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Two Strategies for Economic Development: Using Ideas and Producing Ideas

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The key step in understanding economic growth is to think carefully about ideas. This requires careful attention to the meaning of the words that we use and to the metaphors that we invoke when we construct mathematical models of growth. After addressing these issues, this paper describes two different ways in which ideas can contribute to economic development. The history of Mauritius shows how a poor economy can benefit by using ideas from industrial countries within its borders. The history of Taiwan (China) shows how a developing economy can be pushed forward into the ranks of those that produce ideas for sale on world markets.

The central claim of this paper is that the difference between the economics of ideas and the economics of objects is important for our understanding of growth and development. A subsidiary claim is that academic and policy discussions in these areas might be more fruitful if we spent less time working out solutions to systems of equations and more time defining precisely what the words we use mean. The notion that ideas are different from objects is both familiar and obvious. In the economic analysis of patents, for example, there is a long tradition of recognizing the unique characteristics of ideas as economic goods. The content of the claim lies in the assertion that these differences are more subtle than some presentations suggest and that they matter for aggregate-level policy analysis.

All too often, economists concerned with the economy as a whole have been willing to treat the economics of ideas as a footnote to the rest of economic analysis—important for understanding some of the details but not something that changes how we think about big policy questions. A neoclassical model with perfect competition and exogenous technological change continues to frame many, if not most, policy discussions of growth and development. Ideas are routinely ignored.

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In what follows, two kinds of support are offered for the claim that ideas should be our central concern: abstract arguments about the economic attributes of ideas and descriptions of the role that ideas played in two cases of successful economic development. The abstract arguments presented in the first part of the paper proceed from the observation that ideas are extremely important economic goods, far more important than the objects emphasized in most economic models. In a world with physical limits, it is discoveries of big ideas (for example, how to make high-temperature superconductors), together with the discovery of millions of little ideas (better ways to sew a shirt), that make persistent economic growth possible. Ideas are the instructions that let us combine limited physical resources in arrangements that are ever more valuable.

As economic goods, ideas differ from objects in ways that are more subtle than traditional aggregate models allow. The familiar description of an idea as a public good like a lighthouse beacon overlooks the fact that many ideas are controlled by private individuals who respond to market incentives. An equally misleading approach is to equate ideas with human capital and to treat them as conventional private goods. This misses the notion, correctly suggested by the public good analogy, that an idea can be used by many people at the same time. Adding external effects or spillovers to human capital and physical capital comes no closer to capturing the essential attributes of ideas. Externalities suggest incomplete control or appropriability, but they do not capture the absence of opportunity costs that is the key characteristic of an idea. The combination of some degree of private control and an absence of opportunity costs means that ideas are neither public goods nor private goods—nor a mixture of the two.

To address a frequently expressed objection to this description of an idea, the abstract discussion acknowledges that ideas are used in fixed proportions with objects that do have an opportunity cost. For example, the bit string representing a computer program can be used by an unlimited number of people with no loss of functionality for the first user. In practice, however, it takes a floppy disk to make a copy of the bit string for another user, and the floppy disk does have an opportunity cost. The distinction between capital and labor is useful even though both are needed to produce output; so is the distinction between the bit string and the floppy disk.

The abstract analysis of ideas has special relevance for poor countries. Industrial countries possess a stock of ideas that could yield large increases in standards of living if they were put to use throughout the world. Moreover, since the use of an idea by one person does not limit its use by someone else, the large potential gains available to developing countries need not come at the expense of industrial countries.

In the few instances in which ideas have been controlled by international aid organizations, we can see just how large the gains from worldwide dissemination can be. The idea behind the smallpox vaccine has now eliminated this disease from every country on earth. The simple idea behind oral rehydration

therapy has saved the lives of millions of children who would otherwise have died from diarrhea.

These examples suggest the magnitude of the gains that ideas can offer, but they are not typical. Most ideas with economic value are not controlled by a charitable organization willing to bear the costs of dissemination. Instead, they are controlled by people who will not incur the costs needed to share what they know unless they have a monetary incentive to do so. As a result, the gains from the dissemination of ideas will not be realized if distortions, weak institutions, and bad political structures prevent the holders of ideas from sharing in the gains that accrue when the ideas are brought to a new geographic area.

For this reason, the logic behind the economics of ideas supports the new development orthodoxy that a policy of openness with few distortions offers the potential for large gains in poor countries. The experience in Mauritius, the first of the two economies considered below, supports this view. A poor island whose prospects for development once seemed very bleak, Mauritius successfully exploited a development strategy that consisted almost entirely of trying to make use of ideas that already existed in industrial countries by encouraging foreigners to produce there. This is the first of the two strategies noted in the title of this paper: using ideas. Judging from the increased receptivity of many poor countries to direct foreign investment, it appears that this strategy is gaining favor.

Yet as important as this strategy can be during the early stages of development, the analysis also suggests that there may be limits to how far it can take an economy. Both the experience in the second economy discussed, Taiwan (China), and the logic behind the analysis of ideas suggest that some interventions may encourage growth at intermediate stages of development. Taiwan pursued the second strategy described in the title—producing ideas—and intervention by the government seems to have contributed to the strategy's success.

Most economists would acknowledge that some kinds of intervention to support the production of ideas are appropriate. Few would challenge the assertion that governments should subsidize education and some forms of research. If one follows the logic of the economics of ideas, one sees that there is no basis in economic theory (as opposed to political theory) for restricting government intervention to support for education and research.

Many economists are also convinced that restrictions on trade and direct foreign investment are bad policy instruments for encouraging development. Yet the evidence from Taiwan (China) suggests that those policies were useful there. These observations can be reconciled by adding a political and institutional analysis to the economic analysis. An economic analysis based on the economics of ideas suggests that trade and investment restrictions can be growth-enhancing only if they are complemented by other policies such as support for education and rigorous standards of performance for protected firms. To be effective, these policies must be implemented by a government that is immune to the political pressures associated with rent-seeking and that possesses a competent and relatively honest bureaucracy. Because these conditions are not met in most

of the world, restrictions on trade and investment will almost always be counterproductive. The challenge is to find better forms of government intervention, ones that have better economic effects and pose fewer political and institutional risks.

The temptation for economists, however, has always been to duck the complicated political and institutional issues that this kind of analysis raises and instead to work backward from a desired policy conclusion to a simple economic model that supports it. According to this approach, if we want to discourage counterproductive restrictions on trade and foreign investment in most countries of the world, then the right model is one with perfect markets so that intervention can be shown to be everywhere and always a mistake.

The motivation behind this paper comes from a belief that the poor people of the world will be better served if we resist this temptation and meet head-on the intellectual challenge presented by the economics of ideas. In industrial countries a number of government interventions have evolved to encourage the production and dissemination of ideas. Examples include patents, copyrights, laws to protect trade secrets, subsidies for education at all levels, peer-reviewed research grants, and agricultural extension services. These interventions have been relatively free of political manipulation and, despite some weaknesses, are generally regarded as having had a positive effect.

The same arrogance that made people at the turn of the century think that almost everything had already been invented sometimes leads us to think that there is nothing left to discover about the institutions that can encourage economic development. It is conceivable that the institutions now present in industrial countries exhaust the list of beneficial interventions that would fit the circumstances of low- and middle-income countries. It is far more likely that there are undiscovered institutional arrangements that would work even better. We will never know if we always look at the evidence through a theoretical lens that does not let us consider this possibility.

I. Models and Metaphors

Most theoretical discussions of economic growth revolve around a few mathematical equations built from abstractions such as an aggregate production function. Because of its simplicity, theorists sometimes call such a system of equations a toy model to distinguish it from a multiequation simulation or forecasting model. The label is apt because a good theoretical model should be as easy to manipulate in one's head as the mental image of a child's toy. That is, a successful model invokes a metaphor, and the metaphor has a subtle but pervasive effect on the reader's understanding of the principles behind the equations and his or her belief in the accuracy of its description of the world. To show how one model can obscure our vision of the role of ideas and how a different model can highlight their role, it helps to start by being unusually explicit and concrete about the metaphors behind the math.

A Toy Model

One of the great successes of neoclassical economics has been the elaboration and extension of the metaphor of the factory that is invoked by a production function. To be explicit about this image, recall the child's toy called the Play-Doh Fun Factory. To operate the Fun Factory, a child puts Play-Doh (a form of modeling compound) into the back of the toy and pushes on a plunger that applies pressure. The Play-Doh is extruded through an opening in the front of the toy. Depending on the particular die used to form the opening, out come solid Play-Doh rods, Play-Doh I-beams, or lengths of hollow Play-Doh pipe.

We use the Fun Factory model or something just like it to describe how capital (the Fun Factory) and labor (the child's strength) change the characteristics of goods, converting them from less valuable forms (lumps of modeling compound) into more valuable forms (lengths of pipe). In most applications we imagine that the characteristics being changed are physical characteristics such as shape, chemical composition, or connections with other objects. We push the model slightly when we recognize that the date and location at which a good is available are also relevant characteristics, ones that can be changed by storage and transport. We push the model much further by extending the list of characteristics that can be changed to include a description of who holds property rights. Wallis and North (1986) estimate that by 1970 the transformation of property rights accounted for nearly one-half of gross national product in the United States, so this last extension is particularly important.

The Fun Factory metaphor is powerful because our intuition about production can be pushed to encompass transformation activities and levels of economic analysis far removed from the factory floor. When a worker with a welding rig attaches parts on a car, when a driver with a semitrailer truck moves the car, when a dealer with a showroom sells the car, when a banker with a computer prepares the loan, and when an agent with a tow truck repossesses the car, labor and capital are used to change the characteristics of the underlying goods. In this kind of analysis, the productive unit can range from a household to a firm or industry, even to the nation or the world as a whole.

The production function and the Fun Factory metaphor have been widely used in the neoclassical analysis of aggregate growth. Yet in this analysis the neoclassical model has been successful primarily at establishing a diagnosis by exclusion. Economic growth cannot be understood solely in terms of the accumulation of physical capital and labor—the fundamental concepts in the underlying metaphor. This insight, of course, was Solow's famous result (1957), and it stands to this day despite an enormous effort at refining the econometric techniques for measuring a growth-accounting residual and at extending the notion of effective labor to allow for accumulation of human capital. The formal growth-accounting evidence, historical accounts, and everyday experience all suggest that something extra, something like innovation, invention, technological change, or the discovery of new ideas, is needed to

explain growth. Yet, having made this point, the Fun Factory metaphor offers no guidance about what an idea is, where ideas come from, and how the presence of ideas might matter for development strategy.

Other Toy Models

Another child's toy is a chemistry set. For this discussion, the set can be represented as a collection of N jars, each containing a different chemical element. From the child's point of view, the excitement of this toy comes from trying to find some combination of the underlying chemicals that, when mixed together and heated, does something more impressive than change colors (explode, for example). In a set with N jars, there are $2^N - 1$ different mixtures of K elements, where K varies between 1 and N. (There are many more mixtures if we take account of the proportions in which ingredients can be mixed and the different pressures and temperatures that can be used during mixing.)

As N grows, what computer scientists refer to as the curse of dimensionality sets in. The number of possible mixtures grows exponentially with N, the dimension of this system. For a modestly large chemistry set, the number of possible mixtures is far too large for the toy manufacturer to have directly verified that no mixture is explosive. If N is equal to 100, there are about 10^{30} different mixtures that an adventurous child could conceivably put in a test tube and hold over a flame. If every living person on earth (about 5 billion) had tried a different mixture each second since the universe began (no more than 20 billion years ago), we would still have tested less than 1 percent of all the possible combinations.

Within the metaphor of the chemistry set, it is obvious what one means by an idea. Any mixture can be recorded as a bit string, an ordered sequence of 0s and 1s of length 100. The bit at position j is set to 1 if element j is included in the mixture. In the crude representation used here, an idea is the increment in information that comes from sorting some of the bit strings into two broad categories: useful ones and useless ones. To represent this information, we can add two more bits on the end of each bit string describing a mixture. These are set at 00 if we know nothing about its properties, 10 if it is a useful mixture, and 01 if it is useless.

When a useful mixture is discovered and its trailing bits are changed from 00 to 10, the discovery makes possible the creation of economic value. It lets us combine raw materials of low intrinsic value into mixtures that are far more valuable. Once we have the idea, the process of mixing will require its own Fun Factory (specialized capital and labor). For example, the bit string representing nylon requires a chemical processing plant and skilled workers. Important as these tangible inputs are, it is still the idea itself that permits the resulting increase in value. In this fundamental sense, ideas make growth and development possible.

The potential for continued economic growth comes from the vast search space that we can explore. The curse of dimensionality is, for economic pur-

poses, a remarkable blessing. To appreciate the potential for discovery, one need only consider the possibility that an extremely small fraction of the large number of possible mixtures may be valuable.

There is a branch of physical chemistry that literally cooks up mixtures from the periodic table of elements. New mixtures to be evaluated are selected on the basis of theory, experience, and guesswork. Supporters call this "exploratory synthesis"; detractors call it "heat and beat" or "shake and bake" chemistry. A group of French chemists cooked up one of the 10^{30} possible mixtures, one consisting of lanthanum, barium, copper, and oxygen. More than a decade later, scientists at IBM decided to test the superconductivity properties of the resulting ceramic, even though the prevailing wisdom suggested that it violated several of the basic rules required of a candidate for a good superconductor. The IBM team won the Nobel Prize in physics for their discovery that this mixture became a superconductor at temperatures far exceeding those for all the known superconductors.

This "high-tech" example of a valuable mixture suggests only a small part of the enormous scope for making discoveries of economic importance. If a garment factory requires 52 distinct independent steps to assemble a shirt, there are $52! = 10^{68}$ different ways to order these steps in sequence. The number 52 is a useful reference point because it arises with another familiar toy, a deck of cards. The number of possible orderings for the 52 assembly operations is the same as the number of possible ways to arrange a shuffled deck of cards.

Even though it arises from a very simple toy, a number such as 10^{68} is very big, even in comparison with numbers like 10^{30}. (The total number of protons and electrons in the visible universe is estimated to be on the order of 10^{79}.) For any realistic garment assembly operation, almost all the possible sequences for the steps would be wildly impractical, but if even a very small fraction of sequences is useful, there will be many such sequences. It is therefore extremely unlikely that any actual sequence that humans have used for sewing a shirt is the best possible one.

Corporations that understand this point recognize that there will always be at least as much scope for improvement through large numbers of small changes in the way things are done in a manufacturing process as through laboratory research. Accordingly, they have promoted worker experimentation and systems for encouraging wide adoption of discoveries made on the line.

Conventional wisdom tends to suggest that all the important ideas come from research labs and that nothing remains to be discovered about mundane activities such as assembly line operation or garment assembly—but conventional wisdom completely missed the potential for "continuous improvement," as implemented in Japanese automobile assembly, just as it missed the potential for high-temperature superconductors made from ceramics. To understand growth, we need to understand not only how big ideas, such as high-temperature superconductors, are discovered and put to use but also how millions of little ideas, such as better ways to assemble shirts, are discovered and put to use. To under-

stand development, we need to understand how both kinds of ideas, but especially the millions of small ones, can be used and produced in a developing country.

Human Capital

It is possible to add human capital to both the Fun Factory and the chemistry set models, and it is instructive to do so. In the Fun Factory model there are only two basic kinds of inputs, human and nonhuman. Physical capital is an aggregate of many different durable nonhuman inputs. The concept of human capital lets us recognize and aggregate different kinds of human inputs. One person may be more productive than another, just as one machine may be more valuable than another. Some of the differences in productivity among workers are the result of investments and are durable, so the analogy with capital is close.

As powerful as this analogy is in labor economics, it sheds little light on the fundamental processes that generate growth. In some proximate sense it must be true that increases in human capital and physical capital explain the increases in value that we have experienced. But what does it really mean to say that the average worker today has several times the effective labor power of a worker in the last century? In a biological sense the population of workers today is virtually identical to the population that existed then.

To see how the same physical objects can be arranged in more valuable ways, consider first an example involving physical capital. The computer that I used to write this paper is about fifty times faster than the one I used just ten years ago, yet it is constructed from just about the same assortment of aluminum, copper, steel, plastic, silicon, and other raw materials. It is manufactured in about the same way and is sold for about the same price.

Now consider human capital. In my brain there are different physical connections between my neurons. These connections store the commands I need to use the new computer and new word-processing software. Just as my new computer is a more productive piece of physical capital, I have more valuable human capital than I did ten years ago.

From the point of view of the chemistry set model, the increase in the value of human and physical capital that is possible using fixed tangible inputs is just like the increase in value that arises when elements such as lanthanum, barium, oxygen, and copper are combined to make a high-temperature superconductor. The knowledge that one mixture or arrangement is more valuable than another is just like the knowledge that changing the layout in a microprocessor increases its processing power, that a different design for a hard disk will increase its storage capacity, or that storing the bit string representing the word-processing software on my hard disk will make the computer more useful. It is also just like the knowledge that reading a software manual rearranges connections in my brain and makes my human capital more valuable. (For later reference, note that on-the-job experience with the software is also extremely important for establishing and reinforcing these connections.)

In some accounting sense the combined increase in the value of human and physical capital explains the increased productivity in word-processing experienced in my office. But to explain productivity growth through these increases in human and physical capital begs the question of where the increased value of the capital originates. The increased value is created by new ideas. Whether it takes the form of a hardware design, software code, or an instruction manual, an idea is used to mix or arrange roughly the same physical ingredients in ways that are more valuable. And in each case, these ideas can be represented as pure pieces of information, as bit strings.

Ideas are therefore the critical input in the production of more valuable human and nonhuman capital. But human capital is also the most important input in the production of new ideas. Physical capital (a computer, for example) is sometimes used in an ancillary way, but a trained person is still the central input in the process of trial and error, experimentation, guessing, hypothesis formation, and articulation that ultimately generates a valuable new idea that can be communicated to and used by others.

Because human capital and ideas are so closely related as inputs and outputs, it is tempting to aggregate them into a single type of good. After all, structures and equipment are different goods, and they both fit rather well in the category of physical capital. It is important, nevertheless, to distinguish ideas and human capital because they have different fundamental attributes as economic goods, with different implications for economic theory.

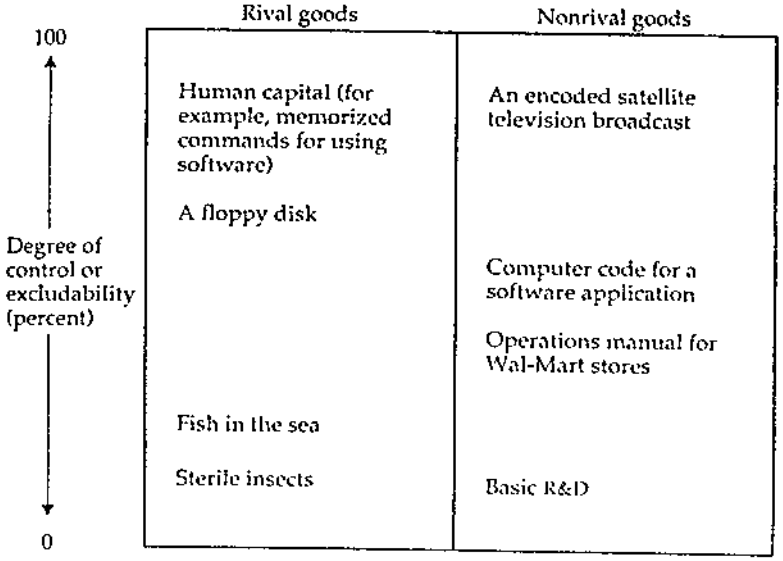
Attributes of Economic Goods

Figure 1 illustrates a two-way classification of different types of economic goods that has been useful in the economics of public finance. The vertical axis measures the degree of control or excludability (or appropriability) that is feasible for a good. The left-hand column lists rival goods—goods that are object-like in the sense that they have an opportunity cost. (The label "rival" reflects the fact that you and I are rivals for the use of one of these goods.) The right-hand column lists nonrival goods, which are like bit strings in the sense that everyone can use them at the same time.

As traditionally defined, a private good in public finance is one that lies in the upper-left-hand corner of the figure; it is both rival and fully excludable. According to this definition, human capital is as close to a perfect private good as one can get. There is no way for anyone to take advantage of my ability to remember commands for my word processor without getting my permission; therefore my ability is fully excludable or is subject to complete control by me. And because there is also no way for many people to make use of my ability at the same time, it is a rival good.

Many economists will find these assertions surprising. We often assert that there are spillovers from human capital, such as incomplete control or excludability. We also have an intuition that since I can teach others to do what I

Figure 1. *Economic Attributes of Selected Goods*



can do, what I know is nonrival. After I teach them, we will all be using the same computer commands at the same time.

These imprecise statements are the result of a failure to distinguish among human capital, the ideas that help produce human capital, and the ideas that human capital can produce. My human capital is literally a set of connections between neurons. Converting this rival good into a nonrival good—for example by putting what I know into comprehensible prose on paper—is a time-consuming activity. Once what I know is expressed in words, it can indeed be used by many people (neglecting for now the trivial cost of making a photocopy). As each person reads my words, the nonrival bit string represented by the text is converted back into the rival human capital. Human capital is therefore used to produce ideas, and ideas are used to produce human capital, but human capital and ideas are conceptually distinct goods. They occupy different places in figure 1 and have different implications for economic analysis.

The bit strings, or the how-to manual for using software, would be nonrival, not the connections in my brain. The bit string would also be difficult to control, as every software firm knows. For most of the successful computer programs, someone has written a book that is a substitute for the original manual and can be used by someone who has bootleg copies of the code for the program.

When I bought my software, I purchased a manual, several floppy disks, and the legal right to use the bit string representing the computer code. I used the manual to produce some human capital that is easy for me to control. The floppy disks themselves are somewhat harder to control because they could be stolen. For this reason they are listed farther down the column of rival goods.

The software code is even harder to control because it can be taken without the knowledge of the owner. This feature tends to make all nonrival goods less excludable and more difficult to control.

Because nonrivalry and limited control are correlated in practice, many informal discussions of ideas do not distinguish carefully between the two concepts, but for economic analysis the difference is important. Private firms survive in the business of writing and selling very costly computer code; therefore they must be able to assert some control over it. Software code is, however, the quintessential nonrival good. Most ideas of economic significance lie in the upper right portion of figure 1. They are nonrival and at least partially excludable.

Such goods are very different from the goods in the lower left side of the figure, the ones that are rival but impossible to control. Fish in the sea are the most familiar example for economists. Only one person can eat a fish. Sterile insects used to prevent the reproduction of agricultural pests are another example. A sterile male insect can mate with unsuspecting fertile insects in one valley or the other, but not in both at the same time. Because it is so difficult to establish property rights over these kinds of goods, market outcomes are inefficient. We overfish, and we underprovide sterile insects. Our understanding of the policy implications of this part of the figure is very clear. Property rights should be provided where possible—for example, tradable rights to catch fish. Where this is not possible, as in the case of the insects, the government must supply the good and use its tax power to cover the costs.

Although the sterile insects seem to be examples of public goods in the everyday use of the term (things that are provided by the government), the formal definition of a public good used by economists is one that lies in the lower right of figure 1; it is a good that is both nonexcludable and nonrival. Basic scientific research is perhaps the best example of a pure public good in this sense. Our understanding of how vaccines prevent disease and how drinking water mixed with electrolytes can prevent death from diarrhea both come from public support for basic research.

In the left-hand column (the rival goods), the policy implication is to move up the column—to create property rights whenever possible and to make them as strong as possible. For nonrival goods, this conclusion does not follow. Property rights to a nonrival good always imply a market price for the good that is higher than its opportunity cost because the opportunity cost is zero. As the usual analysis of patents suggests, strong property rights and the resulting monopoly profits are desirable because they create an incentive to discover new ideas, but they are undesirable because the difference between price and marginal cost creates distortions.

Depending on the type of good involved, we craft different solutions to this conflict between the two conditions required for efficiency. In some cases it is relatively clear which directions for new discoveries are worth pursuing, and the social cost of setting a price higher than marginal cost is very high. In these cases—for example in public health—the government pays for the research and

gives the results away. In other cases the government has no mechanism for deciding what to produce, and the social costs of prices higher than marginal cost seem trivial—for example, in the production of popular music (which these days is literally a bit string on a compact disc). In areas such as biotechnology and software it is unclear exactly how we should proceed. We do not know whether a gene fragment or a programming concept such as overlapping windows should be protected by law or, if so, whether the law of copyrights, patents, or trade secrets should be used. (For additional discussion of the policy dilemma presented by nonrival goods and of the different institutional arrangements that have emerged for dealing with it, see the paper by Paul David in this volume and the references cited therein.)

For thinking about growth and development, the important implications of figure 1 are as follows. First, the distinction between objects and ideas (between rival and nonrival goods) is far more important than the concept of excludability or control or the related concepts of spillovers and externalities. An approach to economic policymaking that neglects nonrival goods will miss most of the interesting issues.

Second, nonrival goods have the unique feature that their value depends on the size of the market in which they can be used. This is obvious for an idea such as the vaccine that is treated as a pure public good but is equally true for nonrival goods such as software or even ideas about how to run a discount store. If Bill Gates could have sold software only in Washington state, or if Sam Walton could have opened discount stores only in Arkansas, they would have been millionaires, at best, instead of the billionaires they became. This is the other side of the gains from trade that ideas can generate if they are widely used.

Third, any discussion of an economy in which nonrival goods such as software are privately provided must allow for departures from price-taking. The textbook description of perfect price-taking competition is logically inconsistent with the private provision of nonrival goods. Even in a case in which a bit string (for example, computer code) must be sold together with an object (for example, a floppy disk), monopoly pricing must still apply. The package consisting of the code and the disk will have a positive marginal cost equal to the cost of the disk, but the package must still sell for a price higher than marginal cost, or no one would be able to earn a return on effort devoted to writing software. Casual empiricism suggests that software sells for a price that is 10 to 100 times marginal cost.

Fourth, and finally, there is no hope that a decentralized equilibrium in which new ideas are discovered will be first-best Pareto optimal. The usual justification for the welfare theorems in terms of price-taking does not apply. No comparable justification on the basis of the Coase theorem will work unless it replicates the essence of a government—a decisionmaker with powers of coercion over everyone else in the economy.

This last point is clear only in a general equilibrium setting, which perhaps explains why it has not been adequately emphasized. In partial equilibrium

analysis, price-setting by a monopolist is consistent with Pareto optimality if control or the ability to contract is strong enough. For example, we know that a perfectly discriminating monopolist or a monopolist who charges a two-part tariff can produce the efficient level of output in a partial equilibrium model.

This partial equilibrium analysis simply does not extend to the economy as a whole. It violates a fundamental adding-up condition. Output for any particular activity can be written as $y = f(k, h; a)$, where h and k are lists of all the different human and nonhuman rival goods that are used in production and a is the idea or knowledge that makes this activity possible. For fixed a, we can think of the production of y in terms of the Fun Factory metaphor. By a standard replication argument, f is homogeneous of degree 1 in the rival goods that must be replicated to make a copy of the existing activity. But Euler's theorem tells us that h and k will exhaust the total value of output in this activity if competition is used to allocate these goods and they are paid their value marginal products. Nothing will be left to pay for a.

What is true for one activity is equally true for the economy as a whole. If aggregate output is written as $Y = F(H, K; A)$, F will be homogeneous of degree 1 in the human and nonhuman rival inputs. It is therefore impossible to use prices to allocate H and K between different activities and at the same time provide the incentives for discovering ideas, A. There is not enough income in the economy as a whole to go around. (See Romer 1990a for an elaboration of this point.)

II. Two Islands

The challenge now is to use the analytical framework outlined above to discuss the different economic activities taking place in Mauritius and in Taiwan (China). In both economies government policy is attuned to the role of ideas. In Mauritius policy changes in the 1970s and 1980s made it attractive for entrepreneurs from Hong Kong to put their ideas to use there. As a result, the citizens of Mauritius achieved large increases in income and employment. A more clear-cut case of the gains from trade could hardly be imagined. In Taiwan (China) ideas from the rest of the world are not merely put to work with domestic labor. To a much greater extent than in Mauritius, the government intervened in market exchange in its attempts to encourage the domestic production and exploitation of ideas that can earn a return on world markets.

Using Ideas: Mauritius

Table 1 reports some basic economic and social indicators for Mauritius over the interval from 1960 to 1985. For comparison, data are also presented for two economies with similar ethnic and economic backgrounds, India and Sri Lanka, and for Taiwan (China), which is discussed below. In Mauritius the share of investment in gross domestic product (GDP) is no better than that in the other

Table 1. *Economic Performance, 1960–88*
(percent, except as otherwise specified)

Indicator	*Mauritius*	*India*	*Sri Lanka*	*Taiwan (China)*
Rate of growth of income per capita, 1960–88	2.8	0.9	1.3	6.4
Rate of growth of population, 1960–88	1.7	2.2	1.9	2.2
Income per capita, 1960 (1985 U.S. dollars)	2,000	600	1,400	950
Share of investment in GDP, 1960–88	12	17	21	23
Literacy rate, 1960	60	28	75	54
Primary school enrollment rate, 1960	98	61	95	96
Average years of schooling, labor force, 1986	4.5	1.9	6.2	8.4

Sources: For income, investment, and population, Heston and Summers (1991); for literacy and schooling, Levine and Renelt (1992).

three economies and in the Heston-Summers data used here, it is substantially lower.[1] Investment in human capital, while better than in India, is not outstanding. Income per capita at the beginning of the sample period was higher than in the other three economies because of the high income earned by the wealthy owners of sugar plantations, but the distribution of income was very uneven.

When Mauritius was preparing for independence from Great Britain in the 1960s, prospects for development did not seem promising. The economy was dependent on sugar exports for 99 percent of its exports. James Meade, commissioned by the British government to comment on economic policy, entitled his 1961 report "Mauritius: A Case Study in Malthusian Economics" and devoted it to a discussion of how to cope with a real wage that would inevitably fall as population on the island grew. Young people with higher levels of education were encouraged to emigrate, but it was feared that not enough would leave. A local import-substituting manufacturing sector existed only because of protective tariffs.[2]

Since independence in 1968, the political situation has been fluid, almost to the point of instability. Up to the present, corruption, fraud, and drug trafficking have been a continuing source of government scandals. Political parties are organized along ethnic and religious (primarily Hindu and Muslim) divisions. There has been no majority government since independence. The emergence of a

1. According to the national income accounts data of the World Bank (see Levine and Renelt 1992), Mauritius, India, and Sri Lanka all invest about 20 percent of GDP. The Heston-Summers numbers adjust nominal investment spending to correct for variation in relative cost of capital goods in different countries. In principle, the real investment numbers from Heston and Summers are more relevant, but the downward adjustment for investment in Mauritius seems implausibly large.

2. The account that follows is drawn from World Bank data and from published studies by Gulhati and Nallari (1990) and Bowman (1991).

left-leaning party and the strikes that it organized in 1971 provoked an assassination attempt instigated by members of a rival party. This led to public riots and a state of emergency that lasted until 1976. Unions were suspended, and union and party leaders were arrested.

The average growth rate for per capita income of nearly 3 percent a year during 1960–88 was achieved despite the terms of trade shocks experienced by all primary goods exporters in the 1970s. Sugar prices soared in the early part of the decade, then fell dramatically in the second half just as oil prices went up. This led to predictable macroeconomic difficulties (budget deficits, inflation, and a balance of payments crisis), followed by a period of austerity and adjustment that was associated with zero growth during the five years from 1978 to 1982. Most of the growth that took place came in two brief spurts, one in the first part of the 1970s and the other in the latter part of the 1980s.

Despite all this, Mauritius stands out as a significant and surprising success story when compared, for example, with India and Sri Lanka. The only obvious candidate for explaining the success of Mauritius is the island's policy of supporting an export-processing zone (EPZ), which made investment attractive to foreigners. The EPZ was an administrative arrangement; it involved no geographic restrictions and no special investment in infrastructure. The main policies in this arrangement were unrestricted, tariff-free imports of machinery and materials, no restrictions on ownership or repatriation of profits, a ten-year income tax holiday for foreign investors, a policy of centralized government wage-setting, and an implicit assurance that labor unrest would be suppressed and wage increases would be moderate.

From the inception of the arrangement in 1971, employment in the EPZ grew to 17,000 workers by 1978, a significant number on an island with a total population of about 1 million. Over this same interval GDP per capita grew at 9 percent a year, fueled partly by the EPZ and partly by favorable sugar prices and harvests. During the macroeconomic difficulties between 1978 and 1982 EPZ employment growth slowed and almost ceased. Once the government had completed its adjustment process, growth resumed with a vengeance. Income and corporate tax rates were halved in 1983 (from about 70 to about 35 percent). Both domestic and foreign investment in the EPZ increased sharply. In 1982 the unemployment rate stood at 22 percent and total employment in the EPZ at about 20,000 workers. By 1988 the economy had essentially reached full employment through the addition of 70,000 jobs in the EPZ. In 1970 agriculture employed 60,000 people and the EPZ did not exist. In 1990 agriculture employed 46,000 workers and the EPZ employed 90,000, about one-third of all workers on the island. Jobs added in the EPZ accounted for two-thirds of the total increase in employment between 1970 and 1990.

Manufacturing in the EPZ is concentrated almost exclusively in garment production and was developed almost entirely because of the participation of entrepreneurs from Hong Kong who were drawn to Mauritius because of contacts with the small ethnic Chinese population on the island. These entrepreneurs

were motivated by the prospect of lower wages, a location free from the threat of expropriation by the mainland Chinese government, and a country of origin that would not be subject to quota limits set by the United States and the European Economic Community (EEC). Investors from Hong Kong now hold nearly three-quarters of the foreign investment in the EPZ.

According to one observer (quoted in Bowman 1991), "textile entrepreneurs flocked to the island bearing sewing machines" because of the EPZ arrangements. In the Fun Factory model, this inflow of capital must explain the increase in employment and output that subsequently took place. A little reflection suggests that the entrepreneurs brought much more than physical capital, for Mauritius had long enjoyed special trade status with the EEC, and sewing machines could always have been purchased on the open market. Nor were foreigners essential as a source of the savings needed to finance investment in physical capital; domestic savings ultimately accounted for a substantial fraction of total investment in the EPZ.

The entrepreneurs did bring a crucial array of ideas about the textile and garment business, including ideas on the specific kind of equipment to use, how to manage a small factory, how to manage relations with textile importers in the industrial countries, how to successfully exploit loopholes in quota limits, and hundreds of other ideas about running a modern garment assembly operation, such as knowledge of the sequence to use in sewing a shirt.

In a model with no ideas or in which ideas are already available throughout the world, it is difficult to explain the experience of Mauritius. If investment in physical capital is the cause of growth, one must understand why domestic investment did not take place prior to the arrival of the foreigners but did subsequently, and why it took place only in garment production. If a scarcity of human capital explains why people on Mauritius were poor, this surely could not have changed much in the interval between 1972 and 1979 or between 1982 and 1989. Moreover, if human capital were all that mattered, why did Mauritius do so much better than Sri Lanka, which had a much better record in education?

In a world in which ideas are under private control, events in Mauritius are easy to understand. Suppose that agricultural output is a constant returns-to-scale function of land, T, labor, L, and capital, K: $F(T, K, L)$ (F for farm). We can summarize garment output in the form $G(K, L; A)$, where A takes on the values 0 or 1 (G for garment). Output of garments is zero if $A = 0$ because no one knows how to run a garment operation. If an entrepreneur does know, $A = 1$ and garments are a constant returns-to-scale function of sewing machines, K, and labor, L.

When $A = 0$, wages are equal to the marginal product of labor in agriculture. For large L, wages can be very low. Sewing machines are freely available for sale at the price p_K, but none are imported because no one knows how to put them to use. Farm equipment is imported, funded either by domestic savings or by foreign investment. Investment in Mauritius earns the same rate of return as in

the rest of the world. Wages were low not because of any restrictions on flows of financial capital or inadequacy of domestic capital investment but because the idea, A, needed for garment production was not in use there.

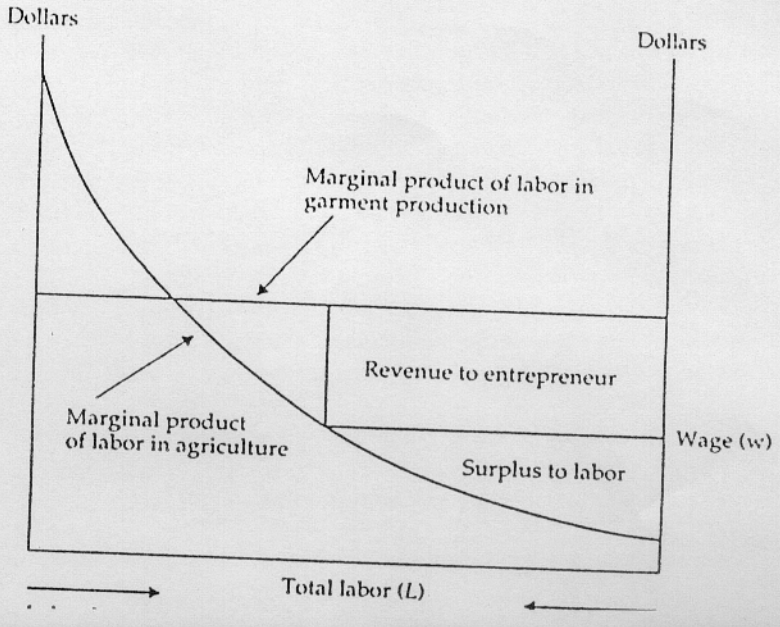
Now suppose that a single textile entrepreneur learns of the low wages on Mauritius, brings knowledge of A, and sets up shop. Sewing machines will now be imported. Income and employment will increase. An examination of many such cases could lead one to conclude that investment, particularly investment in machinery, causes rapid economic growth. (See DeLong and Summers 1991 for cross-country evidence of the correlation between investment in machinery and growth.) What detailed knowledge of the history of Mauritius shows is that investment was the proximate, but not the fundamental, cause of the growth that took place. It was the knowledge, A, brought by the foreigners that caused both the investment and growth.

To represent the private returns for putting an idea to use, let $\Pi(L, p_C, p_K)$ denote the restricted profit function for a single entrepreneur who employs L units of labor on Mauritius and faces a price for sewing machines p_K. Since $G(K, L; A)$ is homogeneous of degree one in K and L, the profit function Π defined by

$$\Pi(L, p_C, p_K) = \max_K p_C G(K, L; 1) - p_K K$$

will be linear in L. The entrepreneur is a monopsonist in the labor market in Mauritius, as depicted in figure 2. The excess supply curve for labor faced by the

Figure 2. *Labor Market with a Monopsonist Entrepreneur*



entrepreneur (which is the same as the marginal productivity curve in agriculture) is upward-sloping. The marginal product of labor for the entrepreneur is constant. The single entrepreneur will employ labor up to the point where wages are equal to w in the figure.

Workers in Mauritius are exploited in the sense that w is strictly less than the marginal product of labor. Yet they also receive a pure surplus or windfall gain from the entry of the entrepreneur (the area labeled "surplus to labor" in the figure). The entrepreneur collects the monopsony rectangle denoted "revenue to entrepreneur." Workers in agriculture also gain at the expense of landholders.

The usual analysis of government policy when faced with this kind of monopsonist recommends a minimum wage. By setting the minimum wage at close to the marginal product of labor in garment assembly, the government can drive the monopsony profits to zero, encourage the efficient level of employment, and capture the largest possible surplus for workers.

The problem with this analysis is that it neglects the possibility that the textile entrepreneurs will not come if they are not offered a large enough profit. Coming to Mauritius is a costly activity, and these entrepreneurs have alternative uses for their time and energy. Welfare on the island is increasing when the minimum wage is raised from the monopsony level, but only up to the point at which the ex post monopoly revenue captured by the textile entrepreneur is just enough to offset the initial cost of coming there. Beyond this point, an increase in the minimum wage makes welfare on the island drop precipitously, back to the Malthusian equilibrium anticipated by Meade.

Extracting surplus from foreigners can therefore be a risky proposition, especially if policy decisions are made in the absence of knowledge about the potential entrants and their costs and alternative opportunities. The dangers of setting too high a value for the minimum wage apply equally to other costs imposed on foreigners—costs such as burdensome customs procedures, high required domestic equity participation, high explicit taxes, high implicit taxes collected as bribes, ex post extraction of rents by organized labor, or poor provision of services by government agencies. An authoritative central government that can centralize the decisionmaking process and lower the total rent extracted from potential investors can generate substantial benefits for the nation as a whole if it changes the EPZ from one that has not attracted any substantial foreign participation (and there are many of these in the world) to one that is attractive. (For a more detailed description of this problem of decentralized extraction of rents, see the analysis of corruption by Shleifer and Vishny 1992.)

The analysis suggests not only that attempts by the government to extract rents may be strongly counterproductive but also that the government must be strong enough to prevent this kind of extraction by other actors in the economy. The government might even be able to improve welfare by subsidizing the entry of the entrepreneur. If the fixed costs for the entrepreneur of coming to the island are greater than the monopsony profit but smaller than the sum of this profit plus the surplus to workers, the government could offer part of the surplus

to induce the entrepreneur to come. In the more realistic case in which a large number of firms, rather than a single monopolist, contemplate entry, the government might even facilitate collusion among the foreign firms to preserve their profits after entry.

Viewed in this way, the timing of the investment in Mauritius is easier to understand. The state of emergency, the banning of unions, and the imposition of centralized government wage-setting were crucial steps leading to the first wave of investment by foreigners. Resolution of government budget difficulties, a devaluation that reduced real wages for workers, and cuts in effective tax rates were the decisive actions in bringing about the second wave of investment. It is also relevant that while employment and income did increase substantially in Mauritius, the government made good on its pledge of wage moderation. Real wages have been allowed to increase very little in garment assembly. Now that full employment has been reached, there are signs that the government is moving away from the previous policy of wage moderation. How it will handle the next phase of development is not yet clear.

What is worrisome about a strategy of encouraging foreigners to employ low-skilled, low-cost labor is that the equilibrium wage for unskilled labor may be very low—even lower than the wages now earned on Mauritius. In the industrial countries during most of this century, A and H have been high and growing in relation to the small quantity of L present in these countries. Because of restrictions imposed by poor countries, labor in the rest of the world was segregated from labor in industrial economies. The restrictions were no doubt encouraged by domestic firms that wanted protection from foreign competition in output markets and in the labor market but may also have been fostered by a fear of exploitation. As a result, wages for L kept pace with growth in A and H in industrial countries.

Now many poor countries understand the advantages that come from removing these restrictions, and a very large quantity of labor from developing nations is on the verge of entering the worldwide market. For example, there are more than 125 EPZs in developing countries, with most of the increase in numbers coming in the last half of the 1980s. Mainland China and even India are now opening to the rest of the world. In addition, improvements in transport and communication have reduced the costs faced by an entrepreneur who wants to move production elsewhere in the world. The first countries to integrate their labor markets with markets in industrial countries experienced relatively large wage gains, but as more labor from other developing countries enters the market, wages will have to fall.

There is already evidence of this process in the pressure on wages for unskilled labor in industrial countries, especially the United States. Skill differentials are increasing as real wages for unskilled labor remain stagnant or fall. In industries where production in low-wage countries can most easily be undertaken (textiles, for example), there is already in place an extensive system of quotas designed to protect wages in industrial countries. Countries such as Mauritius can therefore

expect to be squeezed from two sides. There will be more competition from other countries with low labor costs and increased trade barriers in industrial countries.

In the very long run, the fall in wages will be partially offset by increases in worldwide stocks of K and H. Suppose that the ratio of these stocks to the world stock of labor L reaches the ratio that now prevails in industrial countries. A striking implication of the analysis of ideas as economic goods is that worldwide integration of markets will permanently increase wages for H in relation to wages for L. As emphasized in the discussion of ideas, the value of an idea increases with the size of the market. Because the production of ideas is human-capital-intensive, increased worldwide economic integration will drive up the returns to human capital in relation to returns to labor. There are large gains from trade that arise from worldwide integration. Unfortunately for poor people and poor countries, the gains will be captured disproportionately by the most highly skilled workers. (See Romer 1990b or Grossman and Helpman 1992 for formal models that illustrate this point.)

For a small economy, investing in schooling may not by itself be enough for it to become involved in the production of ideas, where the high returns to human capital lie. The production of ideas requires human capital, but it also requires access to existing ideas. A country like Sri Lanka that invests heavily in education but remains isolated from all the economically important ideas that are in use in industrial countries has no hope of ever becoming a player in the global production of ideas. Recall that before Mauritius opened the EPZ, its policy was to encourage migration of educated youths, for whom there were no prospects on the island.

A more worrisome possibility is that the relatively open strategy toward the rest of the world pursued by Mauritius, or even a strategy of totally free trade, may not be sufficient to bring local human capital into use in the production of ideas. It is easier to use ideas in a small country than it is to begin producing ideas. It takes a relatively narrow range of ideas to open up a particular activity such as a garment factory. Because of constant returns to scale, the market incentives will then be to increase production of the associated good without incurring the cost of starting another activity. In Mauritius only one idea has been put to work because almost all of the EPZ output is in garments. Prospects for developing new products—that is, for producing ideas—are therefore quite weak.

Taiwan (China)

Authorities in Taiwan (China) used a wide variety of approaches to encourage the use of ideas there, with the explicit intention of shifting to the domestic control and production of ideas. Generally speaking, the government moved from a period of import substitution during the 1950s and 1960s toward an export-oriented strategy in the 1970s and 1980s. More recently it has placed increased emphasis on human capital and research subsidies similar to those

used in industrial economies, but in applications with specific commercial goals. The pattern of intervention in several different industries illustrates the eclectic and flexible approach used by the government to achieve its aims.[3]

In the early 1950s the government gave special attention to the textile industry, which got its start with mainlanders who came to Taiwan (China) with their knowledge and looms. Early policy supports included tariffs and quantitative limits on imports of yarn and finished products, restrictions on entry for new firms, and controlled access to raw materials. In the early years the government supplied raw cotton to spinning mills and bought all the finished yarn, which it then supplied to firms with looms. Later the government used cheap credit to encourage firms to operate at larger scales and to integrate vertically, relying on the local office of a U.S. engineering firm to evaluate individual requests for credit. Exports grew rapidly from 1952 to 1958, the year when the island became a net exporter of textiles. After the exchange rate regime was changed in 1958 to encourage exports, textile exports to the United States grew so rapidly that quota limits were imposed in 1961.

To diversify the textile industry away from cotton, the government encouraged a move into synthetic fibers, acting primarily as an intermediary between domestic firms and foreign firms with advanced technologies. By 1954 the domestic chemical industry could produce most of the intermediate inputs needed to make rayon. With the help of advisers from the United States, the government brought together a U.S. firm and several local textile firms and supervised the negotiations leading to the creation of a joint venture that began production in 1957. The U.S. firm provided the planning, the equipment, and worker training. In 1962 this joint venture, in collaboration with a state financing agency, created another joint venture to make nylon, this time relying on technology from a Japanese firm. As private firms began to enter the synthetic fibers industry in the late 1960s and 1970s, they relied increasingly on licensing instead of joint venture agreements. The government continued to assist in finding foreign partners with technology to share and in negotiating the terms of the technology agreements, over which it retained authority for final approval. By 1981 Taiwan (China) was the fourth biggest producer of synthetic fibers in the world.

The electronics industry started like the textile industry, building from a domestic base in radio assembly that was protected by restrictions on imports. As in synthetic fibers, radio assembly was aided in the early years by a technology agreement with a foreign firm. Then, in the 1960s, the government set up an EPZ designed to encourage electronics assembly by foreign firms. By 1965 twenty-four U.S. firms had made arrangements for production in Taiwan (China). The industry developed around a few large foreign assemblers and many small domestic suppliers of components. A government-supported electronics working group assisted in marketing, training of personnel, and product

3. This account is drawn from Wade (1990).

expositions. In 1973 the government opened the Industrial Technology Research Institute (ITRI), which supported advanced training programs for engineers. The Electronics Research and Service Organization (ERSO), which operates under ITRI, supplied the first basic input-output system (BIOS) used in Taiwanese clones of IBM personal computers. More recently ERSO supported a move into semiconductor design and fabrication, opening a model shop for wafer fabrication and negotiating a technology transfer agreement with a U.S. firm. The government has begun to aggressively court Taiwanese nationals who had been trained and were employed in electronics and other high-technology fields in the United States. By 1968 electronics was second only to textiles in total exports, and in 1984 it became number one.

Over time the government in Taiwan (China) has increasingly emphasized exports and has moved away from the traditional import-substituting model of development. It is largely for this reason that Taiwan is regarded as an open, or at least an outward-oriented economy. It has nevertheless continued to employ many restrictions designed to protect and develop domestic industry. Proposals for foreign investment outside of an EPZ must be approved by the government and are often subject to conditions that limit sales in the domestic market, mandate local-content requirements, or set export targets.

Three cases are indicative of the general pattern. When the Singer Sewing Machine Company asked permission to open a manufacturing plant in the 1960s, the government required that within one year the company purchase more than 80 percent of its parts domestically. Singer did facilitate technology transfer and helped upgrade the domestic components industry but was not able to meet its goal by the end of the first year. The agreement with the government was then renegotiated. When the National Distiller and Chemical Corporation from the United States proposed the construction of a polyethylene plant, it was given a five-year tax holiday, permitted to sell in a domestic market that was protected from imports for three years, and allowed unlimited repatriation of profits. In return, the government insisted that after five years the firm would convert to a joint venture, with half of the equity held by residents of Taiwan (China). When Proctor and Gamble opened a plant in the 1970s, it was required to export 50 percent of its output.

Export requirements were initially imposed to generate foreign exchange but were increasingly used to guarantee that a foreign company would bring to Taiwan (China) a technology sophisticated enough to compete in world markets. It is anticipated that through the company's purchases from suppliers, through the experience of workers, and sometimes through mandated sales of equity, aspects of this technology will diffuse to Taiwanese citizens. In general, negotiations with foreign firms are characterized by a wide latitude for discretion and by agreements that are customized to fit the circumstances (and bargaining strength) of each foreign investor. Aggressive targets are set but are subject to renegotiation on the basis of new information.

Explicit tariff barriers have fallen, but nontariff barriers continue to be used as indirect subsidies for domestic firms. Imports of foreign equipment and intermediate inputs are subject to a complicated system of discretionary administrative control designed to support domestic suppliers of a good. One Taiwanese study cited by Wade estimates that in 1984 about half of all imports by value were subject to some form of nontariff barrier. In addition, government officials monitor detailed reports of imported inputs used by foreign firms, watching for cases in which they can arrange for a domestic supplier to provide the imported goods.

A key characteristic of government intervention in Taiwan (China) is the freedom and authority with which government officials can act. Three examples tell the story. The chief economic planner for the government once ordered the public destruction of 20,000 low-quality domestic light bulbs and threatened to liberalize imports if quality did not improve. The government approved the arrangement with Singer Sewing Machines despite the opposition of domestic sewing machine manufacturers, who ultimately benefited from the improved quality of the parts industry. In 1982 the government granted a two-year import ban on videocassette recorders (VCRs) to protect two domestic manufacturers from Japanese competitors. After one year the government gave a public warning that it would bring in a foreign firm in a joint venture if the prices and technology of the domestic firms did not achieve world standards by the end of the two-year ban. The protected firms did not live up to this standard, and eighteen months after the initial ban the government approved a joint VCR production venture between Sony and a new Taiwanese firm.

Some economists see the success of Taiwan (China) as a vindication of laissez-faire. Others attribute it to an explicit industrial policy that steered the economy into a sequence of important activities. A third interpretation is that the particular industrial activities undertaken in Taiwan were determined primarily by market forces and followed the general pattern observed in other countries at similar stages of development (Pack 1992). According to this view, what mattered was not the government's steering but its use of the accelerator. Taiwan moved very rapidly through the stages of industrial development, in large part because of its success in gaining access to and control of foreign technology. This is reflected in a high rate of measured productivity growth, which stands in contrast to the low productivity growth recorded in rapidly developing economies where growth is driven by extremely high rates of capital accumulation. (See Young 1992 for a discussion of Singapore and Pack 1988 or in this volume for a general description of this phenomenon.)

The description in the previous section of the gains from using ideas suggested reasons why government intervention might be useful. Ideas that are privately controlled create more economic value when they are introduced into an economy than the holder of the idea can extract. A description of the opportunities for producing ideas reinforces this point.

The discussion of production on Mauritius focused on a single manufacturing activity and did not consider the production of ideas at all. Suppose that there are many different manufacturing activities which can be indexed by j, and suppose that each activity requires its own idea A_j:

$$Y = F(T, K, L) + \sum_j G_j(K_j, H_j, L_j; A_j).$$

Suppose as well that search, the production of new ideas, depends on human capital, H_A, used exclusively in search, and on the entire list $(A_1, A_2, \ldots)$ of ideas that are in use within a specified geographic area. Suppose also that success in search also depends on the amount of human capital that is used in production in each of the manufacturing activities, $(H_1, H_2, \ldots)$ through a process of "discovering" by doing:

$$\dot{A} = S[H_A, (A_1, A_2, \ldots), (H_1, H_2, \ldots)].$$

Finally, recall the example of learning how to use computer software by using it. To capture this, we can write human capital acquisition as a function of the use of specialized human capital on the job in a conventional learning-by-doing specification:

$$\dot{H}_j = \mu H_j.$$

Note that this description of the accumulation of new ideas and new human capital relies on two different kinds of joint product assumptions. Someone with human capital of type j who is employed in activity j produces manufactured good j, produces more human capital of type j, and (occasionally) makes new discoveries of the "better ways to sew a shirt" variety.[4]

In this complete model it is clear that when a new idea comes into an economy, it helps domestic citizens in three ways. First, as noted above, the new idea creates a surplus for unskilled labor by making possible a new productive activity in which it can be employed. Second, it creates opportunities and production of specialized human capital through on-the-job training. In effect, it creates a new opportunity for investing in human capital, and the returns from this investment may be very high. Finally, it increases the productivity of research and discovery. If enough such ideas are present, this may tip the economy from a no-

4. See Romer (1990b) for a discussion of a basic model with a manufacturing sector and a separate research sector in which search builds on existing ideas. Grossman and Helpman (1992, ch. 8) cover the case assumed here in which only ideas that are available locally can be used in research. They derive the result that government intervention in support of research may be necessary to move a geographic region out of a corner equilibrium with no research. Glaeser and others (1991) describe the theoretical motivation for allowing a diverse set of ideas to enter as inputs in the search process for new ideas and offer evidence from different cities in the United States that supports the importance of this effect. Empirical support for the idea that human capital is acquired on the job in developing countries can be found in the survey of experience in EPZs by Rhee, Katterbach, and White (1990). For example, they find that many managers of domestic firms operating in the EPZ in the Dominican Republic were once employees of foreign-owned firms in the EPZ.

discovery equilibrium to one in which many new products and processes are discovered.

It is possible that the firm that brings an idea to an economy can capture part of these additional gains. For example, it may be able to get educated employees to work at a lower wage in exchange for the opportunity to acquire human capital on the job. Even if this is true, the firm is likely to capture less than 100 percent of the gains—perhaps substantially less. And economists widely agree that a firm captures very little of the gains that its ideas create for others engaged in research.

For all these reasons, the social return to having an idea like the technology for polyethylene in use in an economy may be substantially greater than the private gain that foreign holders can capture. Thus, subsidies from the government to attract these ideas may be essential to get them to come. (Recall the three-year protection from competing imports offered to the polyethylene plant. The total gain for domestic citizens, net of the cost of the subsidy, may still be very large.

III. Policy and Politics

In the United States the Congress gives research grants directly to some colleges and universities. Success in attracting these grants depends on the effectiveness of the lobbying firm employed by the school and on the seniority and committee assignments of local senators and representatives. Because neither the quality of previous research nor the quality of the proposed research plays any important role in allocating these grants, observers have concluded that they encourage rent-seeking but not good science.

In many countries direct and indirect subsidies are granted to firms through measures such as tariff and nontariff restrictions on competing imports. Success in attracting these subsidies depends on the political power of the beneficiaries. Because neither success in introducing new ideas into an economy nor success in reaching worldwide standards for price and quality play any role in the allocation of these subsidies, most observers have concluded that these interventions encourage rent-seeking but not economic development.

One might conclude from the U.S. experience that the government should never give grants to support research. One might even follow the fashion in economics and construct a model to show that the market provides the optimal level of research. Neither conclusion is warranted. We know that there is a valid economic justification for supporting basic scientific research at universities. We also know that some institutional arrangements for allocating grants (mandates from Congress) do not achieve the intended goal but that other arrangements (peer review) do a reasonably good job.

Despite frequent protestations to the contrary, the economic case for intervention to encourage the use of ideas in developing economies is at least as strong as the economic case for supporting basic research in industrial economies. The problematic assertion is that it is possible to create institutions analogous to peer

review that can undertake beneficial economic intervention. The required institutions may not exist, and it may not be possible to create them in a given country. Laissez-faire may be a second-best solution, but we must recognize that deciding whether this is the case depends at least as much on political and sociological analysis as on economic analysis.

Together with the economic analysis outlined above, my amateur political and sociological analysis leads me to the following general conclusions. First, there is much evidence suggesting that the specific arrangements used in Taiwan (China) cannot achieve their goals in a modern democracy or in most open political systems. (For a good summary of the evidence from political science showing that a Taiwanese system of discretionary bureaucratic decisionmaking is not feasible in the United States, see Wilson 1989.) To succeed, these arrangements must be part of a larger political system that can support wide latitude for discretion on the part of a strong, authoritarian government that is willing and able to override parochial interests. In addition, these arrangements require a configuration of bureaucratic competence and ruthless dedication to national economic success that is relatively rare and may be impossible to sustain.

Contemporary evidence suggests that interventionist institutions may not continue to function well even in economies such as Japan, Taiwan (China), Singapore, and the Republic of Korea, where they seem until now to have been a success. In these countries the experience with extensive intervention extends only through the working career of one—perhaps uniquely dedicated—generation of bureaucrats working in an unusual political environment. In Korea the powers of the state, traditionally used to support the large corporations, were turned against the Hyundai group when its head became a candidate for the presidency. In Japan concern with corruption is growing at the same time as the system for allocating political power shows signs of being more openly contested. Neither development bodes well for the long-run viability of a system based on honest, independent bureaucrats with extensive discretionary power.

Until other politically viable institutions for fostering development can be discovered, the one safe piece of advice to offer developing countries is that integration with world markets offers large potential gains. The gains from using someone else's ideas come from a source that is different from the classical gains from trade. The division of the gains may not correspond to intuitive notions of fairness, but they can be very large and very important nonetheless. This is absolutely clear for a small country such as Mauritius, but it is equally clear for the very large and rapidly growing economy on mainland China. The gains it receives from interaction with Hong Kong and Taiwan (China) far outweigh the small and risky gains that might be achieved through a more tightly controlled industrial policy.

The other safe counsel is to increase savings and schooling, but both of these activities require a reduction in current consumption that may be very costly for the poorest countries. Formal education also works with a long lag. In contrast,

openness to investments by foreigners bearing ideas costs nothing, except perhaps a bit of national pride. On-the-job training can in many cases be even more effective than classroom education in developing human capital. Once gains in income from direct foreign investment are forthcoming, high savings and large investments in schooling are easier to finance and can be used to lay the groundwork for further gains in income.

Beyond this, cautious attempts to encourage the development of local expertise may be valuable. For example, government-financed setting of standards and support for advanced training for people in the private sector may be appropriate. These activities are politically safer than direct subsidies for private firms, which inevitably carry a much greater risk of capture and political manipulation and are difficult to make contingent on the desired actions by firms.

In the event that a government does undertake some form of subsidy for firms, the market in the rest of the world must always be used as the benchmark by which success is judged. Protection from foreign competitors is therefore the worst possible way to offer a subsidy for undertaking some activity. Attempts to imitate Taiwan (China) can all too easily end by yielding the closed markets and stagnation of India and Brazil.

Finally, having issued all of the cautions about the risks of intervention and the limits imposed by political and institutional constraints, one must not lose sight of the endogenous nature of political and institutional constraints. Just as in a child's chemistry set, there is far more scope for discovering new institutional arrangements than we can possibly understand. In the United States, if we had naively applied the theory of rent-seeking to the analysis of research grants, we would have concluded that government support for research can never be effective. We would not have invented peer review after World War II.

As the world becomes more and more closely integrated, the feature that will increasingly differentiate one geographic area (city or country) from another will be the quality of public institutions. The most successful areas will be the ones with the most competent and effective mechanisms for supporting collective interests, especially in the production of new ideas.[5]

The challenge for economic analysis is therefore somewhat delicate. We must take seriously the economic opportunities presented by the potential for producing new ideas and for diffusing existing ideas to the widest possible extent. In so doing, we must recognize that ideas are economic goods which are unlike conventional private goods and that markets are inherently less successful at producing and transmitting ideas than they are with private goods. We must be willing to learn from cases where collective action has been socially productive. The experience of Taiwan (China) can teach us something about what is feasible from an economic or technological point of view, even if that island's politics and institutions could not and should not be replicated elsewhere. We must be

5. For a discussion of the role of infrastructure and development and suggestive elaboration of the parallel between development in poor countries and in U.S. cities, see Rauch (1986, 1992).

open to the possibility of the discovery of new kinds of institutions for supporting the production and use of commercially relevant ideas.

Yet at the same time we must send the correct signals to developing countries about what is possible given existing political constraints. Here, the experience in Mauritius is likely to be a better guide, especially in the early stages of development. There is much that can be gained merely by using ideas produced elsewhere. There is great risk in adopting interventions, especially protectionism.

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