

**The Scientific-Technological
Revolution, the Forces of Nature,
and Marx's Theory of Value**

By Enrique Leff

Prologue

This article was published in Spanish in 1980¹ and translated for CNS by Ruth MacKay in 1998. This year I revised the article and also added a prologue and epilogue. Twenty years ago ecological Marxism defined as a contribution to the critique of the materialist concept of history had not yet been established. The same can be said of the paradigm known today as ecological economics.² The article is therefore nominally dated but substantively relevant to the debates between and within eco-Marxism and ecological economics during the past two decades. My intention is to scrutinize the epistemic structure of historical materialism in general and the labor theory of value in particular. Marx's value theory (the labor theory of value) is at the center of Marxism as it is the key force or process organizing the capitalist economic process. I am especially concerned with the meaning of labor theory in the context of the scientific and technological revolution characteristic of modern-day capitalist accumulation. My main theme concerns the impossibility of calculating value by reducing the qualitative productive force of scientific and technological knowledge into a quantitative measure of socially necessary labor-time (which doesn't mean that capitalist accumulation no longer involves the exploitation of labor).

¹E. Leff, "La Teoría del Valor en Marx frente a la Revolución Científico-Tecnológica," E. Leff, *Teoría del Valor* (Mexico City, UNAM), 1980.

²CNS as well as the International Society for Ecological Economics and its journal *Ecological Economics*, were both established in 1988.

This article, then, is a study of the historicity of the Marxist theory of production which I wrote with the aim of deconstructing this theory and opening up new insights into the production process. I wish to give due weight to the actual forms of the exploitation of labor and nature then and now (or the forms of the capitalization of nature and of ecological distribution). I stress that this exploitation includes the emerging power strategies for the appropriation of nature based on the power of knowledge. The article is intended as a kind of internal reflection of historical materialism in order to “reactivate” in thought the dialectics between theory and reality, and between critical economic theory and the actual social processes which give life to and organize the economic process. Hopefully this inquiry into the limitations of traditional Marxism to address the transformation of the power strategies of economic globalization (supported by ecological economics) will assist the attempts to reconstruct ecosocialist theories in this field that began during the last two decades.

While the theory of value cannot be considered to be the cornerstone of Marxist thought, it contains one of the fundamental arguments to turn political economy into a quantitative science, once the social relations of production that oppose capital to labor were established in history. In the work of Adam Smith, the theory of value was still caught within the mesh of representations and similarities typical of the classical *episteme*, which led to tautologies regarding the relationship between labor and commodities.³ Ricardo conceived of labor as the generating principle of value, but value was calculated in terms of salary or model commodities. Only in Marx does socially necessary labor emerge as the basis for value and the structural and quantitative principle that allows us to attain knowledge of the capitalist process as a historical process of transformation of the conditions of production mobilized by technical change. This scientific approach is fundamental in Marx’s work, once he established that historical materialism subordinates the theory of value to class struggle.

For Marx, “the concrete is concrete by virtue of being the synthesis of multiple determinations.” The theory of value explains one of these determinations, that which from within a given capitalist structure produces the development of the forces of production and which, in its constant interaction with the social relations of production and class

³M. Foucault, *Les mots et les choses* (Paris: Gallimard, 1966).

struggle, leads to the transformation of the social structure from which it derives its laws.

For Marx, all commodities have a particular utility, the result of a specific act of labor that transforms distinct objects of labor to produce a variety of interchangeable use values. What gives these different acts of labor one same unit of measure is that they can be reduced to human energy, to “muscles, nerves and brain.”

Productive labor is, for Marx, simple and direct. It generally results from manual efforts upon the objects of production leading to their material transformation. The generalization of this type of labor arises from technical progress which, through industrial development, transforms different forms of labor (in terms of diversity of movements and complexity of physical energy and mental processes) until they are reduced to simple and repetitive manual labor. The determination that makes labor time into a unit on which one can establish the equivalencies of commodity exchange is the result of a historical movement that generates technical progress capable of producing the empirical principle of a quantitative theory of the dynamics of the capitalist mode of production. In this sense, Marx said in one of his earliest writings that:

The use of the quantity of labor as the only measure of value without considering its quality, supposes that...labor has been equalized by the subordination of man to machines or through the extreme division of labor.⁴

The theoretical basis for the theory of value lies in the concept of *abstract labor*. In Marxist theory, this concept is the result of an epistemological breakthrough and a theoretical elaboration leading to the construction of the concept of the social structure and the productive nucleus of economic phenomena. But at the same time, it is the result of a historical process that makes simple and direct labor the productive principle of value. In this way, Marx avoids both the methodological individualism of vulgar economics and the rationalist idealism that derives historical reality from thought:

This abstraction of labor in general is not the mental outcome of a concrete totality of labor....Labor has been converted, not only as a category but also as

⁴“Misère de la philosophie,” *Oeuvres Economie*, vol. 1 (Paris: Gallimard, 1965), pp. 28-29.

reality itself, into a means for producing wealth in general.⁵

This implies that within Marxist thought atemporal concepts of historical materialism — mode of production, social formation, social relations of production, development of the forces of production — coexist with temporal concepts such as those that constitute the theory of value — abstract labor and socially necessary labor as the principles of capital accumulation — whose temporal nature depends on the transformation of the reality to which they correspond. Therefore, Marx says,

Despite their validity for all times, the most abstract categories are within their abstract determination, the product of historical conditions, and retain their full validity only for them and within their limit.⁶

Marx thus attacks the fetishist empiricism of vulgar economics and proposes a quantitative science based on the empirical conditions produced by history, those that emerge from the social relations of production:

Exchange value appears thus as the natural determination of use values in society, as a determination that concerns them as things and based on which they substitute one another in the exchange process according to determined quantitative relations; they form equivalents just as simple chemical substances combine according to determined relations and form chemical equivalencies.⁷

Thus, Marx constitutes political economy as a science with the same epistemological legitimacy as the natural sciences.

Although abstract labor in its empirical manifestation as simple and direct labor is the source of all value, in fact its quantitative determination does not emerge from the application of indeterminate labor time. Abstract labor that produces value is *socially necessary labor*. The social and necessary nature of labor means that use values produced in the crystallization of a given work time represent real “utility” in a commodity market. But, in addition, it implies that the

⁵“Introduction Générale à la Critique de l’Économie Politique,” *ibid.*, p. 259.

⁶*Ibid.*, pp. 259-60.

⁷“Critique de l’Économie Politique,” *ibid.*, p. 285.

labor time that determines exchange value depends on the development of labor productive forces, whose productivity is modified by technology.⁸ In this regard, it is necessary to analyze how technical change affects socially necessary labor.

Once industrial development reduces all labor to the application of simple and direct movements, each step of technical progress imposes certain average conditions of intensity on the application of labor power so that equal values are produced in equal amounts of time. Thus the value contained in any commodity is weighed by the average intensity required in its manufacture.⁹ But, at the same time, technical progress introduces changes in labor productivity. Therefore a fundamental theoretical problem is the establishment of the amount of socially necessary labor that results from technical innovation.

The first problem is to determine which technical conditions define socially necessary labor in a capitalist formation in which technology is heterogeneous and labor productivity is differentiated, not only among different productive spheres but also within one industry producing one use value. There is theoretical confusion in Marx's work regarding this question: In some passages socially necessary labor is determined by the most productive techniques, while in others the measure of value is set by the average technical conditions at a given point.

When Marx analyzed the effect of the introduction of the steam engine in textile production, he said that use values produced in technically inferior conditions reduced its value content; the labor time that produced them, and that continues to produce them, was devalued because "the product of its individual labor-hour represents no more than half a social labor-hour and gives no more than half its value."¹⁰

Nevertheless, in other passages of *Capital* Marx attributes the establishment of socially necessary labor to average technical conditions, not to the most productive techniques:

⁸"By an increase in labor power or productivity of labor we generally mean a change in the processes that reduces the socially necessary time for the production of a commodity such that a lesser quantity of labor acquires the power to produce more use values." *Capital*, vol. 1, *ibid.*, p. 852.

⁹"All individual labor power is equal to all others in that it has the character of an average social force and functions as such (so that) in commodity production it does not use more than the average necessary time or the socially necessary time." *Ibid.*, p. 566.

¹⁰*Ibid.*

The individual value of each piece, produced in (technically) exceptional conditions, will fall below the social value....Now, the value of an article is not its individual value but its social value, and this is determined by the time it costs, not in an individual case, but on the average.¹¹

Regardless of which interpretation of socially necessary labor he opts for, the individual capitalist who introduces new technology reduces the labor time necessary to produce his commodities, leading to greater rent and relative profits over his competitors, and the diffusion of the technology throughout industry generalizes the increase of relative surplus value. But this is not a satisfactory theoretical criterion for determining how much socially necessary labor is the determinant of value. If is the most productive technology which establishes socially necessary labor, then we can speak of a devaluation of commodities produced in inferior technical conditions. But if socially necessary labor is fixed by average technical conditions, then it depends both on the process of technological advance and on the totality of technologies that make up the forces of production applied to a given product.

The resolution of this theoretical problem is an important part of the theses on the progressive elimination of the law of value. If it is the most productive technology which determines socially necessary labor, then the innovation of totally automated technology in an industry would devalue all the articles produced there. But if socially necessary labor is determined by the average technical conditions, then the disappearance of the law of value would have to wait until automation of the productive processes were completely generalized.

Marx sought to resolve this theoretical problem by postulating that “labor for exceptional productivity counts as *complex labor*, or it creates, in a given time, more value than average social labor of the same type.”¹²

This theoretical subterfuge presents two problems: On the one hand, there is no indication that all technical progress, by increasing labor productivity, must at the same time require complex labor, in which case the empirical conditions that allow us to posit simple and direct labor as the determinants of value formation would disappear with technological development. On the other hand, only the reduction of complex labor to simple labor would permit an evaluation of the

¹¹*Ibid.*, p. 854.

¹²*Ibid.*, p. 856.

quantity of value produced. Nevertheless, to paraphrase Maximilian Rubel, the reduction of complex labor to simple labor is not based on experience, contrary to what Marx wrote in the *Critique* and in *Capital*. And the laws governing this reduction were never formulated in *Capital*.¹³

Thus socially necessary labor, as the empirical and quantitative determinant of value formation, becomes an abstract principle whose effects can be seen through market prices and demand which, in an opposite sense, establish the labor time for producing each commodity. The competition of capital in commodity markets reflects the simple and quantitative unit the variable value of commodities derived from different productive activities in which technological innovations are produced at different times, affecting the labor force's productivity in different ways:¹⁴

The law of value determines how much of its available time society can spend on the production of each type of commodity. In the workshop division of manufacturing, the proportional number set primarily through practice, and later through reflection, as a rule determines *a priori* the mass of workers assigned to each particular function; in the social division of labor it acts *a posteriori* as a fatal, hidden, mute necessity, visible only in the barometric variations of market prices, which dominate and prevail over...the irregular arbitrariness of commodity producers.¹⁵

In this way, with the development and division of capital the visible quantitative principle of the capitalist economic process becomes an invisible essence, perceptible only through its effects on the movement of market prices. Political economy thus appears, like any other science, to be based on concepts that represent the hidden structure of the matter that determines and regulates its empirical manifestations (e.g., the unconscious in psychoanalysis or the structure of atomic nuclei in physics). The epistemological peculiarity of Marxist science lies in this transformation of a principle that is both theoretical and empirical — direct and simple labor time produced in a

¹³“Notes to *Capital*,” *ibid.*, p. 1636.

¹⁴“To apply a similar measure we must have a comparative scale of different work days; it is competition which establishes this scale.” “*Misère de la Philosophie*,” *ibid.*, p. 28.

¹⁵In Book III of *Capital*, Marx says values “are disguised behind production prices and in the final analysis they determine them.” *Ibid.*, p. 1592.

given historical moment — which, in the economic process it produces, progressively loses its empirical support. Nevertheless, this has a negative effect in that the law of value, which in the first place overdetermines the laws of supply and demand, runs the risk, by generating the substance around which market prices are brought into balance, of subordinating its theoretical hierarchy, becoming an effect regulated by individual capital competition and the laws of commodity market supply and demand.

It is therefore necessary to analyze the possibility that the law of supply and demand could overdetermine value formation. Marx clearly indicates that in order for a certain labor time to produce value it must at the same time produce use value, a demandable good. In this sense, all commodities for which there is no demand automatically lose their value. Nevertheless, the fundamental question that arises from this problem is whether or not demand can be fixed independently of the law of value.

What Marx contributed to the theory of supply and demand is the fact that both are products of the very dynamic of capitalist accumulation and not of the free play of productive market factors or of a subjective principle based on human desires, needs or preferences. It is the laws of value and of surplus value which determine both the supply and the demand of commodities. The development of the forces of production as a result of capitalist competition and the search for new investment sectors for the recapitalization of surplus value determine the quantity and the diversity of supply. This process modifies the structures of demand, employment and income distribution such that surplus value can be realized through the exchange of commodities and be newly invested so as to ensure the expanded reproduction of capital.

With the theory of surplus value, Marx demonstrated that the determinant law of supply and demand cannot be reduced to an economic problem, such as the free play of factors of production, because it is class struggle within capitalism's social structure that allows the production of surplus value. With the law of value, he sought a quantitative measure of the economic process produced through this structure, not simply through the interplay of economic categories such as wages, earnings, production costs and distribution. For these reasons, the laws of supply and demand, although they can later destroy a given quantity of value constituted by the application of labor time, cannot determine the constituent unit of value. That depends on technological progress; but as long as technological development is a process not directly dependent on the laws of supply and demand, these laws cannot

be the determinant principle of socially necessary labor and value formation.

The determination imparted by technical conditions upon socially necessary labor time comes up again when Marx treats the concept of relative surplus value. Technological progress appears here as a process determined by the very dynamic of capitalist accumulation, which allows the production of a growing relative surplus value from the work force once proletarian struggles have limited the possibility of increasing absolute surplus value through the extension of the work day.

Increased productivity in industries that produce wage goods reduces *socially necessary labor time* for producing the input required to reproduce the labor force. By decreasing the value of the labor force, the *necessary labor time* for its reproduction is reduced and, everything else being the same, the capitalist can appropriate a greater part of the value produced during the work day. In this way, the production of relative surplus value (through the reduction of the cost of wages or necessary labor time) is necessarily connected to the effect that the reduction of socially necessary labor time has on the production of value. Technological progress, at the same time as it devalues capital and the commodities it produces, increases the relative surplus value extracted from the labor force, thus overcoming the law of diminishing returns.

Both processes lead to increased profits for an innovating capitalist. Nevertheless, for theoretical purposes, we should separate the increase in earnings produced through the increase in relative surplus value from that produced through the devaluation that arises when one capitalist introduces a technological innovation. Marx confuses the two processes when he assumes that

the capitalist who uses a perfected technique appropriates in the form of over-labor [surplus labor] a greater part of the work day than his competitors. On a small scale, he does what capital does on a large scale and in general in the production of relative surplus value.¹⁶

Marx, seeking a solution to the unresolved relationship between technological progress, socially necessary labor time and value formation, resorts to the theory of surplus value. This latest theoretical subterfuge arises from a confusion between the concepts of socially

¹⁶*Ibid.*, p. 856.

necessary labor time and necessary labor time. A capitalist who uses a perfected technique devalues the commodities produced by his competitors with less productive means. But this does not allow him to appropriate more over-labor, *because the necessary labor time is reduced only with the generalization of technical change in the production of wage goods*. Marx himself said that “this extra surplus value disappears when the new technique is generalized.”¹⁷ While the innovative capitalist will make more profits as long as his technical innovation is not disseminated, relative surplus value is produced through the generalization of increased productivity of wage goods, that is, a decline in the value content and price of the average consumption basket. The elimination of the specificity of these two processes leads to confusion between the theory of value and the theory of surplus value.

The problem of calculating socially necessary labor time or the amount of value in a commodity gets even more complicated when one considers not only that value is a product of the living and direct labor that the machine extracts from the worker; but also that all commodities contain a proportional part of the value contained within fixed capital, that is, raw materials, intermediate goods and equipment consumed in the production of any given use value.¹⁸ Raw materials and intermediate goods that are part of the composition of a new product transfer to it their original value, which is added to that produced by the socially necessary labor in the productive process; its value is affected, like that of any other commodity, by the changes produced by technological progress in the amount of socially necessary labor time necessary to produce them.

The case of machinery and equipment is different, being that the value they transfer to the product depends not only on the value they themselves contain but also on the rate of utilization and the time period during which they conserve their productive function before being replaced by more productive capital.

Marx assumes that “the time of capital reproduction corresponds to the time necessary for its consumption.”¹⁹ So two techniques that contain the same amount of value but different durabilities because of their material constitution as use values transmit the same value to the product. If the organic composition of this capital is proportional to its durability, both techniques will produce the same surplus value, which allows their recapitalization once the productive life of physical capital

¹⁷*Ibid.*

¹⁸We can call this process today the “productive consumption of nature.”

¹⁹*Grundrisse*, vol. 3 (Paris: Ed. Anthropos, 1968), p. 305.

is completed. This could be a good hypothesis for an abstract theory of capital, but in reality, competition means that replacing one type of equipment with a more productive one depends on a balance between the cost and production rhythm of technological innovation as well as on the profits derived from monopoly over more productive technology, versus losses from quickly reinvesting capital. This means that the time it takes to reproduce capital, especially its revaluation in the form of technological innovation, does not correspond to its natural productive lifetime.

If equipment is replaced through technological innovation before its natural wearing out is completed, this does not logically imply that the value it transmitted to the commodities that it produced during its useful life was equal to the total value transmitted by equipment functioning during the largest share of its natural wearing out with a competitor incapable of introducing technological innovations. The value transmitted by a machine to the commodities it produces depends not only on its own value but also on the time it takes to produce and incorporate a technological innovation that will determine the useful time of value transmission, which is not the same as the “normal” operating time of the machinery in question. In any case, whether due to competition or to the process of technological innovation, the law of value faces *indetermination*.

The proportional part of the value transferred by any equipment to the products it makes does not depend only on the amount of time it functions as a result of competition. It is also affected by technological innovation that is not quantitatively determined by the amount of manual or intellectual labor that goes into scientific discovery and technological development, nor by the amount of value corresponding to the production of this knowledge. In this sense, Marx writes:

The incessant progress of science and technology bestows upon capital a potential for expansion that is independent, within certain limits, of the magnitude of wealth of which they are composed.... The progress of the productive potential of labor that is generated without the contribution of the capital operating at that time, but that it benefits from when it changes its skin, lowers its value more or less during the interval of time during which it continues working under its old form.²⁰

²⁰*Capital, Oeuvres Economie, op. cit.*, p. 1112.

As soon as capital accumulation applies scientific-technological progress as a requisite of capital reproduction, *it is impossible to calculate the value contained in the capital incorporated within new technology or the value transmitted by the commodities it produces.* The introduction of these new means of production devalues the machinery and equipment still operating as well as the value of the commodities they produce. So the value transmitted to the product by the old equipment depends not only on the labor time it contains and which it extracts from the labor force. The value of the machine at the moment when the new technology appears on the market cannot be re-evaluated based on the socially necessary labor time for producing the new machinery, but rather on its productivity, which has no quantitative relationship to labor cost or labor time necessary for its production. Its value is impossible to calculate being that it no longer depends on direct, living labor time applied in the production of consumer and production goods. Its value depends instead on intellectual labor, which cannot be reduced to direct simple labor without running the risk of inverting the overdetermination of the law of value on the law of supply and demand. Moreover, how could ecological processes that contribute to production of wealth be valued as socially necessary labor time in a paradigm that has negated nature?²¹

From this argument, we may conclude that the conceptual bases necessary for establishing a quantitative theory of value in the above-described circumstances do not exist. Yet this does not exclude the possibility of considering a *qualitative* theory of value, although such a theory poses some problems.

Capital has an intrinsic need for technological progress in order to increase the production of relative surplus value and also overcome the negative effects that the increased organic (value) composition of capital has on the rate of profit. But this valuation-devaluation-revaluation of capital occurs in a contradictory fashion tending toward the replacement of value formation as the principle determinant of capital dynamics. In general, any revaluation of capital incorporated within a new technology involves the introduction of fixed capital with a lesser value and with

²¹ For an extended argumentation on this essential point for ecoMarxism, see E. Leff, "Marxism and the Environmental Question: From Critical Theory of Production to an Environmental Rationality for Sustainable Development," *CNS*, 4, 1, 1993, and *Green Production: Towards an Environmental Rationality* (New York: Guilford Publications, 1995). See also J. O'Connor, *Natural Causes* (New York: Guilford Publications, 1998).

less capacity for extracting value from the labor force.²² Nevertheless, the very expansion of capital provokes an increase in the labor mass incorporated into the productive process and is counterposed to the declining tendency of value produced in the individual process.

It is important to stress that the disappearance of value formation as a quantitative principle determining capitalist development does *not* eliminate the social relations of exploitation upon which the capitalist mode of production is based. The resolution of the internal contradictions of capital within the world's leading nations has involved the socio-cultural transformation of precapitalist formations such that the latter have assimilated the capitalist mode of production within their own borders. The maintenance of profits depends in large part on the exploitation of labor and on the resources of so-called underdeveloped countries.

In this sense, although the scientific-technological revolution tends to devalue productive equipment and reduces much of the direct, live labor it sets into motion, we can affirm that the commodities produced with these technological advances contain the value produced in the elaboration of the raw materials and intermediate products consumed in the process, assuming that these are produced with traditional techniques or with modern techniques that use a considerable quantity of labor. That is why the dominant tendencies within Marxism subscribe to value formation as the determinant of development and the internationalization of capital. But this does not lead to or support a

²²“Given the general bases of the capitalist system, the development of the productive powers of social labor always rise to a given point of accumulation to become, from then on, the most powerful mechanism....The development of the productive potential of social labor triggered by such progress crystallizes in qualitative changes...in the technical composition of capital, that is, that the amount of equipment and materials increases more than than the labor forces needed to make them function....These changes in the technical composition of capital are reflected in its value composition, in the progressive increase of constant capital and the decrease of variable capital. However...this change in the value composition of capital does not fully reflect the changes in its technical composition. The reason is that progress in labor potential, manifested through growth in equipment and materials put into motion with a lesser sum of labor, also diminishes the value of most products that function as means of production.” *Capital, Oeuvres Economie, op. cit.*, pp. 1134-1135.

quantitative theory of value, nor does it exclude the growing importance of the application of “natural” scientific forces to production.²³

The main problem with a qualitative theory of value arises with the separation of the conditions of value production as a determinant based on labor time and the development process of the productive forces. On the one hand, the latter should be connected to the former in order to give it its *socially necessary* character. On the other hand, the developmental process of the productive forces appears as a process external to the very production of value,²⁴ or as a historically uniform process that therefore has no effect on value relations.²⁵ *From the moment that the development of the forces of production is conceived as being independent of value formation, the organic cohesion of the theory of value as a determinant of capitalist accumulation is broken.*

This theoretical disarticulation occurs also as a result of the separation between manual labor and intellectual labor as determinants of the development of the forces of production. Although Marx admits the existence of complex labor in addition to simple labor, which make up collective labor within a hierarchy of labor forces, intellectual labor always appears as a property extracted by capital from the proletariat and then concentrated so as to exploit their labor power.²⁶ But Marx never explains the necessary connection between the value produced through the exploitation of the proletariat and the intellectual labor that increases the exploitative capacity of capital. Being that science appears as an “independent productive labor force,” it is impossible to articulate the innovative process that gives labor its socially necessary character or to think of technological progress as an effect of value formation. Nor is it possible to similarly think about the articulation of the “natural” forces that set science in motion in commodity production.

²³See E. Leff, “Ecología y Capital,” *Antropología y Marxismo*, 3, 1980.

²⁴“We have introduced the development of the forces of production as an exterior element.” *Grundrisse*, vol. 2, *Oeuvres Economie, op. cit.*, p. 145.

²⁵“The progressive development of the social forces of production acts almost or entirely uniformly on the labor time necessary for the production of various commodities.” “Critique de l’Économie Politique,” *ibid.*, pp. 289-290.

²⁶“What piece workers lose is concentrated before them in capital...This excision that starts with simple cooperation...is completed with big industry which makes *science an independent productive labor force* enrolled in the service of capital.” *Capital, Oeuvres Economie, ibid.*, p. 905.

Scientific labor and its crystallization in the development of productive forces appear as non-productive labor in the capitalist sense, that is, it does not produce value. For Marx, only direct, simple labor extracted from the labor force is a source of value and, as such, is the key determinant of capital dynamics.

Scientific labor acquires another perspective within the theories of surplus value and circulation. In the capitalist system, “the determinant objective of production is surplus value,” Marx writes. “Therefore only the worker who produces surplus value for the capitalist and whose labor furthers capital can be considered productive.”²⁷ Furthering capital does not simply mean extracting value in the productive process but rather the capacity to reproduce the conditions of the labor force’s exploitation. It is not enough to extract a quantity of value that can be recapitalized in the form of fixed capital once a machine or piece of equipment is used up. Capitalist accumulation and competition require that surplus value, in order to be recapitalized, be crystallized within means of production with growing productivity,²⁸ that is, technological progress.

In this sense, there is no more productive labor for capital than scientific-technological labor. More so than simple, direct labor, it allows the surplus value produced in the direct process to be recapitalized and reproduced in the capital cycle. Furthermore, “through the discovery of new, useful materials or new qualities of the materials already in use, the machine multiplies the investment spheres for accumulated capital. By showing the proper methods for reutilizing capital’s excrements in the circular course of reproduction and social consumption, it converts, with no assistance at all from capital, these non-values into so many additional elements of accumulation.”²⁹

Therefore, if the production of value depends on direct, simple labor, the value of capital depends on scientific labor. Inasmuch as capital accumulation itself determines a growing tendency toward the substitution of direct, live labor and its link with the direct application of scientific forces in commodity production, the specific determination

²⁷*Ibid.*, p. 1002.

²⁸“Surplus value is thus convertible into capital because the net product in which this surplus exists already contains the material elements of a new capital.” *Ibid.*, p. 1084.

²⁹*Ibid.*, pp. 1111-12. By the same token, aren’t genetic natural resources and biotechnology — those “non-values” — the main sources of the most powerful industry today in the era of globalized capitalism?

of value as the fundamental principle of the structural dynamic of capital tends to disappear.³⁰

This poses serious theoretical problems for thinking about capital dynamics in the era of scientific-technological revolutions. Given that value produced by labor is the basis of capital, Marx writes that “if production could be carried out with no labor at all, neither value, nor capital, nor value production would exist.”³¹ Here Marx goes from a past historical moment, which produced the social conditions for thinking about value formation as the basic principle of capital dynamics, to a future historical moment, a utopian moment, in which all labor will have disappeared. Thus a vacuum of thought emerges that impedes the comprehension of the principles that determine commodity production in this transitory phase of the capitalist mode of production.³²

Elsewhere, Marx writes:

The exchange of living labor against materialized labor, in other words, the determination of social labor as the opposition between capital and wage labor constitutes the last development of value relations and of the system of production founded on value. Its permanent condition is the mass of immediate labor time, the quantum of work applied as a decisive factor in the production of wealth. However, as big industry develops, the creation of real wealth depends less on the time and the quantity of labor than in the action of other factors set in movement by labor, whose powerful efficacy has no comparison with the immediate labor time set forth in the production process; it depends over all of the

³⁰“As long as time — the quantum of labor — is established by capital as the only determinant element of production, direct labor considered as the principle for the creation of use values, disappears, or at least is reduced quantitatively and qualitatively to a role that is certainly indispensable, but subordinate, in relation to scientific labor in general, to the technological application of natural sciences, and to the general productive force resulting from the social organization of the entirety of production.” “Principes d’une Critique de l’Économie Politique,” *Oeuvres Economie*, vol. 2, *op. cit.*, p. 301.

³¹*Ibid.*, p. 250.

³²The transit to a sustainable mode of production founded on an environmental rationality.

general state of science and technological progress....When labor, in its immediate form, will have ceased to be the great source of wealth, labor time will cease to be the measure of labor, and exchange value will cease to be the measure of use value. Surplus labor of human masses will cease to be the condition for the development of general wealth....From then on, production based on exchange value collapses and the immediate process of material production loses its form and its miserable contradictions.³³

This passage has served to legitimize a series of theoretical deviations in Marxist historiography and sociology. With the elimination of the law of value, the development of the forces of production appears as the determinant factor in the transformation of social relations of production.³⁴ Some have argued that that social domination in the scientific-technological revolutionary era leading to automation is commanded by the primacy of technological reason and scientific rationality.³⁵ Others view instead scientific-technological revolution as a privileged mechanism for human liberation, taking the place of class struggle and the transformation of the social relations of production as determinants of societal progress.³⁶

³³“Principes d’une Critique de l’Économie Politique,” *ibid.*, pp. 305-06.

³⁴“Inasmuch as progress in production resides in mechanization and widespread industrialization, capital constitutes its efficient, appropriate form of movement. Historically, we can find there a certain justification for the existence of capital as an external, transitory social form of the development of civilization....The relations of production are but a form of the movement of the forces of production.” R. Richta, *La civilization au carrefour* (Paris: Ed. Anthropos, 1969), pp. 30-34.

³⁵“Reason, as conceptual thought, as behavior, necessarily leads to domination. Logos is the law, the command, the order for power over knowledge.” H. Marcuse, *L’homme unidimensionnel* (Paris: Ed. Minuit, 1967), p. 190.

³⁶“Political change cannot become qualitative, social change except by reorienting technical progress, that is, inasmuch as a new technology can be developed.” *Ibid.*, p. 252. “In order to transcend technological reality, a prior condition is that it is first accomplished. By being realized it will constitute at the same time the rationality that will enable its transcendence.” (p. 255) “If technological rationality reached perfection, it would translate ideology into reality, and at the same time it would transcend the materialist antithesis of this culture.” (p. 258) The contradictions in this type of “dialectical thinking” are obvious: Domination is produced not by a

A problem arises when Marx combines two determinations, making appear the exchange of living labor for materialized labor identical to the opposition between wage labor and capital. Now, at present, the production of wealth increasingly depends more on the use of “natural” forces through technology and science than on direct, living labor, which allows us to speculate about a “collapse of production based on the law of value.” But this scientific-technological arsenal is not just a subproduct of proletarian labor appropriated by capital to exploit labor muscle; scientific labor *is* (intellectual) wage labor, exploited by capital.

Furthermore, the progressive elimination of living, direct labor as the basis of the theory of value does not imply the transformation of the capitalist mode of production into a new form of production. General abstract labor is but one determination which, combined with a whole series of other determinations, makes up the structural dynamic of the capitalist mode of production. The disappearance of the law of value as the basis of capital leads to the disappearance neither of the generalization of commodity exchanges nor of the opposition between a wage class and a capitalist class whose power rests on the production, possession and control of scientific knowledge. It is this set of determinations that makes up the capitalist mode of production.

Technological progress first transforms and then progressively eliminates the quantitative determination of value; it then produces a tendency toward the progressive substitution of direct manual labor with indirect intellectual labor in commodity production. But though the quality of labor changes, labor continues being the basis of production. These transformations in the labor process do not automatically eliminate the social relations of production — property-appropriation relations — or exploitation and social control based on the power of the capitalist class over the means of production — including ecological and technological means of production.

Technology, the instrument *par excellence* of calculation and control, paradoxically has made an epistemological project based on quantitative science an impossibility in the social sciences. This does not mean that the science of history has failed, but rather that we must

social structure but by a “technological reason;” but the conditions for its disappearance are the full realization of scientific-technological development. Politically, this implies that liberation depends upon the development of the forces of production and the general automatization of labor processes, not on political practice aimed at transforming social relations of production.

continue working on the conceptual bases of historical materialism as the building block of a political practice of social transformation.

To sum up, the scientific-technological revolution, as a process determined by the dynamics of capital, has led to the dissolution of the empirical principle that was the basis for the theory of value, that is, simple and direct labor as the quantitative determinant of commodity production. This fact has two fundamental repercussions for Marxist thought. The first involves the organic relationship between social theory and social practice; the second involves the epistemological specificity of the science of history.

These two aspects of Marxist thought have always constituted its organic totality. Marx never believed that the internal laws of capital would lead directly to the dissolution of the capitalist mode of production. But by presenting the dynamics of capital as the effect of quantitative and objective laws, he opened the way for Lukacs and others to think of the rise of class consciousness as a product of these laws. *Thus revolutionary practice acquired an objective character, determined by the internal laws of capital.* With the disappearance of the law of value as the determinant quantitative principle of social transformations, political practices were no longer the effect of an automatic mechanism. Social action is not the effect of teleological determinism.

It is history, class struggle, that generates social structures with their temporal, tendentious laws. These structures are not transformed simply as the effect of their internal laws but through the class struggle that develops within them and by power strategies in knowledge. Social practices transform social reality and thus modify its internal laws. Therefore there are no absolute laws that set praxis, but nor is the latter realized free of determinations.

The laws of nature and, above all, of scientific discovery and technological innovation, have become the fundamental determinants of production. The scientific-technological revolution is undergoing a transformation of the labor process that is converting the “forces of nature” into the predominant forces of production in the production of wealth. Time, as a measure of natural and technological processes, time that forges identities and social actors, progressively replaces labor time as the determinant of commodity production.

These natural, theoretical and social processes are not determined by the law of value. Scientific discoveries are not produced simply as the

result of an internal logic³⁷ or technological reason independent of social dynamics and they cannot become the new determinant principles of political economy. Nor is it possible to substitute economic laws with scientific laws that define the natural and technological processes that determine all productive processes in society. All this implies the need to re-evaluate the epistemological foundations and the basic concepts of historical materialism, and to inquire about the power-knowledge strategies that govern social-economic processes, in order to deconstruct economic rationality forged by a mechanistic quantitative episteme, and orient the construction of a new productive environmental rationality based on the productive potentials of nature, technology and culture.

Epilogue

Twenty years is nothing, sings the tango artist. However, in the past two decades the overcapitalization of a globalized world has yielded a complex and diverse array of strategies to “value nature.” With the discrediting of Marxism the dominant perspective in the theory and practice of “sustainable development” is neoliberalism in general and its version of environmental economics in particular. In this economics, the concept of “total economic value” (the addition of a real direct use value, of indirect use value, option value and intrinsic value) veils the omnivorous totalizing will to recodify the whole world — all things and values — as capital, natural capital, human capital, capital-capital. Still trapped in its original epistemological dichotomy of the world into objective and subjective values, the concept of total value is a totalitarian strategy to reappropriate everything — from the actual economic value of natural goods and environmental services, to contingent values assigned to nature in live experiments behind closed doors — “How much are you willing to pay to protect the wilderness? How much would you want to permit a factory to pollute the air you breathe?” It is no longer true that economists know the price of everything and the value of nothing; today they don’t know the price, either.

The problem of an economic theory of value cannot be solved by this pervasive and impossible conversion of the world into market values. But the traditional Marxist approach to the theory of value based on labor-time must also be reviewed. Valuing environmental complexity demands a shift from an objective, quantitative and homo-

³⁷See K. Popper, *La logique de la découverte scientifique* (Paris: Ed. Payot, 1973); T.H. Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 2nd ed., 1970).

genizing metrics to a qualitative theory that articulates market values and also ecological valuations and cultural values (that expresses the true antagonisms of the socio-economic processes of the appropriation of nature), and also the incorporation of ecological conditions of sustainability in the economic process. The economy of labor-time has been replaced by an economy based on the capacity to generate and appropriate scientific knowledge as a means to gain control over the appropriation of nature. This involves the legitimation of intellectual property rights over the genetic resources of biodiversity and the power to invade tropical regions and Third World countries with transgenic products, which are expressions of this growing global ecologized and scientificized economy.

Capital accumulation and concentration are not only based on the overexploitation of cheap labor, but also on the capitalistic appropriation of nature and the “subsidies” provided by the undervaluation of genetic resources, natural goods and ecological services (e.g., free access to genetic resources to be bioprosected, cheap oil and gas to maintain an overcapitalized agriculture and urban services, etc.). The complementarities of objective and subjective values assigned to nature, in the perspective of ecosocialist sustainable development theory, demands a new approach that integrates the valuations of particular ecological conditions of sustainability, on the one hand, and the meanings assigned to nature by cultural values, on the other. This should be seen as a process whereby identities are forged in the interplay of the material and the symbolic, and that are expressed in the emergent cultural, communal environmental rights of indigenous peoples and peasant communities striving to reappropriate their patrimony of natural resources. In CNS’s Democracy and Ecology book series, I have written about this at length in my Green Production: Towards an Environmental Rationality.³⁸ In this way, economic rationality might be deconstructed and historical materialism reconstructed within the perspective of democratic and sustainable ecosocialism.



³⁸E. Leff, 1995, *op. cit.* See also my article, “On the Social Appropriation of Nature,” *CNS*, 10, 3, September, 1999.