From Imitation to Innovation: Public Policy for Industrial Transformation

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What role does public policy play in helping countries accelerate the industrialization process? This note aims to answer this question by applying a framework to analyze the process of transitioning from imitation to innovation. Based on a dynamic model of growth, simulations suggest that learning through imitation may enable firms to improve productivity significantly in a first stage, and that this may eventually benefit innovation activity as well. The model also shows how failure to switch from imitation as the main source of productivity growth to broad-based, homegrown innovation could lead to the “middle-income trap” that has befallen some countries.

The Role of Industry in Economic Development

Recent debate on industrial policy has featured two main positions: the neo-liberal view, which remains critical of any type of (selective) intervention, and the neo-structuralist view, which argues in favor of a revival of selective industrial policies (as well as other types of government interventions), including the protection for infant industries. It is interesting to note that this debate on industrial policy has mostly been about how to grow this sector, and not about why. This is probably because economists have long recognized the important role of industry (mainly manufacturing) as an engine of growth in economic development. In fact, throughout the world’s economic history, there has rarely been a country that has become industrialized without engaging in manufacturing—transforming first from a mostly agrarian society to one that is more industry driven, before relying on services as an engine for growth and employment. This led Kuznets (1959)....
to note that modern economic development is characterized by a structural shift in the composition of output away from agriculture and into manufacturing. Even in developed countries where the share of manufacturing in output and employment has been stagnant or declining, there is evidence that manufacturing involves more production links with other sectors and the transfer of more production skills than is the case in nonmanufacturing sectors. Indeed, between 1950 and 2005, the share of the manufacturing sector in gross domestic product (GDP) doubled in the fast-growing economies in Asia (the Republic of Korea, Malaysia, Singapore, and Taiwan), whereas it stagnated in Latin America and Sub-Saharan Africa. Manufacturing provides employment opportunities for workers with a great variety of skills, including those with little education as well as those highly educated, and instills discipline in the workforce.

But another key channel by which manufacturing contributes to economic development is through learning by doing, first through knowledge externality from imitation activities, and later through innovation activities. This is how the industrial revolution spread from Great Britain to countries in Western Europe, the United States, Russia, and Japan (Chandra, Lin, and Wang 2012). By providing an ever greater variety of inputs (some of which are in the form of new capital goods) with an ever greater degree of technological sophistication, knowledge creation fuels the development and expansion of the manufacturing sector. Initially, technological knowledge can be acquired through mere imitation of foreign processes; but if imitation entails decreasing returns, whereas innovation occurs under constant or increasing returns to scale (at least for a while), over time the expansion of the manufacturing sector requires a shift from imitation activities to true innovation.

At the same time, this transition may require access to highly skilled labor and other inputs, such as advanced communication and information technologies, and these can be critical to move from “light” manufacturing activities, which tend to be associated with an imitation regime, to “heavy” manufacturing activities, which require a broader and more sophisticated set of inputs. Thus, in this context, industrial policy should not only increase emphasis on innovation and knowledge or learning externalities associated with imitation, it must also increase emphasis on fostering local absorption capacity and technological innovation for the development of manufacturing. These key issues are addressed in Agénor and Dinh (2013).

From Imitation to Innovation: A Formal Framework

To study the process of transition from imitation to innovation, and the role of public policy in that context, Agénor and Dinh (2013) developed a dynamic framework. They considered an economy populated by individuals (grouped into families) with different innate abilities, firms, and a government. The “economy” has five production sectors: one producing a homogeneous final good, two producing intermediate goods (core and enhanced inputs from now on), and two creating designs, or blueprints used for the production of each of the two categories of intermediate inputs. The design sectors are “imitation” and “innovation” sectors, and their relative importance—a measure of industrial diversification, as discussed later—varies in the course of development. The final goods are produced by combining both private and public inputs and are used for consumption, private and public investment, and the production of intermediate goods. Public inputs consist of basic public infrastructure, which includes roads, electricity, water and sanitation, basic telecommunications and advanced infrastructure, which consists essentially of high-speed telecommunications. Both types of infrastructure services are provided free of charge, but are subject to congestion. Production in the design sectors combines public and private (labor) inputs as well, but in different ways.

Firms in the final good and design sectors are perfectly competitive, whereas those in the intermediate good sectors are monopolistically competitive, each producing a differentiated variety of goods. The total number of blueprints existing at a certain point in time coincides with the number of intermediate input varieties and represents the stock of nonrival knowledge available in the economy. The composition of that stock is used later on to measure industrial structure and to study its transformation over time. Most importantly, knowledge accumulated in the imitation sector creates an externality that promotes productivity in both design sectors, but this benefit is subject to diminishing marginal returns. Finally, labor (both skilled and unskilled) is perfectly mobile between the final good and design sectors.

Each family maximizes utility so as to determine the optimal evolution of consumption expenditure over time. Individual members also decide whether to enter the labor force as unskilled workers or (following a training period) skilled workers. This decision depends on the relative skilled-unskilled wage, adjusted for the cost of training. Thus, the opportunity cost of becoming skilled is equal to the discounted value of foregone unskilled wage income, because workers earn income while training. In equilibrium, there exists a threshold level of ability which is such that all individuals with ability lower than that value choose to remain unskilled, and all individuals with ability greater than that value choose to undergo training and then enter the labor force as skilled workers.

Production of final goods requires the use of skilled labor, unskilled labor, private capital, basic public infrastructure, and the combination of core intermediate inputs and enhanced intermediate inputs. There are two sets of intermedi-
ate good producers: those producing core inputs, based on blueprints produced by the imitation sector, and those producing enhanced inputs, based on designs produced by the innovation sector. Each firm produces one, and only one, horizontally differentiated intermediate good. In both cases, production of each unit of intermediate goods requires one unit of the final goods. Each producer of core intermediate goods pays a one-off license fee to the firm that produced the relevant design in the imitation sector, before producing its own specialized goods. Thus, the license fee represents a fixed entry cost. Once the fee is paid, each producer sets its price to maximize profits, given the perceived demand function for its goods, which determines marginal revenue. In equilibrium, the license fee must be set equal to current profits.

Each producer of enhanced intermediate goods must purchase an infinitely lived patented design from the innovation sector. Once the patent is paid, each intermediate good producer also sets its sale price to maximize profits, given the perceived demand function for its goods. The price of a patent is equal to the present discounted stream of profits that the potential producer could make by producing the intermediate input.

Designs are produced in two sectors: an imitation sector, which employs only unskilled labor, and an innovation sector, which employs only skilled labor. In the imitation sector, local firms invest resources to absorb and adapt the information needed to replicate new products invented abroad, that is, “reverse engineering.” Thus, imitation differs from innovation in that the number of goods that can be copied at any point in time is limited to the rate at which imitable goods are being discovered elsewhere.

Both imitation and innovation create two kinds of knowledge: private knowledge, which is acquired (for a price) by intermediate good firms to produce a new production input, and public knowledge, which spills over to other firms in the imitation and innovation sectors and increases productivity there. In addition, the framework assumes that there is an externality from imitation for innovation—as agents learn to imitate, they also develop cognitive skills that help them innovate. This is consistent with the idea that imitation can be a “stepping stone” for true innovation. Indeed, this exercise assumes that imitation enhances productivity in the innovation sector. This specification accounts for an efficiency gain associated with imitation—if only during a transitory phase: the more a country engages initially in copying, the more its workers become familiar with existing innovations made abroad, and the easier it becomes for them to innovate as well. Finally, in the innovation sector, a poorly functioning system to enforce property rights (namely, administration of patents) creates inefficiencies, which translate into a lower ability of firms to appropriate the rents created by their activity, that is, the profits of the intermediate good firm using their design. Finally, the government levies a tax on final good outputs, invests in both basic and advanced infrastructure, and provides services free of charge.

Figure 1 summarizes the production structure and supply side of the model. The key result of the model is that it can be used to derive an index of industrial structure, defined as the relative ratio of the stocks of imitative to total knowledge. During the transition, the index tends to fall if the economy is converging toward an innovation-based regime; the “modern” or “innovation-based” economy is achieved when the imitation sector becomes a residual, so that the index takes a relatively small value.

Calibration and Initial Conditions

Because the model is complex, numerical techniques must be used to establish its properties and illustrate policy outcomes. For this exercise, the model is calibrated for a low-income
economy characterized initially by: (i) a positive but low growth rate in income per capita; (ii) an embryonic innovation sector and relatively more developed imitation sector; (iii) high costs for acquiring skills; (iv) a large, unskilled labor force, employed in both the imitation sector and final good production (more so in the latter); (v) a small fraction of skilled workers in the labor force, employed almost entirely in final good production (in line with the assumption that the innovation sector is negligible in size); (vi) limited availability of basic infrastructure and almost nonexistent advanced infrastructure; and (vii) a correspondingly relatively low share of public investment in basic infrastructure and a much lower share of advanced infrastructure. At the same time, both stocks of public capital are relatively small in proportion to the private capital stock.

Figure 2 shows the evolution of the economy’s industrial structure based on the above initial conditions. In the base case, the relative size of the imitation sector increases slightly at first, and comes down fairly slowly, dropping to close to zero after about 80 years. By contrast, if the parameter that measures the strength of the externality associated with imitation activities for the innovation sector is higher, the relative size of the imitation sector falls at a faster pace; in the case shown in figure 2, the index of industrial structure drops to close to zero in about 60 years. Thus, the benchmark case considered is still a rather mixed picture. The learning effect associated with imitation activities does have a substantial impact on industrial structure, and the economy does become eventually a mature, innovation-based economy. That is, given the set of initial conditions (as well as public policies) defined, intrinsic economic forces are sufficient to eventually ensure that the economy moves from an imitation-based regime to an innovation-based regime. However, left on its own (in the absence of additional interventions), this process would take decades to occur. The question then is, to what extent can public policy help to accelerate the transition? As noted earlier, this is the definition of industrial policy.

Public Policy Experiments

To illustrate the role of public policy in promoting industrial transformation in the model, three experiments were conducted: first, on a policy aimed at promoting access to basic infrastructure; second, on a training subsidy aimed at reducing the cost of acquiring skills; and third, on a policy aimed at improving enforcement of intellectual property rights. To highlight the role of policy complementarities, the experiment also considered a sequential, composite program that involves combining some of these policies with investment in advanced infrastructure.

Provision of basic infrastructure

Consider first a permanent, budget-neutral increase in the share of spending on basic infrastructure, financed by a cut in unproductive spending. The first impact of this policy is to promote activity in both the final good sector and the imitation sector. Both effects tend to increase the marginal product of unskilled labor and therefore the economewide wage for that category of workers. In the initial phase, this tends to reduce incentives for workers to acquire skills, and therefore to reduce the (effective) supply of skilled labor. However, the increase in activity in the imitation sector enlarges the pool of knowledge accessible to all workers and generates two types of externalities: it raises productivity not only in the imitation sector, but also in the innovation sector. In turn, this puts upward pressure on skilled wages, which mitigates the initial adverse effect on individual incentives to invest in education. The net effect on economic growth depends on the extent to which these opposite effects on skilled labor supply offset each other. The results show that, as can be expected, the relative size of the imitation sector increases at first; however, as the spillover effects of imitation-related knowledge for innovation begin to kick in, this increase is reversed.

Training subsidy

Consider a policy aimed at permanently reducing training costs. As discussed earlier, this cost is assumed to be proportional to the skilled wage. For this analysis, assume that the policy is financed through a reallocation among components of unproductive spending and is therefore budget neutral. Naturally enough, the reduction in the training cost induces more workers to invest in education. The increase in skilled labor supply, at first, tends to lower wages in that sector; however, because the increase in skilled employment occurs both in the final good sector and in the innovation sector, promoting activity there as well, a secondary, indirect effect is also at play: the increase in the variety of innovation-based (or enhanced) intermediate goods helps to promote activity in the final good sector.
In addition, because the shift toward innovation raises labor productivity in that sector, the initial effect is magnified. At the same time, however, the increase in the supply of skilled labor in the final good sector tends to raise the marginal product of unskilled workers, which tends to raise the unskilled wage—thereby mitigating the initial effect on incentives to acquire skills. Numerical simulations show that the impact of this policy on a country’s industrial structure depends on the strength of the effect of individuals’ abilities on wages; the smaller this effect is, the weaker the impact, which means that individuals with lower abilities would earn less. Even though the quantitative effect of the training subsidy on the industrial structure is relatively small, the net effect of the training subsidy is a higher supply of skilled labor and higher activity in the innovation sector, thereby explaining the initial increase in the relative size of that sector.

**Enforcement of property rights**

Consider a reform of property rights that is designed to promote innovation activities—such as improved functioning of the patent bureau, for instance. This is captured by assuming that firms in the innovation sector earn a higher fraction of the patent price. The economic effects of this policy are fairly intuitive. By increasing the ability of firms engaged in innovation to secure the return to their activities, improved protection of property rights also tends to raise labor demand in that sector—and thus wages as well. The increase in skilled wages induces more workers to invest in skills, thereby promoting growth. Thus, the growth effect is unambiguously positive. The reason for this, of course, is due to the fact that poor enforcement of property rights is assumed to create a dead-weight loss; no one benefits from intellectual piracy. If, alternatively, it is assumed that there are some benefits associated with poor enforcement (because some firms engage in piracy, and those firms employ a sizable number of workers, for instance), it is possible that the net effect would be ambiguous. Numerical results show that a policy aimed at securing property rights may have a significant impact on accelerating the process of industrial transformation—not only because it increases direct returns to innovation, but also because it provides greater incentives for workers to acquire skills.

**Sequential, composite reform program**

Finally, consider a sequential program, characterized by the following components:

(i) during an initial period of years, the share of spending on basic infrastructure is increased and then reduced gradually over time;

(ii) during an initial period of several years, the share of spending on advanced infrastructure is kept at its (small) benchmark level, is then increased for a subsequent period of several years, and finally reduced gradually and kept constant afterward;

(iii) no training subsidy for the first few years, then a subsidy that reduces the cost of training for several years, which is then reduced permanently thereafter; and

(iv) there are no efforts to improve the enforcement of property rights for the first few years, and then gradual improvements in the enforcement of property rights until firms receive the full patent price associated with their innovations.

Of course, there is a significant element of arbitrariness in the timing of these policies. But this experiment is trying to capture a policy focusing first on improving access to basic infrastructure (through a “big push” in public investment) and imitation activities; next, on efforts to promote human capital accumulation through training subsidies and enforcement of property rights; and, soon after, on improving access to advanced infrastructure to promote innovation. This reflects the empirical finding from China, that the nature and depth of government policies assisting manufacturing firms vary according to the business lifecycle of these firms (Dinh et al. forthcoming).

Numerical results suggest that this sequential reform program has a significant impact on speeding up industrial transformation; its effect is stronger as the measure of the parameter of the strength of the externality associated with imitation activities for the innovation sector increases. Thus, if external learning effects are strongly associated with imitation, a sequential reform program that is front-loaded on access to basic infrastructure can speed up the transition process to a mature economy.

Put differently, in a low-income economy, where to begin with unskilled labor is abundant, the imitation sector relatively small and the innovation sector embryonic, public investment in basic infrastructure yields higher marginal growth benefits than investment in advanced infrastructure. The key reason is that expansion of activity in that sector would remain constrained by the lack of skilled workers in the labor force. In a second stage, increased investment in advanced infrastructure—if preceded by a policy that induces more individuals to acquire skills and accompanied by a policy that helps to promote the enforcement of property rights—would generate higher marginal growth benefits than investment in basic infrastructure. The learning externality associated with imitation activity in the first stage can help magnify the benefits that can be generated in this second stage.

**Policy Implications**

The foregoing discussion has important implications both for growth-promoting policies in today’s poor countries in Sub-Saharan Africa and, more generally, for understanding the industrial transformation process whereby countries move from imitation to innovation.
During the past decade, Sub-Saharan Africa’s GDP grew at an average of over 5.2 percent per year between 2001 to 2010, compared to an average of -0.4 percent in the 1990s (Dinh et al. 2012).6 However, to a large extent, this outcome was the result of booming commodity prices, rather than a deep transformation of the industrial structure. Yet, as noted, such transformation is essential to generate sustained growth in output and employment—as illustrated by the experience of East Asian countries during the 1960s, and more recently by China during the 1980s. Indeed, these countries initially followed a growth strategy that relied heavily on the development of light manufacturing, taking advantage of relatively cheap labor and their ability to imitate foreign goods. The lesson from East Asia’s experience in transitioning from low- to middle-income status is clear: a sustainable growth strategy in Sub-Saharan Africa should focus initially on increasing the productivity of medium and large formal firms and on alleviating these firms’ key constraints, namely, access to basic infrastructure (most importantly, electricity, see UNIDO [2011] and Andersen and Dalgaard [forthcoming]). As noted by Dinh et al. (2012), as local producers increase the scale of their operations, improve the quality of their products, and accumulate experience with technology, management and marketing, they become better positioned to take advantage of emerging export opportunities. As China’s competitive edge in the global export market in light manufactures continues to erode—as a result of steeply rising costs of land, regulatory compliance, and especially labor (including both wages and benefits) in the country’s coastal export manufacturing centers—the redistribution of cost advantages in labor-intensive manufacturing presents an opportunity for Sub-Saharan Africa to start producing and exporting a wide range of light manufacturing goods.

This strategy is feasible because Sub-Saharan Africa has two major potential advantages that could help increase its competitiveness in light manufacturing. The first is a labor cost advantage, and the second is an abundance of natural resources that can supply raw materials, such as skins for the footwear industry, hard and soft timber for the furniture industry, land for the agribusiness industry, and so on. Even with its relatively low-skilled workforce, Sub-Saharan Africa could become competitive in a broad range of light manufacturing sectors. In the apparel sector, for instance, small numbers of managers and technicians can guide hundreds of workers.7

For the longer term, upgrading to more complex production will undoubtedly require a better-trained workforce than is currently available. But the expansion of light industry need not await increased school enrollment and better-quality schooling. Industrial transformation can begin rapidly by targeting promising sectors with modest skill requirements and then adopting policy measures—such as industry-specific vocational training programs—that may contribute to lowering the cost of acquiring skills and promote learning-by-doing effects.

This approach would help channel scarce resources for infrastructure services to specific locations or industries, thereby mitigating the adverse effect that the lack of access to these services has had on production costs and labor productivity. As documented by Eifert, Gelb, and Ramachandran (2008) and Foster and Briceño-Garmendia (2010), for instance, indirect costs related to infrastructure services continue to account for a relatively high share of firms’ costs in poor African countries.8 If indeed the lack of access to infrastructure is the most significant constraint on the expansion of labor-intensive light manufacturing industries, then it is important for African governments to focus their scarce resources in that area, ensuring that economies of scale are properly exploited.9

The model presented in this note, and the simulation results that it produced, strongly support this strategy. The key features of the model’s calibration accurately capture some of the characteristics of a typical low-income economy in Sub-Saharan Africa: an embryonic innovation sector and a relatively more developed imitation sector (yet small in terms of the size of the economy); the high costs of acquiring skills, possibly due to a lack of tangible collateral for securing loans to finance human capital accumulation; the small fraction of skilled workers in the labor force, and correspondingly large unskilled labor force, operating partly in the imitation sector; and the limited availability of basic infrastructure and almost nonexistent advanced infrastructure. The simulations help emphasize that learning through imitation may enable firms to improve productivity significantly in a first stage, and that this may eventually benefit innovation activity as well. Put differently, imitation contributes to creating the knowledge base necessary for fostering innovation: by doing so, it helps to increase labor productivity and create incentives for workers to invest in higher education.

The experience of East Asian countries in transitioning from middle- to high-income status also provides important lessons for Sub-Saharan Africa. As noted earlier, these countries successfully relied on a growth strategy based on low wages and technology imitation. However, once the pool of under-employed rural workers started to shrink and wages began to rise, competitiveness deteriorated and productivity gains associated with sectoral reallocation and technology catch-up began to disappear in many countries. Rising wages made labor-intensive manufacturing exports less competitive on world markets. At that point, some countries (most importantly Korea) were able to switch from imitation as the main source of productivity growth to broad-based, homegrown innovation.

Other East Asian countries, however, were unable to make that switch, and as a result ended up in a so-called mid-
dle-income growth trap, with a substantial decrease in growth and total factor productivity. As discussed by Agénor, Canuto and Jelenic (2012), avoiding this trap requires timely implementation of public policies aimed at improving access to advanced infrastructure; improved protection of property rights; reform of labor markets; and promotion of access to finance. These policies have proved key to fostering technological learning and attracting talented individuals into research and development activities, and have allowed inventors to finance the development of their ideas. The lesson from East Asia’s experiences for today’s poor countries in Sub-Saharan Africa is again very clear: governments in the region should act early—rather than late—to take advantage of low wages and the gains from imitating foreign technology to promote knowledge spillover and boost productivity.

The numerical results discussed in this note also support the view that, following a first stage where countries should invest significantly in basic infrastructure, policies aimed at promoting innovation must be put in place without delay; these policies include institutional reforms aimed at promoting property rights related to research activities and the provision of advanced infrastructure, which is essential to encourage the buildup of national and international knowledge networks. Because of the long gestation lag, this second stage should begin well before the benefits of low wages and imitation of foreign technology begin to yield diminishing returns or are completely exhausted.

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Notes

2. Excluding oil-producing countries.
4. See the U.S. Department of Commerce (1995) study of the effects of changes in final demand on flows of goods and services between and within industries in the production process of manufacturing and nonmanufacturing industries.
5. In fact, Sub-Saharan Africa’s share in global manufacturing has even fallen in recent decades, see Dinh et al. (2012).
6. These numbers may actually underestimate the region’s performance in recent years. According to Young (2012), measures of real consumption based on a variety of nonstandard indicators suggest that living standards in Sub-Saharan Africa have risen three to four times faster than the rates indicated in conventional data sets.
7. As noted by Dinh and Clarke (2012), for instance, specialists report that inexperienced workers can learn to operate sewing machines in less than two weeks.
8. Although the survey results reported in Dinh and Clarke (2012) suggest that firm managers in the region are most concerned about electricity, other areas of infrastructure may also constrain firm performance in Africa. Eifert, Gelb, and Ramachandran (2008) highlight, in particular, the high cost of transportation and communication in Sub-Saharan Africa.
9. The successful experience of East Asia with industrial parks is an example; instead of waiting to solve the infrastructure problem for the whole country, they focused instead on providing infrastructure for enterprises located inside the parks.

References


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