Assessing the Performance of Infant Industries

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Abstract

This paper reports findings from a literature survey to learn about the performance of infant industries in less developed countries. Remarkably little direct evidence was uncovered about the costs and benefits of developing these industries. But the findings indicate that infant firms have experienced relatively slow productivity growth. Thus many infants started quite some time ago apparently have so far failed to achieve international competitiveness. The findings suggest tentative conclusions about the causes of the failure. Insufficient productivity growth to achieve and maintain competitiveness seems to reflect the absence of sustained efforts to acquire and use the capabilities necessary for continuous technological change. Far more than stemming from experience alone, these capabilities appear to increase to needed levels only through consciously allocating resources to acquire them.
Le présent document expose les conclusions de toute une série d'ouvrages quant aux performances des industries de création récente dans les pays en développement. On a découvert peu d'éléments probants sur les coûts et avantages d'un développement de ces industries mais il apparaît que leur productivité augmente relativement lentement. C'est ainsi que de nombreuses sociétés créées depuis un certain temps déjà ne sont apparemment pas encore devenues compétitives au plan international et plusieurs hypothèses sont avancées pour expliquer cet échec. Le fait que leurs gains de productivité soient insuffisants pour leur permettre de devenir durablement compétitives semble tenir à l'absence d'efforts soutenus en vue d'acquérir et d'utiliser les moyens nécessaires pour s'adapter à l'évolution constante des techniques. L'expérience ne suffit pas à elle seule et, pour parvenir à disposer des moyens voulus, il est indispensable de procéder à une affectation rationnelle des ressources.
En este documento se detallan los resultados de un estudio de los trabajos publicados sobre el desempeño de las industrias nacientes en los países menos desarrollados. Es sorprendente que se haya obtenido tan poca información directa sobre los costos y beneficios que comporta el desenvolvimiento de estas industrias. Sin embargo, los resultados indican que las empresas nacientes han experimentado un crecimiento de la productividad relativamente lento. De este modo, muchas industrias iniciadas hace bastante tiempo no han logrado aparentemente hasta la fecha alcanzar un grado de competitividad internacional. Se sugieren algunas conclusiones tentativas acerca de las causas de esto último. El insuficiente aumento de la productividad para alcanzar y mantener la competitividad parece reflejar la ausencia de esfuerzos sostenidos a fin de adquirir y utilizar las capacidades necesarias para un continuo cambio tecnológico. Mucho más que derivarse sólo de la experiencia, estas capacidades parecen incrementarse a los niveles necesarios sólo mediante una asignación consciente de los recursos para adquirirlos.
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Summary

The general view in the literature about infant industries is that only a short period is needed for them to become competitive at international standards of cost and product specifications. For the right industry and the right technique -- that is, for an industry and a production method that conform to the country's relative factor endowment -- catching up merely entails productivity growth by overcoming initial technical inefficiencies through the straightforward accumulation of experience. The essence of this model of maturation is that the required increase in productivity is achieved passively, effortlessly, and almost automatically. Common expectations about the duration of infancy are that it will take about three to five years, perhaps stretching to seven or eight.

The evidence from our survey suggests a different model, one in which maturation is achieved by explicit efforts to manage technological change. The literature provides few estimates, however, of the duration of infancy in today's less developed countries. The studies we surveyed show wide variation in rates of productivity change, but they do imply two reasonably clear conclusions. First, productivity growth in infant industries appears to be highly variable, even in apparently similar economic conditions. Second, few of the infant enterprises studied in less developed economies appear to have demonstrated the high and continuous productivity growth needed to achieve and maintain international competitiveness.

Given that infant industrial activities experience modest productivity growth and that the initial productivity gap is wide, the duration of infancy must be long. Long periods of infancy may in part be
explained by a dynamic aspect that usually is neglected. Productivity may be growing not only for infant enterprises, it may also be growing for mature enterprises in other countries where the industry is well established. Thus industrial maturation may and often does require becoming competitive in relation to international standards of cost and product specifications that are changing because of continuing advances in productivity in mature enterprises. For a newly established industry that begins without being internationally competitive, maturity is impossible without productivity growth that is faster paced than that in countries where the industry is already internationally competitive. This fact may be obvious, but it appears frequently to be forgotten.

The central conclusion is that infant enterprises cannot mature unless they accumulate the capability for technological change. The process of accumulating that capability is commonly described as learning, but what this learning involves is not clear. The term has often been used merely to refer to what is thought to underlie rising productivity. Thus, a path of falling unit costs, with an apparently unchanging production system, is often simply described as the result of "learning." Such learning refers to the feedback of information about industrial production: production in one period generates a flow of information and understanding that allows improvements in a subsequent period. But the evidence indicates that the flow of information does not take place without a conscious effort to monitor performance. And the learning from such flows is not effortless; nor is it without cost. Costless learning-by-doing thus has limited relevance for the accumulation of technological capability.

Although all enterprises can take advantage of a vast body of existing technology, maturity depends on the ability to use this technology
effectively. From the evidence it seems that the firm-level absorption of technology for infant industrial activities involves modifying and adapting the technology. Absorption and the accompanying improvements require specific technological changes and the resources to accomplish them. In this respect the technological effort needed to master a technology is difficult to distinguish from that associated with managing technological change more generally. To achieve and maintain international competitiveness thus requires developing the capability to manage continuous technological change. In other words, maturation takes conscious efforts to develop a technological strategy, to invest in resources for technological changes, and progressively to accumulate technological capability.

The apparent failure of many infant industries to attain international competitiveness may be due to any of several causes. The one that has probably received the most attention in previous discussions is the promotion of the wrong infant industries by governments, whether through explicit selection or through the implicit effects of trade and other policies that differ in their combined incidence on incentives across industries. Another possible cause that has received much attention is the use of the wrong production methods. Production would be internationally competitive given the choice of technique that minimizes cost, but it is not competitive because of the choice of a suboptimal technique that leads to permanently higher production costs.

The selection of industries and production methods that do not conform to a country's relative factor endowment have undoubtedly been important factors inhibiting the attainment of internationally competitive production. But given the selections made, what is of at least equal concern is the evidence that many infant enterprises have failed to exert needed
technological efforts and have thus failed to realize the beneficial productivity gains possible. Perhaps of even more concern, this applies to many firms in infant industries that do have the potential for international competitiveness on factor intensity grounds.

Governments have often instituted policies that are ill-advised -- and failed to institute policies that are well-advised -- in relation to fostering rapid and efficient maturation. But the effects of different policies acting in combination with each other -- and with other social, political, and economic factors in the environment -- are far from well enough understood to enable unarguable recommendations for optimal policy packages designed to foster rapid and efficient maturation. We do know that infants can mature. Moreover, the experience in some rapidly industrializing countries suggests that they can even mature very quickly. But reflecting our general ignorance of the maturation process, there is little general agreement on the factors ultimately responsible for the rapid maturation in these countries.

Finding out more about these factors, and how they operate on firms, is urgent business -- particularly if our conclusion about the slow maturation of most infants in most developing countries is correct. Of equal importance is finding out why some firms perform well, whatever the environment, while others do not.
ASSESSING THE PERFORMANCE OF INFANT INDUSTRIES

1. Introduction

Infant industries are industrial activities that are being undertaken for the first time in an economy. The startup costs for plants in a less developed country's infant industries are thought to exceed those for identical plants in economies where these industries are well established. These higher startup costs do not argue against establishing an infant industry if they are expected to be offset by the eventual benefits of lower production costs and positive externalities. The critical question is whether performance matches expectation. Are the startup costs higher? How much higher? Do production costs eventually fall to levels below those in well established industries? After how long? What are the elements of maturation — that is, of achieving international competitiveness? These are the questions that concern us in this paper. They are questions sidestepped in much of the discussion about infant industries that has focused on establishing criteria for selecting the industries to be nurtured and on determining the policies to promote them.

Historical plant-level estimates of the social costs and benefits associated with infant industrial activities are needed to address these questions. With such estimates it would be possible to analyze differences in infant-industry performance across firms, sectors, and economies — to examine how maturation is influenced by the industrial base, the policies adopted for infant activities, and the characteristics of firms and technologies. It would also be possible to spell out the various aspects of maturation and to determine what is needed to reduce the cost of infancy and increase the benefit. Such information should enable better prescriptions for the central
choices in designing industrial development strategies and formulating policies for their realization: choices about what industries to promote -- and how to promote them.

The foregoing framework was our starting point in surveying the literature to learn more about the maturation of infant industries in the less developed countries. But the survey turned up remarkably little quantitative evidence about the cost and benefit of infancy. What we have ended up with is very little idea of the cost, some idea of the rate of productivity growth for the firms covered in the studies surveyed, an impression that there is not much maturation of infants in very many developing countries, and some conclusions about the technological effort needed for industrial maturation.

2. Concepts and line of argument

In this section we lay the groundwork for the following sections on the results of the survey. We first consider the relationship between cost-benefit analysis and productivity measurement as approaches to assessing the performance of infant industries. We do this because the most relevant empirical studies give indicators of productivity but not cost and benefit. We also do this to underscore the importance of the link between productivity growth and maturation. We go on to make a connection between maturation and technological efforts to acquire technological capability. Then we consider whether productivity growth must always reflect -- or be due to -- technological effort. We conclude the section with a reader's guide to the rest of the paper.

1/ Martin Bell carried out the survey. The findings are given in full in Bell (forthcoming), from which many of the arguments and conclusions in this paper are drawn.
2.1. Costs, benefits, and productivity growth

A complete assessment of the performance of an infant industry requires social cost-benefit analysis. Nonetheless, very useful diagnostic information can be obtained by measuring the infant's productivity growth. A brief sketch of the application of cost-benefit analysis will help in understanding both the relevance and the limitations of productivity measurement.

The net benefit of an infant industry's development is properly measured by starting with the difference between the cost of domestic production and the value of that production. The cost of domestic production is obtained by valuing inputs at their appropriate shadow prices (or accounting values). The simplest approach to placing a value on production is to multiply the quantity produced by the unit cost of imports, the latter measured using the shadow price of foreign exchange. This approach assumes that all production simply replaces imports. It correspondingly overvalues any production that satisfies demands in excess of the quantity demanded at a price equal to the unit import cost. It equally overvalues any production

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2/ Such analysis applies the Mill-Bastable test for allocative efficiency (see Corden 1974, ch. 9).

3/ Following Bruno (1972), the appropriate measure of unit production cost is equal to the ex post domestic resource cost of nontraded inputs plus the value of traded inputs per unit of production. Domestic resource costs are measured in shadow prices (or accounting values). Traded inputs are valued by multiplying marginal border prices by the shadow price of foreign exchange. As Bruno discusses, the government's policy regime and the circumstances of the industry in relation to other industries are important determinants of the tradable inputs that are to be counted as traded.

4/ The approach cannot be used if the output produced by the infant industry differs in its characteristics from products that can be imported. The implications of product innovation by an infant industry are discussed at the end of the section.
that is exported. The simple approach thus overstates the net benefit.\textsuperscript{5} We will nonetheless use the simple approach here, because our purpose is only to demonstrate that productivity growth may generally be a necessary condition for a positive net benefit.\textsuperscript{6}

Following this approach, the social cost of developing an infant industrial activity is equal to the cumulative discounted value of the difference between domestic and import costs from the initiation of production to the time of maturation, when domestic production and import costs are the same. The gross social benefit includes, correspondingly, the cumulative discounted value of the difference between domestic production and import costs after the time of maturation, when the average domestic production cost is lower than the import price. To this benefit must be added the externalities typically invoked in the infant-industry argument and not captured in measuring the gross benefit in the foregoing manner.

In figure 1, OA represents the initial unit cost of infant production. OF is the unit cost of importing the product. ABC is the path of falling unit production costs as the productivity of the industrial infant increases.\textsuperscript{7} FG is the path of the unit costs of imports. The figure has two

\textsuperscript{5} The net benefit may also be overstated as a result of neglecting possible efficiency losses from protectionist or other measures to promote the infant.

\textsuperscript{6} Note that a necessary condition for a positive value with respect to an overstatement of the net benefit is equally a necessary condition for a positive value of the net benefit.

\textsuperscript{7} The relationship of the path of ABC to the path of the product's market price depends on how government policies (especially those affecting trade in the product) and the industry's market structure affect price in relation to the unit cost of production in shadow prices. In this paper, however, we leave this relationship unexplored, since we are not concerned with the distribution of costs and gross benefits between producers and consumers.
Fig. 1. The Cost, Benefit, and Duration of Infancy
interpretations corresponding to whether the horizontal axis represents cumulative output or time. Each interpretation is used below according to its relative merit as the vehicle for exposition.

With the horizontal axis representing cumulative output, the areas FAB and CBG have straightforward interpretations. FAB indicates the undiscounted total cost of infancy. CBG represents the readily measurable undiscounted total benefit of the infant's development, to which must be added the externalities not reflected in its measurement.8/ Those benefits are gross benefits. To obtain the net benefit, costs and gross benefits must be properly time-discounted before deducting the former from the latter. As can be seen from the figure, the net benefit can be positive -- leaving externalities aside -- only if the infant's unit production cost eventually falls below the unit import cost. Indeed, for the discounted equivalent of CBG (extended to an infinite horizon) to exceed the discounted equivalent of FAB, the production cost must fall enough relative to the import cost to overcome the compounding effect of time-discounting.9/ In sum: to realize a positive net benefit in the absence of any externalities, not only must the infant mature, the gross benefit achieved after maturation must also be sufficient to recoup the cost incurred as the infant matures.

With the horizontal axis representing time, OT gives the duration of infancy. Unit values are then averages with respect to the total quantity for each period. The slope of ABC is the real rate of change of unit production

8/ If measured at the firm level, costs and benefits as measured here fail to capture the externalities generated by the firm, though the path of ABC will reflect externalities transmitted to it by other firms, both in the industry and outside it. If measured at the industry level, the path of ABC will capture the externalities that are internal to the industry.

9/ This does not mean that the average rate at which domestic costs fall over time relative to import costs must be greater than the discount rate.
costs with respect to time. It is equal to the rate of change of productivity of all inputs combined -- that is, to the rate of change of output minus the rate of change of total inputs, where the latter rate of change is equal to the weighted sum of the rates of change of all inputs (capital, labor, raw materials, energy, and so on), using appropriate weights that vary with time.\textsuperscript{10} As can be inferred from the figure, the net benefit of the infant's development can be positive -- again leaving externalities aside, and assuming an initial cost disadvantage (A greater than F) together with no increase in the unit import cost over time -- only if the infant experiences some productivity growth. But as can also be inferred from the figure, there is a more stringent necessary condition than this for realizing a positive net benefit. The slope of FG is the real rate of change of unit import costs, which is equal -- assuming the shadow exchange rate remains constant -- to the rate of change of productivity for the foreign supplier(s). Thus the net benefit of the infant's development can be positive -- assuming no externalities, an initial cost disadvantage, and a constant shadow exchange rate -- only if the infant experiences faster productivity growth than its foreign competitor(s) during some period.

Suppose -- as may typically be the case -- that the cost of infancy exceeds the value of any externalities generated by the infant. Further suppose -- as is probably most often true -- that changes in the shadow exchange rate over time, if any, do not compensate for this difference.\textsuperscript{11} Faster productivity growth during some period is then a necessary condition

\textsuperscript{10} For references on measurement, see the citations in Nishimizu and Robinson (1984).

\textsuperscript{11} Note that changes in the shadow exchange rate would generally affect the unit cost of production as well as the unit cost of imports.
for the realization of a positive net benefit from the infant's development. (Whether faster productivity growth is sufficient to ensure a positive net benefit depends on how long it is maintained.) Thus the relationship of productivity measurement to cost-benefit analysis is this: productivity measurement provides information to test whether a condition that may generally be necessary for the economic justification of the infant's development has been met, cost-benefit analysis focuses directly on the sufficient condition.

Up to this point we have implicitly assumed that the infant industry produces a single unchanging product that is identical to an importable variety. This assumption affects the measurement of productivity change, but it does not fundamentally alter the relationship of productivity measurement to cost-benefit analysis. With many products, the composition of output is reflected in the measurement of productivity by measuring it with respect to the total real value of output. Changes in productivity then include the effects of changes in the composition of output. Thus an infant's relative productivity growth depends -- among other things -- on changes over time in the variety of products produced. Correspondingly, an infant may experience faster productivity growth by shifting the composition of output among an unchanged set of products or by changing product characteristics or introducing new products.

Import prices cannot be used to value outputs that are innovative or that otherwise differ in their characteristics from those of products that can be imported. Indeed, the inappropriate use of import prices -- by failing to pay adequate attention to differences in product characteristics -- may result in seriously understating the value of an infant's production as well as the changes over time in its productivity. This does not, however, mean that
import prices can be totally neglected. Outputs that differ from importable products are valued through directly estimating the benefits derived by the infant's customers. But these benefits are not independent of the unit import costs of close substitutes. Thus the net benefit of the infant's development does depend on changes in its productivity relative to changes in foreign productivity -- that is, foreign productivity in producing closely substitutable imports. The net benefit similarly depends on product innovations made overseas. In sum: though differentiation among many products makes the measurement of productivity more complex, the relevance of productivity measurement remains.

Even rough estimates of productivity change would help in answering several fundamental questions. For example, in figure 1, with ABC now the time path of the average (over the outputs produced) total production cost (per period) and FG the path of the corresponding average total output value -- it being recognized that changes in output composition and product mix toward higher value products may cause both of these paths to trend upwards during some intervals: What tends to be the gap between A and F for different industries and technologies in different countries? What is the general shape and average slope of the cost reduction path ABC? How do these relate to startup costs in industrial countries? At the very least, it would help to know the average duration, OT, for different industries. Is this short, such that the cost of infancy is small? Or is it long, such that the cost is large? And how does the duration differ in different environments? Is it, as might be expected, shorter if the initial industrial base is large? if the

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12/ The measurement problems here are similar to those encountered -- for products that have identical importable substitutes -- in measuring the value of production that satisfies demands in excess of the quantity demanded at a price equal to the unit import cost.
technology is similar to other technologies already in use? if the policy frame is more outward-looking than protectionist?

2.2. Maturity and maturation

Maturity is the condition of being internationally competitive -- of being at or to the right of T in figure 1. Maturation is the process of becoming internationally competitive -- of going from A to B. We use these terms because they are the metaphorical counterparts of "infancy." Maturity in the sense of achieving and maintaining international cost-competitiveness should not be confused with using the most recent vintage of technology or being at the global frontier in innovating new technology.13/ In many industries neither of these conditions is necessary for achieving maturity as we define it. Also to be recognized is that maturity, once gained, can be lost. The metaphor can thus be extended to geriatric, even senile, industries, but such uncompetitive old industries are not of concern here.

The basic problem of maturation is accumulating the technological capability to become and remain competitive at international standards of cost and product specifications. This follows from the observation that sustained increases in productivity are the result of efforts to acquire and use technological capability. That said, a few definitions are in order.

- **Technology** refers to a collection of physical processes that transform inputs into outputs, to the specifications of the inputs and the outputs, and to the procedural and organizational arrangements for carrying out the transformations. Sometimes the term refers only to a production technique, such as the use of a

13/ Nor should it be confused with achieving particular single-factor (say, labor) productivities comparable with levels attained in industrially more advanced countries.
basic oxygen furnace for making steel in one plant at one time. Other times it is extended to embrace a range of similar techniques, such as basic oxygen furnaces generally -- or all steel-making techniques, including open hearth and electric arc furnaces. Sometimes the term refers only to operational expressions of technological information, such as steel-making furnaces and the tasks involved in their operation. Other times the term is extended to embrace the technological information, such as the blueprints and operating manuals for steel-making furnaces.

- **Technological capability** is the ability to make effective use of technology.\(^{14/}\) Capability in choosing technology and in operating processes and producing products is essential for attaining international competitiveness. Capability in managing changes in products, processes, and the procedural and organizational arrangements in plants is essential for maintaining international competitiveness in an industry.

- **Technological effort** is conscious exertion to use technological information and to accumulate technological knowledge to choose, assimilate, adapt, or create technology. Effort is needed to evaluate and choose technology; to acquire and operate processes and produce products, to manage changes in products, processes, procedures, and organizational arrangements; and to create new technology.

In emphasizing technological effort and capability, we do not mean to imply that relative factor endowments or the imperatives of the product cycle are

\(^{14/}\) Westphal (1982) and Dahlman and Westphal (1982) use the term "mastery" in much the same sense that "capability" is used here.
inconsequential in determining the potential either for achieving or for maintaining international competitiveness. We simply mean to focus on what is involved in realizing the potential for competitiveness -- the growth of productivity.

The requirements of infant-industry development are seen differently by different people, depending on their focus. Some economists and policy makers conceive of infant industrial activities as being akin to operating an espresso machine. As they would have it, all that one needs to enter the competitive fray is to buy an espresso machine and to become proficient in preparing inputs and running the machine. This conception may be correct for some infant activities. But many other infant industrial activities may be more akin to running a good restaurant, for which entering the competitive fray is much more complex. One not only needs a kitchen with an array of equipment, ingredients, and possibilities for what can be produced. One also needs an array of recipes for various dishes and the broader training and specialization associated with each input and product -- and with their interrelations. The difference between operating the espresso machine and running the good restaurant is this: the first involves using a machine that requires a small number of inputs according to a standard recipe to produce a standardized product; the second involves using a variety of equipment in combination with a broad array of inputs according to highly variable recipes to produce a changing array of products. Corresponding to this difference, far more time and effort are needed to achieve proficiency in running a good restaurant than in operating an espresso machine.

Some economists and policy makers would also have it that the efficient operation of an infant industrial plant -- whether akin to an espresso machine or a restaurant -- is something that comes (solely and
automatically) from growing experience in operation. Once again, this may be
so for some industries. But in many instances even getting up to capacity at
international standards of cost and quality may require various technological
efforts. And the output from a given plant rarely increases beyond its
nominally rated capacity without explicit technological efforts. The
achievement of greater output without commensurate changes in the value of
physical capital seems almost always to require changes in processes,
procedures, and organizational arrangements. It often requires changes in
specifications for inputs and outputs as well. None of these changes can take
place without the requisite technological capability.

Maintaining international competitiveness is not merely a matter of
efficient operation according to original design standards. It is a matter
both of efficient operation and of developing the capability to keep up with
ever changing standards in the world. In addition, the efforts needed to
achieve efficient operation apparently are generally similar to the efforts
needed to manage technological changes that enable the producer to maintain
international competitiveness in a changing world.

2.3. Productivity and capability

Technological effort by infant industries is not the only possible
source of growth in their productivity. This fact complicates research on the
performance of these industries because greater productivity cannot always be
associated with increased technological capability. Observed changes in
productivity often include cyclical components related to variations in the
intensity of factor use due to fluctuations in demand and in the availability
of intermediate inputs. Secular changes may reflect similar variations: for
example, firms that overinvest to exploit economies of scale will experience
increasing productivity as excess capacity falls with the growth of demand.
But changes in productivity that are unrelated to changes in technological capability can be detected by using information at the firm level to uncover the sources of productivity change.

Changes in productivity, if measured at the industry level, may reflect structural shifts in the composition of output among firms having different productivity, shifts that include the exit of some firms and the entry of others. Indeed, separating the sources of productivity growth into structural shifts and firm-level changes is an important area for empirical investigation (Carlsson 1981). This is particularly so for analyzing the effects of policy -- because policies affecting the acquisition of technological capability by individual firms can be distinguished from policies affecting the exit and entry of firms and the growth of the market shares held by the more productive firms.

But it is important to recognize where the higher productivity of the more productive firms comes from. It may come from greater and better directed technological effort by the firm to master and adapt the same technology that is used by its local competitors. Or a firm's higher productivity may come from its having chosen to use more productive elements of technology -- "superior" machines, material inputs, or product designs, for instance. Serendipity sometimes accounts for the use of "superior" elements. But more generally the choice of such elements is the result of a search that involves technological effort and must be counted as part of the firm's technological capability.

It also needs to be realized that infant firms may experience cost reductions owing to technological efforts undertaken elsewhere. Over time they may benefit from "improvements" -- in machines, material inputs, or product designs, for example -- sold to them by other firms. Through labor
mobility and other means of information diffusion, they may also benefit from transfers of technological capabilities initially acquired elsewhere. These benefits are externalities resulting from the technological efforts of other firms, which may be local or foreign. In a careful estimation of productivity change, such externalities -- which would be reflected in figure 1 as downward shifts of the cost reduction path ABC -- would show up as abrupt increases in the infant's productivity which could not be attributed -- that is, not fully -- to its efforts. Whether such externalities produce an increase in the infant's international competitiveness depends on the extent of their diffusion to foreign competitors who could also benefit from them.

To assess the full effect of firm-level technological efforts on an infant industry's productivity over time requires detailed analysis of historical information across firms -- among other things to evaluate externalities generated by or transmitted to other local firms whether in the same industry or not. With rare exceptions, such information is not available for today's less developed countries.\(^\text{15/}\) Correspondingly, our survey is largely confined to evidence pertaining to individual firms, whose technological capabilities are generally considered apart from the activities of other firms. Externalities from other firms that benefit the firm, as well as those from the firm that benefit other firms, are thus neglected. This is very unfortunate in view of the frequent appeal to externalities as being an important, if not the principal, social benefit to be derived from the promotion of infant industries.

\(^{15/}\) Research to uncover and analyze such information is under way at the World Bank, in the project on "Productivity Change in Infant Industry" (Ref. No. 672-86) under the direction of Mieko Nishimizu and John M. Page, Jr.
2.4. Outline of what follows

In the following pages we first examine the evidence about the cost and duration of industrial infancy, focusing mainly on the growth of productivity. We look next at evidence of the continuity of technological change: that is, at the interplay between radical technological change (the introduction of a new technology) and incremental technological change (the modification of an existing technology). We then speculate about the requirements for accumulating the technological capability needed for the continuous technological change that characterizes maturity. Far more than stemming from experience alone, that capability appears to increase to needed levels only through conscious technological effort. We end by summarizing the evidence and by assessing the importance of productivity growth in relation to other forces that affect international competitiveness — which prompts us to reemphasize the importance of conscious efforts by infants to build up their stock of technological resources and to develop strategies for technological change.

3. Evidence about performance

The general view in the literature on infant industrial activities is that only a short period is needed in an optimal environment for enterprises to move from low productivity to internationally competitive production. For the right industry and the right technique, catching up merely requires overcoming initial technical inefficiencies through the straightforward accumulation of experience. The essence of this model of maturation is that the required increase in productivity is achieved passively, effortlessly, and almost automatically. The evidence from our survey suggests a different model, one in which maturation is achieved by explicit efforts to manage technological change.
There do not appear to be any readily available, systematic compilations of empirical estimates of the cost, benefit, and duration of infancy. Nor can such compilations be easily constructed from case studies available in the literature or from the mental and physical files of institutions that plan, approve, finance, and implement investment projects. Several well-known empirical studies have investigated the costs of protection in various industrial sectors in developing economies. See, for example, Balassa and Associates (1971) and Little, Scitovsky, and Scott (1970); numerous similar studies have followed in the wake of these pioneering explorations. But almost all these have been cross-sectional studies, which only provide information about the distance between ABC and FG at one time. Needed is information over time, not just at one time (PQ in figure 1). Moreover, these studies are principally concerned with issues of allocative efficiency that are considered important from the perspective of the conventional paradigm of static comparative advantage. For several reasons, then, the studies throw little light on the issues being considered here.

3.1. Changing productivity

Most of the reliable information about productivity change in developing countries derives from data pertaining to individual firms. Many estimates measure single-factor productivity, though some measure the productivity of several inputs combined. Nearly all of the latter estimates pertain to capital and labor inputs and thus neglect changes in productivity associated with changes in intermediate input use. And it is not always clear that adequate account is taken of product innovations and changes in output composition. Only a few firm-level studies examine productivity trends for infant industries over long periods. Moreover, none of the studies surveyed reveals anything definite about how far the observed productivity is from
internationally competitive levels: they give information about the slope of ABC in figure 1, but not the distance of ABC from FG.

The data from the studies surveyed show wide variation in rates of productivity change (table 1). At one extreme is the Usiminas steel plant in Brazil (Dahlman and Fonseca 1978). The plant took four years (1962-66) to reach its rated capacity. Then, constrained by the lack of capital for expansion, it more than doubled its productivity over the ensuing six years. During a subsequent period of capital expansion, productivity continued to improve, though more slowly than before. By the end of that expansion, sixteen years after the infant's birth, Usiminas appears to have achieved international competitiveness. Moreover, it was exporting some of its technological adaptations to steel producers in other developing countries.

At the opposite end of the spectrum represented in table 1 are several negative rates of productivity change. Perhaps the most striking of these are derived from Mlawa's (1983) study of productivity change in the textile industry in Tanzania during 1973-79. A number of the mills had declining productivity for both capital and labor over this period, and the declines were from levels of productivity already well below those expected of the technology involved.

Between the rapid productivity increase at Usiminas and the examples at the other extreme lie cases showing modest rates of productivity growth. None of the studies generating this evidence makes comparisons with established firms and industries producing similar products. But in one case a crude comparison can be made to illustrate two general points: modest productivity growth may be insufficient to ensure maturation; even rapid productivity growth -- if not sustained -- may also be insufficient. The performance of an Argentine rayon plant studied by Katz and others (1978) can
Table 1. Productivity Change in Industries in Less Developed Countries

<table>
<thead>
<tr>
<th>Country</th>
<th>Industry</th>
<th>Period</th>
<th>Source</th>
<th>Labor</th>
<th>Capital</th>
<th>Totala</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>Steel</td>
<td>1966-77</td>
<td>(1)</td>
<td>14.0</td>
<td>13.0</td>
<td>-</td>
</tr>
<tr>
<td>Argentina</td>
<td>Electrical machinery</td>
<td>1960-68</td>
<td>(2)</td>
<td>-</td>
<td>-</td>
<td>10.6</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>Garments</td>
<td>1951-61</td>
<td>(3)</td>
<td>9.5</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Argentina</td>
<td>Metals</td>
<td>1960-68</td>
<td>(2)</td>
<td>-</td>
<td>-</td>
<td>9.3</td>
</tr>
<tr>
<td>Argentina</td>
<td>Chemicals</td>
<td>1960-68</td>
<td>(2)</td>
<td>-</td>
<td>-</td>
<td>9.1</td>
</tr>
<tr>
<td>India</td>
<td>Steel</td>
<td>1914-26</td>
<td>(7)</td>
<td>6.0</td>
<td>-0.4</td>
<td>-</td>
</tr>
<tr>
<td>Argentina</td>
<td>Machinery</td>
<td>1960-76</td>
<td>(4)</td>
<td>5.8</td>
<td>-</td>
<td>2.8</td>
</tr>
<tr>
<td>Turkey</td>
<td>Electrical machinery</td>
<td>1963-76</td>
<td>(5)</td>
<td>-</td>
<td>-</td>
<td>5.8</td>
</tr>
<tr>
<td>Turkey</td>
<td>Apparel and footwear</td>
<td>1963-76</td>
<td>(5)</td>
<td>-</td>
<td>-</td>
<td>5.2</td>
</tr>
<tr>
<td>Zambia</td>
<td>Mining</td>
<td>1954-66</td>
<td>(6)</td>
<td>4.9</td>
<td>-</td>
<td>2.7</td>
</tr>
<tr>
<td>India</td>
<td>General engineering</td>
<td>1951-59</td>
<td>(8)</td>
<td>4.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Argentina</td>
<td>Oil refining</td>
<td>1960-68</td>
<td>(2)</td>
<td>-</td>
<td>4.1</td>
<td>-</td>
</tr>
<tr>
<td>Argentina</td>
<td>Textiles</td>
<td>1960-68</td>
<td>(2)</td>
<td>-</td>
<td>3.0</td>
<td>-</td>
</tr>
<tr>
<td>Argentina</td>
<td>Rayon</td>
<td>1941-67</td>
<td>(9)</td>
<td>2.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>India</td>
<td>Nonelectrical machinery</td>
<td>1960-65</td>
<td>(11)</td>
<td>2.3/2.7</td>
<td>0.7/1.3</td>
<td>-</td>
</tr>
<tr>
<td>Turkey</td>
<td>Basic metals</td>
<td>1963-76</td>
<td>(5)</td>
<td>-</td>
<td>2.2</td>
<td>-</td>
</tr>
<tr>
<td>Turkey</td>
<td>Nonmetallic mineral products</td>
<td>1963-76</td>
<td>(5)</td>
<td>-</td>
<td>-</td>
<td>1.6</td>
</tr>
<tr>
<td>India</td>
<td>Cotton spinning</td>
<td>1961-69</td>
<td>(8)</td>
<td>1.4</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>India</td>
<td>Cotton weaving</td>
<td>1961-69</td>
<td>(8)</td>
<td>1.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Turkey</td>
<td>Textiles</td>
<td>1963-76</td>
<td>(5)</td>
<td>0.7</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Brazil</td>
<td>Machinery</td>
<td>1938-79</td>
<td>(10)</td>
<td>0.5</td>
<td>-</td>
<td>0.1</td>
</tr>
<tr>
<td>Turkey</td>
<td>Food</td>
<td>1963-76</td>
<td>(5)</td>
<td>0.3</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>India</td>
<td>Metal products</td>
<td>1960-65</td>
<td>(11)</td>
<td>-0.8/-0.3</td>
<td>2.1/2.3</td>
<td>-</td>
</tr>
<tr>
<td>Turkey</td>
<td>Chemicals</td>
<td>1963-76</td>
<td>(5)</td>
<td>-</td>
<td>-</td>
<td>0.0</td>
</tr>
<tr>
<td>Turkey</td>
<td>Metal products</td>
<td>1963-76</td>
<td>(5)</td>
<td>-</td>
<td>-</td>
<td>-0.1</td>
</tr>
<tr>
<td>Turkey</td>
<td>Wood and cork</td>
<td>1963-76</td>
<td>(5)</td>
<td>-</td>
<td>-</td>
<td>-3.3</td>
</tr>
<tr>
<td>India</td>
<td>Iron and steel</td>
<td>1913-56</td>
<td>(8)</td>
<td>-2.0</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>India</td>
<td>Chemicals</td>
<td>1960-65</td>
<td>(11)</td>
<td>-1.1/3.9</td>
<td>-2.0/6.0</td>
<td>-</td>
</tr>
<tr>
<td>India</td>
<td>Electrical machinery</td>
<td>1960-65</td>
<td>(11)</td>
<td>-2.8/0.9</td>
<td>-3.1/4.3</td>
<td>-</td>
</tr>
<tr>
<td>Tanzania</td>
<td>Cotton spinning</td>
<td>1973-79</td>
<td>(12)</td>
<td>-9.6/-3.5</td>
<td>-6.9/2.3</td>
<td>-</td>
</tr>
</tbody>
</table>

Notes: A few of the estimates pertain to individual firms; most pertain to groups of firms. In turn, most of the latter estimates are simple averages of firm-specific productivity growth rates, but a few are estimates of the growth of aggregate productivity. Productivity growth estimates joined by a slash indicate the range of estimates for individual firms or subgroups of firms within the respective sectors. Estimates from source (5) are for periods of unspecified length greater than five years within the overall period 1963-76. Estimates for capital and total productivity from source (11) use different measures of capital: in the former case, fixed capital; in the latter, total assets.

Sources: (1) Dahlman and Fonseca (1978); (2) Katz (1973); (3) Reynolds and Gregory (1965); (4) Castano, Katz, and Navajas (1981); (5) Krueger and Tuncer (1980); (6) Woody and Keesele (1972); (7) Dhar and Seth (1962); (8) Ghosal and Ghosh (1964); (9) Katz and others (1978); (10) Da Cruz and Da Silva (1981); (11) Balasubramaniam (1973); (12) Mlawa (1983).

a. Total productivity refers to the productivity of several inputs combined. The measures vary between the studies. Most neglect inputs other than capital and labor.
be set against the performance of two very similar Dupont rayon plants in the United States studied by Hollander (1965).\textsuperscript{16/} Because of differences in the measurements reported in the two studies, only the roughest comparisons of changes in labor productivity are possible.

Of the comparisons that can be made (over different periods and making different adjustments for comparability), nearly all -- and all of the more sensible ones -- show considerably greater average rates of labor productivity increase in the two plants in the United States than in the Argentine plant. Nonetheless, labor productivity in the Argentine plant grew at an average annual rate of about 3.6 percent over its life (1937-75). But productivity growth, like the underlying technological effort, was not continuous. Labor productivity roughly doubled during the first three years after start-up and again during 1963-73, but there was almost no productivity growth during the interim. Whether the plant was able to achieve international cost competitiveness during the initial burst of productivity growth is unknown, but it must have suffered progressively deteriorating competitiveness through the early 1960s, by which time the Dupont plants had been abandoned in the face of continuing technological progress in the industrially more advanced countries. Thus the plant could hardly have remained competitive even if it had once become so.

\textsuperscript{16/} The Argentine plant was owned and operated by a Dupont subsidiary. Thus the comparison also illustrates another point: foreign-owned firms seem to be no more successful (or no less unsuccessful) in accumulating technological capability than locally-owned firms. Or, to state the point in other words, the technological behavior of infant enterprises appears to vary for reasons that are not necessarily related to differences between local and foreign ownership. This is the rationale for our neglect of ownership distinctions throughout the text.
This very rough comparison centers on labor productivity only, but productivity change in established industries in industrial economies appears to follow a multidirectional path. In such economies, the productivity of a wide range of inputs is pushed in different directions and at different rates by a welter of different efforts at technological change (Carter 1970). Various studies of established industries have examined some of these dimensions of productivity growth. Some studies have examined reductions in the cost of both labor and materials: these have often found substantial savings in the cost of materials, though unit material costs usually fall more slowly than unit labor costs. Other studies have shown increased productivity in the use of energy, especially after sharp rises in energy prices. Still other studies indicate important increases in productivity that originate in changes or modifications in products, though the problem of assessing such increases is notoriously difficult.

There is no basis for assessing the significance of these kinds of productivity growth in infant industries. But from several studies that describe patterns of technological change without reporting associated productivity changes, we have the impression that few of the enterprises studied were undertaking multidirectional efforts, manipulating their production technology to reduce the cost of capital, labor, energy, and materials. If real, this failure would retard the growth of productivity and imply the limited evolution of techniques appropriate to conditions in developing economies. In turn, the available evidence about changes in products precludes even an impression of what typically happens, except in the

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17/ For example, Asher (1956) suggests that each doubling of cumulative output in aircraft production tends to be associated with materials cost reductions of around 4 to 10 percent, compared with around 15 to 30 percent for labor costs.
metalworking sector where these kinds of changes appear to be widespread (Katz 1984).

We can therefore draw only two reasonably clear conclusions. First, productivity growth in infant industries appears to be highly variable, even in apparently similar economic conditions. Second, few of the infant enterprises studied in less developed economies appear to have demonstrated the high and continuous productivity growth needed to achieve and maintain international competitiveness.

3.2. Duration of infancy

If infant industrial activities experience modest productivity growth and if the initial productivity gap is wide, the duration of infancy must be long. For example, an infant industry that experiences 5 percent average annual productivity growth will require 23 years to achieve maturity if its unit costs are initially twice the competitive level and if its mature competitors experience 2 percent average annual productivity growth over the same period.18/ The literature provides few estimates, however, of the duration of infancy in today's less developed countries.

Some studies -- of manufacturing in Nigeria (Kilby 1969) and of shoe production in Puerto Rico (Reynolds and Gregory 1965) -- report relatively rapid productivity growth in the first years of operation. The cost reductions are consistent with what seem to be common expectations and beliefs about the duration of infancy: that it will take about three to five years, perhaps stretching to seven or eight. The Indian Tariff Board in the 1920s and 1930s usually set the protection of infant industries at five to eight

18/ The following formula applies: \[ OT = \frac{\ln (OA/OF)}{(g - g')} \]. OT, OA, and OF are as defined in reference to figure 1; \( g \) and \( g' \) respectively denote the annual rates of productivity growth in the infant industry and in its mature competitors.
years (Government of India Tariff Board 1932). Casual familiarity with views elsewhere in more recent years suggests the common belief that similar periods are adequate to overcome industrial infancy. So does some of the current literature on trade: for example, Balassa (1975) prescribes that the extra protection of infant industries should be lifted after five to eight years.

There is perhaps a fivefold to tenfold discrepancy between the duration of infancy commonly expected and the time that often appears to be needed to become internationally competitive. On the basis of fragments in the historical literature, it can be said that the cotton textile industry in Japan took two to three decades to mature (Smith 1955; Sen 1979); the automobile industry in Japan, somewhere between three and six decades, depending on when the date of birth is set (Ono and Odaka 1979; Adachi, Ono, and Odaka 1981); the textile industry in Korea, about four decades (Mizoguchi 1981; Mizoguchi and Yamamoto 1981).19/

Long periods of infancy may in part be explained by a dynamic aspect that usually is neglected. Productivity may be growing not only for infant enterprises; it may also be growing for mature enterprises in other countries where the industry is well established. Industrial maturation may thus involve more than becoming competitive at international standards of cost and product specifications prevailing in the world market at the time of the infant's birth (catching up with a horizontal FG in figure 1). It may and

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19/ These inferences are based on taking the point of maturity as the time at which the industry begins to exhibit sustained export growth. This approach has the advantage of requiring only trade data that are relatively easy to obtain. However, it is not flawless. It may overstate the period of infancy; for example, international competitiveness vis-a-vis imports may be achieved without exports. In turn, exports give evidence of having reached international standards of price and quality, but exports do not necessarily imply cost competitiveness; exports may benefit differentially from government incentives or they may be priced in a discriminatory manner.
often does involve becoming competitive in relation to standards that are changing because of continuing advances in productivity in mature enterprises (catching up with a downward-sloping FG in figure 1).20/

Evidence is accumulating to suggest that industries in the developed countries experience increases in productivity that range between 1 and 3 percent a year, with the average across industries appearing to be around 2 percent [see Nishimizu and Robinson (1984), for references]. Roughly half the cases summarized in table 1 appear to have experienced productivity growth higher than this. Depending on the rate of productivity growth for the same industry in the developed countries, these cases may show some maturation -- though perhaps at widely different rates and with correspondingly differing durations of infancy.21/

For the other firms there may have been no catching up at all. But the validity of this inference is questionable because of the lack of sufficient comparability -- with respect to measurement methodology and level

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20/ The trend of FG also depends on the trend of the shadow exchange rate, which in turn depends on rates of productivity change in other industries, both domestically and internationally, and on pricing behavior in relation to productivity changes. Our focus on global productivity trends in the same industry neglects productivity changes in other industries and assumes -- for an unchanging product -- that the world market for it is competitive, so that productivity changes in other countries are reflected inversely in its world price. Alternatively, one could assume that all world prices remain constant, so that productivity changes in other domestic industries are reflected inversely in changes in the shadow exchange rate -- and so focus on productivity trends in other domestic industries. This alternative approach is the one Krueger and Tuncer (1982) take. A full analysis would have to take all these influences into account.

21/ The inference that some maturation may have occurred is subject to qualification because the measures of productivity growth given in table 1 do not necessarily reflect relative scarcities. The measures use market prices rather than shadow prices, so that the productivity growth may overstate -- or understate, though this is less likely -- the true rate of progress toward international competitiveness.
of aggregation -- in the estimates being used. Nevertheless, the inference is supported by the one reasonably direct comparison that can be made. Recall the differences in productivity growth for rayon plants in Argentina and the United States. As that comparison illustrates, productivity growth in infant industries is not sufficient for maturation. Moreover, product innovations and changes in output composition -- not considered in that comparison but relevant in some cases -- do not in themselves indicate that maturity is being achieved, since product change is a central focus of technological efforts in corresponding industries in the industrial economies. In sum, for a newly established industry that begins without international competitiveness, maturity is impossible without productivity growth that is faster paced than that in countries where the industry is already internationally competitive. This fact may be obvious, but it appears frequently to be forgotten.

Other information about past industrial performance gives further indirect evidence about the duration of infancy. The rapid industrialization and diversified export achievements of such newly industrializing countries as Brazil and Korea imply that infants can mature rapidly. But the implication deserves scrutiny. Information obtained in the research underlying Westphal, Rhee, and Pursell (1981) shows that maturation periods for Korean industries can be as long as four decades (as for textiles, see above) or as short as a year or two (as for shipbuilding). At best, there are only ill-informed speculations to explain the differences across industries in Korea. There appears to have been a trend toward shorter maturation periods for Korean infants, but it again is sheer speculation whether the apparent trend is due to the general broadening and deepening of Korea's industrial base or to other factors, such as continuing changes in the policy regime.
Even if the experience of the very rapidly industrializing countries demonstrates that the duration of infancy can be brief, the fact remains that the industrial performance of most developing countries falls far short of that of countries like Brazil and Korea. This implies that for many industries in most developing countries the duration of infancy has been long -- with many industries started quite some time ago still remaining in their infancy.\footnote{For direct evidence about Turkish infants -- albeit on a different but complementary criterion (see note 20) -- see Krueger and Tuncer (1982).} Ill-advised policies for selecting the infants to be promoted and for nurturing their development undoubtedly share part of the blame. The firm-level evidence does not address this issue; instead, it deals extensively with another side of infant-industry maturation, a side we now turn to.

4. \textit{Maturation of firms}

Technological progress at the global frontier in industry is often conceived as comprising (a) radical innovations and (b) subsequent adaptations of those innovations.\footnote{For the classic and influential study organized around this distinction between original innovation and subsequent adaptation of new processes, see Enos (1962).} From the evidence it seems that the firm-level absorption of technology for infant industrial activities, making modifications and adaptations in the process, is not unlike the adaptation process that follows innovations at the global frontier (Dahlman and Westphal 1982). At least there is persuasive evidence that absorption and improvement involve technological effort. They require the implementation of specific technological changes (in the broad sense used in this paper) and the use of particular kinds of resources to accomplish them. In this respect the technological effort needed to master a technology is difficult to distinguish from that associated with managing technological change more generally. Below
we examine the significance and nature of both the stimuli which seem to prompt change in infant enterprises and the resources which are used to respond to those stimuli.

4.1. **Stimuli for technological change**

Technological change in infant industries is often a specific response to stimuli that impinge on firms from product markets and from input markets. For example, a Korean polyethylene plant (Seoul National University 1980), stimulated by higher energy prices, introduced a sequence of process adaptations that reduced unit energy use 18 percent over three years. Most cases suggest that stimuli in input markets, unless dramatic, may need to be matched by pressure in product markets to induce efforts at technological change. For example, the Argentine rayon plant, after fifteen years of little productivity increase, suddenly boosted its labor productivity, changed product quality, substituted material inputs, and increased efficiency in the use of materials (Katz and others 1978). Why? To defend its market share, which began to erode after two new producers entered its previously secure and growing market and as nylon began to challenge rayon.

What seems usual is that the response is a one-time effort that flags after pressure eases in product and input markets. Rare is the formulation of a conscious strategy for technological change: for example, a strategy that enables responding to a third kind of stimuli — one that emanates from systematically monitoring the performance of the technology in use. The

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24/ See Katz (1984) and Teitel (1984) for more comprehensive reviews of what is known about stimuli for technological change. In addition to the stimuli discussed here, they also consider other factors which might be thought to affect the predisposition of firms to engage in technological change activities, including the size and ownership of the firm, the scale of the domestic industry, and the characteristics of the industry's technology.
Acindar steel company in Argentina was saddled with a plant at Rosario that was losing money at its current capacity and was constrained from undertaking major investments by the government's licensing authorities. This situation led to technological efforts to overcome bottlenecks and production problems and to exploit perceived opportunities for engineering improvements (Maxwell 1982). In essence, monitoring the production system enabled the identification and breaking of bottlenecks, which led to the identification and breaking of other bottlenecks. The company embarked on this path of technological change to reduce its losses, but the sequence of changes was in large part determined by the characteristics of the plant's technology. Thus the monitoring of the technology in use is what provided the proximate stimulus for the successive changes.

Because of its inherently dynamic nature, performance monitoring moves beyond simple responses to external stimuli, but it can still fall short of being a fully effective strategy for technological change. The Rosario plant had a strategy, but it was only for sequential bottleneck-breaking -- through its own efforts and based on its technology already in use. What often is needed for an effective strategy is to search outside the firm. In the face of a situation similar to that at Rosario, the managers of the Usiminas steel plant in Brazil adopted a conscious strategy to reduce costs and increase capacity without major investment. They did this by

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25/ One should not be misled by our use of a simple rubric, "monitoring," into thinking that what is involved is either passive or a single activity. Quite the contrary, the systematic monitoring of performance requires active technological efforts in various directions: to design performance indicators for elements of the production system; to determine feasible targets for improving the performance of each; to devise and implement the changes that could be expected to achieve these targets; to monitor subsequent performance to check progress toward the targets and to revise the targets on the basis of the experience gained; and from there to devise further changes, and so on.
experimenting with modifications of products and processes (Dahlman and Fonseca 1978). But what distinguishes their strategy is that the modifications came not only from experience, but from a worldwide search for steel technology -- with some modifications requiring investments in licensing, consulting services, and specialized equipment (Maxwell 1982, ch. 6). The Rosario and Usiminas plants both greatly improved their performance, but Usiminas went on to become a technological leader in the Latin American steel industry.

So, some firms have a strategy, but most apparently do not. The pressure to pursue some form of change seems generally to be necessary, but the response to pressure seems to be variable and to depend on the stimuli and on the firm. In most of the cases studied, the external stimulus evoked only a transitory response. It seems merely to have temporarily jolted enterprises from prevailing patterns of low or nonexistent activity for change. Effort at technological change was thus a defensive reaction to periodic threats, not an offensive activity driven by a conscious strategy, except in the few firms that had such a strategy. Conscious strategies may involve changes in products as well as changes in processes. (In fact, changes of one kind typically require changes of the other kind.) We focus on process changes because they are better documented in the literature surveyed. But there are a few cases of enterprises that appear to have had strategies for product improvement -- for example, strategies based on monitoring feedback from customers about product performance. A conscious strategy for changes in processes and products, augmented by responses to intermittent stimuli, is what generally distinguishes successful firms in established industries from infants in the less developing countries.
4.2. **Resources for technological change**

Detailed empirical studies suggest that technological change arises from the explicit allocation of resources to innovative activities that produce technological change -- to the specialized activities of seeking, defining, and implementing major and minor changes.

Consider again the experience at Usiminas, where the introduction of a standard cost system was a driving force for technological change (Dahlman and Fonseca 1978). The flow of performance feedback pointed to problems around which the firm could focus its resources on an effort to define and implement change. Regular monitoring of the system's performance thus provided a basis for understanding how and why performance varied. Such monitoring can generate "understanding of why certain things work and others not," which Nelson (1979) suggests cannot be acquired through other means. It can thus help in the effort to identify the adaptations, improvements, and incremental changes that can be made. But an industrial plant can run for years without generating any of this understanding. Nor is this flow of information a function of time or cumulative output. Instead, it depends on the allocation of resources to an effort that can generate, interpret, and act upon that flow.

This example and others suggest that sustained productivity growth has its roots in a demand for technological change that (i) originates in the firm and (ii) has to be specified in operational terms by the firm. As a consequence, sustained productivity growth is unlikely without the specialization of some of the firm's resources on technological effort. But in many of the infants studied, the efforts at technological change were accomplished by temporarily assigning to them resources that were ordinarily allocated to production activities. This finding reinforces other indications
of the general lack of strategies for technological change and of the likelihood that change is limited to intermittent responses to external stimuli.

But in some case histories the firm's growth was accompanied by an increasing specialization of resources in the firm. Individuals, groups, and items of physical capital become allocated more or less continuously to the efforts at change. When that happens, the incidence of technological change becomes correspondingly more continuous and autonomously driven from within the firm, rather than being intermittent and driven only by pressing external stimuli. How this increasing specialization in the firm interacts with the creation of a strategy is likely to depend in part on the scale of the enterprise. In consequence, the improved performance of infant firms that is observed to accompany their growth may in part be traced to the increased specialization of the firm's resources for change.

This emphasis on the firm as the focal point for technological effort obviously does not mean that outside resources play only a minor role in accomplishing technological changes. On the contrary, machinery suppliers, outside consultants, input suppliers, and customers are all noted as supplying important technological elements. But the integration of these elements with the structure of the firm's existing systems requires complementary adjustment and change by resources in the firm. The firm thus has the central role in the management of technological change. At the very least, it must recognize the potential value of changes and absorb them. Doing this requires managing its own resources for change. In sum, not everything is done in the firm, but very little can be done for the firm without its efforts in absorbing, if not initiating, and managing change.
5. Accumulating technological capability

The central point is thus that infant enterprises cannot mature unless they accumulate the capability for technological change. The process of accumulating that capability is commonly described as learning, but what this learning involves is not clear. The term has often been used merely to refer to what is inferred to underlie rising productivity. Thus, a path of falling unit costs, with an apparently unchanging production system, is often simply described as the result of learning. The term has also been used to refer generally to the acquisition of increased skill and knowledge by people, enterprises, and even economies -- regardless of how that skill and knowledge are obtained. And "learning" has been used to refer to the feedback of information about industrial production: production in one period generates a flow of information and understanding that allows improvements in a subsequent period. But as we have argued, that flow does not take place without a conscious effort to monitor performance. The learning from such flows of information thus is not effortless; nor is it without cost. Costless learning-by-doing thus has limited relevance for the accumulation of technological capability.

How far can infant firms progress along the path of maturation by relying on the technological capability they acquire from monitoring performance? Probably not very far. Recall the difference between the Rosario plant, which stayed within the confines of its technology and operations, and Usiminas, which went beyond those confines by purchasing information and specialized equipment. A priori reasoning, and some evidence, suggests that continuing progress along the path of infant maturation requires explicit investment in technological capability -- that is, in human and (firm-specific) institutional capital.
Training is a driving force for technological change -- if it is active, explicit, and directed to more than routine plant operations. Case studies of Korean firms (Seoul National University 1980) show that although various kinds of experience in production played some role in augmenting the technological capability of firms, the effort to undertake explicit training probably was much more significant. This effort created much of the capability needed to exploit what were only potential opportunities for learning, such as taking part in the technological aspects of investment projects or executing subsequent minor changes. But at a steel galvanizing plant in Thailand, where little training was undertaken to do more than impart basic operating skills, there was little technological change over nine years (Bell, Scott-Kemmis, and Satyarakwit 1982). The same was true of textile producers in Tanzania (Mlawa 1983).

Hiring technically skilled specialists is also important in accumulating the human capital needed for technological change. And it often is simpler than training, if trained people can be hired. For example, activities for technological change at the previously mentioned rayon plant in Argentina were associated with distinct peaks in spending on technicians and engineering staff (Katz and others 1978). Such hiring also appears to have been important for several machinery producers in Brazil and Argentina (Da Cruz 1980; Da Cruz and Da Silva 1981; Castano, Katz, and Navajas 1981), as well as for those in Korea (Seoul National University 1980).

The formation of human and institutional capital is thus important for continuing progress along the path of maturation. It is especially important when encountering discontinuities in that path. The reason is that operating experience in one area of technology -- however intensive and prolonged -- is unlikely to provide the full capability needed for changing to
and absorbing another technology. And doing one technological task is unlikely to contribute much to the specific capability for carrying out other, different tasks. Thus, despite the evident importance of experience in some phases, maturation may grind to a halt if the technological effort is limited to the technology in use and to adapting it through localized changes.

The discontinuities in the path of technological change seem to take two forms. First, maturation may involve shifting between different tasks in relation to a given general type of technology. For example, product-centered technological change may move through successive phases based on replicative copying, the specification of minor improvements and modifications, formalized overall redesign, and innovation through R & D. Similarly, cost-reducing change may require the successive mastery of different kinds of technological tasks -- production scheduling versus quality control, for example -- even though the general type of technology remains the same. Second, maturation periodically requires firms to shift to different types of technology. At these points, continuing competitive performance requires the use or production of substantially different processes or products -- often much more complex or sophisticated -- that embody technological knowledge substantially different from that embodied in existing processes and products.

Several firm-level studies have shown the persistence of various kinds of incremental technological change after the start-up of new industrial facilities. But the rate of productivity increase for a given technology seems to fall over time. Crossing major discontinuities in the path of infant maturation is important because the associated investment in new technology

26/ Recent studies have elaborated such stages of technological evolution in developing economies. Progression through those stages is variously described as learning or as being due to learning. See, for example, Lall (1980).
often opens opportunities that substantially increase the returns to incremental changes. Indeed, in the technologically capable firms, the sequential adaptations that follow an investment in a new technology seem typically to have a cumulative impact in changing productivity that exceeds the immediate change from the investment.

A striking feature of the historical record, then, is that firms -- if they are to progress along the path of maturation -- must go beyond the experience accumulated in production. Experience in production, if monitored, is one mechanism for augmenting the capability of infant enterprises for change. It appears to be the dominant mechanism in some phases of change between major discontinuities. But it does not seem to be sufficient to achieve and maintain international competitiveness. Crucially important for crossing technological discontinuities is investment in technological capability -- especially in the human and institutional capital needed to initiate, absorb, and manage technological change. Indeed, as a study of the Taiwan machine-tool industry suggests, exclusive dependence on experience in production may retard the progressive development of an industry (Amsden 1977). Major discontinuities may sometimes be crossed only by the takeover of existing enterprises by a younger generation of entrepreneurs who introduce new technological strategies -- or by the entry of new firms that introduce new technologies to the industry.

6. Conclusion

There is little evidence about productivity growth among infant industries in today's less developed countries. But the evidence does suggest that many infant firms have failed to reach international competitiveness -- or if they have once reached it, have failed to maintain it. This inference is consistent with the record of overall industrial performance in these
countries. It is also consistent with findings from various studies of the costs of protection in developing countries.

In looking for causes of the failure, we have emphasized the lack of technological capability. The case studies convey a pervasive impression that explicit investment in technological capability often is a faltering, intermittent, and low priority use of resources. Although all enterprises can take advantage of a vast body of existing technology, maturity depends on the ability to use this technology effectively. The evidence shows that maturation is not automatic or instant: reaching and maintaining international competitiveness is not simply a matter of developing the right industry or industries, given the existing (aggregate) relative factor endowment. It takes more than effortless learning-by-doing and requires the capability to manage continuous technological change. Maturation takes conscious efforts to develop a technological strategy, to invest in resources for technological changes, and progressively to accumulate technological capability.

The apparent failure of many infant industries to attain international competitiveness may be due to any of several causes. The one that has probably received the most attention in previous discussions is the promotion of the wrong infant industries by governments, whether through explicit selection or through the implicit effects of trade and other policies that differ in their combined incidence on incentives across industries. Thus it is argued that governments have promoted infant industries that are not in line with relative factor endowments and that therefore lack the potential for international competitiveness. The promotion of the wrong infants has undoubtedly been an important causal factor, though its precise significance
is at issue (Westphal 1982). But given that these industries have been promoted, what is of at least equal concern is the evidence that many firms in these industries have failed to exert needed technological efforts and have thus failed to realize the beneficial productivity gains possible. Perhaps of even more concern, the same can apparently be said about firms in infant industries that do have the potential for international competitiveness on factor intensity grounds.

Another possible cause of the apparent failure to attain international competitiveness has also received much attention: the choice of production methods not in line with relative factor endowments (White 1978). Production would be internationally competitive given the choice of technique that minimizes cost, but it is not competitive because of the choice of suboptimal techniques that lead to permanently higher production costs. Inappropriate techniques may be chosen because governments pursue policies that distort relative input prices, or because producers lack complete technological information or have objectives other than cost-minimization. Suboptimal choices of technique have no doubt been an important causal factor in some settings, but they cannot explain slow or nonexistent productivity growth. Moreover, there is evidence in some settings that the increased costs associated with the choice of suboptimal techniques are much less than the increased costs associated with the failure to achieve best-practice levels of productivity (Page 1980).

Ill-advised government policies that contribute to the failure to achieve international competitiveness can take many forms and have ultimate effects on productivity that go beyond those of having selected the wrong
industries and production methods.\textsuperscript{27/} In their ultimate effects, such policies may interfere with achieving potential levels of productivity, as is often the case with badly designed and implemented administrative controls that limit capacity utilization. Alternatively, they may inhibit technological effort and thus slow the growth of productivity. Or they may retard the relative growth of firms having higher productivity or faster productivity growth. Such policy effects have been uncovered even in rapidly industrializing countries, such as Korea (Rhee and Westphal 1977). In turn, policies affecting the inducements that condition the nature of technological efforts may lead to efforts in the wrong direction.\textsuperscript{28/} Where technological changes have occurred, they have not always increased productivity at prices that would properly reflect relative scarcities, even if they have increased productivity at existing market prices and conditions (Teitel 1981).

Governments can also be at fault for not formulating or effectively implementing policies to overcome market failures that may constrain the development of infant industries. Particularly important in relation to the growth of productivity are externalities involving transfers of technological capabilities across firms through various means of information diffusion. These externalities may lead firms to allocate too few resources to

\textsuperscript{27/} Nishimizu and Robinson (1984) present and discuss evidence about possible differences between outward-looking and inward-looking strategies of industrialization in their effects on productivity growth at the sector-level. Pack (1984) evaluates the productivity of Philippine textile firms in comparison with international norms. In looking for sources of their low productivity, he examines the importance of firm-level technological capability in relation to policy-related macro and sectoral influences.

\textsuperscript{28/} By drawing attention to the need for technological effort, we clearly have not meant to imply that all technological effort is equally valuable or that technological effort is its own reward. Such an interpretation would not be consistent with our continued emphasis on international competitiveness as the measure of maturity.
technological efforts -- for example, to underinvest in acquiring technological capability through labor training. In fact, the low priority that many infant enterprises apparently give to investments in technological capability suggests that externalities do precisely that. In turn, the lack of international competitiveness implies -- to the degree it is due to inadequate technological capability -- that these externalities are not being adequately offset by policies specifically designed to address them.

Governments have often instituted policies that are ill-advised and failed to institute policies that are well-advised in relation to fostering rapid and efficient maturation. But the effects of different policies acting in combination with each other -- and with other social, political, and economic factors in the environment -- are far from well enough understood to enable unarguable recommendations for optimal policy packages designed to foster rapid and efficient maturation. We do know that infants can mature. Moreover, the experience in some rapidly industrializing countries suggests that they can even mature very quickly. But reflecting our general ignorance of the maturation process, there is little general agreement on the factors ultimately responsible for the rapid maturation in these countries. Finding out more about these factors, and how they operate on firms, is urgent business -- particularly if our conclusion about the slow maturation of most infants in most developing countries is correct. Of equal importance is finding out why some firms perform well -- whatever the environment -- while others do not.
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**Assessing the Performance of Infant Industries**

Bell, C.3. Martin