SCIENCE, TECHNOLOGY, AND PUBLIC POLICY:

LESSONS FROM THE CLASSICALS

by

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I.

It is a commonplace, even among economists, that science and technology play an important role in economic life. Over the years, indeed, economists have worked to construct theories of how science and technology affect -- and are affected by -- economic variables. One of the most important issues with which economists have attempted to deal is the relationship between technological change and economic growth. Another, perhaps more subtle, issue is the relationship of scientific advancement to technological change -- and hence indirectly to economic growth. And, of course, there is the matter of public policy, an area into which economists have seldom feared to tread. Any coherent set of economic doctrines that addresses all three of these issues is what I will call an economic theory of science and technology.

This essay is about such theories, both past and present. In particular, it argues that there was a coherent "classical" economic theory of science and technology -- and that reexamining that theory may help illuminate the present-day discussion.

II.

The views of present-day economists about science and technology are, of course, many and diverse. Much of this diversity is no doubt due to the increasing intellectual division of labor in the profession, a theme that will take on some importance in this essay. But it is nevertheless fair to say that there developed in the middle part of the twentieth century a quite coherent "neoclassical" theory of science and technology.

The relationship between technology and economic growth in neoclassical theory is encapsulated in a word: the residual. If we view the economy as a huge "aggregate production function," we can ask whether increased use of inputs (capital and labor) account for the whole of growth in output. Abramovitz (1956) and Solow (1957) did this, and discovered that the answer is "no." There is something left -- an unexplained residual -- which can be interpreted as a shift of the production function. And what explains this shift? Technological change. At the macro level, then, technological change entered the neoclassical theory as a kind of exogenous force for growth.

At the more micro level, of course, economists were well aware that technological change must itself be influenced by the marketplace. In the neoclassical framework, this insight translated into a concern with the "inducement" of technical change by changes in relative (factor) prices, a discussion that took place using essentially the same production-function formalism as the aggregate analysis. The key debate here, as touched off by Sir John Hicks (1932), centered on the possibility of bias in favor of innovations that economize on labor inputs as against capital inputs. Unlike most debates in economics, this one resulted in fairly strong agreement: the neoclassical theory of the firm -- contra Hicks -- provides no cause to think that induced technical change should be biased in any particular direction.[1]

What of the relationship of scientific advancement to technological change? There is little discussion in the literature of the period, apart from a few quite sensible reminders that scientific research is not exempt from the strictures of scarcity.[2] But there does seem to have been a shared

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[1] For a succinct discussion, see Rosenberg (1976, pp. 108-109).

[2] Nelson (1959), Machlup (1958).

understanding of the process of technical change as involving sequential "stages," viz., invention, innovation, and diffusion. These three were seen as conceptually distinct, with the innovation stage -- at which new ideas from whatever sources are first put into economic practice -- holding the most economic interest.[3] Inventors and researchers of various sorts contribute to a "pool" of inventions from which innovators draw. The size of the pool may, of course, be influenced by the economic incentives facing inventors and researchers, and more research and invention will increase the supply of potential innovations. But it is the set of incentives for innovation -- the demand for innovation -- that plays the more important role in generating technical advance.[4] In short, the relationship between science and technology in this theory is a linear and unidirectional one, with the principal nexus of interconnection lying at the intersection of a supply curve and a demand curve.

I have, of course, left out one of the most important conceptual tools that neoclassical theory has brought to bear on science and technology: the concept of externality. But this takes us immediately into the realm of policy, for in neoclassical theory the detection of an externality is synonymous with a diagnosis of inefficiency in the market. In this case, the problem is a positive externality of a particular kind. Because the marginal cost of transmitting information is low and the difficulties of preventing its dissemination high, the producer of new knowledge normally confers a benefit on society for which he or she is not adequately remunerated. In the

[3] Rosenberg (1976, p. 67) traces this tradition to the influence of Schumpeter. As we will see shortly, however, he was not the first to cast the process in this fashion.

[4] For a discussion and criticism of this view, see Mowery and Rosenberg (1979).

terminology of Pigou, who inspired this mode of analysis, the social net product of invention and research exceeds the private.[5] This program has been picked up most ardently by Mansfield (e.g., 1968) and his students, who have taken the production-function model to the firm level in order to estimate econometrically the divergence between social and private rates of return to research-and-development (R&D) projects. Specific recommendations are often quite cautious; but the overall thrust of the argument is clearly that there is likely to be too little research and inventive activity in the absence of government assistance.

This portrayal of the mid-twentieth-century neoclassical theory of science and technology is, of course, a somewhat oversimplified account. But it is not, I think, an unfair one.

Needless to say, this theory has not been without its critics. Identifying a clear-cut critical stream is more difficult than identifying the mainstream position itself, and my discussion here will necessarily be somewhat selective. But there are a few well-respected students of the economics of science and technology whose somewhat dissident views have gained increasing attention in the last decade or so; and on these I will rely.

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[5] "Among these examples we may set out first a number of instances in which marginal private net product falls short of marginal social net product, because incidental services are performed to third parties from whom it is technically difficult to exact payment ... Lastly and most important of all, it is true of resources devoted alike to the fundamental problems of scientific research, out of which, in unexpected ways, discoveries of high practical utility often grow, and also to the perfecting of inventions and improvements in industrial processes. These latter are often of such a nature that they can neither be patented nor kept secret, and, therefore, the whole of the extra reward, which they at first bring to their inventor, is very quickly transferred from him to the general public in the form of reduced prices. The patent laws aim, in effect, at bringing marginal private net product and marginal social net product more closely together." (Pigou 1932, pp. 184-85.) The modern theoretical restatement of this Pigovian approach is by Arrow (1962); but compare Demsetz (1969).

Few would find fault with the assertion that technological change is an important force in economic growth. The neoclassical account of the relationship between technology and growth is, however, another matter. The principal complaint is that the production-function approach denatures and miscasts the process of innovation. For one thing, the sharp distinction between changes in technique along the production function (which reflect "existing" technical knowledge) and changes in technique involving shifts of the production function (which involve "new" technical knowledge) is a misleading guide to the actual process of innovation and a serious mischaracterization of the nature of economic and technological knowledge. Response to changes in factor prices always involves acquiring new knowledge -- and therefore involves innovation. (Rosenberg 1976, pp. 62-66.) The neoclassical compartmentalization blinds us to the role of economic adaptation as a source and channel of innovation, making technological change seem both more exogenous and more "neutral" than it really is. Moreover, the production-function formulation lends a mechanical quality -- and an inappropriate implication of inevitability -- to the innovation process. The grinding together of inputs to produce outputs in predictable fashion is not a metaphor well suited to capture what is perhaps the central fact of innovation: its unpredictability and open-endedness. (Nelson and Winter 1977, p. 47.)

At another level, the metaphor of production may also have helped to create an emaciated and simplistic account of the relationship of science and invention to technological change. The depiction of the innovation process as a sequence in which science or invention precedes innovation -- just as one stage of factory production precedes another -- obscures the extent to which science (or even invention) produces a form of knowledge that is quite different from, and often only partly applicable to, the business of technological change in industry. (Rosenberg 1976, pp. 66-68 and passim.) More interestingly, this sequential view of the process rules out some of the more interesting mechanisms of feedback. Far from always preceding technological advance, science is in fact often made possible by developments in technology; moreover, technological problems often set the agenda for basic research and thus serve partly to influence its direction. (Rosenberg 1982, pp. 141-159.)

And what of policy? Few if any would deny that there is operating in science and technology something in the nature of an "externality"; knowledge has a peculiar character to it that gives it properties of appropriability far different from those of ordinary goods. But this recognition does not immediately imply a diagnosis of general undersupply of R&D or a prescription in favor of general government subsidy. The kinds of knowledge -- and the problems of appropriating that knowledge -- vary greatly among sectors. Some kinds of knowledge can be easily kept secret and some kinds cannot. And institutional structures of various kinds (patents are an overworked example) have important and diverse affects on the incentives to invent, to do research, or to innovate. Policy thus might more usefully focus on institutional structures than on the "level" of R&D activity in the large. Such institutions, moreover, ought to be studied with an eye not only to their ability to generate the proper amount of research and innovative activity but -- more importantly -- to generate an adequate diversity of scientific and technological approaches in the face of the unpredictability of the process. (Nelson and Winter 1977, passim.)

There is a good deal more that one could say about present-day views of the economics of science and technology. And, indeed, I will return to the subject before this essay is through. For the moment, though, I wish to reverse the Bard and offer the future as prologue: as a way of framing a look at the classical economic theory of science and technology. Such a prologue no doubt increases the temptation to write Whig History, an account of the past as leading up logically to the accepted view of the present. And, in one case at least -- that of the neglected and oft-maligned J.-B. Say -- I will in fact suggest that the past anticipated the modern mainstream view. For the most part, however, I will argue quite the opposite.

III.

In his Review of Economic Theory (1929, pp. 122-25), Edwin Cannan charged classical economics with an utter neglect of the role of knowledge in economic growth and productiveness. For this he was severely chastised by the late Lord Robbins in his 1966 Chichele lectures.[6] Robbins was able to trot out passages from a number of classical economists and others -- from Francis Bacon to Alfred Marshall -- that mention knowledge, invention, etc. Many of the writers he cites are precisely those with whom I will be concerned shortly, notably Adam Smith, John Rae, Charles Babbage, and John

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[6] Robbins (1968, pp. 83-94).

[7] One curious omission is J.-B. Say. Let me also take this opportunity to apologize for an omission of my own. Karl Marx surely belongs in any discussion of classical economists interested in the economics of science and technology. I omit him partly for lack of space and partly because Rosenberg (1976, chapter 7 and 1982, chapter 2) has discussed Marx's

Stuart Mill.[7] Yet, despite this evidence,[8] and despite my own attempt here to resurrect a classical theory of science and technology, I think Cannan really has the better of the argument. The passages Robbins discovers serve not to show a strong interest by the classicals in matters of knowledge but rather to underscore precisely how peripheral was the classical interest in the place of scientific and technical advance <u>in economic theory</u>. Except for a minority of writers, the classicals confined their discussions of the subject to casual passages or treated the issues elsewhere than in their economic writings.[9] This is true even of those writers -- James Mill and William Whewell come to mind[10] -- who were active in the promotion of British science.

What are we to make of this? And where does it leave a reconstruction of the classical economic theory of science and technology?

In Cannan's view, one of the reasons for the classical neglect of science and technology is that Adam Smith had "tucked away increase of knowledge under the wings of his exposition of the advantages of the division of labour, saying that division of labour encouraged the invention of machinery

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economic theory of science and technology in treatments upon which it would difficult to improve.

[8] Or rather, as we shall see, precisely <u>because of</u> this evidence.

[9] Robbins acknowledges to some extent that Cannan has a point about the mainstream of classical theory as represented by Senior and McCulloch. All he can offer in rebuttal is a McCulloch paean to the powers of science and technology tucked away in a review of Babbage in the <u>Edinburgh Review</u>. (Robbins 1968, p. 91.)

[10] Robbins (1968, p. 90) reports that Mill was a member of a committee of the Society for the Diffusion of Useful Knowledge that sought to educate the working classes to the value of machinery of technical advance. Whewell, the Cambridge mathematician who numbered political economy among his interests, was a member of the Society for the Encouragement of Arts, Manufactures and Commerce and an important advocate of scientific education. (Cardwell 1957, pp. 41-43 and 61.)

and promoted science by specialising particular persons to particular kinds of industry or research" (Cannan 1929, p. 122). The implication is that later writers took up Smith's position, and failed to notice that "the progress of knowledge, though certainly enormously assisted by the division of labour, is not wholly dependent on it" (Ibid). This view, it seems to me, is misleading, and comes perilously close to having the matter exactly backwards. Although it may well be true that the advance of knowledge is not in some sense wholly dependent of the division of labor, it is equally true that a concern with the division of labor serves to focus one's attention quite clearly on science and technology and on the mechanisms by which advances in knowledge contribute to growth and productiveness. Neglect of science and technology comes less from a too-close attention to the division of labor than from a focus away from that Smithian organizing principle.

The neglect of science and technology by the classical mainstream lies, in short, not at Smith's door but at that of Ricardo. While Ricardo and the other classicals took Smith as starting point -- and, indeed, took Smith for granted -- they shifted attention away from the microanalytic explanation of economic growth to a more macroscopic analysis of distribution. Almost all the classicals paid their impatient obeisances to the division of labor; but they moved quickly on to the Ricardian questions of rent, profit, wages, and the distribution thereof.

As a result, the "classical" theory of science and technology with which I'm concerned is decidedly not representative of the mainstream of classical thought from Ricardo through Senior and McCulloch to J. S. Mill. Rather, it is a distinctly Smithian theory, restricted to Smith and a few others for whom the principle of the division of labor served as a foundation for rather than a distraction from the importance of science and technology.

IV.

Let's begin with Smith. He makes it clear no later than the third paragraph of the introduction to The Wealth of Nations that the "produce" of a country depends upon "the skill, dexterity, and judgment with which its labour is generally applied"[11] (Smith 1976, p. 10). It takes but a few pages more for Smith to articulate, in the first sentence of the book, the source of increase in skill, dexterity, and judgment: the division of labor (I.i.1, p. 13).

On the one hand, the division of labor is an organizational innovation, and is thus itself reflective of an increase in knowledge. The application of the division of labor to industry is the application of a new technology. But the division of labor also involves the growth of knowledge and the development of technology in the more conventional sense: one of the main benefits Smith sees in the principle is its tendency to induce mechanical innovation. Indeed, he goes so far as to claim that "the invention of all those machines by which labour is so much facilitated and abridged, seems to have been originally owing to the division of labour" (I.i.8, p. 20). The claim seems somewhat less extravagant when we examine it in detail. One inducement mechanism operates through specialization to generate incremental innovation.

> Men are much more likely to discover easier and readier methods of attaining any object, when the whole attention of their minds is directed towards that single object, than when it is dissipated among a great variety of things. But in consequence of the division of labour, the whole of every man's attention comes naturally to be directed towards some one very simple object. It is naturally to be expected, therefore, that some one or other of those who are employed in each particular branch of labour should

[11] This factor shares the stage with only one other: the proportion of the labor force engaged in "useful" occupations (i.e., "productive" labor in the Smithian sense).

> soon find out easier and readier methods of performing their own particular work, wherever the nature of it admits of such improvements. (Ibid.)

But this is not the only mechanism by which the division of labor leads to innovation.

> All the improvements in machinery, however, have by no means been the inventions of those who had occasion to use the machines. Many improvements have been made by the ingenuity of the makers of the machines, when to make them became the business of a peculiar trade; and some by that of those who are called philosophers or men of speculation, whose trade it is, not to do any thing, but to observe every thing; and who, upon that account, are often capable of combining together the powers of the most distant and dissimilar objects. (I.i.9, p. 21.)

This is a quite rich, if not entirely comprehensive, account of the sources of innovation. The first mechanism operates through what, following Axel Leijonhufvud (1986, p. 211), we can call the vertical division of labor, that is, through organizing production in the manner of the pin factory. The second, and perhaps more interesting, mechanism operates through the horizontal division of labor, in which stages of production spin off to become "peculiar trades."

This second mechanism deserves a closer look, for it encompasses two aspects that lead in different directions. One aspect is the benefit of specialization by "philosophers," that is, within the scientific and research professions. "In the progress of society," says Smith,

> philosophy or speculation becomes, like every other employment, the principal or sole trade and occupation of a particular class of citizens. Like every other employment too, it is subdivided into a great number of different branches, each of which affords occupation to a peculiar tribe or class of philosophers; and this subdivision of employment in philosophy, as well as in every other business, improves dexterity, and saves time. Each individual becomes more expert in his own peculiar branch, more work is done upon the whole, and the quantity of science is considerably increased by it. (Ibid.)

This (rather prophetic) account stresses the efficiencies of narrow concentration. Under one interpretation, at least, this is a model of research along the lines of the pin factory. Taking up this model leads, as we shall see, to a vision of science -- or at least research and invention -- as a routine, predictable, almost mechanical process. Yet Smith's discussion of the role of philosophers in invention has a quite different, even contradictory, aspect. For it is the job of philosophers to specialize quite literally in being generalists. Theirs is the specialism of non-specialization. Their contribution comes from observing widely and "combining together the powers of the most distant and dissimilar objects."[12]

This role of philosophers as generalists is necessarily in tension with the imperative of specialization. As Rosenberg (1965, p. 134) points out, the knack for combining "distant and dissimilar objects" is "precisely the talent which workmen become progressively less capable of exerting as the increasing division of labour continually narrows the range of the worker's activities ..." Rosenberg's concern here is with specialization at the level of factory operatives. But the same issue arises when we consider the pin-factory model applied to research. Must not also narrow specialists in scientific and technical research also progressively lose the ability for synthesis Smith sees as an important mechanism of innovation? This worry

[12] In the 1762-3 lectures on jurisprudence, Smith makes a similar point, describing philosophers as "those men who, tho they work at nothing themselves, yet by observing all are enabled by this extended way of thinking to apply things together to produce effects to which they seem noway adapted. To apply a power of a sort which has been used in that way before is what many, nay any, are capable of who are much employed in that way; but to apply powers which have never been used in that way and seem altogether unfit must be the work of one of these general observers whom we call philosophers." (Smith 1978, vi.43, p. 347.) See also the Early Draft of Part of the Wealth of Nations (paragraph 19; Smith 1978, p. 570), in which the "meer man of speculation" combines together "the powers of the most distant and opposite objects."

becomes more acute when we observe, with Rosenberg,[13] that specialization as a mechanism of innovation is subject to exhaustion -- at least at the level of factory operatives -- as the specialists use up the potential for improvement within their narrow range of experience.

I think we can resolve this apparent tension quite simply by reasserting Leijonhufvud's distinction between the vertical and the horizontal division of labor. The problems of narrow focus that Smith sees in the division of labor arise from the vertical version -- from the "deskilling" of workers (as it is now called in some circles)[14] -- that comes from organizing in the manner of the pin-shop. It is clear, however, that Smith saw specialization among philosophers as primarily a matter of the horizontal division of labor. And, as Leijonhufvud (1986, p. 212) points out, "[i]ncreased horizontal division of labor does not in general carry this implication [of deskilling] and is perhaps more likely to mean an increase in human capital per worker." This is very much the way Smith saw it. The division of labor among philosophers is not a matter of organizing research like a pin factory; scientific specialization may well increase dexterity and save time, but philosophy remains very much a craft. And, as Smith suggests in the History of Astronomy, it is a craft requiring a high level of human capital. The philosopher is trained to recognize overlooked technological gaps or

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[13] "Originally, ... when production involved a relatively simple technology, increasing division of labour, by sharpening and concentrating the focus of a worker's attention, made it easier for him to invent and to institute non-fundamental improvements within the existing technology. As technology becomes increasingly complex, however, and as the solutions to problems require the ability to draw upon sources of knowledge and experience from a wide variety of areas or disciplines, the worker is likely to be increasingly inadequate because of the exceedingly narrow repertory of materials from which he can draw." (Rosenberg 1965, p. 134.)

[14] See Marglin (1974).

scientific anomalies the way a musician is trained to recognize disharmony (Smith 1980, II.11, p. 45).

Understanding the role of the philosopher in Smith's system will require a slightly deeper plunge into this fascinating document, which contains the basis of Smith's theory of the growth of knowledge.[15] Here we learn that the phrase "combining together the powers of the most distant and dissimilar objects" is not merely a quaint way of describing the process of innovation; rather, it is a choice of words rooted deeply in Smith's theory of knowledge and discovery. This theory is fundamentally an empiricist one, influenced by Hume's Treatise (Raphael 1977). But it proceeds along characteristically Smithian lines, deploying the method of analyzing "sentiments"[16] -- in this case the sentiments of Wonder and Surprise. Our knowledge, Smith says, is in the ordinary course of things a matter of habit, of learned connections among ideas. This is the Humean part. What we think of as causal connections are really associations of ideas reinforced by our observing them continually to follow one another.

> When two objects, however unlike, have often been observed to follow each other, and have constantly presented themselves to the senses in that order, they have come to be so connected together in the fancy, that the idea of the one seems, of its own accord, to call up and introduce that of the other. If the objects are still observed to succeed each other as before, this connection, or, as it has been called, this association of their ideas, becomes stricter and stricter, and the habit of the imagination to pass from the conception of the one to that of the other, grows more rivetted and confirmed. (Smith 1980, II.7, p. 41.)

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[15] The standard secondary references here are Becker (1961); Thompson (1965); Lindgren (1969); Skinner (1972, 1974); Raphael (1977); Wightman (1975) and his introduction to Smith (1980); and the General Introduction to Smith (1980) by Raphael and Skinner.

[16] A method for which Smith was to become well known in the later Theory of Moral Sentiments.

As this habitual pattern is reinforced, it begins to form a seamless web of associations: "There is no break, no stop, no gap, no interval." (Ibid.) Moreover, the mind is increasingly serene and untroubled; "thought glides easily along ... without effort and without interruption." (Ibid.)

For Smith, then, one aspect of learning consists of "gap-filling," of weaving the web together more tightly. One way in which such gap-filling proceeds is by classification and subdivision.

> The further we advance in knowledge and experience, the greater the number of divisions and subdivisions ... we are both inclined and obliged to make. We observe a greater variety of particularities amongst those things which have a gross resemblance; and having made new divisions of them, according to those newly-observed particularities, we are then no longer to be satisfied with being able to refer an object to a remote genus, or very general class of things, to many of which it has but a loose and imperfect resemblance. (II.2, p. 38.)

It is not a far leap to connect this model of learning-as-refinement with the notion that the division of labor might lead to increases of knowledge. As the division of labor -- whether in science or in industry -- subdivides tasks, the individual acquires a much more fine-grained understanding of his or her area.

This process of learning is important; but it is not, for Smith, the only way in which knowledge grows. Nor is it indeed the process of learning most characteristic of science (or philosophy, as Smith would call it).[17] The source of major scientific advance is not the refinement of existing categories but the theoretical system-building that comes from dealing with the unexpected, with objects that don't fit into the existing categories. This is where the sentiments of Surprise and Wonder come in. An unusual

[17] Wightman (1975, p. 46) complains about the looseness with which Smith uses the terms "science" and "philosophy," but acknowledges that they are for the most part interchangeable. I return to this point in a different context below.

connection or association of events or ideas disturbs the seamless web and leaves the mind uneasy.

> We are at first surprised by the unexpectedness of the new appearance, and when that momentary emotion is over, we still wonder how it cam to occur in that place. The imagination no longer feels the usual facility of passing from the event which goes before to that which comes after. ... Those two events seem to stand at a distance from each other; it endeavours to bring them together, but they refuse to unite; and it feels, or imagines it feels, something like a gap or interval betwixt them. It naturally hesitates, and, as it were, pauses upon the brink of this interval; it endeavours to find out something which may fill up the gap, which, like a bridge, may so far at least unite those seemingly distant objects, as to render the passage of the thought betwixt them smooth, and natural, and easy. (II.8, pp. 41-2.)

What the imagination finds to fill the gap and unite the "distant objects" is "a chain of intermediate, though invisible, events." (Ibid.) Such a chain is a picture of how things work, a theoretical system or structure that connects together observed events using unobservable theoretical elements. Thus new theory is born out of the desire of the imagination to reclaim its preferred state of indolence and repose.

Skinner (1974, p. 180) has pointed out the remarkably Kuhnian sound of all this. Without wishing to stretch the point too far, we can see Smith's theory as involving a concept of "normal science" or gap-filling. When confronted with a serious enough "anomaly," the established system is disturbed and can be made right only by a "revolution" in favor of a new system that accounts for the anomaly. The new system, for both Smith and Kuhn, would also likely be a simpler account of the phenomena, one that links them together using fewer connecting principles.[18]

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[18] Smith carries this idea to mechanical invention as well, believing that innovation involves simplification through reducing the number of "principles of motion." Ref. needed. See fn at p. 66; Languages, 41; LRBL i.34v.

We now have in hand most of the elements we need to reconstruct Smith's theory of science and technology.

1. Relationship of technology to economic growth. In Smith, technological change and economic growth are inseparable. This is so because both flow from the same source: the division of labor. We might even go so far as to say that Smith's is an innovation theory of economic growth. Growth consists in the increase in the "skill, dexterity, and judgment" of labor, which is to say that it consists in the growth of knowledge in the broadest sense. Growth is driven by increases in the division of labor. This reflects, on the one hand, a continuing organizational innovation; and it leads, on the other hand, to both incremental and systemic mechanical innovations that increase the productivity of labor.[19] Moreover, Smith's theory provides considerable insight into the details of the process of technological change. A theory of learning as gap-filling might incline us to look for "gaps" in technological processes as potential foci for and inducements to innovation.[20] At the same time, Smith's insistence that innovation also involves combining the powers of "distant and dissimilar objects" should alert us to the sometimes unpredictable character of inventive activity.

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[19] Whether we can identify a labor-saving bias in Smithian innovation is problematical. It's clear that Smith saw innovation as "abridging" labor; but, to the extent that, as the previous footnote suggests, Smithian innovation is mechanically simplifying, it is conceivable that there is some offsetting capital-saving involved. Moreover, as Leijonhufvud (1986, p. 210) has argued, the division of labor as an organizational innovation is capital-saving: where once each craftsman needed a complete set of tools, now each specialized worker needs only one tool. For a related argument for the capital-saving effect of organizational innovation, see Field (1986).

[20] Compare Rosenberg (1976, chapter 6), who discusses technological "imbalances" and "bottlenecks" as clues to the direction of technological change.

2. Relationship of science to technological change. Even though Smith wrote before an age in which the importance of science to industry was an obvious fact, it is nonetheless clear that he appreciated the potential contribution of the scientist -- the "philosopher," as he puts it -- to technical advance. It is also clear that Smith sees the role of the scientist as different from that of the technologist (or artisan) and from that of the worker. But the difference in these roles for Smith does not consist in a sequential hand-off of invention from the scientist to the technologist to the worker. Rather, each is the source of a different type of innovation.

Indeed, Smith sees the logic of discovery to be fundamentally similar among the philosopher, the artisan, and the worker. In both the Wealth of Nations and the History of Astronomy, he moves with striking ease between the level of mechanical contrivance and the level of scientific theory. In the Wealth, as we have seen, Smith portrays philosophers as a quite direct source of mechanical innovation. He credits them with having invented the water and wind mills as well as the steam engine.[21] And in the History of Astronomy, Smith uses the work of artisans to illustrate his theory of scientific knowledge. (Smith 1980, II.11, pp. 44-45.) All of this underscores how similar for Smith is the process of technological change and the process of scientific advance.[22] Philosophical systems, as he says in the History of Astronomy, "in many respect resemble machines. A machine is a little system, created to perform, as well as to connect together, in reality, those

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[21] In the Lectures on Jurisprudence (Report of 1762-3), vi.43, (1978, p. 347), and in the Early Draft, 19, (1978, p. 571).

[22] This similarity is rooted in many ways in Smith's "Newtonian" conception of the philosophy of science, about which I will have more to say in the next section.

different movements and effects which the artist has occasion for. A system is an imaginary machine invented to connect together in the fancy those different movements and effects which are already in reality performed." (1980, IV.19, p. 66.)

The modern reader might be inclined to accuse Smith of vagueness about the exact mechanism by which the speculations of philosophers are supposed to be translated into technological practice. Such an accusation would not be entirely without merit, even if we could extenuate Smith by noting that the mechanisms of translation were perhaps fewer and less complicated in his day than in ours. I would argue, however, that Smith is vague only when viewed through a certain lens; the appearance of vagueness diminishes when we notice that, for Smith, the relationship between the work of scientists and that of technicians simply does not _involve_ a "translation" from one to the other. Smith did not see scientist, engineer, and worker as sequential stages in the production of homogeneous technological advance. Rather, he saw them as autonomous sources of very different _kinds_ of technological improvements. Smith conceived of invention as a sort of hierarchy.[23] Workers, with a narrow (deskilled?) field of vision, are responsible for small and incremental advances within the existing technical scheme. Artisans (or "artists"), with a somewhat wider field of experience, are responsible for somewhat more systemic improvements.[24] But only philosophers, those specialists in the distant and dissimilar, are responsible for the most systemic and most radical changes.[25] Indeed, Smith comes very close to _defining_ a philosopher

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[23] A point also made by Rosenberg (1965, p. 132-133).

[24] The ranks of artists would include the makers of machines -- the capital-goods manufacturers -- whose occupations have become peculiar trades. (Smith I.i.9, p. 21; cf. Rosenberg 1965, p. 132.)

as someone capable of major discovery. "When an artist makes any such discovery he showes himself to be not a meer artist but a real philosopher, whatever may be his nominal profession." (Early Draft, 19, p. 570.) If there is an sequential aspect to this hierarchy, it is of a very Schumpeterian sort: the philosopher introduces major new technologies, which are then improved upon by workers and artisans. (Ibid.)

3. Science and technology policy. The implications for policy of Smith's system lie in two related areas: (1) increasing the diversity of ideas and approaches in society, principally by extending the division of labor; and (2) setting up institutions to harness individual self-interest, curb its excesses, and channel it into socially productive directions.

As we saw, the (vertical) division of labor operates by focusing the worker's attention; it therefore has a narrowing effect that may eventually lead to an exhaustion of the possibilities for incremental technological improvement. Even so, says Smith, the division of labor increases technological change overall because, by increasing the diversity of activities in society, it throws up greater technological opportunities for the professional generalists to exploit.

> In a civilized state, ... though there is little variety in the occupations of the greater part of individuals, there is an almost infinite variety in those of the whole society. These varied occupations present an almost infinite variety of objects to the contemplation of those few, who, being attached to no particular occupation themselves, have leisure and inclination to examine the occupations of other people. The contemplation of so great a variety of objects necessarily exercises their minds in endless comparisons and combinations, and renders their understandings, in an extraordinary degree, both acute and comprehensive. (Smith 1976, V.i.f.51, p. 783.)

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[25] Early Draft, 17-20 (1978, pp. 569-570); Lectures on Jurisprudence (Report of 1762-3), 41-43 (1978, pp. 346-347).

While perhaps "deskilling" factory operatives, the division of labor nonetheless increases the collective level of skill and knowledge in the society. (Rosenberg 1965, p. 137.)

Smith's principal policy prescription, then, is to allow the division of labor to increase. Since the division of labor is limited by the extent of the market, and since protective trade practices restrict the market, free trade is called for as a general policy. Indeed, as Smith's friend Hume pointed out, international trade has a direct as well as an indirect effect on the level of diversity in the society. "And this perhaps," Hume says, "is the chief advantage which arises from a commerce with strangers. It rouses men from their indolence; and presenting the gayer and more opulent part of the nation with objects of luxury, which they never before dreamed of, raises in them a desire of a more splendid way of life than their ancestors enjoyed."[26] (Hume 1955, p. 14.)

This is an argument for foreign trade different from what we are used to in economics since Ricardo. It is also not an unqualified argument, nor is it one made in an institutional vacuum. Smith's laissez-faire prescriptions always take form around a concern for the structure of incentives. (Rosenberg 1960.) This helps explain a rather striking omission in Smith. Nowhere do we find a discussion of the knowledge externality and the need to subsidize inventive activity. First of all, Smith sees invention as more a matter of serendipity than of active "production." Now, one could, of course, subsidize the education and leisure of philosophers, and thereby expect more inventive activity. But Smith is suspicious of subvention. He is not

[26] Novelty plays for Hume a role similar to that of Surprise and Wonder for Smith -- which is not, er, surprising, since both systems find their roots in Hume's Treatise. See Eugene Rotwein's introduction to Hume (1955), p. xxxiv. See also Rosenberg (1976, pp. 89-93).

reluctant to advocate government intervention where he thinks it necessary; but he is very careful about the likely incentive effects of that intervention. And he does in fact recommend that government actively promote the study of science. This recommendation comes as part of a discussion of religion. Increasing diversity in society and freedom of religion, he says, is likely to lead to many separate sects. Some of these, especially those that will appeal to the lower orders of society, are likely to tend toward fanaticism and toward extremely narrow and severe moral codes.[27] Smith offers "two very easy and effectual remedies ... by whose joint operation the state might, without violence, correct whatever was unsocial or disagreeably rigorous in the morals of all the little sects into which the country was divided."

> The first of those remedies is the study of science and philosophy, which the state might render almost universal among all people of middling rank and fortune; not by giving salaries to teachers in order to make them negligent and idle, but by instituting some sort of probation, even in the higher and more difficult sciences, to be undergone by every person before he was permitted to exercise any liberal profession, or before he could be received as a candidate for any honourable office of trust or profit. If the state imposed upon this order of men the necessity of learning, it would have no occasion to give itself any trouble about providing them with proper teachers. They would soon find better teachers for themselves than any whom the state could provide for them. Science is the great antidote to the poison of enthusiasm and superstition; and where all the superior ranks of people were secured from it, the inferior ranks could not be much exposed to it. (Smith 1976, V.i.g.14, p. 796.)

This passage captures the flavor of the classical liberalism of the Scottish Enlightenment: an emphasis on diversity and individual autonomy tempered by a bias toward science and enlightened learning. Notice Smith's insistence that the state encourage science in a way that harnesses rather than subverts

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[27] The effects of which are similar to the narrowing influence of the division of labor in manufacturing.

individual self-interest. Notice also that this comes close to a merit-good argument for the promotion of learning. Encouraging science is important not because it increases productivity -- at least not directly -- but because it improves human capital and helps counteract the the more socially deleterious effects of the division of labor. Indeed, science shares the stage with another remedy: "the frequency and gaiety of publick diversions." (Ibid.)

V.

In his History of Economic Analysis, Schumpeter (1954, pp. 491-2) attempts -- quite rightly -- to exonerate J.-B. Say from the charge that he was a mere epigone of Smith. Say was misunderstood in part, says Schumpeter, because his easy style of writing led to a reputation as a popularizer, a label that testifies to the enduring confusion of turgid prose with deep thought. But Say is also miscast as a slavish follower of Smith because, in Schumpeter's view, Say's intellectual heritage is more properly sought among his own French predecessors -- especially Cantillon (if he can be considered French) and Turgot -- rather than in the hills of Scotland. We should remember, of course, that Smith himself was also influenced by Cantillon and Turgot; and Say was certainly influenced strongly by Smith and the Scottish tradition. So this, then, is how I wish to portray Say on questions of science and technology: fundamentally on the Smithian wavelength, but with many ideas either original to him or influenced by the French intellectual tradition. In some respects, I will argue, Say builds on Smith's analysis; in other respects, he parts from Smith in ways that anticipate aspects of the present-day neoclassical economic theory of science and technology.

One very "modern" element in Say is the clear distinction between scientific research and technological innovation. "If we examine closely the workings of human industry," he says in the Treatise, "it will be found, that, to whatever object it be applied, it consists of three distinct operations."

> The first step toward the attainment of any specific product, is the study of the laws and course of nature regarding that product. A lock could never have been constructed without a previous knowledge of the properties of iron, the method of extracting from the mine and refining the ore, as well as of mollifying and fashioning the metal.
>
> The next step is the application of this knowledge to an useful purpose: for instance, the conclusion, or conviction, that a particular form, communicated to the metal, will furnish the means of closing a door to all the wards, except to the possessor of the key.
>
> The last step is the execution of the manual labour, suggested and pointed out by the two former operations; as, for instance, the forging, filing, and putting together of the different component parts of the lock. (Say 1824, I.vi; vol. I, p. 22.)

This is on the one hand clearly Smithian: the three operations are reflections of the division of labor.

> These three operations are seldom performed by one and the same person. It commonly happens, that one man studies the laws or conduct of nature; that is to say, the philosopher, or man of science, of whose knowledge another avails himself to create useful products; being either agriculturist, manufacturer, or trader; while the third supplies the executive exertion, under the direction of the former two; which third person is the operative workman or labourer. (Ibid.)

Yet, unlike Smith, Say gives this tripartite breakdown a much more sequential force. The knowledge of the properties of metal comes before the invention of the lock. Science precedes innovation. "Take for example the sack of wheat," he says, "or the pipe of wine."

> The first stage toward the attainment of either of these products was, the discovery by the natural philosopher, or geologist [agronome], of the conduct and course of nature in the production of the grain or grape; the proper season and soil for sowing or

> planting; and the care requisite to bring the herb or plant to maturity. The tenant, if not the proprietor himself, must afterward have applied this knowledge to his own particular object, brought together the means requisite to the creation of an useful product, and removed the obstacles in the way of its creation. Finally, the labourer must have turned up the soil, sown the seed, or pruned and bound up the vine. (Say, loc. cit., p. 23.)

It is not clear how we should view this. Taken literally, this "conjectural history" of production is probably quite false: wheat and wine were produced long before there was any scientific understanding of agronomy, meteorology, or oenology.

This apparent stress on the primacy of science is probably what is most French in Say. We see it in the writing of the French Enlightenment -- in Condorcet and Turgot,[28] who wrote paeans to the role of science in human progress.

In Say's later Cours complet, however, we get a somewhat more nuanced picture of the sources of innovation. "The great revolution that has operated in the sciences since Bacon and Galileo," he says,

> and which has rendered our knowledge more certain while founding it only on conclusive and well-posed experiments, must be followed by very great progress in the arts, and this has been the case in fact. The inventions and improvements of the last two centuries in industry are immense and never cease to strike with astonishment all those who have had any occasion to observe them and who have recognized their implications. (Say 1828, vol. V, chapter, XXIX, p. 313, translation mine.)

Another testament to the preeminence of science in technological advance? Maybe not, for Say continues immediately:

> Of these improvements some are due to chance, as well as to others more ancient; they are even more numerous than before, because the arts being more cultivated, the occasions for chance have been multiplied. The others are due to research, to experiment, to trials by artists. (Ibid.)

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[28] Condorcet, Esquisse d'un Tableau Historique des progrès de l'esprit humain. (Ref needed.); Turgot, "A Philosophic Review of the Successive Advances of the Human Mind," in Meek (1973).

This begins to sound a bit more like Smith: scientists, technologists, and laborers are to some extent autonomous sources of innovation.

It is clear that Say sees science and technology as imparting quite distinct kinds of knowledge.[29] "Our scientific knowledge," he says, "(of which the arts are simply, as we have seen, the useful applications) have as their basis the observations and experiments of scientists; but independently of the experiments that serve as the foundation of science, there are others that serve as the foundation of the arts." (Say 1828, op. cit., p. 311.) Thus technological experimentation is a major source of innovation. Such experimentation may draw on scientific knowledge; but it is not simply a logical application of that knowledge. "The man who understands plant science most completely, should he wish to set himself to cultivate his land without having received a good deal of practical knowledge, would probably make a quite bad cultivator." (Ibid. See also Say 1824, I.vi; vol. I, pp. 26-27.)

One form of innovation in the arts is the incremental advance of the worker who responds to bottlenecks in the production process. "A worker seeks to save himself from an inconvenience that appears continually in the

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[29] I have said very little of Say's philosophy of knowledge and its influence on his economic theory of science and technology. His longest discussion of methodological issues is in the fist volume of the Cours complet of 1828. Here he comes out strongly in favor of an empiricist theory of knowledge. "Observation, experiment," he writes in a later volume, "here is the basis of all human knowledge." (Say 1828, vol. V, ch. XXVII, p. 278, translation mine.) This already sets Say apart from the Cartesian tradition usually associated with the French Enlightenment. In his brief history of thought at the end of volume VI, for example, he accuses Quesnay of too much metaphysics and not enough observation. (Say 1828, vol. VI, p. 388.) Say appeals frequently to the ideal of Baconian science, but it's not clear that his theory of knowledge is inductivist. I will not mount the argument here, but I think it possible to show that Say's position is probably as close to that of the Scottish school -- as exemplified by Dugald Stewart, whom Say quotes at the beginning of his methodological discussion -- as to inductivism. I will have more to say about these issues below in the context of John Rae.

course of his work, and he sometimes circumvents it in a happy manner; another advises him of a new procedure that has worked for him; the knowledge propagates from one workshop to another, and the arts enrich themselves from it." (Say 1828, op cit., p. 313.) Innovations promising greater payoffs, however, require long and costly experiments. These, Say insists, are fraught with uncertainty.

> One hears little of attempts that fail; they are always more numerous than attempts that succeed; and when they succeed, they never tarry of becoming the object of quick competition, and ultimately it is the public alone who profit from them. Each of the manufacturers who today work cotton, now that the procedures for this are known to everyone, gains no advantage over the other manufacturers, caetera pariter; but the public has gained the enjoyment at very low prices of a multitude of cotton fabrics previously unknown. (Say 1828, op cit., p. 314.)

Here we begin to see the two themes that animate Say's theory of science and technology: the uncertainty and high failure rate of technological experimentation; and the rapid diffusion of innovation through imitation -- the knowledge externality.

Technological experimentation is thus for Say the major source of innovation in business. This in fact is part of Say's explanation for why agriculture is more backward than industry. In agriculture, experiments take at least one complete growing season to (if you'll pardon the expression) bear fruit. In industry, by contrast, experiments have a much quicker turn-around time, so the trial-and-error learning process can proceed much faster. As part of this discussion, Say also adumbrates the concept of what Rosenberg (1982, chapter 6) has recently called "learning by using."[30] He also stresses

[30] "The execution in the large of a procedure that has never been tried out except in the small, is always a more-or-less hazardous experience. A little machine tells us nothing about what will result from a large machine constructed on exactly the same plan, and we do not know completely what the effect will be until after having tried it out over a sufficiently long period." (Say 1828, vol. V, ch. XXIX, p. 321,

that learning by experiment is important even in what we now call the service sector. Finding out about new markets and new techniques of distribution -- including voyages of discovery into unknown parts of the globe -- are part of the same process of learning, and are subject to the same uncertainties and the same problems of appropriability. (Say 1828, op. cit., pp. 317-323.)

With this as background, let me try to delineate Say's economic theory of science and technology.

1. Relationship of technology to economic growth. Say is among the clearest of the classicals in associating technological change with economic growth. The division of labor lies at the back of his discussion, especially in the division among the scientist, the technologist, and the worker. But the division of labor does not dominate the picture as it did in Smith; Say also emphasizes chance discoveries and, especially, imitation and diffusion as sources of economic progress.

Indeed, we can couch Say's view of the relationship of technological change to growth in a way that makes him sound modern indeed. In several places, Say accuses Smith of a particular confusion about the interpretation of innovations induced by the division of labor. After paraphrasing Smith's discussion of how specialization can lead to incremental innovation -- and after quoting at length Smith's quite apocryphal story of the invention of the valve feedback-linkage on the steam-engine[31] -- Say charges Smith with confounding

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translation mine.)

[31] Wealth of Nations I.i.8 (1976, p. 20). Smith claims -- apparently wrongly -- that this linkage was invented by a boy who, charged with the task of opening and closing the valve at the right points in the engine's cycle, preferred to be off playing with his chums.

the discovery that one can in fact attribute to the division of labor, with the creation of utility that is the fruit of the unceasingly repeated action of a natural instrument; it is in this instrument, in the vaporized water, that lies the force that equilibrates the lever to which the valve responds. It is this force that replaces what previously was sought in the young boy; but it is not the action of the first inventor, however ingenious it might have been, that is the generator of all the forces to which it has since merely furnished the idea of using. If the first who thinks of using a force furnished by nature, was the author of all the work executed by that force, the inventor of the steam engine itself would have the priority of being the author of all the works that we owe, and that we will henceforth owe, to steam engines. (Say 1828, vol. I, ch. XV, pp. 344-45, translation mine. See also the similar passage in Say 1824, I.iv; vol. I, p. 17.)

This is, of course, in large part a debate over words. But it does show the extent to which Say wishes to limit the "production of utility" to factors of production (capital and labor) in conjunction with natural agents (raw materials of various sorts, along with the laws of physics). Knowledge is not a factor of production. On the one hand, this way of looking at the matter is quite modern -- that is, neoclassical. It is as if Say is maintaining that output is the result of given inputs like capital, labor, and raw material. Knowledge is not directly productive in the sense of being a factor of production;[32] rather, it <u>indexes</u>, in effect, the level of output obtainable from given inputs. On the other hand, this arguably also sounds a bit French -- that is, physiocratic. Only "free gifts of nature" are directly productive; innovation is merely the revelation of how better to make use of the powers nature provides.

2. <u>Relationship of science to technological change</u>. For Say more than for Smith, science contributes to and indeed leads technological advance. Say is clear that scientific knowledge is different in character from

[32] This contrasts sharply, as we shall see, with the view of John Rae, who saw <u>only</u> invention as productive and the combination of existing inputs as essentially unproductive.

technological knowledge and proceeds from a different source.[33] Moreover, much innovation, especially of the incremental sort, proceeds in the absence of scientific understanding. Nonetheless, Say maintains, scientific advance contributes to -- and somehow precedes -- technological application. This is also a very modern view, even down to its vagueness about the exact mechanisms by which scientific knowledge translates into technological or practical knowledge.

3. Science and technology policy. There is much in Say's policy prescriptions that Smith would have found congenial. For one thing, Say favors free trade. He also opposes most forms of government regulation or direction of production. He does this for reasons that, if anything, are even more institutional in emphasis than those of Smith. In modern terms, we might say that Say saw the disadvantages of "government failure" as more likely on the whole to outweigh those of "market failure."[34] Also like Smith, Say was willing, however, to make exceptions to the general principle of laissez-faire when the benefit to society warranted it. For example, Say like Smith called for general education, and insisted on diversity in its provision.[35] (Say 1828, vol. V, ch. XXVII, p. 286.)

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[33] A difference, however, that may be as much the result of the division of labor as of any inherent epistemological gulf between the two kinds of knowledge.

[34] In fact, there is much in Say that anticipates the present-day Public Choice school. Speaking of nationalized industries, for example, he argue that, although such industries are frequently money-losers, they are typically maintained "because a small number of men profit from them." Why is this possible? "The interest that they defend is personal, active: the public interest that they usurp is vague, less concentrated." (Say 1828, vol. V, ch. XXVI, p. 271, translation mine.) This is a clear statement of one of the central notions of Public Choice.

[35] Say's reasons for opposing state -- or Church -- monopoly in education again underscore the Public Choice flavor of his analysis. Both Smith and Say see the issue in terms of what is now called a principal-agent

When it comes to matters of science and technology, in fact, Say is far more willing that Smith to entertain the possibility of government involvement. This partly because Say gives to science and industrial experiment a larger role in growth than does Smith -- or at least a role less tied to the division of labor, which implies the possibility of spurring growth (through science and technology) quite independently of advancing the division of labor. Say's more activist view of science and technology policy is also -- and perhaps more importantly -- influenced by his concern with the knowledge externality.

> The philosopher, the man who makes it his study to direct the laws of nature to the greatest possible benefit of mankind, receives a very small proportion of the products of that industry, which derives such prodigious advantage from that knowledge, whereof he is at the same time the depository and the promoter. The cause of his disproportionate payment seems to be, that, to speak technically, he throws into circulation, in a moment, an immense stock of his product, which is one that suffers very little by wear; so that it is long before operative industry is obliged to resort to him for a fresh supply. ... [T]he knowledge, acquired with so much difficulty, is probably transmissible in a few pages; and, through the channel of public lectures, or of the press, is circulated in much greater abundance, than is required for consumption; or rather, it spreads of itself, and, being imperishable, there is never any necessity to recur to those, from whom it originally emanated. (Say 1824, II.vii.2; vol 2, p. 54. Compare also I.vi and I.vii; vol. I, pp. 25 and 33.)

Notice how Say's notion of knowledge as "imperishable" adumbrates the modern public-finance notion of nonrivalry in consumption. And the policy implication he gleans from this insight is also the modern one. Since it is the public who benefit from advances in science and technology, "it is not

problem. Smith stresses the incentives for shirking that attend direct subsidy of teachers' salaries. But Say is more worried about the ability of government or the religious orders to propagandize in their own interests instead of educating liberally or in the student's interest. (Say 1828, vol. V, ch. XXVII, pp. 284-86.) Say's earlier discussion in the Treatise is more Smithian in form; but there too he worries about the dangers of entrusting the teaching of morals to state-run institutions. (Say 1824, III.vi; vol. II, p. 182.)

contrary to natural justice that it should be the government, administrator of the public fortune, who pays for them."[36] (Say 1828, vol. V, Ch. XXIX, p. 315, translation mine.)

This principle applies not only in the realm of basic science but also in technology. Say is quite clear in assigning a role to government in supporting what we now call industrial R&D.

> In all but ... extraordinary cases, it is perhaps prudent to defray the charges of experiments in industry, not out of the capital engaged in the regular and approved channels of production, but out of the revenue that individuals have to dispose of at pleasure, without fear of impairing their fortune. The whims and caprices that divert to a useful end the leisure and revenue which most men devote to mere amusement, or perhaps to something worse, cannot be too highly encouraged. I can conceive no more noble employment of wealth and talent . A rich and philanthropic individual may, in this way, be the means of conferring upon the industrious classes, and upon consumers at large, in other words, upon the mass of mankind, a benefit far beyond the mere value of what he actually disburses, perhaps beyond the whole amount of his fortune, however princely it may be. Who will attempt to calculate the value conferred on mankind by the unknown inventor of the plough?
>
> A government, that knows and practices its duties and has large resources at its disposal, does not abandon to individuals the whole glory and merit of invention and discovery in the field of industry. The charges of experiment, when defrayed by the government, are not subtracted from the national capital, but from the national revenue; for taxation never does, or, at least, never ought to touch any thing, beyond the revenues of individuals. The portion of them so spent is scarcely felt at all, because the burthen is divided among innumerable contributors; and, the advantages resulting from success being a common benefit to all, it is by no means inequitable, that the sacrifices, by which they are obtained, should fall on the community at large. (Say 1824, I.vi; vol. I, pp. 27-28.)

[36] "All that the public would have a right to plead," he continues, "is that this branch of administration not be confided to men to little enlightened to appreciate the importance of a discovery or the inappropriateness of a proposed method, those who would constantly deliver the public to pointless expenditures, to a purely gratuitous loss." (Say 1828, vol. V, Ch. XXIX, p. 315, translation mine.)

The first paragraph is extremely classical, with its stress on transferring income from unproductive to productive activities; the second paragraph -- putting aside the curious notion that taxing individual revenue doesn't affect capital formation -- is quite modern.

Nor, believes Say, should government neglect basic science.

> It is observable, too, that the sacrifices made for the enlargement of human knowledge, or merely for its conservation, should not be reprobated, though directed to objects of no immediate or apparent utility. The sciences have an universal chain of connexion. One which seems purely speculative must advance a step, before another of obvious and great practical utility can be promoted. Besides, it is impossible to say what useful properties may lay dormant in an object of mere curiosity. When the Dutchman Otto Guericke struck out the first sparks of electricity, who would have supposed they would have enabled Franklin to direct the lightning, and divert it from our edifices, an exploit apparently so far beyond the powers of man. (Say 1824, I.xviii; vol. I, p. 162.)

This emphasizes again Say's conception of science as deeply uncertain and unpredictable. Notice also the idea that the sciences are bound by a universal chain of connection -- a way of putting things that recalls Smith's theory of the growth of knowledge. In Say, this chain of connection has clear practical implications for policy. Economic growth is enhanced for a nation not by emphasizing science over technology (or vice-versa) but by keeping at the forefront in all three areas: science, technology, and practice. "Industry is, in all cases, divisible into theory, application, and execution. Nor can it approximate to perfection in any nation, till that nation excel in all three branches. A people, that is deficient in one or other of them, cannot acquire products, which are and must be the result of all three." (Say 1824, I.vi; vol. I, p. 23.)

VI.

Charles Babbage -- mathematician, inventor, and Cambridge don -- is a figure on the fringes of classical political economy. But his intersection with political economy was precisely in the area of science and technology, of which he was an important practitioner and advovate.

Babbage's On the Economy of Machinery and Manufactures (Babbage 1835; first edition 1832) is a marvelous disquisition on that Smithian theme: the division of labor. Inspired by his work on the calculating engine,[37] Babbage follows the trail of the division labor through the labyrinth of early-Victorian manufacturing technology. He shows how the principle is applied in a diversity of industries, providing what is in effect an early tract on scientific management. Babbage was also extremely active in the promotion of science and scientific education in Britain.[38] He was, for example, a founder of the British Association for the Advancement of Science and the author of a couple of desultory and tendentious tracts on the state of British science and technology.[39] Taken together, these works allow us to piece together Babbage's theory of science and technology.

Tucked away in The Exposition of 1851 is a discussion of Babbage's work on the Analytical Engine. The chapter starts with these words.

> It is not a bad definition of man to describe him as a tool-making animal. His earliest contrivances to support uncivilized life, were tools of the simplest and rudest construction. His latest achievements in the substitution of machinery, not merely for the skill of the human hand, but for the relief of the human intellect, are founded on the use of tools of a still higher order. (Babbage

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[37] A mechanical calculator that, while never actually finished, is classed as an early precursor of the modern computer.

[38] See generally Cardwell (1957).

[39] Reflections on the Decline of Science in England (1830) and The Exposition of 1851 (1851).

1851, p. 173, emphasis original.)

This passage signals two concerns for Babbage: the role of the tool-making process in mechanical innovation and, perhaps more interestingly, the role of tools -- and, as we will see, the divsion of labor -- in scientific advance.

Babbage's discussion of his research on the Analytical Engine tells a story that may sound familiar. He found his progress continually impeded by deficiencies in complementary areas of technology -- impeded, that is to say, by technological gaps and bottlenecks. Making the gears necessary for the machine required advancing the arts of machine tools, mechanical drawing, and mechanical notation. These are all what we might call "generic" technologies, technologies whose improvement benefits other technological processes. The innovations Babbage and his workmen made soon diffused to other workshops. "Several of the most enlightened employers and constructors of machinery, who have themselves contributed to its advance, have," he says, "expressed to me their opinion that if the Calculating Engine itself had entirely failed, the money expended by Government in the attempt to make it, would be well repaid by the advancement it had caused in the art of mechanical construction" (1851, p. 176).

The Analytical Engine is a symbol of Babbage's views in another respect: for it represents a machine designed to facilitate and abridge intellectual rather than mechanical labor. This idea of applying technology and the division of labor to mental effort appear also in Machinery and Manufactures. Here he argues that "the division of labour can be applied with equal success to mental as to mechanical operation, and that it ensures in both the same economy of time." His example is a French effort to produce mathematical tables, a task requiring a large number of computations. While pondering the problem, the person in charge of the effort, a M. Prony, stumbled upon a copy of the Wealth of Nations in a book store and opened it to a discussion of the division of labor. Voila! The task was soon subdivided and parcelled out to numerous calculators in a hierarchical fashion.

This is exactly a model of science on the pin-shop model. But Babbage does not seize upon it as a model for the organization of all science -- though he does see the French scheme as a model for the organization of enterprise and manufacture, especially in its hierarchiacal aspects.

Babbage does, of course, very much think that science ought to be reorganized. His message is a consistent one. Science in Britain is in sorry shape because (1) it is not sufficiently a professional activity; (2) it is badly organized; and, relatedly, (3) it doesn't pay well enough. He charges the Royal Society with mismanagement and with consisting of far too many amateurs and too much deadwood. And he argues repeatedly for rewards and offices for scientists and inventors.

In short, Babbage fits well into our Smithian "school." Like Smith, he begins from the principle of the division of labor. Like Say -- and, as we will see presently, like John Rae as well -- Babbage is also concerned with the plight of the inventor and the scientist, and sees a strong role for governnment in boosting technology and supporting science.

VII.

The Smithian economic theory of science and technology finds its best exemplification and fullest development in a strange and obscure place: John Rae's Statement of Some New Principles on the Subject of Political Economy (1834).

This may seem at first an astounding assertion. For Rae's treatise is quite pointedly an attack on Smith, with whom he differs on both points of methodology and conclusions of policy. Indeed, Rae's New Principles uses an attack on the Wealth of Nations as a rhetorical focus, in much the same way that Smith's book was an onslaught against mercantilism. Nonetheless, I do intend to portray Rae's theory as genuinely and fundamentally Smithian. I will do this first by showing its similarity in substance to Smith; I will then return to examine Rae's disagreement with Smith, arguing that much of the contention arises from Rae's misunderstanding and misrepresentation of Smith's position and from problems inherent in Rae's own methodology (which is Baconian inductivism). What disagreements remain are the gentle ones of emphasis characteristic of members of the same school rather than the irreconcilable ones typical of fundamental antagonists.

Like Smith, Rae sees economic progress as tied to the level of skill, dexterity, and judgment of labor. But he sees increases in this knowledge as stemming not indirectly from the division of labor but directly from the human faculty of invention, to which he sings a hymn of praise.

> To us, it is the great immediate maker of almost all that is the subject of our thoughts, or ministers to our enjoyments, or necessities, nor is there any portion of our existence, which is not indebted to its antecedent forming power. Wherever it really is, it is recognised as one and the same, by this formative capacity. It is always a maker, and, in a double sense, a maker. From the depths of the infinity lying within and without us, it brings visibly before us forms previously hidden. These are its first works. But neither does it intend to stop, nor does it, in

> fact, stop here. The forms which its eye thus catches, and its skill "bodies forth" into material shape, pass not away; they remain. Things of power, true workers, drawing to themselves, and fashioning to their semblance, the changeable and fleeting crowd, that time hurries down its stream, they are, in truth, the only permanent dwellers in the world, and rulers of it. (Rae 1834, p. 208.)

These images of domination and majesty call to mind nothing so much as the Novum Organum, which, as they say, is no coincidence, since Rae is an avid and avowed follower of Bacon.

The first part of Rae's chapter on invention (of which the passage above is the first paragraph) is given over to a poetic disquisition on the inventor. The flavor is as much Schumpeterian as Baconian. Rae distinguishes the "real inventor" from the "mere transmitter of what is already known" (p. 213). Like Schumpeter -- and, as we saw, like Smith and Hume -- Rae sees the human mind as predisposed to indolence, to running in the accustomed channels of habit. The real inventor, like the Schumpeterian entrepreneur, is an individual capable of breaking the bounds of routine. Mere transmitters, by contrast, "neither oppose, nor direct the current" (Ibid). But Rae's inventor pays a price for breaking the bonds of routine -- or, rather, is paid too low a price in view of the benefits he or she confers on society. "It is enough to restrain the increase of science," says Rae in the words of Bacon, "that energy and industry so bestowed, want recompense. The ability to cultivate science, and to reward it, lies not in the same hands." (Novum Organum, Book I, Aphorism 91, quoted in Rae 1834, p. 216). This is clearly a version of the Pigovian idea that the social return to inventive activity exceeds the private; and it is a theme that animates much of Rae's chapter.

But Rae is not content to lament the plight of the inventor. He moves on to propose a detailed theory of the evolution of science and technology. His scenario has three stages.

> 1st. Arts change materials. It having become difficult or impossible for men to obtain the materials with which they had been accustomed to operate, they have been led to adopt others, and, retaining the knowledge of the qualities and powers of the old, have added to them those of the new.
>
> 2d. Different arts adopt the same materials. Men have been encouraged to operate with new materials, from materials being presented to them, evidently better suited to their purposes than the old, could they be made submissive to their art.
>
> 3d. The operation of these circumstances, has slowly diminished the propensity of mankind to servile imitation, and given a beginning to science, by bringing to light the qualities and powers common to many materials; the general principles of things. (Rae 1834, p. 224.)

In the first stage, people are roused from their preferred state of technological indolence by the press of necessity. A shortage (change in the relative price?) of materials commonly in use forces adaptation to new materials. Technological change for Rae is thus not "neutral," at least in its early stages, and can be induced by changes in factor prices. An example of this first-stage process would be when an old technology is transferred to a country with a different resource endowment.[40]

The next stage is one we could characterize as one of <u>technological convergence</u>, to borrow a term from Rosenberg (1976, p. 16 and <u>passim</u>). "When arts are brought together," says Rae, "they borrow from each other. Men perceive that some materials, or instruments, or processes, employed in the one, could they be transferred to the other, would be the cause of it yielding larger returns" (p. 237). Such convergence requires that many arts

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[40] Rae uses as examples the plough and sacred architecture.

be cultivated simultaneously so that cross-fertilization can take place; and innovative activity is thus heightened by trade and commerce and by the intermingling of cultures. "When individuals meet from different countries, they reciprocally communicate and receive the arts of each, adopt such as are suited to their new circumstances, and probably improve several. Servile imitation can there have no place, for there is no common standard to imitate. Countries again, where only one art is practiced, and where the population is composed of one unmingled race, are generally servilely imitative" (p. 238). Notice how similar this is to the views of Smith and Hume. Innovation consists in seeing -- or making -- connections among things. And diversity is essential to this process.

As technological convergence progresses and technology becomes more sophisticated, people begin to see the general principles underlying the technology. "The progress of the knowledge of the natures and qualities of particular substances," says Rae, "gradually introduced a knowledge of the properties and natures of substances in general. Men first see in the concrete, afterwards in the abstract" (p. 239). Thus is science born from technology. With Bacon, Rae believes that science depends "on the antecedent progress of the arts" (p. 240). "It is only in modern times," he says, "that the science of experience has come to form an element of importance, in the general advance of invention." (Ibid). This too is not far from Smith. As I argued above, Smith saw the the "philosopher" as a source of the more systemic and advanced inventions; and, since the role of the scientist as becomes more important as the division of labor throws up an increasing number and diversity of ideas, it is thus fair to say that Smith also saw the development of science as tied to the antecedent development of the arts.

The similarity goes deeper. Despite Rae's protestations to the contrary, there is, I argue, considerable similarity between his theory of discovery and that of Smith. In order to see this, we need to examine the debate more closely. Rae's plea is for inductivism in the manner of Bacon. This doctrine holds that knowledge is acquired by a movement from the particular to the general; that is, discovery takes place, and knowledge is justified, by acquiring facts from experience and somehow allowing those facts to dictate theory. This is to be contrasted with various forms of deductivism, which reason from axioms or definitions to general conclusions. In some forms of deductivism, especially those associated with Scholastic thought, the source of the axioms or definitions is not principally (or even at all) experience. In other versions, the first principles from which deduction proceeds may be gathered from experience. But, in either case, experience does not lead logically or directly to these general principles.

Rae quite rightly sees Smith as a deductivist of this latter kind. For Smith, one starts with experience in a staunchly Humean way. But general principles arise in an extra-logical way as an act of creation; they are not deduced from experience. Smith calls his methodology "Newtonian" in that he seeks the simplest set of principles that connects together the phenomena under study. Rae explicitly criticizes Smith for this. He cites the History of Astronomy, and expresses some sympathy with Smith's conception of intellectual system-building. "Nor is it to be disputed," Rae says, "that a general system of the sort, besides the pleasure and the advantage derived from it, is likely to be nearer the truth than speculations of the same nature, confined to particular parts." But, he continues, this is not science because it is not induction. When "the loose and popular principles on which such a system proceeds, are adopted as demonstrative axioms, the discoveries of real science," then "instead of serving to bring before the mind a collection of facts, they lead it farther and farther away from truth and reality, into the barren and wearisome regions of mere verbal abstractions." (Rae 1834, p. 351.)

The discussion here is on two levels. On one level is the question of the methodology appropriate to political economy; on another, more general, level is the question of the logic of discovery in science and invention. The two are closely related, of course, and Rae's attack on Smith's methodology of political economy should shed some light on any differences in their respective theories of scientific and technological discovery. In the end, however, it turns out that the differences are more apparent than real.

For one thing, Rae's own practice of political economy is not noticeably more -- or less -- "inductive" than Smith's. The concept of invention plays much the same role for Rae that the division of labor plays for Smith. And both are backed by premises about human nature and human propensities. Indeed, it is a notable irony that Rae's three-stage theory of the evolution of technology grows out of what is essentially a "conjectural history," a not-so-Baconian device characteristic of the Scottish Enlightenment. His scenario is, he believes, what "a lengthened inquiry into the history of inventions would lead to" (p. 224), implying, of course, that it is not in fact the result of such an "inductive" inquiry. There are very good reasons why Rae's Baconianism looks a lot like Scottish epistemology in practice. First of all, both are strongly empiricist doctrines that take sense data as the starting point of knowledge. The only disagreement is over the process by which sense data are transformed into general principles or theories. And, in view of Hume's demonstration that induction is in fact quite impossible,[41] it is not surprising that this disagreement boils down at most to a disagreement about the amount of sense data that should be accumulated before formulating general principles.

Nor is it surprising that Rae in particular should sound like Smith and Hume on the logic of discovery. Quite apart from any similarities between Rae's Baconianism and the Scottish philosophy, Rae was himself a Scotsman, receiving his M. A. from Marischal College, Aberdeen, in 1815 and studying medicine at Edinburgh thereafter (James 1965, pp. 8-9). Little is known of Rae's influences, but he shows himself intimately acquainted with Smith and Hume. Moreover, as Corsi (198?) has argued, Scottish philosophy of the human mind had a wider influence on early-nineteenth-century thought than is generally recognized, especially via Dugald Stewart, who held a chair in Edinburgh during the period of Rae's education.[42]

We can also approach the debate between Rae and Smith on a somewhat less esoteric level. But, here too, I will argue, the differences are less than Rae makes them seem. The attack Rae mounts on Smith is focused on exploding

[41] The fact that I have seen many swans, all of them white, does not allow me to conclude that all swans are white. There may be a black one out there that I have not seen. For a modern discussion of the problem of induction in the context of economic methodology, see Boland (1982).

[42] Corsi (198?) provides a marvelous discussion of the early nineteenth-century epistemological debates over inductivism. He argues that the Scottish school -- of which Smith and Hume were members and of which Dugald Stewart was the last great figure -- provided a middle ground between the inductivists at Cambridge (who included Babbage, Whewell, and Richard Jones) and the proponents of a modified Aristotelianism at Oxford (especially Senior, Edward Copleston, and Richard Whately). The Scottish philosophy, Corsi argues, was taken as a starting point by both sides of the debate. Ultimately, his conclusion is similar to what I am arguing here. The gap between the Scots and the inductivists was from one perspective relatively small, and consisted in an argument about whether logic could provide a satisfactory way of "reasoning up" to the definitions on which theory was based.

what he takes to be the central syllogism underlying the Wealth of Nations. "[T]hrough every part of his work, in the conduct of all his reasonings and arguments, Adam Smith blends together the consideration of the processes by which the capitals of individuals and nations are increased, and always treats them as precisely identical" (p. 9). If the wealth of the nation is just the sum of the wealth of individuals, then it follows that increasing individual wealth will increase national wealth. Moreover, since individuals are the best judges of what increases their own wealth, it follows that, "as all laws for the regulation of commerce are in fact means by which the legislator prevents individuals conducting their business as they themselves would deem best, they must operate prejudicially on the increase of individual and so of general wealth" (Ibid).

The Smithian edifice is built on this syllogism, says Rae, and destroying its premise destroys the entire edifice. This Rae sets out to do: the wealth of individuals, he says, is not in fact identical to the wealth of the nation. Why? An individual can gain wealth by somehow appropriating at someone else's expense wealth that is already in existence; but society as a whole can become wealthy only by creating new wealth. And, Rae believes, individual gain is predominantly a zero-sum game. "Individuals, it is very clear, in general, increase their capitals by acquiring a larger portion of the common funds. While one man is growing rich, another is becoming poor, and the change produced, seems not so much a creation of wealth, as a passage of from one hand to another" (p. 11). To Rae, however, there can be no increase of wealth without something new being created -- without invention.

> Invention is the only power on earth, that can be said to create. It enters as an essential element into the process of the increase of national wealth, because that process is a creation, not an acquisition. It does not necessarily enter into the process of the increase of individual wealth, because that may be simply an

> acquisition, not a creation. The assumption, therefore, that the two processes are perfectly similar is incorrect, and the doctrine which I have designated as that of the identity of the interests of individuals and communities cannot be thus established (p. 15).

What makes Rae think this? In part he is simply engaging in a kind of physicalist fallacy. To the extent that the capital stock isn't growing and transactions consist of the exchange of existing land and equipment, he argues, there can be no increase of wealth (pp. 11-12). From a modern (or even a Ricardian) perspective, of course, this is simply not so, and trade of existing commodities can, and usually does, increase value. We can make some sense out of this argument, however, by focusing on Rae's discussion of imitation. A more charitable interpretation would see him as pointing to our friend the knowledge externality as a reason for the divergence of private from public interest (if not necessarily private from public wealth).

Smith, as we saw, did not deal with this particular problem of "externality." Can we thus say that Rae is successful in undermining the Smithian syllogism? Quite apart from the question of relative importance of this externality, the answer is "no." For discussing Smith's analysis in terms of such a syllogism miscasts and misunderstands the *Wealth of Nations* in a fundamental way.[43] As I argued above, Smith does not *assume* that pursuing individual interests always works toward the general interest. He assumes quite the opposite, and is concerned primarily with finding institutions that will harness and channel private interest constructively. Smith was also well aware that *laissez-faire* -- or, more correctly, the

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[43] Indeed, Rae's characterization of Smith is strikingly like the more recent formulation by Wesley Clair Mitchell that Rosenberg (1960, p. 557) cites as a typical modern misrepresentation. Rosenberg argues "not that this syllogism is wrong, as an interpretation of Smith's views, but that it is uninteresting ... [and] completely short-circuits much of the real substance of Smith's work."

"system of natural liberty" -- is not a perfect set of institutions. But he insisted on evaluating alternatives to that system according to their relative ability to harness private interest effectively. In modern terms, we might say that Smith called for comparative-institutional analysis whereas Rae argued (at least in part) from a Pigovian "market failure" perspective.[44] I will return to this point shortly in the context of Rae's policy prescriptions.

Let me sum up Rae's economic theory of science and technology.

1. Relationship of technology to economic growth. For Rae more than for any other classical writer, technological change -- invention -- is explicitly a component of economic growth. It shares the limelight with capital accumulation alone; and, in the end, it is invention that proves the more important factor, since it prevents a reduction in the return to capital that would otherwise halt accumulation. (Spengler 1959, p. 399.)

2. Relationship of science to technological change. Like Smith's, Rae's theory of invention is one in which a normally indolent mind is roused to create. In Smith, the mind plays an active role in which invention arises from the mind's perception of "gaps" or disharmonies. In Rae, by contrast, the mind seems more passive, at least in the lowest stages of technological development, and is roused to invent by the press of circumstances. Such circumstances include materials shortages of various sorts, including those caused by war or migration, which motivate adaptive innovation. As technology advances, however, there begins a process of convergence. Technologies developed in one area are discovered to have wider application. Eventually, people come to recognize the general principles underlying the

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[44] On which distinction see, for example, Dahlman (1979).

technologies: and science is born. Once recognized, these principles can then be applied to the invention of new technology. Thus, to Rae, necessity is the mother of invention -- and the grandmother of science. Science grows from and is dependent on the arts.

This is in many ways an account of the relationship between science and technology much more detailed than we find in Smith. In one specific area, though, Smith's theory is richer. Because of his commitment to inductivism, which sees the problem of generalizing from experience as largely a logical one,[45] Rae is much less interested in the process of discovery, the process by which technology directs or focuses the search for general principles.

3. Science and technology policy. Promoting invention is one of the three pillars of Rae's policy for economic development.[46] This has two parts: "advancing the progress of science and art within the community" and "the transfer from other communities of the sciences and arts there generated" (p. 362; see also pp. 15-16). How is this to be done? Rae's answer flows from his view that invention is promoted by whatever rouses people from indolence and slavish imitation. Historically, he says, invention and technology transfer have "been brought about by violent causes -- by wars, internal disturbances, and revolutions" (p. 363). As society becomes more civilized,

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[45] Which also means that discovery is more open-ended for Smith than for Rae. The History of Astronomy makes clear that there are a multiplicity of principles that the mind could potentially apply to organize the experience with which it is presented. This is less true for inductivists, who await in vain the formulation of an inductive logic (once thought to have been supplied by John Stuart Mill) that would specify exactly how one must travel from sense data to theory.

[46] The others are promoting the "general intelligence and morality" of the society and preventing "the dissipation, in luxury, of any portion of the funds of the community" (p. 362). High investment in generalized human capital; high savings rate; and the promotion of industry and innovation: is this the "Japanese model"?

such violence, Rae hopes, will diminish. Must invention then also diminish? No, he says, for it is the job of the legislator to replicate, in effect, the spur to innovation that violence had once provided.

Again, this is not unlike the views of Smith and Hume on the role of change and diversity as spurs to growth. Diversity, often attended in history by violence, is also for Rae a principal engine of invention. Unlike Smith, however, Rae concludes that intervention is desirable to set the fires of invention burning.[47] The result is one of the earliest and best treatments of the so-called infant-industry argument for protection and encouragement of domestic industry. Contra Smith, says Rae, we do not have to take national advantage as given for purposes of international specialization. Advantages can be created by the wise legislator, who should protect and subsidize industries that will bear fruit in the future but would not be initially profitable to private projectors. What is seldom noticed about this argument, though, is that it is really an infant country argument rather than an infant industry argument. Writing from colonial Canada, Rae was particularly interested in the problem of economies that are behind the technological frontier. Here again we can see the problem as an externality. Starting industry in a backward country is costly because there do not exist the skilled personnel or markets for complementary inputs there would be in a more highly developed economy[48] (p. 47). Moreover, any expenditure by entrepreneurs to train local workers or import skilled foreigners cannot be

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[47] He cites Alexander Hamilton, in the Report on Manufactures, on the necessity to "cherish and invigorate the activity of the human mind" by multiplying "the objects of enterprise." "Even things in themselves not positively advantageous, sometimes become so, by their tendency to provoke exertion." (Ref needed, quoted at Rae 366.)

[48] That is to say, there are fewer Marshallian "external economies."

completely appropriated because skills come bundled with the worker, and the worker cannot be owned (p. 62).

In part, then, Rae differs from Smith in that he takes a market-failure approach to Smith's comparative institutional-approach. Rae worries about where the market falls down, and doesn't worry much about the problems of "wise legislators."[49] Smith, by contrast, would be worried about the ability of the legislator to choose projects more wisely than private entrepreneurs in view of the different state of information the legislator possesses and the different institutional constraints and influences he or she faces.[50] Another way to see the debate, however, is to notice that Smith's discussion is about countries at the technological frontier whereas Rae's is aimed at countries needing to catch up. Is protection more beneficial, and intervention, even ill-considered intervention, less harmful, in a country trying to catch up than it is in one already at the frontier?[51]

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[49] Indeed, he constructs, in response to a hypothetical Smithian argument skeptical of the motives of legislators, what is in effect a public-interest theory of legislation (p. 377).

[50] "What is the species of domestick industry which his capital can employ, and of which the produce is likely to be of the greatest value, every individual, it is evident, can, in his local situation, judge much better than any statesman or lawgiver can do for him. The statesman, who should attempt to direct private people in what manner they ought to employ their capitals, would not only load himself with a most unnecessary attention, but assume an authority which could safely be trusted, not only to no single person, but to no council or senate whatever, and which would nowhere be more dangerous than in the hands of a man who had folly and presumption enough to fancy himself fit to exercise it." (Smith 1976, IV.ii.10, p. 456.) This is essentially an argument against what is nowadays called "picking winners." (Nelson and Langlois 1983.)

[51] On which issue generally see Rosenberg (1982, chapter 12).

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