Journal of Monetary Economics 32 (1993) 543–573. North-Holland

Idea gaps and object gaps in economic development

Paul Romer*
University of California, Berkeley, CA 94720, USA

Received March 1993, final version September 1993

A nation that lacks physical objects like factories and roads suffers from an object gap. A nation that lacks the knowledge used to create value in a modern economy suffers from an idea gap. Object gaps are emphasized by mainstream economists who make use of formal models and statistical hypothesis tests. Idea gaps are emphasized by dissident economists who make use of a diverse body of evidence and avoid formal models. Economists need to use the formal models from the first approach and the diverse evidence from the second to fully appreciate the importance of idea gaps in economic development.

Key words: Economic development; Multinational firms; Imperfect competition

JEL classification: F12; F23; O1

1. Introduction

To keep track of the wide range of explanations that are offered for persistent poverty in developing nations, it helps to keep two extreme views in mind. The first is based on an object gap: Nations are poor because they lack valuable objects like factories, roads, and raw materials. The second view invokes an idea gap: Nations are poor because their citizens do not have access to the ideas that are used in industrial nations to generate economic value. These explanations are not mutually exclusive. A developing nation can suffer from both gaps at the

Correspondence to: Paul M. Romer, NBER, 204 Junipero Serra Blvd, Stanford, CA 94305, USA.

* Also affiliated with the Canadian Institute for Advanced Research (CIAR) and the National Bureau of Economic Research (NBER). The author gratefully acknowledges comments from the conference discussants, Ishrat Husain and Andre Shleifer. Discussions and comments from Robert King, Charles Plosser, William Easterly, the members of the Russell Sage Working Group on Institutions and Development, and the participants in the Program on Economic Growth of the Canadian Institute for Advanced Research were also helpful during the writing and revision of the paper. This work was supported by National Science Foundation Grant No. SES 9023469.

same time. Moreover, distinguishing between the two gaps is not important for reaching some policy conclusions. According to either view, a functioning legal system, stable monetary policy, and effective support for education will all be desirable policy goals because they can help reduce both gaps.

Nevertheless, each gap imparts a distinctive thrust to the analysis of development policy. The notion of an object gap highlights saving and accumulation. The notion of an idea gap directs attention to the patterns of interaction and communication between a developing country and the rest of the world. In particular, it suggests that multinational corporations can play a special role as the conduits that let productive ideas flow across national borders. Because their implications differ, economists must make an accurate assessment of the relative importance of idea gaps and object gaps before they can provide comprehensive guidance on development policy. The essence of the argument presented in this paper is that progress toward a consensus on the importance of idea gaps will require both the abstract theorizing characteristic of mainstream economics and the emphasis on a broad range of qualitative evidence characteristic of other traditions.

The notion of an idea gap invoked in this paper includes the concepts that some authors have in mind when they speak of a technology gap, but it is intended to suggest something quite broad. The word technology invokes images of manufacturing, but most economic activity takes places outside of factories. Ideas include the innumerable insights about packaging, marketing, distribution, inventory control, payments systems, information systems, transactions processing, quality control, and worker motivation that are all used in the creation of economic value in a modern economy. If one looks carefully at the details of the operations of a corporation like Frito-Lay, one sees that there are as many subtle ideas involved in supplying potato chips to a consumer as there are in making computer chips. In addition, the ideas involved in supplying potato chips are probably more important for successful development in the poorest countries.

One of the chronic temptations in economic analysis is to force a world characterized by these two different kinds of gaps into a conceptual scheme that relies on a single, all-encompassing gap that indexes the stages of development. To see why this is dangerous, it helps to have a concrete example in mind that illustrates how the two gaps differ. Suppose that you are an experienced writer, familiar with word processing on personal computers. An impoverished colleague comes to you with a 1000-page hand-written manuscript and asks for your advice about how to produce a typed version on a word processor. If she has neither a computer nor any experience with word processing software, she suffers from an object gap. She lacks both the piece of physical capital (the computer) and the human capital (knowledge of how to use it) necessary to type the manuscript herself.

Now suppose that a second colleague, who has a computer and knows how to use word processing software, comes to you because he has accidentally issued

a command that has deleted the computer file containing the only copy of his just-completed 1000-page manuscript. He asks you if there is any feasible way to recover the information stored in this file. Suppose you own a copy of a software program that can recover deleted files. Because your colleague does not own this kind of software, and does not even know that it exists, he suffers from an idea gap.

A correct and important assertion made by those who emphasize the importance of object gaps is that human capital – measured the way that a labor economist would measure it, in terms of years of schooling or experience – is one of the most important object-like goods that an economy, or a person, can lack. A prerequisite for careful thinking about the two gaps is the recognition that, from the point of view of economic analysis, human capital is more like the computer in the example of the two writers than the file recovery software.

In other work I have indicated why the distinction between objects and ideas is of fundamental importance for economic analysis [Romer (1993)]. These two types of goods have very different implications about the nature of market equilibria and the potential for gains from trade. This paper begins by outlining the reasons why mainstream macroeconomists seem to have been more comfortable dealing with objects than ideas. For many years, the use of formal mathematical models kept them from being able to talk about the economics of ideas in aggregate level discussions of growth and development. Fortunately, recent developments in growth theory now offer the promise of bringing ideas back into the analysis. The paper also argues that the tendency of the dissidents to reject formal modeling may have been a reasonable temporary strategy when aggregate models could allow only for exogenous technological change, but that a continued rejection of formal modeling may ultimately limit the impact that these economists will have. On the other side, the mainstream economic community would gain a great deal by moving beyond its narrow focus on statistical hypothesis testing and making explicit use of the broad range of evidence that the dissidents have been able to exploit. The correlations in macroeconomic data can suggest orders of magnitudes of possible effects, but will never be able to resolve the most important questions about causality.

There are no easy solutions to an object gap. Objects have opportunity costs. If you want to help your first colleague get her manuscript typed into a computer file, you can buy a computer for her and teach her how to use it. Alternatively, you can tell her that she must save up her money, buy her own computer, and learn how to use it. Either way, the costs will be high. It may take a long time for her to catch up with you. Recent work emphasizing object gaps has therefore lent a pessimistic, almost Calvinistic tone to policy advice. 'These countries are poor because they consumed too much in the past and did not accumulate like we did. To achieve a better standard of living, they must tighten their belts, reduce their current standard of living, accumulate more capital, and pay for a better system of public education.' Bad policy may be identified as the

cause of the previous failure to save, but once policy impediments are removed, this vision offers poor countries that want to grow faster the grim prospect of additional reductions in current consumption.

Idea gaps, in contrast, are relatively easy to solve. Ideas do not have opportunity costs. If you are willing to break the law, you can make a copy of your file recovery software and give it to your colleague with the deleted computer file. At a cost of a few seconds of your time, you can save him thousands of hours of work. Alternatively, you can tell your colleague about file recovery software and encourage him to buy a copy of the program. If he does, the software code itself still has virtually no opportunity cost, but the company that sells the program will capture a small part of the gain that would otherwise accrue to him alone. That is, the software company and the writer will share the gains from trade.

The large surplus that is available in this example is the result of the defining characteristic of ideas as economic goods. An idea-like good such as the software code is something that you can give to someone else yet still retain for your own use.

The idea gap explanation for persistent poverty offers a more optimistic picture of the potential for rapid development, but it also possesses a dark side that has influenced the political economy of development. The large surplus created by trade in ideas raises difficult issues about how the surplus should be divided. Instead of explaining about file recovery software, you could tell your second colleague that you will recover the file for a fee of, say, $10,000. If he is desperate and in enough of a hurry, he might agree. If he did, he would presumably be better off than if he had not met you and had used his computer in a way that made file recovery impossible. But once he learns how simple and inexpensive file recovery is, he will no doubt experience intense emotional distress because of his perception that you have taken advantage of his weakness and ignorance. As a result, he may subsequently pursue a strategy of self-sufficiency to avoid the risk of being exploited in the future. Unfortunately, for people and for nations, a policy that cuts off all contact with the rest of the world can be very costly.

Without denying that objects are important, this paper points to a wide variety of evidence suggesting that an important fraction of worldwide poverty may be due to an idea gap that can be reduced at relatively low cost. Moreover, transmitting ideas to close a gap generates gains from trade that can be shared by the recipient country and the supplying firm. Cross-country regression evidence on the role of machinery imports and direct foreign investment, historical accounts of the transmission of technology, and case studies of individual country performance and individual industries all point to the important role played by international flows of ideas.

The idea gap approach to economic development emphasizes the optimistic fact that people in the industrial nations of the world already possess the knowledge needed to provide a decent standard of living for everyone on Earth.

Citizens of the poorest countries in the world can benefit enormously from this knowledge if they give the holders of this knowledge an incentive to put it to use in their countries. It is true that many countries lack important objects, but these object gaps create the usual opportunities for gains from trade that arise whenever objects are more scarce in one place than another. We can lend them the nonhuman objects that they need to our mutual benefit. As for the human capital they lack, crucial pieces of specialized, highly trained human capital can be put to work domestically by inviting in managers and technicians from abroad. Moreover, much of the human capital required for economic activity can be acquired by domestic workers through on-the-job training.

The optimistic view of the potential for development suggested by idea gaps is consistent with the experience of a few, very rapidly growing economies. In fact, a rapidly closing idea gap offers the best way to explain these cases of dramatic success. But if the potential for rapid development is so great, why is poverty still so common?

Part of the answer is suggested by other papers presented in this volume. If the local government does not provide the basic institutional infrastructure required for market exchange – for example, if the financial system fails to offer an effective payments system or to match borrowers and lenders, if market prices are distorted by an unstable monetary and exchange rate regime, if the government neither provides basic physical infrastructure nor lets the private sector provide it, and if, in extreme cases, property rights flow from the barrel of a gun – it is no surprise that the gains from trade in both ideas and objects cannot be realized. In response to this kind of fundamental governmental failure, economists have little to say except avoid it if possible.

There is, however, another impediment to successful development that economists can help resolve. The poorest countries face the same difficulty in their dealings with the developed world that confronts your colleague with the deleted computer file. Once he learns from you about the existence of file recovery software, he may demand that you give him a copy of the software for free. After all, he may argue, no one is made worse off by this act, and he will be made strictly better off. If he is less fortunate than you, he may even demand that you also help him, for free, showing him how the software works. If you refuse, he may demand that the software supplier sell him copies on concessionary terms. If the supplier also refuses, the writer with the deleted file may suffer unnecessarily and will feel aggrieved. This kind of impasse is especially likely to arise if sometime in the past, this writer has had other dealings that caused him to feel exploited.

One of the legacies of colonialism is an aversion in some developing countries to any contact or exchange with firms from industrial economies. Interaction with multinational firms is sometimes permitted, but only on terms that are so restrictive and unattractive that few foreigner firms decide to participate. These kinds of policies are often rationalized on moral grounds and they can have

strong domestic political appeal. They can also keep the gains from trade from closing an idea gap from being realized. For a developing country with at least a minimally functional government, one of the most important and easily implemented policies is to give foreign firms an incentive to close the idea gap, to let them earn a profit from doing so. Economists can encourage governments to tolerate or support this process by making it clear how costly it is in terms of domestic welfare when a poor nation indulges a taste for self-sufficiency and righteous indignation in its dealings with the rest of the world.

Access to the ideas that are available in the rest of the world can come partly through unimpeded flows of the capital goods that are produced in the industrialized nations of the world. These goods embody many new ideas. For the very poorest nations, this surely is the lesson from the evidence presented for example by De Long and Summers (1991) about the importance of equipment investment. But successful development also requires a mechanism for ensuring adequate flows of the large quantity of disembodied ideas that are used in production. The government of a poor country can therefore help its residents by creating an economic environment that offers an adequate reward to multinational corporations when they bring ideas from the rest of the world and put them to use with domestic resources. Multinational firms can do this through direct foreign investment, joint ventures, marketing and licensing agreements, or many other formal or informal arrangements with domestic firms.

There are other mechanisms for tapping into disembodied ideas that do not require offering profit incentives to multinational firms – sending students abroad for advanced education, for example, or giving incentives for individuals with special skills and knowledge to migrate to the economy. There are also important complementary investments that the government can make – in infrastructure, a legal system, or the general level of education. But for the poorest developing nations, letting multinational firms profit from the international transmission of ideas is the quickest and most reliable way to reduce the idea gaps that keep them poor.

2. Intellectual background on ideas and objects

The basic assertions in this paper – that idea gaps are central to the process of economic development – will ultimately be accepted or rejected on the basis of the empirical evidence that can be produced to support them. Economists do not, however, evaluate evidence in a vacuum. Discussions about evidence and its interpretation take place in the context of a long history of debate. Each paper, and each person, comes into one of these extended intellectual conversations in the middle.

This section reviews part of the intellectual background in the economics profession that shapes the discussion of ideas and objects. It identifies two broad

traditions in economics, the mainstream or neoclassical tradition, that has generally pushed objects into the foreground, and a dissenting tradition, that emphasizes ideas. It also recalls the unfortunate experience of an older dissenting tradition in development economics that isolated itself from the mainstream and suggests that the more recent dissenters may risk the same fate.

2.1. The rise of price-taking and the fall of ideas

There is nothing new about the assertion that ideas and objects both contribute to the creation of wealth. Adam Smith emphasized that it is the objects like land and tools that constitute the true wealth of a nation, not monetary tokens, but even Smith recognized that these objects are of no inherent value as inputs without knowledge of how to combine them in ways that generate valuable output. Economists have used different terms to describe the activities that increased the stock of intangible knowledge or ideas – invention, innovation, discovery, technological change, entrepreneurship – but they have always acknowledged their fundamental importance.

Yet over time, economists relied increasingly on mathematics as the language of intellectual discourse. As they did, objects took precedence over ideas for purely technical reasons. Objects lend themselves readily to analysis in terms of convex opportunity sets and price-taking competition. This lets all of the mathematical machinery of convex optimization come into play, including the suggestive duality between quantities and shadow prices. Ideas, in contrast, are inherently associated with fixed costs or nonconvexities, and are therefore inconsistent with price-taking. Ideas – like Adam Smith's closely related notion of specialization and the division of labor – were pushed aside as the mathematical assumption of convexity and the behavioral assumption of price-taking took on greater importance in economic reasoning.

In Marshallian analysis at the level of firm or industry, it was possible to consider both the price-taking behavior of a competitive firm and the price-setting behavior of a monopolist. But when economists in general, and macroeconomists in particular, pushed formal modeling to the level of a general equilibrium in the economy as a whole, there was no way to maintain this symmetry. Until the middle of the 1970s, economists could give a mathematical description of an entire economy only if they assumed that markets were characterized by perfect competition. There were some tentative early attempts to describe an aggregate equilibrium in which monopoly power was present [most notably by Joan Robinson (1933) and Edward Chamberlain (1933)]. Most economists, however, accepted the challenge of trying first to formalize existing intuitions in terms of perfectly competitive general equilibrium models.

In the three decades following WWII, the mathematical program for the economics profession laid out in Paul Samuelson's *Foundations of Economic*

Analysis came into full fruition. Some areas of aggregate economic analysis were set aside and subjected to an entirely different form of analysis (most notably the Keynesian analysis of demand-driven output determination), but in most areas of aggregative or economy-wide analysis, perfect, price-taking competition reigned supreme. In trade theory (following Samuelson), growth theory (following Solow), and welfare economics (following Arrow and Debreu), our understanding was built on a foundation of price-taking in perfect markets.

With the subsequent application of computable, aggregate models of perfect competition to questions in areas such as economic history, development planning, and tax policy, and with the development of the modern theory of efficient financial markets, price-taking models of perfect competition invaded virtually all of the important areas in aggregate theory. In the 1980s, real business cycle theory brought the last major holdout, macroeconomic fluctuations, under the domain of general equilibrium theory with perfect competition and price-taking. Along the way, ideas receded farther into the background in aggregate models because their intrinsic nonconvexities were inimical to an analysis in terms of price-taking. As the microeconomic analysis of patents makes clear, any economic model of the production and use of ideas must allow for monopoly power.

Economists continued to recognize the importance of invention and discovery, but in a competitive model, it could be discussed only if it was an exogenous force that impinged on the economy from the outside. The development of growth theory after Solow's influential papers (1956, 1957) is illustrative. No one really thought that technological change was exogenous. Everyone presumably expected that this provisional assumption, made only for analytical convenience, would subsequently be abandoned in a second round of theorizing. Yet, despite a variety of early theoretical efforts at understanding technological change at the aggregate level [Arrow (1962), Nordhaus (1969), Shell (1967)] and despite a body of microeconomic empirical and theoretical work on technological change that is far too large to begin to catalog here, aggregate growth theory stayed close to the formulation adopted by Solow. As a result, a whole generation of macroeconomists came to view exogenous technological change less as a provisional theoretical crutch and more as an acceptable description of how the world actually works.

In the development of formal economic theory, it was inevitable that competitive equilibrium theory would be developed before other more complicated notions of aggregate equilibrium could be worked out. A great deal of useful insight emerged from this work. One of the most important illustrations of the surprising power of competitive equilibrium theory came in labor economics with the development of human capital theory. To restate their case in the simplest and most explicit terms, economists like Gary Becker (1975) showed that human capital could be understood in exactly the same way that we understand the canine capital of a seeing-eye dog. Production of a more

valuable worker or dog is just like the kind of production that takes place when a press bends metal. In each case, costly resources are invested to make a durable object (the sheet of steel or the brain of the person or dog) a more valuable input in production. Because slavery is not allowed, we use rental contracts and rental rates for human capital instead of the sale prices and contracts used for canine capital and steel, but the basic elements of competitive analysis are the same.

Technically, human capital theory was an analytical success precisely because it could be studied using the economic tools developed for objects. In particular, it did not require any discussion of monopoly power. As a result, developments in this area could not be used to help us model ideas. Nevertheless, our everyday experience with education, the most important investment activity in human capital theory, suggested that human capital was somehow connected to ideas. By embracing human capital theory, augmented perhaps by some notion of incomplete property rights and spillovers, one might have hoped that economic analysis could somehow get closer to capturing the elusive role of ideas in economic production. A fundamental claim of this paper is that this hope was largely mistaken.

As important as human capital theory is as an extension of the economics of objects, it does not capture the essential aspects of the economics of ideas. Human capital theory gets it right when it explains why the writer with no experience with word processing software faces large costs in learning to type a manuscript. It also gives us the correct framework for thinking about the equilibrium rental price for the time of someone who knows how to use word processing software and who sells his services on the market. But it entirely misses the complexity of the economic analysis of the production and sale of file recovery software or the production and exploitation of the kind of knowledge that lets Frito-Lay keep the right quantity of food on the shelves of thousands of geographically dispersed stores.

2.2. High development theory

Many parallel lines of dissent emerged in response to the trend in mainstream analysis toward more reliance on mathematics and, therefore, on perfect price-taking competition. Politically, these dissenting groups range from the Austrians on the right to the post-Keynesians on the left.

Paul Krugman (1993a, 1993b) gives a penetrating analysis of what happened to one branch of dissent, what he calls 'high development theory'. Work in this area starts with Rosenstein-Rodan's description of 'the big push' (1943). It reaches its peak with the publication of Gunnar Myrdal's *Economic Theory and Under-developed Regions* (1957) and Albert Hirschman's *The Strategy of Economic Development* (1958). It lost its momentum soon thereafter. Krugman

observes that the notions of interdependence, circular and cumulative causation, and linkages that these authors developed were 'stimulating and immensely influential in the 1950s and early 1960s. By the 1970s [when Krugman was himself a student], they had come to seem not so much wrong as meaningless. What were these guys talking about? Where were the models? And so high development theory was not so much rejected as simply bypassed'.

As Krugman shows, the high development theorists were not able to formalize their insights in simple models because the insights depended in a fundamental way on the general equilibrium effects of nonconvexities and increasing returns. At the time when they were writing, economists simply lacked the tools to construct a formal model that could capture these effects. Some development economists made their best efforts to formalize their insights. For example, Arthur Lewis (1954) constructed a conceptually less ambitious formal model based on constant returns and surplus labor that received a great deal of attention and has survived to this day. But rather than compromise their insights so that they could be put into the available simple models, the high development theorists explicitly rejected the tendency in the profession towards rigor and formal modeling. 'Along with some others, notably Myrdal, Hirschman didn't wait for intellectual exile: he proudly gathered up his followers and led them into the wilderness himself. Unfortunately, they perished there'.

Depending on your taste for models, Krugman's tale has either a happy or a bittersweet ending. Most economists ignored Hirschman's call to abandon work on formal models and kept tinkering away, developing new kinds of models that we could add to our tool kit. Work in industrial organization during the 1970s led, unexpectedly, to modeling techniques that let nonconvexities and monopoly power be explicitly handled in aggregate models of international trade, economic growth, urban economics, and development. Using these tools, we now know how to distill the essence of Myrdal's and Hirschman's insights down to a very simple formal model. Krugman shows that this is precisely what Kevin Murphy, Andrei Shleifer, and Robert Vishny did in their paper 'Industrialization and the Big Push' (1989). Their model is abstract and stylized. It cannot convey the eloquence and inspiration in the original works. But it captures the essence. The model has rescued the ideas of the high development theorists from obscurity and irrelevance and preserved them in a form that future generations of economists will understand.

Now that the logic of the high development theorists is well understood, it is clear that their argument relies on a crucial, and problematic, assumption. The big push models assume that demand for the products produced in a nation could come only from the citizens of that nation. Because there are many kinds of goods that are not easily transported (business services for example), there is still room for something like a 'big push' to play an important role in determining geographical patterns of economic activity. In other work,

Krugman (1991) has emphasized that cities are, in effect, big pushes that are concentrated in space rather than time.

Nevertheless, it is clear in retrospect that the high development theorists significantly underestimated the potential for workers in developing countries to combine their labor with technologies from advanced countries, producing goods for sale on world markets. In North America, we now buy computer hard disks made in Malaysia, mountain bikes made in China, and garments assembled in Guatemala, so we take it for granted that there is nothing about the nature of production that prevents workers in a poor country from using their labor to produce sophisticated goods that can be sold anywhere in the world. Economists working on development in the 1940s and 1950s may have neglected this possibility because there was little evidence at the time suggesting that this was possible. (Common sense, pragmatism, and careful attention to the facts do have their limitations as tools for scientific investigation. They may not suggest the potential for genuinely new things to happen. They may keep people from asking simple-minded questions like 'Why can't mountain bikes be assembled in China?')

Less charitably, it is also possible that the development theorists of this era were aware that this kind of trade between advanced and developing nations was possible, but went along with the preference for self-sufficiency expressed by the leaders of developing countries. If so, they may have done the citizens of these countries a grave disservice. Rather than tell these nations how to proceed if they insisted on going it alone, economists should have warned these nations about how costly this strategy would be.

2.3. Technology and development

There is a separate and more recent intellectual tradition that has operated outside of mainstream economics, or at least not entirely inside it. It has focussed on the study of technology. People in this area separated from the mainstream when mainstream economists adopted the assumption that technological change was exogenous. Some of the people working in this area have focused on attempts to understand history. [See for example, David (1991), Rosenberg (1976), Mokyr (1990).] Others, such as the people working at the Science Policy Research Unit at the University of Sussex or at MERIT at the University of Limburg in the Netherlands, have concentrated on the implications of technological change for science policy, trade policy, and development. Some work in these areas exhibits the same kind of pragmatism and reliance on detailed observation that was characteristic of the best work of the development theorists. Other parts of this literature have tried to articulate an explicit alternative to the theoretical structure of mainstream economics. The most influential of these efforts traces its origins to the work of Richard Nelson and

Sidney Winter (1982). It emphasizes an evolutionary approach to economic analysis and requires neither price-taking nor explicit maximization for its description of market outcomes.

Work in this diverse tradition or collection of traditions differs from most mainstream analysis in part because it places ideas or discoveries at the center of the analytical framework. For example, Dosi, Pavitt, and Soete (1990) treat trade theory in this way. Dosi and Freeman (1992) give a similarly motivated discussion of development and catching up. Both of these studies position themselves in opposition to mainstream theory by dismissing, or at least down-playing, the importance of conventional object-related issues like factor endowments and capital accumulation.

Because of the difficulties noted above in giving a mathematical description of ideas as economic goods (and because of an additional difficulty emphasized by the evolutionary theorists, that people have a limited capacity for calculation and memory) the theoretical work in these traditions has relied primarily on what Nelson and Winter call 'appreciative theory', theory that is less abstract, more descriptive, and closer to practice and to real world context. Economists working in this tradition have avoided, and sometimes explicitly rejected, formal mathematical models.

A central concept in what can be called the appreciative theory of economic development is the gap between the level of technology in a developing country and that in the rest of the world. A second concept is the social absorption capability of the developing country. Authors working in this tradition cite Thorstein Veblen (1915) or Joseph Schumpeter (1961) for important early statements of the importance of technology gaps. Alexander Gershenkron (1962) gave an important early application in economic history. Nelson and Phelps (1966) give an early example of a formal model which captures the idea that an increase in human capital leads to an increase in the absorption capability of a nation.

In this work, technology is taken as a largely undefined primitive. It differs from objects in the crucial sense that it can be replicated or transferred between nations. The technology in use in one place can be converted into a communicable form (at some cost) and sent to another place. If the recipients have the capacity to absorb this information and if they invest the effort required to adapt it to fit local circumstances, they can make use of it. Absorption capability is assumed to be a characteristic of an economy or society as a whole. It depends on ordinary inputs like human capital, but also on the larger institutional framework, the 'national innovation system', of the economy. The educational system, firms, and research institutions – both public and private – all contribute to this institutional framework.

The tension in this theory arises from the fact that a technology gap presents an opportunity for rapid growth through technology flows, but a reduced absorption capability makes it more difficult for a country to take advantage of

this opportunity. Because a poor developing economy will typically suffer from both a large technology gap and a reduced absorption capacity, the prediction about the correlation between the initial level of income and the rate of growth is ambiguous. However, high indicators of absorption capacity (for example, a higher level of education in the population) imply a faster rate of growth for a country facing a given technology gap.

3. Endogenous growth theory

The advantage of the appreciative theory of economic development is that it has the ring of truth to it. If one looks at the detailed evidence about the experience in different countries, its description can account for far more of what we see than the vision offered by conventional mainstream models, which typically treat technology as a pure public good that is available everywhere in the world, just like a short wave radio broadcast.

The disadvantage of the appreciative theory is that it also sounds a lot like the kind of theory that the high development theorists did. If this work continues to operate in isolation from the formal modeling traditions of mainstream economics, it too may be lost and ignored. Work in the evolutionary tradition is beginning to supplement verbal theory with simulations of descriptive computer models, following the lead suggested by Nelson and Winter more than a decade ago, but it is too early to tell whether 'theory on the computer' is finally going to take off. Even if it does, it is quite possible that any insights from this kind of work will not survive without being codified in simple formal models that supplement the simulations and the appreciative theory.

Ultimately, to make progress as a discipline, we may need more than insight. We may need to understand in detail how the mechanism works. To understand, we must be able to strip the descriptions and simulations down and be very precise about how each component of the whole system works. In particular, it is not enough to give general descriptions of technology. We need to be as precise about the attributes of ideas as economic goods as we are about the attributes of our more familiar objects. In particular, we need to be explicit about how these two types of goods differ.

Recent work on endogenous growth theory offers some prospect of helping to codify some of the insights from the appreciative theory of development. Endogenous growth theory is clearly in the mainstream tradition in its style of modeling – simple, abstract mathematical models that rely on optimization and foresight. It nevertheless begins to move part way toward the position advocated by the dissenters because it recognizes that ideas are of central importance in growth and development.

The first round of endogenous growth models relied on Marshallian external increasing returns and avoided explicit recognition of monopoly power. [See

Arrow (1962), Romer (1986), and Lucas (1988).] A second round of growth models subsequently made the leap to equilibrium models of monopolistic competition – that is, to models with monopoly power and free entry. These models were made possible by developments in theoretical industrial organization of the 1970s. Now, patents, *ex post* market power, product cycles, and innovation that destroys the rents captured by others could finally be brought back into the discussion of aggregate growth. In a remarkable early effort, Nordhaus (1969) allowed for partial property rights over ideas and monopoly power in a model of aggregate growth, but it was only after the formal model of differentiated goods developed by Dixit and Stiglitz (1977) was introduced that models with monopoly power could easily be adapted to aggregate level analysis.

With a lead of several years over that of the growth theorist, trade theorists made the switch from models with external increasing returns to models with monopolistic competition. [See the discussion in Krugman (1990).] Explicit dynamic models of the aggregate effects of patents and invention by Judd (1985) and Shleifer (1986) also showed how nonconvexities and market power at the micro level could have important, and surprising, aggregate effects. Given all of these developments, it was inevitable that fully dynamic models of persistent growth resulting from intentional research activities would follow along these lines. Some of the early examples were Aghion and Howitt (1992), Grossman and Helpman (1990, 1991), Romer (1987, 1990b), and Segerstrom et al. (1990).

These second-round or 'neo-Schumpeterian' models of growth with monopoly power may help bridge part of the gap between the mainstream theorists and appreciative theorists. Mainstream economists may begin to look at the world and see that intentional efforts to produce and transmit ideas are ubiquitous in economic life. Just as the appreciative theorists have always claimed, it is monopoly power, sometimes only temporary or partial, that motivates these efforts. Appreciative theorists and evolutionary economists may find that a simple formal model can highlight crucial issues that have been obscured in more complicated settings. For example, formal models show that weak property rights are logically independent from nonrivalry or multiple use, the unique attribute of ideas and the one that leads to nonconvexities. Because control and multiple use are independent concepts, it is not sufficient to use the traditional one-dimensional characterization of goods along a continuum that extends from private goods at one end to public goods on the other. [For an elaboration of this point, see Romer (1993).]

To cite two other issues that have been illuminated by the formal work, it is now clear that the value of an idea is directly proportional to the extent of the market within which it is used, so that the economic analysis of technological change is intimately linked to issues of market size and international trade. [See Grossman and Helpman (1992) for an elaboration of some of the complicated links between trade, innovation, and growth.] It is also clear that a divergence

between the social marginal product of some activity and a private marginal product is not necessarily an indication of spillovers or incomplete property rights. This divergence can arise at the aggregate level entirely as a result of monopoly pricing distortions. The usual interpretation of a finding such as that of De Long and Summers (1991) suggesting that there is a large divergence between the private and social marginal product of additional equipment investment is that some kind of externality must be present. This interpretation is typically called into question by observing that there is no micro-level evidence for external effects of the required magnitude. There is, however, abundant evidence of divergence between price and marginal cost. Simple models of monopolistic competition show that this kind of microeconomic divergence, with no true external effects in production, can lead to important aggregate-level differences between private and social marginal products that resemble aggregate-level external effects. [For an example where this is true, see Romer (1994).]

4. Mainstream empirical work on endogenous growth

At the same time that one branch of mainstream growth theory was making its way down the path from perfect price-taking competition to price-taking with external increasing returns, then on to internal increasing returns and monopolistic competition, another branch of theory made the case for retaining the familiar framework of perfect price-taking competition. This line of work made the logically correct point that persistent or 'endogenous' growth could take place in a world in which there are only objects. If there are no ideas, there are no nonrival goods, no increasing returns, and no nonconvexities. To oversimplify the contribution of a complicated set of models, this work showed that it is theoretically possible that output is proportional to the stock of some object-like capital good that can be accumulated without bound. In this case one can write $Y = AK$. Growth can then be understood to result purely from the accumulation of K, where K is interpreted as a broad measure of all relevant types of capital, human and nonhuman. [For details, see for example Becker, Murphy, and Tamura (1990), Jones and Manuelli (1990), and Rebelo (1991).]

Given the split that developed between the neo-Schumpeterians (who wanted to bring ideas into growth theory even if this meant abandoning perfect competition) and the new classicals (who wanted to preserve perfect competition even if this meant abandoning the distinctions between capital and technology as different kinds of inputs in production), one might have hoped that empirical work would play a decisive role in resolving the fundamental issue in growth and development: Must economic theory recognize a different kind of good – ideas – if it is to explain both long-run growth and cross-country patterns of

development? As the parable about the two writers given in the introduction to this paper is intended to suggest, much turns on the answer. If there are only object gaps, the implications for poor countries are much more pessimistic than if there are also idea gaps.

Unfortunately, mainstream empirical work has so far had almost nothing to say about the importance of ideas. This failure is the result of the style of empirical work that is judged to be convincing in mainstream economic discourse. In their efforts at being serious scientists, mainstream economists have advocated both formal mathematical modeling and formal statistical hypothesis testing. Both of these styles of research have something important to offer, but if they crowd out other kinds of theorizing and other approaches to the evidence, they can do serious harm.

One problem in evaluating the importance of ideas in economic development is that there is very little statistical evidence that one can collect on the economic role of ideas, especially if one wants to do regressions on the performance of a cross-section of developing countries. We measure investment in physical capital, we measure schooling, and we can measure proxies for various policy measures, so recent cross-country regressions have inevitably focussed on these kinds of variables.

In retrospect, the effects of pressure to use explicit statistical evidence is apparent in my own work. My first theoretical paper on growth [Romer (1986)] relied primarily on historical evidence about trends in rates of growth to motivate the theory in the paper. The discussion focussed explicitly on the economics of knowledge.

In a subsequent, commissioned piece of work that was supposed to have more empirical content, I used time series and cross-section regressions to support the claim that output took the form $Y = K^{\alpha}L^{1-\alpha}$ with a value for α that is close to 1. [Romer (1987)]. My interpretation of the unusually large coefficient on K was that investments in physical capital tended to be accompanied by investments in new ideas. Looking back, I think that this work did more harm than good. It has pushed the discussion away from knowledge and ideas and toward a more narrow focus on the marginal productivity of capital. The paper also contained discussion of historical evidence and contemporary qualitative evidence, but it was the regressions that had the most impact.

Subsequent empirical work showed that there were other specifications that could fit the cross-country data. For example, Greg Mankiw, David Romer, and David Weil (1992) showed that one could equally well interpret the data as supporting a specification of the form $Y = AK^{1/3}H^{1/3}L^{1/3}$. That is, one could not reject a neo-classical specification in which output in all countries of the world is a homogeneous of degree one function of physical capital, human capital, and labor and in which the level of the technology A is the same in all countries. [However, Steven Durlauf and Paul Johnson (1992) directly test and

reject the hypothesis that the coefficients in these cross-country regressions are the same in different subsets of the sample of countries.] In addition, Mankiw et al. (1992) and Barro, Mankiw, and Sala-i-Martin (1992) (along with many other papers) have argued that the observed tendency for initial income to be negatively related with subsequent growth in cross-sectional regressions could be interpreted as evidence in favor of a neo-classical model with diminishing returns to capital accumulation.

This kind of evidence has been interpreted to mean that it is appropriate for economists to think about development without explicitly acknowledging the existence of ideas and idea gaps, but the evidence is almost completely uninformative about the relative importance of ideas versus objects. Testing for a coefficient on the stock of physical capital that was equal to one as a way to get evidence about ideas was an act of desperation dictated by the lack of direct evidence on technology and ideas. A rejection of this restriction is a rejection of the hypothesis that capital and ideas move in lockstep, but the finding is perfectly consistent with a world in which ideas matter but in which there is independent variation in the stock of physical capital that is not caused by variation in the stock of ideas. [This point is made in Romer (1990c).] More importantly, the finding that *ceteris paribus* poor countries grow faster than rich countries shows that poor countries suffer from some kind of gap that can be closed, but it tells us nothing about whether this gap represents an idea gap, an object gap, or both. [See Barro and Sala-i-Martin (1992) for a recent discussion of convergence that acknowledges these two possible interpretations.]

The difficulty here is twofold. First, we lack direct statistical measures of intangibles like ideas. Second, a given pattern of correlations in macro data can be produced by many different underlying causal structures. As a result, someone who starts from a belief that there are important technology gaps will interpret a more rapid growth rate in poor countries as evidence for this view. [See Fagerberg (1987) for an early paper that approaches the question of catching up from the point of view of the technology gap theorists and interprets the data this way.] Someone who believes that the neoclassical model gives a good picture of reality will interpret the same data quite differently.

One of the inherent disadvantages of using macro data in an attempt to falsify a narrowly posed hypothesis is that it encourages an excessively classical approach to statistical inference. It lets us treat an identifying assumption (for example, that a high level of school enrollment causes faster income growth instead of vice versa) as if it reflects prior knowledge that is certain, even when there is little basis for the assumption. It also lets us treat null and alternative hypotheses asymmetrically. This lets mainstream economists indulge their theoretical preference for the mathematically friendly world of convex sets by giving perfect competition preferential treatment as the null. In a body of data that can support many different identifying assumptions and in which the

statistical power to reject alternative hypotheses is weak, the freedom to select the null hypothesis and the identifying assumptions is tantamount to freedom to guarantee acceptance.

In addition, an emphasis on falsification tends to focus attention on only those parts of the broad spectrum of evidence that can readily be quantified. A more natural Bayesian approach would treat different hypotheses symmetrically and would weigh all of the available evidence in the process of attaching posterior probabilities to them. If you follow the usual methodological prescriptions and run a cross-sectional growth regression using aggregate output, investment, and education data from the states of the United State, you may conclude [as Holtz-Eakin (1992) does for example] that you cannot reject a model with exogenous technological change and that 'the data provide strong support for the Solow model' (p. 3). If you get data from the National Science Foundation on research and development expenditures by firms, or if you look at the mark-ups above marginal cost in the most dynamic and technologically intensive areas of the economy (microprocessors, software, pharmaceuticals), you will probably come to a different conclusion about whether growth in the United States is well described by a model with perfect competition and exogenous technological change. The real challenge is not to see if we can accept or reject models in using little bits of evidence taken in isolation, but instead to see if we can come to reasonable conclusions that make sense of all of the available evidence. Unfortunately, much of the available evidence about the most important economic questions does not come in the form of official statistical series.

5. Alternative types of empirical evidence

The previous section suggests that low-power positivism tends to be used as a methodological defense of frail models based on perfect competition. These models presumably would not win a symmetrical contest against other models that makes use of all of the available data.

If this suggestion about the correlation between narrow positivism and mainstream economic theory is correct, one would expect that economists working outside the mainstream would be relatively unconstrained and would be willing to make use of a much broader range of evidence than mainstream economists. They would evaluate all of the evidence in something closer to a Bayesian fashion, assigning a weight to each piece of data in proportion to its reliability and precision, and aggregating it to generate posterior probabilities for alternative explanations.

This does seem to be a reasonably accurate description of the empirical work undertaken by students of technology and by the evolutionary theorists. [The lines separating the different traditions are not always sharply drawn. For

example, the paper cited above, by Fagerberg (1987), relies on regression tests, and one of the early papers on growth regressions by macroeconomists, Barro (1991) is closer to the spirit of exploratory data analysis than rigid hypothesis testing.] Historical accounts of growth and technology (in fact most of economic history) cite isolated facts and anecdotes that fill in the gaps between the various statistical series and that provide the identifying information that lets us make inferences about causality. Most attempts to understand the behavior of specific industries studies or events in specific countries are presented as case studies.

The examples of historical analysis along these lines by Paul David (1991), Nathan Rosenberg (1976), and Joel Mokyr (1991) have already been cited. To give just a few additional examples of empirical work in this style, a recent volume edited by Nelson (1993) collects 15 different studies of the national innovation systems in a variety of industrial and newly industrializing countries. This comprehensive effort at summarizing qualitative data stands in sharp contrast to the kind of statistical variables (e.g., secondary school enrollment rates) used as indicators in regression analyses (including the ones reported below). In a similar vein, Dahlman and Nelson (1991) combine this kind of detailed qualitative evidence with available statistical series, using all of the evidence to give a detailed comparison of the development experience in a small collection of countries (Singapore, Korea, Hong Kong, Taiwan, China, Hungary, Brazil, Yugoslavia, Israel, Mexico, India, and Argentina).

At an even more detailed level, there are many detailed industry case studies. For example, the studies conducted in the Industry and Energy Department of the World Bank cover industries ranging from footwear to steel mini-mills. Publications such as the World Investment Report, published annually by the Transnational Corporations and Management Division of the United Nations, document the extensive patterns of direct foreign investment, cross-national alliances, and other means of technology transfer that operate between industrial and developing nations.

The cumulative persuasive effect of all of this qualitative evidence probably exceeds the effect of all of the cross-country regressions and growth accounting that has been done in the economics profession. More often than not, what seems to happen is that economists form a belief on the basis of the qualitative evidence and theoretical frameworks, and then amass whatever statistical evidence they can find to support it.

In monetary economics, for example, the beliefs of most economists seem to have been determined by some combination of the *Monetary History of the United States* by Milton Friedman and Anna Schwartz (1963) and reading the newspaper. All of the econometric work using formal tests of causality between money and income seems to have changed few minds.

In the theory of growth, there is enough flexibility in how one constructs growth accounting residuals that one could no doubt drive the technology

residual to zero. Dale Jorgenson and Zvi Griliches (1967) came close, and Jorgenson's more recent estimates are not far off [Jorgenson et al. (1987)]. If economists had been inclined to believe the results, we would certainly have driven this nuisance term out of existence. If we made a serious effort, we could surely fail to reject the hypothesis that the growth residual was statistically different from zero. But our knowledge of economic history, of what production looked like 100 years ago, and of current events convinces us beyond any doubt that discovery, invention, and innovation are of overwhelming importance in economic growth and that the economic goods that come from these activities are different in a fundamental way from ordinary objects. We could produce statistical evidence suggesting that all growth came from capital accumulation, with no room for anything called technological change. But we would not believe it.

For evaluating questions about development, most mainstream economists have far less contact with the corresponding information about different national experiences than they have with the evidence about the recent history of technology. Economists who are familiar with this evidence seem to be convinced that the determinants of cross-national flows of ideas about production are of decisive importance in influencing aggregate outcomes. It is not possible, for example, to read the story of how Taiwan moved from a position with essentially no industrial base to become the fourth-largest producer of synthetic fibers in 1981 [Wade (1990)] without being impressed by the importance of the specific joint ventures and licensing agreements undertaken with firms from the United States and Japan. This did not come from a high level of secondary school enrollment. Similarly, the development of the electronics industry in Taiwan was decisively influenced by the government's decision to induce foreign electronics firms to set up assembly operations in a free trade zone opened specifically for this purpose. Moreover, it is no surprise that firms in India (a country with a large quantity of highly skilled human capital, but which places suffocating constraints on the activities of foreign firms) failed to develop comparable industries. In the face of this kind of evidence, the assumption that all technological knowledge is broadcast like short wave radio transmissions to every country in the world seems as inappropriate as the assumption that there has been no technological change.

To cite another instance in which knowledge of the details can change how one interprets aggregate outcomes, consider China. The superficial view of reform in China is that movement to an undistorted market system has unleashed large increases in output by changing factor supplies or by changing the proportions in which different factors are used. This view (especially with respect to labor supply) no doubt helps explain much of the early success in agricultural reform, but it does not fit the recent, spectacularly successful development of manufacturing in the special economic zones of the coastal provinces.

Reductions in distortions did not let people there take advantage of knowledge that was already present. China continues to be far from a model of an undistorted market economy with strong property rights. 'Even a casual reading of World Bank reports on China would give the impression of an economy suffering from rigidities and complexities in its labor, capital and input markets, in its provision of education and infrastructure, and in its enterprise structures. These descriptions create the impression of an economy more distorted than, say, the India economy' [Bateman and Mody (1991)]. Second, the notion of a purely domestic response to policy reform misses the enormous flows of direct foreign investment that China has received since the last half of the 1980s and grossly underestimates the importance of Hong Kong. (Bateman and Mody observe that the best one-variable explanation for development in China, even if one restricts attention to the special economic zones, is geographic distance from Hong Kong.) Investors from Hong Kong provided more than 60% of all of the direct foreign investment in China. In addition, entrepreneurs and traders from Hong Kong have acted as intermediaries with investors from other countries. In both capacities, they have supplied crucial expertise in areas such as marketing, management, training, and technology acquisition.

The decisive role played by flows of ideas that are controlled by individuals and firms outside a developing country becomes most evident when one descends further, to the industry level. Three illustrative examples can only be briefly mentioned here. A recent World Bank study of the bicycle industry shows how firms from United States, Hong Kong, and Taiwan are in the process of rapidly converting the bicycle industry in China from a low-technology, low-quality producer of bikes for the domestic market into the world's largest exporter of bicycles [Mody et al. (1991)]. The new firms or joint ventures assemble high-quality bikes using modern manufacturing techniques. Assembly operations in China are now attracting local manufacturing facilities from Taiwanese producers of key components such as chains and derailleurs.

The large-scale cross-national study of productivity in automobile assembly plants conducted by the MIT International Motor Vehicle Program [and summarized in Womack, Jones, and Roos (1990)] clearly demonstrates the role of multinational firms in transmitting fundamental discoveries about automobile production across national boundaries. For example, after Henry Ford's refinement of the techniques of mass production and their adoption by General Motors, these ideas were transferred to Europe through direct investments, first by Ford, then by GM. The project documents in much greater detail the process whereby the techniques of lean production developed in Japan have been transmitted back to producers in North America, through local production by Japanese firms and by joint ventures such as that between Ford and Mazda or between Toyota and GM. This account also makes clear that a foreign firm can set up a world class production facility in a middle income, newly industrializing

economy. It reports that, on the basis of detailed measurements, the Ford assembly plant in Hermosillo, Mexico had the highest quality of any high-volume (i.e., nonluxury car) assembly plant in the world, better than the best performing Japanese plants and the best transplants in North America. The Hermosillo plant assembled a Japanese designed car (a variant of the Mazda 323). The plant was developed by Ford after it had gone through a period of crisis in the early 1980s and learned how to restructure its manufacturing operations along Japanese lines through an equity stake that it had acquired in Mazda. Mazda, in turn, had acquired this knowledge in the mid 1970s, when it reconfigured its production facilities in Hiroshima as a close copy of Toyota's operations.

Finally, there are a few countries small enough so that a case study of an industry is equivalent to a case study of the nation as a whole. Mauritius is one such country. Events there went through three main phases during the 1970s and 1980s. [This account is drawn primarily from Gulhati and Nallari (1990); for additional details, see also Romer (1993).] In 1970, after a policy of encouraging an import-substituting manufacturing sector had clearly failed, the government in Mauritius adopted a policy of export promotion centered around an export processing zone (EPZ). This 'zone' was in fact an administrative arrangement that gave a number of incentives to firms that produced exclusively for export. These included tariff-free imports of capital goods, intermediate inputs, and raw materials, tax concessions, advantageous financing, unrestricted repatriation of profits, and special flexibility in discharging workers. During the years from 1970 to 1975, the government also adopted a policy of wage restraint for the island as a whole. During this period, the island experienced a rapid increase in sugar prices (the main export commodity), which generated both a large quantity of domestic saving that was invested in the EPZ (accounting for about one half of all capital investment there). Less fortunately, this prosperity also created strong pressures for the government to increase social spending. As sugar prices declined in the second half of the 1970s and oil prices increased, the government was making the shift from a policy of fiscal conservatism and wage restraint to a new policy of increased spending and accommodation. By 1979, wage rates had increased by roughly 40–50% in real terms and the currency had appreciated. In the last half of the decade, government spending grew by 18% per year. For several years, the current account deficit and the government budget deficit were equal to about 12% of GDP. During this period of macroeconomic difficulty, foreign and domestic investment in the EPZ declined dramatically, as did overall economic growth.

From 1979 to 1982, the government, in consultation with the IMF and the World Bank, adopted a stringent program of macroeconomic stabilization that included depreciation of the currency, declining real wages, spending restraint. It subsequently increased the incentives for manufacturing firms, primarily by substantially cutting corporate tax rates and simplifying permit and certification

procedures. In response to these measures, investment in the EPZ resumed and output and employment in the EPZ once again grew rapidly, as did GDP for the island as a whole (at about 6% per year from 1982 to 1989). By the end of the 1980s, employment in the EPZ accounted for one third of all employment on the island and two thirds of the total increase in employment between 1970 and 1990.

The first salient fact from this account is that foreign investors were crucial to the success in the EPZ and in the economy as a whole, *not* because of the financial resources that they brought to the island, but rather because of the knowledge they possessed. Some of this knowledge was specific to production, but much of it pertained to issues like marketing. The second salient fact is that participation by foreign investors was highly responsive to both direct costs (e.g., tax rates and wage rates) and to the perceived indirect costs associated with macroeconomic instability and political instability. This link, between macroeconomic instability and participation by multinational corporations, offers one mechanism that can help explain the correlation noted by Stanley Fischer (1993) between bad macroeconomic performance and slow growth. If one looks narrowly at direct, domestic effects of inflation on growth, it may be hard to justify why aggregate growth should be much affected by the inflation rate. But if the flow of ideas from foreigners is sensitive to the perception of macroeconomic instability (and the associated political instability) and if these flows are important for growth, large effects from macroeconomic instability are easier to explain.

This account offers an additional perspective on the finding by Easterly et al. (1993) that growth rates can be highly variable over time. Growth in Mauritius was highly variable over time because the flow of ideas in from the rest of the world is highly sensitive to incentives, and therefore to the domestic policy environment. Relatively small variations in policy, especially if they are associated with changes in perceptions of political stability, can have large effects.

6. Cross-country regressions revisited

The advantage of micro-level evidence (e.g., the specific role played by the foreign firms in setting up bicycle production in China) or of case-study evidence (e.g., the sequence of events in Mauritius) is that one can confidently resolve mechanisms of action and the causal chains. It is quite clear that foreign bicycle firms showed the Chinese firms about the kinds of bicycles that would sell on foreign markets, undertook much of the design work, and taught workers specific skills such as quality control. It is also quite clear that foreign investors brought to Mauritius a specific set of ideas. Equipment investment (funded by both foreign and domestic firms) followed in response. The disadvantage of this qualitative evidence is that it is difficult to know how to add it all up.

Aggregate level evidence, which is not very revealing about causality, can give some indication about orders of magnitudes if one has some other basis for making causal inferences.

If the claims made above are correct – that there are important ideas gaps and that these can be exploited by importing equipment from industrial economies and by inviting in direct foreign investment – one would hope to be able to find some sign of this in the aggregate data. Blomstrom, Lipsey, and Zejan (1992) report results consistent with this view. They consider a regression of per capita income growth rates on a set of right-hand-side variables that includes the share of investment in GDP, the share of machinery and transportation equipment imports in GDP, and direct foreign investment as a share of GDP. They find that foreign direct investment (FDI) has a strong association with the rate of growth. In panel estimates over five-year time intervals, they also report that FDI seems to lead, rather than lag, income growth. Holding constant the FDI variable, the imported equipment variable did not seem to have an independent effect in their growth regression.

Because their specification uses a different functional form from that used in several other empirical studies in the literature, and because their sample includes Singapore, a data point that is highly influential in any regression equation that includes FDI or equipment imports as a share of GDP, table 1 reports regressions using different specifications and that exclude Singapore.

To illustrate the different interpretations of the aggregate data that are possible, eq. (1) in table 1 reports a standard cross-country growth regression equation using a minimal set of explanatory variables:

$$Growth = c + \beta_1 \frac{I}{Y} + \beta_2 Y_{1960} + \beta_3 Sec + \varepsilon. \tag{1}$$

Here the variable I stands for the usual national-income-accounts measure of total investment, and the variable *Sec* stands for the secondary school enrollment rate in 1960. This equation is estimated on a sample of 76 developing economies. For comparability with eq. (2) below, this sample consists of all countries for which data on the included variables and the measure of equipment imports are available, with the exception of Singapore, which is excluded for the reasons noted above. As usual, the investment share and the secondary school enrollment rate have positive coefficients, and initial income has a negative coefficient. According to the standard interpretation, β_1 is interpreted as a measure of the marginal product of capital. A negative value for β_2, the standard finding of conditional convergence, is typically interpreted as an indication of diminishing returns to capital investment and therefore of the importance of an object gap in explaining differences in income in different countries. As a result, these data can be interpreted as providing support for

Table 1

Cross-regression results.[a]

Dependent variable: Per capita income growth

	Equation					
	1	2	3	4	5	6
Constant	1.1 (0.61) [0.08]	− 2.3 (0.86) [0.008]	− 2.2 (0.87) [0.01]	− 2.4 (0.88) [0.008]	− 2.4 (0.87) [0.007]	− 2.2 (0.86) [0.01]
I/Y	13.2 (3.1) [0.000]	19.3 (4.2) [0.000]	20.8 (4.4) [0.000]	19.7 (4.3) [0.000]	20.0 (4.3) [0.000]	24.6 (4.8) [0.000]
$(I/Y)\times Y_{1960}$		− 8.9 (3.4) [0.01]	− 8.8 (3.4) [0.01]	− 9.7 (3.7) [0.01]	− 9.0 (3.5) [0.01]	− 7.4 (5.4) [0.18]
Y_{1960}	− 0.51 (0.22) [0.02]	1.6 (0.78) [0.05]	1.5 (0.78) [0.06]	1.8 (0.88) [0.05]	1.7 (0.79) [0.04]	1.3 (1.3) [0.30]
Sec[b]	5.8 (1.9) [0.003]			− 1.9 (3.4) [0.58]		4.5 (11.7) [0.70]
EM/Y[c]			− 9.6 (7.6) [0.21]			− 20 (97) [0.04]
$Sec\times(EM/Y)$		65 (17) [0.000]	80 (21) [0.000]	81 (33) [0.02]	92 (36) [0.01]	180 (52) [0.001]
$(I/Y)\times Sec$					− 14 (16) [0.39]	− 60 (52) [0.26]
R^2	0.34	0.41	0.43	0.42	0.42	0.46

[a] Standard errors in parentheses under coefficient estimates. P-values, i.e., the marginal significance level of a two-tailed test of the hypothesis that the coefficient is equal to zero, are given in square brackets under the standard errors. For all six regressions, there are 76 observations. See the appendix for a description of the data.

[b] Sec = Secondary school.

[c] EM = Machinery and equipment import.

a neo-classical model of growth, with no role for international transmission of ideas.

Eq. (2) in the table offers a complementary perspective on the same data. Let EM denote machinery and equipment imports. It is used here as a measure of interaction with the rest of the world and has the advantage that it is available for a relatively large number of countries. (The direct measure of direct foreign

investment is available for a much smaller sample of countries.) The regression takes the form

$$Growth = c + \beta_1 \frac{I}{Y} + \beta_2 \left(\frac{I}{Y} * Y_{1960} \right) + \beta_3 Y_{1960} + \beta_4 \left(Sec * \frac{EM}{Y} \right) + \varepsilon. \quad (2)$$

The estimates for this equation find significant positive estimates for β_1, β_3, and β_4, and a significant negative coefficient for β_2. The interpretation on the negative coefficient β_2 is the same as the one suggested above: A higher level of initial income is, everything else equal, associated with a lower marginal product of capital. One can equally well interpret this as saying that the advantages to starting from a low level of development accrue in proportion to the amount of investment that a nation undertakes. Either way, it can be interpreted as a sign of diminishing returns to physical capital accumulation, i.e., as being consistent with an object gap.

The positive coefficient on initial income (which is only marginally significant) suggests that there is something about the level of development that makes it easier for a richer country to grow. In the case of an idea gap model, this would presumably reflect the fact that the ability to take advantage of the ideas available in the rest of the world is higher for countries that have higher initial income. Finally, the positive coefficient on the product of the secondary school enrollment rate and equipment imports as a share of GDP is consistent with the view that a country benefits from interaction with the rest of the world in proportion to the level of human capital that it possesses. Consistent with the technology gap interpretation of development, rapid growth is a function of both access to foreign technology and a domestic capability for using it. [Lee (1992) offers other evidence suggesting that imported equipment investment has a particularly strong effect on growth. His results, however, are not strictly comparable because he uses a slightly different definition of equipment, and includes industrial economies and Singapore, in his sample.]

It is worth emphasizing that the estimate effects here are large. An increase in initial income of \$1000 reduces the implied marginal product of capital by 9% (e.g., from 19% to 10%). An increase in the secondary school enrollment rate by 0.1 increases the implied return on equipment imports by 6.5%. [To do these calculations, one must be told that annual growth rates are measured as percent, i.e., that an average annual growth rate of 2% gives a data point recorded as 2. The investment share, the equipment import share, and the enrollment rate are all fractions between 0 and 1. Income in 1960 is the Summers and Heston (1988) estimate of income in thousands of 1985 dollars. See the data appendix for details.]

The other regressions in table 1 allow for the inclusion of other cross-products or additional terms and show that none of them add anything to specification 2.

In particular, there is no evidence of an interaction between national investment and the secondary school enrollment rate, and there is no evidence that equipment imports divided by GDP (which are already included in total investment divided by GDP) have a direct effect on output that is different from the effect of investment itself.

If one were to judge purely by the size of the R^2, eq. (2), the one with the cross-terms would have an edge over eq. (1), but this is a weak basis for reaching any definitive conclusions about idea gaps versus object gaps. The point of the two regressions is that this kind of evidence is equally consistent with the view that there are only object gaps and with the view that there are both idea gaps and object gaps.

A caricature of many previous interpretations of cross-country regression is that there is nothing in the data that will force someone who wants to believe in an object gap model to abandon it. The point of this section is that one can claim with equal justification that there is nothing in these data that will force someone who wants to believe that idea gaps are important as well to abandon this position. This is why the additional evidence that appreciative theorists cite is so important for reaching a consensus.

7. Directions for future research

This paper makes two basic claims: that poor countries suffer from idea gaps and that both mainstream macroeconomic analysis and other less formal approaches have something important to offer to the study of development. These claims suggest a natural division of labor in future research. For example, mainstream theory has yet to provide a simple abstract model that shows how disembodied ideas, ideas that are free from any connection with a piece of equipment, can affect production. Once this has been done, the theory needs to show how corporations are able to keep control over this kind of idea, and show why international operations by corporations can channel ideas all over the world better than arms-length market transactions. Ideally, this work would shed some light on the wide and rapidly growing variety of joint venture or collaborative arrangements that firms use for exchanging ideas or sharing the risks in producing them.

Economists working outside the narrow confines of macroeconomic theory could push the kind of evidence that they have collected in two directions. First, they could try to aggregate all of the diverse bits of evidence and come up with some kind of qualitative assessment of how important idea-related economic transactions are. Aggregate level regressions will continue to be a very crude method for making overall quantitative assessments, so other estimates of this kind would be helpful. Second, these economists could selectively push the analysis of the evidence down further, to the most detailed microeconomic level.

For example, it would be very helpful to have a complete picture of how one set of ideas (e.g., about modern bicycle production) actually made their way into the Chinese economy from Hong Kong and then steadily diffused throughout its productive structure, somewhat along the lines of the work done on machine tools in the early United States by Rosenberg (1976). This kind of detailed, almost epidemiological account analogous to the spread of a disease would help elucidate the variety of mechanisms whereby ideas are spread, and might give a better sense of how far-reaching the effects of international flows of ideas can be and about how best to model them.

Appendix: Description of the data

All data other than the data on machinery imports were taken from the data set used by Levine and Renelt (1992). This data set is available from the World Bank.

Growth: Average annual rate of growth of per capita income from 1960 to 1989. Label in Levine–Renelt (LR) data set: *RYGDP60*. Original source, World Bank data. Mean = 1.8.

I/Y: The share of investment in GDP. Label in LR data set: *INV6089*. Original source, World Bank data. Mean = 0.22.

Y_{1960}: Initial income in 1960 in thousands of 'international' 1985 dollars. Label in LR data set: *RGDP60*. See, Summers and Heston (1988) for definitions. Mean = 1.2.

Sec: Secondary school enrollment rates. Label in LR data set: *SEC*. Original source, Barro (1991). Mean = 0.14.

EM: Average for 1960–1985 of imports of machinery and transport equipment, SITC 7, to GDP. From Blomstrom, Lipsey, and Zejan (1992). Mean of $EM/Y = 0.065$.

References

Aghion, Phillipe and Peter Howitt, 1992, A model of growth through creative destruction, Econometrica 60, 323–351.

Arrow, Kenneth J., 1962, The economic implications of learning by doing, Review of Economic Studies 29, 155–173.

Barro, Robert J., 1991, Economic growth in a cross section of countries, Quarterly Journal of Economics 106, 407–443.

Barro, Robert J. and Xavier Sala-i-Martin, 1992, Convergence, Journal of Political Economy 100, 223–251.

Barro, Robert, N. Gregory Mankiw, and Xavier Sala-i-Martin, 1992, Capital mobility in neoclassical models of growth, NBER working paper no. 4206.

Bateman, Deborah A. and Askoka Mody, 1991, Growth in an inefficient economy: A Chinese case study (World Bank, Washington, DC).

Becker, Gary, 1975, Human capital (Columbia University Press, New York, NY).

Becker, G., K. Murphy, and R. Tamura, 1990, Human capital, fertility, and economic growth, Journal of Political Economy 98, S12–S37.
Blomstrom, Magnus, Robert E. Lipsey, and Mario Zejan, 1992, What explains developing country growth?, NBER working paper no. 4132.
Dahlman, Carl and Richard Nelson, 1991, Social absorption capability, national innovation systems and economic development, Mimeo. (World Bank, Washington, DC).
Chamberlain, Edward, 1933, The theory of monopolistic competition (Harvard University Press, Cambridge, MA).
Dasgupta, P. and J. Stiglitz, 1988, Learning-by-doing, market structure, and industrial and trade policies, Oxford Economic Papers 40, 246–268.
David, Paul, 1991, Computer and dynamo: The modern productivity paradox in a not-too-distant mirror, in: Technology and productivity: The challenge for economic policy (OECD, Paris).
De Long, J. Bradford and Lawrence H. Summers, 1991, Equipment investment and economic growth, Quarterly Journal of Economics 106, 445–502.
Dixit, K. Avinash and Joseph Stiglitz, 1977, Monopolistic competition and optimum product diversity, American Economic Review 67, 297–308.
Dosi, Giovanni and Christopher Freeman, 1992, The diversity of development patterns: On the processes of catching-up, forging ahead and falling behind, Mimeo. (University of Rome La Sapienza, Rome).
Dosi, Giovanni, Keith Pavitt, and Luc Soete, 1990, The economics of technical change and international trade (Harvester Wheatsheaf, New York, NY).
Durlauf, Steven and Paul Johnson, 1992, Local versus global convergence across national economies, NBER working paper no. 3996.
Easterly, William, Michael Kremer, Lant Pritchett, and Lawrence Summers, 1993, Good policy or good luck? Country growth performance and temporary shocks, Journal of Monetary Economics, this issue.
Fagerberg, Jan, 1987, A technology gap approach to why growth rates differ, Research Policy 16, 87–99.
Fischer, Stanley, 1993, The role of macroeconomic factors in growth, Journal of Monetary Economics, this issue.
Friedman, Milton and Anna J. Schwartz, 1964, A monetary history of the United States (1867–1960) (Princeton University Press for the National Bureau of Economic Research, Princeton, NJ).
Gershenkron, Alexandar, 1962, Economic backwardness in historical perspective (Belknap Press, Harvard University, Cambridge, MA).
Grossman, Gene and Elhanan Helpman, 1990, Comparative advantage and long-run growth, American Economic Review 80, 796–815.
Grossman, Gene and Elhanan Helpman, 1991, Quality ladders in the theory of growth, Review of Economic Studies 58, 43–61.
Grossman, Gene and Elhanan Helpman, 1991, Innovation and growth in the global economy (MIT Press, Cambridge, MA).
Gulhati, Ravi and Raj Nallari, 1990, Successful stabilization and recovery in Mauritius, EDI development policy case studies: Analytical case studies no. 5 (World Bank, Washington, DC).
Hirschman, Albert, 1958, The strategy of economic development (Yale University Press, New Haven, CT).
Holtz-Eakin, Douglas, 1992, Solow and the states: Capital accumulation, productivity and economic growth, NBER working paper no. 4144.
Jones, Larry and Rodolfo Manuelli, 1990, A convex model of equilibrium growth: Theory and policy implications, Journal of Political Economy 98, 1008–1038.
Jorgenson, Dale W., Frank Gollop, and Barbara Fraumeni, 1987, Productivity and U.S. economic growth (Harvard University Press, Cambridge, MA).
Jorgenson, Dale W. and Zvi Griliches, 1967, The explanation of productivity change, Review of Economic Studies 34, 249–283.
Judd, Kenneth L., 1985, On the performance of patents, Econometrica 53, 567–585.
Krugman, Paul, 1990, Rethinking international trade (MIT Press, Cambridge, MA).
Krugman, Paul, 1991, Geography and trade (MIT Press, Cambridge, MA).
Krugman, Paul, 1993a, Towards a counter-counter-revolution in development theory, Proceedings of the World Bank Annual Conference on Development Economics 1992, Supplement to the World Bank Economic Review, March, 15–38.

Krugman, Paul, 1993b, The fall and rise of development economics, Mimeo. (MIT, Cambridge, MA).
Lee, Jong-Wha, 1992, Capital goods imports and long-run growth, Mimeo. (International Monetary Fund, Washington, DC).
Levine, Ross and David Renelt, 1992, A sensitivity analysis of cross-country growth regressions, American Economic Review 82, 942–963.
Lewis, W. Arthur, 1954, Economic development with unlimited supplies of labor, The Manchester School 22, May, 139–191.
Lucas, Robert E., Jr., 1988, On the mechanics of economic development, Journal of Monetary Economics 22, 3–42.
Mankiw, N. Gregory, David Romer, and David N. Weil, 1992, A contribution to the empirics of economic growth, Quarterly Journal of Economics 107, 407–437.
Mody, Ashoka, Jerry Sanders, Rajan Suri, Chandu Rao, and Fernando Contreras, 1991, International competition in the bicycle industry: Keeping pace with technological change (World Bank, Washington, DC).
Mokyr, Joel, 1990, The lever of riches: Technological creativity and economic progress (Oxford University Press, New York, NY).
Myrdal, Gunnar, 1971, Economic theory and underdeveloped regions (Harper, New York, NY).
Murphy, Kevin, Andrei Shleifer, and Robert Vishny, 1989, Industrialization and the big push, Journal of Political Economy 97, 1003–1026.
Nelson, Richard R., 1993, National innovation systems: A comparative analysis (Oxford University Press, New York, NY).
Nelson, Richard R. and Edmund S. Phelps, 1966, Investment in humans, technological diffusion, and economic growth, American Economic Review 56, 69–75.
Nelson, Richard R. and S. Winter, 1982, An evolutionary theory of economic change (Belknap Press, Harvard University, Cambridge, MA).
Nordhaus, William D., 1969, An economic theory of technological change, Papers and Proceedings, American Economic Review 59, 18–28.
Rebelo, Sergio, 1991, Long run policy analysis and long run growth, Journal of Political Economy 99, 500–521.
Robinson, Joan, 1933, The economics of imperfect competition (Macmillan, London).
Romer, Paul M., 1986, Increasing returns and long-run growth, Journal of Political Economy 94, 1002–1037.
Romer, Paul M., 1987a, Growth based on increasing returns due to specialization, American Economic Review 77, 56–62.
Romer, Paul M., 1987b, Crazy explanations for the productivity slowdown, NBER macroeconomics annual.
Romer, Paul M., 1990a, Are nonconvexities important for understanding growth?, American Economic Review 80, 97–103.
Romer, Paul M., 1990b, Endogenous technological change, Journal of Political Economy 98, S71–S102.
Romer, Paul M., 1990c, Capital, labor, and productivity, Brookings Papers on Economic Activity: Microeconomics, 337–367.
Romer, Paul M., 1993, Two strategies for economic development: Using ideas and producing ideas, Proceedings of the World Bank Annual Conference on Development Economics 1992, Supplement to the World Bank Economic Review, March, 63–91.
Romer, Paul M., 1994, New goods, old theory and the welfare costs trade restrictions, Journal of Development Economics, forthcoming.
Rosenberg, Nathan, 1976, Perspectives on technology (Cambridge University Press, New York, NY).
Rosenstein-Rodan, Paul, 1943, Problems of industrialization in Eastern and South-eastern Europe, Economic Journal 53, 202–211.
Schumpeter, Joseph, 1961, The theory of economic development (Harvard University Press, Cambridge, MA).
Schumpeter, J., 1942, Capitalism, socialism, and democracy (Harper and Brothers, New York, NY).
Segerstrom, Paul, T.C.A. Anat, and Elias Dinopoulos, 1990, A Schumpeterian model of the product life cycle, American Economic Review 80, 1077–1091.

Shell, Karl, 1967, A model of inventive activity and capital accumulation, in: Karl Shell, ed., Essays in the theory of optimal economic growth (MIT Press, Cambridge, MA).
Shleifer, Andrei, 1986, Implementation cycles, Journal of Political Economy 94, 1163–1190.
Solow, Robert, 1956, A contribution to the theory of economic growth, Quarterly Journal of Economics 70, 65–94.
Solow, Robert, 1957, Technical change and the aggregate production function, Review of Economics and Statistics 39, 312–320.
Summers, Robert and Alan Heston, 1988, A new set of international comparisons of real product and price levels: Estimates for 130 countries, 1950–1985, Review of Income and Wealth 34, 1–25.
Veblen, Thorstein, 1915, Imperial Germany and the industrial revolution (Macmillan, New York, NY).
Wade, Robert, 1990, Governing the market (Princeton University Press, Princeton, NJ).
Womack, James P., Daniel T. Jones, and Daniel Roos, 1991, The machine that changed the world (Harper Perennial, New York, NY).