Industrial Policies, the Creation of a Learning Society, and Economic Development[1]

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Industrial policies—meaning policies by which governments attempt to shape the sectoral allocation of the economy-- are back in fashion, and rightly so. The major insight of welfare economics of the past fifty years is that markets by themselves in general do not result in (constrained) Pareto efficient outcomes. (Greenwald-Stiglitz, 1986).

Industrial policies seek to shape the sectoral structure of the economy. This is partly because the sectoral structure that emerges from market forces, on their own, may not be that which maximizes social welfare. By now, there is a rich catalogue of market failures, circumstances in which the markets may, say, produce too little of some commodity or another, and in which industrial policies, appropriately designed, may improve matters. There can be, for instance, important coordination failures—which government action can help resolve.

But there are two further reasons for the recent interest in industrial policy: First, it has finally become recognized that market forces don't exist in a vacuum. Development economics routinely emphasizes as central to growth the study of institutions All the rules and regulations, the legal frameworks and how they are enforced, affect the structure of the economy, so unwittingly, government is always engaged in industrial policy. When the U.S. Congress passed provisions of the bankruptcy code that gave derivatives first priority in the event of bankruptcy, but which said that student debt could not be discharged, even in bankruptcy, it was providing encouragement to the financial sector. Secondly, it has also been realized that when the government makes expenditure decisions—about infrastructure,

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education, technology, or any other category of spending—it affects the structure of the economy.

This paper is concerned with one particular distortion: that in the production and dissemination of knowledge. Markets, on their own, are not efficient in the production and dissemination of knowledge (learning). Sectors in which learning (research) is important are typically characterized by a wide variety of market failures.

Both econometric and historical studies highlight the importance of learning and innovation. Maddison's (2001) research, for instance documents that from the origins of civilization to the early 1800s, there was essentially no increase in incomes per capita. The economy was close to static. The subsequent two centuries have been highly dynamic, leading to unprecedented improvements in standards of living.

Since the work of Solow (1957), we have understood that most increases in per capita income—some 70%-- cannot be explained by capital deepening; for the advanced developed countries most of the "Solow residual" arises from advances in technology. At least for the past quarter century, we have understood that a substantial part of the growth in developing countries arises from closing the "knowledge" gap between themselves and those at the frontier. Within any country, there is enormous scope for productivity improvement simply by closing the gap between best practices and average practices. (Greenwald-Stiglitz, forthcoming.)

Knowledge is different from conventional goods; it is, in a sense, a public good (Stiglitz, 1987a, 1999)—the marginal cost of another person or firm enjoying the benefit of knowledge (beyond the cost of transmission) is zero; usage is non-rivalrous. Markets are not efficient in the production and distribution of public goods. It is inevitable that there be, or that there ought to be, a role for government.

Moreover, as Arrow (1962a) pointed out fifty years ago, the production of knowledge is often a joint product with the production of goods, which means that the production of goods themselves will not in general be (intertemporally) efficient.

If it is the case that most increases in standard of living are related to the acquisition of knowledge, to "learning," it follows that understanding how economies best learn—how economies can best be organized to increase the production and dissemination of productivity enhancing knowledge-- should be a central part of the study of development and growth. It is, however, a subject that has been essentially neglected. That would, by itself, be bad enough. But Washington Consensus policies based on neoclassical models that ignore the endogeneity of learning often have consequences that are adverse to learning, and thus to long-term development.

Creating a learning society

Not only is the pace of learning (innovation) the most important determinant of increases in standards of living; the pace itself is almost surely partially, if not largely, endogenous. The speed of progress has differed markedly both over time and across countries, and while we may not be able to explain all of this variation, it is clear that government policies have played a role. Learning is affected by the economic and social environment and the structure of the economy, as well as public and private investments in research and education. The fact that there are high correlations in productivity increases across industries, firms, and functions in firms suggests that there may be common factors (environmental factors, public investments) that have systemic effects, and/or that there may be important spillovers from one learner/innovator to others. But the fact that there are large, persistent differences across countries and firms—at the micro-economic level, large discrepancies between best, average, and worst practices-- implies that knowledge does not necessarily move smoothly either across borders or over firm boundaries.

All of this highlights that one of the objectives of economic policy should be to create economic policies and structures that enhance both learning and learning spillovers: creating a learning society is more likely to increase standards of living than the small, one time improvements in economic efficiency or those that derive from the sacrifices of consumption today to deepen capital. [2]

And this is even more so for developing countries. Much of the difference in per capita income between these countries and the more advanced is attributable to differences in knowledge. Policies that transformed their economies and societies into "learning societies" would enable them to close the gap in knowledge, with marked increases in incomes.[3] Development entails learning how to learn.[4]

Market failure and learning. While the fact that knowledge is a (global) public good means that the production and dissemination of knowledge that emerges in a market economy will not, in general, be efficient, there are several other market failures that inevitably arise in an important way in the context of a learning economy.

The first set is related to the fact that those who produce innovation seldom appropriate the full value of their societal contributions. There are large externalities, and these externalities will play a pivotal role in the analysis below. Even when an innovator becomes rich as a result of his innovation, what he appropriates is sometimes but a fraction of what he has added to GDP. But even more, many of those who have made the most important discoveries—those who regularly contribute to the advances of basic science and technology—receive rewards that are substantially below their social contributions: Think of Turing, Watson and Crick, Berners-Lee or even the discovers of the laser/maser and the transistor.[5]

But externalities are more pervasive. Individuals who learn about better ways of doing business transmit that knowledge when they move from one firm to another. (We'll discuss these spill overs at greater length below.)

[2] As Solow (1956) pointed out, an increase in the savings rate simply leads to an increase in per capita income, not to a (permanently) higher rate of growth.
[3] See Stiglitz 1998, which describes development as a "transformation" into a society which recognizes that change is possible, and that learns how to effect such.
[4] Stiglitz 1987b
[5] One should, perhaps, not put too much emphasis on the fact that these individuals did not appropriate the full benefits of their innovations: there is little evidence that they would have worked any harder with fuller appropriability. Discussions among economists focus on economic incentives; these may be far from the most important determinants of learning/innovation.

The second set is related to our imperfect attempts to provide incentives for innovation, through intellectual property. The result is that private rewards are typically not commensurate with (marginal) social returns, in some cases exceeding the social returns (me-too innovations, innovations that are designed to lead to "hold-up" patents)[6], in other cases being markedly less. The fact that the distortion which industrial policy may be attempting to partially "correct" arises from a government policy highlights an aspect of industrial policy upon which we comment further in the concluding section of this paper: it is not just market failures which lead to "distortions" in the economy, but also "government failures." (One could argue that it would make more sense to eliminate the government failure than to introduce another intervention in the market. But for one reason or another, typically related to political economy, it may not be easy to eliminate some government policies; it may be easier to introduce a new countervailing policy.)

A third source of inefficiency which industrial policies may address arises from capital market imperfections (themselves endogenous, arising from information asymmetries). But capital market imperfections can be particularly adverse to learning: Because R & D investments (or "learning investments"[7]) typically cannot be collateralized, unlike investments in buildings, machines, or inventories, it is more likely that there will be credit and equity rationing, leading to underinvestment in these areas, compared to others.[8]

There are other important interactions between traditional market failures, like imperfect competition, and learning: sectors in which innovation is important are naturally imperfectly competitive—research expenditures are fixed costs, and give rise to increasing returns. Because sectors in which competition is limited, output will be lower, and accordingly returns to cost-reducing innovations are lower. (Arrow, 1962b)

Still another market failure arises from imperfections in risk markets. Innovation is highly risky—research is an exploration into the unknown. But firms cannot purchase insurance

[6] The social return is related to the arrival of an innovation earlier than would otherwise be the case. For a more extended discussion of these issues, see Stiglitz (2006, 2008, 2013).
[7] Optimal learning may involve producing at a loss, necessitating borrowing. See Dasgupta and Stiglitz (1988).
[8] This is an explanation of the high observed average returns to investment in technology. See Council of Economic Advisers, 1997.

against these risks (because of well-known problems of moral hazard and adverse selection). But because of imperfections in capital markets, firms act in a risk-averse manner, particularly in the presence of bankruptcy costs (Greenwald-Stiglitz, 1993), and this discourages investment in riskier innovation.

Problems of appropriability of returns and imperfections of capital markets (including the absence of good risk markets) result in barriers to the entry of new firms (entrepreneurs) and the exploration of new products—products or processes that might be particularly appropriate for a developing country. Consider an "experiment" to discover whether conditions in a country are particularly suitable for growing a particular kind of coffee. If the experiment fails, those who conduct the experiment lose money. If it succeeds, there may be quick entry. The country benefits, but the "innovator" can't capture much of the returns. In short, an experiment that is successful will be imitated, so the firm won't be able to reap returns; but the firm bears the losses of an unsuccessful experiment. As a result, there will be underinvestment in this kind of experimentation (Hoff, 1997).

A similar argument holds for why private markets will lend too little to new entrepreneurs. The borrower who becomes successful will be poached by other lenders, so the interest rate which he can charge (after the entrepreneur has demonstrated his success) will be limited to the competitive rate. But Stiglitz-Weiss adverse selection and adverse incentive effects limit the interest rate that can be charged in the initial period, which implies that there will be limited lending to new entrepreneurs. (Emran-Stiglitz, 2009).

In the absence of lump sum (non-distortionary) taxation, there is a fundamental tension: research is a fixed cost, and there is no marginal cost to the use of an idea, so that knowledge should be freely provided. But that would imply that the producer of information (knowledge) would receive no returns. Thus, it is inevitable that there be an underproduction of knowledge (relative to the first best) and/or an underutilization of the knowledge that is produced. The patent system (in principle) attempts to balance out the dynamic gains with the short-run costs of the underutilization of knowledge and imperfections of market competition.[9] When the government finances research and disseminates it freely, there is still a static distortion (from the distortionary imposition of taxes), but no distortion in the dissemination and use of knowledge.

In light of the pervasive market failures associated with innovation and learning, the commonly heard objection to industrial policies—the mantra that government should not be involved in "picking winners"[10]--is beside the point: the objective of the government is to identify, and "correct" externalities and other market failures. While it is now widely accepted that there can be large negative externalities (e.g. from pollution, or from excessive risk taking in the financial sector), we are concerned here with an equally important set of *positive* externalities.

While government may not be perfect in identifying negative externalities, there is by now consensus (except among polluters) that environmental regulations have been very beneficial; so too for positive externalities: even if government identifies such externalities imperfectly, it is wrong to assume that they are "zero": government can improve upon the market allocation. The best way of doing so is a matter of controversy, upon which we comment in the concluding section. But it is clear that many governments (both in developed and developing countries) have a credible record of industrial policy interventions.[11]

A closer look at learning spillovers

We emphasized earlier that there are important positive externalities from learning. Such spillovers are pervasive and large, and they are larger in some industries than in others. And obviously, markets will not take into account these externalities.

[9] Inappropriately designed intellectual property regimes can actually inhibit innovation. (See the references cited earlier in footnote 6.)

[10] In this view, it makes no difference whether the economy produces potato chips or computer chips. Let the market make the decision—not some government bureaucrat.

[11] The returns on US government investments in technology and science are even higher than those of the private sector (which in turn are far higher than private sector returns elsewhere.) See Council of Economic Advisers 1997.

Spillovers occur even in the presence of a patent system. Many advances cannot be patented (advances in mathematics, for example); and the benefits of much of what is learned in the process of research cannot be appropriated. Indeed, the disclosure requirements of a patent are intended to enhance these societal benefits. We'll provide further illustration below.

There are many aspects of learning spill-overs. There are direct technological spillovers: the production of any good involves many stages, and some of the stages may involve processes that are similar to those used in another seemingly distinct sector. Atkinson and Stiglitz (1969) noted, learning is localized: it affects production processes that are similar to those for which there has been learning.[12] But the learning is not limited to a single process and related processes for a particular product. Innovations in one sector may benefit other sectors that look markedly different, but use similar processes. Sectors that are, in one way or another, more similar may, of course, benefit more. (Indeed, the same argument holds within a sector. An innovation in one technology in a given sector may have limited spillovers for other technologies—the spillovers may be greater to other products using analogous technologies.)

There are especially important spill-overs in methods of production. Inventory control and cash management techniques affect virtually every firm in an economy. Just-in-time production or assembly lines are examples of production processes that affect many industries.[13]

Improvements in skills (techniques) in one sector have spillover benefits to other sectors in which analogous skills are employed. Hidalgo and colleagues (2007) characterized the product space, attempting to identify the "capabilities" that different sectors have in common. Presumably, if two

[12] Because countries differ, too, some learning that may be relevant in one country may be of limited benefit in other countries. Most changes in technology, however, *could* confer benefits across borders. The extent to which that is the case may depend on the level of skills (human capital) and the institutional arrangements.

[13] They are also examples of ideas that are hard to be protected by patents, though in some cases, America's business process patents attempt to do.

products entail similar capabilities, learning that enhances a particular capability in one sector will have spillover benefits to related sectors for which that same capability is relevant.[14]

It is, as we have suggested, impossible to appropriate the benefits of much of this learning. An idea like just-in-time production, replaceable parts, or assembly lines spreads quickly throughout the economy, and can't be protected by intellectual property. Learning what grows well in a particular climate with a particular soil is information that is not patentable. The result, as we noted earlier, is that there will be insufficient investment in exploration. There are equally important economy-wide "technologies,"and improvements in these have society wide benefits. These include those that arise out of the development of institutions. A financial system developed to serve the manufacturing sector may equally serve the rural sector. Improvements in the education system, necessary for an effective industrial sector, too can have benefits for the service sector or the agricultural sector.

Knowledge is embodied in people. This is especially relevant for what is called *tacit knowledge,* understandings that are hard to codify, to articulate as simple prescriptions, that could easily be conveyed through textbooks or classroom learning. Workers move from firm to firm, and thus convey some of the learning that has occurred in one firm to those in others. But knowledge is also embodied in firms that supply inputs to multiple firms. What they learn in dealing with one firm in one industry may be relevant for another firm. There can be backward, forward, and horizontal linkages (Hirschman, 1958).

Technological knowledge is also embodied in machines, and a machine constructed for one purpose can often be adapted for quite another. It is not an accident that the Ohio Valley (stretching up to Michigan) gave rise to innovations in bicycles, airplanes, and cars: while the products were distinct, the development of these products shared some of the same technological know-how. This illustrates the principle that it may be difficult to identify ex ante what are "nearby" products, products such that advances in learning in one affects the other.

[14] We do not comment here whether their empirical approach really does capture fully the set of related capabilities. The effects of an improvement in one sector on other sectors depends not just on the similarity of those sectors, but on the institutional arrangements, e.g. providing scope for exploiting linkages. Thus, the fact that natural resource sectors have traditionally not been closely linked to other sectors may be partly a result of the absence of effective industrial policies, and the exploitive relationships often evidenced in that sector.

Knowledge, in this sense, is like a (good) disease: it can spread upon contact. But some kinds of contact are more likely to lead to the transmission of knowledge than others. Some of the people who might possibly come into contact with the knowledge are “susceptible,” i.e. they are more likely to learn, to use the knowledge, and perhaps even develop it further. Firms, realizing that knowledge is power (or at least money), seek to limit the transmission of knowledge—it might help one’s rivals, who might be able to build on it, putting oneself at a disadvantage. Thus, firms go to great lengths to maintain secrecy. While for the advancement of society, it is desirable that knowledge, once created, be transmitted as broadly and efficiently as possible, profit maximizing firms have traditionally sought to limit to the extent possible the transmission of knowledge.

The architecture of the economy--including all the rules concerning intellectual property--affects the speed and extent of transmission of knowledge.

There is, in this, however a trade-off that is fully analogous to that in the design of patents and that is at the root of the critique of the efficient markets hypothesis: if knowledge were perfectly transmitted, there would be no incentive to expend resources on gathering and producing knowledge. There would be underinvestment in knowledge creation (and in the case of developing countries, gathering knowledge from others). Hence, an optimally designed learning society does not entail the perfect transmission of knowledge (except for knowledge that is publicly provided.)[15]

There are, however, natural impediments to the perfect transmission of knowledge. It is plausible that a market economy engages in excessive secrecy (relative to the social optimum). This, of course, has been the contention of the open source movement. Collaborative research in the open source movement is still economically viable, both because there are still economic returns (e.g. because of the tacit knowledge that is created by the learning/innovation process itself) and because there are important non-economic returns to and incentives for innovation. (Dasgupta and David, 1994).

[15] And indeed, this is one of the advantages of public support for the creation of knowledge.

We can thus think of the economy as a complex network of individuals interacting directly with each other and via institutions (like corporations, schools) of which they are a member, ideas (knowledge) being created at various nodes in this network, being transmitted to others with whom there is a connection, being amplified, and re-transmitted, a complex dynamic process the outcomes of which can be affected by the topography of the network, which, together with the rules of the game, affect the incentives to gather, transmit (or not to transmit) , and amplify knowledge.

A sub-problem within this systemic problem is the design of the component institutions (e.g. corporations). For within the institution, there may be incentives to develop knowledge and to hoard or to transmit it. The issue of the architecture of a learning firm is parallel to that of the architecture of a learning economy. In some ways, the two cannot be separated: Traditional discussions of the boundary of firms (Coase, 1937) focused on transactions costs; but equally important is the structure of learning. It may be easier to transmit information (knowledge) within a firm than across enterprises, partly because the "exchange" of knowledge is not well-mediated by prices and contracts[16]. If so, and if learning is at the heart of a successful economy, it would suggest that firms might be larger than they would be in a world in which learning is less important.[17] (On the other hand, the difficulties of developing appropriate incentives for the reward of innovation may militate against large enterprises. There is an ongoing debate over whether large or small enterprises are most conducive to innovation. Large firms may have the resources to finance innovation, typically lacking in smaller enterprises, but there is an impressive record of large firms not recognizing the value of path breaking innovations, including Microsoft being too wedded to the keyboard, and Xerox not recognizing the important of a user friendly interface, like Windows.)

[16] That is, it is hard to write good incentive compatible innovation contracts, to know, for instance, when a firm fails to produce a promised innovation whether it was because of lack of effort or because of the intrinsic difficulty of the task. Cost plus contracts, designed to share the risk of the unknown costs required to make an innovation, have their own problems. See, e.g. Nalebuff and Stiglitz, 1983

[17] An alleged major disadvantage of firms is that transactions within firms are typically not mediated by prices, with all of the benefits that accrue from the use of a price system. But if the benefits of using prices exceeded the costs, firms presumably could use prices to guide internal resource allocations, and some enterprises do so, at least to some extent. There is another perspective on these issues, related to accountability and control. See Stiglitz 1994.

In the discussion below, we mostly abstract from microeconomic structures, focusing on broader policies, on the principles which should guide government intervention, and on alternative instruments. Section I summarizes key results on the implications of learning externalities. Section II discusses how, in the presence of capital constraints, access to finance may be an important instrument of industrial policy. Section III discusses other instruments. Section IV focuses on the role of government investment policy. We conclude, in Section V, with a general set of remarks about industrial policy, especially as it relates to the promotion of a learning economy and society.

II. Learning Externalities

A central thesis of this paper is that government should encourage industries in which there are large learning externalities. A simple two-period model in which labor is the only input to production suffices to bring out the major issues.[18] We show that government should encourage (i) the production of goods in which there is more learning; (ii) the production of goods which generate more learning externalities; and (iii) the production of goods which enhance learning capabilities.

Assume (for simplicity) that utility is separable between goods in the two periods and between goods and labor:

(1) $W = U(\mathbf{x}^t) - v(L^t) + \delta[\, U(\mathbf{x}^{t+1}) - v(L^{t+1})]$,

where $\mathbf{x}^t$ is the vector of consumption $\{x_k^t\}$ at time t and L^t is aggregate labor supply at time t. The disutility of work is the same in all sectors, and L^t is aggregate labor input in period t:

$L^t = \Sigma L^t_k$ and $L^{t+1} = \Sigma L^{t+1}_k$,

where L^i_k is the input of labor in sector k in period i.

Production is described by (in the appropriate choice of units)

(2) $x^t_k = L^t_k$.

In this simple model, the more output of good j in period t, the lower the production costs in period t+1. We assume

(3) $x^{t+1}_k = L^{t+1}_k H^k[\mathbf{L}^t]$,

where $\mathbf{L}^t$ is the vector of labor inputs at time t $\{L_k^t\}$.

The learning functions H^k and their properties are at the center of this analysis. In the following analysis, two properties of these learning functions will play a central role:

[18] Similar results obtain if learning is related to investment, as in Arrow's original 1962 paper. See Greenwald and Stiglitz (forthcoming).

(a) Learning elasticity—how much sectoral productivity is increased as a result of an increase in labor input.

We define

(4) $h_k = d \ln H^k / d \ln L^t_k$.

h_k is the *elasticity of the learning curve in sector k*.

(b) Learning spillovers—the extent to which learning in sector i spills over to sector j.

$\partial H^k / \partial L^t_j > 0, j \neq k$, if there are learning externalities,

while

$\partial H^k / \partial L^t_j = 0, j \neq k$, if there are no learning externalities.

Full learning externalities. One interesting case is that where there are full learning externalities, i.e. knowledge is a public good, so $H^k = H^j = H$.

Then we choose L^t to

$$\max U(\mathbf{L}^t) - v(L^t) + \delta[U(\mathbf{L}^{\mathbf{t+1}} H[\mathbf{L}^{\mathbf{t}}]),$$

so

$$U_i - v' + \delta H_i[\Sigma L^{t+1}{}_k U_k (L_k{}^{t+1} H[\mathbf{L}^{\mathbf{t}}]) = 0.$$

If we assume homotheticity, $U = u(\Phi (x))$, with $\Sigma \Phi_k (x) x_k = \Phi$, then we can rewrite the above as

$$u' \Phi_i - v' + \delta h_i U\upsilon = 0$$

where

$$\upsilon = d\ln U/d\ln \Phi$$

We can generate the optimal allocation by providing a subsidy of τ_i on the ith good, for with such a subsidy an individual

$$\text{maximizes } U(\mathbf{x}) - v(\Sigma x_i(1 - \tau_i))$$

or

$$U_i = v' - v' \tau_i$$

We can get the optimal allocation by setting

$$\delta h_i U\upsilon = v' \tau_i$$

or

$$\tau_i = \delta h_i U\upsilon/v'$$

Consumption should be subsidized the more the value of future consumption (the larger δ*), and the higher the learning responsiveness* h_i.[19]

Optimal subsidies with no cross sectoral spillovers, full within sector spillovers. Similar results hold in the case where there are no spillovers across sectors, but there are full spillovers within the sector. A competitive firm again will take no account of the learning benefits—learning is a sectoral public good. We illustrate with the case with separable ulility. With separability of utility across goods (so $U = \Sigma u_i$), the first order condition for welfare maximization becomes

$$u_i^{t\prime} - v'^t + \delta h_i \eta_i u_i^{t+1} = 0$$

where

$$\eta_i = d\ln u_i/d\ln x_i.$$

[19] The sensitivity of the subsidy to the learning elasticity or to δ depends on the proportionality variable $U\upsilon/v'$. Later discussions in the case of separable utility functions will provide some sense of the factors that determine that variable. See also Stiglitz, 2012.

The optimum can be achieved by setting a subsidy on the consumption of good i at

$\tau_i = \delta h_i \eta_i \; u_i^{t+1} \; / v'^t$

Again, it is apparent that, as before, *consumption should be subsidized the higher the value of future consumption (the larger* δ), *and the higher the learning responsiveness h_i.* Now, there is a third factor—the elasticity of marginal utility. If the elasticity is low, then the benefits of learning diminish rapidly.[20]

The case of full symmetry. In the case of *full* symmetry (both in consumption and in learning), the only distortion is in the *level* of output, i.e. if there are n commodities, 1/nth of income will be spent on each, but in a competitive market with full spillovers within the sector, whether or not there are spillovers to other sectors, no attention is paid to the learning benefits. Hence, the market equilibrium will entail too little production (labor) the first period.

Monopolistic competition. In the case of monopolistic competition, where there is a single firm in each sector, and no learning spillovers, the firm will fully take into account the learning benefits, but now, because of imperfections of competition, output will be restricted. There is again less than the socially desirable level of learning.

Differential spill-overs. The formal analysis so far abstracts from the third determinative factor—the extent of spillovers—for we have assumed that there are either no cross-sector spillovers or perfect spillovers from every sector.

There are a variety of reasons that learning may be higher in one sector than another, and why spillovers from one sector may be greater than in other. Historically, the industrial sector has been the source of innovation. The reasons for this are rooted in the nature of industrial activity. Such activity takes place in firms that (relative to firms in the other sector) are (1) large; (2) long-lived; (3) stable; and (4) densely concentrated geographically. Agricultural/craft

[20] There is a complicated fourth factor $u_i^{t+1} \; / v'^t = (u_i^{t+1} / u_i^t) / (v'^t / u_i^t) = (u_i^{t+1} / u_i^t)(1 - \tau_i)$, so $\tau_i/(1 - \tau_i) = \delta h_i \eta_i \; (u_i^{t+1} / u_i^t)$. u_i^{t+1} / u_i^t reflects the diminution of marginal utility as a result of increased consumption of good i over time. See Stiglitz (2012).

production, by contrast, typically takes place on a highly decentralized basis among many small, short-lived, unstable firms.

In the following paragraphs we describe in more detail some of the reasons for the comparative advantage of the industrial sector in learning and why that sector is more likely to give rise to learning externalities.

(1) *Large enterprises.* Since particular innovations are far more valuable to large organizations that can apply them to many units of output than to smaller ones with lower levels of output (see Arrow, 1962b), there is far greater incentive to engage in R&D in the industrial sector than in the agricultural/craft sector. The result will be higher investments in innovation in the former sector than the latter. This can be looked at another way: Large firms can internalize more of the externalities that are generated by learning.[21] Moreover, innovation is highly uncertain, and firms and individuals are risk averse. Large enterprises are likely to be less risk averse, and thus better able to bear the risks of innovation. Moreover, because of information imperfections, capital markets are imperfect, and especially so for investments in R & D, which typically cannot be collateralized. Capital constraints are less likely to be binding on large enterprises.

(2) *Stability and Continuity.* The accumulation of knowledge on which productivity growth is based is necessarily cumulative. This, in turn, greatly depends on a stable organization for preserving and disseminating the knowledge involved and on continuity in jobs and personnel to support these processes. In large organizations, with the resources to provide redundant capacity where needed, the required degree of stability and continuity is much more likely to be present than in small dispersed organizations where the loss of single individuals may completely compromise the process of knowledge accumulation. As a result, steady productivity improvement will be much more likely to arise from industrial than agricultural/craft production. There is another

[21] As we noted earlier, it is these learning benefits that help explain an economies industrial structure—the boundaries of what goes on inside firms. In general, the diseconomies of scale and scope (related, for instance, to oversight) are greater in agriculture than in industry. In the case of modern hi-tech agriculture, there are increased benefits of learning, and that will affect the optimal size of establishments.

way of seeing why stability/continuity contributes to learning: As we noted earlier, the benefits of learning extend into the future. Long lived firms can value these distant benefits—and because industrial firms are typically larger, longer lived, and more stable than, say, firms in other sectors, they can have access to capital at lower interest rates. They are likely to be less capital constrained, act in a less risk averse manner, and to discount future benefits less.[22]

(3) *Human Capital Accumulation.* Opportunities and incentives for accumulating general human capital are likely to be far greater in large complex industrial enterprises with a wide-range of interdependent activities than in small, dispersed narrowly-focused agricultural /craft enterprises. (There is, for instance, a greater likelihood of benefits from the cross-fertilization of ideas.) Long-lived stable firms may have a greater incentive to promote increased human capital that lead to greater firm productivity, better ability to finance these investments, and more willingness to bear the risks. The resulting human capital accumulation is a critical element in both developing the innovations on which productivity growth depends and in disseminating them as workers move between enterprises and across sectors.

(4) *Concentration and Diffusion of Knowledge across firms.* Diffusion of knowledge among densely collocated, large-scale industrial enterprises (often producing differentiated products)[23] is likely to be far more rapid than diffusion of knowledge among dispersed small-scale agricultural/craft enterprises. (Recall that earlier we had emphasized the importance of the diffusion of knowledge, and stressed the key role that geographical proximity plays. More recent discussions of the role of clusters have re-emphasized the importance of geographical proximity. See Porter, (1990).

(5) *Cross border knowledge flows*. While learning is facilitated by geographical proximity, especially developing countries (where many firms are operating far below "best practices") can learn from advances in other countries. While agricultural conditions

[22] The importance of these factors has clear implications for the conduct of macro-economic policy, which we discuss later in this paper.

[23] The fact that they are producing different products enhances the likelihood that they will make different discoveries. The fact that they are producing similar products enhances the likelihood that a discovery relevant to one product will be relevant to another.

may differ markedly from one country to another, the potential for cross-border learning may be greater in the industrial sector; and the existence of large, stable enterprises with the incentives and capacities to engage in cross-border learning enhances the role of that sector in societal learning. Indeed, it is widely recognized that success in the industrial sector requires not just knowledge, but also the ability to acquire knowledge, that is common across borders. Again, some of this knowledge and these abilities are relevant to the agricultural sector, and disseminate to it.

(6) *The Ability to Support Public Research and Development.* Learning by one firm or sub-sector spills over to other firms and sub-sectors within the industrial sector, through, for instance, the movement of skilled people and advances in technology and capital goods that have cross-sector relevance. But the benefits spill-over more broadly, even to the agricultural sector, and in the following paragraphs we describe some of the ways that this occurs, especially as a result of the tax revenues that a growing industrial sector can generate. Large-scale, densely concentrated activities are by this very nature far easier to tax than small-scale dispersed activities. Thus, economies with large accessible industrial sectors will be far better able to support publicly sponsored R and D than those consisting largely of dispersed, small-scale agricultural/craft production units. This factor may be especially important in the support of agricultural research, like that undertaken by Agricultural Extension Service in the United States. These activities directly contribute to agricultural productivity growth, but could not be supported without a taxable base of industrial activity.

(7) *Public Support for Human Capital Accumulation*. Just as in the case of R and D, private capital market failures may mean that public support in the form of free primary and secondary education is a critical component of general human capital accumulation. Moreover, the high returns to education in the industrial sector lead to a greater demand for an educated labor force. Again, the greater susceptibility of concentrated industrial enterprises to taxation is key to funding. And again, as workers migrate across

sectors, ultimately higher productivity growth in the agricultural/craft sector will be engendered as well.

(8) *The Development of a Robust Financial Sector.* Greater investment in the industrial sector leads to higher levels of productivity both directly through capital deepening and the embodiment of technical progress (Johansen, 1959, and Solow, 1960), and indirectly through the capital goods industry, which is often a major source of innovation. Some of the innovations here (such as those relating to mechanization) have direct spillovers to the agriculture sector. But so do the institutional developments that are necessary to make an industrial economy function. The heavy investment of a modern industrial economy requires finance, It is not surprising then that an industrial environment should be characterized by a more highly-developed financial sector than an agricultural/craft environment. Once developed, a strong financial sector facilitates capital deployment throughout the economy, even in the rural sector.[24]

The implication of this analysis is that it pays government to take actions (industrial policies) to expand sectors in which there are more learning spillovers (in the above analysis, the industrial sector; within the industrial sector, there may be subsectors for which the learning elasticity is higher and from which learning spill overs are greater).

[24] Exploitation by money lenders in the rural sector led to the development of rural cooperatives, e.g. in the United States and in Scandinavia.

II. Finance and Industrial Policy

One of the reasons that markets fail to allocate resources efficiently to "learning" are capital market constraints. R & D is hard to collateralize, and optimal learning entails expanding production beyond the point where price equals short run marginal costs.

Imperfections of information often lead, especially in developing countries, to credit and equity rationing. Interestingly, a key instrument of industrial policy in East Asia was access to finance, often not even at subsidized rates. (Stiglitz and Uy,1996).

There are several aspects of "learning" in the design of financial policy. The first, emphasized by Emran and Stiglitz, is learning about who is a good entrepreneur. The problem, as we noted earlier, is that because of "poaching" the benefits of identifying who is a good entrepreneur may not appropriated by the lender. There will be too little lending to new entrepreneurs.

Secondly, information is local, which means foreign banks may be at a disadvantage in judging which entrepreneurs or products are most likely to be successful in the specific context of the particular less developed country. Foreign banks are more likely accordingly to lend to the government, to other multinationals, or to large domestic firms. Financial market liberalization may, accordingly, have an adverse effect on development.[25] (Rashid 2012).

III. Other instruments of industrial policy

Previous sections have argued that the objective of industrial policy is to shift production towards sectors in which there is likely to be more societal learning, meaning more learning and more learning externalities. There are a variety of other instruments --- indeed, as we comment in the concluding section, almost every aspect of legal and economic policy has some effect in shaping an economy.

Here, we focus on intellectual property. In a sequel (Greenwald-Stiglitz, 2012) we discuss exchange rate policy and foreign direct investment.

[25] The extent to which this is true may vary, e.g. if the foreign bank buys a local bank, it may, at least for a while, provide it with some autonomy.

Intellectual property regimes are supposed to encourage innovation, by providing incentives to do research, enhancing the ability to appropriate the returns. But intellectual property interferes with the dissemination/transmission of knowledge and encourages secrecy, which impedes learning. Increasingly, there is an awareness of other adverse effects of intellectual property regimes, as developed in the advanced industrial countries, especially for developing countries. (See Stiglitz, 2006). Knowledge is the most important input into the production of knowledge, and by restricting the availability of knowledge, the production of knowledge (learning) is inhibited. The patent system gives rise to monopoly power; monopolies restrict production, thereby reducing incentives to innovate. The patent system can give rise to a patent thicket, a complex web of patents, exposing any innovator to the risk of suit and holdup. Because patents "privatize" knowledge while challenging patents moves knowledge into the "commons," there will be underinvestment in challenging patents and overinvestment in patenting. No wonder then that it is estimated that in the United States, more money is spent on patent lawyers and litigation than on research.

There are two implications of this analysis. The first is that, given the critical role of closing the knowledge gap for successful development, the appropriate intellectual property regime for developing countries and emerging markets is likely to be markedly different than that appropriate for the advanced industrial countries. In this area, more even than others, one size fits all policies are inappropriate. Secondly, there are alternative ways of designing an innovation system, with greater emphasis on prizes and on open source. Patents will play a role, but a good patent system has to pay more attention to disclosure, to problems of hold up,[26] to designing better systems of challenging patents. (See Stiglitz, 2013).

IV. Government Investment

[26] e.g. through the use of the "liability system." The US Supreme Court, in its decision for eBay Inc. v. MercExchange, L.L.C. in 2006, recognized the adverse consequences of the patent system and its enforcement as it had developed in the United States.

In some ways, governments cannot avoid questions of industrial policy; for they have to make decisions about the direction of public investment, say in education and infrastructure, and this has to be based on beliefs about the future directions of the economy, which are in turn affected by these public decisions. But the policies with which we are concerned go well beyond this. For government can use public expenditure policies to partially compensate for deficiencies in market allocations.

To see what this implies, let's extend our earlier learning model by introducing Public Goods, denoted by **G**, in each period. For simplicity, we assume we can impose a lump sum tax to finance them and that there are full spillovers. We focus on the "direct" control problem, where we choose the level of spending on each private and public good. Focusing on the first period, we

$$\text{Max } U(\mathbf{L}^t,\mathbf{G}) - v(\Sigma L^t + \Sigma G) + \delta[\ U(\mathbf{L}^{t+1} H[\mathbf{L^t}\ \mathbf{, G}])$$

where the output of public good G_i in period t is just equal to the labor input in its production.

$$U_G - v' + \delta \Sigma U_i\, L_i^{t+1}\ H_G\ = 0$$

In deciding on the optimal level of investment, we look not just at the direct benefits, but also at the learning benefits.

But in the absence of subsidies on private goods that take into account the learning benefits and spillovers, the provision of the public good can have another benefit. By expanding the production of public goods which are complements to goods with high learning elasticities and large externalities, the government can help create a more dynamic economy. To see this, we reformulate our optimization as an indirect control problem (still assuming the public good is financed by a lump sum tax)

$$\text{Max } V(\mathbf{p}^t, I\text{- }G^t, G^t) + \delta\ V(\mathbf{p}^{t+1}, I\text{- }G^{t+1},\ G^{t+1})$$

where V is the indirect utility function, giving the level of utility as a function of prices, income net of lump sum taxes, and public goods. In the absence of product subsidies, equilibrium is characterized by price equaling marginal cost, or

$p^t = 1$; $p^{t+1} = 1/H(L^t, G^t)$

The set of equations can be solved simultaneously for $\{x_i^t = L_i^t\}$ as a function of the vector $\{G^t, G^{t+1})$.[27] An increase in G_i^t, financed by a lump sum tax, has complex income and substitution effects on the demand for each commodity. For instance, if some public good is a close substitute for some private good, the lower spendable income as a result of the additional provision of the public good combined with the availability of a public substitute will lead to a reduction in the private demand for that good, but if the public good were a strong enough complement (a free road to a ski resort), it might increase the demand for the good (trips to the ski resort.) We denote by $\partial L_j^t/\partial G_i$ the change in the demand for (consumption of) good j as a result of an increase in public good i.

Standard results give $V_{pi}^t / V_I^t = L_i^t$.

Hence, optimizing with respect to G_i^t yields

$$V_{Gi}^t - V_I^t = V^{t+1}_I \, [\Sigma L_k^{t+1} \{H_{Gi} + \Sigma_j \, L_j^{t+1} \, (\partial L_j^t/\partial G_i)(H_j \, /H_j^2)\}]$$

The first term (H_{Gi}) on the left hand side are the direct learning benefits, the second term $[\Sigma_j L_j^{t+1} (\partial L_j^t/\partial G_i)(H_j /H_j^2)]$ is the indirect effects on learning as the composition of demand changes.

We expand the production of public goods not only to take into account the learning benefits, but also the indirect effects in inducing more consumption of some goods and less of others, taking into account the total net effect on learning.

V. Concluding Comments

Theory of the Second Best

[27] With stronger assumptions about separability, it is possible to solve for L_i^t as a function of G^t, but we consider here the more general case.

Industrial policies distort consumption from what it otherwise would have been. Conventional economics (such as the Washington Consensus policies) emphasized the costs of these interventions. We have emphasized that when there are market failures (as is always the case when there are learning externalities), there will be benefits. Optimal policy weighs the benefits and costs as the margin.

The economics of the second best is of particular relevance here: R&D and learning give rise to market imperfections, sometimes referred to as distortions, where resources are not allocated in a "first best" way. Well-designed distortions in one market can partially offset distortions in others.

I use the word "distortions" with care: Common usage suggests that governments should simply do away with them. But as the term has come to be used, it simply refers to deviations from the way a classical model with, say, perfect information might function. Information is inherently imperfect, and these imperfections cannot be legislated away. Nor can the market power that arises from the returns to scale inherent in research be legislated away. That is why simultaneously endogenizing market structure and innovation is so important (e.g. Dasgupta and Stiglitz, 1980). Similarly, the costs associated with R&D (or the "losses" associated with expanding production to "invest" in learning) cannot be ignored; they have to be paid for. Monopoly rents are one way of doing so, but—as we argue here—a far from ideal way.

As always in the modern economics of the public sector, the nature of the optimal interventions depends on the instruments and powers of government. Whether the government can abolish monopolies or undo their distortionary behavior has implications for the desirable levels of research and learning. It makes a difference, too, if the government can raise revenues to subsidize or support research or learning only through distortionary taxation rather than through lump sum taxes. There are ways to impose even distortionary taxes (i.e., taxes that give rise to a loss of consumer surplus) that increase societal well-being and the speed of innovation. But the optimal investment in innovation is still likely to be less with distortionary taxation than with lump sum taxation.

Industrial Policies and Comparative Advantage

Justin Lin (2012) has distinguished between industrial policies that defy comparative advantage, which he argues are likely to be unsuccessful, and those that are consistent with comparative advantage, which can be an important component of successful development. While there is considerable insight in this distinction, the key question is, what are a country's endowments, which determine its comparative advantage? This is equivalent to asking, what are the relevant *state* variables? And what is the "ecology" against which the country's endowments are to be compared, i.e. what are the *relevant* endowments of other countries?

It has become conventional wisdom to emphasize that what matters is not static comparative advantage but dynamic comparative advantage. Korea did not have a comparative advantage in producing chips when it embarked on its transition. Its static comparative advantage was in the production of rice. Had it followed its static comparative advantage (as many neoclassical economists had recommended) then that might still be its comparative advantage; it might be the best rice grower in the world, but it would still be poor.

Ascertaining a country's static comparative advantage is difficult; ascertaining its dynamic comparative advantage is ever harder. Standard comparative advantage (cf. Heckscher Ohlin) focused on *factor* endowments (capital-labor ratios).[28] But with capital highly mobile, capital endowments should matter little for determining comparative advantage. Still, capital (or more accurately, the knowledge of the various factors that affect returns, and that is required to use capital efficiently) doesn't move perfectly across borders: that means that the resident of country j may demand a higher return for investing in country i. There is, in practice, far less than perfect mobility.

[28] Krugman's research made it clear that something besides factor endowments mattered: he observed that most trade today is between countries that have similar factor endowments.

Thus the "state" variables that determine comparative advantage relate to those "factors" that are not mobile, which, in varying degrees, include knowledge, labor, and institutions.

Multinationals can, however, convey knowledge across borders. Highly skilled people move too. Migration has resulted in large movements in unskilled labor, but in most cases, not enough to change endowments of the home or host country significantly. Even institutions can sometimes effectively move across borders, as when parties to a contract may agree that disputes will be adjudicated in London and under British law. Still, there are numerous aspects of tacit knowledge, about how individuals and organizations interact with each other, and norms of behavior that affect economic performance, and most particularly from our perspective, how (and whether) they learn and adapt.

The "endowment" from our perspective which is most important is a society's learning capacities (which in turn is affected by the knowledge that it has and its knowledge about learning itself) which may be specific to learning about some things rather than others. The spirit of this paper is that industrial policy has to be shaped to take advantage of its comparative learning and learning abilities (including its ability to learn to learn) in relation to its competitors. Even if it has capacity to learn how to make computer chips, if a country's learning capacity is less than its competitors, it will fall behind in the race. But each country makes, effectively, decisions about what it will learn about. There are natural non-convexities in learning, benefits to specialization. If a country decides to learn about producing chips, it is less likely that it will learn about some other things. There will be some close spill-overs, perhaps say to nano-technology. The areas to which there are spill-overs may not lie near in conventional product space. There may, for instance, be similarities in production technologies (as in the case of just-in-time production or the assembly line.) That is why the evolution of comparative advantage may be so hard to predict.

But while standard economic analysis may provide guidance to a country about its current (static) comparative advantage (given current technology, what are the unskilled-labor intensive goods), guidance about its comparative advantage defined in this way (dynamic learning capacities) is much more difficult, partially because it depends on judgments made by other countries about their dynamic comparative advantage and their willingness to invest resources to enhance those advantages. Whether ex ante U.S., Japan, or Korea initially had a dynamic comparative advantage in producing chips, once Korea had invested enough in learning about certain kinds of chip production, it would be difficult for another country to displace it.

Looking at what other countries at similar levels of per capita income did in the past or what countries with slightly higher levels of per capita income are doing today may be helpful, but only to a limited extent. For the world today (both global geo-economics and geo-politics, and technology) is different than it was in the past. Competing in textiles today requires different skills and knowledge than in even in the recent past; it may (or may not) be able to displace a country that currently has a comparative advantage in some product; the country may (or may not) be in the process of attempting to establish a comparative advantage in some other area.

Industrial Strategies

A key issue of industrial strategy is not only the direction (should Korea have attempted to reinforce its comparative advantage in rice, or to create a comparative advantage in some other area?), but also the size of the step. Should it try a nearby technology (product), nudging along a gradual, evolutionary process that might eventually have occurred anyway? Or should it take a big leap? The latter is riskier: perhaps greater returns if successful, but a higher probability of failure.

We have not formally modeled this critical decision, so the following remarks are only meant to be suggestive: The ability to learn (costs of learning) increase significantly the bigger the leap; but so may the benefits. There are natural non-convexities in the value of information/knowledge (Radner-Stiglitz, 1984), implying that it pays to take a *moderate* step: small incrementalism is not optimal.

By the same token, using another analogy, to corporate strategic policy, it pays to move to a part of the product space where there are rents which can be sustained (e.g. as a result of entry barriers, arising, for instance, out of returns to scale and/or specific knowledge.) This almost surely entails not doing what others are or have been doing.

The inevitability of industrial policy

We have argued that government cannot escape thinking about its industrial structure. It is necessary as it makes decisions about public investments (in education, technology, and infrastructure). But the legal framework of a society too inevitably shapes industrial structure. If, as in the United States, derivatives are given seniority in bankruptcy, while student debts cannot be discharged, and large banks are effectively allowed to undertake high risks, with governments bearing the downside, and speculators are taxed at lower rates than those in manufacturing, the financial sector is encouraged at the expense of other sectors. This is an industrial policy.

Developing countries have to think carefully about every aspect of their economic policy, to make sure that they shape their economy in a way which maximizes learning. But their learning challenge is markedly different from that of the advanced industrial countries, where one of the main objectives is moving out the knowledge frontier. The focus of developing countries should be to close the knowledge gap between them and the more advanced countries (though for some of the more advanced among the emerging markets, one of the challenges it to be at the forefront, at least in some particular areas, something at which both China and Brazil have succeeded.)

But this in turn has one important implication: legal frameworks and institutional arrangements (such as for intellectual property) that are appropriate for developed countries are not likely to be appropriate for developing countries and emerging markets.

Industrial Policies and Government Failures

We began the discussion of this paper arguing that industrial policies are, in part, a response to market failures. The sectoral allocations resulting from unfettered markets are not in general optimal. But some of the inefficiencies in markets arise, as well, from government policies. A natural response is to remove the government distortions, rather than to create a new, offsetting distortion. But such an approach ignores the complexity of political economy and the difficulty of fine-tuning public policies. Earlier, we referred to the impact of intellectual property. But a country's intellectual property regime is greatly affected by TRIPS, the WTO agreement, in ways which may not accord with its own best interests. It may, accordingly, attempt to undo or "correct" the distortions arising from that intellectual property regime.

The objectives of industrial policy

Industrial policy is usually conceived of as promoting growth, but it should be seen more broadly, as any policy redirecting an economy's sectoral allocation where market incentives (as shaped by rules and regulations) are misaligned with public objectives. Governments are concerned about employment, distribution, and the environment in ways in which the market is often not. Thus, in those countries with persistent high levels of employment, it is clear that something is wrong with market processes: labor markets are not clearing. Whether the explanation has to do with inherent limitations in markets (e.g. imperfect information giving rise to efficiency wages), unions, or government (e.g. minimum wages), the persistence implies that "correcting" the underlying failures may not be easy. The social costs of unemployment can be very high, and it is appropriate for government to attempt to induce the economy to move towards more labor intensive sectors or to use more labor intensive processes.

In each of these instances, shadow prices differ from market prices. This is evidently the case in many areas of the environment, where firms typically do not pay for the full consequences of their action. The consequences for investment—including investments in R & D—are obvious. Firms in many countries are searching for labor saving innovations, even in countries with high unemployment, when from a social perspective, there are high returns to innovations that protect the environment.

Political economy

A persistent criticism of industrial policies is that, even if market allocations are inefficient, even if market prices differ from shadow prices, government attempts to correct these failures will simply make matters worse. There is neither theory nor evidence in support of this conclusion.

To be sure, there are instances of government failure, but none on the scale of the losses resulting from the failures of America's financial market failure before and during the Great Recession. Virtually every successful economy has employed, successfully, at one time or another, industrial policies. And this is most notable in the case of East Asia. (Stiglitz, Wade, Amsden, Chang).

In the sequel to this paper (Greenwald and Stiglitz, 2012) we explain that limitations in government capacity ("political economy problems") should play an important role in shaping the design of industrial policies—what kinds of instruments should be employed.

In short, the debate today should not be about whether governments should pursue policies that shape the industrial structure of the economy. Inevitably, they will and do. The debate today should center around the directions in which it should attempt to shape the economy and the best way of doing so, given a country's current institutions and how they will evolve--recognizing that the evolution of the institutions themselves will be affected by the industrial policies chosen.

Appendix: A simple model of investment in R & D

In the text of this paper, we focused on how learning spill-overs affected the optimal production structure—leading to an industrial structure that might be markedly different from that which might emerge in an unfettered market economy. Here, we extend this work by looking at how knowledge spill-overs affect the optimal pattern of R & D.

Assume there are two products, produced by a linear technology

$Q_i = A_i(R_1, R_2)\, L_i$

where R_i is the amount of research on product I and L_i is the labor devoted to production .

$E_i = L_i + L_i^r$.

Total employment in sector i is the sum of production and research workers. If $A_{ij} > 0$ $(i \neq j)$ implies there are spill-over benefits for product i from research on product j. For simplicity, we assume $R_i = L_i^r$, the amount of labor devoted to research in sector i.

Social welfare maximization entails

Max $U(Q_1, Q_2) - L$

After some manipulation, the first order conditions can be written

$\alpha_1^1 (L_1 / L_1^r) + \alpha_1^2 (L_2/L_1^r) = 1$

$\alpha_1^2 (L_1 / L_2^r) + \alpha_1^2 (L_2/L_2^r) = 1,$

where $\partial \ln A_i / \partial \ln L_j^r = \alpha_j^i$.

Role of spill-overs

With no spill overs $\alpha_i^j = \alpha_j^i = 0$, so

$(L_i^r / L_i) = \alpha_i^i$.

The ratio of employment in research in sector i to production labor is directly related to the own elasticity of productivity. If the elasticity is high—research increases productivity a lot—then a large fraction of labor should be devoted to research.

It is easy to see that if there are externalities (i.e. $\alpha_i^j > 0$), research is increased. Consider the symmetric case, where $L_1 = L_2$ in equilibrium. Then

$$L_1^r/L_1 = \alpha_1^1 + \alpha_1^2.$$

With perfect spillovers,

$$\alpha_1^1 = \alpha_1^2,$$

so the effect is to double the ratio of research workers to production workers.

Comparison with a market economy

In a perfectly competitive economy with a large number of firms and perfect within-industry spillovers, there would be no research, as each would try to free ride on others: $L_i^r = 0$—clearly an underinvestment in research.

At the other extreme, assume that there were no spill-overs. Then each firm would engage in some research. It would maximize output for any given input, i.e.

$$\text{Max } A_i (L_i^r)(E_i - L_i^r),$$

generating

$$A'_i (E_i - L_i^r) = A_i$$

or

$$\alpha_i^i = L_i^r/L_i,$$

an equation that identical to that derived earlier for the optimal allocation, in the case of no spillovers—highlighting the crucial role of spillovers in industrial policies. (The overall level of employment may, however, differ in the two situations.)

But there is another critical issue: whether there are spill overs or not is, in part, a matter of industrial policy, e.g. concerning compulsory licensing, cooperative research efforts, and disclosure policies.

Thus, assume there are n firms in the industry, and that $A_i = A_{ii} + \beta\Sigma A_{ij}$. Government policy can increase β (the spillovers from research j to sector i) and thus the optimal amount of research. Moreover, if sector i has learning as well as research potential, and the other sector does not, then L_i will be much greater with $\beta >> 0$, and hence so will L_i^r.

More typically, sectors in which research is important are imperfectly competitive. Assume that again there is no knowledge spill over, and that each sector faces an elasticity of demand of ε. Then, as before, we can show that $L_i^r/L_i = \alpha^i_i$.

But now

$$U_i = p_i = A_i/(1 - 1/\varepsilon),$$

where p_i is the price of the ith good (taking labor as the numeraire); while in the competitive case

$$U_i = p_i = A_i.$$

Production (output) is lower, i.e. for any given level of productivity (A_i), L_i is smaller; and hence L_i^r is correspondingly smaller. The exploitation of market power results in under production, and thus underinvestment in research, since the value of research is related to the cost savings—i.e. the level of production.

In the case was identical learning functions but differences in demand elasticities, interestingly, the percentage reduction in output is the same, and hence relative increases in productivity stay the same. The monopoly engages in less than optimal research[29]—but more than the competitive market (with full spill-overs, where there is no research.)

[29] We note, however, that we have assumed implicitly the ability to impose lump sum taxation. With distortionary taxation, the optimal amount of research will obviously be less than with lump sum taxation. See Stiglitz [1986]

The long term growth and structure of the economy depends critically on the nature of competition (which itself is endogenous) and spillovers. A Cournot duopoly with full spill-overs may, for instance, result in more R & D than a monopoly with a similar R & D functionOver time, the effects can be cumulative, i.e. the more monopolized sector has lower productivity growth. Its scale is, as a result, diminished, with resulting diminution in incentives to engage in research. It is (in this case) not because monopoly has induced laziness, but simply that it does not pay to do as much research.

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