Determining the best way to organize and fund agricultural research is a topic that has received considerable attention in recent years (GFAR 2011), particularly in relation to Africa south of the Sahara (SSA) (Roseboom 2011). Although national governments hold the primary responsibility for the organization and funding of agricultural research, these issues have inherent international dimensions, because most agricultural research challenges extend beyond national borders. The resulting incongruence between internationally relevant problems and nationally driven solutions leads to wasteful duplication of effort, as well as underinvestment. A key concept in the discussion of these issues is what economists call “technology spillovers,” whereby the benefits of advances in knowledge and technology developed in (and paid for by) one jurisdiction spill over into another.

This chapter first presents an overview of current thinking about agricultural research spillovers; it goes on to summarize recent attempts to quantify the potential for agricultural technology spillovers globally, across SSA’s subregions, and between member countries of the subregional organizations (SROs) of national agricultural research systems (NARSs) in SSA; it then provides an assessment of the implications of this information for regional collaboration in agricultural research. The remaining discussion focuses on benchmarking some of the key characteristics of crossborder collaboration in agricultural research in the United States, the European Union (EU), and SSA. The chapter closes with a summary of the main conclusions.

The author would like to thank participants of the writers’ workshop organized by Agricultural Science and Technology Indicators in July 2013 for their feedback on an early draft of this chapter and various reviewers for their comments at various stages.

1 The SROs are the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA), the Centre for the Coordination of Agricultural Research and Development in Southern Africa (CCARDESA), and the West and Central African Council for Agricultural Research and Development (CORAF/WECARD).
Technology Spillovers

It is a commonly held notion that—in addition to local investment in agricultural research—technology spillovers play an important role in explaining local changes in agricultural productivity. Nevertheless, few agricultural productivity studies have actually tried to capture this effect quantitatively, and those that have often attribute a sizable share (in many cases more than half) of the measured productivity increase to such technology spillovers (Alston 2002). These results suggest that agricultural productivity studies that do not account for technology spillovers substantially overestimate the contribution of local research. A better understanding of how agricultural technology spillovers occur should help to improve the design of more effective agricultural research systems.

Byerlee and Traxler (2001) distinguish three types of research spillovers:

1. knowledge-related spillovers, involving knowledge generated elsewhere, such as a new discovery or research method, that is applied in developing a new technology;

2. technology-related spillovers, which occur when an actual technology is transferred or adapted to a new environment; and

3. price-related spillovers, involving the adoption of a more efficient technology that affects the price of a commodity in locations both where the technology was adopted, and—through market effects—where it was not adopted.

Research spillovers are usually cast as spillovers across locations, but they can also occur across stages of research—that is, between basic, applied, and adaptive research (Box 14.1, Figure 14.1). The spillover from basic to applied

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**BOX 14.1 The different stages of research**

*Basic research* aims to increase understanding of fundamental principles; it is curiosity driven, without any concrete (economic) application of the knowledge in sight. In contrast, *applied research* uses the knowledge generated through basic research to develop technologies and solutions that target concrete problems and opportunities. *Adaptive research* aims to modify an existing (prototype) technology or solution to local circumstances.

Source: Author.
research is mostly knowledge spillover, whereas the spillover from applied to adaptive research is technology spillover. The dominant direction of the spillover flows from basic to applied research, and from applied to adaptive research, but feedback loops also occur (for example, information from adaptive research trials feeding back into the applied research agenda). Moreover, these spillovers between different phases in the research process are usually intended. Not highlighted in Figure 14.1 are unintended technology spillovers between applied research programs—for example, a technology developed for irrigated rice production spilling over to rainfed rice production.

Knowledge spillovers from basic to applied research can have huge and long-lasting impacts by affecting multiple domains of applied research; take, for example, the discovery of DNA. Nevertheless, such scientific discoveries are rare and unpredictable. In today’s highly interconnected world, the diffusion of basic research results is almost instantaneous, whereas in the past it could take centuries to spread across the world. The more critical bottleneck nowadays is whether countries have the scientific capacity to absorb and apply this knowledge. All countries in the world are aware of what can be done with modern biotechnology, but only the larger and richer ones actually have the capacity to deploy that knowledge.
The spillover of agricultural technologies from applied to adaptive research varies by technology. Some (such as mechanical and chemical technologies) can be used worldwide with little or no adaptation to local circumstances, while others (particularly biological technologies) can require significant adaptation to local circumstances. Moreover, in certain instances, it is not a matter of adapting an existing technology; rather, it relates to conducting applied research to develop an original technology for a specific location (for example, natural resource management technologies).

A gamut of combinations of applied and adaptive research exists in the conduct of agricultural research to generate both widely applicable and location-specific technologies. Whether a prototype technology should undergo adaptive research depends (a) on the additional yield per hectare generated by the adaptive research program, (b) on the area under production affected by the adapted technology, and (c) on the costs of conducting the adaptive research program. Adaptive research only makes sense when the additional benefits it generates \((a \times b)\) can at least pay for its additional costs \((c)\).  

This stylized representation of the research process assumes a world without national borders and markets, and with a single supranational entity deciding on the optimal design of the agricultural research system. Introducing national borders, markets, and competing approaches significantly complicates the research process and brings price-related research spillovers into play.

First, depending on the factors affecting the supply and demand of a particular commodity, producers will pass on some or all of the research benefits to consumers in the form of lower prices. The more inelastic (that is, fixed) the demand, the larger the share of the benefits consumers will receive through lower prices. The impact of price-related spillovers in four “stylized” markets is presented in Table 14.1. By adopting the perspective of a national planner, these price-related spillovers affect the optimal allocation of research resources. Not only does the absolute size of the research benefits matter (relative to the cost of generating them), but also to whom the benefits will accrue. For example, investing in research that targets foreign markets with fairly low demand elasticity does not make much sense from a national perspective because the research benefits will go to foreign consumers. Moreover, insight into who benefits from research helps to determine who should pay for it. For example, in commodity markets with high demand elasticity, it is more opportune to tax producers for the costs of the research, because they have a lot to

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2 Byerlee and Maredia (1999) point to a common mistake that adaptive research programs make in assuming there will be no yield improvement without adaptive research. This is not necessarily so.
gain through the potential to increase their sales; however, the same cannot be
said in commodity markets with low demand elasticity.

Second, a further distinction can be made between adopters and non-
adopters of technology. Nonadopters are not directly affected by technology
changes, but are indirectly affected by lower prices induced by improved tech-
nologies; hence, they may lose market share to technology adopters (particu-
larly in markets with low demand elasticity). Therefore, innovation processes
not only generate winners (technology adopters and consumers), but also los-
ers (technology nonadopters).

A third aspect is that the introduction of multiple national jurisdictions
(rather than a single supranational one) causes a fragmentation of applied and
adaptive research into parallel, national research efforts targeting the same
commodity, agroecology, production system, or problem. This leads not only
to research duplication, but also to less ambitious research agendas founded on
decisionmaking processes that account only for the national benefits of agri-
cultural research investments.

At the same time, because of the duplication in research effort, national
(and state and provincial) jurisdictions create a substantial amount of unintended
technology spillover between parallel research programs in different jurisdic-
tions targeting the same commodity, agroecology, production system, or problem. Because countries differ by size and stages of economic devel-
opment, unintended technology spillovers tend to run from large to small
countries and from technologically more advanced to less advanced coun-
tries—a factor that is often captured in the form of yield differences (technol-
ogy spillovers generally run from countries with higher yields to those with
lower yields). However, countries that operate in isolation, have perfect tech-
nology proximity (that is, high similarity in agricultural production and agro-
ecology), and are equal in size and technology advancement have little to gain
from each other in terms of these unintended technology spillovers. They
can be expected to conduct very similar research, resulting in a high degree of
research duplication.

<table>
<thead>
<tr>
<th>Demand</th>
<th>Local market</th>
<th>Foreign market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low elasticity</td>
<td>Research benefits are passed on to local consumers in the form of lower prices</td>
<td>Research benefits are passed on to foreign consumers in the form of lower prices</td>
</tr>
<tr>
<td>High elasticity</td>
<td>Research benefits are mainly captured by local producers</td>
<td>Research benefits are mainly captured by local producers</td>
</tr>
</tbody>
</table>

Source: Author.
A fourth dimension requiring consideration is the economies of size of the research itself. Byerlee and Traxler (2001) present a conceptual framework incorporating this aspect together with market size and spill-ins in order to determine the optimal size of national research investment in a given market. They distinguish the following strategies, outlining increasingly more ambitious, complex, and costly research agendas through which countries can take advantage of emerging innovation opportunities:

1. *Spontaneous diffusion of improved technologies* without the benefit of local research and development (R&D)—as argued above, spontaneous spill-ins vary considerably across technologies (the higher the spill-in, the less the need for additional action)

2. *Direct transfer of technologies* after testing and screening by local R&D programs for suitability to local environments

3. *Adaptive transfer of technologies*, whereby final technologies from elsewhere are subject to local adaptive research before local release (for example, the use of imported varieties as parents in local breeding programs)

4. *Comprehensive applied research*, whereby imported knowledge from basic research conducted elsewhere is used in local applied research programs to produce homegrown technologies

5. *Comprehensive basic and applied research* that uses imported knowledge and includes the ability to conduct basic and pretechnology research

Byerlee and Traxler (2001) argue that these increasingly complex research capacities often lead to discontinuities in the research production function. For example, the transition from Strategy 2 to Strategy 3 involves the addition of a crossing program and early generation selection, which is considerably more complex and expensive to undertake than is simple testing of imported varieties. Depending on the volume of research benefits that can be captured by a country (mostly defined by market size), countries will adopt a more ambitious research strategy.

Because of limited market size, small countries probably best settle for Strategies 1 and 2, or Strategy 3 in the case of a technology that affects a major commodity or multiple commodities. Strategies 4 and 5 are largely out of reach for small countries because of the high costs of such activities relative to the limited volume of national production that could benefit. These countries
are very much net beneficiaries of technology spillovers, but at the same time have to accept technologies that are not necessarily a perfect match for their circumstances. Nevertheless, despite their less ambitious research agendas, small countries tend to invest proportionally more in agricultural research than large countries (Pardey, Roseboom, and Anderson 1991).

**Exploring SSA’s Technology Spillover Potential**

The presence of agricultural technology spillovers has mostly been addressed in the context of agricultural productivity studies that try to establish a link between research investments and advances in productivity. All have struggled with how to capture the spillovers and how to attribute observed productivity changes to research conducted locally, to the spillover of technology from elsewhere, or to a combination of both of these factors. Alston (2002) discusses how different studies have dealt with these problems and shows that the assumptions imposed can result in significant differences both in the volume of research benefits and in the attribution of those benefits to an individual’s or organization’s own research and that of others. How best to capture technology spill-ins in agricultural productivity studies is still subject to extensive discussion and experimentation.

Another line of research, pioneered at the International Food Policy Research Institute (IFPRI), looks at the potential for technology spillovers across locations based on similarities in production, agroecology, and other factors. The result is policy-relevant, geospatial “domains,” such as agroecological zones, that take into account large amounts of data on rainfall, sunshine, altitude, soil type, infrastructure, population, production, and so on.

**Global and Regional Technology Spillovers**

Pardey et al. (2007) present a global picture (based on 156 countries) of technology proximity based on similarities among countries and groups of countries in terms of agroecology and output mix. They calculated a measure of proximity for both factors on a scale of 0, indicating no similarity, to 1, indicating complete similarity (Table 14.2). Together, the agroecological and output proximity scores result in a technology proximity score. The results of their study reveal very low technology proximity between low-income and high-income countries, which is unfortunate. High-income countries are technologically more advanced and account for around two-thirds of global

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3 For details on the methodology used to measure similarity, see Pardey et al. (2007).
public and private spending on agricultural R&D. Pardey et al. (2007) argue that the structural differences in agroecology and agricultural output very much curtail the potential for technology spillovers from high-income to low-income countries. Another concern is that in recent years the public agricultural research agenda of high-income countries has shifted away from productivity enhancement to more qualitative aspects, such as health and ecological issues. These are not necessarily the research priorities of low-income countries that are still struggling with food security. In other words, low-income countries are very much on their own when it comes to developing better agricultural technologies.

Using the same methodology and dataset, Pardey et al. (2007) also focus more closely on Africa (Table 14.3). Results reveal that North Africa has very low agroecological proximity to SSA; its output proximity to SSA is slightly better, but is weaker than its proximity to the rest of world. These results

| TABLE 14.2 Agroecological and output proximity of countries clustered by income level |
|-------------------------------------|-------------------------------|-------------------------------|-----------------|-----------------|-----------------|
| Income bracket                      | Agroecological proximity     | Output proximity              |                 |                 |                 |
|                                    | High income                  | Higher middle-income          | Lower middle-income | Low income | High income | Higher middle-income | Lower middle-income | Low income |
| High income                         | 1.00                         | —                             | —                | —            | 1.00           | —                             | —                 | —         |
| Higher middle-income                | 0.81                         | 1.00                          | —                | —            | 0.95           | 1.00                          | —                 | —         |
| Lower middle-income                 | 0.56                         | 0.69                          | 1.00             | —            | 0.74           | 0.71                          | 1.00              | —         |
| Low income                          | 0.06                         | 0.13                          | 0.44             | 1.00         | 0.38           | 0.38                          | 0.64              | 1.00      |

Source: Pardey et al. (2007).

| TABLE 14.3 Agroecological and output proximity among African subregions and with the rest of the world |
|-------------------------------------|-------------------------------|-------------------------------|-----------------|-----------------|-----------------|
| Subregion                          | Agroecological proximity     | Output proximity              |                 |                 |                 |
|                                    | North Africa                 | East Africa                  | Southern Africa | West Africa | North Africa | East Africa | Southern Africa | West Africa | Rest of the world |
| North Africa                        | 1.00                         | —                             | —                | —            | 1.00           | —                             | —                 | —         |
| East Africa                         | 0.00                         | 1.00                          | —                | —            | 0.41           | 1.00                          | —                 | —         |
| Southern Africa                     | 0.13                         | 0.75                          | 1.00             | —            | 0.53           | 0.70                          | 1.00              | —         |
| West Africa                         | 0.01                         | 0.85                          | 0.81             | 1.00         | 0.21           | 0.52                          | 0.40              | 1.00      |
| Rest of the world                   | 0.27                         | 0.32                          | 0.29             | 0.36         | 1.00           | 0.73                          | 0.60              | 0.71      | 0.31 | 1.00 |

Source: Pardey et al. (2007).
suggest that the potential for technology spillovers between North Africa and SSA is low, and that North Africa would be better off seeking research collaboration elsewhere.

The agroecological proximity between East, West, and Southern Africa stands out as being relatively high. Surprisingly, however, output proximity is substantially weaker. In particular, West Africa stands out as having a relatively low output-proximity score, both with the other subregions and with the rest of the world, which reduces the potential for technology spillovers. Southern Africa includes South Africa, which is an important stronghold of agricultural research capacity in the region. Individually, South Africa’s agroecological proximity to the other subregions is weak (less than 0.2); its output proximity to the other subregions is also lower than that of Southern Africa, but less dramatically so. This finding dampens high expectations regarding South Africa’s potential lead role in agricultural innovation in the region.

Pardey et al. (2007) also point to the fact that geographic proximity does not necessarily translate into technological proximity. It may be that a country has more in common in terms of its technology needs with countries in other parts of the world than with its direct neighbors. Moreover, linking with countries with similar agroecological and output mixes is all the more interesting when they are technologically more advanced.

**Intraregional Technology Spillovers**

In recent years, IFPRI has conducted priority-setting exercises on regional agricultural research for each of three SROs,4 which take into account the potential technology spillovers between countries within each of the sub-regions. Johnson et al. (2011) discuss the common methodological framework used in these three studies (Box 14.2), as well as the specific strengths and weaknesses of each study. To capture the technology spillover potential across subregions for specific commodities, all three studies use spatial analysis tools to define “development domains” that present similar characteristics in terms of agroecology, climate, population density, and market access, and that can be expected to have similar agricultural development problems and opportunities. These specific domains allow for a more realistic depiction of technology proximity (and, hence, technology spillover potential), as well as a differentiation in innovation approaches.

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4 ASARECA (Omamo et al. 2006), CORAF/WECARD (Nin Pratt et al. 2011), and Southern African Development Community (SADC) (Johnson et al. 2014).
BOX 14.2 A common analytical framework

All three regional studies used a common framework, starting with a highly disaggregated spatial analysis based on key biophysical and socioeconomic factors of geographic areas sharing similar characteristics and endowments and, in turn, their degree of agricultural suitability, type of production systems and commodities, and available technology options (Panel A). The resulting distinctive agricultural development domains, which are not limited by political boundaries, provided a measure of the technological proximity of different countries and, hence, the potential for technology spillovers among them. Second, more detailed economic analysis was undertaken using a regional economywide multimarket model (Panel B) and IFPRI’s Dynamic Research Evaluation for Management (DREAM) model (Panel C). The DREAM model was typically used to measure the potential magnitude of economic benefits derived from different commodity-based R&D investment options that rely on the distributional pattern of each development domain across countries. The multimarket model was developed to capture economywide implications of the same investments, including the potential benefits from technology spillovers on overall sector growth, incomes, prices, and consumption. Results from the economic analyses were then used to derive alternative rankings of R&D investments based on weighted criteria of a commodity-specific R&D investment’s potential to contribute to overall sector growth, generate greater spillover benefits, and provide larger welfare outcomes in terms of regional food security and poverty reduction objectives (Panel D).

A. Spatial analysis

Spatial disaggregation of agricultural development domains and spillover potential

B. Economywide analysis of future growth alternatives

Growth → Price → Income

C. Analysis of economic returns to regional R&D investments

Community-based producer and consumer benefits from greater regional cooperation

D. Ranking R&D priority options

Rankings based on economic benefits derived from the contribution of research to growth, food security, and poverty reduction, and potential spillover benefits

Source: Johnson et al. (2011). Text updated by author.
Notes: IFPRI = International Food Policy Research Institute; R&D = research and development.
In addition to technology proximity, several other factors need to be considered in estimating the technology spillover potential:

1. **The difference in technological advancement between countries**, captured here as yield differences. The technology spillover is expected to run from a country with a high yield to one with a low yield. Moreover, the yield difference needs to be sufficiently large to trigger a spillover.

2. **Whether the recipient country has sufficient absorptive capacity** in the form of adaptive research capacity to capture the full technology spillover potential. The ASARECA and CORAF/WECARD studies assume that all countries in their subregion have the same absorptive capacity, so this factor does not affect their estimates of the potential volume of technology spillover. The SADC study, however, introduces a differentiation in absorptive capacity on the basis of country-specific rates of return for crop and livestock research. Countries with low rates of return on agricultural research investment are assumed to have limited absorptive capacity, and vice versa.

3. **The maximum adoption rate in the recipient country**, which may be affected by such factors as the education of farmers; the quality of the extension services; the availability of credit, land tenure, communications, and market structure; previous exposure to technical change; and so on (Davis, Oram, and Ryan 1987). In all three studies, this factor is ignored, and it is implicitly assumed that the development domains have the same maximum adoption rate across countries.

4. **The time lags in technology development and diffusion**, stylized in Figure 14.2 taken from Davis, Oram, and Ryan (1987), illustrate a process of slow initial adoption, followed by fast adoption and then a return to slower adoption before the adoption ceiling is reached. By differentiating the adoption ceiling across countries, the model also allows the presence of nonadaptors to be differentiated. In the country where the research is undertaken, an initial research lag occurs before results become available (research lag A); this is followed by an adoption process that can take another $x$ years before the adoption ceiling is reached. If no adaptation of the technology is needed, the adoption process in the recipient country can be assumed to begin at the same time as in the country that conducted the research; hence, the only difference in the adoption process between the country of origin and the recipient country may be the assumed adoption ceiling. However, if adaptive research by the recipient country is needed to adapt the technology to local circumstances, an
additional lag (research lag B) enters into the picture. Time lags in technology development, adaptation, and adoption are very much technology specific and may result in very different technology spillover patterns ranging from almost complete and immediate to very incomplete and slow. This requires extensive detailed information regarding the technologies being developed for each commodity. In practice, such differentiation has never been attempted at the scale needed for these subregional studies, so a standard technology development, adaptation, and adoption process is usually assumed for all commodities and all technologies, or time lags and adoption ceilings are not considered at all.

By taking technology spillovers into account, the three studies suggest a prioritization of commodities at the subregional level different from when only the national benefits of technology improvements are accounted for. The CORAF/WECARD study does not present the “without spillover” case, but the ASARECA and SADC studies do (Table 14.4):
### TABLE 14.4 Ranking of commodities per region based on research-induced benefits, including spillovers

<table>
<thead>
<tr>
<th>Commodity</th>
<th>ASARECA benefits</th>
<th>CORAF/WECARD benefits</th>
<th>SADC benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>National Spillovers Total (US$ millions)</td>
<td>National Spillovers Total (US$ millions)</td>
<td>National Spillovers Total (US$ millions)</td>
</tr>
<tr>
<td>Cassava</td>
<td>5,200 2,581 7,781</td>
<td>Rice na na 8,200</td>
<td>Maize 4,870 1,226 6,096</td>
</tr>
<tr>
<td>Cow’s milk</td>
<td>4,456 2,984 7,440</td>
<td>Cassava na na 5,550</td>
<td>Cassava 3,263 264 3,527</td>
</tr>
<tr>
<td>Plantains</td>
<td>6,575 659 7,234</td>
<td>Groundnuts na na 4,280</td>
<td>Wheat 2,272 71 2,343</td>
</tr>
<tr>
<td>Maize</td>
<td>5,659 1,477 7,136</td>
<td>Sorghum na na 3,560</td>
<td>Rice 1,722 426 2,148</td>
</tr>
<tr>
<td>Beef</td>
<td>3,741 2,409 6,150</td>
<td>Maize na na 3,540</td>
<td>Cattle 1,508 294 1,802</td>
</tr>
<tr>
<td>Coffee</td>
<td>2,566 1,461 4,027</td>
<td>Yams na na 3,390</td>
<td>Chicken and eggs 1,646 78 1,724</td>
</tr>
<tr>
<td>Sorghum</td>
<td>1,064 2,059 3,123</td>
<td>Cocoa na na 2,375</td>
<td>Beans 877 184 1,061</td>
</tr>
<tr>
<td>Vegetables</td>
<td>1,742 956 2,698</td>
<td>Millet na na 2,300</td>
<td>(Sweet) potatoes 787 79 866</td>
</tr>
<tr>
<td>Dry beans</td>
<td>1,701 626 2,327</td>
<td>Cotton na na 2,125</td>
<td>Sheep and goats 797 46 843</td>
</tr>
<tr>
<td>Rice</td>
<td>854 1,355 2,209</td>
<td>Bananas na na 2,100</td>
<td>Pigs 686 35 721</td>
</tr>
<tr>
<td>Mutton/lamb</td>
<td>467 1,399 1,866</td>
<td>Coffee na na 460</td>
<td>Sorghum 383 190 573</td>
</tr>
<tr>
<td>Groundnuts</td>
<td>553 1,254 1,807</td>
<td>Oil palm na na 120</td>
<td>Groundnuts 407 82 489</td>
</tr>
<tr>
<td>Potatoes</td>
<td>982 490 1,472</td>
<td>Cotton na na 234</td>
<td>Sugar 185 11 196</td>
</tr>
<tr>
<td>Cotton</td>
<td>427 251 678</td>
<td></td>
<td>Millet 135 26 161</td>
</tr>
<tr>
<td>Cashews</td>
<td>396 5 401</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total** 36,383 19,966 56,349  **Total** na na 38,000  **Total** 19,772 3,052 22,824

**Sources:** Omamo et al. (2006), Nipratt et al. (2011), and Johnson et al. (2014).

**Notes:** ASARECA = Association for Strengthening Agricultural Research in Eastern and Central Africa; CORAF/WECARD = West and Central African Council for Agricultural Research and Development; SADC = Southern Africa Development Community; na = not applicable.
1. The intraregional spillover benefits are substantial: 35 percent of the reported research benefits in ASARECA’s subregion and 13 percent in SADC’s subregion are due to spillovers. Moreover, most (98 percent) of the spillover benefits in the SADC subregion accrue to low-income countries, whereas hardly any accrue to the middle-income countries. However, a substantial part (54 percent) of the technology spillover in the SADC subregion originates from low-income countries, which is somewhat counterintuitive. South Africa, which represents about half the agricultural research expenditure in the SADC subregion (Beintema and Stads 2011) and is technically the most advanced country in that subregion, only generates 19 percent of the technology spillover. This is consistent with the finding of Pardey et al. (2007) that South Africa has relatively little in common with the rest of SSA in terms of agroecology and agricultural production. Given South Africa’s large weight in the total, this also explains why spillovers play a much smaller role in the SADC subregion than they do in the ASARECA subregion.

2. Large variations can occur across commodities in terms of the relative importance of the spillover effect. In the case of the ASARECA subregion, the spillover share in benefits ranges from 1 percent for cashews to 75 percent for mutton/lamb. In the SADC subregion, it ranges from 3 percent for wheat to 33 percent for sorghum.

3. The rankings presented in Table 14.4 focus on research benefits, but not all research benefits have the same impact in terms of reducing poverty, improving food security, and so on. This is where IFPRI’s economic model (Box 14.2) provides more differentiated information on the expected research benefits, which can be used to give preferred research benefits (for example, those with a higher impact on reducing poverty) an artificially higher weight in the priority-setting process.

4. One of the issues for the SROs is how to interpret the information presented in Table 14.4. The ranking of commodities by total research benefits would be the relevant ranking if an SRO had control over all the agricultural research funding within its subregion. This is not the case, however. Most of the agricultural research funding within a subregion is controlled by national governments. Collectively, they can be expected to prioritize research on the basis of their national benefits, as depicted in the relevant column. This positions the SROs as
complementary actors: they should prioritize their research funding based on the spillover benefits, not the total benefits. Even when a commodity is big within the subregion, the SROs should not get involved (at least this is the logical consequence of the IFPRI approach) when little or no (unintended) spillover benefits accrue.

Technology Spillover and Centers of Excellence

What stands out is that in all three IFPRI studies, the volume of the estimated technology spillover potential is mainly driven by development domain similarities and yield differences. Yield differences also determine the direction of the technology spillover. Other factors in the technology spillover process have been captured with little differentiation (the same values for all commodities) or not at all. The potential spillover effect being captured in these studies is that of unintended technology spillovers resulting from the separation of agricultural research into national jurisdictions. What these studies do not capture, however, is the possibility of creating intended technology spillovers.

This scenario of creating intended technology spillovers is particularly relevant when development domains are similar, yield differences between countries are low, and the technology exchange is limited (Table 14.5). This is a situation under which all countries do a little bit of the same research (the incidence of research duplication is high), but none of them are really pushing the technological frontier. In such a situation, technology spillovers could be created purposefully by promoting a more differentiated agricultural research landscape at the subregional level by creating centers of research excellence (or specialization or leadership). The idea is that countries would voluntarily assume research leadership for one or more commodities of subregional interest and generate intended technology spillovers for the other countries of that subregion. By allocating these leadership roles equally across the subregion

<table>
<thead>
<tr>
<th>Yield difference</th>
<th>Similarity of development domains</th>
<th>Low</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>Low (unintended and intended) technology spillover potential</td>
<td>Low (unintended) technology spillover potential, but a high likelihood of research duplication</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Low (unintended and intended) technology spillover potential</td>
<td>High (unintended) technology spillover potential</td>
<td></td>
</tr>
</tbody>
</table>

Source: Author.

Note: The combination “high similarity, low yield difference” can also represent a situation of perfect technology spillover.
(which requires the necessary coordination and collaboration), the distribution of costs and benefits among countries of such an approach could be roughly equalized.

The center of excellence approach has been strongly promoted in recent years by the Forum for Agricultural Research in Africa (FARA) and the SROs in the context of the Comprehensive Africa Agriculture Development Programme, which was initiated in 2003 under the New Partnership for Africa’s Development to strengthen African agriculture. World Bank funding has backed this approach by providing loans (some $636 million to date)\(^5\) to clusters of countries in each of the subregions, (1) to transform existing national research programs or institutes into centers of research excellence that aim to have subregional impact, and (2) to facilitate the technology uptake by recipient countries through training and joint research activities and standardization of national technology policies. These World Bank, multi-country program loans are sitting together in three subregional agricultural productivity programs, which are coordinated by the three SROs.

IFPRI’s measure of technology spillovers only focuses on the “high domain similarity, high yield difference” part of the subregional research agenda, whereas the center of excellence approach focuses on the “high domain similarity, low yield difference (and no technology exchange)” part of the agenda. In a high domain similarity, high yield difference situation, it is quite likely that there are already one or more informal centers of excellence within the subregion. The SROs should identify and support these informal centers of excellence to push the productivity frontier even further (and, hence, maintain the potential volume of spillovers), while countries that are the recipients of technology spillovers should invest (more) in adaptive research and technology transfer.

The center of excellence approach starts with the premise that no centers of excellence are yet in existence and that they need to be created.\(^6\) Moreover, such centers have to link up with research stations and extension services in neighboring countries in order to facilitate technology spillover. However, this aspect has not received the same attention in each agricultural productivity program. In West Africa, far more resources are going to facilitating spillovers—even to (small) countries that do not contribute in the form of a center

\(^5\) For more detail, see Table 2.3 in Chapter 2, this volume.

\(^6\) In reality, the selection of research programs to become a regional center of excellence was based in part on their past track record and the importance of the commodity to the national economy.
of excellence of their own—than in East Africa. The stream of “intended” technology spillovers that will be created by such an intervention is not taken into account by the IFPRI studies. They have just ignored this possibility and, hence, portray an incomplete picture of the technology spillover potential. Between these two contrasting situations are many shades of gray. The key issues discussed above are summarized in the form of a decision tree (Figure 14.3).

Benchmarking Crossborder Collaboration Models in Agricultural Research

The political problem facing agricultural research is how to capture the apparent economic benefits of crossborder collaboration in agricultural research. Key to this problem is organizing the political will to address the issue, and finding a way to organize and fund a crossborder agricultural research agenda. To get a better understanding of this issue, this section benchmarks the SSA situation against the United States and the European Union in order to see what can be learned from their experiences.

United States

The overall “architecture” of public agricultural research in the United States is fairly simple, because from the very beginning (the late 19th century) it was designed as a national system with a relatively clear division of federal- and state-level responsibilities. The principal agencies at the federal level are the Agricultural Research Service (ARS), the Economic Research Service (ERS), and the Forestry Service, which all fall under the United States Department
of Agriculture (USDA). In addition to its headquarters, ARS also operates four regional agricultural research stations that function as intermediaries for national and state-level agricultural research agencies.

State-level agricultural research has benefited greatly from the federal government initiative of the late 19th century to establish land grant universities in combination with agricultural experiment stations in each of the states. This initiative has resulted in a great deal of uniformity in how agricultural research is organized at the state level throughout the United States. Moreover, this uniformity has been sustained by substantial federal funding (and, in particular, formula funding) going to state-level agricultural research organizations (Table 14.6). The growth in federal funding for state-level agricultural research between 1997 and 2007 mainly came from non-USDA federal resources, such as the National Science Foundation and National Institutes of Health. These agencies operate large, competitive funding schemes that target national research priorities. The schemes stimulate collaboration between research agencies in different states, but it is usually not a binding requirement.

USDA funding for state-level agricultural research is somewhat of a mixed bag, comprising allocations using formula funding, competitive funding schemes, and ad hoc research contracts. USDA’s formula funding for state-level agricultural research ($300 million in 2007) primarily targets the local research agenda. In addition, there is a specific funding line for multistate agricultural research projects ($76 million in 2007). The competitive funding schemes for agricultural research managed by USDA (through its newly established National Institute for Food and Agriculture, which replaces the old Cooperative Research, Education, and Extension Service) target multistate, regional, and national research topics. They promote interstate research collaboration, but they do not impose it as a requirement for funding. They channeled some $294 million to state agricultural research in 2007.

The balance between federal- and state-level agricultural research has been quite dynamic over the years. Agricultural research capacity at the state level is now significantly larger than at the federal level, but this has not always been the case. Before 1950, federal agricultural research capacity exceeded the combined state-level capacity. Since 1950, however, state agricultural research capacity has expanded far more rapidly than federal agricultural research capacity (Alston, Christian, and Pardey 1999). This suggests a strong shift toward more localized, applied, and adaptive agricultural research after 1950.

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7 Alston, Christian, and Pardey (1999) also point to the redistributive impact of this formula, favoring the poorer and less productive states.
McCunn and Huffman (2000) found strong positive interstate technology spillover effects in their agricultural productivity study across 48 states. They share this finding with several other agricultural productivity studies, but they relate this to the question, “What is an optimal setup for agricultural research in the USA?” They suggest that independent state planning of agricultural research is inefficient, and cooperation across state boundaries, including the establishment of new political jurisdictions for financing public agricultural research, can enhance efficiency. They also suggest that rigid, centralized national planning is inefficient, as technology spillovers tend to concentrate regionally. Huffman and Evenson (2006) compared the impact of “federal formula” versus “federal competitive grant” funding of state agricultural research and found that federal formula funding yielded a higher impact on state-level agricultural productivity than the federal competitive grant funding. They explain this difference by arguing that local (that is, state-level) administrators have better knowledge about local circumstances than do federal administrators located far away and, hence, are in a better position to pick winners.

In more recent years, the long-term decentralization trend in agricultural research capacity in the United States has started to change. The strong growth in federal funding for state-level agricultural research is now coming mainly from national competitive funding schemes and, in particular, from non-USDA competitive funding schemes, which mobilize state-level agricultural research capacity to address national research priorities, representing a move away from local, adaptive research to more upstream applied and basic research.

**European Union**

The institutional setup and development of agricultural research in the EU is radically different from that of the United States. The EU came into existence...
only in 1957, long after national agricultural research structures had been established across Europe in the late 19th and early 20th centuries. In contrast to the United States, the European agricultural research structure lacks a central design or plan. Moreover, it took the EU another 25 years before research and technology development (including agricultural research) was placed on the EU agenda. The Common Agricultural Policy of the EU, which dates back to the late 1950s, did not do much to promote European agricultural research. This part of the agricultural policy agenda was initially left to the EU Member States.

When research and technology development were added to the common EU agenda in the early 1980s, the idea of creating European (agricultural) research agencies was discussed at length, but was rejected by the Member States on the principle of subsidiarity.8 Instead, a policy was adopted to mobilize national research capacity to address transborder research problems through crossborder collaboration. This policy has been implemented through a series of Framework Programs for Research and Technological Development. About 60–70 percent of the Framework Program budget goes to competitive funding schemes for collaborative, applied research across countries (Table 14.7).

For the most recent period (2007–2013), the budget reserved by the EU for collaborative food, agriculture, fisheries, and biotechnology research

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**TABLE 14.7 Framework Program and collaborative agricultural research budgets**

<table>
<thead>
<tr>
<th>Framework Program</th>
<th>Time period</th>
<th>Total Framework Program budget</th>
<th>Collaborative research budget</th>
<th>Collaborative agricultural research budget</th>
<th>Collaborative agricultural research per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(millions of euros)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1984–1990</td>
<td>3,271</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>2</td>
<td>1987–1995</td>
<td>5,357</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>3</td>
<td>1991–1995</td>
<td>6,552</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>4</td>
<td>1995–1998</td>
<td>13,121</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>5</td>
<td>1999–2002</td>
<td>14,960</td>
<td>10,843</td>
<td>520</td>
<td>104</td>
</tr>
<tr>
<td>6</td>
<td>2003–2006</td>
<td>19,256</td>
<td>14,682</td>
<td>928</td>
<td>186</td>
</tr>
<tr>
<td>7</td>
<td>2007–2013</td>
<td>50,806</td>
<td>32,413</td>
<td>1,935</td>
<td>276</td>
</tr>
</tbody>
</table>


*Note:* na = not applicable.

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8 Exceptions are the European Centre for Nuclear Research, the European Space Agency, and the European Molecular Biology Laboratory, but they were created long before research in general was placed on the EU agenda.
yielded €1,935 million, or an average €276 million per year. This collaborative research budget is allocated competitively through calls for proposals. During the first five Framework Programs, the calls for collaborative research proposals were relatively unspecified. As long as proposals fitted the thematic area of the call (usually very broadly defined) and met research quality and cross-country collaboration criteria, the project would be eligible for funding. As of Framework Program 6, however, more effort has gone into identifying a European agricultural research agenda (including broad-based consultations and forecasting exercises) and in making that part of the calls for proposals.

Starting with Framework Program 7, the EU also began to fund basic research projects under its “Ideas Program,” managed by the newly established European Research Council (ERC). Under Framework Program 7, €7.5 billion (or 15 percent of the total Framework Program budget) was allocated to this new Ideas Program. In contrast to the Collaborative Program, the research projects funded under the Ideas Program do not require cross-country collaboration and are selected purely on the basis of their scientific excellence. The competition for this funding is high (the approval rate is about 10 percent). It is difficult to identify how much of this investment is of relevance to agriculture. A keyword search for “agriculture” or “agricultural” in the 3,400 research projects in the ERC project database resulted in some 102 project matches. This would suggest that the Ideas Program funds agricultural research to the tune of at least another €32 million per year. It is expected that this line of research funding will increase substantially under Horizon 2020, which is the follow-up to Framework Program 7.

Compared with the national budgets for agricultural research, the European funding for agricultural research is fairly small (Table 14.8): close to 9 percent of the EU’s total public agricultural research expenditures. This is in stark contrast with the United States, where 55 percent of public funding

<table>
<thead>
<tr>
<th>Type of program/funding</th>
<th>EU implemented</th>
<th>Nationally implemented (millions of euros)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideas Program (1)</td>
<td>None</td>
<td>32</td>
</tr>
<tr>
<td>Collaborative Program (2)</td>
<td>None</td>
<td>276</td>
</tr>
<tr>
<td>Total EU funding (1+2)</td>
<td>None</td>
<td>308</td>
</tr>
<tr>
<td>National funding</td>
<td>None</td>
<td>3,159</td>
</tr>
</tbody>
</table>

Sources: Data on EU funding are from European Commission (2013); data on national funding are from EUROSTAT (2013).
for agricultural research at the state level comes from the federal government. Moreover, a substantial amount of federal funding ($1,383 million in 2007) is spent on federal agricultural research agencies; the EU has no similar agencies.

The EU considers its rather fragmented research capacity a great disadvantage. One of the key features of the Lisbon Agenda, launched in 2000, is the idea of creating a European Research Area (ERA), which is the research equivalent of the Common Market and aims to improve the integration of the European research base to minimize duplication, encourage excellence, and enhance the contribution of research to economic growth (European Commission 2012). The EU presented a new 10-year economic strategy (that is, the EU 2020 Strategy) in 2010. One of the strategy’s seven flagships is the creation of an Innovation Union, which targets a considerably broader set of actors and instruments than does ERA (that is, more emphasis on the actual application and exploitation of knowledge). The idea of an Innovation Union can be seen as a continuation and further strengthening of the policies launched in 2000.

In addition to competitive funding for collaborative agricultural research and fundamental basic research, the EU has introduced various other instruments that aim to stimulate crossborder collaboration and coordination in (agricultural) research:

1. European Cooperation in Science and Technology (COST) is one of the longest-running programs supporting cooperation among scientists and researchers across Europe. Established in 1971, COST facilitates coordination among nationally funded research activities across Europe, focusing on a particular topic or challenge. COST does not fund research (this is left to the participating national governments), but it absorbs the international coordination costs of the research network for a defined period of four years. After this kickoff period, the network members can continue their collaboration, but without assistance. COST’s food and agriculture cluster currently supports a portfolio of some 34 networks, and every year, five to seven new networks are established.

2. The objective of the European Research Area Network (ERA-NET) project, which was first launched under Framework Program 6, is to strengthen coordination and collaboration between EU members at the research policy and funding level. Only “program owners” (typically national ministries and regional authorities) and “program managers”
(for example, research councils and funding agencies) are considered eligible partners in an ERA-NET action. ERA-NET actions provide research program owners and managers with a platform from which to explore joint activities, strategy development, and in some instances joint calls for transnational research programs. Opening national calls for research proposals from researchers in other EU countries is also on the agenda.

3. European Technology Platforms (ETPs) were first introduced under Framework Program 6. They aim to bring together relevant stakeholders with various backgrounds (for example, regulatory bodies at various geopolitical levels, industry, public authorities, research institutes and the academic community, the financial world, and civil society) to develop a long-term R&D strategy in areas of interest to Europe. The platforms also have a role in helping to further mobilize private and public R&D investments. The structure of an ETP follows a bottom-up approach in which the stakeholders take the initiative, and the European Commission evaluates and guides the process. The agendas developed by these ETPs guide the calls for proposals under the Collaboration Program.

Africa South of the Sahara

In comparison with the United States and the EU, the development of the institutional structure of agricultural research in SSA also has its peculiarities. In particular, the crossborder dimension of the institutional structure continues to be problematic because of weak political and economic integration at subregional and regional levels. African governments often already have problems raising taxes for national causes, let alone for supranational causes. This void has been filled by donors (Table 14.9) who have backed the research activities of the CGIAR Consortium targeting SSA ($255 million in 2008) and the activities of FARA and the SROs (some $25 million in 2008). The CGIAR centers implement agricultural research primarily through their own research capacities and facilities, and target research problems that have a strong transborder dimension. The advantage of the CGIAR centers is that they do not have to organize crossborder collaboration (with all its inherent political problems) before they can set out to conduct transborder research.9

9 Nevertheless, CGIAR is also increasingly trying to coordinate its activities with the other actors in SSA, for example, through the Dublin consultation process.
FARA and the SROs aim to address more or less the same agenda (that is, transborder research problems), but by mobilizing national agricultural research capacity for its implementation. The Framework for African Agricultural Productivity (FARA 2006) proposed a massive increase in investment in this category, from $25 million in 2004 to US$200 million per year by 2010. It was expected at that time that FARA and the SROs would manage the allocation of most of these resources through competitive or commissioned agricultural research grant schemes (CARGSs).

A meeting by development partners in Brussels in 2012 reported that funding in the category of “donor-funded, regionally oriented, but nationally implemented” research had reached US$250 million in 2012. However, only a small part of that money is actually being channeled through the CARGSs of the SROs. Despite the establishment of multidonor trust funds for FARA and the SROs, the lack of clear accountability in the form of robust results frameworks has made donors hesitant to channel their money through FARA and the SROs. Hence, the CARGSs have remained small, waiting for more donor funding to materialize. Most of the growth since 2008 in the “donor-funded, regionally oriented, but nationally implemented” research category can be attributed to the subregional agricultural productivity programs that have been funded by the World Bank (at a total volume of $636 million in loans and grants to national governments since 2007; see Table 2.2 in Chapter 2, this volume) and that promote centers of excellence.

10 This figure seems to be rather high, and its source is unclear.
Lessons for Africa South of the Sahara

The idea that crossborder collaboration in (agricultural) research can pay significant dividends is widely accepted. Nevertheless, reaping those dividends is difficult because it requires collaboration across different jurisdictions, whether provinces, states, or nations. Some higher-level authority is seemingly required to make this happen.

The United States stands out as the geographic area where this higher level of authority is most strongly developed in the form of a federal government with major powers and resources, whereas the EU has substantially weaker institutions that are still very much under development (and political debate). In contrast to the EU, the United States has a layer of federal agricultural research agencies that are specifically dedicated to national agricultural research issues. In the case of SSA, higher-level authorities do exist (that is, the various subregional economic unions and the African Union), but the political and economic integration is still very much in its early stages compared with both the United States and the EU.

The capacity and political will to raise local taxes for a supranational agenda are still very much underdeveloped. Nevertheless, SSA has substantial supranational agricultural research capacity in place (particularly in the form of CGIAR centers), but this is funded and organized by the international development community. While for the moment a highly valuable contribution, in the long run African governments will have to assume responsibility for agricultural research (including funding), at not only the national but also the supranational level.

The alternative approach promoted by the three subregional agricultural productivity programs is an interesting institutional innovation, because it attempts to circumvent the funding problem of transborder research by establishing an exchange of research benefits between countries in the form of intended technology spillovers. A significant effort is definitely needed for a long time to pull this off. The hope is that once a more differentiated research landscape has been established, it will sustain itself without further financial support by World Bank loans and grants. Whether this will actually happen is doubtful, given experiences with donor support to African NARS causing boom-and-bust cycles in funding (see Chapter 4, this volume). Moreover, the reciprocity on which the model is based can easily be derailed. At the same time, the higher the stakes, the more difficult it will be for countries to pull out.

For example, Mali had to pull out of the second phase of the West African Agricultural Productivity Program because of internal political instability and war; CORAF/WECARD has tried to minimize the resulting fallout.
Given it is so much more difficult to mobilize funding for supranational than for national causes, it makes sense to adhere to the subsidiarity principle of keeping implementation (and funding) of government activities at the lowest level possible. In that sense, channeling research funding through the SROs that ultimately ends up funding national research priorities with limited spillover potential should be avoided. These research activities are best funded by national budgets. Interestingly enough, the formula funding that state-level agricultural research entities in the United States receive from the federal government does not seem to adhere to this principle. It funds agricultural research oriented toward local state priorities. However, one argument often used in the United States in favor of the formula funding is that state-level agricultural research creates significant (unintended) spillover benefits for other states. Moreover, formula funding requires a counterpart contribution by state governments. The mechanism is assumed to leverage more state funding into agricultural research, although whether this is actually true is up for debate.

Both the United States and the EU give fairly little attention to the facilitation of technology spillovers, because they are mostly unintended. If, ex ante, it is clear that there will be strong spillovers, researchers are usually advised to solicit funding from a higher-level jurisdiction. Alternatively, and common in the EU, is to have an informal supranational research program that is implemented by a network of national research groups, each taking the lead on a particular aspect of the problem at stake. Under this scenario, each participant funds its own research but benefits from the contributions of others. Such collaboration helps to reduce research duplication at the pretechnology stage but requires upfront coordination. This is another important role that the research program leaders based at the SROs could play.

**Conclusion**

Although technology spillovers provide the overall economic rationale for crossborder collaboration in agricultural research, it is rare that they are actually quantified ex ante and used to guide the allocation of research funding. In that sense the IFPRI studies are unique. Nevertheless, by focusing only on the potential of *unintended* technology spillovers, these studies have overlooked the potential of *intended* technology spillovers, which can be purposefully created through a more differentiated research landscape (that is, centers of excellence) at the regional level. Although this approach has received extensive support from the World Bank through the subregional agricultural productivity programs in recent years, no attempts have been made to quantify
the potential of these intended technology spillovers; they are just assumed to exist.

Because SROs only control a small part of their subregion’s agricultural research funding, their funding role is indisputably a complementary one and should concentrate on that part of the research agenda that is truly supranational (that is, having wide application across national borders). The advantage of the center of excellence approach is that it circumvents the need for a subregional funding mechanism. The role of the SROs in this approach (as well as in the research network approach) is one of coordination, rather than funding.

Information about technological proximity should help SROs to identify clusters of countries that would benefit from research collaboration on certain commodities or specific challenges. Imposing the same type of collaboration across the whole research agenda and all countries should be avoided. It is more realistic to strive for a patchwork of different coalitions of countries working together on different research topics with different intensities of collaboration. It is definitely not a case of one approach fits all. The high dependence on donor funding makes the overall design of the African agricultural research system—and in particular its supranational component—quite vulnerable. Both stronger national governments and further political and economic integration at the supranational level are needed to create a local funding base for crossborder agricultural research. As the EU example shows, this is not something that can be created overnight; it takes not just years, but decades.

References


