

Ricardo versus Wicksell on Job Losses and Technological Change

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Are technological innovations net destroyers of jobs? Many think so and point to the information technology (IT) revolution and its progeny, the offshore outsourcing of service activities, as prime current examples. Here the simultaneous advent of (1) undersea installation of mega-bandwidth fiber optic cable allowing virtually costless transmission and storage of data, (2) global spread of personal computers, and (3) standardization of software applications allegedly have made it profitable to export abroad service functions once performed in the United States, thereby throwing Americans out of work (Friedman 2004).

Others, however, disagree and contend that new technology, including outsourcing, creates at least as many jobs as it destroys (Drezner 2004). It lowers costs, cheapens prices, stimulates demand, boosts output, and provides new employment opportunities. Historical experience, these observers contend, reveals such to be the case. Since the start of the industrial revolution, the number of jobs has grown as fast as the level of technology. Were the opposite true and innovation continually to displace workers, firms employing ever-advancing technology requiring ever-fewer hands to operate it eventually would produce the entire GDP with a labor force of one person. That outcome, the observers note, has not happened.

Concern with the jobs-versus-technology issue is hardly new—think of Karel Capek’s famous 1920 play *R.U.R.* Its plot has factory automation permanently replacing human workers with robots, a possibility Paul Samuelson modeled mathematically in 1988. Samuelson and a few others aside,

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however, commentators all too often have addressed the jobs-innovation question in an ad hoc, anecdotal manner conducive to selective reasoning, ambiguous conclusions, and emotional rather than rational responses. Too rarely has a coherent analytical framework capable of yielding dispassionate, clear-cut answers disciplined the discussion.¹ This article traces the first attempts to overcome this deficiency and to resolve the issue of technology's effect on jobs theoretically with the aid of a rigorous analytical model.

The model in question is David Ricardo's famous machinery example. It has capital-embodied innovation converting the wage-fund stock of consumable goods that sustains workers over the production period into fixed machinery that cannot sustain them. The result is to lower permanently the demand for labor, the number of jobs, and the level of output. Reversing his original position that innovation benefits all, Ricardo in 1821 constructed his model to demonstrate that workers have much to fear from technical change. "All I wish to prove," he said, "is, that the discovery and use of machinery may be attended with a diminution of gross produce: and whenever that is the case, it will be injurious to the labouring class, as some of their number will be thrown out of employment, and population will become redundant, compared with the funds which are to employ it" (Ricardo [1821] 1951, 390). Almost one hundred years later, Knut Wicksell deployed essentially the same model, albeit with a different assumed coefficient of elasticity of labor supply and a different theory of labor demand, to argue that Ricardo's predictions were flawed and that jobs and real output need not be lost to technological progress.

Wicksell's contribution was to refurbish Ricardo's model with new ideas emerging from the celebrated marginal revolution in economic theory that occurred in the 1870s, 80s, and 90s. He replaced Ricardo's classical wage-fund theory of labor demand with a neoclassical marginal productivity explanation. Likewise, he substituted a fixed-factor-endowment interpretation of labor supply for Ricardo's old-fashioned subsistence-wage approach. These improvements rendered the machinery model amenable to marginal analysis, thereby bringing it closer to modern theorizing on the jobs-innovation issue. They enabled Wicksell to challenge Ricardo's melancholy predictions within the framework of his own rehabilitated model. In short, in their respective readings of the model, Ricardo was the pessimist and Wicksell the optimist as far as innovation's impact on jobs and the well-being of labor were concerned.

Among the few who have commented extensively on these opposing outlooks is Paul Samuelson. In his 1989 *Scandinavian Journal of Economics* article "Ricardo Was Right!" Samuelson writes that "in the famous suit K.

¹ Exceptions include research on the jobs-innovations question recently initiated by Gali (1999), Basu, Fernald, and Kimball (1998), and Francis and Ramey (2002). These studies use formal modeling to conclude that technical progress reduces employment in the short run, but not the long. Job loss is transitory, not permanent.

Wicksell vs. D. Ricardo—in which Knut Wicksell denied that a viable invention could reduce aggregate output [and jobs],” a “modern judge must rule . . . against the plaintiff. My title therefore could have been . . . Wicksell was wrong!” (Samuelson 1989, 47–8).

What follows takes issue with Samuelson, arguing, contrary to him, that while both men were right in theory—that is, within the context of their particular variants of the hypothetical machinery model—only Wicksell was right in practice. Realizations match the predictions emerging from his reading of the model, but not from Ricardo’s. True, with respect to theory, both economists employed impeccable logic and valid reasoning in constructing and manipulating their versions of the model to grind out the solutions they did. Their versions left nothing to be desired on internal consistency grounds. With respect to practice, however, only Wicksell’s optimistic predictions have stood the test of time. He rightly foresaw that output and jobs would expand with labor-saving technological progress. He likewise predicted that labor-neutral and labor-using innovations would boost real wages as well. History has confirmed his predictions and falsified Ricardo’s. It has revealed his version of the model to be the more realistic of the two.

Besides providing historical perspective on the outsourcing issue, the Ricardo-Wicksell controversy is of interest for at least six other reasons. First, it shows how the same analytical model can, with different assumptions about the values of its coefficients and the shapes of its functions, yield opposite results. In Ricardo’s machinery model where labor demand is key, technology essentially enters the labor demand function as a variable bearing a negative sign. It thereby ensures that innovation harms, rather than helps, labor. A positively signed technology variable, Wicksell noted, would reverse that result. So too would a negatively signed variable if offset or negated by compensating profit-sharing schemes. Another key is the assumed slope of the labor supply curve. Depending on that slope, labor-saving innovation either shrinks or expands real output just as it destroys or preserves jobs.

Second, in spotlighting these polar results, the controversy shows how a single model under alternative parameter settings can, when used to organize discussion, encompass the entire range of opinion on the issue of jobs and innovations. Whether one believes innovations on balance are job destroyers, job creators, or merely job preservers, one’s stance on this issue (albeit not necessarily one’s acceptance of the model) falls somewhere between the extremes of Ricardo and Wicksell.

Third, the controversy shows that even the greatest economists’ most cherished beliefs are not fixed and immutable. Ricardo recanted his long-held position that technical progress is Pareto-improving (that is, benefits all parties and harms none) only when he became convinced that he had been in error and that innovation could hurt labor even while it profited capital.

Fourth, the controversy shows that mainstream economists, notwithstanding their theoretical differences and social sympathies, tend to favor, on efficiency grounds, public policies conducive to technical progress. With respect to innovation, both Ricardo and Wicksell recommended that governments refrain either from suppressing or discouraging it regardless of whether it destroys jobs (Ricardo) or preserves them (Wicksell). Ricardo in particular argued that anti-innovation policy magnifies job destruction and intensifies harm done to labor. That is to say, he thought that while innovation hurts workers, attempts to prevent it only make matters worse. And Wicksell, though a redistributionist, welcomed pro-innovation policies. They would, he believed, help maximize the size of the pie—gross product—to be shared.

Fifth, the controversy shows how the study of a practical social issue such as technology's effect on jobs spurs new concepts and ideas that advance economic science. Here, in addition to the machinery model itself, the new concepts include Wicksell's distinction between labor-saving, labor-using, and labor-neutral innovations, namely those that lower, raise, or leave unchanged, respectively, labor's marginal productivity relative to capital's. Still another novel idea was the compensation principle according to which winners in an economic change compensate losers so as to make both groups better off. Wicksell devised this concept to argue that capitalists could profitably bribe workers to accept technological innovations that otherwise would hurt them.

Sixth and most of all, the controversy serves as a cautionary tale. Economists (not to mention general observers) have been discussing the effects of innovations on labor for a long time. The analysis has always been fraught with pitfalls, so one should be careful in jumping to conclusions, especially regarding policy responses. A common pitfall (albeit one largely avoided by Ricardo and Wicksell) is failure to distinguish between immediate and longer-run effects of innovation. Initially, technical progress is quite likely to hurt groups of workers possessing specific acquired skills and abilities. One must weigh this short-run cost of innovation against potential long-run benefits. In the long-run, workers will invest in acquiring a different set of skills that will enable them to operate the new technology. But this adjustment process may involve a painful transition period, and society may wish to ease the pain of those adversely affected during the transition. Yet because pain provides an incentive to undertake the necessary changes, too much assistance may delay the adjustment for an inefficiently long time.

1. THE MACHINERY QUESTION

Fears of job destruction through new technology antedate both today's outsourcing scare and David Ricardo. Think of the manuscript copyists whose skills Johannes Gutenberg's 1436 invention of the printing press rendered

obsolete. Later, like their medieval counterparts, 18th- and 19th-century observers watching the mechanization of textile and other key manufactures also saw machinery as the source of technological unemployment (Rashid 1987; Berg 1980). Workers and their advocates then posed the celebrated *machinery question*: Could new machines embodying advanced technology permanently destroy jobs? Like modern economists, 18th-century economists generally answered in the negative, and with the same reasoning, too. New machines lower production costs. Lower costs mean cheaper prices. Cheaper prices extend the market. They stimulate demand for consumption goods and make it profitable for firms to expand output to satisfy the demand. Since extra output requires hands to produce it, increased production absorbs the initially laid-off workers and other workers as well. Technical advance, in addition to benefiting workers by giving them lower prices, begets more jobs than it destroys. Josiah Tucker said it all in his 1757 explanation of the effects of machinery:

What is the Consequence of this Abridgment of Labour, both regarding the Price of the Goods, and the Number of Persons employed? The Answer is very short and full, *viz.* That the Price of Goods is thereby prodigiously lowered from what otherwise it must have been; and that a much greater Number of Hands are employed. . . .

And the first Step is that Cheapness, *ceteris paribus* is an inducement to buy—and that many Buyers cause a great Demand—and that a great Demand brings on a great Consumption; which great Consumption must necessarily employ a vast Variety of Hands, whether the original Material is considered, or the Number and Repair of Machines, or the Materials out of which those Machines are made, or the Persons necessarily employed in tending upon and conducting them: Not to mention those Branches of the Manufacture, Package, Portorage, Stationary Articles, and Book-keeping, &c. &c. which must inevitably be performed by human Labour. . . .

That System of Machines, which so greatly reduces the Price of Labour, as to enable the Generality of a People to become Purchasers of the Goods, will in the End, though not immediately, employ more Hands in the Manufacture, than could possibly have found Employment, had no such machines been invented (Tucker [1757] 1931, 241–2, quoted in Rashid 1987, 265).

Other classical economists, including Adam Smith, Jean Baptiste Say, and most notably David Ricardo, echoed this optimistic view. Ricardo, for example, wrote that mechanization (“a general good”) benefits all social classes including workers, capitalists, and landlords alike. Mechanization conserves scarce resources, improves efficiency, increases output, and lowers production costs. The resulting fall in prices gives all consumers more purchasing power to spend on an augmented bundle of goods. In this way “the labouring class . . . equally with the other classes, participate[s] in the . . . general cheapness of commodities arising from the use of machinery” (Ricardo [1821] 1951, 388).

2. LABOR UNREST AND RICARDO'S ABOUT-FACE

Ricardo, in other words, initially believed that mechanization benefited workers by giving them more and cheaper goods. And it did so without destroying jobs or lowering money wages. "I thought that no reduction of wages would take place," he wrote, "because the capitalist would have the power of demanding and employing the same quantity of labour as before, although he might be under the necessity of employing it in the production of a new, or at any rate of a different commodity" (Ricardo [1821] 1951, 387). Cheaper prices at accustomed money wages together with availability of jobs in the innovating and non-innovating sectors of the economy—what more could workers want? They should welcome mechanization, not oppose it. That was certainly Ricardo's initial expectation.

Then came episodes of labor unrest—the violent strikes, riots, protests, and machine-breaking of 1811–21—that overlapped with periods of high unemployment in the post-Napoleonic War years of 1815–30. Famous among the rioters of this time were organized bands of English handicrafters known as Luddites. Taking their name from Ned Ludd, an apocryphal 18th-century Leicestershire handloom weaver who supposedly destroyed two stocking frames in a fit of rage, the Luddites conspired to smash the textile and cloth-finishing machines that they thought were threatening their jobs. Observing these uprisings, Ricardo changed his views radically in the famous Chapter 31 "On Machinery," which he added to the third (1821) edition of his *Principles of Political Economy and Taxation*.

In that chapter, which Samuelson (1988, 274) calls the best in the book, Ricardo took labor agitation seriously. He had always modeled agents as rational maximizers acting in their own self-interest (Maital and Haswell 1977, 365). Might not workers, as such agents, have a legitimate case against machines? Might not machines be inimical to their interests as they themselves maintained? Answering in the positive, Ricardo proceeded to construct a formal model (with a numerical example as its core) to demonstrate that "the opinion entertained by the labouring class, that the employment of machinery is frequently detrimental to their interests, is not founded on prejudice and error, but is conformable to the correct principles of political economy" (Ricardo, [1821] 1951, 392).

3. OVERVIEW OF THE MODEL

Ricardo's general equilibrium model says that when a capitalist installs new labor-saving technology in the form of a machine, that same capitalist permanently displaces labor and renders it superfluous. That is the initial effect. The intermediate, or transition, effects come when the redundant workers, in an effort to regain their lost jobs, bid down the wage rate. Since in Ricardo's model, as in the labor-market models of most classical economists, the initial

wage rate already is at the equilibrium (or Malthusian minimum subsistence) level where the work force barely maintains its size with neither increase nor diminution, the fall in wages below that level means that fewer workers can survive and indeed must die off (see Samuelson 1994, 621). They continue to die off in sufficient numbers until the wage rate returns to its subsistence equilibrium. In that new, long-run equilibrium, the output-reducing effect of labor force diminution dominates the output-raising effect of the machine's greater efficiency so that gross output falls. Final steady-state equilibrium features these conditions: smaller output, fewer jobs, fewer workers to fill those jobs, subsistence wages, and raised profits (a necessary condition for the capitalist to install new machinery in the first place).²

It is hard to avoid noticing the model's current relevance. Replace the word "machinery" with "outsourcing" and downplay the Malthusian overtones. What you get is the typical current complaint that technical progress in the form of offshore outsourcing hurts labor at the same time it helps capital.

4. RICARDO'S EXAMPLE

The model itself has a group of laborers working for a single capitalist farmer who represents the entire productive sector of the economy. The capitalist initially has a total capital stock of £20,000, of which £7,000 is *fixed capital* (buildings, equipment, and the like), and £13,000 is *circulating capital* (stores of food and necessities used to provision, or grubstake, labor over the period of production and thus the wherewithal to employ, or demand, workers). The importance to the model of circulating capital cannot be overstressed. It and it alone constitutes the capitalist's ability to employ workers. Nothing else, neither the lower prices and higher profits that innovation yields, nor the increased spending spurred by them, can affect employment in the model. To Ricardo, circulating capital, rather than demand for commodities, constitutes demand for labor. Anything that shrinks the stock of such capital automatically shrinks labor demand. No compensating mechanism such as the previously mentioned price and profit effects leading to increased demand for goods can offset, or negate, the resulting adverse employment effects of reductions in the stock of circulating capital.

Ricardo makes the foregoing point exceedingly clear in his example. He begins by assuming that year after year in stationary equilibrium the capitalist and his workers produce annual output worth £15,000. Of this sum, £13,000

² In his Chapter 31 Ricardo always speaks of the new machine as raising profit, or net income. Yet in his model and numerical example, profit remains constant. There is no inconsistency here. Ricardo recognized that profit must rise by some positive amount, however small, call it epsilon, to motivate the capitalist to invest in the risky new machine. To simplify his model, however, he let epsilon assume a limiting value of zero. Nothing would have changed if he had assigned it a positive value. See Barkai 1986, 599-600, footnote 2.

goes to replace the circulating capital stocks of food and necessities workers have consumed over the year, and £ 2,000 goes to the capitalist as profit (a 10.0 percent profit rate) to reward him for the use of his capital. Ricardo assumes that the capitalist consumes, rather than invests, his profit such that no capital growth occurs.

Things change when the capitalist decides on profit grounds to divert half his labor force from the production of food and necessities to the fabrication of a new machine. Since the workers reassigned to machine-building produce no food and fiber, farm output is halved to £ 7,500 while fixed capital rises from £ 7000 to £ 14,500 by the £ 7,500 value of the new machine. The machine, of course, is counted in final output during the time of its construction. But it is not so counted afterward when, its fabrication completed, it assumes its place in the economy's stock of fixed capital assets and production reverts to farm product only. When the capitalist extracts his £ 2,000 profit (still 10.0 percent of his capital stock) from the £ 7,500 value of farm output, barely £ 5,500 worth remains to provide for the maintenance of labor in the following year. In other words, circulating capital, or means of employing labor, falls from £ 13,000 to £ 5,500. Given that circulating capital constitutes demand for labor in Ricardo's model, the capitalist can now employ but 42.3 percent, or $5,500/13,000$, of the labor he employed before to produce a gross output of half its former size. In short, switching labor from food production to machine installation permanently reduces the fund available to grubstake and therefore to hire workers. "There will," Ricardo gloomily concludes, "necessarily be a diminution in the demand for labour, population will become redundant, and the situation of the labouring class will be that of distress and poverty" (Ricardo [1821] 1951, 390).

Attempting to regain their lost jobs, the redundant workers put downward pressure on the real wage rate forcing it to drop below the minimum subsistence level, which the Malthusian iron law of wages—represented in Ricardo's model by a horizontal labor supply curve—dictates as the equilibrium wage. The resulting starvation of workers shrinks the population, the labor force, and with it the gross product until the real wage returns to its subsistence level.

Here then is the second crucial component of Ricardo's machinery model, namely the iron law of wages. Developed by Richard Cantillon, Adam Smith, and above all by Thomas Malthus, it says that population and labor force numbers respond to gaps between actual and subsistence wages. Their response together with diminishing returns to extra doses of labor applied to the fixed factor land keeps wages gravitating to subsistence. Thus below-subsistence wages lead to starvation, high death rates, low birth rates, and population and labor force decline. With fewer workers tilling the fixed amount of land, the land-to-man ratio rises, which means that each laborer has more land to work with and so experiences a rise in his productivity. Real wages rise with productivity until both return to the subsistence level where population shrinkage

ceases and the labor force stabilizes in size. Conversely, above-subsistence wages encourage population growth and the crowding of more workers on the fixed land. Each worker has less land to work with and so experiences a fall in his productivity and real wage, both of which converge to the subsistence equilibrium where population growth ceases and the labor force stabilizes. In short, diminishing returns together with the feedback of wage deviations from subsistence on population growth operate to keep wages at subsistence. Operating through these channels, mechanization in Ricardo's model not only displaces workers but kills them off as well. Workers indeed have a legitimate case against machinery, or more precisely, against the ultra labor-saving bias of the technical progress embodied therein.

5. REACTION TO THE MODEL

Ricardo's demonstration appalled his classical contemporaries who found it incompatible with the rest of his work. Typical was the reaction of John Ramsay McCulloch who complained that Ricardo's machinery chapter ruined the book (see St. Clair [1957] 1965, 234, 237). How could Ricardo, creator of the comparative-advantage theory of gains from trade, contend that technological innovation, a key source of comparative advantage, hurts labor? How could he be so inconsistent? "[N]othing can be more injurious," wrote McCulloch to Ricardo on June 5, 1821, "than to see an Economist of the highest reputation strenuously defending one set of opinions one day, and unconditionally surrendering them the next" (McCulloch [1821] 1951, 382). "I will take my stand," declared McCulloch, "with the Mr. Ricardo of the first not of the third edition [of the *Principles*]" (385).

Ricardo's peers also feared his analysis might discredit the free-market precepts of classical economics, not to mention the aid and comfort it would provide to anti-market reformers. "[A]ll those who raise a yell against the extension of machinery," wrote McCulloch to Ricardo, "will fortify themselves by your authority" and claim that "the laws against the Luddites are a disgrace to the Statute book" (384–5).

6. RICARDO'S QUALIFICATIONS

Ricardo himself seemed sufficiently uncomfortable with his theoretical demonstration to express reservations about its practical relevance. At the end of his chapter he noted that capitalists often mechanize their operations gradually instead of suddenly, thus allowing time for smoother adjustment. He also noted that machine installation may be a manifestation of saving-financed *growth* in capital rather than of conversion of the circulating-into-fixed components of a capital stock of constant size. With no conversion, or shrinkage, of circulating capital there is no displacement of labor. Jobs are not destroyed.

Indeed, circulating capital (and jobs) conceivably might expand together with fixed capital. Tracing a causal chain from mechanization to falling production costs to cheaper product prices to rises in the real purchasing power of nominal profit incomes, Ricardo suggested that such increased real profit incomes could generate the saving from which investment in circulating, as well as fixed, capital would come. Alternatively, capitalists might spend their profit increases on the hiring of menial servants or on the purchase of luxury consumption goods. These expenditures would create new demands for labor. But such demands, Ricardo realized, could reabsorb but a fraction of the workers displaced by wage-fund contractions that exceeded profit expansions in size. He further pointed out that, in the context of an expanding population, mechanization, far from occurring autonomously, is often induced by rising money wage rates relative to the cost of machines. (The money wage hikes are, of course, necessary to maintain real wages at subsistence in the face of rising food prices caused by diminishing returns as the growing population resorts to more intensive cultivation of the fixed land). Capitalists then attempt to economize on costly labor by substituting relatively cheap machines for it. This point, however, refers to pure capital-labor substitution under given technology. It does not refer to technological change and so hardly qualifies as an exception to Ricardo's example.

Most of all, Ricardo warned of the futility and harmfulness of limiting or discouraging the introduction of new machines in a world where foreign competitors would introduce them anyway. By lowering the return on domestic capital relative to foreign capital, such restrictions would spur the export of capital, leading to even less demand for labor at home. In short, whereas conversion of circulating capital into machinery lowers domestic labor demand, capital exported abroad annihilates the demand altogether (Ricardo [1821] 1951, 397). Another point recognized by Ricardo is that the banning of machines makes a nation less efficient than its trade partners so that it obtains fewer labor hours' worth of imports per each labor hour's worth of exports given up. In other words, rejection of machinery turns the country's double factorial terms of trade against it (O'Brien 1975, 226).

The upshot of these considerations is that no restrictions should be placed on the introduction and use of machines. As Ricardo put it, "he would not tolerate any law to prevent the use of machinery. The question was,—if they gave up a system which enabled them to undersell in the foreign market, would other nations refrain from pursuing it? Certainly not. They were therefore bound, for their own interest, to continue it" ([1823] 1951 303). Ricardo's disapproval of anti-machinery policies aimed at preserving jobs indicates that were he alive today he would likewise oppose all restrictions on offshore outsourcing.

Nevertheless, Ricardo's reservations and doubts about his model evidently were not so serious as to invalidate his conclusion that capital-embodied inno-

vations may harm labor. Thus when speaking before the House of Commons on May 30, 1823, he abandoned all mention of doubts and reservations and instead firmly reiterated “his proposition . . . that the use of machinery was prejudicial . . . to the working classes generally. It was the means of throwing additional labour into the market, and thus the demand for labour, generally, was diminished” (Ricardo [1823] 1951, 303).

7. MCCULLOCH ON THE MODEL

Ricardo’s model was a very special one with several curious features. Job destruction results solely from the conversion of circulating into fixed capital. The introduction of machinery leaves the total stock of capital (albeit not its composition) unchanged. Fixed capital bears no depreciation charges, implying that it has infinite life. Wages cannot fall permanently below their Malthusian minimum subsistence limit. Profits, too, cannot fall and indeed must rise by some amount, however small—call it epsilon—to induce innovation. (Here Ricardo created unnecessary confusion by having epsilon assume a limiting value of zero so that profits apparently remain unchanged.) Output falls.

Classical economist John Ramsay McCulloch, who as we have seen objected to Ricardo’s analysis, focused on some of these peculiarities (see O’Brien 1975, 227–28). He argued that displaced workers would find jobs in making machines, including new machines to replace worn-out ones. On this point he disagreed with Ricardo who, thinking that replacement was of little importance, modeled machines as lasting forever and so incurring no depreciation.

Regarding profits, McCulloch claimed that the capitalist would require a rise (rather than the apparent zero change) in them to compensate for the uncertainty of investing in untried new technology. Without additional profits, the capitalist would have no incentive to install the risky new machine. This criticism, too, missed its mark because, as previously mentioned, Ricardo agreed that profit rises were necessary. The zero rises in his model were but a proxy for and lower limit to the required positive rises.

McCulloch concentrated the bulk of his attention on the model’s output result. Machines, he said, raise, not lower, output. They do so through a causal chain running from lower production cost to lower product prices to increased consumer demand in response to cheaper prices, and thence to the profitability of producing extra output (and hiring extra hands) to satisfy that demand. Replacing Ricardo’s concept of circulating capital as demand for labor with the alternative notion of demand for goods as demand for labor, McCulloch argued as follows (see O’Brien 1975, 227–8): If product demand is unitary elastic such that price falls induce proportionate rises in quantity demanded, then labor re-absorption is complete. The machine-installing sector rehires

the displaced workers. Similarly, if product demand is elastic such that price falls induce more-than-proportionate rises in quantity demanded, then labor re-absorption is more than complete. The sector rehires more workers than it laid off.

Conversely, if product demand is inelastic such that price falls induce a less-than-proportionate rise in quantity demanded, then labor re-absorption is incomplete. Even so, the price cuts in this last case still leave consumers with more purchasing power to spend on other goods, leading to increased hiring of workers to produce those other goods.

Of course, consumers may choose not to spend all the extra purchasing power that price cuts bring. If so, those consumers save. The saving, upon its deposit in banks, is loaned out to capitalists to finance investment in new capital goods. Demand for those goods and the labor to produce them rise.

Finally, if capitalists fail to pass cost reductions on into price reductions, the resulting extra profits they receive are used either to increase their own consumption or their purchases of investment goods. Either way, demand for goods and, in turn, for labor, rises, and displaced workers are reabsorbed. To be sure, re-absorption implies that workers must acquire new skills to enable them to adapt to the better technology. Likewise, it implies that they must learn new trades so that they can occupy new jobs to replace the old ones lost to mechanization. These adjustments may involve pain. But such distress is a reasonable cost to pay considering the gains to be made. Here in a nutshell was McCulloch's elaboration of Tucker's earlier analysis.

8. WICKSELL'S CRITIQUE

McCulloch's 19th-century critique of the machinery model was quite perceptive. But it remained for the Swedish neoclassical economist Knut Wicksell, writing a hundred years after Ricardo, to deliver the definitive critique. In his 1901 *Lectures on Political Economy* and his 1923 manuscript "Ricardo on Machinery and the Present Unemployment"—a manuscript that *Economic Journal* editor John Maynard Keynes rejected for publication in 1923 and that Lars Jonung shepherded into print in that same journal in March 1981—Wicksell argued that Ricardo had it all wrong. The latter's long-run steady state equilibrium had no room for lower wages and the resulting re-absorption of displaced labor. Nor did it have room for the increased output that the fully employed labor force equipped with improved technology could produce. Using the classical assumption that the long run equilibrium wage rate is fixed exogenously at minimum subsistence, Ricardo was denied the neoclassical insight that the equilibrium wage rate is instead determined endogenously by labor's marginal productivity at full employment. Deprived of that understanding, he failed to see that innovations do not reduce production, but rather augment it. In short, there is no floor to equilibrium wages. The labor supply

curve is vertical rather than horizontal. The demand for labor determines the wage rate rather than the level of employment. Labor's marginal productivity, not the stock of circulating capital, constitutes labor demand. Labor-saving "machinery"—a word Wicksell uses to denote disembodied technical progress rather than fixed-capital-embodied technical progress in Ricardo's sense of the word—drives that demand through its influence on worker marginal productivity. If innovation is biased against labor, marginal product falls although gross product rises.

Incorporating these changes into Ricardo's model ensures that neither jobs nor output are lost to the machine, that is, to innovation. On the contrary, Wicksell ([1923] 1981, 200, 203) thought that with a sufficient drop in wages, all the workers displaced by the machine would be rehired and, with the aid of the new technology, would produce more output than they did before. The innovation-induced fall in wages, variously estimated by him ([1901] 1934, 138; [1923] 1981, 202) to be between 10.0 percent and 1.0 percent in size, was absolutely crucial.³ It ensured continual equality between the wage rate and labor's lowered marginal productivity, this equality being a necessary condition for output to reach its maximum allowed by the innovation.

9. REDISTRIBUTION SCHEMES, OR PARETO OPTIMAL BRIBES

As for Ricardo's claim that the lower wages would invariably decimate labor through starvation, Wicksell ([1923] 1981, 204–5) denied it. True, Wicksell recognized that the post-innovation reduction in wages necessary to clear the labor market and to allow output to reach its maximum level makes workers worse off. Their jobs are preserved, but at dwindled pay. And he also realized that if the resulting reduced wage is below subsistence, the labor force would have to undergo Malthusian shrinkage just as in Ricardo's case. But Wicksell insisted that this outcome was not inevitable. Distinguishing between technical conditions necessary for maximum production on the one hand versus distributional requirements of maximum social welfare or satisfaction on the other, he noted that lower wages (equaling as they do labor's marginal product at full employment) satisfy the first set of conditions but not necessarily the second. Maximizing satisfaction requires that everyone's welfare, notably labor's, be improved. To obtain that maximum, the government, Wicksell said, must supplement wages with welfare relief payments sufficient to maintain workers at the subsistence standard of living or above.

³ These wage falls are relatively small. In later writings, however, Wicksell entertained the notion that wages might have to fall to zero or close to it to clear the labor market following the introduction of new labor-saving technology (see Boianovsky and Hagemann 2003, 24–5). But he seems to have regarded such extreme wage falls as purely hypothetical. In his careful and detailed 1901 and 1923 critiques of Ricardo's model, he posits small, not large, reductions in wages.

Of course these relief payments ultimately would come from taxes on profits. Even so, profits net of tax would be higher with the machine than without it, thanks to the machine's capacity to raise the profit rate. Nor would the profit tax itself discourage production and so dry up the very proceeds that constitute the source of relief payments. No such disincentive effects could wreck the scheme; for Wicksell ([1896] 1958, 256–7) elsewhere had used a model of imperfect competition to prove that a lump sum profit tax, being independent of the level of output, is like a fixed cost. It does not affect producers' marginal cost and marginal revenue schedules and so leaves the profit-maximizing level of output unchanged. The tax, in other words, shifts the hump- or inverted U-shaped profit function downward by the amount of the levy. But it does not change the output level where the function reaches its peak or maximum value. Desiring to reach that peak, maximizing capitalists might complain about the tax. Still, they would be doing the best for themselves by maintaining the level of production rather than by curtailing it.⁴

The upshot was that society could devise a post-innovation tax-transfer scheme that would leave capitalists better off and workers at least no worse off than before. In this way, the fruits of technical progress could be shared by all. Via income transfers, capitalists could effectively bribe workers to accept those innovations that threatened to lower labor's marginal product and so real wages.

Wicksell, of course, realized that not all innovations would lower labor's marginal productivity and real wages. On the contrary, he thought that some, perhaps most, innovations would raise those productivity and real wage variables instead of lowering them. "[T]he great majority of inventions and technical improvements," he wrote, "tend to increase the marginal productivity of both labour and land, together with their share in the product" (Wicksell [1901] 1934, 143). For such labor-using innovations, transfers and bribes would be unnecessary since workers would benefit anyway.

And although he excluded capital accumulation from his disembodied-technical-change version of Ricardo's model, he elsewhere stressed the modern view that such accumulation creates jobs while raising labor's marginal productivity and real wages. "[T]he capitalist saver," he wrote, "is thus, fundamentally, the friend of labour, though the technical inventor is not infrequently its enemy" (Wicksell [1901] 1934, 164). It follows that innovation accompanied by, or embodied in, new capital requires no income transfers to benefit labor.

⁴ Wicksell failed to note that, under certain circumstances, taxing the profit that innovation yields may dry up the future supply of that activity. If profit includes a cost payment, or normal rate of return, necessary to coax forth innovation, then removing that return would destroy the incentive to innovate. In other words, if the supply of innovation is elastic with respect to profit, taxing profit will reduce the quantity of innovation supplied.

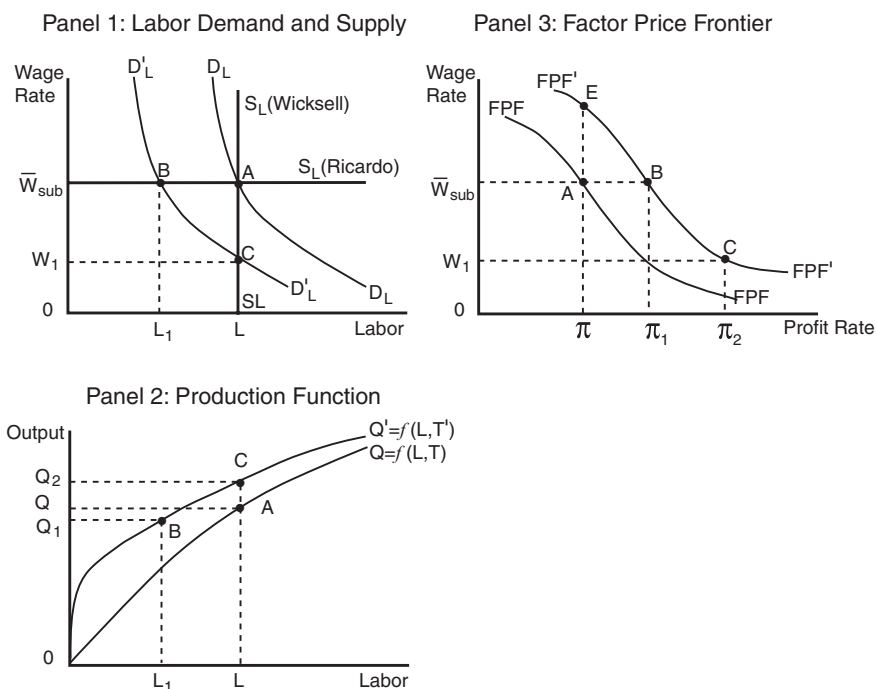
To summarize, Wicksell disputed Ricardo's ideas of (1) a lower bound, or floor, to wages, (2) a post-innovation decline in output, jobs, and the labor force, and (3) the absence of tax-transfer profit-sharing schemes.⁵ Discarding these notions, Wicksell showed that the freedom of wages to fall to market-clearing levels where labor receives its marginal product promotes the re-hiring of displaced workers. Equipped with the improved technology, these workers together with their already employed counterparts produce additional output. Redistribution mechanisms then allow labor to share the extra output with capital so that both parties enjoy higher incomes after the innovation than before it. In Wicksell's own words, "the only completely rational way to achieve the largest possible production [is] to allow all production factors, including labour, to find their equilibrium positions unhindered, under free competition, however low they may be, but at the same time to discard resolutely the principle that the worker's only source of income is his wages. He, like every other citizen, ought rather to be entitled to a certain share of the earnings of the society's natural resources, capital, and (where they cannot be avoided) monopolies" ([1924] 1969, 257).

10. DIAGRAMMATIC ANALYSIS

Geometrical diagrams illustrate Ricardo's and Wicksell's cases (see Figure 1, suggested by Samuelson [1989], 53). Panel 1 shows how Ricardo's capitalist—when converting circulating (wage fund) capital into fixed capital via the installation of the machine—causes the labor demand curve to shift downward and to the left. The shifted demand curve intersects the horizontal labor supply curve, the height of which is fixed by the Malthusian minimum subsistence wage rate, at new equilibrium *B*. There the labor force is halved. Despite the machine's effect in enhancing efficiency, shown by the upward shift in Panel 2's aggregate production function, fewer workers spell less output so that gross product falls. At the same time, the innovation, by shifting outward Panel 3's factor price frontier, or menu of alternative maximum wage rate-profit rate combinations, reveals that the rate of profit rises from *A* to *B*. The end result is that output is down, jobs are down, the labor force is down, the wage rate is unchanged, labor income (wage rate times labor force) is down, and the profit rate and profit income (profit rate times total capital, a constant) are both up.

⁵ Hansson (1983, 55) argues that Wicksell's criticism of the lack of a tax-transfer redistribution mechanism in Ricardo's model is misguided for two reasons. First, no such mechanism existed in Ricardo's time when welfare aid to unemployed workers, such as it was, consisted of poor relief and charity. Second, 19th-century English capitalists operated in a political system that catered to their interests. Given this state of affairs, they would have no incentive to depart from the Ricardian equilibrium and agree to income transfers. No pro-labor social and legal sanctions were in place to make them to do so.

Figure 1 Wicksell vs. Ricardo on Technological Innovation and Job Loss



Ricardo: Conversion of circulating into fixed capital via the installation of a machine shifts down the labor demand curve in Panel 1. At the same time, the advanced technology embodied in the machine shifts up Panel 2's production function and Panel 3's factor price frontier. The horizontal labor supply curve in Panel 1 dictates that equilibrium move from A to B in all panels. Output, jobs, and the labor force drop. Wages remain at subsistence. Profits rise.

Wicksell: Panel 1's vertical labor supply curve dictates that innovation moves equilibrium from A to C in all panels. Jobs and the labor force remain unchanged. Output and profits rise. But wages fall below subsistence. The remedy for reduced wages is a tax-financed subsidy that redistributes profit income from capital to labor. Move from C to B along Panel 3's factor price frontier to restore labor's subsistence standard. Move further from B toward E to make both parties better off than they were at initial point A.

Here is Ricardo's conclusion that machine-embodied technical progress hurts labor and helps capital.

Wicksell's case, by contrast, replaces Ricardo's horizontal labor supply curve with a vertical supply curve corresponding to the assumption of fixed factor endowments fully employed. As before, the labor-saving innovation shifts down Panel 1's labor demand curve at the same time it shifts up Panel

2's production function and Panel 3's factor price frontier. To ensure that the post-innovation production function is consistent with the downwardly shifted labor-demand curve, the former has been drawn in the relevant range with a flatter slope than its pre-innovation counterpart. Since the slope of the production function represents labor's marginal productivity—which, in turn, constitutes the demand-for-labor curve in Wicksell's analysis—it follows that a flatter post-innovation production function signifies a lower marginal product of labor and so corresponds to the lower labor demand curve.

Now, however, because the labor supply curve is vertical, labor demand determines the wage rate rather than the level of employment. Equilibrium moves from *A* to *C* rather than from *A* to *B*, as in Ricardo's analysis. The wage rate is allowed to fall to its new market-clearing level where all workers, including those temporarily displaced by the machine, are (re)hired. The wage fall is crucial. It keeps the wage rate equal to labor's lowered marginal productivity and allows output to rise to *C*, the maximum permitted by the unchanged labor force working with the new technology. Most of all, the wage fall permits the rise in the profit rate that spurs capitalists to expand production and re-hire labor.

Of course the new equilibrium wage rate is below subsistence. But workers need not starve. The government can compensate—indeed more than compensate—labor for below-subsistence wages by taxing profits and redistributing the proceeds to workers in the form of relief payments. The resulting move from *C* to *B* and thence toward *E* on the new factor price frontier is equivalent to restoring wages to and then raising them above their subsistence level. While helping labor, such redistribution hardly hurts capital. On the contrary, the transfer leaves both parties, capital and labor, better off than they were at initial point *A*. With extra output to share, everybody gains.

11. WICKSELL ON OUTSOURCING

Wicksell's analysis can be applied to the current offshore outsourcing problem. His advice to labor and the policymakers would go something like this: Don't discourage outsourcing. Like Ricardo's machine, it has the potential to benefit all parties through the extra output it permits. Instead, prevent domestic job losses by letting wages fall to market-clearing levels where it becomes profitable to re-hire laid-off workers. Offset the wage reductions if you must with compensatory profit-sharing or tax-transfer schemes. Such schemes, designed in cooperation with employers and/or the government, can spread the gains from outsourcing over all parties, labor as well as capital. In this way, outsourcing will prove to be unanimously beneficial despite being sharply labor saving.

12. CONCLUSION

Innovation destroys jobs in Ricardo's model. But that model, the first rigorous treatment of the machinery question, is too sparsely specified and idiosyncratic to support the generalizations he drew from it. His assumptions of a horizontal supply-of-labor curve, a minimum bound to wages, and a wage-fund-determined demand-for-labor curve—all essential to his contention that technological change decimates jobs, output, and the labor force—already were becoming anachronistic descriptions of the English labor markets of his day. Certainly his assumptions are unrealistic characterizations of labor markets in developed nations now. Drop the assumptions, and you get Wicksell's optimistic results.

Labor-saving innovations, Wicksell often noted, represent the worst-case scenario as far as job losses are concerned. And if such innovations cannot hurt labor under flexible wages and compensatory profit-sharing schemes, how much less do workers have to fear from labor-neutral and labor-using innovations? Indeed, Wicksell considered labor-saving innovations of the kind depicted in his rendition of the machinery model to be the outliers, and labor-neutral and labor-using innovations the norm. Counting on future technical progress to raise, not lower, labor's marginal productivity, he expected such advances to boost the demand for labor so much that the resulting wage increases would render profit-sharing schemes unnecessary. Historical evidence, showing that innovation, employment, and real wages have advanced together for centuries, supports his view and contradicts Ricardo's.

As an economic theorist, Ricardo was in a class by himself. Arguably the best pure theorist who ever lived, he was at least Wicksell's equal and head and shoulders above Tucker and McCulloch. But on the machinery question, their vision of the job-creating power of technical change seems far more convincing than his pessimistic view. President Richard Nixon in 1972 famously said, "We are all Keynesians now." Similarly, most economists today are Tucker/McCulloch/Wicksellians when it comes to technological progress. They would say with some assurance that innovation and its offspring, offshore outsourcing, are beneficial for the overall American economy and promise to create more jobs in the long run than they destroy in the short.

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