more than another (Sulter, 1966). From the labor side, however, mechanization always involves labor-saving (greater output to labor ratio). A third consideration is to recognize the irreducible human element in all labor processes, regardless of technological proficiency and the drive for surplus-value. While people may be constructed along common lines, lending a homogeneity to all labor processes, labor can never be entirely rationalized and given over to machines. The creative human element remains, if only in seeing that the machines perform as programmed (Aronowitz, 1978; Cressy & Machon, 1980; Manwaring & Wood, 1984). Every labor process demands special skills that can only be learned through practice on the job. It also requires that workers mobilize their labor and exercise their creativity. Production requires not merely choosing the right mix of "labor inputs" to fit technically given tasks, but hiring and molding, through the experience of work and managerial control systems, the kind of labor force that will get the job done and done well. This is no mean trick. It only happens through a process of class-structured maneuver and conflict that includes group socialization, the application of managerial power, and various forms of worker resistance within the context of the job to be done, the leverage given workers by their skills, labor market conditions, product market conditions, and the like (Storper & Walker, 1984).

Because there is no unique outcome to the social order of the workplace, labor demand cannot be read off from production technique and organization. The concepts of strictly technically determined "skill" levels and "marginal products" of labor are untenable.

The variable condition of the employment relationship augments the differences among industries. Furthermore, as has been frequently observed, the state of labor relations affects the course of technical change. Machinery has often been used to break the hold of skilled and/or unionized workers; conversely, militant workers may prevent the introduction of new techniques or decline and low-paid workers blurt the capitalist's drive for technical change (Mars, 1967; Rosenberg, 1976, 117-120). Thus, the path down which technology travels and the rate of movement depend on the social relations of
The process of industrialization involves the transformation of agricultural economies to industrial ones, marked by an increase in the production of goods and services through the use of machinery and technology. This process is not just about economic growth; it also has profound social and environmental consequences.

The technological and industrial development aspect of this process involves the replacement of labor-intensive methods with mechanized production, leading to increased efficiency and productivity. The introduction of new technologies in manufacturing and construction has also contributed to significant changes in the way goods are produced and delivered to consumers.

In the context of the current technological landscape, it is crucial to consider the role of innovation in driving industrial growth. The development of new technologies, such as automation and robotics, has the potential to further enhance productivity and efficiency, leading to increased output and economic gains.

However, the transition to an industrial economy is not without challenges. Issues such as employment displacement, environmental degradation, and social inequality are common concerns associated with industrialization. Addressing these challenges requires a comprehensive approach that balances economic growth with sustainable development.

At the core of the industrialization process is the development of infrastructure and the integration of new technologies into various sectors. This involves investments in research and development, education, and training to ensure that workers are equipped with the necessary skills to operate in a modern industrial environment.

In conclusion, the process of industrialization is a complex and dynamic phenomenon that has shaped human societies for centuries. Understanding its impact and managing its consequences are key to ensuring that future industrial growth is sustainable and equitable.
according to the realist conception, scientific explanation deals chiefly with underlying mechanisms abstracted from intervening contingent causes, and not the complexities of real situations in which the latter are heavily implicated (Bhaskar, 1978; Sayer, 1982a). It is one thing to know how gravity affects the fall of the apple, another to design an apple picker.

Technical innovation derives principally from practical experience with production. Practical problems are encountered, practical solutions are proposed. "Innovation [is] a process of learning by experience." Moreover: "the process of learning tends to be technology specific" (Piore, 1986: 605).

This does not mean that innovation only takes place on the shop floor, that research and design workers may not be a separate group of workers laboring in another corner or even another building, or that industrial engineers do not refer to scientists and scientific journals as they search for solutions (Price and Bass, 1969). Nonetheless, "the gap of science lies in indicating what is not possible" (Sahal, 1981: 62). Practical inventions do not, as a rule, flow from scientists and little industrial R&D is basic research. Industrial engineers have to interact with the production line and the marketing office, and good ideas come from ordinary workers all the time (Piore, 1986). Working production processes are rarely captured in formal blueprints (Piore, 1986).

One must also carefully consider the conditions under which scientific principles may be applied to production—e.g., after a degree of rationalization and division of labor (Marx, 1967; Rosenzweig, 1982: 39-51). Despite all the attention to R&D in the literature, there is little evidence that R&D effort explains technical change (for reviews, see Mansfield, 1972; Kennedy and Thrall, 1972, 44-50; Sherer, 1970). This is partly because it is sometimes hard to distinguish cause and effect (as in the case of the "inventive" performance of an industry determined mainly by the nature of its technology (Sahal, 1981: 57; Phillips, 1971). Promising industries have both high levels of R&D and high rates of technical change; hence, R&D is highly concentrated in a handful of industries (Mansfield, 1972).

(2) "Inventions," do not burst, fully formed, upon the industrial stage. Technical change is made up of a stream of small innovations and incremental improvements in products and equipment, not a handful of revolutionary ones. This is to be expected from a process based on practice and tinkering. Technical change is part of a larger process of improving production through experience, which has been dubbed "learning by doing" (David, 1975; and literature cited there). Even the best ideas need a long series of improvements to perform well. Virtually all inventions require years to be adopted initially (a commonly cited figure is 11 years). 30 years more to be adopted widely, and longer to hit their peak performance. All of these lags result from the need to improve or alter a basic product or process for different specific uses (Gold, 1979; Rosenberg, 1976: 71-73). As Gold (1976: 2) observes, "innovations trigger a continuing process of changes... . It is through the ensuing complex of interactions that the innovation is 'digested' by means of progressively more far-reaching adaptations and its effects thereby diffused through the system and over time... . as a result, the distinctive effects of the given innovation become increasingly indistinguishable." Because of the time lag, several innovations are likely to be in the process of digestion at any time. The reach of an innovation will depend on its adaptability to related activities; apparent pathways may be blocked. Both major and minor innovations are clustered unevenly (Sahal, 1981: 59). Such events are unpredictable because of the inevitable dialectic of dull labor and creative breakthroughs, of human effort and the possibilities inherent in a technology (Sahal, 1981: 41; Jewkes et al., 1959; Peters, 1983).

Because learning and innovation are object- and process-specific and build on one another, technical change is "localized"; every technological choice circumscribes the course of further development (Davis, 1975: 55-94; Sahal, 1981: 199). This adds further force to the idea of restricted industry development paths.

(3) Technology creates its own "compulsive sequences" of problems and solutions (Rosenberg, 1976: 112). This pushes industries even harder down technically structured paths. The basis of such sequences are the technical complementarities between related parts of a single machine, of a unified production process within a factory, or between different sectors of the social division of labor (Marx, 1967; Rosenzweig, 1976: 110-117, 201-206; 1982, 56-72, 70-80; Nelson and Winter, 1977; Piore, 1986). An improvement in one area reveals the inadequacies of another, as when miniaturization so reduces computers that the conventional TV picture tube becomes a barrier to portability. Or the imbalance may be felt in terms of bottlenecks in the
Eras of industrial progress (e.g., mechanical age, electrical age, electronic age). Industries will differ, however, in their ability to exploit such basic technologies (Nelson and Winter, 1977).

TECHNOLOGY AND THE RHYTHM OF ACCUMULATION

The technological determinist views of growth now in vogue are the product cycle for individual industries (Burns, 1934; Kuznets, 1930; Vernon, 1966; Hirsch, 1967) and the wave of innovations view for whole epochs (Mensch, 1979). The evidence does not support either. There is no universal S-curve of growth; sectoral output grows in a variety of patterns (Gold, 1964). Growth paths are characterized by revivals as much as declines, by short-run business cycles as much as long-run patterns. On an aggregate basis, long swings in economic growth bear no obvious relationships to "lurching" of innovations (Freeman et al., 1982).

From what has already been said, what might we expect of the strictly technological contribution to temporal growth patterns? Because technical change is levered, lumpy, and unpredictable, we would expect its effects to be jerry despite the incremental nature of innovative activity or broad structural patterns of development. Nonetheless, structural breakthroughs may open up substantial periods of growth. Such growth might well take a wavelike pattern of upswing and exhaustion of technical change within a distinct design structure in an industry. Because breakthroughs are possible, we would not expect an organs pattern of maturity and decline in most cases, but a process of periodic renewal appearing either as a series of cycles or relatively continuous long-run growth (see Gold, 1964). The chance element in creativity also may lead to clusters of innovations that give shape to a period of growth (Sahal, 1981: 57-60). Finally, technical linkages and common principles across a range of industry means that a major structural breakthrough and period of evolution in one field may trigger a broad front of growth, as is now happening with microelectronics (Freeman et al., 1982; Nelson and Winter, 1977; Rosenberg, 1976; de Brison and Townsend, 1978). We should not be lulled, however, into forgetting the disjointedness of technical change, the lags and unevenness of application, the odd pathways down which it moves, the multiple waves of innovations, and even the reversals, all of which roil the surface waters and render underlying wave patterns of technical change consistent with a highly incongruous set of events in different industries.

The structural patterns of technology have force in the development paths of industry simply because production involves physical products, techniques of production, hardware, and a division of labor, and capital must take a "fixed" form as productive and commodity capital (Harvey, 1982). As Rosenberg (1978: 110) says, "the technological level has been more badly neglected than the economia generally recognizes."

Conversely, technical change depends on the other conditions of capitalist growth. From what we know of the process of technical change, we can see the multitude of openings for economic and social influence. The organization of production in profit-guided units linked together by markets obviously means that technical decisions are guided and mediated by market considerations. Moreover, its incremental, practical origins lay technology open to continuous input of cost and price information (David, 1975). Technology requires investment in fixed capital to be installed, so its rhythms bump against those of capital recovery over time. Markets rest on social conditions of consumption, distribution, and division of labor; market saturation, for instance, may be a spur to technical change. Technology is also a means of class struggle between capital and labor.

The rhythms of capital accumulation are themselves prime movers of technical change. Even if innovations are chance events, changes are increased by the degree of effort made, which depends in turn on the rate of investment—and not just R&D. Growth itself means accumulated learning, pressing problems to solve, and the will to tackle them (Sahal, 1981: 110, and references cited there). A notable case is the way postwar Japanese steel makers, pressed by booming growth, broke through supposed technical barriers of scale (Gold, 1979). Indeed, a mere increase in scale throughout growth demands change in technical structure (including division of labor) of an activity (Sahal, 1981: 65-66; Gold, 1980). Schmookler's (1966) well-known data on innovation actually do not show "market pull" determining technical change, but innovation by learning and adoption by level of investment (Rosenberg, 1976: 288-279). In part, then, growth generates its own technical change, it is self-generative.35

In the end, the most fruitful way to look at the problem is in terms of the dialectic between the technical relations of production and value relations, as Harvey (1982: 135) suggests.36 There is a whole constellation of things that must be in place for accumulation to proceed: labor-power, the money and credit system, market institutions, business organization, and so forth. Despite his great attention to technology,
THE EFFICIENCY OF THE ECONOMIC SYSTEM AND ITS ROLE IN THE DEVELOPMENT OF THE NATION

The economic system plays a crucial role in the development of any nation. It determines how resources are allocated, how goods and services are produced, and how wealth is distributed. An efficient economic system can lead to economic growth, increased productivity, and improved living standards.

In order to achieve this, the economic system must be designed to encourage innovation, entrepreneurship, and competition. It must also be flexible enough to adapt to changing economic conditions and technological advancements.

The government plays a significant role in the economic system by creating policies that promote economic growth and stability. This includes setting monetary and fiscal policies, regulating industries, and providing incentives for businesses to invest.

However, it is important to note that the efficiency of the economic system is not solely determined by government policies. The private sector also plays a crucial role in shaping the economic environment. Private enterprises contribute to economic growth by providing goods and services, creating jobs, and generating revenue.

In conclusion, the economic system is a complex and dynamic entity that requires careful design and management. By understanding the role it plays in the development of the nation, we can work towards creating a more efficient and sustainable economic system.

REFERENCES:


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cost structures, and hence in turn its locational patterns. This complexity is compounded by the divisions among work units within companies and within industries. It makes all universal statements about location patterns immediately suspect, for the primary pattern to grasp is that of a fine mosaic of industrial places.

If industries start from different conditions and follow different development paths because of their technology (as well as their history of labor relations, marketing, etc.), why would we expect them not to start in different places, move differentially, and end up in widely diverse places? All that is required is that the spatial distribution of conditions of production be uneven. This is the valid starting point of Weberian location theory that was lost in the subsequent fixation on transportation and market, homogeneous plains, and homogeneous production functions (Lesch, 1954; Isard, 1956). But one cannot end with Weberian theory, which takes linkages as given, sees technical change only in terms of factor substitution, treats labor as a one-dimension commodity, and has no theory of economic growth. My position on these topics has already been stated; it will be further amplified as we proceed to consider some theories that go beyond Weberianism in these areas, but still come up wanting.

An issue I have not previously introduced, on which Weberian theory also fails, is the interaction between geography and industry. Weberian models allocate industries to places based on their factor endowments. But there are no such initial conditions once industry is in place. Industry evolves along with places. First of all, industries have a tremendous influence over the spatial distribution of factors of production; they draw labor through migration, they create markets for other industries, they intervene in local politics, and so forth (Piore, 1979; Walker et al., 1981). In other words, industry produces industrial space to a considerable degree (Storper, this volume). Geographic unevenness of "factor endowments" is continually recreated by industry's use of space, which affects future location decisions (Massey, 1978, 1983).

Second, pre-existing spatial configurations not only steer industry to a spot, they also alter the way industry develops. Geography adds another dimension to industrial evolution. Consider strategy: Companies may seek lower cost either through technical change or by relocating to cheaper labor. The outcomes of such moves become the preconditions of future decision concerning technology, labor relations, and location. And because technology and labor relations evolve incrementally through experience, such steps are, to a large extent, irreversible; one cannot jump back onto the road not taken (Storper and Walker, 1983). In short, industry growth paths are altered by spatial practice. As a result, one will often find geographically distinct technologies and labor practices within a single industry—notably across national boundaries (Gettel, 1984; Storper and Walker, 1983; Brunn, 1974). At the same time, regional growth paths depend on the way industry develops in places.

Because the technical factor is essential to the character of industries and their locational needs, it should be possible to make some statements about the relation of types of technologies and industry location patterns. One such approach is to use production-based categories such as batch versus continuous flow processing (Storper, 1982, Storper and Walker, 1984). But one must not exceed the limits of what can be said about underlying technological patterns versus empirical geographical regularities. Some limitations are due to the disjunction between structure and outcomes, given intervening contingencies in each particular circumstance; these impede empirical generalization, but not statements about underlying patterns (Sayer, 1982b). Too many things intervene to break the tidy connection between technology and the shape of an industry and between industry structure and its spatial strategy (e.g., the talents of Henry Ford compared to failed car makers who located elsewhere than Detroit). But some of the disjunction involves structural transformation in technology and industry because of their geographic history. The substantial differences between the English and the American automobile industry can be put in no lesser terms.

A case of inappropriate generalization is the search for the golden fleece of the locational patterns of high tech industry. Why should we expect certain shared technological characteristics, such as rapid product development or high automation, to have uniform locational effects across otherwise different factors? Although electronics in Japan conform to electronics in the United States, given their very different social bases? The search is rendered even more problematic because the uncertainty surrounding the category of high tech itself. Does it refer to product, process, or division of labor? To the rate of technical change? What sort of scale of high and low technology is used? What definition of industry? These may not be insuperable barriers to an analytic meaning for high tech, but the theoretical work is not there as yet.

Are there no broad patterns to the diversity of the spatial mosaic? It will not suffice to end with a plea for specificity alone. Among those who have broken with the neoclassical model of regional specialization of industry and equilibration of income, models of spatial
First, the idea rests on an organic notion of growth and maturation that sees the world as a dynamic and evolving entity. Second, it is based on the idea that society is a complex system of interrelated parts, each of which interacts with the others. This system is designed to function as a whole, with each part contributing to the overall efficiency of the system. Third, it is based on the idea that society is a network of relationships, with each individual connected to others in a web of interactions. These relationships are not fixed, but rather can change and evolve over time. Finally, it is based on the idea that society is a constantly changing entity, with new ideas and technologies constantly emerging and altering the course of events. These four ideas are interrelated and work together to shape the course of history.
More generally, the industrial revolution in the United States of America, by opening one industry after another to the development of new activities, in any number of ways, as Mr. Chalmers puts it, "The search for an environment of research, a technical maturation of the industry, a culture of industrial achievement." China, too, is seeking new sources of growth opportunity. In this, the Peking-based company, known as the "Great Wall of China," is an example of a company that is pursuing a strategy of industrial maturation. This is much more far-reaching than just the traditional, industrial-type changes that have been made in the Far East, of the kind that are occurring in the United States. The chart shows the percentage of the population that is involved in technical work in China, which is at least twice as large as that in the United States.

In the United States, the percentage of the population involved in technical work is about 60%. In China, it is only about 20%. This is not because China is less skilled or less educated than the United States, but because the industrial base is not as well developed. China, however, is working hard to develop its industrial base, and there is no necessary relation between the level of technical work and the overall level of industrial activity. For example, the percentage of the population involved in technical work in China is about 20%, which is about the same as in the United States. The chart shows the percentage of the population involved in technical work in China, which is at least twice as large as that in the United States.

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become increasingly important with continuous flow, integrated machine systems, and assembly-line processes with microelectronic control systems, which commonly enter under the heading of "automation." In general, we need a better grasp of chemical and electronic process improvement, comparable to the treatment of mechanical systems.

10. Of course, there are also generalizable principles involved in the physical processes of production—which is why one can speak of "technological systems" based on episcopal technologies and families of machines. But these are not as widespread or as readily available to division of labor or mechanization.

11. It is not about minimizing any time which offers a more available techniques to the best, indeed, it means the physical efficiency of any process is hard to grasp in a single, comparable measure (Gold, 1979).

12. There is also a good deal of unveracity in the mechanization and automation of various stages in the production (Brignall, 1958; Kimura, 1983).

13. The labor-saving bias is augmented by considerations other than cost, of course; especially the mobility of capital in the machinery over relatively intensive production. (Peter 1900).

14. Peter 1900 found a consistent class bias of engineers against labor-intensive methods. But he also emphasizes the priority of technological imperatives over casual weighing of labor considerations in the development of production.

15. The following text, briefly on my reading of Rosenbom (1978), especially 109, 212, 308, 125, 182, 55, 80; David (1975); Nelson and Winter (1971); Solow (1980); Feld (1978, 1979); and Peter (1900).

16. I use the term "science" here in the way it is commonly understood in the historical and theoretical research. If the term is broadened to mean the systematic use of mechanical, chemical, or electronic principles, rather than relying on the traditional knowledge of the worker about a craft, then, of course, science is applied constantly in modern industry (Marc, 1967; Rosenbom, 1978: 12: 130: 1967: 141: 163).

17. Indeed, excessive social stratification and lack of communication between high-level engineers and lower-level people often blocks technical change.

18. There are, however, considerable problems in dating innovations (Rosenbom, 1978: 72; Foust et al., 1962: 45-55; Gold, 1979).

19. There is a common misconception that process improvements are mechanized. It is true, and in fact, unequally developed. Thus, highly sophisticated technologies are not found with a wholly manual operations (Bright, 1958; Kimura, 1983; Peter, 1960).

20. Such effects are felt in the price sphere also, even when the changes are not direct.

21. Within a basic structure of product and production there is likely to be an evolution of the labor process toward greater mechanization of markets are expanding (Adams, 1978).

22. And they are often overlapping because old products in the same industry do not necessarily die out as the new comes in (e.g., blender versus crockpot).

23. However, full capacity restrictions does not always appear to be conducive to experimentation, as innovations may come earlier and later in the basic industry. (Moutfield, cited in Smith, 1965).

24. Only the net can be cast more widely to include value relations of commodity consumption and work, so far as these cannot be vitally reduced to either technology or value.

25. Mandel has also sometimes been interpreted as a technological determinist, wrongly I think.

26. Although we should be able to rank the use all importance of different parts.


RICHARD A. WALKER 263


MICHAEL STROGER

Technology and Spatial Prediction

and Industrial Development

DISCUSSION, Technical, and Spatial Prediction Relations

2