The Cause of the Industrial Revolution: a Brief, « Single-Factor » Argument

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I. Introduction

Accepted descriptions of the phenomenon of " industrial revolution, " or the process by which a nation or region becomes industrialized,* emphasize the substitution of inanimate mechanized energy for that provided by animal or human power (1, 7). Another characteristic of industrialization is the acceleration of economic growth (3, 9), involving increased national investment (9) and rising per capita income. If it is allowed that these conditions are socially desirable, then the achievement of an industrial society can be regarded as a legitimate aim of state policy. Naturally, it would also be highly advantageous to develop proficiency at cultivating, or influencing, the industrialization process. Given the urgent need in most areas of the world for the benefits provided by industrial development, this accounts for much of the interest in isolating the causal factors which produced the industrial societies that presently exist, including the prototype case of Great Britain.

Regarding these underlying causes, a number of factors are generally considered to be necessary conditions for industrialization. These are: a sufficient population, agricultural development, capital accumulation, technological innovation, adequate demand and markets, a sufficiency of natural resources, and a favorable economic climate. Although there is more agreement about what constitutes the entire set of variables that precipitates industrialization (and,

* The term " industrial revolution " will be considered synonymous with " industrialization," ignoring the issue of whether industrialization has ever occurred rapidly enough to be considered a revolution.

therefore, caused the industrial revolution in Britain) than there is concerning any " chief cause ", there have been some attempts to identify a single, primary cause (5). The following presentation is such an endeavor. An argument will be developed, based on analytical grounds with empirical support, that there was, indeed, a single factor which was primarily responsible for the occurrence of the industrial revolution in Great Britain in the XVIIIth century. Although a conjunction of circumstances, as enumerated above, must have been present to provide a foundation for industrialization, it is suggested here that only one of the factors represents a sufficient condition, because it alone could have induced the others. That factor is technology.

The basic format of the analysis, then, will be to consider the various factors regarded as necessary for industrialization, demonstrating how each individually, with the exception of technological advancement, could not have been sufficient to cause the industrial revolution. Finally, the process by which technology — even in the absence of these other necessary conditions — can be expected to produce them, will be examined.

II. Necessary, non-sufficient conditions

Population

Human resources contribute to industrialization not only qualitatively, but also numerically. A sizable population supports industrial development by providing a supply of cheap labor and a market for industry output. With insufficient numbers of people, economic stagnation results. As such, population represents a necessary condition for an industrial revolution.

However, even casual empiricism reveals population to be less than sufficient to cause industrialization. The observed prevalence of overpopulated, underdeveloped nations confirms this. Excessive, as well as deficient, population may be a detriment to industrial development, therefore. This effect operates through restriction of per capita output, saving, and capital formation (4). What all this suggests is that an optimal range of population is needed for successful development. But even if optimal population size represents a necessary condition for industrialization, it, too, is clearly not sufficient. While the desired level of population may promote growth through its impact on demand, capital accumulation, and agricultural and industrial labor supply, it is difficult to imagine a sequence of events by which population optimality could result in the creation of natural resources where they do not exist, or the spontaneous generation of technological innovations when the humans included in the population are not capable of producing them. The latter is an effect of population quality, not quantity, all of which seems to disqualify level of population as a sufficient condition for industrial development.

Agriculture

Increased agricultural productivity assists the industrialization process in a number of ways. The most basic is that it allows the industrial labor force to be fed without massive importation of food and the resulting leakage of foreign exchange(2). This also suggests the financing role of agricultural productivity and saving. Essentially, fewer resources expended on food production means that more are available for industrial production. In addition, agricultual earnings provide demand for manufactured goods.

Another expected outcome of agricultural development is that labor will be released to work in industry. Whether it was literally true in the case of Great Britain that a net movement of labor from agriculture to industry occurred is uncertain, but it is highly probable that improved agricultural productivity permitted a higher ratio of industrial to farm labor than would otherwise have prevailed at a given level of agricultural output. For this and the other reasons stated, an agricultural revolution is a necessary prerequisite for an industrial revolution.

Agricultural development cannot be regarded as sufficient for industrialization, however. Since much of the improvement in agricultural productivity occurred a century or more prior to the industrial revolution in Britain (6), this temporal disparity confirms the presence of an agricultural revolution without a corresponding one in industry, and undermines any possible case for a sufficient causal relationship.

Capital Formation

By definition, capital accumulation is indigenous to the process of industrialization. The substitution of capital for labor is a valid expression of "the substitution of inanimate energy for human energy (1,7)," and increased capital investment is necessary for industrial and economic growth. Human labor must be complemented by more and better capital goods in order to achieve the increases in productivity which allow greater per capita output and a rising standard of living. But despite the close association between capital and industrial development, and the enormously facilitating impact of capital, capital formation is not a sufficient condition for industrialization. According to Flinn (3), capital growth could not have caused the industrial revolution in Britain unless it was absent before, and it was not. Considerable capital already existed long before XVIIIth century industrialization (8) so, by analogous argument to that of the previous section, capital formation is eliminated as a sufficient cause of the industrial revolution.

Demand and Markets

The necessity of market demand for manufactured goods as an incentive for industrial development should be self-evident. The prospect of financial

reward from sales volume is the indispensable inducement for high-risk investment in manufacturing facilities. Even on the supply side, as important as capital accumulation is, well-developed capital markets and financial institutions are required in order to translate capital into productive investment.

Actually, the potency of market demand as profit incentive is such that a fairly strong argument can be made for this factor as a sufficient condition for industrialization. This is due to the ability of demand and profit potential to activate other necessary conditions such as capital formation, resource and agricultural development, population, and a favorable economic climate. For instance, recognition of market demand as an indicator of profitability is a stimulant to capital investment and, in turn, encourages capital accumulation. As the benefits of investment and industrialization become apparent, the social and public policy environment would be expected to support such development. The profit incentive should operate as an inducement to greater agricultural productivity in similar fashion. Also, while market potential cannot produce natural resources where they do not exist, it can certainly encourage importation of raw materials and greater efforts to develop those present domestically. The same can be said of human resources, with the presence of attractive markets serving as incentive for producers to offer rewards for immigration and even increased domestic production of labor supply. Markets remain more a reflection of population than a cause, though.

In spite of the capacity of market demand to evoke many of the other necessary conditions for industrialization, it still cannot be a sufficient factor because of its inability to generate technological innovation autonomously. Although demand is undeniably a powerful incentive, it is only one of the two conditions necessary for innovation. The other is technical feasibility (10), which must exist in conjunction with demand before innovation will occur. No matter how strong the demand and enormous the reward for devices which would provide unlimited amounts of energy at low cost, instantaneously transmit matter over great distances, or neutralize atomic weapons, these have not been produced because they are beyond present human capabilities. The same applies to the devices which contributed to the industrial revolution. Had humans been incapable of producing them at the time, no amount of demand could have made them appear.

Resource Endowment

Natural resources, or the raw materials which are converted into products by industry, are obvious components of the industrialization process. Adequacy of resources, therefore, represents a necessary, although not sufficient, condition. Resource endowment can easily be dismissed as a sufficient condition for industrialization merely on the basis of the many underdeveloped countries with abundant resources that can be observed, in Africa for example.

Economic Climate

Favorable social and, especially, governmental attitudes toward industrialization are also necessary for the process to succeed in the sense that an unfavorable posture, resulting in policies restrictive of industrial development, would be prohibitive. In other words, a national government can either prevent industrialization if it chooses to (as in some traditional societies of the Middle East), or support it through facilitative fiscal policy, trade regulations, property rights laws, and the like. But such measures, while necessary for industrialization, are not, by themselves, sufficient. Social and governmental encouragement cannot induce all the other necessary conditions for industrialization, especially technological innovation, any more than the encouragement of market demand is able to.

III. The sufficient condition: technological innovation

The argument so far has presented nothing controversial. That the factors which have been reviewed are all necessary for industrialization, with none alone sufficient, would be generally accepted without strenuous objection. The proposition that technology is sufficient to precipitate an industrial revolution may require some defence. The following is an elaboration of the theme that technological development can, and did, cause industrialization because it tends to elicit the other necessary conditions. (Since most scientific laws are, to a degree, tendency laws, failure to express this generalization as an absolute relationship should not be considered a serious weakness).

To begin with, technological innovation will be defined as the invention of the kind of machines or gadgets that are vital to industrial and economic progress. In the XVIIIth century these included such things as the steam engine, the spinning jenny, the coke smelter, and the cotton gin. Technological advancement is necessary for industrial and economic growth because labor must continually be provided with better machinery if increases in output per capita are to be sustained. Without improvements in industrial machinery, i.e., technological innovation, the productivity of human labor is limited. Technology not only overcomes this impediment, it also is capable of producing the other factors which are necessary for an industrial revolution. The processes by which this occurs are described below.

Essentially, the argument is that recognition of the promise of technology will inspire the other necessary conditions, and is similar in form to the previously outlined projection of the impact of market demand. First, however, a precondition must be stipulated. It is presumed that technological innovations are developed to satisfy human needs. Now, as in XVIIIth century Britain, there is little reason to produce innovations which do not satisfy human needs. Observation confirms that inventors recognize this. The foregoing may seem

to suggest that need is a necessary prerequisite for technological innovation, removing the latter as a potential sufficient cause of industrialization. Indeed, if it is proposed that underlying human needs were necessary for the industrial revolution to occur, this will not be challenged. Neither will the assertion that the existence of the universe was necessary for the industrial revolution to occur. The point is that factors such as these are such fundamental aspects of nature that it is useless and superfluous to include them among any set of necessary conditions. In other words, causal regress must be terminated at a reasonable point.

Care must also be taken to distinguish need from demand. The difference is that demand equals need activated by purchasing power. While demand was proposed as a necessary condition for innovation, "unsatisfied need" more accurately expresses the factor. Once a need is identified, innovation can proceed with the expectation that the output of the improved technology will create its own demand via Say's law of markets. The basic sequence is that adoption of a new technology results in increased per capita output, which translates into greater per capita wealth and purchasing power. This, then, is the cornerstone of the argument: concurrence of technology and market demand is sufficient for industrialization because the other necessary conditions tend to follow rather automatically, as will be described, and since technology is capable of producing the other jointly crucial factor, it becomes the sole sufficient condition.

The manner in which the other necessary conditions for industrial development proceed from the conjunction of technology and demand is straightforward and has already been suggested. The prospect of financial reward from a need-satisfying innovation induces capital accumulation, if not already present, and investment. Application of capital to technology will then stimulate greater productivity and, in turn, more wealth for consumption and investment. The obvious implications of this for national economic welfare should be sufficient to evoke supportive public policy. By providing jobs and higher wages, those engaged in industrial activity can encourage population/labor supply growth through immigration and increased domestic production (of offspring). Technological innovation in transportation and the extractive industries increases the supply of raw materials where they were inaccessible before, and agricultural innovation, naturally, improves agricultural productivity. Technological innovation, or the invention of new and better gadgets, thus appears to be the kind of exogenous, "God-given" factor capable of inducing the other conditions necessary for industrialization. The technological developments of the XVIIIth century would have caused the industrial revolution in Britain, therefore, even if all the other necessary conditions were absent. Although these other conditions can contribute to technological progress, none is capable of generating technological inventions when such inventions are not within human intellectual capabilities. In fact, this may be a more precise

expression of the technology factor which has been identified as sufficient: a critical level of human intellectual attainment permitting creation of the machines vital to industrialization. Although this again raises the issue of where to interrupt the chain of causal regress, either the point of technological innovation, or the newly-evolved ability to produce it, would seem more realistic and meaningful than a more remote factor such as "the origin of life on earth which would result in intelligent beings ultimately capable of the technology for an industrial revolution".

If the technology factor, by whatever interpretation, is deemed sufficient for industrial development, there remains a problem of accounting for the existence of non-industrialized, underdeveloped countries in a technologically advanced world. This phenomenon can be explained by a variety of circumstances. First, it is quite possible that the indigenous populations of such regions are not capable of technological innovation and have been unable to effect its transfer from outside. Or, where adequate technology does exist, local governments may have impeded the process by which the other infrastructural components would have evolved. Finally, while technological innovation appears capable of stimulating population growth, a parallel ability to reduce excessive population is dubious. So even if technology is introduced, and its impact on productivity and per capita income will eventually be felt, overpopulation can drastically elongate the industrialization time-frame. The underdeveloped regions of the world may, indeed, be industrializing, but with little perceptible result as yet.

In summary, the position argued is that technological development or, more properly, the human capacity for it, is the ultimate cause of industrialization. This is tantamount to a statement that the invention of better machines was responsible for XVIIIth century British industrial development. Frankly, the proposition that industrial machinery caused the industrial revolution hardly seems startling, or revolutionary.

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