

The Social Consequences of Technological Change in Capitalist Societies

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1. Introduction

No one would dispute that modern capitalist societies have exhibited a historically unprecedented level of technological dynamism. In contrast, assessments of the social consequences of this dynamism diverge widely. It is not possible here to provide a comprehensive overview of competing assessments. I shall first present three important theoretical perspectives on this issue in normative social theory: classical liberalism, liberal egalitarianism, and Marxism. I shall then develop a historical narrative of some of the most significant social consequences of technological change in recent decades. I conclude that a Marxian framework illuminates the role of technical change in shaping the present moment of social history better than the competing frameworks considered in this paper.

2. Classical liberalism and the social consequences of technology

“Liberalism” is one of the most ambiguous words in our language. It has become one of the strongest terms of opprobrium used by “conservative” advocates of free markets in the United States today against their enemies, despite the fact that they are themselves part of the tradition of classical liberalism beginning with John Locke and Adam Smith.¹ For adherents of this tradition individuals are the basic unit of moral concern, and all individuals are asserted to be equally worthy of moral respect. From this *moral equality principle* it follows as a corollary that all individuals should be free to decide for themselves both their life plans and how best to carry them out. Private property rights are an essential component of a social order based on these ideas. Individuals are asserted to have a right to privately appropriate previously unowned things as well as the things they themselves make (either alone or with the aid of others who freely chose to cooperate with them). They also have the fundamental right to freely decide how to use their acquired property, including a right to undertake exchanges should they wish to do so. The exercise of these rights is, of course, subject to the constraint that the equal rights of others to do the same are acknowledged and respected.

Classical liberal theorists affirm free markets on the grounds that they institutionalize rights to liberty and property better than any feasible alternative. This rights-based argument is

¹ “Classical liberalism,” “egalitarian liberalism,” and “Marxism” are ideal types. Particular theorists grouped under a particular heading can approach the ideal type in question more or less closely. A fairly pure form of the perspective on the social consequences of technological change in capitalism developed in the following paragraphs is found in Hayek, 1976.

usually conjoined with claims about the positive consequences of free market economies, with technological dynamism at the top of the list. In these societies producers have a strong incentive to introduce process innovations enabling goods and services to be produced more efficiently, since if they lower unit costs they can lower prices and win market share. There is an equally strong incentive to introduce product innovations that allow purchasers to fulfill existing wants and needs in more satisfactory ways, or to develop new wants and needs in ways they freely choose.

The social consequences of this technological dynamism have profound normative significance within the classical liberal framework. Life plans require goods and services to be carried out. Free markets allow individuals themselves to choose the goods and services that they regard as most important to the fulfillment of their life plans. The drive to product innovations ensures that over time the goods and services that are produced necessarily tend to be those that contribute to freely chosen life plans to the greatest feasible extent. Further, the drive to process innovations ensures that over time that greatest feasible amount of those goods and services will be provided. If human flourishing can be defined as carrying out the lives we have chosen to live to the greatest feasible extent, then technological change in capitalist market societies provides the material preconditions for human flourishing.

Technological change will only have these beneficial social consequences if market competition operates effectively. This in turn requires that economic agents are confident that their property rights will be respected, that they will be able to enter into voluntary contracts providing mutual benefits, and that the terms of these contracts will be adhered to. The main role of the state in the classical liberal framework is to provide a coercive apparatus ensuring that liberty and property rights can be enjoyed in security under “the rule of law.”

For libertarians the legitimate functions of the state do not go beyond measures to protect individual citizens against force and fraud. Libertarianism, however, is only one species of classical liberalism. Relatively few advocates of classical liberalism argue against government funding of basic research or basic infrastructure. Many also hold that public resources should be mobilized for training programs to ensure that the workforce possesses needed technical skills. The belief is also widely shared that environmental problems can sometimes be serious enough to warrant regulation of polluting technologies. These sorts of state policies are said to complement free markets, enhancing their technological dynamism beyond what it would otherwise be and ensuring that this dynamism contributes to human flourishing to the greatest feasible extent.

Despite support for such policies, however, there is still an important sense in which even non-libertarian classical liberals defend a “minimal state.” This can be seen by considering the technology policies that classical liberalism either excludes completely or accepts to a very limited degree.

- Capital markets must be able to shift investment funds smoothly and rapidly to new innovative sectors, or to established sectors undertaking significant innovations. Burdensome state regulations of capital markets must be avoided if the positive social consequences of technological change are to be enjoyed to the fullest extent.
- Labor markets must be flexible so that labor can shift from less innovative sectors and regions to more innovative sectors and regions as smoothly and rapidly as possible. Here too state regulations impeding flexibility must be avoided.

- Restrictions on trade should also be limited in order to enable consumers to enjoy the benefits of innovative imports, and to spur domestic firms to innovate in order to compete successfully in the world market.
- Environmental regulations must not be considered prior to a complete and scientifically sound assessment of their costs and benefits. The former must not be understated, or the latter given undue weight, out of nostalgia for a romanticized and unrecoverable past. Further, the extent to which innovations can mitigate problems should not be underestimated; markets, for example, provide powerful incentives both to use costly natural resources more efficiently and to search for technological substitutes. In general, the best way to confront environmental and other difficulties is through market-driven innovation.

These arguments can easily be generalized to justify free trade and free capital flows across borders. A regime of global governance eliminating restrictions on foreign trade and investment, encouraging flexible labor markets, and avoiding unsound environmental restrictions, follows as well. If anything, these conclusions have even greater normative force on the global level. Global justice demands that individuals throughout the world have access to the material preconditions for human flourishing. Technological dynamism has proven to be the single most effective means of generating these preconditions. Global justice, classical liberals conclude, therefore demands the adaptation of measures spurring technological dynamism, and the avoidance of public policies hampering it.

3. Liberal egalitarianism and the social consequences of technology

Like classical liberals, liberal egalitarians take individuals as the basic unit of moral concern and affirm that all individuals are equally worthy of moral respect. They question, however, whether free markets, minimal states, and a global regime based on free trade and free flows of capital adequately institutionalize the moral equality principle. John Rawls, perhaps the most influential political philosopher of the twentieth century, insisted that this principle demands a substantial (and not merely formal) equality of basic liberty rights, fair equality of opportunity, and a distribution of income and wealth in which all citizens benefit from economic growth (Rawls, 2001). Rawls and other liberal egalitarians hold that the institutional order defended by classical liberals necessarily tends to generate forms of concentrated economic power and severe inequality that are not consistent with these values. Liberal egalitarians conclude from this that the legitimate functions of the state exceed the more or less minimal set of functions acceptable to classical liberals. Public policies are required to limit concentrations of economic power and severe inequality. More specifically, the work of leading liberal egalitarians clearly implies a defense of technology policies beyond those proposed by classical liberals.

For liberal egalitarians the moral equality principle implies a right to participate as an equal in social and political life. Technological change should not have the social consequence of eroding this right. The “creative destruction” of technological change in capitalism threatens to do precisely that. The life prospects of the workers and communities associated with established firms and sectors can be profoundly harmed by the rise of new firms and sectors operating at (or close to) a new scientific-technical frontier. In order to minimize the social harm resulting from technological advances liberal egalitarians call for public policies supporting the transfer of new technologies into threatened communities, the extensive

retraining of workers in those communities, and the provision of benefits sufficiently generous to ensure that affected individuals can continue to participate in social and political life as an equal during the transition period in which a new techno-economic paradigm is diffused.

Liberal egalitarian theorists also regard the standard classical liberal response to environmental harms associated with the use of industrial technologies as inadequate. Markets encourage concern with environmental harms when they take the form of internal costs affecting a firm's bottom line (if a rapidly depleting natural resource increases in price in a way that threatens profits, there is indeed an incentive to undertake a search for a technological substitute). A great number of environmental harms, however, are negative externalities, that is, harms that do not impact a polluting firm's bottom line. In this case market competition does not merely fail to provide an incentive to search for innovations to eliminate or minimize the harm; in so far as this search involves additional costs there is a disincentive for undertaking it. Human flourishing requires a livable environment; that too forms part of the material precondition for being able to live lives of our own choosing. If liberal egalitarians conclude, we are to ensure that the social consequences of technological change in capitalism are normative acceptable, we must institute far more comprehensive regulation of environmentally harmful technologies than those defended in the classical liberal tradition.

A third point of contention arises from the consideration that in certain circumstances capitalist markets left to themselves will generate a rate of innovation significantly less than what is socially optimal from the standpoint of liberal egalitarianism (that is, less than what would provide the means of human flourishing to the greatest feasible extent). Technological change in a capitalist society ultimately depends upon allocations of financial capital. Classical liberals assume that the financial sector automatically functions as a means for efficiently allocating capital to the most technologically dynamic firms and sectors in the "real economy." As heterodox economists have long understood, this is not necessarily the case. Unless the financial sector is subject to effective political regulation it will tend to treat its own profits as an end in itself, generating self-sustaining speculative bubbles in the process.² In these circumstances increasing numbers of non-financial firms will be tempted to make profits from ownership of financial assets their ultimate end as well.³ Past a certain point this hampers, rather than aids, technological dynamism (Perez, 2002). Funds that could have gone to investments in innovative products or processes in the "real economy" are diverted to, or remain within, the financial sector. When the speculative bubbles burst, as they always do, the production of goods and services in the "real economy" to meet human wants and needs is further harmed. Liberal egalitarians conclude that the potentially

² An inflow of funds into the market for a particular category of financial asset will raise its price. The higher price can then attract a yet higher inflow of funds into that market, raising prices yet further. The increase in (paper) wealth serves as collateral for loans, which can then also be pumped back into that market, raising prices, increasing (paper) wealth, and providing greater collateral for further loans. Human ingenuity will invariably be able to generate myriad reasons why "this time it's different," and the inflation of capital assets is not "irrational exuberance." Just as invariably, these reasons will be mistaken, and the bubble will inevitably burst. In the meantime, however, the profits that can be made from foolishly purchasing a capital asset at an overinflated price, and then selling it to a bigger fool, may greatly exceed that from alternative investments in the "real economy" (Soros, 2009).

³ For example, retained earnings and borrowings will increasingly be devoted to stock buy-backs that raise the value of shares still outstanding (to the great benefit, we may add, of managers fortunate enough to hold stock options).

positive social consequences for human flourishing from technological change will be significantly restricted if the financial sector is not subject to effective political regulation.

Another way in which unregulated markets can distort the process of technological innovation brings us back to the notion of creative destruction. Technological change disrupts existing equilibriums. Individual firms and entire industries are threatened with being eradicated by the emergence of new firms and sectors operating close to a new scientific-technical frontier. This gives established incumbents a strong incentive to oppose the rise of new technologies, at least until they have received a minimally satisfactory return on investments in older technologies. If these incumbents possess sufficiently concentrated economic power, the rate of innovation will be significantly less than the socially optimal rate. Effective technology policies by governments can counter-act this danger. Strong antitrust legislation can prevent the stifling of new technological developments by powerful incumbents. State procurements providing a guaranteed market for innovative products can have the same effect. The use of public funds for development projects extending into the so-called “valley of death” can also determine a rate and path of technological change superior to that which would be selected by markets alone.⁴ And intellectual property rights regimes must leave ample space for newcomers, rather than act as barriers to entry protecting incumbents from innovators.

The conflict between incumbents and innovators is a major theme of Yoachai Benkler’s *The Wealth of Networks*, perhaps the most important recent book examining the social consequences of technological change from a liberal egalitarian perspective. Benkler begins by noting that the technologies and forms of social organization of industrial capitalism limited the extent to which core liberal egalitarian values (autonomy, democracy, global justice) could be institutionalized.

Autonomy is a relatively simple matter for classical liberals; one either lacks it (slaves, indentured servants, serfs) or one does not. For liberal egalitarians, in contrast, autonomy can be a matter of degrees. When effective use of the most advanced technologies for producing goods or services requires massive investments in fixed capital, the vast majority of the populace will lack access to the requisite financial resources. They will be able to participate in the process of producing goods and services – and thereby gain access to the monetary resources necessary to support themselves and their dependents – only if those who own fixed capital grant them permission to do so. For Benkler, this need to ask permission to engage in socially productive activity counts as a significant restriction of autonomy. Further, the owners and managers of firms have an overwhelming incentive to obtain a satisfactory return on investment in fixed capital before the technologies embedded in it become obsolete, leading managers to exert control as much control as they can over workers’ labor process. This too significantly restricts the degree of autonomy enjoyed by the workforce.

In the liberal egalitarian view, the moral equality principle demands that each citizen should have the opportunity to participate as an equal in public life. Open public discourse is seen as the crucial component in the *democratic will formation process* at the heart of a democratic society (Habermas, 1998). In what Benkler terms the industrial information economy, however, public discourse was profoundly restricted. The use of advanced communication

⁴ The “valley of death” is the metaphorical place where research projects falling between basic research and research foreseen to have immediately commercializable results would otherwise languish (Wessner, 2001).

technologies required massive investment in fixed capital, and here too the vast majority of the populace lacked access to the requisite funds. Concentrated private ownership of the technological means for circulating information distorts the process of democratic will formation in two ways. First, the private owners of the means of communication have a disproportionate ability to shape public opinion, both through the content they choose to transmit (or not transmit, as the case may be) and through the manner in which this content is presented. The second difficulty is perhaps even more important. In capitalism privately owned mass media requires a mass audience to attract advertising revenue. Suppose there are three different issues a newspaper could cover, or three different programs a television station could run, the first of great interest to a large minority, the second of great interest to a different large minority, and the third of mild interest to a vast majority. The third will tend to be selected for distribution through the mass media technologies of industrialized capitalism. This counts as a systematic restriction of public discourse (Benkler, 2006, 204-11).

A third example of a tension between technological development and liberal egalitarian values concerns *global justice*. The areas of greatest market demand are not necessarily the areas of the greatest social need. Imagine two health ailments. One is a relatively minor condition that afflicts a number of affluent people in wealthy regions of the globe; the other a serious and potentially deadly affliction affecting far more people in poor regions, few of whom with significant disposable income. When pharmaceutical companies allocate investment to research proposals, priority will be given to research proposes aimed at developing drugs to address the former condition (Kremer, 2002). Similarly, research in agricultural technologies will be systematically biased in favor of innovations designed to improve the condition of affluent farmers, neglecting research on crops grown by producers in underdeveloped countries. Here too a strong case can be made that the social benefits per dollar invested would be much greater if research designed to aid those lacking purchasing power were given more priority.

Benkler is well aware that anti-trust legislation, labor regulations, publicly owned mass media, government laboratories researching medical drugs and agricultural technologies, and other familiar public policies supported by liberal egalitarians, can lessen the extent to which the technologies of industrial capitalism are associated with these negative social consequences. But he also holds that these negative consequences could not have been avoided in the past without having to sacrifice many of the benefits of liberal capitalist societies—which, all in all, have still advanced the normative values of autonomy, democratic will formation, and the fulfillment of the important social priorities better than any alternative social formation in history. Today, however, technological developments are setting the stage for the new mode of production he terms “commons-based peer production.”⁵ These developments have the potential to generate a quite different set of social consequences than those associated with industrial technologies.

⁵ The contemporary significance of commons-based peer production should not be underestimated: “Ideas like free Web-based e-mail, hosting services for personal Web pages, instant messenger software, social networking sites, and well-designed search engines emerged more from individuals or small groups of people wanting to solve their own problems or try something neat than from firms realizing there were profits to be gleaned” (Zittrain, 2008, 85). Encryption software, peer-to-peer file-sharing software, sound and image editors, and many other examples can be added to this list. “Indeed, it is difficult to find software *not* initiated by amateurs” (Zittrain, 2008, 89). Individuals cooperating outside

Unlike the technologies of the industrial age, important means of production today (computers and internet connections especially) are now widely affordable, thanks to the incredibly steep upward slope of the trajectory of information technologies.⁶ As a result, an ever-increasing number of individual agents are now able to own relatively advanced means of production themselves. Those who choose to develop the required expertise now have the power to decide for themselves what projects they wish to work on and with whom they wish to co-operate. By definition this expansion in the scope of free choice counts as an expansion of autonomy. Information technologies also enable a “many to many” model of communication to replace the “one to many” model of the mass media technologies of the industrial information age. This allows a tremendous expansion of the issues that can become subjects of public discourse. Democratic will-formation processes are furthered as the systematic limitations imposed by private ownership of the means of social communication are overcome. Finally, commons-based peer production greatly expands the ability of researchers with the time and expertise to collaborate effectively in developing drugs addressing the needs of those suffering from particular ailments, and seeds for farmers facing particular challenges, even if those helped by these technological products lack sufficient purchasing power to be of interest to pharmaceutical or agribusiness firms. This too clearly counts as a normative advance from the standpoint of the moral equality principle according to Benkler.

Benkler is not a technological determinist; the fact that a new mode of production is technologically possible does not imply that it will automatically emerge and grow. Commons-based peer production threatens powerful incumbents, such as media conglomerates. Incumbents can be expected to use their immense resources to push technology policies in a direction serving their interests, stifling the development of this new mode of production, thereby preventing the social consequences of contemporary technologies from being as positive as they could be. Commons-based peer production, for example, both requires free knowledge goods as inputs and produces free knowledge goods as outputs. The more knowledge goods are treated by the legal system as free public goods, the more commons-based peer production can flourish. But the more the intellectual property rights regime is extended in response to the political pressure of incumbents, the more difficult it will be for this new mode of production to mature. Liberal egalitarians, Benkler concludes, cannot be indifferent to technology policy debates. A commitment to the moral equality principle requires a political commitment to struggle against the agenda of those wishing to extend intellectual property rights in order to maintain their rents (Woo, 2010).

Liberal egalitarians are not romantics longing for a pre-modern world with little technological dynamism. They instead call for a social world in which the consequences of technological dynamism are consistent with the moral equality principle to the greatest feasible extent. In the absence of states and regimes of global governance implementing technology policies consistent with liberal egalitarian values, technological change in capitalism will necessarily tend to generate economic inequalities exceeding what is consistent with a substantive equality of civil and political liberties, a fair equality of

capitalist firms have also collectively produced encyclopedias that have proven useful to millions, entirely new genres of music, unprecedented access to diverse sources of information and commentary about events across the globe, and so on.

⁶ The shape of this trajectory is captured in “Moore’s Law,” according to which computing power per dollar invested doubles every eighteen months.

opportunity, and a wide diffusion of the benefits of technological advances. To a considerable extent, then, the debate between classical liberalism and liberal egalitarianism is a debate about the social consequences of technological change in capitalism.

4. The Marxian analysis of technology and social change in capitalism

For Marx too there is a sense in which the individual is the fundamental unit of moral concern. His notion of “the social individual” is different from the concept of the atomistic individual found in many writings in the classical liberal tradition. But it is not so different in principle from the conception held by liberal egalitarian theorists, who echo Marx’s call for “a society in which the full and free development of every individual forms the ruling principle,” and in which “the free development of each is the condition for the free development of all” (Marx, 1976, 739; Marx and Engels, 1976, 506). Further, Marx does not deny that the technological dynamism of capitalism has provided the material preconditions for human flourishing to an unprecedented extent. First-time readers are often surprised by the depth of Marx’s appreciation of capitalism’s technological dynamism:

The bourgeoisie, during its rule of scarce one hundred years, has created more massive and more colossal productive forces than have all preceding generations together. Subjection of Nature’s forces to man, machinery, application of chemistry to industry and agriculture, steam-navigation, railways, electric telegraphs, clearing of whole continents for cultivation, canalisation of rivers, whole populations conjured out of the ground—what earlier century had even a presentiment that such productive forces slumbered in the lap of social labour? (Marx and Engels, 1976, 489).

He also agrees with the liberal egalitarian claim that in the classical liberal model the social benefits of technological dynamism are profoundly restricted. For Marx, however, the problem goes deeper than the failure to provide effective political regulation of markets. From the Marxist point of view liberal egalitarianism, no less than classical liberalism, overlooks the fundamental inversion of ends and means at the very heart of capitalism.

No one disputes that economic agents often make the acquisition of money their goal. But classical liberals and liberal egalitarians both consider money a merely proximate (short-to-medium term) end. For members of both groups money is inherently a means to make exchange more efficient and convenient, thereby serving the ultimate end of providing men and women with the goods and services they require to meet their wants and needs. The disagreement between defenders of the two viewpoints centers on whether money automatically furthers this end in forms of capitalism with only a “minimal” state and regime of global governance, or whether the more extensive state and global regime defended by liberal egalitarians is required. However, Marx asserts, in a capitalist society “use-values must never be treated as the immediate aim ... [The] aim is rather the unceasing movement of profit-making ... [t]he ceaseless augmentation of value” (Marx, 1976, 254). In a society of generalized commodity production and exchange, most units of production necessarily must make the attainment of a M' exceeding initial investment (M) their overarching goal. If they do not, over time they are increasingly likely to be pushed to the margins of social life (if not forced out of operation altogether) by units of production that do systematically make the appropriation of surplus value (the difference between M' and M) their overarching end. Most individual agents simply seek the material resources

required to implement their life plans. In a society of generalized commodity exchange, however, obtaining those goods and services requires monetary resources, and this generally requires some sort of association (whether as an investor, a creditor, a wage worker, or a pensioner) with a unit of production that successfully aims at the “unceasing movement of profit-making ... [t]he ceaseless augmentation of value.” Marx concludes from these considerations that the *valorization principle* is an organizing principle of social life on the level of society as a whole. Money is not a mere means adopted for the convenience of human agents; the accumulation of money capital is an end in itself.

If this is correct, then the valorization principle must also be seen as the organizing principle of technological change. Technology cannot simply be seen as a means of furthering human flourishing; in a capitalist society technology is first and foremost a means to capital accumulation. Human ends are, of course, furthered by technological change. But they necessarily tend to be furthered if and only if doing so furthers (or is at least compatible with) the end of capital accumulation.

Marx derived a set of structural tendencies regarding technological change from this starting point (Smith, 1997, 2010). The beginning of Volume 1 of *Capital* shows the need for producers to continually seek product innovations, lest their privately undertaken production turn out to have been socially wasted when competitors introduce products desired more by consumers. In Volume 2 Marx explains why advances in transportation and communication technologies necessarily tend to be sought in capitalism: they allow units of capital to complete circuits of investment, production, and sale at a faster rate, enabling more capital to be accumulated in a given period of time (Smith, 1998). Volume 3 explores how the valorization imperative is manifested in the drive to introduce innovations lowering the costs of raw materials, machinery, plants, and infrastructure. Volume 3 also sketches how technologies speeding and extending the scale of sales to consumers aid the valorization process, as do communication technologies speeding financial transactions and expanding the geographical range from which financial centers appropriate savings and to which they can transmit credit and investments.

Throughout all three Volumes Marx remarks on the threat technological development in capitalism poses to the environment. In Marx’s discussion the fundamental problem stems from the discordant temporalities of capitalism and the environment of which human life is but a part. A productivity advance of, say, twenty percent, could be used to produce the same level of output in twenty percent less time. Or it could lead to the production of a twenty percent greater output in the same time. In capitalism the latter option necessarily tends to be selected, since competition among units of capital imposes the imperative to accumulate as much capital as possible as fast as possible, and this goal is generally advanced by producing and selling more commodities. Past a certain point this accelerated temporality will come into tension with the temporality of ecosystems: the capitalist economy tends to extract natural resources at a faster rate ecosystems can reproduce them, and engender wastes at a faster rate than ecosystems can absorb them. This state of affairs can continue for an extended period of time without serious difficulties arising, and technological fixes (such as the creation of substitutes for exhausted natural resources, the discovery of technical processes that use fewer natural resources, or generate less waste, or process wastes into non-harmful or even useable substances, and so on), can extend this period. Nonetheless, the underlying tension remains. For Marx, the probability that a society

whose main organizing principle is "Grow or die!" (or, more exactly, "Ceaselessly augment value!") will generate environmental crises approaches one (Harvey, 1996, Part Two).

The dimension of technology and social change for which Marx is best known has to do with the labor process in the capitalist workplace. Marx thought that the pernicious effects of the valorization imperative for the satisfaction of human ends are most apparent in the capital/wage labor relation. Wage laborers are required to perform surplus labor beyond that producing an amount of value equivalent to their wages. Insofar as technologies in the workplace reduce the latter period of time, they extend the former:

Like every other instrument for increasing the productivity of labour, machinery is intended to cheapen commodities and, by shortening the part of the working day in which the worker works for himself, to lengthen the other part, the part he gives to the capitalist for nothing. The machine is a means for producing surplus-value (Marx, 1976, 492).

Under these conditions the scientific-technological knowledge embodied in machinery is experienced by individual workers as an "alien force":

In no respect does the machine appear as the means of labour of the individual worker ... (T)he machine, which possesses skill and power in contrast to the worker, is itself the virtuoso ... Science, which compels the inanimate members of the machinery, by means of their design, to operate purposefully as an automaton, does not exist in the worker's consciousness, but acts upon him through the machine as an alien force, as the force of the machine itself (Marx, 1987, 82-3).

Collective organization can overcome an individual worker's sense of powerlessness. But collective organization is difficult to maintain if the workforce is divided, and technological change can be used to foster such divisions: technologically-induced unemployment can set those desperate for work against those desperate to retain their jobs (Marx, 1976, Chapter 25), while communication and transportation technologies make the threat of shifting investment from one group of workers to another more effective. Technologies that deskill those enjoying relatively high levels of remuneration and control over their labor process also shift the balance in power between capital and labor in favour of the former (Marx 1976, 549). Technologies undercutting the effectiveness of strikes warrant mention as well:

[M]achinery does not just act as a superior competitor to the worker, always on the point of making him superfluous. It is a power inimical to him ... It is the most powerful weapon for suppressing strikes, those periodic revolts of the working class against the autocracy of capital ... It would be possible to write a whole history of the inventions made since 1830 for the sole purpose of providing capital with weapons against working-class revolt (Marx, 1976, 562-3).

It is important to stress that the social consequences of technological innovation are indeterminate in particular cases. Labor history shows that the very technologies introduced to divide the work-force, deskill certain categories of workers, or break strikes, may in other contexts contribute to worker unity, enhance the skills of different workers, and help labor struggles succeed. Nonetheless, ownership and control of capital grants its holders the "operational autonomy" to initiate and direct the innovation process in the workplace (Feenberg, 2010). As long as this power is in place, Marx thought, technological change will

tend to reinforce the structural coercion and exploitation at the heart of the capital/wage labor relation.

A final point regarding the workplace to be mentioned here refers again to productivity advances associated with technological change. As we saw above, the “default setting” in capitalism is for this advance to be used to increase output without sufficient regard for long-term environmental impacts. This use of technologies is also correlated with an intensification (and often extension) of the workday, despite the fact that gains in productivity could in principle be used to reduce labor time with no loss of livelihood or living standards. Marx wrote, “Since all *free time* is time for free development, the capitalist usurps the *free time* created by workers for society” (Marx, 1987, 22). Marx thought that from a world historical perspective this was the ultimately the single greatest way in which technological change in capitalism hampers human flourishing.

There is one final issue to be considered in this survey of Marx’s account of the social consequences following technological change in capitalism. Marx argued that the very investments in technological change intended to further capital accumulation tend to undercut the accumulation process. New plants and firms will enter a sector when investments in fixed capital embodying more advanced technologies promise to generate above average profits due to higher levels of efficiency or products of superior quality. But as they do so, established firms do not automatically withdraw at a rate that would maintain an equilibrium of supply and demand. While the very weakest will go under, others will be content to obtain an average (or perhaps even below average) rate of profit on their circulating capital (raw materials, labor costs, etc.). There are a variety of reasons why this is a rational course for them to take. These units of production have already made the fixed capital investments (machinery, buildings, and so on) that allow profits to be won from circulating capital; if they walk away these investments will be wasted. Further, the management and work force of these firms have sector-specific skills that likely would be difficult to duplicate in any reasonable time period were the firms to shift operations to a different sector. They will also have established relationships with suppliers and distributors operating in the given sector that would be difficult and costly to establish elsewhere. They may also have relations with local governments and universities that provide important support (infrastructure, research, etc.), support they might not enjoy if they were to shift operations to a different sector. There is, finally, the hope that if they hold on they may be able at some later time to make investments in advanced technologies and leap-frog over their competitors. While these actions are rational from the standpoint of individual units of capital, they can have a collectively irrational result: the rate of profit in the sector as a whole tends to decline as the lower profits of older firms in the sector outweigh the above average profits appropriated by a relatively few newcomers (Reuten, 1991). When this dynamic occurs simultaneously in a number of key sectors, Marxists speak of an *overaccumulation crisis*. One of the most important theses of the Marxian theory of technological change is that the technological dynamism of capitalism necessarily tends to generate such crises.

The contrast between the Marxian perspective on the social consequences of technological change in capitalism and the classical liberal and liberal egalitarian viewpoints is complex. Marx actually agrees that the technological dynamism of capitalism furthers the provision of the material preconditions for human flourishing more than any previous form of social organization. But he did not agree that technological change in an institutional context of so-

called free markets and “minimal” states allows individuals the greatest opportunities of living lives of their own choosing, as classical liberals hold. Nor did he accept the liberal egalitarian assertion that all individuals could stand as an equal in social life if only the proper political regulations were in place.

No attempt will be made here to definitively resolve the controversy among these three competing perspectives. In the concluding section I shall attempt to show the continuing relevance of the Marxian account of technological change by presenting a brief historical narrative of major developments in the global economy in recent decades. My goal is to suggest that the Marxian framework illuminates important dimensions of the present historical moment overlooked in competing accounts.

5. Technology and social change in recent decades

Global politics today is dominated by the crisis of state finances. The public debt of many countries has reached 60% or more of their gross domestic product, and is estimated by some to soar to as much as five times GDP within a generation. In the United States and elsewhere commentators in the classical liberal tradition proclaim that their view of the predatory and profligate nature of more-than-minimal states is fully confirmed. Invoking moral obligations to future generations, they call for deep cuts in state programs, while resisting calls to raise taxes on the wealthy whose investments “create jobs and economic growth.”

Writers sympathetic to liberal egalitarian values tell a different story. State deficits have metastasized primarily because of the \$20 trillion of bailouts and stimulus provided by governments to the private sector in the wake of the “Great Recession” that began in 2008. The U.S. government in particular has allowed banks to exchange practically unlimited amounts of toxic assets for good money. This state spending saved the global economy from catastrophic collapse; banks have been recapitalized, and non-financial corporations have returned to profitability. But unemployment remains high, housing prices continue to decline, and the global economy remains extremely fragile. To reduce state deficits now would be to repeat the mistakes of the U.S. in the 1930’s and Japan in the 90s, when weak economies were pushed back into recession by premature budget cuts. In the short term, state spending must increase to create jobs. If public investments are made in infrastructure, education, and new (especially “green”) technologies, this will spur economic growth, making a reduction of state deficits in the future far less onerous than it would be today.

Liberal egalitarian analysts insist that inadequate financial regulation, the root cause of the crisis, be addressed as well. Seduced by the “efficient market hypothesis,” regulators allowed paroxysms of “irrational exuberance” to generate one speculative bubble after another. The government bailouts following the bursting of these bubbles encouraged even more reckless behavior until, inevitably, the scale of the bailout overwhelmed state finances. Insufficient financial regulation also allowed debt levels in numerous regions of the global economy to exceed rational bounds, resulting in a growing and unsustainable imbalance between debtor and creditor regions. Funds lent to the former fueled consumption of imports and speculation in real estate or financial markets, neither of which generated the monetary returns necessary to repay the loans. A rebalancing of the global economy must now take place. Surplus regions must expand their domestic economies to compensate for the retrenchment of overly indebted consumers elsewhere and to help deficit regions reduce their debts through increased exports. In the worst cases (such as Greece) foreign lenders

must write off many of their foolish loans (their failure to do this has brought the Eurozone project into question). Most importantly, lending and borrowing institutions throughout the globe must be regulated to ensure that such imbalances never again arise.

In the view defended here, the roots of the 2008 financial crisis can be found in the global slowdown of the 1970s after a quarter century of exceptionally high rates of investment, growth, and profits. The causes of this slowdown were varied and complex. *However, one essential element was undoubtedly the technological dynamism of Japanese and European (predominately German) producers.* In 1945 the Japanese economy was roughly a century behind the U.S., while Germany lagged a half century or so. By the 70s both had more than caught up. In many of the most technologically sophisticated sectors of the world market (consumer electronics, autos, motorcycles, chemicals, business machines, steel, and so on), these firms produced higher quality products much more efficiently than their U.S. competitors. U.S. producers in these sectors did not shut down as Japanese and German companies added to productive capacity in the global economy, and over time the rate of growth of productive capacity increased faster than the rate of growth of markets to absorb it. The result of this technological development was an overaccumulation of capital, manifested in excess productive capacity in all the leading sectors of the world market. This overaccumulation soon led to lower rates of investment, profits, and economic growth in the world market as a whole (Brenner 2006).

Economic crises are capitalism's way of renewing itself by destroying excess productive capacity through bankruptcies. The recessions of the 1970s and early 80s were certainly destructive. But there was no "Great Recession" devaluing capital investments on a scale commensurate with the problem. A number of measures allowed the global system to go down a different path, often referred to as "neoliberalism." Some of these measures essentially involved technological developments. Some did not. But they must all be considered social consequences of technological change in the sense that they were all responses to the overaccumulation difficulties brought about by technological development in the post WWII global economy.

1. Following Nixon's unilateral decision in 1971 to in effect replace gold as the ultimate form of world money with the dollar, there was a *historically unprecedented increase in liquidity* (credit money) in the global economy in general, and the United States in particular. In principle this made it possible for markets to expand and absorb productive capacity that could not otherwise be absorbed.
2. If increased liquidity simply set off inflation, that would not have offered the capitalist world economy a promising way forward. Accordingly, labor was disciplined through the "Volcker Shock" of 1978, a sudden rise in interest rates designed to raise the rate of unemployment in the "core" regions of the world economy beyond what had been politically acceptable previously. The pressure on real wages that followed kept inflation contained and set the stage for a significant *increase in the rate of exploitation*. The technological changes associated with the rise of "lean production" (or "flexible production") were a major part of this story (Smith, 2000). Improvements in productivity due to the introduction of information technologies into manufacturing led to waves of layoffs in the most organized sectors of the workforce. Information technologies also furthered corporate "downsizing," allowing parts of production chains to be outsourced without sacrificing management control of the production process as a whole. The advance of transportation technologies played a major role as

- well in the emergence of a “networked economy” of decentralized production chains. These technological changes had a profound social consequence: the balance of power between capital and labor fundamentally shifted to the favor of the former. The increased effectiveness of the threat of unemployment from downsizing allowed capital to impose real wage cuts (despite increasing productivity), speed-ups, lengthened work days, tiered wages, and the spread of precarious employment (part time and temporary work), all of which contributed to the increase in the rate of exploitation (Basso, 2003; Head, 2003).⁷ In neoliberal workplaces, no less than the factories of Marx’s day, technology remained “a means for producing surplus-value.”⁸ Despite the contemporary rhetoric of worker “empowerment,” workers’ role in determining the design and use of machinery in the labor process continued to be radically restricted. The process of objectifying workers’ skills in machinery accelerated with information technologies, as did the use of these technologies to continue operations during strikes. The electronic monitoring of the workforce on a massive scale is another feature of the neoliberal workplace corroborating the continued relevance of Marx’s account of technological change in the capitalist workplace (Darlin, 2009).
3. The information technologies and transportation technologies that made increased subcontracting possible also enabled production chains to extend across borders through foreign direct investment and subcontracting to locally-owned producers. The majority of foreign direct investment continued to flow from one wealthy region of the world economy to another. But Japanese foreign direct investment in China and other developing economies in East Asia exploded; more and more U.S. plants were built in Mexico, China, and elsewhere; and after the implosion of the Soviet model German capitals shifted considerable funds to investment in facilities in Eastern Europe. A relatively small portion of this production was intended for the local domestic market; most was exported back to the “core” regions of the world economy. This “globalization” of trade and investment contributed to the increase in the rate of exploitation though the increased ability of corporations to play one sector of the global labor force against another, further shifting the balance of power between labor and capital in the latter’s favor (Huws, 2007; Smith, 2009). Inexpensive imports from low waged regions of the global economy offered workers in the “core” regions some compensation for the decline/stagnation of their real wages.
 4. Increased liquidity in the world market (#1) resulted in the accumulation of vast reserve of “Eurodollars” outside the U.S. and other forms of “stateless” money, as well as increased cross-border flows of financial investment. The globalization of trade and investment (#3) required companies and governments to exchange currencies on a much greater scale, while Nixon’s abandoning of the gold standard led to a tripling of volatility in currency exchange markets. New financial products designed to limit the risks associated with currency fluctuations were developed. Financial firms rapidly expanded, profiting from ever-more exotic forms of financial assets. Over these decades the financial sector undertook the largest private-sector investment in information

⁷ The anti-union policies of leading states played a key role as well.

⁸ In the U.S., for example, after 1979, “The value of labor power fell for the remainder of the century (as productivity grew but hourly real wage rates for production workers did not), so that the rate of surplus value (the ratio of money surplus value to the wages of productive labor) increased by about 40%” (Mohun, 2009, 1028).

technologies, hired the greatest concentration of advanced knowledge workers, and achieved the fastest rate of product innovation in the global economy with the aid of the massive computing power they had purchased. The “financialization” of the economy exacerbated economic inequality due to the highly concentrated ownership of financial assets, further shifting the balance of power introduced in #2. The main point to insist upon is that in a world of persisting overaccumulation difficulties in non-financial sectors, financial speculation is “rational” from the standpoint of capital, and therefore must be considered as another social consequence of the technological developments that generated persisting overaccumulation difficulties.

5. The final measure defining neoliberalism is the role of consumption as an “engine” of global growth, reflected in the increasing imbalance between “deficit” regions of the world economy and “surplus regions.” In the United States, wealthy households were able to go on a binge of hyperconsumerism due to the income gains they enjoyed as a result of the increase in the rate of exploitation (#2) and their gains from financial speculation (#4). Less affluent households were able to expand consumption levels despite the stagnation of real wages due to an unprecedented increase in household debt (#1) and in the appreciation of the value of their homes in the Great Housing Bubble (#4). An increasing proportion of this consumption took the form of imports, allowing exporting nations (Germany and China especially) to expand and enjoy greater trade surpluses, while the trade deficits of the U.S. and other nations (Greece, most notably) began their remorseless expansion. Banks in regions enjoying trade surpluses had a strong incentive to continue extending credit to agents in deficit countries, since that allowed domestic exporters with which they were tied to continue exporting to deficit regions. These loans also limited the appreciation of the currencies of exporting nations, which would have made their exports more expensive. With the dollar serving as world money (necessary for the purchase of oil and weapons, as well as a relatively secure store of value in an increasingly turbulent global economy) foreign investors and governments were happy to hold massive amounts of their reserves in U.S. Treasury bills (a form of credit receiving much lower returns than U.S. investors appropriated from their foreign investments). Speculative bubbles in the U.S., Ireland, Iceland, and elsewhere were fueled by foreign borrowings. The imbalances between deficit/debtor regions of the world market and surplus/credit regions increased over time to unsustainable levels, as many commentators have pointed out. But the problem goes deeper than the usual explanations, which place the primary blame either on irresponsible borrowers or on an international financial architecture that does not provide adequate supervision of cross-border financial flows. These global imbalances were a “rational” response to the need for an engine of growth in a world economy in which technological developments generated persisting overaccumulation difficulties.

From the standpoint of capital, these measures were a success. They allowed profit levels to be (partially) restored in the global economy after the slowdown of the 1970s. Levels of investment and growth in the global economy were sufficient to avoid a “Great Recession,” at least in the “core” of global economy. The value of financial assets in general, and the U.S. stock market in particular, trended steeply upwards for an unprecedented period of time. The information technology revolution continued to spawn dynamic new firms and industries. The explosion of trade and foreign direct investment facilitated rates of growth in East and South Asia that were also absolutely unprecedented.

We are now, however, at a different moment in world history. The U.S. consumer market can no longer serve as the engine of growth for the global economy. With real wages stagnant, expansion of this consumer market required a constant expansion of household debt, a process that was always bound to reach a limit point. The same was true of other regions whose expanding debts provided exporting countries with growing markets.

Financialization also appears to have reached a limit point. As more and more of the profits in the global economy were appropriated by the financial sector, more and more of the credit money created there remained there (household debt, great as it was, was dwarfed by debt levels in the financial sector), and more and more of the profits of non-financial firms flowed into the financial sector (for stock buy-backers, mergers, etc.). This led to self-sustaining speculative bubbles occurring with increasing frequency and increasing scale over the course of the neoliberal period. They all eventually burst. When they did, the specter of the repressed Great Recession haunted the financial pages. But each time Central Banks came to the rescue, pumping liquidity into the financial sector and setting the stage for another round of speculative excess. The massive liquidity provided by Central Banks, and the ever-growing reserves held by surplus countries, pushed global interest rates to historical lows. Investors were happy to borrow immense sums at these rates and invest them in capital assets promising higher returns. The financial sector was happy to use its immense computing power to create ever more exotic financial products for these investors, most (in)famously by slicing and dicing “subprime” (risky) mortgages into exotic and all but incomprehensible securities (“collateralized debt obligations cubed,” anyone?). Rating agencies assured investors that there was relatively little risk from purchasing these products, using computer models that assumed that the future would be like the past, despite the fact that in the past there was neither (almost) unlimited cheap credit nor financial instruments of such computer-generated incomprehensibility. The social consequences of these (mis) uses of technology were all too predictable. When a relative handful of subprime mortgages went bad, the immense edifice of global finance collapsed, revealing the fraud and collective delusion upon which it had been based. No one knew exactly which financial institutions were insolvent from their toxic loans and toxic securities; soon enough it was reasonable to think almost all were. Firms that had offered insurance against bad loans and losses in the value of securities (using the same flawed computer models) did not have anything close to the funds required to meet their obligations. The housing market collapsed, eroding the wealth of deeply indebted households to the point where additional credit was all but impossible to obtain. The specter of the long-deferred Great Recession arose once again. And once again Central Banks rode to the rescue. This time, however, the scale of the bubble was such that the scale of the bailouts threatens the solvency of those governments forced to undertake them. Here too a limit point seems to have been reached.

6. Conclusion

The classical liberal view fails to grasp the magnitude of the market failures that have occurred in recent decades. From a Marxian standpoint the standard liberal egalitarian position is flawed as well. Immense indebtedness, global imbalances, and recurrent financial bubbles are not accidental and irrational occurrences that could have been avoided if only regulators had fulfilled their responsibilities. Together with an increased rate of exploitation these measures were a rational (from the standpoint of capitalist rationality, at least)

response to the global slowdown of the 1970s, the legacy of the technological dynamism of the post WWII "golden age." They could have been avoided only at the cost of turning the sharp but relatively brief recessions of the 1970's and early 80's into a massive destruction of excess productive capacity in the global economy.

The question now is where we go from here. If the consumer and government spending of overly-indebted economies has reached a limit point, what can take its place?

Non-financial firms sit on trillions of dollars of cash. Writers in the classical liberal tradition in the United States and elsewhere believe that radical cuts to state deficits and the eradication of "burdensome" state regulations will automatically lead to an investment binge, setting off a new period of dynamic growth in the global economy. This is pure fantasy. Overaccumulation problems have not dissipated in the global economy. In fact, new productive capacity added to the world economy in China and other developing countries has exacerbated these difficulties. Key sectors of the "networked economy" (computers, communication equipment, semi-conductors, and so on) have proven to be as susceptible to overcapacity as core sectors of the old industrial economy ever were. This explains why the rate of investment in the world market has a whole has trended downward since the 1970s, despite the recovery of profits and despite the amazing growth of investment in China and other developing countries; that growth has failed to compensate for declining or stagnating rates elsewhere (Brenner, 2006).

What of the liberal egalitarian hope that the right mix of additional government regulation and additional government stimulus could give birth to entirely new industries, dedicated to the development and use of "green" technologies? Could this provide an outlet for private investment, spurring a new "golden age" of capitalist development? There are good reasons to fear that this too is wishful thinking. This brings us to what I take to be an absolutely central issue regarding technology and social change in the contemporary global economy, the paradoxical social consequences of the spread of national innovation systems across the globe (Nelson, 1993; Smith, 2007).

Today four countries spend over three percent of their Gross Domestic Product on research and development, and another six devote over two percent of GDP of their annual economic output on R&D (*The Economist*, 2011). These nations in addition provide extensive public and private funding for scientific-technical training, public expenditures providing markets for innovations, and public policies to encourage private sector investment in advanced technologies (such as accelerated depreciation of the fixed capital that embodies technological change, a major tax break). They also possess financial sectors capable of allocating credit rapidly to start-ups operating at the technological frontier. As a result of this unparalleled proliferation of national innovation systems the moment a cluster of innovations with significant commercial potential emerges anywhere in the global economy a plethora of extensive research expenditures, tax breaks, other direct and indirect subsidies, and allocations of credit, are mobilized in a number of regions more or less simultaneously. In use-value terms this is a recipe for continued technological dynamism. In value terms, however, things are more complicated. The more national innovation systems are in place, the sooner innovating industries and sectors in the world market are threatened with overcapacity problems. This compresses the period in which high profits can be won from a competitive technological advantage. The period in which the commercialization of new

innovations spurs a high rate of investment is compressed as well. In brief, a world in which effective national innovation systems have proliferated is a world of persisting overaccumulation difficulties. As long as this is the case, technological dynamism in the future (whether of “green technologies or any other sort) is not likely to lead to a new “golden age” of high rates of investment, economic growth, and real wages gains over an extended period.⁹

In this context the hope that surplus regions will expand their domestic economies to allow deficit nations to export their way out of debt is naïve. Given the facts that the ever-increasing debt card has been played, government stimulus programs cannot increase without limit, leading sectors of the world market remain plagued by serious overcapacity, and no new investment boom is likely to be inaugurated, the odds are extremely good that a considerable portion of excess productive capacity in the global economy is going to be destroyed in coming years. Political and economic elites in Germany and China, the two leading surplus/creditor nations, know that increasing the share of the world market possessed by capitals operating in their territories will lessen the odds that these capitals will be the ones devalued. Increases in domestic real wages of sufficient magnitude to compensate for the lost purchasing power in overly indebted regions would threaten this goal. Such increases would raise the prices of exports, and heighten the risk of capital fleeing Germany and China for Eastern Europe and even lower-waged areas in East Asia. Looking at the matter from another perspective, Germany and, increasingly, China have their own serious overaccumulation problems. No remotely feasible expansion of their domestic economies would be able to absorb their productive capacity; their continued growth demands the conquering of export markets (more accurately, this is a demand of capitalist rationality in the circumstances these countries find themselves in). Germany and China have reached the position they have in the world market—with Germany the unquestioned power of Europe and the Chinese economy now projected to surpass the size of the U.S.’s far sooner than anyone thought possible not long ago—due in good measure to their success in appropriating surpluses. Political and economic elites in these countries no doubt look at the U.S. and Greece and see the fate of regions that further the good of the capitalist world market by expanding domestic consumption to absorb excess productive capacity in the global economy: sooner or later they are presented a bill they cannot pay. From the standpoint of capitalist rationality, what would be rational about going down that path?

⁹ Innovative products and processes can still be correlated with high profits for an extended period of time despite the proliferation of national innovation systems if intellectual property rights are extended in scope and enforcement. There are, however, serious social costs from doing this. It threatens to hamper innovation in society as a whole. Firms will increasingly avoid promising lines of research that might possibly infringe patents. Funds that would have otherwise gone into research will be shifted to support the armies of patent lawyers necessary to defend IPR claims and attack those of others. Fewer small firms will engage in innovative activities, lacking the funds required by the legal system. The tendency to concentrate of economic power in large corporations will be reinforced, since they are better able to fund legal costs and in a better position to come to mutually beneficial cross-licensing agreements with each other. From the liberal egalitarian perspective of Benkler, the extension of the intellectual property rights regime has another truly tragic consequence: commons-based peer production, which has the potential to become the most positive social consequence of the information technology revolution, will not be allowed to develop that world historical potential. Commons-based peer production requires that information be treated as a free public good, while the extension of intellectual property rights intensifies a commodification of information preventing this (Smith, 2012).

In these circumstances, capital's best bet for pursuing profits is a yet greater ratcheting up of the rate of exploitation¹⁰ and household debt, and a yet more desperate search for speculative bubbles from which easy money can be made before the "smart money" gets out. From this perspective the mainstream policy debate between adherents of classical liberalism and liberal egalitarians comes down to the question whether the austerity inflicted on ordinary citizens is to be immediate and brutal, or somewhat more gradual and somewhat less brutal. Either path leads to persisting mass unemployment, a worsening gap between productivity gains and real wages, a reduction if not elimination of pensions, extended work lives, cuts to health programs, cuts to education, and cuts to anti-poverty programs at the very time rates of poverty, homelessness, and hunger skyrocket (McNally 2010).

In contemporary capitalism technological development and the productivity advances associated with it have brought about a social world in which there is *greater* material insecurity rather than less, a world where technical rationality is increasingly conjoined with social irrationality. Surely another world is possible.¹¹

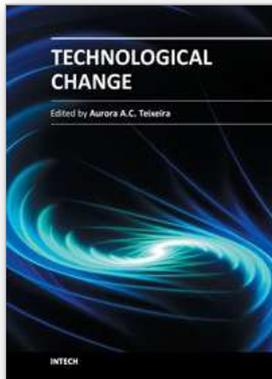
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¹⁰ Baker anticipates a revolution in capital/labor relations in the near future, based on the use of massive computing power to develop mathematical models of labor processes and employees based on huge data bases. Labor processes will be disaggregated into the smallest possible fragments, and workers across the globe with the capacities to complete a particular fragment will be identified. These workers will then bid against each other for the privilege of being employed as long as it takes to complete the fragment (Baker 2008). The technologies are almost in place, Baker thinks, to extend the precariousness that already afflicts increasing numbers of the global labor force to almost all categories of workers.

¹¹ The main question for future research concerns the shape of an institutional framework that could combine the technological dynamism of capitalism with a higher form of social rationality. Steps in this direction have been taken in Schweickart, 2011; Smith 2000, Chapter 7, and 2009, Chapter 8.

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Technological change is today central to the theory of economic growth. It is recognised as an important driver of productivity growth and the emergence of new products from which consumers derive welfare. It depends not only on the work of scientists and engineers, but also on a wider range of economic and societal factors, including institutions such as intellectual property rights and corporate governance, the operation of markets, a range of governmental policies (science and technology policy, innovation policy, macroeconomic policy, competition policy, etc.), historical specificities, etc. Given that technology is explicitly taken up in the strategies and policies of governments and firms, and new actors both in the national and international arenas become involved, understanding the nature and dynamics of technology is on demand. I anticipate that this book will decisively contribute in this regard.

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