African Technology Development Forum

ATDF JOURNAL

Volume 4, Issue 3

INNOVATION; TECHNOLOGY; TRADE; DEVELOPMENT

"Competition is the keen cutting edge of business, always shaving away at costs"
(Henry Ford)

HIGHLIGHTS:

Biofuels In Africa: A Criteria To Choose Crop Models

Scaling Up the Innovation Ecosystem

Knowledge, Technological Learning and Innovation for Development

Benefiting from Biotechnology: Promoting small-farm competitiveness

TNCs, Extractive Industries and Development

The Rise, Fall, Rise, and Imminent Fall of DDT

And more inside!!

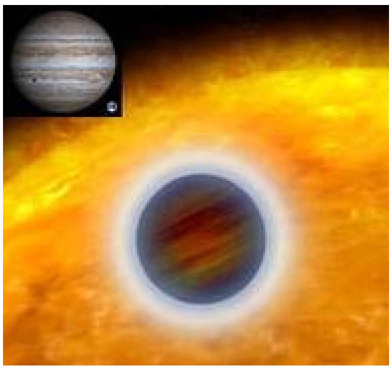
ISSN: 1817-2008

Official abbreviation: Afr. Technol. Dev. Forum j

http://www.atdforum.org/

November 2007

INSIDE THIS ISSUE



Cover picture: Kenyan youngsters compete.

Above: Pictures from the South African Space Agency related facilities and two planets just discovered

Biofuels In Africa: A Criteria To Choose Crop Models for Food and Fuel

Seetharam Annadana

ASR BIOTEC, 71/2, 21st A Main, Marenahlli, JP Nagar II Phase, Bangalore 560078, India
e-mail: info@asrbiotec.com

Abstract

The bioeconomy is based on two components: biomass and bioprocess, which is related to natural resources (energy crop, agro-residue, under-utilised waste, soil fertility, land-water availability) and novel technologies (industrial biotechnology, bio/chemical and/or thermo-chemical technology). The shift from fossil fuels to a bio-based economy is necessary, if the world aspires to a "reduced reliance on fossil fuel, mitigating climate change and benefiting rural community". Biomass to biofuels and bio-materials brings in the paradox of food verses fuel, more so in developing countries, with limited natural resources. Employing micro-agriculture resource in LDC's to meet future food-feed-fuel demands is a challenge. Africa which has the bulk of the LDC's should find a balance to meet the need for food and demand for sustainable fuel, surely not at the cost of the each other. Keeping in mind dry land agriculture, this paper explores a possible criteria to choose a crop-based model, to meet feed-fiber-fuel demands of Africa.

Introduction

Henry Ford designed the famed Model T Ford to run on alcohol, he said it was "the fuel of the future". Similarly Dr. Rudolph Diesel invented his compression ignition engine in the 1890's which ran on peanut oil, the original "diesel fuel". Dr. Diesel believed biomass fuel to be a viable alternative to the resource consuming steam engine. The oil companies thought otherwise. Due to the prevalence and price of petroleum products, diesel fuel soon came to be accepted as a petroleum product as well (1). However the oil crisis of the early 1970s gave ethanol fuel a new lease of life.

In 2003, the biologist Jeffrey Dukes calculated that the fossil fuels we burn in one year were made from organic matter "containing 44×10^{18} grams (44 billion tons) of carbon, which is more than 400 times the net primary productivity of the planet's current biota."(2) This is equivalent to four centuries' worth of plants and animal material.

Bioeconomy can be defined as an economy whose basis is biomass and technology for sustainably meeting societies requirements of energy, fuels and products. Strategically countries across the globe are attracted to this development for several reasons,

1. Reduce dependence on Fossil Fuels
2. Better market values for agricultural produce
3. Adopt climate friendly energy, fuel and industrial feedstocks
4. Diversification and total utilization of agricultural potential; beyond food

However the first two reasons would be stronger attraction for developing & developed countries, while the last two reasons would be additional compulsions or luxury so to say for developed nations. However it is a fact that fossil fuel resources are unevenly distributed across the globe, however with better agricultural technology, production could be evenly distributed, overcoming the uneven distribution of other natural resources supporting agriculture. Industrial Biotechnology is revolutionizing the conversion of biomass (sustainable alternative to fossil fuels) to energy, fuel and industrial feedstocks. Developments in Industrial Biotechnology to make clean

The economy of going green: the science, infrastructure, products and markets

and cost effective processes is the driver for renewed interest in the bioeconomy. The key categories of products, of this bioeconomy are bioenergy, biofuels, biomaterials, bulk and fine chemicals. The bioeconomy is a sector worth over 1.5 trillion euros (European Commission, 2005).

Fuels mainly diesel & petrol can be replaced by similar or actually better chemical quality and eco-friendly products by processing biomass, hence the term biofuels. In general plant & animal fat is used as raw material for the production of biodiesel, however recent developments have also led to the use of lingo-cellulosic biomass for production of biodiesel by gasification (synthesis gas) and Fischer-Tropsch (FT) process. Fats are converted by a process of trans esterfication to make biodiesel and glycerol, shown in Figure 1 (www.utahbiodiesel.org).

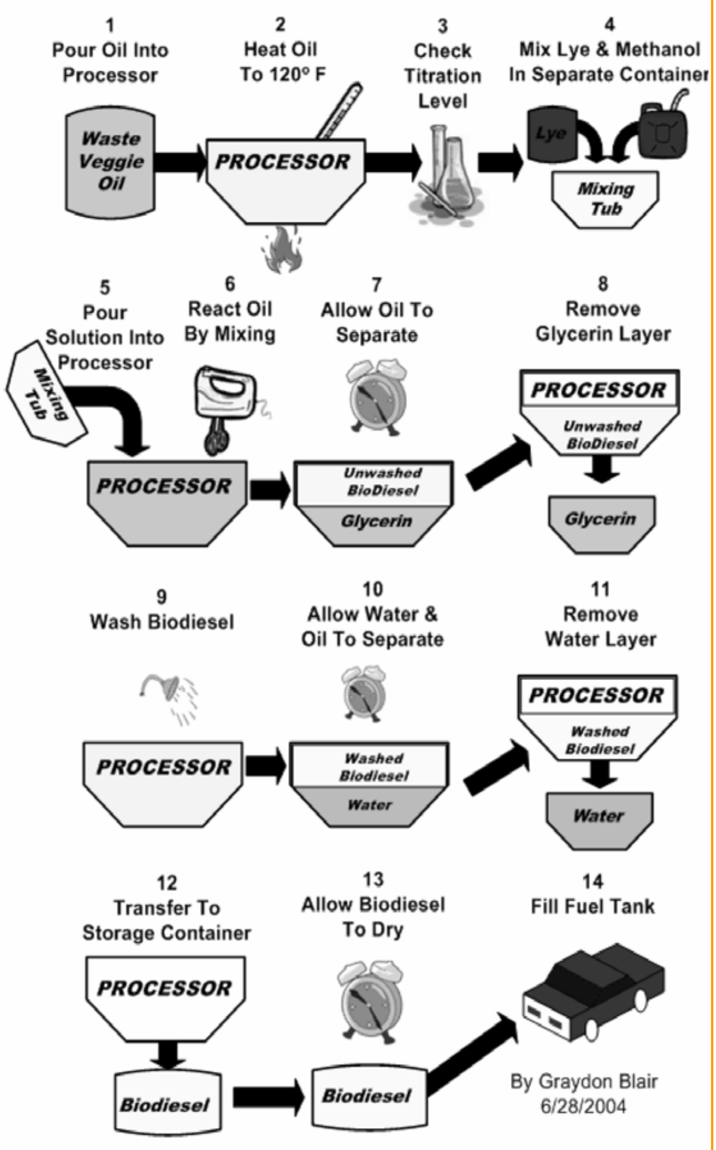
However the production of ethanol from unconventional complex sugar like lignoceullosic biomass (corn stover, straw, sugarcane bagasse, forest residues, municipal solid waste), or through conversion of methane to Ecalene (Gas to liquid, GTL) are recent trends, dynamically evolving. The focus for technology development (Figure 2) has been in the four areas:

-Cellulosic biomass fractionation to its components (cellulose, hemi-cellulose, lignin)

Box 1. Crop wise oil/fuel data per hectare

Crop	kg oil/ha	litres/ha
corn (maize)	145	172
cashew nut	148	176
oats	183	217
lupine	195	232
kenaf	230	273
calendula	256	305
cotton	273	325
hemp	305	363
soybean	375	446
coffee	386	459
linseed (flax)	402	478
hazelnuts	405	482
euphorbia	440	524
pumpkin seed	449	534
coriander	450	536
mustard seed	481	572
camelina	490	583
sesame	585	696
safflower	655	779
rice	696	828
tung oil tree	790	940
sunflowers	800	952
cocoa (cacao)	863	1026
peanuts	890	1059
opium poppy	978	1163
rapeseed	1000	1190
olives	1019	1212
castor beans	1188	1413
pecan nuts	1505	1791
jojoba	1528	1818
jatropha	1590	1892
macadamia	1887	2246
brazil nuts	2010	2392
avocado	2217	2638
coconut	2260	2689
oil palm	5000	5950

Figure 1. A pictorial overview of fats to Biodeisel



-Breakdown to simpler sugars like glucose, fructose, xylose

-Conversion to ethanol and other bioproducts

-GTL: Solids to gas to liquids using FT as an alternative to hydrolysis-fermentation route

Tremendous progress is being made at a rapid rate, on the technology platform front for conversion of biomass to bioproducts. However a similar progress is still to be seen in the development of biomass for bioproducts, or development of energy crops so to say. It remains to be seen, how the era of crop genomics will be able to contribute to the re-design of major crops grown in different parts of the world. If we can double the productivity of rice with one fourth of the current water required and reduce the lignin content in the straw and design it to have more easily fermentable complex sugars, it could make a tremendous impact on the need for food and sustainable fuel.

2 Paradox of Food & Fuel

The world already grows more than enough food & feed for all, but still a billion people don't have enough food to meet basic daily needs. There's more food per capita now than there's ever been before, enough to make everyone fat. People starve because they're victims of an inequitable economic system, not because they're victims of scarcity and overpopulation. Seventy percent of Global food production is in the north, while the bulk of malnutrition, poverty, lowest energy/capita is in the south with only 30% agricultural production, (4). Countries challenged with poverty and malnutrition face the paradox of food vs. fuel as the bioeconomy emerges. If they have not met their food requirements in the past, how will they now cope with the additional stress of having to produce fuel also from agriculture?

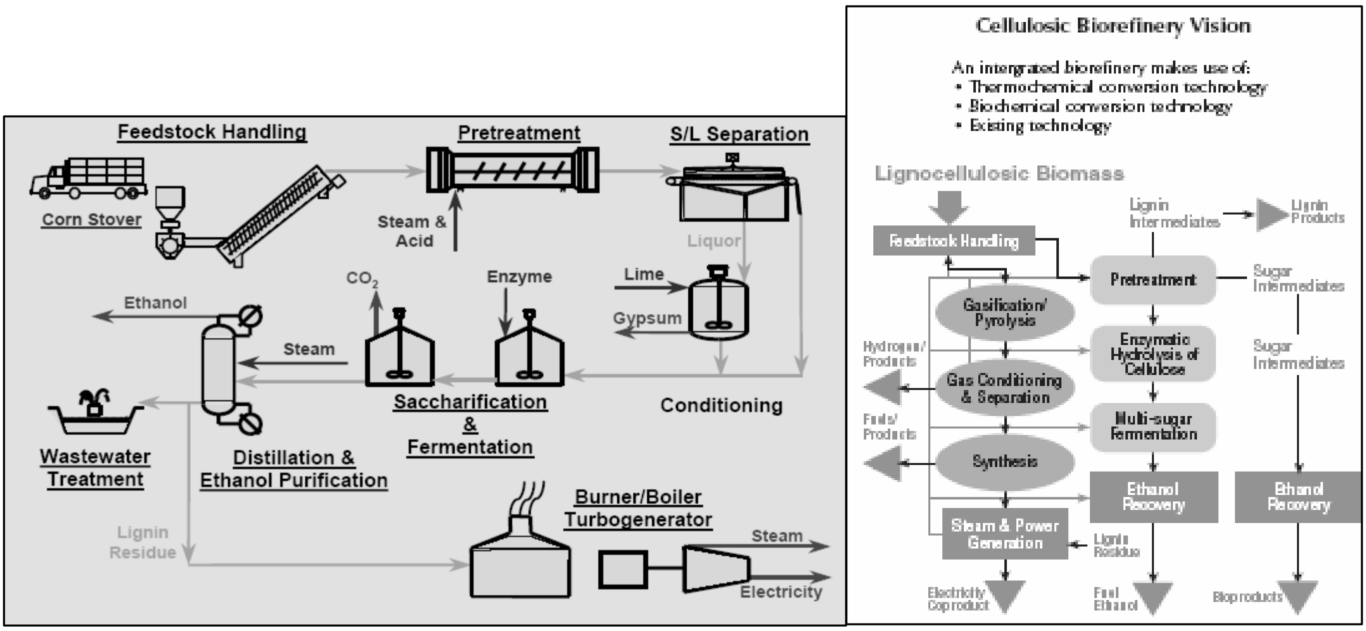
The correct Biomass (S & SF) for production in developing countries can only be decided after looking into a maze of issues like their food-feed-energy requirement, existing malnutrition, potential for irrigated/ dryland production, existing and potential to expand forests, agricultural productivity constraints, underutilised agricultural/ forestry residues, net carbon emission, energy balance etc. With the biomass economy, the paradox of S & SF arises due to the following:

Should a grain crop be distilled to make ethanol fuel or should the villagers eat the grain? If they use the grain for livestock feed, it can be used for ethanol and still feed the livestock: the distillation process to produce ethanol converts the carbohydrates in the grain while leaving the protein (Table 3). The protein residue is excellent stock feed, which can be supplemented by forage crops which humans can't eat. This could mean improved utilization of the available resources.

But what is the net GHG emission and energy balance for grain-ethanol? Is cellulosic a better option? (Figure 4).

Should a crop such as soybeans be used to make methyl esters (biodiesel), or it is better for villagers to live by eating off the bean's products? Or selling them? Or should they press them to make oil, for cooking or for selling (the most efficient would mean hexane extraction in large scale), and feed the high-protein residue "cake"

Figure 2 Sugar/biomass to ethanol via hydrolysis- fermentation- distillation route and *LCB via biorefinery route to ethanol using thermo chemical as add on* (NREL)



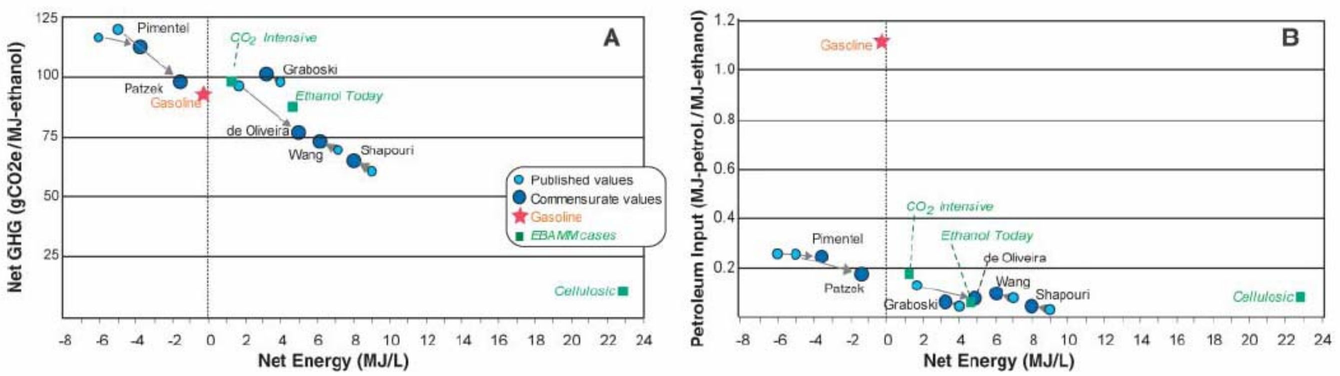


Figure 4 Net energy and net greenhouse gases for gasoline, six studies, and three cases. (**B**) Net energy and petroleum inputs for the same. In these figures, small light blue circles are reported data that include incommensurate assumptions, whereas the large dark blue circles are adjusted values that use identical system boundaries. Conventional gasoline is shown with red stars, and EBAMM scenarios are shown with green squares. Adjusting system boundaries reduces the scatter in the reported results. Moreover, despite large differences in net energy, all studies show similar results in terms of more policy-relevant metrics: GHG emissions from ethanol made from conventionally grown corn can be slightly more or slightly less than from gasoline per unit of energy, but ethanol requires much less petroleum inputs. Ethanol produced from cellulosic material (switchgrass) reduces both GHGs and petroleum inputs substantially.

to livestock (small scale), which in turn they can either eat or sell, while using the livestock wastes (and the crop wastes) to make compost to renew the soil, or to generate biogas for cooking and heating? (The heat generated by the composting process can also be harnessed for heating). Or should they grow a native crop, instead of one imported? (4)

A major criticism often levelled against biomass, particularly against large-scale fuel production, is that it could divert agricultural production away from food crops, especially in developing countries. The basic argument is that energy-crop programmes compete with food crops in a number of ways (agricultural, rural investment, infrastructure, water, fertilizers, skilled labour etc.) and thus cause food shortages and price increases. The subject is far more complex than has generally been presented since agricultural and export policy and the politics of food availability are factors of far greater importance.

Usually the "answer" is in a blend of technologies. Biofuels can be used to power small-scale farm and workshop machinery and electricity generators as well as local vehicles, if you choose the right crop & process technology (Table 3). The question is how do we ensure that available technologies are put to use in the poorest countries, the driver is missing. Capacity building is therefore essential in micro communities to sustainably exploit natural resources like land, water, forest for feed-food-energy needs. The argument should be analysed against the background of the world's real issues like, the use of biomass for food, as animal feed, the under-utilized agricultural potential, the potential for productivity, and the dis/advantages of producing biofuels (4). The rest of the article briefly indicates the potential for biomass production in Latin America, Asia and dwells with African continent in greater detail, in the background of their existing soci-econo-evironmental (triple bottom line of sustainability) conditions, from which arises the paradox of S & SF.

3 Feed-Food-Fuel Security for Africa

South Africa (SA) produces corn among other crops in surplus but there are 10 other nations in the continent on deficit for the same grain, which is one of the problems of the African continent. Should SA focus on production of crops for ethanol, overlooking regional food security? Concentrating more on regional food security on the short-term basis and re-looking at Biofuels with improved technology (lingo-cellulosic biomass to ethanol) may be a justifiable decision due to following reasons. Firstly, SA produces surplus maize/sorghum, which are not the ideal biomass for fuels, as it is competitive to food & feed. Secondly, technology is fast moving to displace corn with lingo-cellulosic feedstocks, due to lower net GHG emission (17) and higher energy balance (18) as indicated in Fig. 6 (17). Thirdly, technology progression should be sector wise, and the full potential of agricultural biotechnology is yet to be diffused into the African continent, as for example only 24% of the corn grown is transgenic. It's optimal to start developing capacities in themes essential for the bioeconomy, ensure Africans truly benefit by green biotechnology, before ushering in white biotechnology, as green drives white biotechnology in a bioeconomy. Biomass is very crucial for ensuring the food-feed-fuel security of Africa, and green biotechnology is yet to make an impact on the African economy. Biotech processes to convert biomass to bioproducts (biofuel, chemicals, materials), varies dependent on the source of biomass and currently most of the biomass is material used in the past for food-feed-energy. Developing biomass specifically for the production of bioproducts is the target for green biotechnology and a lot of information and resource is hidden in the biodiversity of Africa, which should be explored. Bioprospecting for an ideal biofuel crop is a major branch of prospecting, just emerging and we must put in place capacities to benefit from this wave. Bioprospecting for Feed-Food-Fuel Security in Africa is a very interesting theme.

4 Energy Security or Energy Crops?

Contrastingly biofuels in Africa has to be one of the three major produces expected from agriculture in addition to grain and fodder. Two-thirds of the African domestic energy supply currently relies on biomass (19). Therefore, biofuels has to be noncompetitive to feed, food and domestic energy. It directly implies that energy crops like oil palm, jatropha, sugarcane, corn requiring large scales of production with limited sector benefits (Table 3), are not suited to address this unique problem. Therefore Africa needs a crop that addresses all issues, it should be preferable native to Africa, suited for arid agriculture, C4 instead of C3, and a crop already adopted into African food. A crop justifying all needs and promising for African agriculture is "SWEET SORGHUM"(20), and this article christens it as Africa's Millennium crop. This can potential usher in ever green revolution, a terminology recently coined, to ensure sustainable development by Prof. M. S. Swaminathan.

Sweet Sorghum the Saviour of Africa?

Sweet sorghum has many uses, with potential to aid development. Sweet sorghum is a high biomass-yielding crop, grown for grain, feed, sugar and recently as an energy crop for ethanol-electricity and serving human-animal food-feed requirements. (Ecoreport, Imperial College, London). Its excellent growth characteristics (high yield, drought-waterlogging-saline-alkali-resistance, wide adaptability), makes it an ideal choice for Africa. Prof. Li Dajue (Chinese Academy of Sciences) and Peter Griffee (FAO) coined the name "**Four F's Crop**" for sweet sorghum representing Food, Fuel, Fodder (feed), & Fiber (feedstock). Sugarcane is propagated from stem cuttings (4.5 –6 T/ha) while sweet sorghum is sown with just 4.5 kg/ha of seed.

Sweet sorghum is a potential energy crop as it produces up to 7,000 liters of ethanol per ha making it highly attractive for developing countries (FAO). For example Chinese agricultural planners see Sorghum as key for sustainable agricultural development in areas suffering from aridity and saline/alkaline soils. In the Huang Huai Hai region and Northwest China, where the total area of saline-alkaline and salinized land is estimated at more than 170,000 sq km, plants germinate with difficulty, grow slowly, produce poor harvests, if not completely fail.

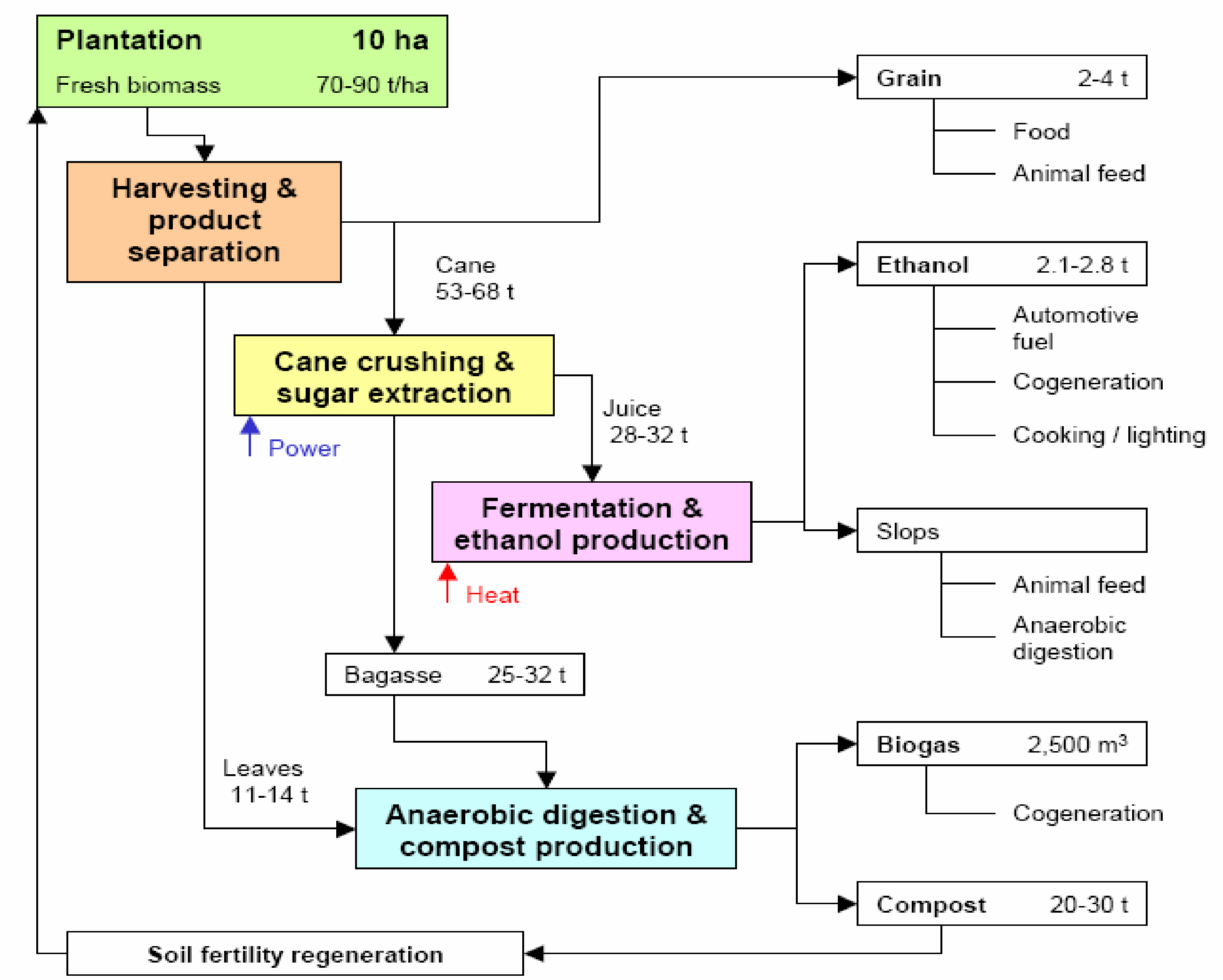
This lack of agricultural development is the cause of poverty in many rural areas and a threat to China's long-term food security (FAO). Chinese since 1970 have developed sweet sorghum varieties yielding 5 T of grain, 7.5 T of sugar and 14.5 dry T of lignocellulosic biomass per ha per crop of 4-5 months duration and currently there are over 7000 varieties/hybrids indicating its importance in China (21). China and Italy are setting up large bioethanol projects with sweet sorghum planted in 21000 and 7000 ha, resulting in 112302 & 42202 T of ethanol/annum respectively (22).

Similarly Nimbkar Agricultural Research Institute, identified sweet sorghum as the ideal crop for feed-food-fuel security of rural India and developed solar distillation of sugar juice to ethanol and used the ethanol for energy efficient stoves (http://nariphaltan.virtualave.net/index.htm, 23, 24). It's demonstrated that sweet sorghum juice can be used as feedstock for the production of hydrogen using thermophilic bacteria (25). Sweet sorghum stalk has 15-18% fermentable sugars and has the potential for cane yield of 40 T/ha or more, but should be crushed within 48 hours of harvest (AICSIP, NRC for Sorghum, Hyderabad, India). ICRISAT India station initiated an identification-development program for sweet sorghum in 2002, and has hybrids for release in India, with industry-incubators for ethanol production trials.

Research on Sorghum and harnessing its prospects would be an excellent program for south-south cooperation for sustainable development. A 8-year agronomic trial and a 2-year industrial trail concluded that 1/3rd of Southern Africa's fuel could be purely met by sweet sorghum grown in only 1% of the total existing cropland. It suggests sweet sorghum future with CDM (http://cdm.unfccc.int/) options is excellent, as an sustainable alternative to the OECD fossil route for development (26). In tropical countries one can easily take two crops of sweet sorghum and produce more ethanol per unit land, in addition to serving food-feed requirements (20). When common African crops corn, sweet sorghum, sugarcane, cassava, sweet potato were compared, for their potential suitability for cultivation with 25% and 50% increase in production, without compromising on food security, next to corn it is sweet sorghum as the second largest crop (27).

However when compared with corn for ethanol production (Fig.6, 15), sweet sorghum is a clear winner due to

Figure 5. Aschematic representation of sweet sorghum based bioenergy Village complex, encompassing microdistillery for ethanol, grain for human consumption and fresh-dried fodder for animal production (20)



yield (28) and lower net GHG emissions (IEA, 17, 18). Sweet Sorghum has shown promising results also in southeastern United states, yielding ethanol (600 gallons/acre) equivalent to sugarcane, and at BECON Iowa state University, it is being studied as a alternative to corn (400 gallons/acre, 28). The seasonality in crop production and instability/difficulty in conversion of some of sweet sorghum sugars have been bottlenecks. The problems of seasonality would be mainly in temperate countries, while difficulties of extraction/ conversion of sorghum is now overcome with thermopermiation technology of Praj, India. These global experiences clearly sends home a strong message to Africa, which suffers from poverty, malnutrition, low energy/capita, desertified landscapes and drought. There is a lot of information on sweet sorghum uses in Africa, role in African bio-energy security etc., however it is not clear, as to why they are no functional sweet sorghum based establishments.

This has to be the focus for change from existing African scenarios. As per FAO 1991, Africa has in total, a potential land for expansion at 752 Mha, next to Latin America is size, of which over 50% is waste lands with the balance divided 20% each of arid, irrigated and 10% of flooded zones.

5 Conclusion

Africa has some of the poorest countries, suffering the most of Aids, with the most severe droughts and cases of malnutrition globally (www.data.org/whyafrica/). 2025-30 global population addition will be 67 million, 2045-50 (943 million), practically all increase in developing countries, and by 2050, every second person added will be in sub-Saharan Africa (43). This in addition to existing malnutrition, signals to concentrate on food security, hence the FEED-FOOD-FUEL strategy; with the 4F crop SWEET SORGHUM for Africa. Almost 1.6

Figure 6. Estimated Ethanol gallons per ton biomass (dry basis, 28)

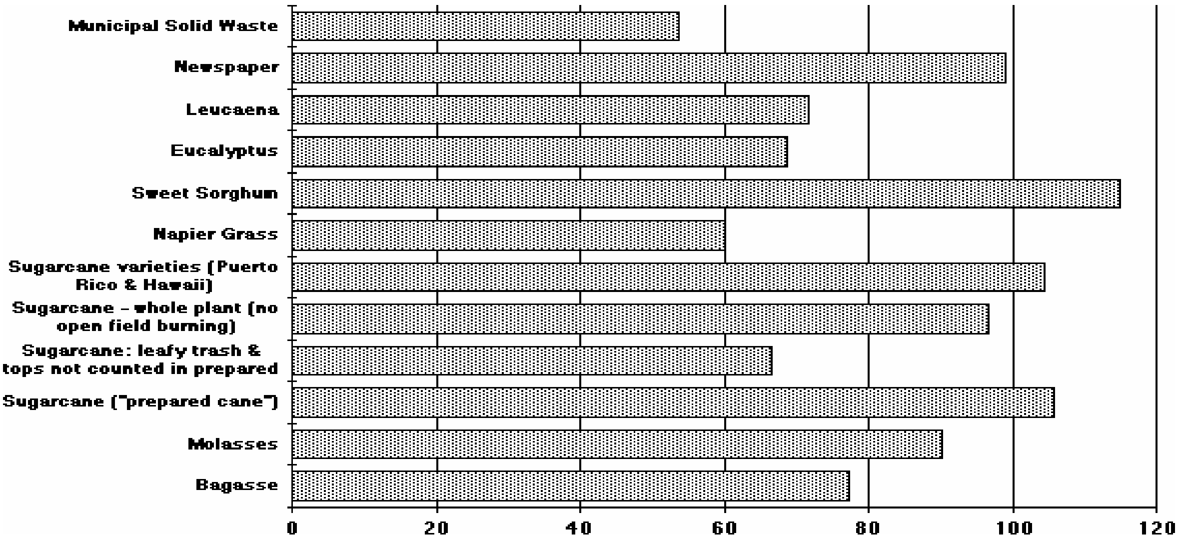


Table 3. A table summarizing salient characteristics of biomass production, processing technology status and potential bioproduct generatability with an LDC's idealistic contrast (sweet sorghum) as the last example in the table. This is a hypothesis based on brief literature search and basic agricultural and environmental science. Conducting a study to validate this hypothesis is worthwhile. Column 11 indicates that resources currently emitting high GHG would be potential candidates for alternate processing and attraction for CDM.

Biomass: Energy Crops	1	2	3	4	5	6	7	8	9	10	11
Arable-land Non-edible oil	++	+++	+	BFI	+++	++	++	++	+	+	+
Corn/Grain	+++	+++	+	BF	+++	+	+++	+	+	+++	+++
Edible oils	+++	+++	+	BFEI	+++	+	+++	++	+++	++	+++
Bamboo/Fibrous	+	+	++	BFI	+++	+++	+	+++	++	+	+
Strach/Tubers	++	++	+	BFEI	++	++	++	+	+++	++	++
Sugarcane/Beet	+++	++	+	BFEI	++	+	+	+	+++	+++	+++
Waste-land Non-edible oil	++	+	++	BFI	+++	+++	+	++	++	+	+
Woody species	+	+	+++	BFI	+++	+++	+	+++	+++	+	+
Biomass: Production Residues											
Agriculture/Industry	+	++	+	BFEI	+	+++	+	+/++	+++	++	+++
Animal Husbandry/Industry	+	+	+	BFEI	+	+++	+	+/++	+++	+++	+++
Aquaculture/Industry	+	++	+	BFEI	+	+++	+	+/++	+++	++	+++
Forestry/Industry	+	+	+	BFI	++	+++	+	+++	++	+	++
Biomass: Waste											
Industrial Waste	+	++	+	BI	++	++	++	+/++	+	++	+++
Municipal Solid Waste	+	+	+	BFI	++	+++	+	+/++	++	+	+++
Municipal Liquid Waste	+	+	+	BFI	+	++	+	+	+	+	++
Oil Waste	+	+	+	BI	+	+++	++	+++	++	+	++
LDC's Ideal Biofuel Biomass	+/++	+	+	BDFEI	+/++	+++	+	+/++	+++	+++	++/+++

Note that:

1: Biomass production Inputs
2: Competition to Land, water, Food, Feed
3: Risk to Biodiversity & Environment
4: B; Biofuel, D: Food, F: Biofertilizer, E: Feed, I: Industrial feedstock
5: Scale
6. Net Energy Balance
7. Net GHG Emission
8. Technology
9. Sectors Benefited
10. Maturity of Technology
11. Current GHG emission

+++ High/Large/Complex , ++ Medium , + Low/small/Simple.

Sectors: Feed-Food-Fuel

billion people in developing countries do not have access to electricity today, representing a little over one-third of world population. Most of the electricity deprived are in Asia and sub-Saharan Africa. By 2030, half the population of sub-Saharan African will still be without electricity; and Africa is the only region where the absolute number of people without access to electricity will increase (44). The proportion of the population using traditional fuels will remain highest in sub-Saharan Africa, where 996 million people will rely on traditional biomass for cooking and heating in 2030 (44). Much of this can change if we address fuel security using Sweet Sorghum, is the authors opinion. This crop can provide energy security at microlevel by the micro energy village complex (20) and considerable percentage of transport biofuels for Africa (26), in addition meting a part of food & feed requirement. Studies indicate the possibility to produce ethanol competitive to Brazilian ethanol or cheaper at 19 US cents per liter (45), promising a biofuel revolution for Africa.

Sweet Sorghums real potential lies in the fact that the crop can establish well in sub-optimal conditions, allowing production of sugar and fiber rich stem, where others struggle. Secondly it consumes one-third the water required by sugarcane, therefore the net water consumption per liter of ethanol is significantly lower (26), which address drought problems of Africa. This feature of sorghum is very important in the background of climate change, which will have more adverse effects in tropical areas than temperate. Developed countries will be beneficiaries with higher productivity in Canada, northern Europe and parts of the former Soviet Union, however poorest developing countries are likely to be negatively affected (46). Here the next 50-100 years will see widespread declines in the extent and potential productivity of cropland (47) particularly in sub-Saharan Africa and southern Europe (48, 49). Some of the severest impacts seem likely to be in the currently food-insecure areas of sub-Saharan Africa with the least ability to adapt to climate change or to compensate for it through greater food imports (43). Growth in the livestock sector has consistently exceeded that of the crop sector. The total demand for animal products in developing countries is expected to more than double by 2030. Livestock production is the world's largest user of land, directly through grazing & indirectly through consumption of fodder/feedgrains (43).

In sub-Saharan Africa, low consumption levels of animal products have changed little over the last 30 years, contributing only 5 percent to per capita calorie consumption, about half the percentage of the developing countries as a whole and a fifth of that of the industrial countries (43). The situation clearly indicates the need to also address feed security in Africa.

Sweet Sorghum can be used in existing sugarcane based ethanol industries, it's an excellent alternative during sugarcane off-season (26). It's also suited for the introduction of community based bottom up approach for development of Africa and several sorghum models are being tested now (50), based on success stories with sugarcane (51). The need of the hour in Africa is to develop capacities very similar to the ones in Asia. In addition to this, the climate for investment and participation by the private sector in development of the continent, like in Asia is extremely essential for Africa.

Can we replace an economy whose every fibre vibrates with the logic of cheap oil and careless pollution with one which runs on renewable energy, heals our surrounding ecosystems and creates no waste? Can biofuels truly compete with petrol? Is it just replacing Biofuels with fossil fuels the solution, without a introspection of our lifestyles which could be highly energy consuming (each family member driving a car alone to work and back, instead of public transport or car pooling)? Will the future be biofuels with a significantly fuel efficient vehicle or is hydrogen the solution? Recent projections suggest that ethanol could represent up to 5% of the world's transport fuel by 2010. That figure may seem modest at first glance, but it is significant, considering no other alternative fuel has had an equivalent impact on the gasoline market in over 100 years (IEA). However, there is a mismatch between those countries where biofuels can be produced at lowest cost and those where demand is rising most quickly (IEA). Arable land expansion will remain an important factor in crop production growth in many countries of sub-Saharan Africa, Latin America and some countries in East Asia, although much less so than in the past (43), indicating future expansion for biofuels. A key long-term concern is that higher usage of biofuels will lead to land being drawn away from other purposes, including food, feed or fiber production, leading to higher prices (IEA). Developed countries would switch to import of biomass to satisfy local biofuel demand, resulting in further aggravation of the developing countries paradox of sustenance and sustainable biofuels. Export of biomass for biofuels by developing countries can be a serious threat than an opportunity if nations use land-water-labour at the cost of feed-food and environment. Bioeconomy in developing countries therefore must act as a bridge between food & non-food uses for a crop, and not independent of them, thereby ensuring feed-food-fuel security. **Africa** must start developing sweet sorghum based microdistilleries and micro energy village complexes. The South African National Biodiversity Institute suggests that over 1080 Mha of land is suited for Jatropha, which can make a tremendous impact on its energy security. All countries have to seriously address energy, fuel and water efficiency in all sectors of economic activity, and develop capacities for optimal use of natural resources for sustainable biomass (unicellular-energy crops-residues-waste) production to address MDG.

The Author

Dr. Seetharam Annadana is a freelance consultant for agricultural biotechnology in India. He operates through his own firm ASR BIOTEC, whose main focus is on Bio-fertilizers, plant Molecular Biology and Biofuels. Dr. Annadana has been helping agencies to develop a model for sustainable biomass production and keeps himself updated with the evolving technology platforms, which is highly dynamic. He has been consulting for the Indian Industry for over 5 years now and has had close contacts with Dutch Biotech firms and obtained his Masters and PhD education at Wageningen UR in The Netherlands. He has been resource persons to UNEP-GEF and UNIDO on subjects like Biosafety and Biofuels in the past.

References

1. Biofuels Coming of Age, Keynote address, Ignacy Sachs, IEA, June 2005
2. Jeffrey S. Dukes, Burning Buried Sunshine: Human Consumption Of Ancient Solar Energy. Climatic Change 61: 31-44 (2003)
3. Report on Ethanol Production in Hawaii, Energy Division of DBEDT, Robert S, (1994).
4. http://journeytoforever.org/biofuel_food.html
5. Biodiesel The new fuel from Brazil, National biodiesel production and use program, Ministry of Mines, Brazil.
6. The Brazilian fuel-alcohol program, Goldemberg J, Renewable Energy. Sources for Fuels and Electricity. Island Press (1992).
7. Gasifying Switchgrass Lignin for Biopower Applications, Zygarlicke et al., Energy & Environmental Research Center, University of North Dakota; and Millicent R. Moore, Tennessee Valley Authority, USA. Paper presented at The 30th International Technical Conference on Coal Utilization & Fuel Systems (2005)
8. http://www.fedepalma.org/oil_uses.htm
9. http://peakoil.com/nextopic4434.html (22-01-2005)
10. Friends of the Earth et al, September 2005. The Oil for Ape Scandal: how palm oil is threatening orang-utan survival. www.foe.co.uk/resource/reports/oil_for_ape_full.pdf (2005)
11. Worse than fossil fuel: http://www.monbiot.com/archives/2005/12/06/worse-than-fossil-fuel/
12. http://southasia.oneworld.net/article/view/113032/1/7
13. Physic Nut; Jatropha curcas, IPGRI, (1996)
14. A new tumour promoter from the seed oil of Jatropha curcas L., an intramolecular diester of 12-deoxy-16-hydroxyphorbol, Hirota et al., Cancer Research, Vol 48, Issue 20 5800-5804 (1988).
15. Energy and dollar costs of ethanol production with corn. David Pimentel, Hubbert Centre Newsletter # 98/2, M. King Hubbert Centre for petroleum supply studies, Colarado Scholl of Mines, Colorado, USA (1998).
16. Ethanol can contribute to energy and Environmental Goals, Farell AE et al., Science, Vol 311 (2006).
17. Fossil Fuels: Technical, Economic and political issues on the horizon, 2030-2050, The Transport Challenge, Paper presented by Haug, International colloquium, Paris, IEA (2004).
18. How much energy does it take to make a gallon of ethanol, Loren & Morris, Institute of local-self reliance, Washington DC, USA (1995).
19. Fueling Development: Energy Technologies for developing countries, 246-258, Office of Technology Assessment, United State Congress, (2005).
20. LAMNET: Latin America Thematic Network on Bioenergy, http://www.bioenergy-lamnet.org/ (2005)
21. Introduction of Sorghum (Sorghum bicolour (L.) Moench) into China. Kangama CO & Rumei Xu, African Journal of Biotechnology, Vol 4 (7), 575-579, July (2005).
22. Large Bio-ethanol project from sweet sorghum in China and Italy (ECHIT): description of site, process schemes and main products, Chiaramonti D et al., 12th European conference on biomass for energy, Amsterdam (2002).
23. Ethanol from Sweet Sorghum for Use as Cooking and Lighting Fuel, Spirit of Enterprise - The 1990

Rolex Awards (ed. D. W. Reed), p. 109-111, Buri International, (1990).

24. "Sweet Sorghum Success", Rajvanshi, A. K., Asia Tech, Vol. 4, Issue 1, p. 26-28, (1996)

25. Biological hydrogen production from sweet sorghum by thermophilic bacteria. Classen et al., 2nd world conference on biomass for energy, Industry and climate protection, 10-14 May, Rome (2002).

26. The potential for energy production using sweet sorghum in southern Africa, Woods. J, Energy for sustainable development, Vol. V No. 1 (2001).

27. Ethanol and gelfuel: clean renewable cooking fuels for poverty alleviation in Africa, Utria BE, Vol VII No. 3 (2004).

28. Beyond Corn: Alternative Feedstocks for ethanol production, Brekkle K, Ethanol Today, 31-33, (2005).

29. Ethanol production in Hawaii, Processes, Feedstocks, and Current Economic Feasibility of Fuel Grade Ethanol Production in Hawaii, Hawaii Department of Business, Economic Development & Tourism (1994)

30. Contributions from Latin American Experience, Maletta, Papers to the World Commission on Dams (1999)

31. http://www.iogen.ca/cellulose_ethanol/what_is_ethanol/process.html (2005)

32. http://www.dedini.com.br/english/dhr.html (2005)

33. http://www.latintrade.com/dynamic/index.php?pg=site_en/pastissues/Jul05/connections2.html (2005)

34. Animal production based on crop residues: Chinese experiences. Edited by Guo Tingshuang, Manuel D. Sánchez & Guo Pei Yu. FAO, Rome (2002).

35. Future energy trends and carbon mitigation strategies for India, chapter in Global Climate Change: Perspectives on Economics and Policy from a Developing Country. Resources for the Future, Washington DC, U.S.A. pp 11-35 (2003).

36. Senate Interim Committee on Natural Resources: Opportunities for alternate fuels and fuel additives; Technologies for converting waste to fuel (2002)

37. Using MSW and Industrial residues as Ethanol feedstocks, Broader et al., Biocycle 42; 10, P23 (2001)

38. http://www.powerenergy.com/images/process_flow.gif (2005)

39. Biogas Technology in the Third World: A Multidisciplinary Review, MF 24-570, book, 132 pages, by Andrew Barnett, Leo Pyle, and S.K. Subramanian, 1978, IDRC, out of print in (1985)

40. Lerner, J., E. Matthews, and I. Fung. 1988. Methane emission from animals: A global high-resolution database. Global Biogeochemical Cycles 2 (2): 139-56.

41. Other greenhouse gases and aerosols; assessing their role for atmospheric radiative transfer, Bolle et al., In: The Greenhouse Effect, Climatic change and Ecosystems (Editors: B Bolin, B R Doos, B Warrick and D Jager) John Wiley and Sons: New York (1986)

42. http://www.epa.gov/methane/

43. World Agriculture: Towards 2015.2030, FAO (2003).

44. World Energy Outlook, Fact Sheet; Energy & Development, IEA (2004).

45. Integrating sweet sorghum for bioenergy; Modelling the potential for Electricity and Ethanol Production in SE Zimbabwe, PhD, Thesis, Kings College London, Woods J, (2000).

46. IPCC. Climate change 2001, impacts, adaptation and vulnerability. Third assessment report: report of working group II. Cambridge, UK, Cambridge University Press (2001).

47. Global agro-ecological assessment for agriculture in the 21st century. Fischer, G. et al., Laxenburg, Austria, IIASA (2001).

48. Climate change and world food security: a new assessment. Parry M et al., Global Environment Change, 9: 51-67 (1999).

49. Assessment of potential effects and adaptations for climate change in Europe – the Europe acacia project. Parry, M., ed. Jackson Environment Institute, University of East Anglia, Norwich, UK (2000).

50. Demonstrating increased resource use efficiency in the sugar industry of Southern Africa through environmental sustainable energy production, Mvududu E, Et al, CFC sweet sorghum progress reports, (2000).

51. Small holder sugarcane production in South Africa: Historical Trends 1979 to 2000, Eweg M, SA sugar research station, mount Edgecombe, 4300, South Africa, (2000).

52. BCIL: Biotechnology Consortium of India Limited, New Delhi 110002, India.

Scaling Up the Innovation Ecosystem

Thomas D. Nastas[2]

Overview

BRIC, Chile, Hungary, Mexico, South Africa and others are replicating the strategies that made Israel, the US, Korea and others so successful in the creation of knowledge economies. Do alternatives exist with less risk and better chances of success in taking a seat at the global table of tech developers?

SMEs in partnership with governments and foreign investors are working to create technology capacity and ensure their future in a knowledge-based world. Much energy is directed at replicating the strategies that made SMEs in Israel, Ireland, Korea, Singapore and Taiwan successful: they all focus on the development of technologies for global markets with government and donor support financing technology creation and VC initiatives.

Are these the best strategies with the greatest chances of success? Do alternatives exist, to build from a base of technical needs for the local market instead, to move developing country SMEs up the path of knowledge creation incrementally with greater numbers succeeding domestically, and help position a few for entry into world markets? If yes, how can SMEs, governments and multinationals work together to generate new wealth and prosperity?

In this article I present a GoForward plan to scale up the innovation ecosystem and the investment needed for execution. I draw upon my experiences in transacting VC investments in Africa, Canada, the CEE (Central & East Europe), the CIS (countries of the former Soviet Union), Western Europe and the US.

The Leverage of Venture Capital

In the U.S., companies that raised VC from 1970-2005 created 10 million new jobs and contributed more than $2.1 trillion in revenue in 2005 to the economy. [1] Ten million new jobs are 9% of the total private sector workforce in the US and 16.6% of U.S. GDP, an increase from 8.7 million jobs and $1.5 trillion in revenues in 2000.

Before Hotmail, people communicated by telephone, telex, fax and letter; no big deal. Once Hotmail was launched, communication was turned upside down as users realized huge gains in productivity, simplicity and convenience by accessing e-mail over the Web, 24/7, from any computer, anywhere in the world; with such benefits it's easy to see why new industries formed around this solution.

Before eBay, people bought and sold collectables at auctions for centuries; no big innovation here either. But eBay created an innovative trading platform that combined live auctions, the Internet and collectables that became the biggest online marketplace and seeded the creation of entire industries based on online trading.

Retailing and delivery existed for centuries too. Amazon's big innovation was in the graphical interface to make product ordering simple, combining it with efficiencies in warehousing and distribution.

What these successes have in common is that each created an innovative business model, mostly around a GameChanging technology; disruptive technology with superior performance or high cost reduction features. GameChanging solutions make products and services

Table 1: Some top firms that were supported with venture capital [2]

Company	Venture Investor
Microsoft	August Capital
Intel & Apple	Venrock
United Healthcare	Warburg Pincus
Cisco & Yahoo	Sequoia
Hotmail	Draper, Fisher & Jurvetson
Genentech, Amazon.com, AOL, Intuit & Netscape	Kleiner Perkins
eBay	Benchmark
Google	Kleiner Perkins & Sequoia
Skype	Draper, Fisher & Jurvetson, Index Ventures & Others

accessible to global customers.

Each of these tech and business model platforms spawned business ecosystems of new suppliers and partners. It's estimated for example, that for every $1.00 of revenue that Microsoft earns in Chile, another $11 is made by partners, suppliers, system integrators and the like in the Microsoft Chilean ecosystem; [3] in Argentina, $17 of supply chain revenues are generated for every $1 of Microsoft sales. [4] Such leverage demonstrates the broad economic value generated by integrating new ideas, innovation, technology and VC.

The Allure of Global Technology Markets

Emerging market country governments see the business and financial successes of SMEs solving global needs. They encourage their enterprises to attack world markets with government money like VC to support this strategy.

Large opportunities attract the best scientific minds, entrepreneurs and investors: cures for human health problems in aging and disease, needs for security in a world that is increasingly perceived to be violent and energy alternatives in the face of climate change and rising oil prices. In solving global needs and wants, new wealth and prosperity results as the reward for industrial creation.

Actions of the governments in the CEE, the CIS and Latin America illustrate the commitments that they execute to jump into the global technology, commercialization and VC game. The Mexican Government made a commitment to grow its $3 billion a year IT and software industry into a 'near-shore' destination as an alternative to India for US customers. The Brazil and Argentina Administrations finance innovation through PPPs (public-private partnerships) in healthcare, global biotech and alternative energy. The Hungarian Government seeded the Development and Innovation Program, Microcredit Program for SMEs and Enterprise Promotion.

The Putin Administration is spending billions of petrodollars to diversify Russian growth from oil to knowledge creation, an experiment that other CIS and Latin American oil producing countries are monitoring; is economic diversification possible, with what results and leverage, at what cost and sacrifice? Russia is investing state money in infrastructure including enterprise zones, technoparks and incubators, 'build it and they will come' strategies to catch-up to leap-ahead of competitors in global technology.

Especially ambitious is the creation of the Russian Venture Company, a US$500 million fund-of-funds modeled after Israeli's Yozma fund-of-fund scheme (Box 1). Its PPP mandate is to co-invest with the private sector and create up to twenty new Russian technology VC funds with a total capitalization of $1 billion, half from the Russian Government with the matching of $500 million

Box 1. What is Yozma All About?

The 'Yozma' fund-of-funds was an investment company capitalized with $100 million by the Israeli Government, $80 million for investment into the creation of new VC funds and the remaining $20 million for direct investment into Israeli technology SMEs. Yozma invested $8 million into a private VC fund. A minimum of $12 million/fund was invested as partnerships between Israeli and foreign venture capitalists. Yozma gave fund managers the option to 'buy-out' the government's equity stake after five years.

In the first three years of operation, Yozma catalyzed the creation of ten VC funds with a total capitalization exceeding $200 million. Yozma is correctly given the credit for creating the VC industry in Israel in the 1990s.

'Yozma' fund-of-fund schemes [10] are terrific solutions if a country has a capital markets problem like Israel had in the early 1990s; proven technology but little access to global markets, little capital for commercialization and SME creation. At the time, Israeli technology came from strategic R&D investments made by the military and released to the private sector. Other success factors include an Israeli industrial policy that funded innovative basic and applied R&D to create deal flow, and the unlikely and unplanned creation of entrepreneurs through military training in the '8-200' intelligence unit.

Fund-of-fund strategies are not solutions if a country has a deal flow problem; when the quality and quantity of investment opportunities are just too low to meet the requirements of financial VC investors. Chile has experienced disappointment with its fund-of-funds initiative; few investments transacted by Chilean venture funds due to the low and poor quality of the deal flow, not a lack of money in Chile.

Poor quality or low deal flow is not confined to just the performance of the technology, but also the availability of good mangers and specialists to operate technology start-ups. In Russia for example, it's a challenge to attract good entrepreneurs and managers to technology SMEs. They have employment alternatives with better career opportunities, higher salaries and the potential to get rich quickly through an IPO in non technology like construction, retailing, branded consumers goods and transportation as examples.

from the private sector. All these initiatives are developed with the intention of taking a seat at the table of global technology development.

The private sector is active in the CEE, the CIS and Latin America too. Global powerhouses in multiple industries – Intel, Ford, TI, Nokia, Siemens, Motorola, Microsoft, Boeing, IBM, United Technologies, Samsung, Cadence and Sun – established R&D centers and selectively incorporated domestic technology into their products. A few international VC funds invested in Argentine, Brazilian, Hungarian, Mexican and Russian innovations.

Yet with all this capital and horsepower invested and to-be-invested, something is amiss in many emerging markets. A critical mass of seed and early stage SME investment opportunities do not exist for domestic or foreign VCs. This is not due to a lack of money as these economies are awash with capital and investors looking for opportunities.

Moreover CEE and CIS governments have advantages that their counterparts in Latin America, SE Asia and Africa lack; scientific accomplishments in defense, space and security that fed the Soviet military machine with cutting-edge universities and world class researchers in knowledge creation.

Innovators in Technology

Hungary-born American software developer Charles Simony led the development of Microsoft Excel and Word, products that revolutionized financial analysis and word processing to create billions of dollars of new wealth for his employer and himself.

In the 1950s, 43 horizontal oil wells were drilled in the Soviet Union, one of the most ambitious drilling efforts for the untested technology. Building on this work and that of U.S. scientist Lester Uren, Alexander Grigoryan put theory into practice by branching the oil wellbore, and in doing so, he became the father of multilateral drilling.

In 1953, the Soviets drilled a main bore in the Bashkiria field (Bashkortostan today) with nine laterals and a horizontal reach of 136m (446ft). Although the cost was 1½ times more expensive than other wells, it penetrated the oil reservoir 5½ times better and generated 17 times more oil per day. From 1954-1974 the Soviets drilled 110 multilateral wells; 30 of them drilled by Grigoryan himself. [5]

Other Russian technologies widely used in hydrocarbon E&P (exploration & production) include *in-situ* combustion and vertical seismic profiling (VSP), invented in 1957 by geophysicist Evsei Galperin of the Soviet Institute of Earth Physics. His VSP profiles showed the structure of seismic wave fields, which generated huge productivity gains in locating hydrocarbons more accurately. After 50 years of improvements by Western developers (led by Bob Hardage of Phillips Petroleum), VSP is used throughout the world.

With such technology successes in the petroleum industry and others in aerospace, IT and space exploration, investors and technology customers naturally look to the CEE and CIS for innovation in other spheres.

Few GameChanging Technologies

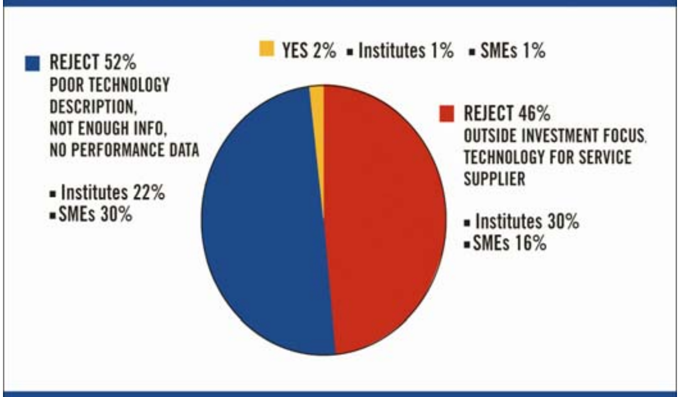
Over the last seven years, Innovative Ventures Inc., or IVI, and other VC investors evaluated hundreds of Russian deals in IT, telecoms, biotechnology, medical and others; yet collectively we have invested in only twenty-five or so. Likewise only a few dozen investments have been transacted in the CEE and the Baltics during the last ten years.

Specifically, over the past three years, we have looked at oil E&P technologies for investment. Our findings provide a microcosm and a reflection of current events in the market, and why so few VC investments in technology are made. Leveraging the Soviet science and scientific foundation into knowledge based economies is a real challenge.

In Russia for example, only 2% of the E&P innovations evaluated (**Figure 1**) have the performance characteristics that one might classify as disruptive, with superior performance or cost reduction features. Such Game-Changing benefits are required to attract international customers and investors and compete in global markets.

Even though the technologies evaluated had interesting features, they are not ready for customers or VC. They are R&D stage concepts and require money and time for testing and development, to get them market ready, cus-

FIGURE 1: OPPORTUNITIES AND DECISIONS



Source: Innovative Ventures, Inc., 2006

Box 2. What does VC invest in?

Money, innovation and hard work are the forces that drive entrepreneurship forward. Witness the super profits earned by the founders and investors in Skype, the VoIP telephony company. Skype began operations in 2003; eBay acquired the (unprofitable) company in 2005 for $2.5 billion+, an astronomical return on $20 million invested by Skype investors.

Contrary to myth, venture capitalists fund only a fraction of innovation vs. the investments in R&D by governments ($100+ billion) and corporations ($200+ billion). In clean technology in 2006 for example, corporations invested $22 billion in R&D, governments $24 billion, and VC investors just $2 billion worldwide. [11]

80%-90% of the money invested by VC pays for infrastructure costs required for SME growth, not technology development. VC is medium-term money, to build the SME to a sufficient size until it can be sold three-seven years later to a corporate buyer or to public market investors.

The niche for VC exists because of historical practices and inefficiencies in the capital markets. Technology is IP and banks won't lend unless tangible assets exist as collateral for a loan; the risks of start-up ventures require a higher interest rate than what banks can charge due to usury laws (e.g., in the US) and what SMEs can afford to pay.

Historically an SME needs sales of $10 million, several years of operating history (best with profits) and a balance sheet of several million dollars to access the public equity markets. In the US for example only 4%-5% of US corporations have sales $10 million or more, so newly created and growing SMEs are squeezed into a high risk, but high financial return niche for a particular type of investor; the venture capitalist.

The venture capitalist raises money from financial institutions like pension funds, insurance companies and foundations. VC invests in growing industries; investing in growth is more profitable and easier than investing in a slow or no growth market. While some exceptions do exist (e.g., biotechnology), the job of VC is to pick and invest in the right industry, take the market risk and management's ability to execute, not the technology risk.

Venture capital operates to the 2-6-2 rule of success; for every ten investments, two fail with all money invested lost, six generate a return equal to 1x or 2x of investment, and two are super winners (e.g., Skype) generating financial returns of 10x, 20x or even 100x of investment.

tomer ready and advanced enough for VC investment. Contrary to conventional wisdom, venture capitalists rarely invest in R&D (see box 2).

Our findings disprove the notion that Russian institutes and SMEs have great technologies, but investors are blind to the potential. No, what institutes & SMEs have are great ideas, but customers buy products not concepts, and investors invest in deals, not conceptual stage ideas.

Returning to Figure 1, 52% of the technologies were rejected due to poor descriptions of the value of the idea, inconclusive performance data and competitive benchmarking. Many ideas appear interesting and worth a second look if only reliable performance data was available. Rejection was not due to lack of intellectual property (IP), business plans, management or capital markets; typical reasons given as why so few VC technology investments are made in the emerging markets.

Good test data is essential to prove performance benefits. Once an SME decides to compete in technology markets, it positions itself against global competitors, many with closer and deeper access to customers and a customer orientation that provides buyers with the information they require to make purchase decisions.

Even with good performance data, attacking international markets requires disruptive technologies to overcome the purchasing habits of customers and penetrate established supply chains. However GameChanging technologies are far and few as they frequently result from coincidence and timing vs. planned innovation (Box 3)

If the chances of creating disruptive solutions are so slim, what can a country, its scientists, universities and SMEs do to get into the technology and commercialization business? Given so few GameChanging technologies in oil E&P, IT, biotechnology, etc., what can Estonia, Hungary, the Czech Republic, Russia and others with money and lots of talent but only ideas, do to build their place in the knowledge world? And what actions can Argentina, Brazil, Chile, Malaysia, Mexico, Vietnam and others adopt when they lack the technical foundation of Soviet science institutions?

Let's return to Russia to see what an alternative strategy might be and its learning curve lessons for emerging countries to move up the innovation chain.

Box 2. Moving Up the Innovation Value Added Chain

Small countries are at a disadvantage to larger ones in creating knowledge based economies. Fewer technology customers results in developers and investors applying their energy, intellect and capital to problems and needs in big markets. Yet within all countries, whether small or big, pockets of opportunities exist for SMEs to move up in the innovation value chain as the following three examples illustrate.

Incremental Improvements

Import substitution is only one aspect to building a supply chain and increasing local content by domestic SMEs. Adding more technology to increase product functionality and user experience is another strategy to build more knowledge based SMEs.

Donnelly Mirrors (DMI, now Donnelly Mirrors Magna) was a small family-held supplier of inside and outside automotive mirrors to the Big Three (Chrysler, Ford & General Motors). With revenues of $10 million, they were in a low tech, low valued segment of the business vs. suppliers of high value power train components (engines, transmissions) and other parts. Moreover DMI was headquartered in Holland, Michigan, out-of-sight, out-of-mind and geographically distant from their customers.

In the 1980s, DMI developed new skills in photo-electronics, glass/plastic fabrication, coatings and plastic molding; engineering embarked on a program to add new product content to mirrors and cost reduce production. Technical staff incorporated interior lighting and informational content to the mirror (through electronic sensors and microprocessor technology) that displays vehicle direction and temperature, both inside the car and on the street.

Not satisfied with just increasing driver convenience, engineering innovated in other directions; electro-chromic glass that keeps exterior mirrors clear from ice, rain, snow and fog, a value-added convenience that improved road safety and security for all. Improvements in small motor performance resulted in exterior mirror assemblies so drivers could move the position of outside mirrors from inside the car without taking their eyes off the road.

Over a ten year period these and other innovations led to an increase in sales to over US$300 million for DMI even as US domestic production slid to new lows as Japanese imports captured the hearts and pocketbooks of US consumers.

Entrepreneurial Resourcefulness

Backward thinking as a holdover of the Soviet legacy restricted growth in countries under their influence, even after the fall of the Berlin War, independence of the Baltics and freedom for states of the Former Warsaw Pact. Where some saw only bureaucracy and limited choices, others saw opportunity.

Riga, Latvia based SAF Tehnika was founded in the early 1990s by an engineer frustrated with the six year wait for a telephone line from the local telephone monopoly. Using his engineering talents learned at a former Soviet institute, he invented a microwave link that bypassed the local telecom. He provided dial tone to his neighbors through his innovation and later raised money from them, friends and family to offer his solutions to others.

Go forward fifteen years and SAF Tehnika now sells its telecom equipment in over forty (40) countries with its equity publicly traded on Riga's stock exchange since 2004.

Make Solutions from Problems

New innovations provide a set of benefits for customers and users. Yet all technologies have problems or inconveniences that set the stage for the creation of new SMEs, for new and more innovation.

Dr. Alejandro Zaffaroni, from Montevideo, Uruguay, earned his Ph.D. in biochemistry at the University of Rochester, the USA. Writing his dissertation on steroids, he started Syntex in Mexico City near a jungle where the plants grew for the raw material used in steroid production. The company grew rapidly as doctors and patents adopted their drugs for contraceptive and dermatological needs.

Pharmaceuticals at that time were delivered into the bloodstream by either inoculations or pills. While effective, their rapid release caused highs and lows of drug concentration in the bloodstream and steroids were no exception. Turning his attention to the side-effects of steroids, Dr. Zaffaroni developed new solutions to more slowly deliver drugs into the body through skin patches and time release pills. He launched Alza to manufacture and sell these products to market, innovations that spawned new thinking in drug delivery techniques.

Turn Personal Passion into Money [12]

Ole Evinrude's family immigrated to the US and he learned about machinery and mechanics by working on the family farm, working in factories and starting his own one-man motor shop. At a picnic on a hot day on the island of a Wisconsin lake, Ole's future wife Bess asked for some ice cream. The Norwegian made the three kilometer journey in his boat and oars, but when he returned, the ice cream had melted.

Thinking that a better way existed, Ole created a lightweight, detachable motor that could power small boats. He started a new company two years after making his 1st test, raised seed capital from a tugboat operator Chris Meyer, and obtained a patent in 1911, four years after his 1st prototype. Soon thereafter the company employed hundreds of employees with the advertising motto: "Don't row! Throw the oars away! Use an Evinrude motor."

Ole was forced from the business due to his wife's poor health and a bad relationship with Chris. In 1912, Ole began work on what would be the flywheel magneto, a major innovation that made starting and operating outboard motors easier for customers. In 1919, Ole showed Mr. Meyer drawings for a new lightweight motor, which Meyer rejected, a major mistake. In 1921 Bess and Ole Evinrude started a new company to market new light twin outboards, which became the industry standard, generating billions of dollars of revenue, making the lives of millions easier, more fun, and needless to say, helping sell more ice cream.

Information without Borders [13]

Larry Page and Sergey Brin initially disliked one another when they first met at Stanford, but they found common ground in solving one of computing's biggest challenges: retrieving relevant information from a massive set of data. In 1996, a year after their 1st meeting, poor, begging and borrowing university computers to build a network, their unique approach to link analysis was building a reputation. In 1998, they used credit cards to purchase a terabyte of memory to build their first data center in Larry's dorm room. Despite dotcom fever, they had little interest in building a company of their own, but instead, to license the technology.

Unable to interest the major Internet portals, Larry and Sergey decided to commercialize the technology themselves. All they needed was a little cash. So they wrote a business plan, put their Ph.D. plans on hold, and went looking for money. A Stanford friend introduced them to Andy Bechtolsheim, an angel investor and one of the founders of Sun Microsystems. Impressed with the demonstration but short of time he said: "Instead of us discussing all the details, why don't I just write you a check?' It was made out to Google Inc. for $100,000."

The investment created a small problem. There no legal entity known as 'Google Inc.,' and no way to cash the check. It sat for a few weeks until the two organized a corporation and raised a $1 million on the testimony of Andy's investment from family, friends and acquaintances.

In September 1998 three years after Sergey and Larry first met, Google Inc., opened its doors for business. The door came with a remote control, as it was attached to the garage of a friend's house who rented space to the new corporation. The office offered several big advantages, including a washer and dryer and a hot tub. It also had a parking space for the first employee hired: Craig Silverstein, now Google's director of technology.

Sources: Excerpts from 'The Story of Evinrude, http://www.tecsoc.org/pubs/history/2002/jul12.htm, http://www.boatmotors.com/outboard/evinrude/; "Google History." http://www.google.com/corporate/history.html

Overlooked Opportunities in the Domestic Sector

While few Russian innovations have GameChanging qualities for international buyers, others (Figure 2) have value in domestic E&P. Most were rejected as their technologies are behind those offered by international competitors like Schlumberger and Halliburton. But a few are low cost solutions that give customers (domestic and international oil companies) almost world class performance, but with lower prices compared to Western competitors. Low cost technologies attract price sensitive customers.

What makes this set of opportunities appealing is that they represent an alternative to pursuing a GameChanging strategy. Instead of trying to outperform international competitors on all fronts, one can build a locally competitive SME technology sector for domestic use. Once this base is established, invest new resources to develop their international capabilities for global marketing.

Several countries took a domestic approach to building more knowledge based content as the following examples illustrate:

Years ago the Israeli Government mandated that all Israeli homes have solar water heaters which resulted in an entire ecosystem of local manufacturers and suppliers. With growing interest in alternative energy for the 21st century, dozens of new Israeli start-ups are leveraging their solar expertise and innovating in photovoltaic cells, solar power, heating and lighting for global needs.

Estonia is one of the most wired countries in the world, due to the rapid adoption of technology by citizens and proactive support from the Government. Legislators introduced a number of reforms to bring Estonia into the information age, which stimulated innovation and technology development from the private sector.

E-school is an early stage company that sells a software solution that almost all schools in Estonia have adopted. Teachers send grades and attendance records to parents' computers or mobile phones; they receive an SMS if their child is absent from school. As this product is adopted in Estonia, opportunities open for E-school to sell to regional and global markets since its value is validated by Estonian users.

New Zealand proves that even the agriculture industry benefits from more technology and knowledge creation. New Zealand's transition strategy from low tech to high tech is illustrative of how a domestic focus created a technology SME industry.

In the mid 1990s, New Zealand government planners invested in biotechnology R&D to create more flavorful and different varieties of wine, cows and lamb with more meat and less fat. Their focus was on new solutions for domestic needs in agriculture and animal husbandry, not global biotechnology where New Zealand had little comparative advantage. Five years later, government initiatives yielded results and VC investors financed the commercialization of New Zealand SME innovations.

Today New Zealand meat and wine are found in Australia, Europe, Japan, Russia and the US. Their SMEs sell technology products and services to Australian, European and US wine producers and animal growers, truly a win-win for all.

Opportunities sometimes develop in the use of underutilized, domestic human capital to serve local and international markets and build a knowledge based service sector. In 2005 CzechInvest, the Czech Republic's business development agency and Cadence Design Systems, the US based electronic design house, formed ChipInvest at the Brno University of Technology. The center provides engineering talent from the CEE to chip companies worldwide.

ChipInvest is focused on global needs for engineering skills in analog design, which converts temperature, light and sound into the 1s and 0s needed for digital processing. In the 1980's the digital revolution shifted work from analog to digital with analog relegated to Europe due to its strength to serve its customers in the automotive and telecom with mixed signal designs.

ChipInvest is making use of knowledge learned under Soviet control, talent in short supply now. Closed Soviet and E. European universities emphasized analog skills as they were cut off from the global race to shrink circuits. With limited resources and money, engineers had to find ways to make due with what they had. That skill is in high demand now as cost pressures force work out of W. Europe and transform ChipInvest into a microelectronics R&D magnet for global and domestic customers.

The GoForward Plan in Technology and Knowledge Creation

Given higher probabilities of growing a locally competitive technology sector, a GoForward strategy consists of building technology platforms in and around domestic assets rather than diversifying resources ***away*** from home market advantages like natural resources, energy and commodities. And if overlooked potential exists in technology for the domestic sector, then how does one do a better job in identifying opportunities early, to nurture them into commercialization?

Action Item #1: Target Domestic Users First

SMEs and governments cite the low absorption rate of technology by domestic users as the reason to pursue a GameChanging innovation strategy for world markets. Yet every country has industries that are knowledge based; some are clusters formed around a particular industry while others exist from natural advantages.

The automobile industry is a technology cluster with excellent growth in Latin America, the CEE and the CIS as Ford, General Motors, Toyota, VW, Peugeot and others increase production in Argentina, Brazil, the Czech Republic, Hungary, Russia and Slovakia to meet customer demand. These auto multinationals need to build the domestic auto component supply chain to a Western equivalent to meet their business plans just as Shell, Chevron, LUKoil, KazMunaiGaz, PETRONAS, Petrobras, Pemex and others seek more and better oil field service suppliers in the CIS, SE Asia and Latin America.

When all fails, some creativity and initiative may be necessary

Both industries struggle to localize more local purchasing and satisfy local content commitments. "The local car industry 'is handicapped by the quality of local suppliers, who are far below world standards,' said Carl Hahn, chairman emeritus of Volkswagen. 'That's the most challenging part for our team' Skoda chairman Detlef Wittig said." [6] In Argentina, the auto parts sector attracted new firms and investment of $1.75 billion, but the number of domestic suppliers fell from 1,200 to 400; [7] their demise was due to a lack of product quality, investment and technology.

Yet the GoForward plans of many governments are to build knowledge based sectors like IT, bio & nanotechnology, etc., but not technology investment for domestic needs in auto components, oil field services, mineral extraction/processing and alternative fuels; sectors with immediate payoffs to catalyze a chain reaction in domestic technology absorption.

Israel is well known as a powerhouse of GameChanging technologies for global markets. What are less known are the innovations of Israelis for domestic use, e.g., solutions for clean and pure water. Israel could have had a water shortage as its population surged from less than one million in 1948 to more than seven million in 2006. [10] But it didn't due to actions of the Government in technology.

To provide the fresh water needed for life, the Israeli Government sponsored R&D in low pressure irrigation systems (for agriculture), rain harvesting, wastewater treatment and desalination. The private sector built on these foundations to innovate water security/management, onsite biological treatment of solid waste, medical waste and biologically contaminated materials to name a few. While the focus was and is on domestic demand, pure water needs from global customers stimulated the creation of an new Israeli export sector for clean water technology that now exceeds $800 million/year.

With a proposed new government investment of $160 million over the next five years, Israeli firms are projected to increase exports of clean water technology to $2 billion by 2010, $5 billion by 2015 and $10 billion by 2020 in a world water market estimated at $400 billion a year with growth of 7%/year. [9] With citizens of Planet Earth forecasted to have a 35% water shortfall over the next 15 years, luck (opportunity + preparation) and timing again work to the favor of Israeli SMEs and their VC investors.

Other SME development approaches are possible to build technology sectors for domestic needs, when single technology hubs are less obvious, e.g., in logistics, where multiple technologies intersect. For instance, Latvia sits on the Baltic Sea with new technologies required in IT, warehousing and transportation to grow a nascent logistics platform into a regional distribution powerhouse.

Russian and international corporations are establishing back office administrative centers in Siberia, Budapest, Tallinn and other cities to escape high cost Moscow thereby stimulating new clusters and VC investment opportunities. The city of Kirov a small Russian regional city with a population of about 500,000 and 1,200 kilometers from Moscow is funding bio-clusters to manufacture creams, lotions and emollients used in the domestic production of everyday cosmetics.

Action Item #2: Provide 'Mini Grants' to Document Business Opportunities

Once domestic industry technology hubs are identified, fund a 'mini-grant' program to define the business opportunity for proposed technologies. A mini-grant of $3,000-$10,000 is not intended to fund an entire business plan, but a 3-4 page document detailing the technology's potential.

Action Item #3: Capitalize a 'Proof of Concept' Fund

Commercialization of new technology starts with R&D and product development to demonstrate 'proof of concept' and the value of novel ideas. SMEs are only able to approach customers and investors when they clearly present technology strengths and weaknesses, conducted through a comprehensive analysis under different user conditions.

A 'proof of concept fund' finances the costs of testing a technology and benchmarking it to direct competitors, alternatives or substitutes. To invest capital wisely, mandate that developers and SMEs benchmark the technology early and often to products/services that buyers purchase from domestic or international competitors.

Action Item #4: Inventory SME/Institute Technologies and Publish as a Database

Provide an Organizational Service (OS) that gives customers and investors the information needed to consider technology from your country:

SMEs/institutes organized by technology, product & market segment, with full contact information

Benefits of the technology with performance & cost benchmarked against domestic and international competitors with data generated to international testing standards

Stage of development, meaning R&D, product development, alpha or beta testing

Product development plan with timetable & milestone inflection points, line item budgets

Patents issued or filed, by country, date and number, & competing technologies similar in form or function

Publish this information as an Internet database and searchable by keywords like technology or market.

Action Item #5: Establish an IP Facility to Protect Your Country's Intellectual Assets

The IP Facility pays legal costs of filing domestic or international patents with costs reimbursed through revenues generated from product sales. Royalty repayments replenish the Facility so it becomes a revolving instrument with a one-time investment.

Action Item #6: Offer Targeted Business Development Support

Innovations too often sit on the shelf since scientists lack the knowledge to make the business case for the technology, the energy and drive to move them into the market. Many scientists and (some) development stage SMEs lack the skills to make the transition from development to commercialization and growth.

Establish a business development office which actively 'scouts' for opportunities in the SME community and academia. This office identifies and develops projects for financing by the 'mini-grant' program and 'proof of concept' fund, and helps sell innovations from academia/SMEs to customers.

One responsibility of the business development office is to identify IP early in the development cycle and work with legal council to protect it. Scientists and businessmen are rightfully proud when they create new innovations. Yet they sometimes announce their solutions in the public domain before protecting them and inadvertently weaken their legal rights. Business developers must educate scientists and SME managers to the issues of IP, what can and can't be said in public.

Action Item #7: Organize R&D & Supply Chain Competitions for Users of Technology

R&D competitions are used in combination with VC forums or a substitute when deal flow is too scarce to attract VC investors. R&D competitions present technology, to generate interaction between technology developers and the R&D staff from corporations. R&D competitions are organized in areas like nanotechnology, alternative energy, green technology, engineered materials and biotechnology as examples. The audience is corpora-

Box 3. Integrating Multinationals into the Innovation Ecosystem

Corporations are entering a 3rd stage of evolution, a change that bodes well for emerging market SMEs and their governments. The 1st stage was the 19th century's 'international model' when corporations established sales offices in foreign countries, with minimal economic impact on host countries.

When I worked at Ford Motor Company in the 1970s, it grew by replicating itself with small versions of 'me-toos' in foreign countries, each with their own management, manufacturing, logistics, purchasing, HR and supply chain operations and staff. This 2nd stage is being replaced by 'globally integrated enterprises,' executing their strategies, operations and investments where work is best done.

Instead of having separate supply chains for different markets, 3rd stage global enterprises have an international footprint with a single supply chain. Such innovation means new opportunities flowing to countries and SMEs with the right skills and a focus on expertise, openness and/or cost.

Cheap is not the only strategy for growth; if it were, pharmaceutical multinationals would not be building new R&D centers in Europe, Japanese auto firms would not be adding manufacturing capacity in the US and companies like IBM would not be conducting R&D in Bangalore and operating their financing back office in Rio De Janeiro.

Internationalization of the supply chain benefits all; it enables emerging market SMEs to learn from global players, accelerating skill transfer and knowledge creation to start locally and grow globally, it enables multinationals to capitalize on local resources and talent.

Multinationals hunt for technologies and ideas independent of their origin, and they are able to benchmark technologies from one country to another, to help developers identify strengths and weaknesses of their technology to global competitors. Others have a strategic priority to integrate technology as supply chain linkages, thereby stimulating innovation, growth and job creation in ways such as:

1.) to be the technology platform that helps SMEs model and scale their solutions in advance of customer demands
2.) to reduce development time and get to market quickly
3.) to lower investment risk and help SMEs secure funding
4.) to enable the jump-start of sales
5.) to expand the market reach of SMEs by integrating them into corporate & international business ecosystems.

Untapped potential exists in many developing countries. So how might a globally integrated enterprise increase its contribution to emerging country innovation ecosystems and benefit itself at the same time? Let me make this suggestion.

Mix and match domestic and foreign technology to create new business models—Western companies frequently learn that their solutions are better but too expensive for domestic buyers when they sell to local customers. Consequently their products are confined to niche applications with limited revenue potential.

In order to reduce cost, combine domestic technology with complementary technology and people skills from the West. For the measurement of pressure and temperature in oil wells, the price of a distributed pressure/temperature system from a UK- based SME was reduced by 20% thanks to a Russian SME innovation in fiber optics. This cost reduction expanded sales to oil companies operating in the CIS and abroad.

Linking these two companies generated other benefits. It accelerated commercialization for the Russian counterparty since it lacks the international sales, distribution and service networks of the foreign SME. This supply chain partnership builds their international reputation and demonstrates their dependability as the prelude to selling directly to end users in oil producing regions of the Middle East and North Africa.

Governments not need start from scratch when it strives to integrate the domestic economy into the global knowledge economy. Instead it can tap Western ideas, management and system skills and link them to domestic counterparties—institutes and SME s—through appropriate economic incentives and by investing in the education and the technical skills of its people.

tions and corporate venture capitalists, not financial VC investors.

Attracting large corporations to R&D competitions has many benefits. They are able to invest in promising technologies, guide development with customer feedback, speed commercialization and help access opportunities in the supply chain (box 3).

The venture capital arms of multinationals are especially helpful to scale up the innovation ecosystem. They create leverage in the market like Intel Capital's dedicated $50 million VC country fund to finance Brazilian technology, and Microsoft's Innovation Centers, stimulating interaction in the infrastructure resulting in more innovation and more Brazilian software startups being funded. And they add-value in ways that financial venture capitalist can't.

Corporate VCs take technology risks by investing VC in the R&D of young SMEs, and invest directly in IP with technology right-of-use, a structure that accelerates the diffusion of technology to markets and customers. They also provide access to corporate R&D budgets for the funding of technologies at their early stages of development, before financial VCs are able or willing to invest.

Corporations help SMEs apply their technology to customer needs. As Esther Dyson, an investor in emerging market startups remarked: "One thing that the [emerging] market requires is a more demanding customer base. They need to become better buyers and users. They have all the necessary technical skills, but they don't have the business experience to apply the technology as well as they should."

Concluding Remarks: The Role of Governments in Technology Creation

Knowledge-based and entrepreneurial economies can't happen without the political will and investment of federal and national governments. Knowledge creation touches on so many of their duties like education, public investment in basic and applied R&D, economic incentives to invest in private R&D, innovation, trade and investment policies and the enabling environment, just to name a few.

Achieving political consensus on the mission and the means to fund the execution of this facilitator role can be a challenge. Therefore, some governments take intermediate and smaller steps that are achievable and realistic in the move towards knowledge creation.

In the case of Israel, the Government legislated to save energy and reduce dependence on foreign hydrocarbons, to increase its security in an insecure region of the world. The Estonia Government acted to speed its integration into the global economy after decades of being a closed society under Soviet domination. The Government of New Zealand funded R&D for agricultural applications to improve domestic products. Initiatives of all three set the stage for new knowledge creation by the private sector; start-ups formed to satisfy market needs, provide more innovation and creativity with positive effects far beyond their original missions.

African governments want more knowledge creation for their countries and citizens too. Yet the development of home-grown African technologies is unlikely to happen until more of the building blocks of an innovation ecosystem are present, e.g., research institutes collaborating with like-minded international universities in collaborative research, doing contract research for large and small companies alike, and grant making schemes to provide the R&D financing that SMEs need to upgrade their technology and technical skills to compete for supply chain contracts as examples.

Small but measurable steps are being taken by African entrepreneurs themselves to integrate into the global community. Export oriented flower suppliers imported foreign technologies, adopted new ideas and business processes to improve yield, reduce cost and the time to get fresh flowers from the field into the vases of customers around the world. Domestic SMEs in agriculture, natural resources and minerals invested donor monies to adopt best practices in production and processing to win more supply contracts and used profits to fund new product development programs; all with the intention of dominating small, local markets. Such efforts build a reputation of quality products and services with the reliability, performance and cost standards that global customers expect.

About the paper and author

[1]This article is an adaptation of the author's article that appeared in the July/August 2007 edition of the Harvard Business Review (Russian edition) and the November 2007 issue HBR, Hungarian edition.

[2]Venture capitalist Thomas D. Nastas is president of Innovative Ventures Inc., the USA & Russia (www.IVIpe.com, Tom@IVIpe.com). He also organized three funds in Africa for the World Bank/IFC. Mr. Nastas is also Instructor of Marketing, American Institute of Business and Economic College, Moscow.

Endnotes and references

1. National Venture Capital Association, Arlington, Va., (www.nvca.org) & Global Insight Inc., Waltham, MA., (www.globalinsight.com)
2. Venture Economics, Boston, MA, (http://www.thomson.com/solutions/financial/privateequity), National Venture Capital Association, Arlington, VA., (www.nvca.org), ThinkEquity Partners (http://www.thinkequity.com) & CapitalIQ (http://www.capitaliq.com)
3. Blog posting of Dan'l Lewin titled 'Innovation vs. Invention,' 16 November 2005, (http://alwayson.goingon.com/permalink/post/1508). Dan is VP, Net Business Development, Microsoft
4. Blog posting of Dan'l Lewin titled 'Travels with Dan'l. Part 1, The Perception & Reality of Innovation Abroad,' 8 Feb., 2006, http://alwayson.goingon.com/permalink/post/1510
5. Source: Society of Petroleum Engineers Web site (www.spe.org), Oil & Gas Basics
6. 'A Lot of Car Plants but not Enough Parts,' by Anna Smolchenko, Moscow Times, page 1, 30 March 2007
7. http://209.85.129.104/search?q=cache:pRVcnI8zP3YJ:www.brazil.ox.ac.uk/confreports/Conf%2520Report%2520%2520Auto%2520Industry%2520Reform%252015.11.04.pdf+Developments+in+Auto+Sector+in+Brazil&hl=en&ct=clnk&cd=17
8. 'Innovations in Water Solutions: Where Israeli Companies are Making Waves,' Israeli Venture Capital Journal, May 2007
9. Ibid, Israeli Venture Capital Journal, May 2007
10. See web site ifise.unipv.it/Convegno/Evolution%20of%20th%20-%20Kaufman.ppt for a review of the Yozma scheme
11. 'Global Spending on Cleantech R&D to Rise,' by Andrew Quong, Red Herring, 31 May 2007 Red Herring
12. Excerpted from 'The Story of Evinrude, http://www.tecsoc.org/pubs/history/2002/jul12.htm, and http://www.boatmotors.com/outboard/evinrude/
13. Excerpted from "Google History." http://www.google.com/corporate/history.html

Knowledge, Technological Learning and Innovation for Development: The Findings, Arguments and Recommendations of UNCTAD's Least Developed Countries Report 2007

Charles Gore, Zeljka Kozul-Wright and Rolf Traeger *

Abstract

This paper summarizes the main findings, arguments and policy recommendations of UNCTAD's *Least Developed Countries Report 2007: Knowledge, Technological Learning and Innovation of Development*. It shows that although most of the least developed countries (LDCs) are closely integrated into the global economy through trade and foreign direct investment, their level of technological development is very low and the capabilities of their domestic firm and farms to acquire and effectively use technology is very weak. The current situation is one in which there is liberalization without technological learning and global integration without innovation.

In a situation where international markets are not working to support the international diffusion of technology, there is a strong case for ODA to support technological development. But in practice aid for science, technology and innovation (STI) in LDCs is very weak both in quantitative and qualitative terms. In addition, many LDCs are being adversely affected by emigration of skilled personnel, and some asymmetries within the international IPR regime can discourage technological catch-up in LDCs. Nevertheless there are constructive and pragmatic policies which can be adopted to support the promotion of STI for development in the LDCs. The paper summarizes the current situation and makes some key practical policy proposals.

Introduction

Since 2000, UNCTAD has published a series of flagship Least Developed Countries Reports which are devoted to examining how development can be started and sustained in the poorest countries in the world (UNCTAD 2000; 2002; 2004; 2006; and 2007). The Reports are based on the view that much development thinking is derived from, and oriented to, the conditions of more advanced developing countries and that there is a need for deeper analysis of the challenge of development in very poor countries. Together, these reports have undertaken a critical assessment of current national and international policies to promote development and poverty reduction in the least developed countries, and also proposed constructive and pragmatic policy alternatives.

The Reports have elaborated a production- and employment-centered approach to development and poverty reduction which is distinct from both the World Bank and IMF approach to economic reform and also UNDP's human development approach. This approach is set out most fully in *The Least Developed Countries Report 2006: Developing Productive Capacities*, and it is deepened in *The Least Developed Countries Report 2007: Knowledge, Learning and Innovation for Development*. The present paper provides a summary of the main findings, arguments and policy recommendations of the latter Report, which was published in July 2007.

The overall argument of the Report is that to escape the current trap of poverty, underdevelopment and marginalization, the governments of the least developed countries (LDCs) and their development partners need to adopt new policies designed to narrow the technology

Moving up the technological ladder?

gap between themselves and the rest of the world and to increase the knowledge-intensity of their economies. This argument is based on three propositions: 1. Science, technology and innovation (STI) matter even in the poorest countries, 2. Current policies to promote STI in LDCs are unsatisfactory and 3. There are constructive and pragmatic alternative policies to promote STI available to LDC governments and their development partners.

This paper summarizes the main findings, arguments and recommendations of the Report in relation to each of these propositions. Attention is paid to both national policies and international policies, with specific attention to the weaknesses of the current policy configuration and possible alternatives in the areas of: (i) aid for STI, (ii) the intellectual property rights (IPR) regime, and (iii) the brain drain.

STI Matters Even in the Poorest Countries

The Report is founded on the view that sustained economic growth and poverty reduction in the LDCs requires the expansion of their productive capacities in a way in which the population of working age becomes more and more fully and productively employed. The development of productive capacities of a country occurs through two major processes – capital accumulation and technological change – which in turn lead to structural change. Capital accumulation and technological change are closely interrelated processes but each requires the mobilization and application of different key elements. On the one hand, capital accumulation requires the mobilization and investment of financial resources. On the other hand, technological change requires the mobilization and application of knowledge. Finance and knowledge are the key ingredients for the development of productive capacities.

Finance and knowledge are inseparable twins in successful processes of development. But in national and international policy debates the spotlight has usually been on finance rather than knowledge. Knowledge is the neglected sibling in national and international development policy. Around the notion of financing development, there is a common vocabulary and accepted terminology. But in policy terms, what does it mean to mobilize and invest in knowledge for development?

One focus of attention might be investment in education. Another focus of attention may be investment in information and telecommunications infrastructure and bridging the digital divide. Both of these issues are certainly important. But in the LDC Report 2007, the focus is on how technological change can happen in LDCs, and more particularly how knowledge is commercially applied in production by firms and farms.

For poor developing countries, innovation occurs through technological learning. LDCs cannot be expected to be at the global frontiers of technology. But innovation occurs when enterprises introduce products which are new to them or to the country. Such a form of innovation – which differs from the commercial application of inventions which are new to the world – depends on enterprises learning to master, adapt and improve technologies that already exist in more technologically advanced countries.

This is not a passive process but an active process of learning, assimilation and creative imitation in which physical technologies and skills concerning their use, as well as associated organizational routines, are applied and adapted in new contexts. Such adaptation often requires a blending of foreign and local knowledge in new ways. This is a process in which the absorptive capabilities of firms and farms, and also of the domestic knowledge systems within which they are embedded, are critical. Such absorptive capabilities encompass not simply the ability to access knowledge, but also the ability to assimilate and use it in local conditions.

This type of innovation is not a matter of hi-tech production. It involves rather the incremental introduction of new ways of doing things by firms and farms, as well as their introduction of new products and their targeting new markets. It is this myriad of small and large innovative acts which underlie improved productivity, increase local value-added, increased competitiveness, better quality products and the introduction of new activities into an economy.

It is through these innovative acts by firms and farms that LDC economies can move away from strong dependence on primary commodities and low-skill manufactures.

It is through these innovative acts that substantial poverty reduction will occur – though the relationship between technological change and poverty reduction is complex depending on the labour-intensity of technology and also on the economy-wide processes of creative destruction in which employment opportunities decline in some sectors whilst they expand in others through technological change.

It is through these innovative acts that LDCs will reverse their marginalization in the global economy and start to achieve catch-up growth. The marginalization of the LDCs ultimately reflects the fact they are falling behind other countries technologically. Unless LDC governments and their development partners adopt policies which help stimulate technological catch-up they will continue to fall behind.

Weaknesses of Current National and International Policies

When one looks at where LDCs currently stand in terms of their level of technological development and the capabilities of their domestic firm and farms to acquire and effectively use technology, the situation is depressing. Their domestic knowledge systems which enable the creation, accumulation, use and sharing of knowledge are also ineffective and divorced from production needs. Like the domestic financial systems of which they are a key counterpart, they are dualistic – separated into a traditional and modern knowledge system. Moreover, they are weakly integrated with the rest of the world. The state of technological underdevelopment of the LDCs is an expected pattern as weak technological development and economic underdevelopment go hand in hand. But what is perhaps remarkable in the current situation – and also perpetuating the current situation – is the failure of both domestic and international policy to address the problem.

This is particularly paradoxical as a key insight in the understanding of processes of economic growth in the last 25 years – perhaps the key insight – is that technological change is central. But neither LDC governments nor their development partners are seriously drawing policy implications from this.

For the LDCs this is a long-standing neglect. It is worth noting in this regard that the year 2007 is the 25th anniversary of the global introduction of structural adjustment programmes. Some LDCs began implementing these programmes right back in 1982, but since the late 1980s they have been particularly intensely implemented by the majority of the LDCs. Active promotion of technological change has not been part of these policies. Indeed SAPs often sought to dismantle the institutions and incentives of active agricultural and industrial development policies which – though certainly often flawed in design - were at the heart of developmentalism of the 1960s and 1970s and which usually involved the promotion of technological change as a central element.

Since 2000, SAPs have been replaced by PRSPs. But the new poverty reduction strategies continue to have the classic SAP recipe of stabilization, liberalization and privatization at their heart, with the addition of social elements. Technological change has not been conceptualized as critical to processes of poverty reduction. Thus, for example, there is no chapter of the World Bank PRSP Sourcebook on this issue. Moreover, only 4 out of a sample of 11 recent PRSPs undertaken in LDCs include science and technology as a priority policy for poverty reduction. The latest poverty reduction strategies are all committed to economic growth as a basis for poverty reduction. But essentially they ignore one of the key sources of economic growth – technological change – and the role of national policy in promoting such change in a way that enables both economic growth and poverty reduction to occur.

The present national policy configuration is based on a flawed understanding of how technological progress occurs in follower countries. The basic assumption is that openness to trade and investment, coupled with investment in basic formal education and more lately also investment in ICT infrastructure ("closing the digital divide"), will automatically lead to transfer of technology. But in practice, this has not worked. The Report provides evidence to show that this underlying assumption is false. Access to technology is not equivalent to its effective acquisition and use. International transfers of technology to LDCs are not occurring through international market linkages.

The current situation is one in which there is liberalization without technological learning and global integration without innovation. LDCs are already highly integrated to the world economy in terms of trade and investment flows. Exports and imports constitute 50 per cent of GDP, and FDI is equivalent to almost one fifth of gross fixed capital formation. But strong market integration through trade and FDI is associated with weak technology acquisition in LDCs and also weak development of the capabilities required to facilitate the effective use of technology diffusion.

Some fact and figures from the Report can show this.

⇒ First, LDC investment in imported machinery and equipment -- which is a major channel for the arrival of new technology -- is very low. In 2000-2005, LDC capital goods imports corresponded to 6 per cent of GDP, only half the level for ODCs.

- ⇒ Second, participation in international value chains -- in which products go through numerous steps from raw materials to finished forms -- are doing do little to infuse technology into LDCs. Processes of export upgrading have various dimensions. But an analysis of 24 value chains in which LDC exports play a role shows that export upgrading in the sense of increased processing of raw material before export has only occurred in 9 of them since the 1990s, involving just 18% of total merchandise exports from LDCs.
- ⇒ Technological "spillovers" to domestic firms are expected from foreign direct investment (FDI) in LDCs. But in African LDCs, most FDI is focused on mineral extraction, and spillover into domestic firms is limited. In Asian LDCs, case study evidence shows that the rapid growth in FDI in garment manufacturing has not led to a corresponding development of domestic firms' technological capabilities.
- ⇒ Technology licensing -- payments for the right to undertake activities protected by patents -- in LDCs is very weak and has been stagnant since the 1990s. On a per capita basis, it is 80 times higher in other developing countries than in LDCs.

In the present situation where international markets are not working to support the international diffusion and assimilation of technology, there is a strong case for official development (ODA) to be used to ensure through public action that technological transfers occur and domestic capabilities are developed so that technology can be acquired and effectively used. It is likely that there needs to be a minimum threshold level of domestic technological competences and capabilities in place before market forces start facilitating international technology flows. But in practice aid for STI is very weak both in quantitative and qualitative terms.

The quantitative situation is difficult to portray because an aspect of donors' failure to recognize the relevance of STI is that they do not monitor aid for STI. But focusing on just two categories – aid for research and aid for advanced skills – one finds that these activities receive only 3.6 per cent of total aid to LDCs. Moreover, most of it goes to higher education. There is a particular stark failure to support technological development within firms and farms, which are the places where technological change occurs. Aid commitments for agricultural research, extension and education within LDCs are actually falling. Aid for industrial technological development in LDCs – a category which includes industrial standards, quality management, metrology, testing, accredition and certification – is even more insignificant than for agricultural development. Technological upgrading is also generally overlooked within the Aid for Trade initiative which is presently being developed and also within the Integrated Framework for LDCs, with the issue of building supply-side capacities being conceptualized more in terms of the provision of physical infrastructure.

The quality of the aid for STI which is actually provided to LDCs is also unsatisfactory. Aid projects to deepen domestic STI capacity are disjointed rather than systemic, and STI policy capacity-building in LDCs ignored. Global linkage initiatives, such as international scientific cooperation and business-to-business matchmaking schemes, tend to exclude LDCs. The provision of global and regional public goods in terms of scientific research is not sufficiently responsive to LDC needs.

Technical cooperation could be an important avenue for building domestic technological capabilities. Free-standing technical cooperation is actually defined as "the provision of resources aimed at the transfer of technical and managerial skills or of technology for the purpose of building up general national capacity". But in practice this transfer of skills and technology is going mainly to support social sectors and particularly governance, rather than productive sectors and the capabilities of private firms and farms. In fact, in 2003-2005 aid commitments to LDCs for technical cooperation in relation to governance were equivalent to $1.3 billion per year, whilst the total annual aid commitments to agricultural extension were $12 million.

On top of the omission of technological change as a central objective of the national policies of LDC governments and of the aid policies of their development partners, another weakness of the current policy configuration is that there are some disturbing asymmetries within the international IPR regime that can discourage technological catch-up in LDCs. This is important as innovation and technological learning in developing countries depend increasingly on the intellectual property rights (IPR) regime.

In this regard, LDCs theoretically have a window of opportunity. They are subject to the same rules as other countries but they have a breathing space in the sense that until 2013 they do not have to apply global IPR norms as mandated by the TRIPS Agreement of the World Trade Organization (WTO). However, in practice, this breathing-space has become more hypothetical than real. TRIPS-plus obligations are being written into free trade agreements, bilateral investment treaties, regional organizations and also into the terms of accession of some LDCs to the World Trade Organization (as happened for example with Cambodia). This is of particular concern because it is evident that creative imitation is at the heart of technological learning and innovation in circumstances of catch-up. This was how successful developing countries assimilated technology in the past and it is also critical for follower countries to catch-up now.

A case study of the impact of IPRs in Bangladesh was undertaken especially for the Report and it shows that the IPR regime is mainly benefiting TNCs and that domestic companies are not benefiting from it as innovation is not occurring through invention. Indeed many domestic firms are worried abut the negative impact of IPRs as many patents are being taken out by non-residents as a defensive monopolistic strategy and the cost of key inputs, such as seeds, is rising.

The final weakness of the current policy configuration is that there are no effective national or international initiatives to deal with brain drain from LDCs. This has become a significant problem for many LDCs. The loss of skilled people is adversely affecting the quality for governance and also endangering the development of private sector technological capabilities. The available statistics show that brain drain is high and intensifying in many LDCs. In fact, 1 million out of 6.6 million people from LDCs with tertiary level education qualifications are working in developed countries. Moreover 12 LDCs have lost more than one third of their qualified professionals to emigration in recent years.

Constructive and Pragmatic Proposals

3.1 National Policies

What can be done? The Report argues that there are constructive and pragmatic possibilities for new national and international policies. Indeed, focusing on innovation and technological learning can potentially offer a new departure after 25 years of structural adjustment programmes, either in their initial form or adapted with social elements in the transformed medium of PRSPs.

In terms of national policies, the Report argues that LDC governments should integrate STI policies into their development strategies and poverty reduction strategies. Successful developing countries adopted technological catch-up with more advanced countries as a strategic goal and there is no reason why LDCs should not do likewise. However, it will be necessary to adapt policies to the challenges of the earliest phases of catch-up.

The precise nature of the policies will depend on each country. But the Report argues that given the employment transition they are experiencing, with an increasing number of persons seeking employment in cities, they should promote technological change in both agriculture and non-agricultural activities.

For agriculture, what is critical is the promotion of science-based agricultural productivity growth, particularly through a Green Revolution in basic staples. This will require increased investment in adaptive research and extension as part of a broad effort to promote agricultural development. This includes infrastructure investment and improved marketing.

For non-agricultural activities, the key is to promote business formation and upgrade the core competences and technological capabilities of domestic firms. This will involve training and skills development in design and engineering as much as the encouragement of R&D. What matters in particular is to increase the absorptive capabilities of firms, i.e. their ability to search for and use technologies and information which are available elsewhere, and to blend them with their existing knowledge to improve their practices. For this, the improvement of the domestic knowledge systems - the networks connecting the users of knowledge (private enterprises) and the providers of knowledge, notably research institutes and technology centres - is also important, as well as the leverage of more learning from international linkages through FDI and global value-chains.

There are difficult implementation issues and the promotion of learning does not mean going back to old style industrial policy. But there will be need for providing incentives to promote learning and innovation as these are risky activities. Moreover there is a need for a mix of horizontal measures to encourage innovative activities by domestic firms as well as targeted measures which foster innovation through dynamic linkage effects, such as the development of rural non-farm productive activities and also value-added production clusters associated with exploitation of natural resources.

3.2 International Policies

A critical aspect of technology issues is that they cannot be solely dealt with in a national context. They have national and international dimensions and thus action by the development partners of LDCs is necessary, as is the creation of international arrangements which can enable rather than constrain innovation and technological learning. In this regard, the Report points to action that is required in three main areas: the IPR regime; brain drain; and knowledge aid.

3.2.1 The IPR Regime

The major recommendation of the Report in terms of the TRIPS Agreement of the WTO is that realistic deadlines be established for compliance with global IPR norms. The Preamble to the TRIPS Agreement gives the LDCs a grace period on the grounds that this will allow them to establish a "sound and viable technological base". But is it realistic to expect that this will occur by 2013. The Report argues that this deadline is arbitrary and thus the transitional period should last until the LDCs have achieved "a sound and viable technological base".

On top of this the Report recommends that Article 66.2 of the TRIPS Agreement should be clarified and effectively operationalized. The Article foresees that developed countries will grant incentives for the transfer of technology to LDCs. But as yet nothing has been done to make this a reality.

The Report also argues that technical assistance for LDCs with regard to IPRs should be unbiased and development focused. In addition TRIPS-plus provisions should be excluded from bilateral and regional agreements and should stopb being a requirement for other LDCs acceding to the WTO.

Finally, it is recommended that LDCs should not focus exclusively on IPRs as an incentive mechanism for innovation but rather explore alternative ways to incentivize innovation. In this regard, such mechanism as open source software, publicly-funded research, patent buy-outs and development prizes may be particularly promising.

3.2.2 Brain Drain

With regard to the emigration of skilled persons, the critical policy issue is to transform brain drain into brain circulation. This requires actions by the LDC themselves, in particular to encourage return –especially short-term stays which can be used to transfer skills – and also mobilize the knowledge resources of the diaspora. But acion by development partners which are destinations for emigrants is also vital. In this regard, possible measures include:

- ⇒ Hiring on a temporary rather than permanent basis
- ⇒ Establishing development assistance programmes which help LDCs to retain their professionals
- ⇒ Creating programmes to help skilled emigrants return to their home country
- ⇒ Avoid hiring some professionals most urgently needed in LDCs (which is a complex issue)

Ultimately the brain drain problem will only be solved through the development of economic opportunities in the LDCs. Continued economic marginalization will not be conducive to converting brain drain to brain circulation.

3.2.3 Knowledge Aid

The case for ODA is usually made on the basis of the lack of domestic financial resources. But knowledge is equally important, as we pointed at the beginning of this presentation. Donors are not insensitive to the importance of boosting the role of knowledge in development. But they have tended to focus on using knowledge to improve aid delivery rather than to support knowledge accumulation in partner countries. Such aid – knowledge aid – can be a key to aid effectiveness, and aid for STI is an essential part of this. Such aid is a type of aid which is not a hand-out but a hand-up.

Conclusion: In terms of aid for STI, the Report makes a series of recommendations.

Firstly, it is important to boost aid for agricultural research, extension and education in LDCs. Agricultural research intensity (agricultural R&D as percentage of agricultural GDP) in LDCs is at the lowest level since 1971 and has been falling in recent years. It will be difficult for LDC governments to increase it without foreign aid. Donors must reinforce their support to the network of international agricultural research centres under the umbrella of the Consultative Group on International Agricultural Research (CGIAR) and ensure that its work is oriented towards increasing agricultural productivity of smallholders.

Secondly, it is suggested – as in the UN Millennium Project Report *Innovation: Applying Knowledge in Development* led by Professor Calestous Juma – that aid-funded physical infrastructure projects should all be designed in such a way that they support the development of domestic design and engineering capabilities. In other words, a component of knowledge transfer and domestic skill accumulation by national professionals should be included in all such projects.

Thirdly, innovative uses of aid should be designed to leverage more learning from international linkages, particularly from FDI and global value chains. Most attention has been directed thus far to promoting FDI though ODA. But the thrust of this suggestion is more focused on increasing the technological effects of FDI by using ODA to build the capability of domestic firms that are engaged in international trade or that have business links with transnational corporations. The aim is to strengthen the transfer of skills through market transactions.

Fourthly, the Report recommends that technological upgrading is explicitly elaborated as an aspect of development in the Aid for Trade initiative currently being developed and in the Enhanced Integrated Framework for LDCs.

Finally, it is proposed that the economic effects of trade preferences for LDCs (such as the Everything But Arms Initiative) could be enhanced by deepening such preferences through National Innovation Funds which finance technological learning and innovation by domestic firms whose activities are stimulated through trade preferences. Such Funds would seek in particular to spread the benefits of trade preferences to more firms, to encourage technological upgrading by exporters and to catalyze dynamic linkage effects. Technological upgrading is particularly important at the present moment for garment firms faced by competition following the end of the transitional arrangements at the end of the Agreement on Clothing and Textiles.

Conclusion

The Report focuses on making practical suggestions. But more broadly, the Report argues that knowledge-based development can be the foundation for a reinvigorated and forward-looking partnership for development in LDCs. There is a wide sense of restlessness with the ineffectiveness of current policies and a desire to find a new policy model, the report notes. Focusing on science, technology and innovation can provide a platform for innovative solutions and fresh thinking. It is in this area that more effective policies to promote sustained growth and poverty reduction can be found.

Authors

Charles Gore is Chief of Research and Policy Analysis in the Division for Africa, Least Developed Countries and Special Programmes, and Team Leader of UNCTAD's Least Developed Countries Report. Zeljka Kozul-Wright and Rolf Traeger are Economic Affairs Officers in the same Division. The research in the Report was also supported by Lisa Borgatti, Michael Herrmann and Pénélope Pacheco-Lopez. The Report, and also background papers, can be downloaded at www.unctad.org/ldcr

References

1. UNCTAD (2000) *The Least Developed Countries Report 2000: Aid, Debt and Private Capital Flows – The Challenge of Financing Development in the LDCs*, United Nations, Geneva and New York.
2. UNCTAD (2002) *The Least Developed Countries Report 2002: Escaping the Poverty Trap*, United Nations, Geneva and New York.
3. UNCTAD (2004) *The Least Developed Countries Report 2004: Linking International Trade with Poverty Reduction*, United Nations, Geneva and New York.
4. UNCTAD (2006) *The Least Developed Countries Report 2006: Developing Productive Capacities*, United Nations, Geneva and New York
5. UNCTAD (2007) *The Least Developed Countries Report 2007: Knowledge, Technological Learning and Innovation for Development*, United Nations, Geneva and New York.

Benefiting from Biotechnology: Promoting small-farm competitiveness and intellectual property rights

Baris Karapinar and Michelangelo Temmerman

Swiss National Centre for Competence in Research, World Trade Institute, Berne, Switzerland

Abstract

The Green Revolution has contributed to alleviating poverty and hunger of hundred of millions of people, but remained technically and institutionally limited: it has largely bypassed small farms located in dry agro-ecological regions and its institutionally "top-down" approach was not equipped to address social, economic and environmental variations at the local level. However, with new developments in biotechnology, including genetic engineering, unprecedented possibilities to address the competitiveness of small farmers in Africa have risen. Yet, there are new challenges too. The new technology is driven by the private sector, which is not attracted to investing in research towards developing biotechnology specifically addressing the needs of small farms in Africa. Moreover, the accessibility of the existing technologies to small farmers is argued to be impeded by the intellectual property rights (IPR) leading to monopoly prices and hindering technology diffusion. Therefore, this paper analyses how intellectual property rights can be domestically tailored within the existing international commitments so as to incite the development of technologies that are favouring and accessible to small-scale farmers in Africa.

Introduction

The agricultural sector in developing countries is dominated by around 500 million small farms, with labour force working at low levels of productivity. Based on FAO's database, 85 per cent of these farms are small-scale, operating less than 2 hectares (Nagayets, 2005, p.356). Hence, there is an urgent need to boost the competitiveness of small-farm agriculture and its contribution to poverty alleviation through science and technology. In this context, new biotechnology, including genetic engineering, may play a historic role. Some advanced developing countries have already made significant progress in fostering technological innovation and knowledge transfer. For those lagging behind, designing an institutional framework to promote pro-small-scale agriculture is essential.

An effective intellectual property rights (IPR) regime can play an important role in such an institutional design - as the accessibility of any existing technology to farmers is equally important as its technical availability. However, there are concerns that small-scale farmers in poor countries by and large are being excluded from the benefits of new biotechnology. This is of particular importance because leading biotech companies in research and innovation have substantial market dominance in the field. Hence there is a situation whereby a highly sophisticated private industry investing heavily into research and innovation in agriculture does not seem to address the technological needs of the majority of developing country farmers. From legal and institutional perspectives, this paper addresses some of the question of why small farmers in developing countries, particularly in Africa, seem to have been left out of the process of technological development.

This takes the paper into the analysis of the WTO's Agreement on Trade-Related Aspects of Intellectual Property Rights which obliges member countries to implement a patent system. The paper will assess the extent in which the protection requirement is flexible in its essence and content so as to leave some room for member countries to develop their own IPR regimes. We argue that the institutional challenge for African countries is to design an efficient framework that is compatible with multilateral (and in some cases regional and bilateral) IPR regimes, but more importantly capable of offering incentives for specifically pro-small scale biotechnology research and innovation in agriculture. Given the great heterogeneity of farming systems and variations in domestic institutional capacities, these countries should design their own IPR frameworks promoting both home-grown innovation and technology transfer.

This paper is organised as follows. It begins with an analysis of some of the new opportunities that new biotechnological applications offer to small-scale farmers in developing countries. Second, it provides an overview of physical, technical and institutional factors affecting the accessibility of biotechnology to small farmers. Then, the focus moves on to the flexibilities that the international patent law provides for developing countries to design their own

IPR regimes. Finally, the paper draws attention to some alternative institutional approaches and provides some policy recommendations to promote specially tailored intellectual property right regimes conducive to endogenous development through biotechnological innovations.

Making small farms more competitive

The Green Revolution has left large numbers of poor farmers located in dry agro-ecological regions untouched, especially in Africa (Hazell and C. Ramasamy, 1991). Since both the availability and the timing of water are vital for chemical fertilizers and semi-dwarf seeds to work effectively, the impact of the Green Revolution in dry ecologies without irrigation has been small. Mainly in sub-Saharan Africa and large pockets of areas in Asia, there are now an estimated number of 1 billion people living in rain-fed dry and cold ecological regions (Dixon, et al., 2001, p. 310), which has hardly been affected by the Green Revolution. Both poverty and malnutrition are prevalent in these regions where the ecological performance of staple food production needs to be improved. With innovative crop pattern diversification, these regions may become competitive in local, domestic and even international markets.

New biotechnological developments promise to offer varieties with higher photosynthetic efficiency and enhanced resistance to abiotic-stress, such as draught, excessive cold and heat. It is now possible to identify the network of genes that is associated with tolerating abiotic stress which conventional breeding technology would only identify as a result of far larger number of target traits (Garg, et al, 2002, p. 15898). For instance modifying rice to overproduce trehalose – a compound that exists in certain organisms such as bacteria, yeast, and resurrection plants which stabilises biomolecules under stress condition – proved to improve its tolerance to salt, drought and cold stresses (Garg, et al, 2002, p. 15898). Similarly, research on frost tolerant potatoes in Bolivia, salt tolerant wheat in Egypt and cold tolerant tomatoes in China has been underway (FAO, 2002). Using genetic engineering to improve pest and disease resistance in East African bananas also offer higher productivity gains as compared to conventional breeding (Smale, et al. 2006). Similarly, biotechnological tools, such as marker-aided selection, has been used to improve the efficiency of conventional breeding techniques in order to identify drought tolerant maize traits to be bred with other varieties, such as African maize, which has improved the crop's biomass efficiency (i.e. higher proportion of seed development as compared to overall vegetation); (Nuffield Council on Bioethics, 2003, p. 21; Bruce, et al., p. 13).

Another major challenge facing small farmers in Africa is to diversify their production from staple foods to higher value cropping patterns with an increasing share of vegetables, fruits and livestock. Since these commodities have higher income elasticity for demand, they provide new opportunities for competitive farmers in the continent experiencing population growth, increasing urbanization with a widening middle-income class. However, the conventional applications of the Green Revolution in the 1970s and 1980s focused only on staple food products, mainly wheat and rice, paying almost no significant attention to horticultural crops and livestock products. Hence, African farmers now need scientific research and technological innovation in a wide range of high-value farm products.

Molecular biotechnology in horticultural crops has potential to offer improvements in both reducing costs and achieving high standards. However, the vast diversity of varieties in horticulture covering relatively small acreages makes it difficult to achieve adequate economies of scale, attractive enough for the private sector to undertake extensive biotechnology research (Alston, 2004, p. 86). Some genetic traits have been developed, such as herbicide tolerant tomato and lettuce, pest-resistant broccoli and potato, virus resistant raspberries and plums (Clark, et al., 2004, p. 89-94). Similarly, tomato with a silenced gene associated with fruit softening was developed with the effect of improved taste and longer shelf life (Clark, et al., 2004, p.90). [1] Although the marketing of genetically modified horticultural crops is not yet feasible given the unfavourable perception of consumers, biotechnological tools, such as marker-aided selection, could be used to improve the efficiency of conventional breeding techniques in horticultural crops. Nevertheless, the new technology remains underutilized and the vast majority of the new varieties remain uncommercialized (Clark, et al., 2004, p. 89).

In the field of livestock products, scientific research and innovation is also crucial for the competitiveness of farms in Africa. Livestock plays a vital role in rural livelihoods by providing farmers with a vital source of protein, asset base and income. Similar to horticultural crops, markets for livestock products have been growing in Africa. Biotechnological tools such as molecular markers and quantitative trait loci (QTL), identifying genes associated with desirable traits, and methods like artificial insemination, embryo transfer and in vitro fertilization that are used to disseminate superior germ plasm offer potential benefits for the poor. Productivity growth through these scientific innovations is expected to come from enhanced breeding scheme designs, improved quality and welfare of offspring, higher productivity and nutritional value in milk and meat production. Biotechnology is also used to improve the nutritious efficiency of livestock by modifying either the feed to improve its digestive productivity or the animals to improve their metobolismic productivity to make betters use of existing feeds (higher weight-gain and milk production per feed intake) (Madan, 2005, p. 133). Finding more effective ways of fighting animal diseases is also of crucial importance in the vast majority of African countries lacking good veterinary services.

The development of animal biotechnology, however, has been slow as compared to crop biotechnology due to higher costs, inefficiencies in gene transfer techniques and the low rates of reproduction in animals (Madan, 2005, p. 130). Performance traits such as growth are associated with many genes, making research more complicated and potentially more expensive (Van Eenennaam, 2006, p. 136). Apart from transgenic research animals, there are only a few genetically modified animal product commercialized for the world agricultural markets. Moreover, the private sector's interest in investing in pro-poor livestock biotechnology has been absent. As a result, although reproductive techniques such as artificial insemination and embryo transfers are used in developed countries, African countries are lagging behind. For instance, more than 60 per cent of all embryo transfers (around 450,000), mainly in diary cows, in 2001 were undertaken in North America and Europe (Madan, 2005, p. 131). Since many animal species are unique to their local environment, each with different nutrient efficiency, disease resistance and development productivity (Madan, 2005, p. 133), there is an increasing need for specifically designed biotechnology applications addressing the needs of farmers in Africa. East Coast Fever Vaccine project coordinated by the International Livestock Research Institute (ILRI) in Kenya is a good but rare example of such applications.

International Intellectual Property Law and Agricultural Patents: Overview of Obligations and Flexibilities

The new biotechnology can be problematic when it comes to promoting competitiveness in developing countries. On the one hand, there is an increasing knowledge gap between developed and developing countries (Rausser, et al., 2000, p. 512). The fact that the new biotechnology has become increasingly more sophisticated, scientific research and trials requires heavy investment, excluding many African countries with limited resources to spend on R&D. The US, the UK, Sweden, Australia and Switzerland are leading countries in the field, while there are only a few developing countries making significant progress, such as South Africa, China and India. On the other hand, the knowledge gap between public and private research institutions is also widening. The research and development activities and subsequent technological adaptations have been dominated by the private sector which holds key methodological knowledge necessary for further innovation (Timmer, 1998). Some experts even argue that increasing scientific gap between developing and developed countries and the dominance of the private sector is creating a "scientific apartheid" (Serageldin, 2001).

Small-scale farmers are particularly disadvantaged – as leading biotech companies are inclined to design their products based on the needs of large-scale farms, especially in developed countries. First, given the limited purchasing power of small farms, it is only natural that a profit-propelled industry is interested in serving the interest of those high-income farms with a propensity to buy new technologies. Second, since large farms are the main target of the industry, the companies invest more on capital and labour saving technologies, such as pesticide and herbicide resistant varieties, rather than water efficient and extra-nutritious varieties which are more relevant for small-scale farms in Africa. Similarly, in developed countries, there has been a trend of shifting research priorities from productivity to quality attributes, reflecting affluent consumer preferences (organic products, functional foodstuff etc.); (Pardey, et al., 2006). Fourth, major biotech companies tend to protect the potential gains of their innovations through contract farming rather than investing in so called 'terminator' technologies which are not always technically possible and/or economically feasible. As a result, transaction costs associated with contract farming are extremely higher with small-scale farms as compared to large ones, making it more feasible for biotech companies to deal with the latter.

Intellectual property rights (IPR) also constitute a major factor affecting the level of accessibility of the new biotechnology to small farmers - as its various applications have been patented all over the globe. Traditionally the argument is made that IPRs only favour development in countries after achieving a certain stage of development. Below that level, they might rather hinder infant industries to develop (Spence, 2001, p. 270). For example, European industries at the beginning of the 20th century and Japanese industry until a few decades ago were able to develop their innovative hi-tech, car and pharmaceutical industries by using the lack of patent protection and copy technologies disclosed at foreign patent offices. Swiss chemical industry, Dutch audio fabrication and Swedish car production all saw daylight in period with no active patent law in their territory. These countries had already reached a certain stage of locally induced development, however. The argument above could hence nowadays be applied to countries like India, but in theory hardly to Africa and Least Developed Countries (LDCs).[2]

In biotechnology, however, this might be different. Indeed, not only is the field relatively more investment sensitive than any other, but IP laws and patent laws in general seem to offer greater flexibilities in relation to biotechnology than in any other field of technology. Indeed, small-scale farmers might have a stronger interest in (adjusted) IPRs that incentivize the home-grown local innovation of useful biotechnology products, than it has in the possibility to freely copy technologies as developed and disclosed at foreign patent offices. Hence, it comes down to implementing an IP system that securely protects investments, while using the flexibilities allowed under TRIPs and regional patent conventions to adjust the system to local needs.

The minimum obligations that African national patent laws have to fulfil operate basically at two levels: the international and the regional level. At the international level, the WTO Agreement on Trade Related Aspects of Intellectual Property (the 'TRIPs' Agreement [3]) constitutes the major international treaty on IP law, harmonising to a large extent basic rules of patent law. [4] At the regional level, IPR treaties such as AIPO's Bangui Agreement or ARIPO's Harare Protocol are to be taken into account.

The TRIPs Agreement makes patents -enshrining the right to prevent third persons to use the patented invention without the consent of the patent holder [5] - available for any type of new, inventive and industrially applicable inventions [6]; whether products or processes; in all fields of technology; for a minimum term of 20 years [7]; and without discrimination as to the field of technology, the place of invention, or whether products are imported or locally produced. As the Agreement is imbedded in the WTO dispute settlement system, it enjoys a strong enforcement mechanism. In fact, for the first time in history, disputes over intellectual property rights can be brought before an international court. However, based on this foundation, the agreement allows for high levels of flexibilities and exclusions, particularly in the field of biotechnology.

First, there is flexibility in the date of final implementation of the TRIPs agreement depending on a member country's level of development. While developed countries had to implement the Agreement by the 1st of January 1995 already; developing countries [8] enjoyed a maximum period of implementation up to the 1st January 2005. [9] For LDCs [10], the period of transition lasted until the 1st of January 2006 [11]; except for pharmaceutical patents which are excludable from patent protection until 2016 [12]. The Council for TRIPS can, however, upon duly motivated request, extend this period. In 2005, the Council decided to extend the general transition period until the 1st of July 2013. [13] However, it is important to note that laws, regulations and practice made during the additional transitional period may not result in a lesser degree of consistency with the provisions of the TRIPS Agreement. This means that the rules which had already been established before the extension of the period may not be changed in the direction of a lower level of protection.

Secondly, within the patentability criteria of novelty, inventiveness and industrial application, member states are free to design to concrete content of these concepts. Limited exceptions of the rights [14] are possible to the extent that they do not unreasonably conflict with the normal exploitation of the patent and that they do not unreasonably prejudice the legitimate interests of a patent owner. [15] Also, the possibility to implement limitations aiming at allowing the use of patented inventions without the patent holder's consent, e.g. compulsory licenses, is fully accepted. [16] Moreover, as for the possibility of patentability exclusions for inventions whose commercial exploitation would be going against the ordre public [17] and/or morality [18], member states are free to fill in themselves. [19]

Third, as for flexibilities specifically addressing biotechnology and living matter, the TRIPs Agreement allows for excluding plants and animals from patentability, provided that an effective sui generis system [20] is established for the protection of plant varieties.[21] As regards living matter, in fact, the Agreement requires only microorganisms, non-biological processes for the production of plant and animals, and microbiological processes to be set patentable.[22] It seems hence that plant and animal related inventions, other than non-biological processes and micro-organisms, can be excluded from patentability without infringing the basic TRIPs principle that all inventions in any field should be patentable.

Furthermore, the TRIPs Agreement offers several portals for flexible interpretations of its provisions. Although it aims at securing effective IPR protection mechanisms provided that “measures and procedures to enforce intellectual property rights do not themselves become barriers to legitimate trade”, the agreement indeed also recognizes in its preamble “the underlying public policy objectives of national systems for the protection of intellectual property, including developmental and technological objectives”. This is further strengthened by Article 7, ruling the TRIPs Agreement is to contribute to the promotion of technological innovation and the transfer of technology in a manner that is “conducive to social and economic welfare, and to a balance of rights and obligations”. Furthermore, Article 8 provides in a portal to adopt measures necessary to protect public health and nutrition, as well as to “promote the public interest in sectors of vital importance to their socio-economic and technological development” – however, only to the extent that such measures are consistent with the provisions of this Agreement. This latter limitation would mean such concerns can only be taken into account within the borders of the TRIPs obligations and scope of rights; rendering the Article 8 possibility quite marginal. However, in literature, Article 8 has been interpreted fairly largely to eventually even serve as a legitimate portal to exclude certain inventions in the pharmaceutical or agricultural sector from patentability, if this would otherwise make the cost of access prohibitive or cause economic harm (Llewelyn, 2003, p. 330). Furthermore, still under Article 8, it is also allowed to take actions aimed at preventing the abuse of IP-rights (by the right holders) that would adversely affect the international technology transfer.

Plants and animals can be excluded from patentability under the TRIPs Agreement, provided an effective sui generis system is established for plant varieties.[23] The most largely established system of sui generis protection, the UPOV system [24], provides IP protection for plant varieties that are found -after a two year period of testing- new, distinct, uniform and stable.[25] Hereby, major differences exist as compared to the patent system which requires the disclosure of the invention that is applied for patent protection and also works with a requirement of non-obviousness; both lacking under the UPOV system. Hence it is argued that while the patent system is meant to protect <u>innovation</u>, the UPOV system protects <u>investment</u> (Llewelyn, 2003, p.316). Furthermore, as for the scope of the rights conferred, the UPOV system provides in a so called farmer’s privilege, enabling farmers to save and reuse harvested seeds, and embodies a breeder’s exemption, allowing the development of new plant varieties based upon an existing, protected variety.

The possibility to establish a sui generis system for the protection of new plant varieties, however, does not necessarily mean countries must join the traditional UPOV-system of plant variety protection. They may choose to design a system specifically tailored to their local needs and interests.[26] Here, the major uncertainty is to know whether or not such systems would comply with TRIPs by providing effective protection mechanisms. Before WTO judicial bodies, their effectiveness is likely to be judged upon sufficient strength of the rights conferred (Llewelyn, 2003, p. 310). This ‘sui generis’-possibility is limited to plant varieties and does not cover the full range of biotechnological inventions. In particular, it does not address the protection of nucleic (‘gene’) sequences, nor any processes. In this context, it must be mentioned that it remains unclear to what extent countries can refuse the patenting of plant and/or animal gene sequences under the TRIPs Agreement, which only allows its member parties to exclude ‘plants’ and ‘animals’.[27] However, it is obvious that the flexibilities and exceptions discussed above provide room for various interpretations.

The second multi-national level of intellectual property regulation affecting domestic African patent laws is composed of two regional intellectual property organisations and their conventions. On the one hand the African Intellectual Property Organisation (‘AIPO’) [28] brings together English speaking African countries, mainly playing a role of simplifying the administrative procedure for patent applications to its member states.[29] On the other, French speaking African countries are grouped by the African Regional Intellectual Property Organisation (ARIPO) [30] which incorporates a similar simplified application procedure but also rules substantial patent law provisions. As for biotechnology and the patentability of plants and animals, AIPO's Bangui Agreement establishes an exclusion form patentability for plant varieties, animal species and essentially biological processes for the breeding of plants or animals other than microbiological processes and the products of such processes.[31]

African countries are not making use of existing flexibilities in their patent laws. In fact, they tend to implement patent laws more or less copied from developed countries' patent acts and their patent offices tend to simply follow patentability decisions of major patent offices (United States Trademark and Patent Office; European Patent Office; Japanese Patent Office). They seem to be reluctant to implement sui generis systems for plant variety protection too. Although, many developing countries are pressured to join the UPOV system in bilateral free trade agreement-negotiations, a majority of African countries has not adhered to UPOV, let alone benefiting from the possibility to implement sui generis systems tailored to their local needs. UPOV adherence is limited to only a few African countries which have mostly joined the weaker 1978 version of the UPOV convention.[32]

IPR and Competitiveness - Public-Private Partnership

Following the era of the 'welfare state' in the 1979s and early 1980s and that of 'neo-liberalism' over the 1990s, there has been a significant shift in political/policy approach to institutional development over the recent years. The state-led centralist approach of the Green Revolution to scientific research and technological innovation is no longer considered to be feasible. In many developing countries, public research institutions, which were never designed to be competitive, find it increasingly difficult to obtain adequate resources and expertise to innovate in a rapidly developing technology field. They do not have the market knowledge and entrepreneurial drive to respond to today's world of extremely diversified and sophisticated agricultural markets. Furthermore, the design of these institutions had been based on the conventional neo-classical assumption that there is a linear path from investment and research to innovation and the subsequent adoption by farmers (Hall, et al., 2001, p. 785). This has been called into question as being simplistic and infective. Instead, the 'process' approach proposes that the technological innovation is affected by many dynamic factors leading to setbacks and irregularities requiring micro management and extensive farmer participation (Hall, et al., 2001, pp 785). Hence, there is an increasing need for developing countries to move away from the conventional institutional approaches considering scientific research and technological innovation as explicit 'public goods' achievable through linear pathways which only the welfare state has the responsibility to provide.

There is a need for new policy approaches designed to provide more institutional incentives that would enhance the role of the private sector, both local and international, to invest in biotechnology. However, without a sound legal framework stably protecting the investments/innovations, biotechnological industries cannot flourish. A specially tailored IPR regime reflecting country specific realities and priorities would be a vital tool within a comprehensive institutional framework promoting agricultural competitiveness. Hence, rather than simply imitating European intellectual property laws, African countries should benefit from the flexibilities provided under TRIPs, UPOV and Regional African Intellectual Rights Conventions to tailor special IPR frameworks. These frameworks should not only be sophisticated enough to promote home-grown biotechnological innovation and technological transfer but also conducive for public-private partnerships which are becoming increasingly common in advanced developing countries.

Public-private partnerships (PPPs) offer new institutional opportunities for enhancing biotechnological research. There are various types of institutional design for PPPs, but in general public institutions and the private sector pool their resources for research which would then benefit both the private sector and the overall public. It is usually the case that the private sector provides its methodological knowledge, financial resources and marketing expertise while the public sector is providing institutional and infrastructural support, such as introducing supportive legislation, allowing the use testing facilities and germplasm varieties. In this way, private biotech companies can gain access to large domestic agricultural markets. For big multinational biotech companies, it is also considered to be a tool of building a pro-developmental public image (Kameri-Mbote, et al., 2001, p 12). PPPs can also help public institutions convert their research outputs into end-user oriented products. They can also promote private sector development in countries with agricultural sectors dominated by state-owned monopolies (Spielman, et al, 2007, p34). More importantly, innovation-driven PPPs can play a major role in making technology both available and accessible to poor farmers.

Conclusion

The new biotechnology offers new opportunities to provide pro-small farm growth and development in rural areas in Africa. It can address the needs of small farms in unfavourable ecologies where ecological frontiers have been reached and the marginal benefits that the conventional technology has to offer has already been exhausted. Through more robust staple varieties which are tolerant to abiotic stresses, it offers farmers in ecologically unfavourable areas opportunities to improve their productivity. Research in high-value agricultural commodities such as horticultural crops and livestock which are becoming increasingly more important sources of income for African farmers is also promising. The advances in technological applications addressing malnutrition and diseases would also be major breakthrough in the fight against poverty. Hence, new biotechnology is rapidly improving its technical capacity to provide breakthrough innovation with the potential to benefit African farmers.

The technical availability, however, is no guarantee for availability and accessibility which can only be dealt with establishing right economic incentives and institutional frameworks. There is a widening knowledge gap between developed and developing countries on the first hand, between public and private sector on the other. Furthermore, multinational companies governing the market at this moment are inclined to design their products based on the needs of large-scale farms, ignoring small farms with limited purchasing power. There is a need for designing new institutional frameworks tailored ensure high accessibility for small farms while providing adequate incentive to the private sector to invest in innovation and technology transfer.

Establishing an adequate IPR regime seems essential in this context. Traditionally the argument is made that IPRs only favour economic development of countries who have reached a certain stage of development; and developing as well as least developed countries are characterized by a persistent reluctance to IP rights. Yet, small scale farming might have a stronger interest in (adjusted) IPRs that incentivize the innovation of locally useful biotechnology products, than it has in the possibility to freely copy technologies as developed and disclosed at foreign patent offices and hence in the lack of IPRs. In fact, absence of IPR regimes providing incentive and reward for innovation is seen as a major institutional constraint hindering local innovation

IPRs, in particular patents and sui generis rights for plant or animal variety protection, need however to be implemented in a well thought manner balancing rights and obligations of the right holders to the local circumstances. In this, it seems that African countries have not used flexibilities to do so as they are provided in both International and Regional patent law treaties. Hence, we argue that least developed countries need to design new institutional frameworks for intellectual property protection exclusively in the field of biotechnology. A specially designed IPR regime should be a patent protection system (rather that UPOV- system) sophisticated enough to cover nucleic ('gene') sequences and methodological processes while also being conducive to public-private partnerships.

The Authors

Baris Karapinar is a senior research fellow for the Swiss National Centre for Competence in Research (NCCR – International Trade Regulation; IP-5 'Sustainable Agriculture'), World Trade Institute in Berne.

Michelangelo Temmerman is a PhD student for the Swiss National Centre for Competence in Research (NCCR – International Trade Regulation; IP-9 'Biotechnology'), World Trade Institute in Berne.

Endnotes

1. Development of new technologies extending the shelf life of horticultural crops that has short post-harvest lives such as banana, mango, papaya is very important. Biotechnology has been used in several flower varieties, such as carnation, rose and gerbera for the purpose of modifying a greater variety of flower colour (currently produced in South America for markets in north America) (Clark, et al., 2004, p. 93).
2. In fact, of a list of 50, 32 LDCs are WTO member states. As regards Africa, this includes Angola; Benin; Burkina Faso; Burundi; Central African Republic; Chad; Congo; Democratic Republic of the Djibouti; Gambia; Guinea; Guinea Bissau; Lesotho; Madagascar; Malawi; Maldives; Mali; Mauritania; Mozambique; Niger; Rwanda; Senegal; Sierra Leone; Tanzania; Togo; Uganda; and Zambia. Furthermore, Cape Verde; Ethiopia; Sao Tome & Principe; and Sudan are in the process

of accession (http://www.wto.org/English/thewto_e/whatis_e/tif_e/org7_e.htm (last visited 7 October 2007)).

3. Agreement on Trade Related Aspect of Intellectual Property Protection, Annex IC to the Agreement Establishing the World Trade Organization, Marrakech, 15 April 1994, 33 International Legal Material 1197 (1994).

4. For a list of (African) member states to the WTO: http://www.wto.org/english/thewto_e/whatis_e/tif_e/org6_e.htm (last visited 10 October 2007).

5. Article 28 § 1 (a) TRIPs Agreement (as regards product patents) & Article 28 § 1 (b) TRIPs Agreement (as regards process patents).

6. Article 27 § 1 TRIPs Agreement.

7. Article 33 TRIPs Agreement.

8. The decision to classify as a developed or rather as a developing country does not depend upon strict WTO criteria, but on (challengeable) self designation.

9. Article 65 TRIPs Agreement.

10. As regards LDCs, WTO follows the UN categorisation of LCDs which sets three cumulative criteria for the identification of the LDCs. According to Article 11 § 2 of the WTO Agreement (Agreement Establishing the WTO, Marrakech, 15 April 1994, 33 International Legal Material 15 (1994), available at: http://www.wto.org/english/docs_e/legal_e/04-wto.pdf (last visited 7 October 2007).

11. [Article 66 TRIPs Agreement.

12. WTO, Doha Ministerial Declaration on the TRIPs Agreement and Public Health, 14 November 2001, WT/MIN(01)/DEC/2, at § 7, available at: http://www.wto.org/english/tratop_e/dda_e/dda_e.htm (last visited 7 October 2007).

13. TRIPs Council, Decision of the extension of the transition period under Article 66 § 1 for least developed countries, 29 November 2005, available at: http://www.wto.org/English/news_e/pres05_e/pr424_e.htm (last visited 7 October 2007).

14. As guaranteed under Article 28 of the Agreement.

15. [Article 30 TRIPs Agreement. See on the concrete content of these criteria: WTO Dispute Settlement Body, Panel Report Canada – Patent Protection of Pharmaceutical Products, WT/DS114/R, 17 March 2000.

16. Under Article 31 of the TRIPs Agreement.

17. This concept is generally linked to safety issues. In fact, the Technical Board of Appeal of the European Patent Office established the principle that claimed subject matter that is likely to seriously prejudice the environment should be excluded from patentability for being contrary to the ordre public (Technical Board of Appeal of the European Patent Office, Plant cells/PLANT GENETIC SYSTEMS, 21 February 1995, T 356/93, Official Journal of the European Patent Office (1995) 545, § 18). Obviously, issues of biosafety and biodiversity immediately come to mind (See for instance: G. VAN OVERWALLE, Influence of Intellectual Property Law on Safety in Biotechnology, in World Congress on Safety of Modern Technical Systems, Saarbrücken 2001, TÜV-Verlag, pp. 664–670). Yet it remains to know to what extent patent examiners can assess safety.

18. Under EPO case law, the concept of morality is a belief about whether a certain behaviour is right or wrong, based on the totality of norms that are deeply rooted within European society and civilization (see Technical Board of Appeal of the European Patent Office, Plant cells/PLANT GENETIC SYSTEMS, 21 February 1995, T 356/93, Official Journal of the European Patent Office (1995) 545, § 6).

19. [Article 27 § 2 TRIPs Agreement.

20. This basically refers to IP systems of a different nature from those categorized under the TRIPs Agreement (Patents; Trademarks; etc.)

21. No such obligation has been incorporated as regards animal varieties, however.

22. Article 27 § 3 (b) TRIPs Agreement.

23. [The distinction between plants as a generic term and plant varieties as a taxonomical rank has been largely discussed in case law of the European Patent Office; see: Enlarged Board of Appeal of the European Patent Office, Transgenic Plant/NOVARTIS II, 20 December 1999, G1/98, Official Journal of the European Patent Office (2000) 125.

24. [UNION INTERNATIONALE POUR LA PROTECTION DES OBTENTIONS VEGETALES, International Convention for the Protection of New Varieties of Plants, 2 December 1961, as Revised at Geneva on 10 November 1972, on 23 October 1978, and on 19 March 1991, 1861 United Nations Treaty Series 281, available online at: http://www.upov.int/en/publications/conventions/1991/act1991.htm (last visited 2 October 2007), 'UPOV Convention 1991'.

25. Article 5 of the UPOV 1991 Convention.

26. [See in relation hereto: P. CULLET, Intellectual Property Rights and Food Security in the South, 7 The Journal of World Intellectual Property 3 (2004). Also, as regards protection of 'traditional knowledge': T. COTTIER and M. PANIZZON, A New Generation of IPR for the Protection of Traditional Knowledge in PGR for Food, Agricultural and Pharmaceutical Uses, in T. COTTIER & S. BIBER-KLEMM, Rights to Plant Genetic Resources and Traditional Knowledge: Basic Issues

and Perspectives, Swiss Agency for Development and Cooperation and World Trade Institute, Cabi Publishing, 2006, pp. 203-238; and also: G. DUTFIELD and J. POSEY, Indigenous Peoples and Sustainability: Cases and Actions, Utrecht, IUCN International Books, 1997.

27. In law, see the Costa Rican ‘Ley de Biodiversidad’ (1998) and the Andean Community’s Common System on Access to Genetic Resources (1996).

28. In Europe for instance, plant, animal or even human genetic sequences are not considered to fall under the definition of ‘plants’, ‘animals’ or ‘humans’ but are instead equalled to chemical substances. However, the scope of a patent on a gene sequence might be larger than covering merely the gene sequence in its isolated laboratory form and might instead extend to the (plant-) organism in which the gene sequence has been entered and is performing its function, regardless of whether the organism itself is patentable. In this context, moreover, the possibility to exclude plants and animals is strongly limited by the fact that non-essentially biological processes (e.g. processes of genetic engineering) must be patentable and that the ‘product obtained directly by that process (Regardless of whether this itself is patentable or not) (which can very well be a plant or an animal) has to fall under the scope of protection of such process patents under Article § 1 (b) of the TRIPs Agreement.

29. Member states to AIPO Bangui Agreement are: Benin; Burkina Faso; Cameroon; Central Africa; Congo; Cote d'Ivoire; Equatorial Guinea; Gabon; Guinea; Guinea Bissau; Mali; Mauritania; Niger; Senegal; Chad; Togo.

30. Cf. AFRICAN REGIONAL INTELLECTUAL PROPERTY ORGANIZATION (ARIPO), Protocol on Patents and Industrial designs within the Framework of the African Regional Intellectual Property Organisation, Harare, 11 December 1987, as last amended at 13 August 2004, available at: http://www.oapi.wipo.net/doc/en/bangui_agreement.pdf (last visited 7 October 2007).

31. Members to ARIPO are: Botswana; Gambia; Ghana; Kenya; Lesotho; Malawi; Mozambique; Namibia; Sierra Leone; Somalia; Sudan; Swaziland; Tanzania; Uganda; Zambia; and Zimbabwe.

32. Article 6 (c) of the Bangui Agreement on the Creation of an African Intellectual Property Organization, Bangui (Central African Republic), 24 February 1999, available at: available at: http://www.oapi.wipo.net/doc/en/bangui_agreement.pdf (last visited 7 October 2007).

33. Two versions of the UPOV convention can be adhered to: UPOV 1978 and UPOV 1991.

References

1. ALSTON, J., ‘Horticultural biotechnology faces significant economic and market barriers’, in California Agriculture, Volume 58, Number 2, 2004, pp 80-88, available at http://repositories.cdlib.org/anrcs/californiaagriculture/v58/n2/p80 (last visited 9 October 2007).

2. BRUCE, W.B.; EDMEADES, G.O.; and BARKER, T.C., ‘Molecular and physiological approaches to maize improvement for drought tolerance’, in Journal of Experimental Botany, Volume 53, Number 366, 2002, pp. 13-25.

3. CLARK, D.; KLEE, H.; and DANDEKAR, A., ‘Despite benefits, commercialization of transgenic horticultural crops lags’, in California Agriculture, Volume 58, Number 2, 2004, http://repositories.cdlib.org/anrcs/californiaagriculture/v58/n2/p89 (last visited 9 October 2007).

4. COTTIER, T., and PANIZZON, M., ‘A New Generation of IPR for the Protection of Traditional Knowledge in PGR for Food, Agricultural and Pharmaceutical Uses’, in T. COTTIER & S. BIBER-KLEMM, Rights to Plant Genetic Resources and Traditional Knowledge: Basic Issues and Perspectives, Swiss Agency for Development and Cooperation and World Trade Institute, Cabi Publishing, 2006, pp. 203-238

5. CULLET, P., Intellectual Property Rights and Food Security in the South, 7 The Journal of World Intellectual Property 3 (2004).

6. DIXON, J.; FULLIVER, A.; and GIBBON, D., Farming System and Poverty: Improving Farmer’s Livelihoods in a Changing World, Rome/Washinton D.C., FAO/World Bank, 2001.

7. DUTFIELD, G., and POSEY, J., Indigenous Peoples and Sustainability: Cases and Actions, Utrecht, IUCN International Books, 1997.

8. FAO Electronic Forum on Biotechnology in Food and Agriculture, ‘What should be the role and focus o fbiotechnology in the agricultural research agendas of developing countries?’, in Background Document to the Conference 8, 13 Nov - 11 Dec 2002, available at: http://www.fao.org/biotech/C8doc.htm (last visited 10 October 2007).

9. GARG, A.K., ‘Trehalose accumulation in rice plants confers high tolerance levels to different abiotic

stresses', in Proceedings of the National Academy of Sciences of the United States of America, Volume 99, Number 25, 10 December 2002), pp. 15898-15903.

10. HALL, H.J.; SIVAMOHAN , M.V.K.; CLARK, N.; TAYLOR, S.; and Bockett, G., 'Why Research

11. Partnerships Really Matter: Innovation Theory, Institutional Arrangements and Implications for

12. the Developing New Technology for the Poor', in World Development, Volume 29, Number 5, 2001, pp. 783-797.

13. HAZELL, P.B.R.; and RAMASAMY, C., (eds), The Green Revolution Reconsidered: The Impact of High-Yielding Rice Varieties in South India, Johns Hopkins University Press, 1991.

14. KAMERI-MBOTE, P.; WAFULA, D.; and CLARK, N., Public/Private Partnerships for Biotechnology in Africa: The Future Agenda, African Centre of Technology Studies, International Environmental Law Research Centre, 2001, available at: http://www.ielrc.org.

15. LLEWELYN, M., 'Which Rules in World Trade Law-Patents or Plant Variety Protection', in T. COTTIER and P. MAVROIDIS (Eds.), in Intellectual Property, Trade, Competition, and Sustainable Development, Studies in International Economics, Michigan, The University of Michigan Press, 2003.

16. MADAN, M.L., 'Animal biotechnology: applications and economic implications in developing countries', in Rev. sci. tech. Off. int. Epiz., Volume 24, Number 1, 2005, pp. 127-139.

17. NAGAYETS, O., 'Small farms: Current Status and Key Trends', in Information Brief Prepared for the Future of Small Farms Research Workshop, Wye College, June 26–29, 2005.

18. NUFFIELD COUNCIL ON BIOETHICS, The use of genetically modified crops in developing countries: a follow-up Discussion paper, 2003, available at http://www.nuffieldbioethics.org/fileLibrary/pdf/GM_Crops_Discussion_Paper_2004.pdf (last visited 9 October 2007).

19. PARDEY, P.G.; ALSTON, J.M; and PIGGOTT, R.R., Agricultural R&D in the Developing

20. World: Too Little, Too Late?, Washington D.C., International Food Policy Research Institute, 2006.

21. RAUSSER, G.; SIMON, I.; and AMEDEN, H., 'Public–private alliances in biotechnology: Can they narrow the knowledge gaps between rich and poor?', in Food Policy, Volume 25, 2000, pp. 499–513.

22. SERAGELDIN, I., 'Changing agendas for agricultural research', in J.M. ALSTON; P.G. PARDEY; and M.J. TAYLOR, Agricultural science policy: Changing global agendas, Baltimore, Johns Hopkins University Press, 2001.

23. SMALE, M.; EDMEADES, S., and DEGROOTE, H., 'Promising Crop Biotechnologies for Smallholder Farmers in East Africa: Bananas and Maize', in Genetic Resource Policies Brief 19, Washington D.C., International Food Policy Research Institute, 2006.

24. SPENCE, M., Which intellectual property rights are trade-related?', in F. FRANCIONI (ed.), Environment, human rights and international trade,. Oxford, Hart Publishing, 2001, p. 263-285.

25. SPIELMAN, D.J.; HARTWICH, F.; and VON GREBMER, K., Sharing Science, Building Bridges, and Enhancing Impact: Public–Private Partnerships in the CGIAR, International Food Policy Research Institute, Discussion Paper 00708, Washington, D.C., 2007.

26. TEMMERMAN, M., The Patentability of Animal Genetic Systems, Berne, NCCR Working Paper 2007/04, pp. 76-105, available at www.nccr-trade.org (last visited 24 September 2007).

27. VAN EENENNAAM, A., 'What is the future of animal biotechnology?', in California Agriculture, Volume 60, Number 3, 2006, pp. 132-139. http://repositories.cdlib.org/anrcs/californiaagriculture/v60/n3/p132 .

Transnational Corporations, Extractive Industries and Development

UNCTAD

Contact: Torbjorn Fredriksson—torbjorn.fredriksson@unctad.org

Overview

Foreign direct investment (FDI) represents the largest share of external capital flows to developing countries. Through their investments, transnational corporations (TNCs) can bring new technology, management know-how and improved market access to a host country. FDI can therefore be an important force for development. At the same time, benefits cannot be taken for granted. To secure development gains from FDI, it is essential that countries establish adequate institutions and policies, and build domestic productive capabilities. This is particularly important in the case of the extractive industries.

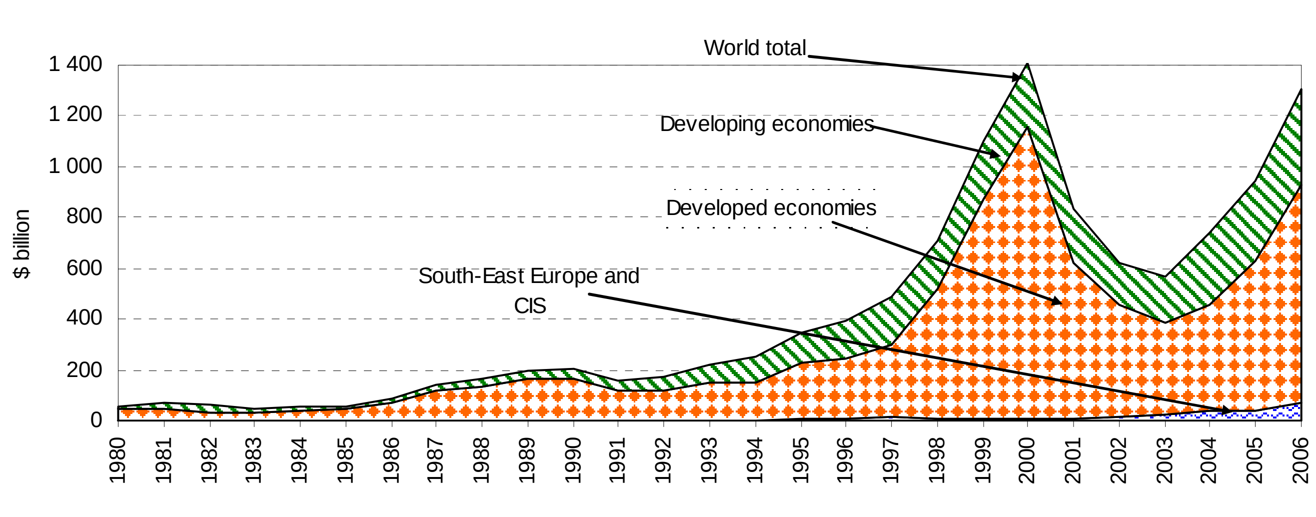
Record FDI flows to developing countries in 2006

Reflecting strong growth in the global economy and high corporate profits, world FDI inflows grew by 38% in 2006 to reach $1.3 trillion (see Figure 1). Investments increased in virtually all parts of the world. Among the developing regions, Asia was the top recipient. With record inflows of almost $260 billion, it received more than two thirds of all FDI to developing countries. The second largest destination was Latin America and the Caribbean, with $84 billion. Africa saw its highest inflows ever: $36 billion, or twice as much as in 2004. Despite this increase, Africa's share in global FDI fell to 2.7% in 2006, compared with 3.1% in 2005. FDI to South-East Europe and the Commonwealth of Independent States increased to a new record level: $69 billion.

The United States was the top recipient in 2006, followed by the United Kingdom. China again ranked first among developing countries, and the Russian Federation attracted the largest inflows of the transition economies. While most FDI originated in the developed world, outflows from developing and transition economies rose to a record high, underscoring the growing clout of TNCs from emerging economies. In fact, for the first time, as many as seven companies from developing countries are among the world's top 100 TNCs. This trend is important, as a large part of these outflows go to other developing countries, resulting in closer South-South economic ties.

As in previous years, cross-border mergers and acquisitions were responsible for large parts of global FDI. This was particularly the case in developed countries. In North America, cross-border M&As almost doubled. In Europe, the United Kingdom was the main target country, while Spanish companies were very active as ac-

Figure 1. FDI inflows, global and by group of economies, 1980-2006 (Billions of Dollars)



Source: UNCTAD, FDI/TNC database

quirers. Companies from developing and transition economies have also been increasingly engaged in such transactions, the largest in 2006 being the $17 billion acquisition of Inco (Canada) by CVRD (Brazil). As many as 172 mega deals (i.e. deals worth over $1 billion) were recorded in 2006.

Global FDI figures are expected be even higher in 2007. UNCTAD surveys suggest that investment activity may continue to grow in the next two years. But such forecasts are inherently uncertain, and future FDI prospects will depend largely on how well risks and uncertainties — such as financial instability and high energy prices — in the global economy are addressed.

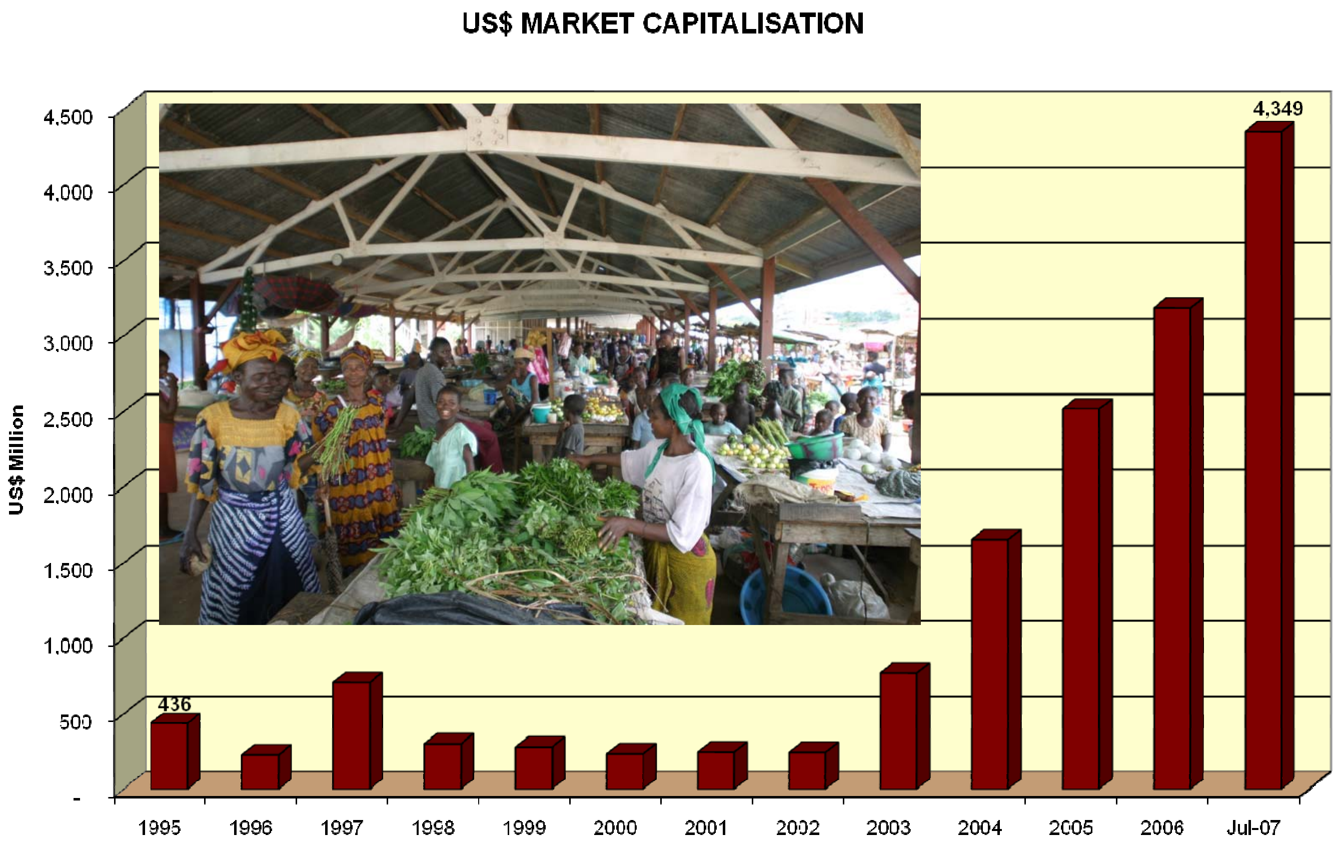
The perception that these and other changes might trigger renewed protectionism has led to some concern. However, this trend appears to be confined to a relatively small number of countries, and to specific industries. In 2006, 147 policy changes making host-country environments more favourable to FDI were observed. They included, in particular, measures aimed at lowering corporate income taxes and expanding promotional efforts. Further liberalization of specific industries is under way in various countries, such as that relating to professional services, telecommunications, banking and energy. In some industries, however, new restrictions on foreign ownership or measures to secure a greater government share in revenues were observed. Such steps were the most common in extractive industries and in industries deemed to be of "strategic" importance.

High mineral prices have brought natural resources back in focus

Recent years have seen a revival of FDI in extractive industries, reflecting the commodity price boom. This represents a window of opportunity for mineral-rich countries to accelerate their development. This is especially important as we reach the midpoint in our efforts to reach the Millennium Development Goals. The boom has reminded all countries of the importance of secure supply of natural resources. No modern economy can function without adequate, affordable and secure access to these raw materials.

Booming African markets: FDI and the common man

Lusaka Stock Exchange added $1.1 billion in the first 7 months of 2007, - 3-folds FDI inflows for Zambia in 2006 and Africa's best performer (in US$) for the period. A clear FDI-Stock market policy may be needed to grow the markets and broaden participation. (Source: Brian Tembo, LuSE)



Global mineral markets are characterized by an uneven geographical distribution of reserves, production and consumption. These imbalances sometimes create concerns among importing countries over the security of supply, and concerns among exporting countries over market access. TNCs are important for both groups of countries. Mineral-rich developing countries that lack the domestic capital and expertise to exploit their natural resources often rely on TNCs to supply the necessary inputs. This is particularly the case for metal mining and for relatively remote or inaccessible oil and gas fields. Meanwhile, developing countries whose demand for mineral resources is fast expanding are increasingly encouraging their State-owned companies to invest abroad to secure long-term, stable access to such resources.

Although extractive industries make up only 9% of the global stock of FDI, in all the major country groups, they account for a significant share of the total inward FDI stock in some countries. This applies, for example, to Australia, Canada and Norway among developed countries; Botswana, Nigeria and South Africa in Africa; Bolivia, Chile, Ecuador and Venezuela in Latin America and the Caribbean; and Kazakhstan in South-East Europe and the CIS. In a number of low-income, mineral-rich countries, extractive industries account for the bulk of inward FDI; many have few other industries that can attract significant FDI, due to their small domestic markets and weak production capabilities.

Investments in the extractive industries are spanning the globe. In *metal mining*, 15 of the 25 leading companies in 2005, ranked by their share in the value of world production, were headquartered in developed countries. Eight others were from developing countries and the two remaining were from the Russian Federation. The top three were BHP Billiton (Australia), Rio Tinto (United Kingdom) and CVRD (Brazil). The relative importance of foreign companies in the production of metallic minerals and diamonds varies considerably. Foreign affiliates account for virtually all of the (non-artisanal) production in LDCs such as Guinea, Mali, the United Republic of Tanzania and Zambia, as well as in Argentina, Botswana, Gabon, Ghana, Mongolia, Namibia and Papua New Guinea. In these countries, TNCs generally operate through concessions granted in the form of exploration and mining licences. By contrast, in the Islamic Republic of Iran, Poland and the Russian Federation their share is negligible.

In *oil and gas*, world production is no longer dominated by developed-country TNCs, as was the case in the early 1970s when the so-called "Seven Sisters" reigned. Today, State-owned companies from developing and transition economies are the biggest producers. In fact, the world's top three oil and gas companies all belong to this category: Saudi Aramco, Gazprom and the National Iranian Oil Company. In recent years, a number of State-owned oil and gas companies from the South have made significant inroads into foreign locations. Foreign affiliates generally account for a lower share of production than in metal mining. In 2005, they were responsible for an estimated 22% of global oil and gas production, with the average share being higher in developed countries (36%) than in developing countries (19%) and transition economies (11%). However, there was wide variation among developing countries. Foreign companies accounted for more than half of production in Angola, Argentina, Equatorial Guinea, Indonesia, Sudan and the United Kingdom. On the other hand, no production was attributed to foreign affiliates in, for instance, Kuwait, Mexico and Saudi Arabia.

Development and policy implications

Mineral endowments provide opportunities for economic development and poverty alleviation in the countries where they are located. Too often, however, the impact of extractive activities has been and remains disappointing. The well-known costs and benefits of FDI extend equally to the extractive industries. In fact, more than in other industries, the impacts of resource extraction are not just economic, but encompass the environmental, social and political dimensions as well. The net development outcome depends on the quality of governance, specific policies and institutions in the host countries, the nature of minerals extracted, the domestic capabilities of the host country, and the behaviour of the TNCs.

From an economic perspective, TNCs can contribute capital, technology, management expertise and access to markets. Such inputs are particularly important in countries with weak domestic capabilities and for technologically complex projects. They can help expand production and exports, improve productivity and generate government revenues. But TNC involvement comes at a price. Foreign investors claim a significant share of the revenue generated, and repatriate what is often a large part of the profits. The potentially most important contribution from TNC participation may be a rise in host-country income, including government revenue.

In both the oil and gas and the metal mining industries, the evolving arrangements reflect an ongoing process through which governments seek to find an appropriate balance between the respective rights and obligations of States and firms. As government revenue is among the

Table 1. The world's 10 largest metal mining and oil and gas companies, ranked by total production, 2005

Rank 2005	Company name	Home country	State ownership (%)	Share in world production (%)	Number of host economies with production
		Metal mining			
1	BHP Billiton	Australia	-	4.8	7
3	Rio Tinto	United Kingdom	-	4.6	10
2	CVRD	Brazil	12	4.4	-
4	Anglo American	United Kingdom	-	4.3	9
5	Codelco	Chile	100	3.2	-
6	Norilsk Nickel	Russian Federation	-	2.2	1
7	Phelps Dodge	United States	-	2.0	2
8	Grupo México	Mexico	-	1.6	2
9	Newmont Mining	United States	-	1.3	7
10	Freeport McMoran	United States	-	1.3	1
		Oil and gas			
1	Saudi Aramco	Saudi Arabia	100	8.8	-
2	Gazprom	Russian Federation	51	7.7	2
3	NIOC	Iran, Islamic Rep.	100	3.9	
4	ExxonMobil	United States	-	3.7	23
5	Pemex	Mexico	100	3.5	
6	BP	United Kingdom	-	3.3	19
7	Royal Dutch Shell	United Kingdom / Netherlands	-	3.2	25
8	CNPC	China	100	2.4	14
9	Total	France	-	2.1	27
10	Sonatrach	Algeria	100	1.9	1

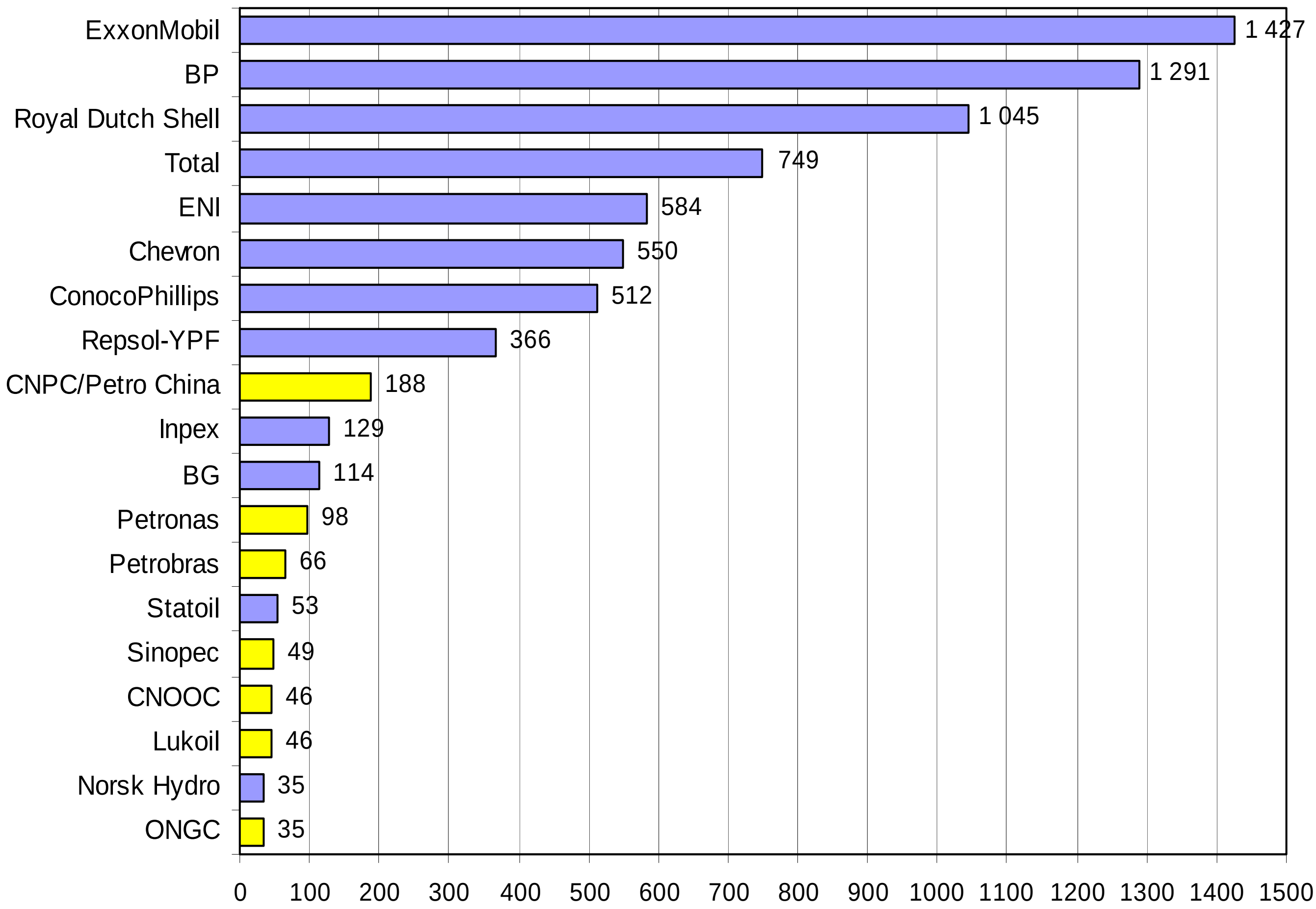
Source: UNCTAD, based on data from the Raw Materials Group and IHS.

most important benefits from mineral extraction, it is not surprising that policymakers devote much attention to finding a mechanism that assures the government an appropriate share in the profits from mineral extraction. As the result of higher mineral prices in the past few years, a number of governments have taken steps to increase their share of the profits generated by amending their fiscal regimes or their contractual relations. Recent regulatory changes in developed, developing as well as transition economies suggest that many governments believed their previous regulations may have been overly generous vis-à-vis foreign investors.

In order to reap not just more revenues, but more development gains as well, government revenue from natural resources has to be managed and used so as to promote development objectives. In this context, it is important to enhance revenue transparency. Available information on the sharing and distribution of revenue is patchy at best. One major way to address this is for more TNCs, host countries and home countries to commit to the principles of the Extractive Industry Transparency Initiative (EITI).

Managing the considerable environmental, social and political risks associated with extraction projects, and promoting sustainable development, will require that many countries improve their institutions and policies. Securing long-terms gains from such projects, especially when TNCs participate, must involve a concerted effort not only by host-country governments, but from the TNCs and their home countries as well. Home countries should promote the responsible behaviour of their TNCs, especially when they own the investing companies. Home countries can also help recipient countries build efficient policy and governance. The role of TNCs, in turn, is to contribute to more efficient production while respecting the laws of the host country. When the extraction takes place in a weakly governed or authoritarian State, companies need to carefully consider the

Figure 2. Oil and gas production of selected TNCs outside their home country, 2005(Millions of barrels of oil equivalent)



Source: UNCTAD, based on data from the Raw Materials Group and IHS.

implications of such investments, and if they do invest, need to abide by internationally acceptable standards.

Voluntary initiatives can be a useful supplement in countries where appropriate legislation or its enforcement is absent. A number of multi-stakeholder initiatives have been established with the aim of reducing the risk of conflict-related resource extraction and setting standards for corporate behaviour in conflict situations. The most notable ones include the EITI, the Kimberley Process Certification Scheme, the Voluntary Principles on Security and Human Rights and the Global Reporting Initiative. However, it is important for more countries and TNCs in extractive industries to become involved in these initiatives. Their impact will depend on universal compliance.

The challenge is to develop frameworks that create proper incentives for local and foreign firms to produce efficiently, while at the same time respecting environmental and social requirements that reflect the interests of local communities and society at large. The current commodity price boom represents a window of opportunity for developing economies to use their mineral resources to promote sustainable development. And particularly for the least developed countries endowed with natural resources, the boom should help them meet the Millennium Development Goals. In this endeavour, all countries and companies concerned have a role to play.

About the Paper

The article is based on the World Investment Report 2007 by UNCTAD accessible at www.unctad.org/wir

The Rise, Fall, Rise, and Imminent Fall of DDT**

Roger Bate

American Enterprise Institute for Public Policy Research, 1150 Seventeenth Street, N.W. Washington, DC 20036

Abstract

DDT is probably the single most valuable chemical ever synthesized to prevent disease. It has been used continually in public health programs over the past sixty years and has saved millions from diseases like malaria, typhus, and yellow fever. Despite a public backlash in the 1960s, mainstream scientific and public health communities continue to recognize its utility and safety. DDT's delisting for various uses in the United States in 1972 was a political, not a scientific, judgment. After decades of extensive study and use, DDT has not been proven to be harmful to humans. But by 1997, its future looked bleak. Environmentalists were pushing for it to be banned worldwide, and its most articulate champion, the South African Department of Health, stopped using it. Surprisingly, DDT recovered its reputation, and in 2006 the World Health Organization (WHO) championed it again. But celebrations have been short-lived. The momentum to increase DDT use has stalled for lack of increased political and financial support.

Introduction

Bill and Melinda Gates recently called for the eradication of malaria. They were supported in this ambitious demand by Margaret Chan, the head of WHO. The first attempt to eradicate malaria in the 1950s relied almost solely on the chemical DDT; the latest attempt probably will not. But until a cheap and effectual vaccine is available, DDT will still have a crucial role to play.

DDT, the scientific name of which is dichlorodiphenyltrichloroethane, was first synthesized by Othmar Zeidler in 1874, but it was not until the 1930s that a scientist working for a Swiss chemical company discovered its insecticidal properties. Paul Mueller happened upon it when looking for an insecticide to control clothes moths. He sprayed a small amount of DDT into a container and noted the slow but sure way it killed flies. He wiped the container clean, but when he added new flies, they died, too. Mueller soon realized he had come across a persistent, powerful residual insecticide.

DDT was first used by the Allies during World War II to control lice-borne typhus. Typhus had always been a problem during wars, especially in camps for prisoners,

The Mosquito and rolling back malaria

refugees, or political detainees. In October 1943, Allied forces liberated Naples as they advanced northward through Italy. A typhus epidemic broke out shortly after the liberation, posing a significant threat to both troops and civilians.[1] The U.S. military mixed DDT with an inert powder and dusted it on troops and refugees, to great effect. Public health expert Fred Soper noted that "a thorough application of 10 percent DDT louse powder to the patient, his clothing and bedding and to the members of his household will greatly reduce the spread of typhus in the community."[2]

Dusting stations were set up around the city, and in January 1944, two delousing stations dusted 1,300,000 civilians. Within three weeks of the dusting (along with other less important treatment and vaccination programs), the epidemic was under control. The number of civilian cases was halved in the first week alone. The Allies administered more than three million applications of DDT powder in Naples.

For his achievements, Mueller was awarded the Nobel Prize for physiology and medicine in 1948. Presenting the prize to Mueller, the Nobel Committee remarked that "for the first time in history a typhus outbreak was brought under control in winter. DDT had passed its ordeal by fire with flying colours." The committee went on to note that "DDT has been used in large quantities in the evacuation of concentration camps, of prisoners and deportees. Without any doubt, the material has already preserved the life and health of hundreds of thousands. Currently DDT treatment is the sovereign remedy the world over for the prophylaxis of typhus."[3]

The paper was first published in Health Policy Outlook No. 14, November 2007, American Enterprise Institute for Policy Research.

DDT was to prove itself to be the most effective weapon not only against typhus, but also against many other insect-borne diseases. Indeed, near the end of World War II, on September 24, 1944, Winston Churchill noted the vital importance of DDT:

We have discovered many preventives against tropical diseases, and often against the onslaught of insects of all kinds, from lice to mosquitoes and back again. The excellent DDT powder which had been fully experimented with and found to yield astonishing results will henceforth be used on a great scale by the British forces in Burma and by the American and Australian forces in the Pacific and India in all theatres.[4]

Malaria and DDT

Malaria is a parasitic disease that has plagued mankind for centuries. Today the disease is mostly confined to tropical and subtropical areas of Africa, Asia, and Latin America, but this was not always so. Until the 1950s, malaria was widespread in Europe and North America, and epidemics were even recorded above the Arctic Circle.

In 1898, Ronald Ross, a medical doctor stationed with the British army in India, discovered that mosquitoes transmit malaria. Shortly thereafter, a leading Italian zoologist, Giovanni Battista Grassi, identified the specific genus of mosquito (Anopheles) responsible for transmitting the malaria-causing parasite.[5] The knowledge that mosquitoes transmitted malaria gave public health experts a powerful new way to control the disease: targeting the mosquitoes as the carriers--or vectors--of the parasite that causes malaria.

Insecticides, notably pyrethrum, had been used in malaria control prior to DDT. They were sprayed on the inside walls of houses where the Anopheles mosquito rests after feeding. The mosquito takes up the insecticide while she rests on the wall and the toxicity kills her. One of the significant limiting factors of this form of vector control--known as indoor residual spraying (IRS)--was that it is labor-intensive and therefore expensive, especially since the insecticides used before DDT had to be sprayed every two weeks.[6] DDT, however, lasted for over six months.[7] This long-lasting residual action meant that a malaria control team could cover many more houses and protect far more people.

When used in malaria control, DDT has three separate mechanisms: repellency, irritancy, and toxicity, which together are remarkably successful at halting the spread of the disease. Repellency is the most important mechanism, and along with DDT's long residual time, it makes DDT superior to other insecticides. Its repellency qualities have long been known, but they have largely been forgotten by the malaria-fighting community.[8]

The United States funded "vector control"--that is, control of mosquitoes--for much of the early twentieth century and had considerable expertise and experience in this field. Infectious diseases such as malaria, yellow fever, and dengue were common throughout most parts of the United States until the 1950s.[9]

Shortly after World War II, the U.S. Public Health Service (PHS), along with the Tennessee Valley Authority and the Rockefeller Foundation, started to fund the use of DDT in malaria control. Malaria had been declining in the United States before DDT was introduced because of improved standards of living, notably window screens and other methods of protection from mosquitoes. In urban areas, better drainage and larviciding improved mosquito control, which in turn led to fewer cases of malaria. DDT proved to be a crucial intervention in rural areas, however. As a PHS document from 1944-45 notes:

Drainage and larviciding are the methods of choice in towns of 2,500 or more people. But malaria is a rural disease. Heretofore there has been no economically feasible method of carrying malaria control to the individual tenant farmer or share cropper. Now, for the first time, a method is available--the application of DDT residual spray to walls and ceilings of homes.[10]

Mosquito control officers in the United States used DDT in two ways: as a residual insecticide on the walls of houses [11] and as a larvicide. The results were dramatic. By 1952, there were virtually no cases of malaria transmitted domestically, in contrast to the 1-6 million cases just a few years earlier.[12] Of the 437 confirmed malaria cases in the United States in the first half of 1952, only two were domestically caught (the many soldiers returning from the Korean War caused a significant number). Most cases treated in the United States after 1952 were those caught overseas.[13] Just as DDT was being used within the United States, it was also saving lives in Europe, and within a few years, malaria was almost eradicated from Europe.

South Africa was one of the first countries to use DDT in malaria control. It started using the insecticide in 1946, and within a few years, the malarial areas had decreased to just 20 percent of those observed in 1946.[14] India's malaria control program began to use DDT and shortly thereafter saw spectacular health benefits. Between 1953 and 1957, morbidity was more than halved from 10.8 percent to 5.3 percent of the total population, and malaria deaths were reduced almost to zero.[15] After DDT was introduced for malaria control in Sri Lanka (then Ceylon), the number of malaria cases fell from 2.8 million in 1946 to just 110 in 1961.[16] Taiwan adopted DDT for malaria control shortly after World War II. In 1945, there were over 1 million cases of malaria on the island; by 1969, however, there were only nine cases, and shortly thereafter the disease was permanently eradicated from the island.[17] Similarly spectacular decreases in malaria cases and deaths were seen everywhere DDT was used.

The United States was not the only country in the Americas to use DDT to great effect. Table 1 details the dramatic impact of DDT on malaria cases in selected countries in the Americas. Notably, success was greatest in island countries, where the vector could be contained most easily. In 1955, WHO launched its own malaria eradication program, based on the extraordinary successes seen thus far with DDT. The program was funded mostly by the U.S. government.

In the early 1950s, cases of DDT resistance among various Anopheles species were detected by public health experts. In order to preempt the development of insecticide resistance, WHO proposed to overwhelm the mosquito population with spraying to reduce the population dramatically before any insecticide resistance could develop.[18] This ultimately failed due to donor fatigue, weak public health infrastructure, and poor management. DDT resistance contributed to the failure, but it is often discussed as the only reason the campaign failed, when its contribution in most areas was negligible. The meme that resistance to DDT was the reason for its demise is a key reason why the public health community continues to ignore DDT's main strength: repellency, which is as far as we know unaffected by resistance.

DDT and Its Delisting

The modern environmental movement began with concerns about DDT. Rachel Carson's 1962 book *Silent Spring* questioned the effect that synthetic chemicals were having on the environment. Her argument was that DDT and its metabolites make bird eggshells thinner, leading to egg breakage and embryo death. Carson postulated that DDT would therefore severely harm bird reproduction, leading to her theoretical "silent spring." She also implied that DDT was a human carcinogen by telling

Table 1. Malaria morbidity before and after malaria was controlled or eradicated by DDT

Country	Year	Cases	Percent Change
Cuba	1962	3,519	
	1969	3	-99.9
Dominica	1950	1,825	
	1969	0	-100
Dominican Republic	1950	17,310	
	1968	21	-99.8
Granada and Curacao	1951	3,233	
	1969	0	-100
Jamaica	1954	4,417	
	1969	0	-100
Trinidad and Tobago	1950	5,098	
	1969	5	-99.9
Venezuela	1943	817,115	
	1958	800	-99.9

Source: WHO, Executive Board, 47th Session, Appendix 14, The place of DDT in operations against malaria and other vector-borne diseases, No. 190, January, 19-29, 1971 (Geneva: WHO, 1971) 177 anecdotal stories of individuals dying of cancer after using DDT.[19]

But while Carson's influence increased over the next decade, DDT continued to be used around the world, saving lives from disease. In 1971, after considerable pressure from environmentalist groups, the newly formed Environmental Protection Agency (EPA) held scientific hearings investigating DDT. The hearings lasted for more than eight months, involving 125 witnesses with 365 exhibits. The administrative law judge in charge of the hearings, Edmund Sweeney, ruled that DDT should remain available for use. With reference to the supposed environmental harms associated with DDT, he noted that "[t]he uses of DDT under the registration involved here do not have a deleterious effect on freshwater fish, estuarine organisms, wild birds or other wildlife."[20] He added, "DDT is not a carcinogenic hazard to man. . . . DDT is not a mutagenic or teratogenic hazard to man."[21]

In other words, after many months of hearings, DDT was not found to represent a cancer threat to humans, to cause mutations in humans, or to threaten the development of fetuses. DDT was relatively benign, and the allegations against it did not stand up to scrutiny.

Although Sweeney ruled that any existing uses of DDT should not be cancelled, he was overruled in 1972 by the administrator of the EPA, William Ruckelshaus, who did not attend one hour of the hearings. According to a report in the Santa Ana *Register* quoting Ruckelshaus's chief of staff, Marshall Miller, Ruckelshaus did not even read the entire hearing report.[22] The decision to cancel certain uses of DDT was essentially a political one without any grounding in good science.[23]

Evidence of the political, as opposed to scientific, nature of DDT's delisting can be found in remarks made by Ruckelshaus before the delisting. As assistant attorney general, Ruckelshaus stated in a report to the U.S. Court of Appeals on August 31, 1970:

DDT is not endangering the Public Health. To the contrary, DDT is an indispensable weapon in the arsenal of substances used to protect human health and has an amazing and exemplary record of safe use. . . . DDT, when properly used at recommended concentrations, does not cause a toxic response in man or other mammals and is not harmful.[24]

When he addressed the Audubon Society on May 2, 1971, however, less than a year later but after he had joined the EPA, he said, "As a member of the Society, myself, I was highly suspicious of this compound [DDT], to put it mildly. But I was compelled by the facts to temper my emotions."[25]

Although many believe that DDT was banned after 1972, it actually was not. It continued to be used in emergencies for pest control, for which exemptions were granted by the federal government, and it is still available for public health use today. In January 1979, DDT was used to suppress flea vectors of murine typhus in Louisiana.[26] As late as June 1979, the California Department of Health Services was permitted to use DDT to suppress flea vectors of bubonic plague.[27] Texas got an exemption to control rabid bats in October 1979.[28] Between 1972 and 1979, DDT was used to combat the pea leaf weevil and the Douglas-fir tussock moth in the Pacific Northwest; rabid bats in the Northeast, Wyoming, and Texas; and plague-carrying fleas in Colorado, New Mexico, and Nevada.[29] State governments, with the permission of the federal government, continued to leverage DDT to protect public health and agriculture. Manufacturing DDT for export was also allowed.

DDT and Human Health

Since its discovery, countless millions of people have been exposed to DDT in one way or another. A 2000 article in *The Lancet* concluded that "in the 1940s many people were deliberately exposed to high concentrations of DDT through dusting programmes or impregnation of clothes, without any apparent ill effect. There are probably few other chemicals that have been studied in as much depth as has DDT, experimentally or in human beings."[30] Furthermore, since the 1940s, thousands of tons of DDT have been produced and distributed throughout the world, and millions of people have come into direct contact with substantial amounts. Initially, DDT distribution was restricted to soldiers in World War II and those saved from concentration camps in Germany, and then to the general public in the aftermath of World War II. When demand for DDT escalated after the war, a plethora of studies were conducted on DDT's safety for humans.

The *Lancet* article summed up the prevailing evidence on DDT human toxicity as follows: "Ingestion of DDT, even when repeated, by volunteers or people attempting suicide, has indicated low lethality, and large acute exposures can lead to vomiting, with ejection of the chemical." Furthermore, "If the huge amounts of DDT used are taken into account, the safety record for human beings is extremely good."[31]

There are other important studies of those exposed more recently. Chris Curtis of the London School of Hygiene and Tropical Medicine has studied the health of Brazilian and Indian insecticide sprayers who had been exposed to DDT. He found that their health "was similar to other men of their age"--in other words, DDT spraying did not noticeably affect their health.[32]

The Agency for Toxic Substances and Disease Registry (ATSDR) at the Centers for Disease Control and Prevention (CDC) is the agency in charge of evaluating the health effects of hazardous substance exposure. ATSDR reviewed DDT's association with breast cancer, pancreatic cancer, Hodgkin's disease and Non-Hodgkin lymphoma, multiple myeloma, prostate and testicular cancer, endometrial cancer, and the occurrence of any other cancer. One of its assessments was that "taking all factors into consideration, the existing information does not support the hypothesis that exposure to DDT/DDE/DDD increases the risk of cancer in humans."[33]

Leading U.S. toxicologists Bruce Ames (a 1998 recipient of the U.S. National Medal of Science) and Lois Gold (of the University of California at Berkeley) place the cancer risk associated with DDT in broader perspective. Their research shows that even at the height of DDT's use in agriculture, the cancer risk associated with the chemical was far lower than the cancer risks of everyday foods.[34] Ames sums up the risk of pesticides and their carcinogenic threat to man as follows:

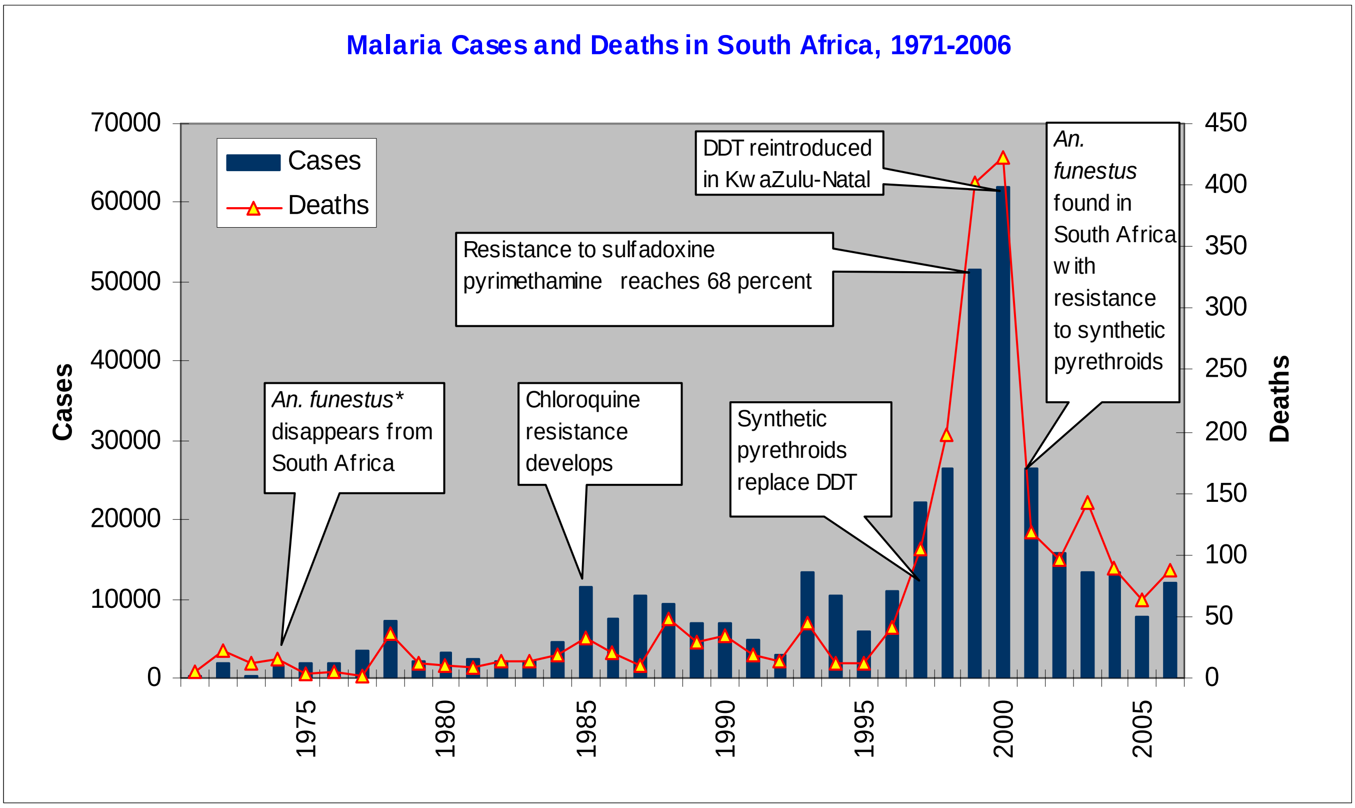
You would certainly put your attention on cups of coffee before you'd put your attention on dietary residues of pesticides. You get more carcinogen in one cup of coffee than from a year's worth of potentially carcinogenic pesticide residues. Pesticides just aren't something that inherently seem very interesting as possible causes of human cancer.[35]

Public health agencies and the written literature have found no strong evidence linking DDT or its metabolites with human cancer. Given the fact that DDT has been used in enormous quantities for over six decades and that many studies into its potential carcinogenicity have been conducted without drawing any evidence thereof, we can be relatively sure that DDT is not responsible for human cancer.

The Return of DDT

DDT leaves stains on mud walls, which was the primary reason South Africa's malaria control program replaced the use of DDT in 1996 with another chemical class--synthetic pyrethroids--although pressure from environmentalists certainly contributed. What followed was one of the country's worst malaria epidemics. Over four years, malaria cases increased by around 800 percent and malaria deaths increased tenfold (see figure 1).

At the same time, environmentalist pressure against the chemical was increasing. Environmental groups that had previously shown no interest in malaria, such as the World Wildlife Fund, started to profess expertise in alternatives to DDT use--any alternative, as long as it



was not DDT.[36] Between 1997 and 2000, member states of the United Nations Environment Program negotiated the Stockholm Treaty on Persistent Organic Pollutants, with DDT as one of the "dirty dozen" chemicals targeted. Green groups wanted the chemical banned and set 2007 as the year for its demise.[37] Ironically, because of the disastrous surge in malaria cases in South Africa, coupled with Johannesburg being chosen as the final negotiating location in December 2000, DDT was not banned; instead, it was to be phased out when "cost-effective alternatives" were available.[38]

In 2000, the South African Department of Health reintroduced DDT. In just one year, malaria cases fell nearly 80 percent in KwaZulu-Natal province, which had been hit worst by the epidemic. In 2006, malaria cases in the province were approximately 97 percent below the previous high of 41,786 in 2000. DDT remains an essential part of South Africa's malaria control program, and the success of its use in that country has encouraged other countries in the region to follow suit.

The South African epidemic, tragic though it was, not only ultimately strengthened the case for DDT and IRS in general, but also gave strength to other malaria control programs in Africa that wanted to use DDT and expand their insecticide spraying.

In 2000, a private mining company in Zambia restarted a malaria control program that had been discontinued in the early 1980s due to economic constraints. This malaria control program, managed and paid for by the Konkola Copper Mine, was designed to protect over 365,000 people living in almost 32,500 dwellings. Almost 80 percent of these dwellings were sprayed inside with DDT, and after the first spraying season, malaria incidence fell by 50 percent.[39] After the second spraying season, malaria cases declined further by 50 percent, and today malaria mortality at the mine clinics has fallen to zero. This program has been so successful that other private companies in the region have adopted similar approaches, and the Zambian government--with funding from the Global Fund for AIDS, Tuberculosis and Malaria--has restarted similar programs in five other districts.

In July 2005, the Mozambican government started using DDT again. Others have wanted to follow suit. Approximately 93 percent of Uganda's population, for example, is at risk from malaria. According to the CDC, the incidence of the disease has increased from 5 million cases in 1997 to 16.5 million in 2003.[40] The Ugandan health department has wanted to use DDT since at least 2005, and in January 2007, DDT passed its environmental assessment.[41] But as of October 2007, it has not been used.

In 2005, President George W. Bush anounced the President's Malaria Initiative (PMI) under the auspices of the U.S. Agency for International Development (USAID). The PMI was designed as a $1.2 billion intervention over five years targeted to fifteen African countries where there was both an urgent need and an ability to have an impact.[42] In September 2006, Rear Admiral Tim Ziemer, the PMI coordinator, announced: "I anticipate that all 15 of the country programs of President Bush's $1.2 billion commitment to cut malaria deaths in half will include substantial indoor residual spraying activities, including many that will use DDT."[43]

For over fifty years, DDT has been on WHO's list of approved insecticides for use in vector control. It experienced a resurgence with reforms to WHO's malaria control policy in late 2005 when the then-director-general, the late J. W. Lee, appointed Arata Kochi to lead the malaria unit. On September 15, 2006, Kochi launched WHO's revised policy position on IRS. In his candid remarks, he explained how and why WHO had arrived at a position that strongly supports IRS and DDT:

I asked my staff; I asked malaria experts around the world: "Are we using every possible weapon to fight this disease?" It became apparent that we were not. One powerful weapon against malaria was not being deployed. In a battle to save the lives of nearly one million children every year--most of them in Africa--the world was reluctant to spray the inside of houses and huts with insecticides; especially with a highly effective insecticide known as dichlorodiphenyltrichloroethane or "DDT."[44]

Today, even some of the largest environmental groups have accepted the WHO position. The Sierra Club officially states that it "does not oppose the indoor use of DDT to control malaria where it is critically needed and proven to be effective."[45] The Global Fund acts as a funding entity, providing support for projects that an expert panel considers feasible and valuable. Since its inception in 2002, it has provided funds for IRS programs, including the purchase of DDT.[46]

DDT is not always the appropriate intervention. In some instances, other insecticides will be better, especially for use outside. Nor is DDT a magic bullet. Other interventions, such as insecticide-treated bed nets, play a useful and sometimes critical role in malaria control. IRS programs with DDT or any other insecticide require a sound health system infrastructure. Some complain that in poor countries with year-round malaria, IRS is not a good use of resources and is not sustainable.[47] In a few settings, spending any money on malaria control of any variety is not the best use of very scarce resources, but it is debatable whether bed-net distribution programs under such conditions have any significant impact on malaria either. As for sustainability, if funding is not found to make a program sustainable, it will not be sustained, whether the program distributes bed nets or drugs or conducts spraying. Mozambique, which has very poor health infrastructure, has managed to sustain a well-run IRS program for over seven years by partnering with neighboring South Africa and Swaziland in the Lubombo Spatial Development Initiative.[48] As a result of this initiative, the country's malaria burden has dramatically decreased.[49] Regional leaders decided to make malaria control sustainable, and this is what has happened.[50]

The Imminent Fall of DDT

The voices arguing against DDT have become louder recently, in part because funding for other interventions has come under threat. Countries are using other insecticides in their expanded spray programs, but they are not using DDT. Since the late-2005 turnaround at USAID and the September 2006 statements from WHO about the benefits of DDT, no country has started to use it again. Uganda has come closest so far, but to no avail. Health department malaria experts in Kenya and Tanzania have told me and others that they would like to use DDT, but business continues as usual.

This is not the fault of senior management at the PMI. But according to field sources and from personal experience, the same cannot be said of all USAID staff, many of whom are still upset about the PMI's scientifically valid but nevertheless politically charged 2005 decision to promote DDT once again. Furthermore, Global Fund support is weak, and anecdotal field reports indicate that its contractors in the field are not always supporters of DDT. Many other aid agencies are even worse, often actively opposing IRS, and DDT in particular, on the ground. The environmental movement continues to exaggerate the dangers of DDT. Some corporations go even further. Bayer actively discouraged the use of DDT in Uganda, citing a possible threat to the country's supply of food for export. But the company's business manager admitted that more was at stake than food safety: "DDT use is for us a commercial threat."[51]

Bias in the academic literature is accelerating. A recent article in *The Lancet Infectious Diseases* alleges that superior methods for malaria control exist--without providing a single reference for this claim.[52] The authors claim that DDT represents a public health hazard by citing two studies that, according to a 1995 WHO technical report, do not provide "convincing evidence of adverse effects of DDT exposure as a result of indoor residual spraying."[53] Furthermore, the authors misrepresent those defending the use of DDT. They claim that supporters view DDT as a "panacea"--dogmatically promoting it at every opportunity--yet they do not provide any evidence to back up their opinion.

The United Nations is once again ramping up opposition to the use of DDT. At its third session, ending on May 4, 2007, "the Conference of the Parties of the Stockholm Convention requested its secretariat in collaboration with the World Health Organization and interested parties to develop a business plan for promoting a global partnership to develop and deploy alternatives to DDT for disease vector control."[54] Since there are so many players who want to sell alternatives to DDT, the chemical has few champions, and since those represented in this group are no friends of DDT, the partnership is likely to be broad, well-financed, and politically connected. It may prove to be the final nail in DDT's coffin.

DDT is no panacea, but it has a better track record on malaria control than any other intervention. Lives are lost every day because of continued opposition to its use. With development and modernization and, perhaps, a vaccine, DDT will one day no longer be necessary, but that day is still a long way off.

The Author

Roger Bate (rbate@aei.org) is a resident fellow at AEI.

AEI research assistant Karen Porter and editorial assistant Evan Sparks worked with Mr. Bate to edit and produce this Health Policy Outlook.

Notes

1. See Fred L. Soper, W. A. Davis, F. S. Markham, and L. A. Riehl, "Typhus Fever in Italy, 1943-1945, and Its Control with Louse Powder," American Journal of Hygiene 45, no. 3 (May 1948): 305-334.
2. Ibid.
3. G. Fischer, "The Nobel Prize in Physiology or Medicine 1948 Presentation Speech," in Nobel Lectures, Physiology or Medicine 1942-1962 (Amsterdam: Elsevier,

1964), available at www.nobelprize.org/nobel_prizes/medicine/laureates/1948/press.html (accessed October 24, 2007).

4. Trustham Frederick West and G. A. Campbell, DDT: The Synthetic Insecticide (London: Chapman and Hall, 1946), 11.

5. Until then, there were numerous explanations of how malaria spread. The most accepted was that the foul air emanating from swamps gave people fevers, and hence the name of the disease derived from the Italian mal (bad) and aria (air).

6. See Gordon A. Harrison, Malaria, Mosquitoes and Man: A History of the Hostilities since 1880 (London: John Murray, 1978); and B. L. Sharp and D. le Sueur, "Malaria in South Africa--The Past, the Present, and Selected Implications for the Future," South African Medical Journal 86, no. 1 (1996): 83-89.

7. Studies have shown that DDT is actually active against mosquitoes for far longer. One study found that DDT was active on walls for at least eleven months.

8. The first published reference to repellency was R. L. Metcalf, A. D. Hess, G. E. Smith, G. M. Jeffrey, and G. W. Ludwig, "Observations on the Use of DDT for the Control of Anopheles quadrimaculatus," Public Health Reports 60, no. 27 (July 1945). The latest is from this year: John P. Grieco et al., "A New Classification System for the Actions of IRS Chemicals Traditionally Used for Malaria Control," PLoS ONE 2, no. 8 (2007): e716, available at www.pubmedcentral.nih.gov/articlerender.fcgi?artid=1934935 (accessed October 24, 2007).

9. Erwin Heinz Ackerknecht, Malaria in the Upper Mississippi Valley, 1760-1900 (Baltimore: Johns Hopkins University Press, 1948).

10. U.S. Public Health Service (PHS), Malaria Control in War Areas, 1944-45 (Washington: Federal Security Agency, 1945), 134.

11. Ibid. The program was slated to spray 1,222,225 homes (17); by the end of the fiscal year, only 300,000 were sprayed (18), with about eight ounces of DDT used per house. A house was estimated to have an average size of 2,200 square feet, and DDT was sprayed at 100 milligrams per square foot (18).

12. Ibid.

13. U.S. Department of Health, Education, and Welfare, PHS, Communicable Disease Center, "Activities," 1951-52, 27-29. Copy on file with author.

14. Richard Tren and Roger Bate, Malaria and the DDT Story (London: Institute of Economic Affairs, 2001), available through www.aei.org/book473/.

15. Gordon A. Harrison, Malaria, Mosquitoes and Man: A History of the Hostilities since 1880.

16. Ibid.

17. World Health Organization (WHO), Executive Board, 42nd Session, Appendix 14, The Place of DDT in Operations Against Malaria and Other Vector-Borne Diseases, 177.

18. Gordon A. Harrison, Malaria, Mosquitoes and Man: A History of the Hostilities since 1880.

19. Rachel Carson, Silent Spring (1962; New York: Houghton Mifflin, 1972), 198, 200-201.

20. Edmund Sweeney, "EPA Hearing Examiner's Recommendations and Findings Concerning DDT Hearings," 40 CFR 164.32 (April 25, 1972).

21. Ibid.

22. "EPA Chief Did Not Read All Evidence," Register (Santa Ana, CA), July 23, 1972.

23. The delisting of DDT was the first project that the EPA undertook, and Ruckelshaus was probably eager to demonstrate the authority of the newly formed agency.

24. Environmental Defense Fund v. Hardin, 428 F.2d 1093 (D.C. Cir. 1970).

25. Barron's, November 10, 1975.

26. Federal Register 44, no. 68 (April 6, 1979), 20785.

27. Federal Register 44, no. 147 (July 30, 1979), 44611.

28. Federal Register 45, no. 14 (January 21, 1980).

29. Federal Register 39, no. 129 (July 3, 1974); Federal Register 39, no. 171 (September 3, 1974); Federal Register 41, no. 224 (November 18, 1976); Federal Register 42, no. 8 (January 12, 1977); Federal Register 41, no. 144 (July 26, 1976); and Federal Register 42, no. 159 (August 17, 1977).

30. A. G. Smith, "How Toxic is DDT?" The Lancet 36, no. 9226 (July 22, 2000), available at www.malaria.org/smithddt.html (accessed October 24, 2007).

31. Ibid.

32. C. F. Curtis and J. D. Lines, "Should DDT Be Banned by International Treaty?" Parasitology Today 16, no. 3 (March 1, 2000): 119-121. See also Melville Litchfield, "Estimates of Acute Pesticide Poisoning in Agricultural Workers in Less Developed Countries," Toxicological Reviews 24, no. 4 (2005): 271-78.

33. U.S. Department of Health and Human Services, PHS, Agency for Toxic Substances and Disease Registry, Toxicological Profile for DDT, DDE and DDD, September 2002, 108, available at www.atsdr.cdc.gov/toxprofiles/tp35.pdf (accessed October 24, 2007).

34. Bruce N. Ames and Lois Swirsky Gold, "The Causes and Prevention of Cancer: Gaining Perspectives on Management of Risk," in Risks, Costs, and Lives Saved: Getting Better Results from Regulation, ed. Robert W. Hahn (Oxford: Oxford University Press, 1996), 4-35, available through www.aei.org/book663/. See also Roger Bate, ed. What Risk: Science, Politics and Public Health (Oxford: Butterworth-Heinemann, 1998), available through www.aei.org/book467/.

35. Bruce Ames, personal communication with the author, October 15, 2003.

36. Amir Attaran, Richard Liroff, and Rajendra Maharaj, "Doctoring Malaria, Badly: The Global Campaign to Ban DDT--Ethical Debate," British Medical Journal 321 (December 2, 2000), available at www.bmj.com/cgi/reprint/321/7273/1403.pdf (accessed October 24, 2007).

37. See Richard Tren and Roger Bate, Malaria and the DDT Story.

38. WHO, "WHO Position on DDT Use in Disease Vector Control under the Stockholm Convention on Persistent Organic Pollutants," 2005, available at www.who.int/malaria/docs/WHOpositiononDDT.pdf (accessed September 28, 2007).

39. Brian Sharp et al., "Malaria Control by Residual Insecticide Spraying in Chingola and Chililabombwe, Copperbelt Province, Zambia," Tropical Medicine and International Health 7, no. 9 (September 2002), 732-36.

40. National Center for Infectious Diseases, Division of Parasitic Diseases, "Malaria Control in Uganda--Towards the Abuja Targets," April 23, 2004, available at www.cdc.gov/malaria/control_prevention/uganda.htm (accessed October 24, 2007).

41. Roger Bate and Richard Tren, "AFM Writes to EU to Demand Explanation on DDT & Uganda Issue," news release, April 6, 2006, available at www.fightingmalaria.org/pressrelease.aspx?id=709 (accessed October 24, 2007).

42. See the President's Malaria Initiative's website at www.fightingmalaria.gov (accessed October 24, 2007).

43. WHO, "WHO Gives Indoor Use of DDT Clean Bill of Health for Controlling Malaria," news release, September 15, 2006, available at www.who.int/mediacentre/news/releases/2006/pr50/en/index.html (accessed October 24, 2007).

44. Arata Kochi, "WHO Malaria Head to Environmentalists: 'Help Save African Babies as You Are Helping to Save the Environment'" (press statement, National Press Club, Washington, DC, September 15, 2006), available at http://malaria.who.int/docs/KochiIRSSpeech15Sep06.pdf (accessed October 24, 2007).

45. Sierra Club, "Sierra Club's Position on the World Health Organization's Promotion of Indoor Use of DDT to Control Malaria," November 2006, available at www.sierraclub.org/toxics/ddt/ (accessed October 24, 2007).

46. For two malaria control programs--Zambia's and that of the Lubombo Spatial Development Initiative (LSDI)--Global Fund monies were used to purchase DDT.

47. This was argued in the case of India. See Gordon A. Harrison, Malaria, Mosquitoes and Man: A History of the Hostilities since 1880, 251-54; and WHO Expert Committee on Malaria, Twentieth Report, WHO Technical Report Series 892, 2000, 38, www.rbm.who.int/docs/ecr20.pdf (accessed October 24, 2007).

48. LSDI, "Background," available at www.malaria.org.za/lsdi/Background/background.html (accessed October 24, 2007).

49. LSDI, "Progress," available at www.malaria.org.za/lsdi/Progress/progress.html (accessed October 24, 2007).

50. For a more extensive discussion of Mozambique's more-than-twenty-year-old malaria eradication campaign, see Musawenkosi L. H. Mabaso, Brian Sharp, and Christian Lengeler, "Historical Review of Malarial Control in Southern Africa with Emphasis on the Use of Indoor Residual House-Spraying," Tropical Medicine and International Health 9, no. 8 (August 2004): 846-56.

51. Alan Beattie, "Commercial Motive Hinted At in Restrictions on DDT," Financial Times, September 29, 2005.

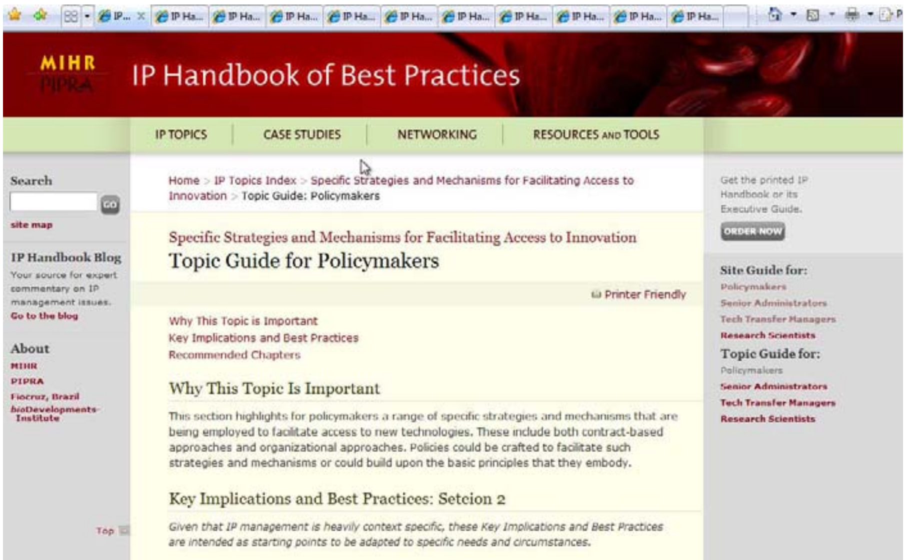
52. Hans J. Overgaard and Michael G. Angstreich, "WHO Promotes DDT?" The Lancet Infectious Diseases 7, no. 10 (October 2007): 632-33.

53. WHO, Vector Control for Malaria and Other Mosquito-Borne Diseases: Report of a WHO Study Group, Technical Report Series 857, 1995.

54. United Nations Environmental Program, letter to potential partners, August 10, 2007.

NOW ONLINE: IP *HANDBOOK*

A new and unique resource in intellectual property and innovation management is now available Online.



For more information contact:: **www.ipHandbook.org**