Globalization and Technology: Africa's Participation and Perspectives

Concept Paper and Research Agenda

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This concept paper has two objectives. First, it analyses the extent to which World Trade Organization (WTO) agreements, particularly the technology-related provisions, could enlarge the capabilities of African countries to procure and develop modern technologies. Second, the paper proposes research agenda to study the resulting empirical implications, ultimately to identify specific technology policy issues that African countries should emphasise in the continuing debate on the effect of global market integration. Insights from this research should also prove useful in analysing the qualitative implications of technical aid, particularly that directed to technologically disadvantaged sectors of a country's economy.

The specific issues raised so far in research linking trade and technology are as varied as the models that have been developed to address them. Often the answers depend on the particular assumptions made about the nature of the economic environment. Here, we are concerned with the *endogenous creation of comparative advantage* through technology, but under the economic environment of free trade and perfect patent protection (taken to mean the complete policing and enforcement of intellectual property rights). This endogenous creation of comparative advantage can occur in two main ways: through research and development (R&D) and through learning-by-doing (LBD). We begin by reviewing the relationship between intellectual property rights and technology. Then we examine the two ways in which comparative advantage can be endogenously created. In conclusion, we draw insights from these ideas, and from the empirical literature, to suggest specific research agenda of immediate relevance to policy formulation and advice in Africa, and for democratizing global economic relations.

1. Intellectual Property Rights and Technology

The implementation of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS) in principle adds another inescapable obligation to the commercial policy of member countries. African countries struggling to elevate their technological base need to scrutinize carefully the "tying of hands" implied in TRIPS so that they can be clear on where their interests lie with regard to the enforcement of this component of WTO agreements. This is also important to the management of intellectual property, where the goal should be to choose the terms and conditions that maximize the value of the intellectual property, not the terms and conditions that maximize its protection.

Without doubt, a certain level of protection of intellectual property rights is necessary for the ex ante optimal amount of investment in R&D in the aggregate. However, protection is rarely perfect for a variety of reasons. Strict enforcement of patents, copyrights and licenses could be very costly. "Reverse engineering", imitation, or inventing "around the patent" might be easy. Several explanations and product-cycle models have been developed to study this phenomenon, as well as to study the technological implications for the South of a lax enforcement. Vernon (1966) and Krugman (1979) studied product cycles, according to which the North produces and exports newly invented goods while the South specializes in goods that have been around for a longer period. The South's specialization in more "mature" goods underscores the implicit assumption that technology spreads to low-tech countries more slowly.

Other authors such as Chin and Grossman (1990) and Deardoff (1992) have studied whether the South benefits from protecting foreign intellectual property rights, and whether not doing so is particularly harmful to the North. Chin and Grossman construct a partial equilibrium duopoly model in which it may be in the South's interest to provide no patent protection at all. In their construct, the North always suffers from a failure of the South to protect while the South typically gains by allowing imitation unless its share of the world consumption of the product is very large. Deardoff establishes a similar result for product innovation and shows that as patent protection spreads to a larger portion of the world, the marginal benefit on aggregate welfare becomes negative. Taylor and Silberston (1973) also agree that R&D protection and other incentives to engage in R&D are necessary to ensure an optimal amount of investment in research effort. However, these authors observe that a survey of 27 British companies in research-oriented industries suggests that the reduction in R&D if patents did not exist varies across industries. Schmalensee (1988) and Levin et al. (1987) make similar observations on the varying effects of patent protection across industries. According to Taylor and Silberston (1973), the proportion of research expenditures in the two major areas of chemicals and engineering that executives view as depending on patent protection were as follows: In chemicals: pharmaceuticals (64%), other finished and speciality (25%) and basic (5%); in engineering: mechanical engineering, of which plant, machinery and equipment (7%), components and materials (2%), and electrical engineering (negligible).[1]

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[1]Cited in Carlton and Perloff (1994), p. 674.

Diwan and Rodrik (1991) develop a model that explores if and when the South can use protection strategically to influence the direction of technological progress in the North. In their model, both classes (the North and the South) have different preferences over the direction that technological progress should take, meaning the type of goods that should be invented. "The North would like to develop drugs against cancer and heart disease, whereas the South benefits more from drugs against tropical diseases. Labor is cheap in the South but expensive in the North, so the North's labor-saving innovations are less useful in the South" (Diwan and Rodrik, 1991: 29). The authors derive several implications of immediate relevance to this paper: One is that South negotiations can take different views for different products. In products where, a priori, we can expect fewer differences in needs and tastes between the North and the South (software and textbooks in certain disciplines), the incentive not to enforce is the greatest. In others where differences in taste and needs are strong, such as in pharmaceuticals and agricultural innovations, a failure by the South to protect would deprive the South of the opportunity to influence the development by the North of technologies more suitable to the South.

But what about the incentives that innovators themselves have to transfer knowledge and technologies abroad? Why would a firm wish to locate its activities offshore where it might be at some competitive disadvantage with local firms? The answers are many: Production costs might be lower overall. It may be a viable means of serving foreign markets, net of transportation charges and tariffs. Keeping trade secrets secure is another motivation. However, Siotis (1999) derives an opposite result in which technological spillovers are primarily localized, so that the risk of dissipation of trade secrets prevents foreign direct investment (FDI) by a technologically superior multinational corporation (MNC). Siotis's model considers the incentives for FDI that confront MNCs in a strategic environment. His premise is that MNCs derive their competitive strength from "knowledge-based intangible assets". He models a two-stage game in which the strategic decision of how the MNC will serve the foreign market is made in the first stage. This is followed by a Cournot game (tactical rivalry in quantities) in the second stage, conditional on the choice of how to serve the foreign market made in stage one.

Three sources of incentives for FDI emerge in equilibrium: Under the assumption that both countries are endowed with human capital, the MNC undertakes FDI to source an advantage associated with foreign location since technological spillovers could be a two-way process. When the firm contemplating the FDI is technologically well ahead of it competitors, spillovers reduce expected profit and the firm will choose to export rather than risk dissipation. When there is no distinct technological lead by the MNC, spatially bounded externalities generate an FDI-enhancing effect in that FDI always occurs.

What are the implications of these outcomes when the foreign countries are not endowed with human capital? Put differently, what is the position of an African country that has no comparative advantage in imitation, or cannot cost-effectively imitate in the new WTO world? According to Siotis (1999), the answer is that technologically laggard countries do not count (i.e., influence decision making). With trade barriers out of the way, an MNC has a choice of either engaging in foreign direct investment or of serving the market through exports. This is a remarkable result: Market integration and lax enforcement of intellectual

property rights could generate some benefits for countries having comparative advantage in imitation, and having an added advantage of an "attractive" market. But otherwise (i.e. under a strict regime of enforcement), free trade constrains the capabilities of low-tech countries to leapfrog technologically. China is a nation that could have benefited under the first scenario and indeed may have exploited that advantage (before TRIPS).

Hortsman and Markusen (1992) also build a model of foreign direct investment showing that MNCs are most likely to emerge when the fixed costs of adding a plant or maintaining a subsidiary are small, particularly in comparison with the size of transport costs, trade barriers and fixed costs of operating a firm. It turns out that R&D expenditure is the type of firm-level fixed cost that generates economies of multi-plant production. His model highlights the indirect role of technology in inducing technology transfer by innovators (in a bid to exploit multi-plant economies). How strongly this effect operates in practice is yet to be clearly determined.

As a choice in the MNC menu of serving foreign markets, licensing comes with complications that have been well explored in the literature (Ethier, 1986; Grossman and Helpman, 1991). Being incomplete, such contracts are necessarily inefficient and riddled with agency problems. Opportunistic behaviour on the part of the licensee or the licensor can create additional costs. The licensee may exploit the technology to develop a better product. The licensor may renege on promised exclusivity. Anticipating such behaviour, the licensee may bid for less than the license is worth and so the innovator suffers dissipation in expected profits.

Of course there is always the risk that both direct investment and licensing might speed up the process of imitation and diffusion. It may be that learning spillovers which may take different forms including reverse engineering and the gleaning of products and processes, are more probable when production takes place locally than when goods are imported from a foreign manufacturing base.[2] Then the potential MNC/licensor must weigh the gains associated with having lower production costs against potential losses from a rapid erosion of its monopoly position. Evidently the focus of many of the papers in this area is on a firm's choice of how best to exploit the technological advantage it has gained. Of utmost relevance to the South is the question of how to encourage technology transfer to an indigenous base without causing the innovators to take their business elsewhere**.** Grossman and Helpman (1995) suggest that for that we need to study how knowledge is transmitted within and between firms**.** In other words, how technological capabilities are actualized within economies, which the theoretical literature seeks to understand by modelling the endogenous creation of technological progress that can come either from LBD or from investments in R&D.

[2]Available empirical evidence (discussed subsequently) seems to support this view.

2. Models of Learning by Doing

Learning-by-doing is the repetition of certain production processes that may in turn allow firms and industries to discover more efficient ways of doing thing *process innovation*. When a learning experience is confined to a single plant or firm, the distinction between learning-by-doing and more formal R&D activities may not be of essence, because in both cases the firm recognizes a cost of creating knowledge, which it weighs against the potential benefits of a new or improved technique (i.e. the firm fully internalizes the decision).

The literature notes that once it is recognized that knowledge spreads, the pertinent (empirical) question is to identify the universe of learning: Does learning occur from the activities of firms in the same industry within national borders, across national borders, or both within and across national borders? From local firms in other industries, or from other industries outside the national borders? To cite three examples, Irwin and Klenow (1994) investigated the existence and the geographic scope of knowledge spillovers from learning-by-doing. They found that firms do learn from the experience of others, and that learning does spill over as much across borders as it does within firms located in the same country. Karshenas and Stoneman (1995) and Sarkar (1998) provide recent surveys of theoretical and empirical studies on technological adoption. The literature suggests adoption frequencies as crucial to understanding how technological possibilities are actualized within an economic system, as well as how effective are different economies and regions at upgrading or mimicking.

Grossman and Helpman (1995) provide a unifying perspective in a model that facilitates the isolation of the specific implications of each assumption driving the various special cases in which spillovers are limited in some way. Examples would be the cases in which spillovers are limited to a firm in a given industry, or to a cluster of industries, or to a firm operating in a given country or in a geographical area (such as an industrial conurbation). The elements of the model may be summarized thus: All outputs are produced solely by labour, and production everywhere exhibits constant returns to scale. The labour necessary to manufacture a unit commodity in some country depends not only on the commodity-specific productivity of labour "intrinsic productivity"), but also on the technical know-how ("accumulated knowledge") available. In these models, the accumulation of knowledge occurs simply in the course of manufacturing output.

2.1 Complete International Spillovers

This is the case of bi-directional spillover benefits. Technical information flows readily across international borders, and the experience of local producers contributes just as much to the overall knowledge base (i.e. as much at home as abroad). And although industry specific, learning is external to firms in the industry. Learning is proportional to cumulative industry output globally. In this case, learning (technical progress) is neutral to comparative advantage and hence does not influence the pattern of trade. Nonetheless, trade may affect

national rates of productivity (since manufacturing increases knowledge) and output growth across all time horizons.

2.2 National Spillovers

Basically, firms are assumed to learn more from the experiences of other domestic producers than from firms abroad. So, learning increases productivity in own goods (locally manufactured tradeables) to the total exclusion of foreign rivals. Similar results obtain in the foreign country. The comparative advantage widens and the initial trade pattern gets locked into place. The lesson is that *history matters* since the initial pattern of specialization depends on both intrinsic productivity and in dustry know-how.

Some of these models that analyse a two-good world (say, high-tech goods and low-tech goods), with complete or incomplete specialization, raise the possibility that countries lagging in technological development and having an initial comparative advantage in "non-dynamic" sectors might want to use trade policy to alter the pattern of specialization (to "break out"). Grossman and Helpman (1995) note that a laggard small country at the margin of competitiveness in the faster growing sector would gain from a policy-induced switch. Both these authors and Rodriguez and Rodrik (1999) note that the trade-off between the static efficiency loss from the intervention and the dynamic gains (from productivity boost) favour intervention. The key issue here is that intervention needs to be "time bound" and predictably so.[3]

According to Rodrik (1992), once firms reach the world technological frontier and the learning effects are exhausted, the protection should be stopped. Unfortunately, asymmetric information between the protected group and the policy makers generate perverse incentives. As policy makers can only observe imperfectly how well the protected firms appear to be doing, firms have an incentive to misrepresent their position relative to the technological frontier. All too often, temporary protections become permanent under political pressures. Rodrik sees the prevalence of a "soft-policy" regime as a powerful argument for eschewing selective protection of industries and downplaying the discretionary element in trade policy. A central message is that policy success in this regard (measured in terms of net welfare position) will depend significantly on the qualitative dimensions of trade policy and the nature of the state. He cautions that as policies are not implemented in a vacuum, their consequences are mediated through the state and markets to produce qualitatively different outcomes from that primarily envisaged. Hence the analyst must be aware of these conditioning influences.

Krugman (1987) makes a slightly different point about policy in his analysis of two large countries with numerous goods. Under the assumption of localized spillovers in learning,

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[3]There is yet another dimension to LBD that calls for policy intervention. Besides the "break out" effect, there is also th e policy intervention to correct the spillover benefits from industry know-how. According to Rodrik (1992), the true marginal cost from LBD is lower that the current marginal cost of production by the discounted sum of future benefits (cost savings) of the know-how geneated today. So, in the absence of intervention, the ex ante optimal amount of learning will not be generated.

each country has an incentive to subsidize production of a few goods near the margin of competitiveness so that it can gain technological advantage in their production. Hence it expands its range of manufactures, continues to boost productivity and creates more employment. The implicit assumption is that protection is for only a short term. The incentive to nibble at products, or slice out sectors, continues for a while. Observationally, trade protection is seen to endure while this phenomenon, which Krugman dubbed the "narrow moving band", continues. The protection does not last indefinitely, as eventually the wage differential between the countries becomes sufficiently large that the marginal social cost of the next slice exceeds the expected value of the discounted future stream of benefits.

2.3 Inter-industry Spillovers

Models in this category examine the implications for inter-sectoral learning when there are differential contributions to knowledge from industries. Using a case in which learning takes place only in the course of producing one good although productivity is imparted equally in each of the two sectors, a particular specification of the model yields an equilibrium in which an exogenous improvement in the productivity of the technologically disadvantaged sector can lead to a decline in growth rate (Grossman and Helpman, 1990, for instance). Moreover, if a country happens to accumulate more of the factor specific to the disadvantaged sector, it also can generate the effect noted above. As an example, one can think of a sector investment programme (delivered as aid) that is targeted to the disadvantaged sector. Or, one can imagine as well, a boost in export (from the disadvantaged sector) brought on by free trade. Under free trade in a technologically-driven world, high-tech countries may be altogether too willing to forgo competition in the low-tech sectors. Conceding these sectors to developing countries in a free trade regime will, in our context, dynamically lead to a decline in growth.

2.4 Industry Clusters

The possibility that industrial conurbation might gravitate to particular nations was first noted in Posner (1961). He argued that this dynamic process might occur if LBD generated spillovers within but not between clusters, with these spillovers limited in their geographic reach. The intuition is that if a country initially produces a large quantity of any one good in a cluster, then the learning spillovers from this activity will tend to confer a dynamic comparative advantage in other industries in the same cluster (consistent with the forces of inter-industry spillovers discussed in the preceding section). This occurs even if productivity in the neighbouring industries is low initially. Here again, history would seem to matter, for then a country that has an initial comparative advantage in producing the most popular good or goods in a cluster would tend, over time, to gain competitive advantage in producing the remaining less-popular goods. Resting basically on the same principles, this prediction is similar to Krugman's "narrow moving band", according to which sectors are sequentially sliced off, or products are systematically nibbled off.

3. Technological Leapfrogging

Bresiz, Krugman and Tsiddon (1993) identify conditions under which a country that begins technologically behind may eventually surpass its trading partner, only to be overtaken again in a subsequent phase of the periodic steady state. This pattern obtains because new and superior technologies, arriving exogenously in their model, may be adopted by the lagging country even though they are not profitable in the leading country.[4] Grossman and Helpman (1995) note that leapfrogging can indeed arise anytime LBD is bounded for a given product and specific to the product and country. Then, if the eventual superiority of the new arrival is not enormous, inertial forces will propel existing producers to pass over the new in favour of the "tried and tested".

No single firm in the experienced country will find it profitable to switch, particularly as it is unable to internalize the externalities from learning.[5] However, because of its lower wage level, the firm in the lagging country could adopt the new arrival even without the benefit of any experience in the new technology. Post adoption, the firm experiences a productivity boost over time, and by virtue of superiority of the new technology, displaces the previous leader. By construction, the "laggard country" in the current technology always enjoys a comparative advantage in any new technology that may "happen along". Such a set up, in which leadership contains the seeds of obsolescence and the follower is "heir apparent", generates (in steady state) the alternating (now advantaged, next disadvantaged) technological identities of the countries. To place any great faith in the possibility of leapfrogging as a source of growth for Africa, one would first have to think hard about how often technology exogenously "happens along". It can happen, though, through licensing. It turns out that for firms in low-tech countries, possessing the opportunity to purchase inventions and innovations mimics an "exogenously arriving" technology.

The possibility of technology transfer under licensing to other firms leads to a consideration of the incentives to license (for a firm) or to license multiple firms (in the case of an independent inventor). For an independent inventor (i.e. a firm specializing in R&D), it may be the only way to exploit a patent. In general, a firm will be reluctant to license a rival because the knowledge transfer might allow the rival to invent around the patent, or even to develop a superior technology (leapfrog, in our context).

Closely related is the issue of "sleeping patents" or "shelving" in order to foreclose access to technology.

One way around this allegation is to force the patent holder to license others. Moreover, "shelving" should become part of WTO agreements in order to eliminate the free-rider

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[4]This outcome is driven by the pre-adoption wage in favour of the less technologically advanced country.

[5]Recall the LBD here is assumed specific to the product and country , but not to the firm. So, workers can migrate across rival firms in the same industry, carryiong with then the sunk investment from previous employers. As a practical matter, researchers such as Jovanovic (1997) and Giovannetti (2000) emphasize adoption costs as key parameters in understanding technological diffusion. In fact, Jovanovic finds that adoption costs outweigh invention costs roughly 20 or 30 to 1, and suggests further that in "LDCs the ratio must be astronomical".

problem that can prevent aggrieved firms from seeking redress by way of compulsory licensing. The free-rider problem arises when one firm invests in proving "shelving", only to have other firms costlessly benefit from a successful challenge. One last point on the subject of incentives to license is the fact that licensing may also increase product market competition (and so possibly reduce expected profits) unless the licensee serves a segmented market. The global trend towards market integration narrows the set of markets that may now be considered segmented on the basis of trade barriers. Next, we turn to models that examine the connection between trade and technology when new technologies arise from planned investment.

4. Research and Development

The literature takes the protection of intellectual property rights as fundamental before an environment can be considered conducive to R&D.[6] Without such protection, under-investment results as investors cannot fully appropriate the benefits of their investments, or so the argument goes. Protection can take a variety of forms: Explicitly through a grant of patents, or implicitly from imitations being a costly process, or from success at preserving trade secrets. Because proprietary rights to technology confer market power, imperfect competition is at the core of models that explore this aspect of trade. The extant model in this area is due to Ethier (1982). Helpman and Krugman (1985) and Dixit and Stiglitz (1993) are important additions. Contributions and extensions focusing on the impact of the proprietary access to innovative technology include Grossman and Helpman (1990) and Coe and Helpman (1994). In these models, the innovation is in the proliferation of the variety of intermediate inputs. More varieties are associated with increased specialization and hence productivity. Therefore, on going innovation requires sustained increases in research productivity. The nature of the stock of knowledge determines the evolution of trade in a global economy.

4.1 Knowledge Spillovers – Global

Whereas trade is neutral on productivity in an LBD model with complete international knowledge spillover, access to intermediate goods through trade is a substitute for international spillovers in this R&D modelproductivity depends on the variety of intermediates, but not on the sources. However, this is only with respect to manufacturing. The country that imports inter-mediates will lag behind in technological innovation since knowledge stock is proportional to the number of projects undertaken, and own productivity in research is proportional to that country's local stock of knowledge.

Suppose that nature smiled on a country so that it invented a disproportionate number of intermediates before trade commenced. Grossman and Helpman (1991) demonstrate that history (initial conditions) is irrelevant in determining the ultimate pattern of trade when knowledge is a global public good, as any competitive advantages due to prior experience are bound to be short lived. Where factor compositions are uniform, trade accelerates every country's long-run rate of innovation, just as in the case of one final good and one primary factor. With global knowledge spillovers the stock of wisdom grows faster in a larger economy.

Where the countries differ in factor composition, innovation must accelerate if the differences in factor abundance are small. But if the differences are large but do not rule out

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[6]As an historical aside, we are reminded in Juma (1999) that when "The United States was still a relatively young and developing country...it refused to respect international intellectual property rights on the grounds that it was freely entitled to foreign works to further its social and economic development." He cites further examples from the pharmaceutical industry, where patent legislation was passed by Germany in 1968, Japan in 1976, Switzerland in 1977, and Italy and Sweden in 1978, presumably after attaining a certain level of technological competence and global competitiveness.

factor price equalization, trade mimics an enlargement of the economy to which the human-capital poor country is now a part. Since an increase in the relative access to human capital benefits the poor country, it experiences an increase in the rate of innovation in its high-tech sector. Trade also has the effect of forcing the poor country to specialize more in the production of traditional goods than would be the case in autarky.[7] The forces between the increase in productivity in the high-tech sector and the increased production in the low-tech sector might on balance slow the country's rate of technological progress. A very high gain in a relatively small sector and a small decline in a large sector could on average yield a decline (much like the dependence of changes in total revenue, on the relative adjustments of price and quantity along a segment of a demand curve).

4.2 Knowledge Spillovers – National

Grossman and Helpman (1991) and Markusen (1991) are extant models in this area. As usual, the stock of knowledge that determines national research productivity accumulates in proportion to local research activity. A traditional consumer good is manufactured with constant returns to scale, while the high-tech product is assembled from differentiated inputs of which research generates the blueprints. Starting with equal sized countries, each always producing some of the traditional goods, competitive forces equalize wages. With wage rates always the same, prices of intermediates are the same in both countries. This implies that the R&D activity will be more profitable under a lower cost of innovation. Since the cost of invention (by specification) depends only on wages and knowledge stocks, R&D blossoms in the country with the larger knowledge stock. Several results follow from this model: (1) Initial lead is self-reinforcing so that the leader dominates in the high-tech sector. Yet again, history matters. (2) Trade can reduce the rate of innovation in the lagging country as, post integration, competitive forces drive its resources out of R&D activities (see also Feenstra, 1990, and Matsuyama, 1992).

It is quite possible for a country with a natural comparative advantage in R&D arising, for instance from an abundance of human capital to initially lag in accumulated knowledge. In this case, its cost advantage may offset its weakness from a low base of accumulated knowledge. As well, a large country even though lacking in natural advantage and no sizeable accumulated wisdom can overcome its history through its largeness. Helpman (1984) demonstrates that since R&D is an activity with dynamic increasing returns to scale, the benefit of size when there is a national stock of knowledge is similar to national increasing returns to scale in production.

We end this section by underscoring the model predictions about the effect of trade on technological progress given country size, history and restrictions on technology dissemination. As specified above, trade can slow a technologically laggard country's rate of innovation, if there is another sector to which its resources might be driven (as would realistically be the case). Feenstra (1990) analyses the size effect. Assuming one final-goods sector in each country, using intermediates invented in the research lab, profits (incentives for R&D)

[7]Grossman and Helpman (1995) elaborate on this point, but we take it as intuitive.

erode faster under integration for the small country, and so slow down the steady-state rate of technological progress. The enlarged market effect is conducive to the large country for which technological progress is accelerated everywhere along the transition path to steady state.

5. Process Innovation and Vertical Differentiation

This involves investments to reduce production costs either through improvements in the quality of inputs or declines in the primary resource costs of manufacturing final goods. Hence the present analysis contrasts with previous discussions that dealt with models of horizontally differentiated varieties. The building blocks here are due to Aghion and Howitt (1992) and Segerstrom, Anant and Dinopoulos (1990).

There exists at any given time, the latest version of an input used by firms for production. The final good is assembled from a fixed number of intermediate inputs. Other than these modifications, the structure of the model is similar to that used to explore models of horizontal product differentiation. The linkages between process innovation and growth are also similar to those found in the horizontal case. The productivity of the economy once again depends on the accumulated investment in R&D. Hence innovation rate and growth rate of final output are both proportional to the total R&D baseresearch activities are here also subject to dynamic scale economies. Under market integration, there is a boost to technological progress because the instantaneous probability of a breakthrough is higher when two potential winners are pooling in the race than in autarky. Another distinction of process innovation models is that international spillovers occur naturally with trade because innovations are observed or broadcast through the arrival of the "latest" input. Therefore, localization of spillovers such as may occur under horizontal differentiation does not obtain. In summary, therefore, a small country that is a high-tech laggard may be disadvantaged by trade. But when the learning process is characterized by dynamic scale economies, the opportunity for gains from market integration may be brighter than is suggested even by static considerations of trade benefits. Evidently (as we prepare to jump into the empirical side of things), many of the answers to the questions that motivated research along the lines reviewed here turn on the nature and extent of technological spillovers. Empirical evidence on these important pivots, although still scanty, nonetheless suggests that spillovers are mostly geographically localized.

6. Insight from Empirical Studies

Many of the key issues on technology and trade cannot be meaningfully addressed without firm-level data, particularly if as Grossman and Helpman (1995) emphasize, we need to understand how know-how is transmitted within and between firms. Nonetheless, as a framework for the study of these phenomena, models of technology diffusion and adoption have been developed. Some more recent surveys of the theoretical and empirical work in this area include Karshenas and Stoneman (1995) and Sarkar (1998).

Empirical studies on adoption have usually focused on the diffusion of technology over time and on assessing the factors that determine the diffusion rate. These studies have determined that adoption of newly available technology follows a logistic curve and that the diffusion rate varies across industries and technologies. More recently, other researchers have used duration models to assess the relevance of different explanatory variables on the probability of adoption. The literature (exclusively descriptive of western industrialized nations) so far seems to have settled on the following stylized facts (Giovannetti, 2000): (1) At any point in time, adoption frequency is asymmetric in a given industry, and (2) in the adoption of new technologies, there are highly diversified geographic patterns. There is also mounting evidence that diffusion is localized. Among the most recent studies are Keller (2000) and Audretsch and Feldman (1996).

In general, the theoretical underpinnings of most recent empirical studies of technology diffusion can be categorized into the neoclassical equilibrium models, and the evolutionary disequilibrium models. And although the seminal research on diffusion relied on epidemic models of diffusion, it lacked theoretical rigor and soon fell out of favour among researchers in economics. The new models emphasize modelling the decision making process of adopters, and the microeconomic foundations of the dynamics of the diffusion process. The focus of these models has been primarily on how to characterize the mechanics of the diffusion process and that of the decision making procedures driving the diffusion process. Accordingly, the neoclassical equilibrium models assume rational agents with full information, while disequilibrium models rooted in evolutionary theory are based on limited information and a more open loop decision making process and diffusion dynamics. The evidence from empirical and historical studies on these alternative approaches is mixed. Sarkar (1998) notes that "As with the theoretical studies, distinct divisions, often conflicting, can be identified in existing empirical evidence, and in the technological historians interpretation of the dynamics of technological diffusion" (p. 133).

The literature makes a distinction between intra-firm and inter-firm diffusion. Intra-firm studies the level of use of technology by a firm—the proportion of firm output or the proportion of its capital stock tied to the new technology. Inter-firm is quantified by the proportion of firms in the industry using the new technology. Through a broad consideration of both the rates of intra- and inter-firm diffusion, researchers can extract the growth rate of the share of total industry output produced by the new technology. This share would be a more aggregated measure of the diffusion in an industry. Aggregating over industries provides an economy-wide measure of diffusion.

A review of the advantages of both the neoclassical and the disequilibrium models leads us to favour an eclectic approach to the study of diffusion. Under this framework, we find that the game theory approach is capable of encompassing the vital elements of both sides. In the game theory framework, the process of diffusion is modelled as an outcome of the strategic behaviour among potential adopters. Timing is the decision parameter, which is chosen so that adoption leads to staying ahead of the pack. Game theory perspective forces a consideration of rivals' decisions, a sensible point when one recalls that competition (or spillovers, which here has the same effect as competition) reduces the expected benefits from imitation and so implicitly raises the cost of imitation. Game theory models are also capable of identifying externalities. In particular, the network models of Farrell and Saloner (1986) and Katz and Shapiro (1986) incorporate positive externalities in a more general way, rather than focusing only on informational externalities and learning.[8] In their models, potential users are assumed heterogeneous with different preferences for the innovation. They simultaneously decide whether to switch to the innovation or stick with the status quo, given that the benefits from adoption are positively related to the number of existing adopters. In the non-cooperative equilibrium, switching strategies depends on an individual firm's preference parameter, which is increasing in adoption-propensity. Within low values, a firm will not switch regardless of rivals' behaviour in period one. For intermediate values, a firm decides to switch in the second period conditional on observing that rivals shifted in the first period. And for high values, a firm decides to switch in period one. Therefore, in equilibrium, the diffusion profile will depend on the configuration of individual preference values. In a duopoly, if both firms have preferences that range from low to intermediate values, diffusion will be characterized by *excess inertia* where neither firm adopts the innovation. Conversely, when both preferences assume high values, the diffusion profile will be characterized by *excess momentum* whereby the firms rush to adopt. Internalizing these kinds of externalities may require the government to co-ordinate on the equilibrium.[9]

Evolutionary theorists point to the importance of institutions, and call to question the realism of rational choice in contexts where existing cultural values, moral attitudes, folkways, traditionally oriented behaviour, fear of ostracization, power relationships and vested interests may impinge on rational decision makers, causing them in many cases to stick to existing routines of behaviour rather than switching to new ones (Sarkar, 1998). These concerns can be incorporated into the models described above through the preference parameter. They can also be studied empirically as part of the imitation costs in the nature of inertial forces to be overcome. The real challenge is to surmount data problems involved in explicitly incorporating these important qualitative elements into a model. This is perhaps the reason evolutionary theories of diffusion that emphasize the influences of qualitative factors on the incentives for, and on the capabilities of, adoption rely mainly on historical descriptive methods.

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[8]Models that focus on information externalities include Kapur (1995). Surveys of this strand of literature can be found in Tirole (1998) and Reinganum (1989).

[9]To achieve a proper evolution of telecommunications technology, for example, governments may need to coordinate on standards to ensure compatibility.

7. The Research Agenda

The survey of the literature and the conceptual issues covered in this paper present us with a number of research entry points. New knowledge in these areas would be critical for strengthening the technological position necessary for Africa's effective and equitable participation in the global economic system. The underlying philosophy of the proposed research programme is to add Africa's voice in shaping the emerging international regimes and to contribute to the debate or to challenge the "consensus" that has emerged without any serious consideration for its impact on Africa. This philosophy forces us to choose a few research areas where the African Technology Policy Studies Network (ATPS) can make some meaningful contributions. We recognize, though, that the incentive to engage in international relations is derived from strong domestic policies, national capabilities and ultimately a robust regional position. The research agenda that follows will reflect these positions.

7.1 International Patenting Regime and TRIPS

The enforcement of the WTO agreements under TRIPS has serious consequences for the technological base of African countries in their fight against poverty and disease. While respecting the need for intellectual property protection, the proposed research would examine the specific provisions of TRIPS and relate them to the needs, tastes and natural endowments of selected African countries so as to understand the conditions that maximize the value of the intellectual property, as well as the terms that would minimize protection. What would be the implications of strict enforcement of patents on reverse engineering, imitation, specialization and inventing around the patent? Are there ways in which to democratize the protection regime in some products where access is critical for sustaining and improving livelihood, as in pharmaceuticals? What of agriculture and biotechnology? What sort of influence can Africa exert in terms of the technological progress in the North in these areas? How do these relate to the incentives that innovators have to transfer knowledge and technologies abroad? There is a current debate in Africa on the edge of these issues, but it is largely lopsided and has not been motivated by research with an African perspective.

7.2 Globalization, Diffusion and Imitation Costs

Under this proposed agenda we intend to examine market integration and its impact on technological possibilities and how these possibilities are exploited within economic systems in Africa. How effective are different economies and regions at the technology upgrading necessary for exploiting the gains from globalization? Studies of adoption frequencies provide part answers to these questions of critical importance to technology policy formulation, and research on logistic diffusion and innovation surveys are some of the available research strategies.[10]

Critical aspects of this agenda for determining how technology opportunities are exploited under globalization are the study of imitation and adoption costs, the study of transport and communication costs, and the cataloguing (taxonomy) of technology opportunities or "innovation size", as Giovannetti (2000) indicates, where size refers to its likely impact (cost saving) on production processes. What is the international regime under which imitation can be carried out successfully? In which sectors are these most profitable for Africa? Are there loopholes in the international trade regime (WTO) that Africa can exploit? Is the globalization of technology, i.e., the market for technology, becoming more competitive, and hence improving the accessibility and availability of technology to developing countries in Africa? What sets of innovation policies do African countries need to put in place in order to engage meaningfully in the globalized market? We would also explore the extent of market integration for technology by looking at logistical costs. The lower the costs, the more integrated are markets and vice versa. When markets are geographically close but subject to prohibitive logistical costs, these markets from an operational standpoint remain segregated. Other imitation related costs are schooling and on-the-job training, including labour training externalities whereby firms risk losing valuable investments in an employee upon a job change. The externalities arise because firms are unable to guarantee full appropriation of the value of their investment in an employee who can migrate to rivals' plants. These factors suggested for study are important building blocks for testing the prediction that unless imitation costs, or adoption costs, or costs of upgrading (as the case may be) are progressively reduced, adoption processes will not spread uniformly in space when markets are highly integrated. Under globalization, the implication of the foregoing prediction is that the North–South technology gap will be exacerbated by integration unless globalization comes with reductions in the costs of adoption. Are there ways of minimizing these costs without violating the WTO agreements?

7.3 FDI,Technology Transfer and Localized Diffusion

In the globalized and WTO world, foreign direct investment (FDI) flows are supposed to reflect comparative advantage for the recipient as well as the originating country. In view of the mounting evidence that diffusion is geographically bounded, the role of foreign direct investment in technological spillovers becomes crucial. Therefore, given the mixed evidence (Markusen, 1995) as to whether the level of foreign investment is positively related to the existence of trade barriers or transport costs, the proposed research agenda includes the task of assessing the sensitivity of foreign direct investment to tariffs within the region and the implications of this for technological capabilities in Africa (e.g. learning-by-doing, etc.). This might shed some light on whether globalization would affect knowledge spillovers from MNCs by eliminating the need to overcome trade barriers through offshore location. The proposed study would further examine whether there are particular industries, sectors

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[10]Innovation surveys provide data on the proportion of firms that have introduced an innovation in a given time period.

or firms where FDI flows are consistent with technology transfer. Other questions are: How do firms identify important technologies in the globalized world? Do they automatically choose the right technology based on the market signals? And what role for government and institutions? What do these say for Africa's technological competitiveness and participation in the global market? The result of this study will provide the ammunition the continent needs not only to be selective in FDI promotion, but also to argue at the WTO for certain special concessions for investments that have huge technological spillovers and for protection where learning-by-doing (LBD) appears greatest. A detailed analysis would also reveal the nature (firm specific characteristics including ownership structure) of the firms where spillover is consistent with poverty eradication.

8. Programme Framework

In consultation with a multi disciplinary team of scientists, social scientists and lawyers in the ATPS Network, as well as our collaborating experts in institutions such as the United Nations Institute for New Technologies in Maastricht, the Netherlands, and the African Centre for Technology Studies, ATPS will develop a detailed methodology for addressing the questions raised in this research agenda.

The research process will start with a validation/methodology workshop that will elaborate the research questions, formulate the research methodology and lay out the implementation process. This workshop will have a mix of researchers, policy makers and key actors in the NGO sector. Papers that have mapped the research questions and the methodologies in the three categories mentioned above will form the core of the workshop agenda, while this concept paper will become the foundation of the very practical work programme articulated by the workshop. Implementation of the work programme will be carried out by country teams who will constitute the base for fieldwork and for robust regional positions grounded on a synthesis of findings in the areas identified. Two additional workshops will be required for reviewing the progress of the research and for in situ dissemination. Policy briefs and country level as well as regional dissemination exercises will be an integral part of this research process. In order to carry all the actors along, we intend to invite researchers and interested others to all the workshops. A senior African scholar in this field will be hired by the ATPS Secretariat to provide the overall intellectual leadership for the programme.

9. References

Aghion, P., and P. Howitt (1992). A Model of Growth Through Creative Destruction," *Econometrica*, 60: 323351.

Audretsch, D., and M. Feldman (1996). "Knowledge Spillovers and the Geography of Innovation and Production," CPER discussion paper series 953.

Bardham, P. (1970). *Economic Growth, Development, and Foreign Trade*. New York: John Wiley & Sons Ltd.

Besley, T., and A. Case (1992). "Modelling Technology Adoption in Developing Countries," *American Economic Review Papers and Proceedings,* 82(2): 396402.

Bresiz, E., P. Krugman and D. Tsiddon (1993). "Leapfrogging in international competition: A theory of cycles in national technological leadership," *American Economic Review*, 83: 12111219.

Carlton, D., and J. Perlo (1994). *Modern Industrial Organization*, second edition. New York: Harper Collins.

Chin, J., and S. Grossman (1990). "International property rights and NorthSouth trade". In Jones and Krueger, eds., *The Political Economy of International Trade*. Cambridge, MA: Basil Blackwell.

Coe, D., and E. Helpman (1994). "International R&D spillovers," NBER working paper 4444.

Dasgupta, P. and J. Stiglitz (1980). "Uncertainty, industrial structure, and the speed of R&D". *Bell Journal of Economics,* 11: 128.

Deardoff, A. (1992). "Welfare effects of global patent protection," *Econometrica*, 59: 35–51.

Dixit, A., and J. Steiglitz (1993). "Monopolistic competition and optimum product diversity," *American Economic Review*, 83: 302304.

Diwan, I., and D. Rodrik (1991). "Patents, appropriate technology, and North South trade,"*Journal of International Economics,* 30: 2747.

Ethier, W. (1982). "National and international returns to scale in the modern theory of international trade," A*merican Economic Review*, 72: 389405.

(1986). "The multinational firm," Quarterly *Journal of Economics*, 80: 805 833.

Farrell, J., and G. Saloner (1986). "Installed base and compatibility: Innovation, product pre-announcements and predation," *American Economic Review*, 76: 940955.

Feenstra, R. (1990). "Trade and uneven growth," NBER working paper 3276.

Freeman, C. (1994). "The economics of technical change," *Cambridge Journal of Economics*, 18: 463514.

Giovannetti, E. (2000). "Technology adoption and the emergence of regional asymmetries," *The Journal of Industrial Economics*, 48(1): 71102

Grossman, G., and E. Helpman (1990). "Trade, innovation and growth," *American Economic Review,* 80: 8691.

(1991). *Innovation and Growth in the Global Economy*. Cambridge, MA: MIT Press.

(1995). "Technology and trade" In G. Grossman and K. Rogo, eds., *Handbook of International*

Economics, vol. 3. Amsterdam, North Holland: Elsevier Science B.V.

Helpman, E. (1984). "Increasing returns, imperfect markets, and trade theory." In Jones, R. and P. Kenen, eds, *Handbook of International Economics* vol. 1. Amsterdam: North-Holland.

Helpman, E. and P. Krugman (1985). *Market Structure and Foreign Trade*. Cambridge, MA: MIT Press.

Hortsman, I., and J. Markusen (1992). "Endogenous market structures in international trade," *Journal of International Economics*, 33: 109129.

Irwin, D., and P. Klenow (1994). "Learning by doing spillovers in the semiconductor industry,"*Journal of Political Economy,* 102: 12001227.

Jaffe, A., M. Trajtenberg and R. Henderson (1993). "Geographic localization of knowledge spillovers as evidenced by patent citations," *Quarterly Journal of Economics*, 108: 577598.

Jovanovic, B. (1997). "Learning and growth" In Kreps, D. and K. Wallis, eds., *Advances in Economics and Econometrics: Theory and Applications,* vol. II. Cambridge, UK: Cambridge University Press.

Juma, C. (1999) "Intellectual property and international trade: Development policy options," Science, Technology and Innovation Working Paper, CID, Harvard University.

Kapur, S. (1995). "Technological diffusion with social learning," *The Journal of Industrial Economics,* 53: 173195.

Karshenas, M., and P. Stoneman (1995). "Technological diffusion" In P. Stoneman, ed., *Handbook of the Economics of Innovation and Technological Change*. Oxford, UK: Blackwell.

Katz, M. and C. Shapiro (1986). "Technology adoption in the presence of network externalities," *Journal of Political Economy* 94(4): 82241.

Keller, W. (2000). "Geographic localization of international technology diffusion" NBER working paper 7509.

Krugman, P. (1979). "A model of innovation, technology transfer, and the world distribution of income," *Journal of Political Economy*, 87: 253266.

(1987). "The narrow moving band, the Dutch disease, and the competitive consequences of Mrs. Thatcher: Notes on trade in the presence of dynamic scale economies," *Journal of Development Economics*, 27: 4155.

(1991). "History versus expectations," *Quarterly Journal of Economics,* 106: 651667.

Levin, R., A. Klevorick, R. Nelson, and S. Winter (1987). "Appropriating the returns from industrial R&D." Mimeo. Yale University

Markusen, J. (1991). "First mover advantages, blockaded entry, and the economics of uneven development" In E. Helpman and A. Razin, ed., *International Trade and Trade Policy*. Cambridge, MA: MIT Press.

(1995). "The boundaries of multinational enterprises and the theory of international trade," *Journal of Economic Perspectives,* 9(2): 169189.

Matsuyama, K. (1992). "Agricultural productivity, comparative advantage and economic growth," *Journal of Economic Theory*, 58: 317334.

Posner, M. (1961). "International trade and technological progress," *Oxford Economic Papers,* 13: 323341.

Reinganum, J. (1989). "The timing of innovation, research, development and diffusion" In Schmalensee, R. and R. Willig, eds., *Handbook of Industrial Organization*. Amsterdam: North-Holland.

Rodriguez, F. and D. Rodrik (1999). "Trade policy and economic growth: A skeptic's guide to the cross-national evidence." Unpublished. University of Maryland and Harvard University.

Rodrik, D. (1992). "Conceptual issues in the design of trade policy for industrialization," *World Development*, 20(3): 309320.

Sarkar, J. (1998). "Technological diffusion: Alternative theories and historical evidence," *Journal of Economic Surveys*, 12: 131-176

Schmalensee, R. (1988). "Industrial economics: An overview," *The Economic Journal*, 98: 643681.

Segerstrom, P., T. Anant and E. Dinopoulos (1990). "A Schumpeterian model of product life cycle," *American Economic Review,* 80: 10771091.

Siotis, G. (1999). "Foreign direct investment strategies and firms' capabilities,"*Journal of Economics and Management Strategy*, 8(2): 251270.

Taylor, C., and Z. Silberston (1973). *The Economic Impact of the Patent System*. Cambridge: Cambridge University Press.

Tirole, J. (1988). *The Theory of Industrial Organization*. Cambridge, MA: MIT Press.

Vernon, R. (1996). "International investment and international trade in the product cycle," *Quarterly Journal of Economics,* 80: 190207.

Preface

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