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Measuring Agricultural Innovation System Properties and Performance

Illustrations from Ethiopia and Vietnam

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INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

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Notices

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[2] IFPRI Discussion Papers contain preliminary material and research results. They have not been subject to formal external reviews managed by IFPRI's Publications Review Committee but have been reviewed by at least one internal and/or external reviewer. They are circulated in order to stimulate discussion and critical comment.

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ABSTRACT

The rapidly changing nature of the global food and agriculture system suggests the need to rethink how innovation can contribute to developing-country agriculture. While scientific and technological changes in agriculture can help foster productivity growth and poverty reduction, their contributions are incomplete without commensurate changes in the wider system of which they are a part. A more systems-oriented understanding of how innovation occurs in a society and economy is critical to promoting dynamism, responsiveness, and competitiveness in developing-country agriculture and, ultimately, to enhancing productivity and reducing poverty.

However, without adequate measures of the properties and performance of an agricultural innovation system, it is difficult for policymakers, investors, donors, and practitioners to promote policies and investments that foster greater innovativeness in agriculture. This suggests the need for a measure of agricultural innovativeness that preferably extends beyond the "black box" approach of measuring only inputs and outputs, focusing on the underlying processes that contribute to building the capabilities needed to create an innovative agricultural sector.

To this end, this paper attempts to provide a "proof of concept" that innovativeness in developing-country agriculture can be measured. It first identifies a set of indicators from secondary data sources that measure the key elements of an agricultural innovation system. Several hundred indicators are reviewed, validated, and aggregated into a unique Agriculture, Development, and Innovation Index (ADII). The paper then provides a toolkit for collecting and analyzing "systems-oriented" indicators that add more process-related nuances to the ADII with both attributional and relational data. This is illustrated with data collected in Ethiopia and Vietnam in 2007–08.

Keywords: agriculture; developing countries; innovation; Ethiopia; Vietnam

1. INTRODUCTION

Today, more than ever before, global food and agricultural systems are undergoing a process of rapid change. Growing consumer demand and changing consumer preferences have emerged as key drivers of agricultural prices, technology, and trade. Global integration of agricultural markets, supply chains, and communications systems have created new opportunities for sharing of goods, services, and ideas among consumers, farmers, scientists, and entrepreneurs. These changes have been accompanied by new scientific achievements in microbiology, genomics, nanotechnology, bioinformatics, and other fields that have the potential to change the quantity and quality of food and agriculture produced and consumed worldwide.

With this process of rapid change comes the intensification of conflict over contested claims. Battle lines are being drawn in the fight over allocating public and private resources to food versus fuel, and between high-yielding, input-intensive production versus low-productivity organic production. Similar struggles are playing out over long-term investments in priorities such as climate change mitigation and adaptation versus short- or medium-term investments in increasing food staple yields.

These rapid changes and emerging conflicts strongly suggest that developing countries will need to develop more responsive, dynamic, and competitive agricultural sectors in the short to medium term to benefit from the changing global system. Agricultural innovation will be the order of the day, and developing countries will need innovative policies, programs, and investments just to keep up.

Unfortunately, there are few tools with which to benchmark innovativeness in the agricultural sector. Thus, few developing countries know how dynamic, responsive, or competitive their agricultural sectors really are.

This suggests the need for a measure of agricultural innovativeness, preferably one that extends beyond the "black box" approach of measuring only inputs and outputs, focusing on the underlying processes in which capabilities evolve and develop to create an innovative agricultural sector. The proposed measure should combine policy and investment indicators that foster innovativeness in agriculture (the "inputs") with more systems-oriented indicators that characterize underlying innovation processes (the "process"), and performance indicators such as value addition and productivity in the agricultural sector (the "outputs"). Moreover, this proposed measure should be driven by an informed theory of innovation that considers supply-side factors such as research and education, demand-side factors such as agricultural business and enterprise, factors such as the institutions that bridge these two domains, and the wider policy environment that enables innovation.

Efforts to design such a measure might do well to draw on the increasingly popular "innovation systems" conceptual framework (Edquist 1997; Nelson 1993; Lundvall 1992; Dosi et al. 1988; Freeman 1987). This framework emphasizes the study of sets of interrelated actors who engage in the generation, exchange, and use of knowledge in processes of social or economic relevance and the institutional context that conditions their actions and interactions.

This system-based framework is further described by Arnold and Bell (2001) as being made up of three main components: the knowledge and education domain, the business and enterprise domain, and the bridging institutions that facilitate the transfer of knowledge and information between these two domains. This schema adheres closely to that set forth in Figure 1. Bounding these domains are the socioeconomic institutions that influence innovation processes. This includes both formal institutions, such as public policies on science, technology, and agriculture, and informal institutions, such as the shared beliefs, rules, and practices that condition how individuals and organizations within each domain behave and interact.

The borders of the system, though drawn somewhat arbitrarily, separate the interior domains, where influence over the innovation process is direct, from the exterior domains where influence is more indirect. Thus, the exterior domains include general policies on science and technology that influence agricultural innovation; foreign sources of knowledge, information, and learning; other sectors of the economy that are tied to the innovation system through backward and forward linkages; and the political system, which captures the interests and influence of various actors on the system.

Hidden within this system are the essential processes that facilitate innovation—for example, the development of capacity among individuals and organizations to learn and change the ways in which they organize production and the iterative learning processes that occur among different actors through different forms of interaction. By highlighting these hidden attributes, the innovation systems framework captures something more than a linear interpretation of innovation as a sequence of research, development, and dissemination. Rather, it portrays innovation as a complex web of related individuals and organizations that all contribute to the application of new or existing information and knowledge to production.

Indicator and indexing exercises based on the innovation systems framework have been used with considerable effect to guide innovation policy, improve innovation performance, and inform national and global discourse on science and technology for innovation, particularly in industrialized-country manufacturing. Notable efforts to characterize and measure innovation and innovation systems include the following.[1]

- The Organization for Economic Cooperation and Development's (OECD's) Science, Technology and Industry (ST&I) Scoreboard compiles country-level data on innovation-related topics from 1981 to the present. The ST&I scoreboard measures indicators in the areas of research and development, human resources in science and technology, intellectual property rights performance, information and communications technology infrastructure, knowledge flows embedded in trade and investment, and global enterprise and the impact of knowledge on productive activities (OECD 2005).
- The European Union's (EU's) European Innovation Scoreboard (EIS) is a compilation of technical innovation and economy-wide indicators used as benchmarks for the innovative capabilities of EU member states. The EIS measures and indexes indicators in four main thematic groups: human resources; creation of new knowledge; transmission and application of knowledge; and innovation finance, output, and markets (CEC 2006; Hollanders and Arundel 2004).
- The World Bank's Knowledge Economy Index (KEI), which is a benchmarking tool designed to support the efforts of developing countries to transition into knowledge-based economies. The KEI covers indicators in four main areas: economic incentives and institutional regimes, education, innovation, and information and communications technologies (KAM 2006).
- The World Economic Forum's (WEF's) Global Competitiveness Index (GCI) combines a range of indicators to measure a country's potential for productivity growth and, ultimately, international competitiveness. The GCI measures and indexes 89 indicators, covering institutions, infrastructure, the macroeconomy, health and primary education, higher education and training, market efficiency, technological readiness, business sophistication, and innovation (WEF 2007).
- The United Nations Development Program's (UNDP's) Technology Achievement Index (TAI) aims to capture how well a country is creating and diffusing technology and building a human skill base, thus reflecting its capacity to leverage current and future technological innovations. The index measures technology achievement in four dimensions: technology creation, diffusion of recent innovations, diffusion of old innovations, and human skill development for creating and adopting technology (Desai et al. 2002).

However, none of these exercises specifically addresses developing-country agriculture. Indeed, the application of the broader innovation systems framework to developing-country agriculture is still

[1] See Spielman and Birner (2008) for a review of other innovation system-based indicator initiatives.

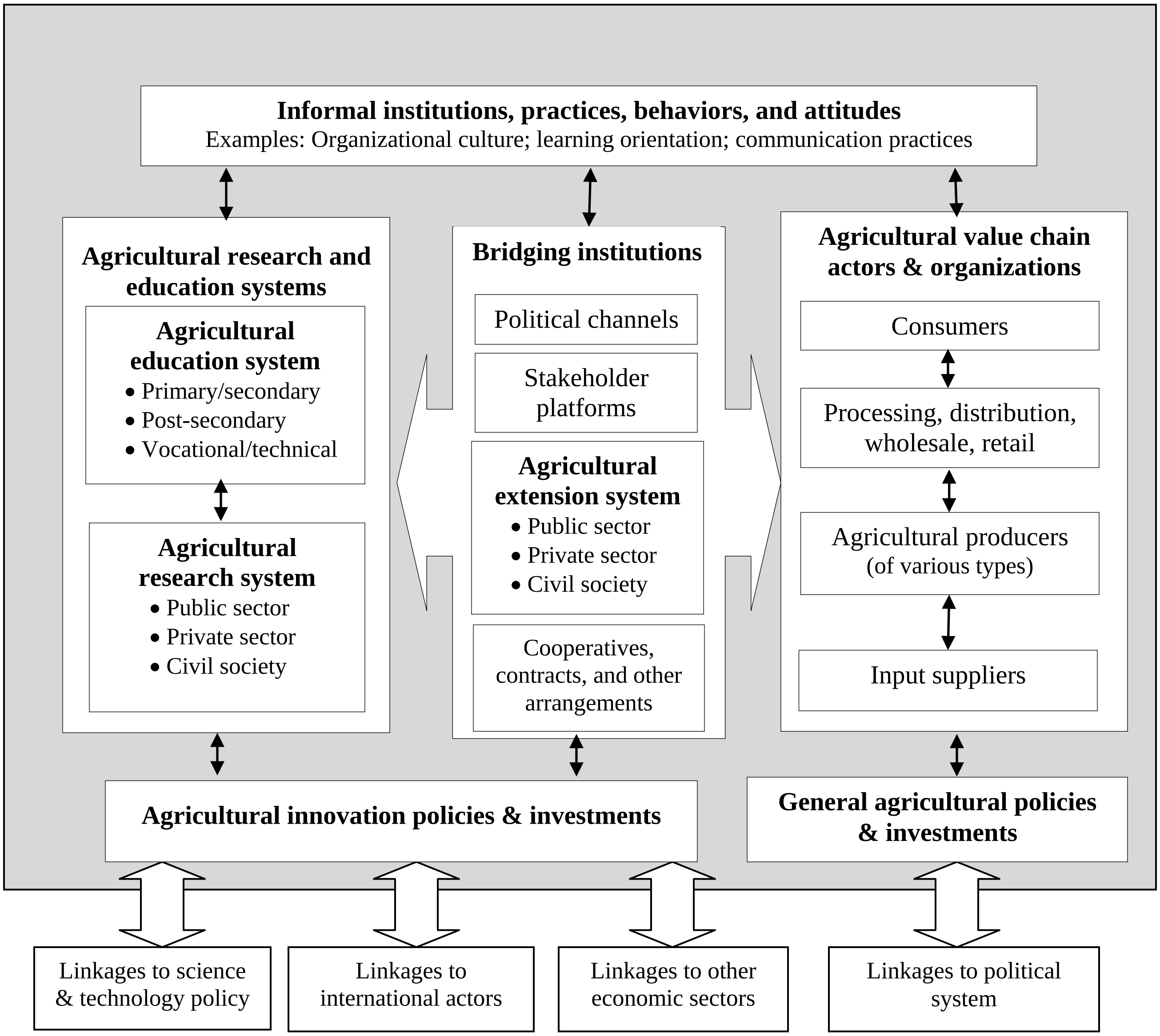
fairly nascent (see, for example, World Bank 2006; Spielman 2006), despite its inherent value in providing insights into the processes underlying agricultural development, socioeconomic change, and technological advancement.

In an effort to bridge this knowledge gap, this paper uses the innovation system framework to design a measure of innovativeness in developing-country agriculture. Specifically, this paper aims to demonstrate "proof of concept" of whether indicators can be designed to measure innovation system properties and performance with respect to developing-country agriculture. In doing so, the paper attempts to measure the emergent properties of an innovation system—properties that go beyond the sum of a system's constituent parts—by combining conventional input and output indicators with more process-oriented, systems-specific indicators.

This paper does so by first identifying a set of country-level indicators from secondary data sources that measure key elements of an agricultural innovation system and that can be combined to form a composite innovation index. Next, this paper identifies a set of more "systems-oriented" indicators, based on data collected from expert opinion surveys conducted in Ethiopia and Vietnam in 2007-08 to add more process-oriented nuances to this composite innovation index. Finally, this paper provides the design for a toolkit with which to measure agricultural innovativeness in a way that extends beyond the "black box" of input–output matrixes and models by adding elements that capture the underlying processes that contribute to building innovative capabilities in the agricultural sector.

This paper proceeds as follows. Section 0 explores indicators from secondary data sources that measure key elements of an agricultural innovation system and the conceptual and technical aspects of building a composite innovation index based on these indicators. Section 0 discusses the findings from this exercise using a sample of 35 developing countries. Section 0 describes how more systems-oriented indicators can be introduced into this type of analysis, accompanied by a toolkit for obtaining such data and illustrations from Ethiopia and Vietnam. Section 0 provides several broad recommendations for policymakers and researchers to motivate further investment in this field of inquiry. Additional information concerning the indicators is presented in Appendixes A to E.

Figure 1. A conceptual diagram of an agricultural innovation system



Source: Spielman and Birner (2008), adapted from Arnold and Bell (2001).

2. THE AGRICULTURE, DEVELOPMENT, AND INNOVATION INDEX (ADII)

Innovation indicator initiatives such as those mentioned above share several important properties (Archibugi and Coco 2005). In general, they are all based on similar conceptual frameworks and made up of similar components that capture aspects of knowledge generation, knowledge diffusion, human capital, and competitiveness. They all include fairly similar choices of indicators, for example, research and development (R&D) expenditures, patents, scientific publications, educational attainment, foreign direct investment, and economic competitiveness. And most use similar quantitative and statistical approaches such as symmetric weighting and factor analysis.[2]

The composite innovation index introduced in this paper shares many of these properties. Indicator selection was primarily driven by the conceptual framework described by Arnold and Bell (2001) and illustrated in Figure 1. This framework was then broken down into its component parts, namely four distinct domains covering (1) knowledge and education, (2) bridging institutions, (3) business and enterprise, and (4) the enabling environment. Weighting of these domains was symmetrical, based on the use of tools of data reduction and statistical analysis that are commonly applied to indexing exercises.

In this section, we review the conceptual and technical considerations that went into the design of a composite innovation index for developing-country agriculture—the ADII. This index, based only on data from secondary sources, is meant to highlight innovation system properties and performance in two focal countries, Ethiopia and Vietnam. In order to do so in a meaningful way, the index covers an additional 33 developing countries. Six of these additional countries are regional comparators against which Ethiopia and Vietnam could be constructively compared (Kenya, Tanzania, and Uganda for Ethiopia; Malaysia, the Philippines, and Thailand for Vietnam). Five of these additional countries are global comparators (Brazil, China, India, Mexico, and South Africa) that were selected for similar purposes. The remaining 22 countries are neighbors or countries with other similarities that make them useful comparators for either Ethiopia or Vietnam.

As part of the ADII design process, several hundred indicators relating to agriculture, development, and innovation were reviewed. Major sources for these indicators included OECD (2008), World Bank (2008a), WEF (2007), IFAD (2005), FAO (2006), and SNSF (2005). Ultimately, the data review and validation process yielded 41 indicators from 25 sources that offered relatively complete coverage of the 35-country sample. Highlights of the ADII design process are presented below. Additional information on individual indicators is provided in Appendix A, with technical notes provided in Appendix B, and country data presented in Appendix D.

Conceptual Aspects of Indicator Selection

Any attempt to identify and measure indicators requires some form of theoretical framework that is at least minimally grounded in the basic concepts of innovation systems thinking (Archibugi and Coco 2005). The theoretical framework should somehow recognize that science and technology capabilities and production capacity are distinct domains of an innovation system, and that the generation and dissemination of knowledge are similarly distinct processes. Moreover, the framework should somehow recognize that innovation is much more than knowledge embodied in a technology: Rather, innovation is the generation, exchange, and use of knowledge in processes of social or economic relevance, where knowledge can be characterized as embodied or disembodied, codified (explicit) or tacit (implicit), and scientific (technical) or organizational (managerial). We explore these ideas and the wider issue of framework-consistent indicator selection here.

[2] Archibugi and Coco (2005) specifically consider the indexes from WEF and UNDP mentioned above, as well as the United Nations Industrial Development Organization (UNIDO) Industrial Development Scoreboard, the RAND Corporation Science and Technology Capacity Index, and their own Technological Capabilities Index (ArCo).

In doing so, we first consider the influence of the conceptual framework on the choice of countries or, more specifically, the choice made here to consider only developing countries. We argue that the geographical context, factor endowment, industry structure, and historical experience of a given country influence the structural coherence or maturity of its innovation system (Balzat and Hanusch 2004). Differences in structural coherence or maturity would suggest that it is difficult to identify a set of indicators that can be consistently used to describe innovation systems at different levels of coherence or maturity. One approach to addressing this issue is to identify sets of indicators that can be used to address countries with certain underlying commonalities. For this reason, we argue that it is possible to construct a composite index covering a select set of developing countries that are somewhat similar in terms of maturity levels, development trajectories, and structural attributes. The choice of focal countries, regional comparators, and global comparators in the ADII attempts to do this.

Second, we consider the influence of the conceptual framework on the selection and interpretation of indicators. This is often a subject of controversy among those who design and use databases and indexes such as those described above.[3] The indicators used in the ADII are either indicators that contribute to or explain an individual domain's performance, or influence the ways in which these indicators perform. This is different from output measures—innovation outcomes—that are described in more detail below. To shed further light on this consideration, we review here the conceptual grounding that underlies the indicators used in each domain of the ADII.[4]

The Knowledge and Education Domain

The main indicators used to describe the ADII's knowledge and education domain include those that measure various aspects of investment in agricultural R&D, a well-established enabler of innovation in developing countries (Alston, Pardey, and Smith 1999; Alston, Norton, and Pardey 1995). We capture this with four indicators: (1) public researchers per $100 million of agricultural GDP, (2) public-sector agricultural R&D intensity (both in ASTI 2005), (3) official development assistance (ODA) to agricultural research, and (4) ODA to agricultural education and training (OECD 2008).

While the first indicator captures human capital investment in agricultural R&D and the second captures financial investment in agricultural R&D, the ODA variables are somewhat controversial. If ODA is viewed as a "good," then it would be positively associated with public investment, itself a less controversial "good" in an innovation system. But if ODA were viewed as "bad," that is, a substitute for public investment, then it would be a more problematic indicator. In the country sample examined here, the correlation between ODA for agricultural R&D (measured as an intensity with respect to agricultural GDP) and public spending on agricultural R&D (similarly measured as an intensity) is not significantly different than zero, suggesting that at the very least this notion of substitutability does not hold.

Next, because public spending and ODA do not say much about the quality of the knowledge and education domain, we include several indicators in the ADII that broadly capture this notion. The quality of scientific research institutions and the quality of the educational system, both of which are based on expert opinion polls conducted by the World Economic Forum (WEF 2007), are introduced as proxies for the quality of *agricultural* research and education. In addition, because global interconnectedness is of

[3] For example, Tunny (2007) criticizes OECD studies on innovation by arguing that many of the indicators used are weakly correlated with innovation (for example, R&D intensity or patents per capita), while other highly correlated indicators are not sufficiently captured (for example, learning-by-doing, or the reorganization of production). Related to this is the concern that indexes tend to compress the complex innovation systems framework into a single synthetic indicator that is meant to summarize system properties and performance (Archibugi and Coco 2005). Of course, this criticism carries through to measures such as gross domestic product (GDP), the Human Development Index (HDI), and other composite indicators that are today commonly accepted indicators of complex systems.

[4] A statistical comparison of five innovation indexes by Archibugi and Coco (2005) suggest that a significant degree of divergence exists between and among indexes, even despite their ostensibly similar purpose of measuring innovation. They attribute this divergence to differences in the level of indicator aggregation (the use of national-, sectoral-, and firm-level data); difficulties in measuring countries at different stages of development (rapid-growth, catching-up countries with less predictable performance in Asia versus slower-growth, leader countries with more stable performance in Europe and North America); and different empirical questions motivating the construction of individual indexes.

growing importance to scientific research (see, for example, Wagner and Leydesdorff 2005; Byerlee and Fischer 2002), we include an indicator that captures a country's participation and membership in the global and regional agricultural research networks. Further, we include a composite indicator that captures technological readiness as an efficiency enhancer for a competitive economy (WEF 2007) to convey the importance of such factors as information and communications technology on the research and education system in a country.

Next, we include an indicator that captures the extent to which a country's research and education system actually produces some type of scientific output. A commonly accepted measure of this is the publication of scientific journal articles (see, for example, Hayami, Kikuchi, and Morooka 1989), and this benchmark is introduced here specifically with respect to publications in the agricultural sciences and related fields (measured in per capita terms). While additional indicators such as the number of plant varieties, technologies, or patents generated by research organizations and universities are desirable, data availability and consistency are issues with these indicators (see Spielman and Birner 2008). Note that none of these indicators should be viewed as "innovation products" or "innovation outputs" per se. Rather they are inventions or outputs that may or may not be adopted into social or economic use by other actors in the innovation system. Thus, they are used here only to describe the performance capacity of a research and education system.

We consider several additional indicators in an effort to provide a complete description of the nature and performance of the knowledge and education domain. First, innovation in many developing countries is constrained by outmigration, brain drain, and losses in human capital, particularly in the fields of research and education where higher returns in industrialized countries draw scientists and educators away from their own countries (Docquier and Marfouk 2004). Thus, we introduce an indicator that captures the migration rate of tertiary (university) education holders as a proxy for losses of human capital stock in the agricultural sciences and related fields.

Second, innovation in many developing countries is constrained by high rates of illiteracy among farmers and other members of the rural population. Despite the high returns to basic and agricultural education, investment in farmer and rural education remains low in many developing countries, thus limiting the capacity of rural communities to engage in knowledge-intensive agriculture, on-farm value-adding activities, and modern contract-based markets (World Bank 2007; Psacharopoulos 1994; Lau and Yotopoulos 1989). In an agricultural innovation system, education levels within rural communities are important determinants of innovative capability: Hence, we include access to education in rural areas as an indicator within this domain.

Bridging Institutions

Indicators that describe the nature and performance of the bridging institutions domain are difficult to come by. We use three indicators in the ADII to capture key characteristics of the domain that facilitates or mediates between the knowledge and education domain and the business and enterprise domain. The first indicator captures the availability of agricultural extension, that is, the extent to which agricultural extension (and research) services are accessible to poor farmers, based on data from IFAD (2005). The second indicator captures investment in agricultural extension by using ODA to agricultural extension (and cooperatives) (OECD 2008) as a proxy for public investment, again assuming that ODA is a complement to, not substitute for, public investment in extension and cooperatives. The third indicator captures the importance of university–industry linkages in this domain, that is, the key channels through which agricultural research findings are translated into socially or economically relevant innovations in the wider agricultural sector. This is proxied by an indicator that measures the extent to which businesses collaborate with universities to support businesses' R&D activities, based on expert opinion polls conducted by the WEF (2007).

Business and Enterprise

Indicators that describe the nature and performance of business and enterprise, particularly with respect to innovation in the agricultural sector, are less difficult to obtain, in light of the presence of several available proxies. The indicators used in the ADII to represent this domain can be divided into two groups: (1) measures of the nature and performance of business and business innovation in the agricultural sector, and (2) measures of the quality of institutions and infrastructure that enable business and business innovation in agriculture.

This first area of interest is captured or proxied by several business or production-related indicators. The cost of business start-up procedures (World Bank 2008a) captures the ease with which agribusinesses can be established, while composite indicators such as access to agricultural input and produce markets (IFAD 2005) provide a broader performance measure. Foreign direct investment (FDI) inflows (World Bank 2008a) proxy the potential for technology transfers to the agricultural sector that is channeled through FDI (see Pray, Oehmke, and Naseem 2005). A composite index that measures the status of innovation factors in economic competitiveness, based on an expert opinion survey conducted by WEF (2007), provides a proxy for the role of innovation in the agricultural sector.

In addition to these indicators, we include agricultural machinery (tractors per 100 square meters of arable land) and fertilizer consumption (plant nutrients used per hectare of arable land) (World Bank 2008a) to provide, respectively, measures of capital stock and modern input use in the agricultural sector. These two indicators capture critical measures of innovative potential in farm-level enterprises and are often used to distinguish between subsistence and commercially oriented agricultural production in developing countries. Alternative or additional measures of farm-level capital stocks, such as productive agricultural assets (implements, equipment, draught animals, or land) held by farm households, are unfortunately difficult indicators to obtain, as are measures of other key inputs such as improved seed use.

The second area of interest—the quality of the institutions and infrastructure that make business and enterprise innovation possible—is captured by the following indicators in the ADII. ODA to agricultural financial services and agro-industries (OECD 2008) provides a proxy for public investment in agricultural market development. Indicators that measure the enabling conditions for rural financial services and the investment climate for rural businesses (IFAD 2005) capture the extent of rural market development. The total roads network (World Bank 2008a) and information and communications technology expenditure (World Bank 2008a) are proxies for the enabling infrastructure needed to support business and enterprise in the agricultural sector.

Enabling Environment

Indicators for the enabling environment domain capture a broad range of factors that promote innovation at a general level in a given economy or in the agricultural sector. These indicators can be divided into three general categories: (1) property rights, (2) governance institutions, and (3) covariate risks.

Property rights in agriculture provide important incentives to investment in agriculture: Property rights allow innovators to appropriate the returns on their investments in innovation, thus stimulating greater investment in innovation (Pray, Fuglie, and Johnson 2007; Pray and Umali-Deninger 1998). Property rights in the ADII are proxied by a property rights index (Heritage Foundation 2008) that captures the general rights of individuals and households to own and benefit from various forms of property (both physical and intellectual), a more specific index that measures the strength of a country's intellectual property rights regime (Park and Wagh 2002), and an index that captures a country's membership in various agricultural resource-related intellectual property rights regimes.

Governance institutions in the agriculture sector are an increasingly central issue in the analysis of agricultural development and innovation (World Bank 2008b; Paarlberg 2002). Good governance, whether at the community level, at the level of the nation-state, or at a more global level, influences the extent to which resources are allocated in an efficient or equitable manner to a range of competing development priorities. Governance issues are captured in the ADII with the inclusion of several composite indexes from various sources. The most general governance indicators used in the ADII are measures of the centralization of economic policymaking (WEF 2007), the general quality of governance (Kaufmann, Kraay and Mastruzzi 2006) level of corruption (World Bank 2008a), and governance and legal institutions index (Zhang et al. 2004).

Additional agriculture-specific governance indicators include external assistance to agriculture as a proxy for broadly defined public investment in agriculture (FAO 2006; World Bank 2008a) and allocation and management of public resources for rural development (IFAD 2005) as a proxy for how efficiently this investment is managed. Other agriculture-specific governance indicators include three composite indexes that measure the extent of dialogue between government and rural organizations; the policy and legal framework for rural organizations; and accountability, transparency, and corruption in rural areas (IFAD 2005).

Covariate risks are proxied by a measure of cash crop price volatility and a measure of the years in which a country has been in conflict (Zhang et al. 2004). These two variables capture the disruptions to production and innovation that are caused by rapid changes in price signals that result from negative shocks, many of which are common phenomena in developing-country agriculture.

Outcome Indicators

An additional five innovation *outcome* indicators are identified to allow for more statistical and econometric inferences to be made into the relationship between the ADII and its possible economic outcomes. These indicators are (1) agricultural GDP per worker from World Bank (2008a); (2) the average growth rate of agricultural GDP from World Bank (2008a); (3) agricultural total factor productivity change (1980–2000) from Coelli and Rao (2003); (4) per capita agricultural production index from FAO (2006); and (5) cereal yields from World Bank (2008a). Note that these indicators measure the overall outcomes of an entire agricultural innovation system and are strictly different from innovation outputs that might measure the performance of an individual domain within the system.

Technical Aspects of Indicator Selection

Even with a conceptual framework to guide the selection of indicators, there are several technical challenges to designing a robust composite innovation index. The use of many indicators based on different units of measure, the possibility of using closely correlated indicators that contribute only marginal amounts of additional information, the need to standardize indicators that measure “goods” with indicators that measure “bads,” and other such issues are central concerns in index design.[5] In this section, we discuss these issues and the approaches used to address them.

Input and Output Indicators

Caution was taken to separate input and output indicators in the design of the ADII. As mentioned in the previous section, the indicators used to calculate the ADII were all inputs to the individual domain’s performance (for example, public expenditures on agricultural education and training, research and development, and agricultural cooperatives and agroindustry), or parameters that affect these inputs (such as quality of scientific research institutions or migration rate of tertiary education holders). Other variables that might be viewed more ambiguously (such as agricultural scientific journals published) are similarly taken to be measures of the domain’s performance, that is, its outputs to the wider innovation

[5] For example, Grupp and Mogee (2004) argue that aggregating different measures of innovation without a common unit of measure raises the possibility of misspecification in the resulting composite index. They demonstrate this problem by subjecting the 2001 EIS data to alternative aggregation procedures, producing scoreboards with significantly different values. Katz (2006) raises the related issue of scaling, or the need to normalize key measures of an innovation system to account for different group sizes. He illustrates the problem by showing how R&D intensity and national wealth can be scaled to the sizes of European countries and Canadian provinces to improve the accuracy of measurement. In sum, these criticisms argue that innovation indicators and indexes must be designed with extreme attention to a range of technical considerations.

system. These are strictly different from innovation outcomes that measure the performance of the entire system.

Years and intervals. Where possible, data were standardized to account for different assessment periods as follows. First, where time series data existed, five-year averages of the most recent yearly intervals were used. Second, where time series data were unavailable, observations from the most recent year was used which, in all cases, was recorded within the last 10 years.

Monetary units. Indicators with a monetary value were measured in terms of constant (2000) US dollars, using the GDP deflators provided by the World Bank (2008a).

Goods and bads. While certain indicators were "good" (for example "access to agricultural research and extension services," for which a higher measure is unequivocally better than a lower measure), other indicators were "bad" (such as "migration rate of tertiary education holders.") Inclusion of these measures in the ADII required that the "bad" indicators be rescaled, such that a low or absent score against this indicator earns a higher score in the rescaled version of the indicator. This was handled as part of the standardization procedure that is described in more detail below.

Hard and soft data. Indicators used in the ADII are drawn from a combination of both hard and soft data. For instance, the WEF Global Competiveness Index (WEF 2007) consists of 113 variables, 39 of which are "hard" data collected from national and international sources, and 79 are "soft" data collected from top business leaders through the WEF's annual Executive Opinion Survey. The IFAD rural performance indicators (IFAD 2005) are grades assigned through a consultative process conducted by IFAD with rural stakeholders in 2004 and are largely based on expert opinions. The ADII uses several indicators and composite indexes from these sources in its design.

Highly correlated data. Necessarily, multiple indicators exist to measure closely related concepts. Because the inclusion of multiple indicators for a single concept provides limited additional information to the ADII and may affect the value and weighting of individual ADII domain scores, an effort was made to review the data closely for correlations. Specifically, pair-wise correlations of within-domain indicators were examined to eliminate potential overlapping. The indicators that were selected for the ADII are indicators that are not significantly correlated with other variables within their respective domains.

For example, the "climate of political freedom" index drawn from Heritage Foundation (2008) was found to be closely correlated with several other governance-related indexes and was ultimately excluded in favor of a set of more specific indicators including the quality of governance from (Kaufmann, Kraay and Mastruzzi 2006). Yet three fairly similar sounding measures of rural governance (dialogue between government and rural organizations; the policy and legal framework for rural organizations; and accountability, transparency, and corruption in rural areas) from IFAD (2005) were found not to be highly correlated and thus were included in the ADII as separate indicators.

Missing values. For certain countries and indicators, data were either unavailable or incomplete. This was particularly the case for five countries (Bhutan, Ghana, Laos, Myanmar, and Thailand) for which more than six indicators were missing. Calculation of the ADII and its various subindexes was adjusted to account for missing values. See Appendix B for further details.

Indicator standardization. The raw data used to develop the ADII are measured with a wide range of units. Indicators such as public spending on agricultural research and development or official development assistance to agro-industries and scientific publications in agriculture-related fields are measured as intensities with respect to agricultural GDP. Others, such as road network coverage and fertilizer consumption are measured in per capita or per hectare terms, respectively.

Another set of indicators used in the ADII were drawn from existing indexes developed by other sources. For example, the quality of governance indicator is based on a composite index developed by (Kaufmann, Kraay and Mastruzzi 2006). Other indicators used in the ADII such as the status of innovation factors in economic competitiveness, technological readiness as efficiency enhancers for a competitive economy, centralization of economic policymaking, and quality of scientific research institutions, are actually composite subindexes of the larger Global Competitiveness Index (GCI) developed by the WEF (2007).

To provide comparability across indicators and countries, all indicators were standardized to an intuitive scale of 1 to 10, ranging from the lowest to highest level of performance for a given indicator. The aggregate ADII was then calculated as the simple (unweighted) average of the scores for each of the domain's subindexes. The standard formula used to standardize indicators comprising the ADII is

$$I_i = 9\left(\frac{x_i - \min(x)}{\max(x) - \min(x)}\right) + 1 \tag{1}$$

where I_i denotes the standardized indicator for the i^{th} country, x_i denotes the indicator's original (nonstandardized) value, *min(x)* denotes the within-sample minimum of the original indicator, and *max(x)* denotes the within-sample maximum.

For those indicators that are considered "bad" (as described earlier), the standardization technique is slightly reversed, that is,[6]

$$I_i = -9\left(\frac{x_i - \min(x)}{\max(x) - \min(x)}\right) + 10 \tag{2}$$

Weighting and principal component analysis. Each domain subindex was assigned an equal weight in the ADII for lack of a conceptual basis on which to assign weights. However, a case could be made for weighting in such indicator exercises from both a statistical and conceptual standpoint (see Roodman 2007). We explore this further with the application of principal component analysis (PCA) to the ADII. See Appendix B for further technical details.

To employ PCA effectively, a significant number of indicators (24 out of the original 41) and countries (5 out of the original 35) were dropped from the model. However, based on an analysis of Spearman rank correlation coefficients, the resulting PCA-weighted ADII (denoted ADII^{pca}) is not significantly different from the equally weighted ADII described here, nor is it significantly different from an equally weighted ADII (denoted ADII^{prn}) that is made up of the 17 (principal) indicators identified by the PCA process. See Appendix B for further details.

We interpret these findings as sufficient evidence to allow rejection of an alternative to equal weighting. The technical grounds for this choice are based on the finding that a PCA-weighted version of the composite index based on 17 innovation indicators (nor an equally weighted version for the composite index using the same set of indicators) is significantly different from the original composite index. Furthermore, there are conceptual grounds for this choice. The fact that PCA simply discerns interdependence among a set of variables and does not make inferences about relationships is explained by the conceptual framework articulated in this paper.

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6 In future versions of this exercise which compare changes in the ADII across time, an additional step will be needed to normalize indicators to equal means and variance as a means of avoiding within-domain weighting (see Roodman 2007; Lambsdorff 2002). This can be done with use of the following formula:

$$I_{i,t+1} = [I_{i,t} - \mu(I_{i,t})]\left[\frac{\sigma(I_{n,t})}{\sigma(I_i)}\right] + \mu(I_{n,t})$$

where $I_{i,t+1}$ denotes the standardized indicator in period *t+1,* $\mu(I_{i,t})$ denotes the mean of the standardized indicator in the initial period *t,* $\sigma(I_{n,t})$ denotes the standard deviation of the ADII in the initial period, $\sigma(I_{n,t})$ denotes the standard deviation of ADII in the initial period, and $\mu(I_{n,t})$ denotes the mean of ADII in the initial period.

3. FINDINGS FROM THE ADII

Descriptive statistics for the 35-country ADII and its subcomponents are provided in Table 1. These results reveal two immediate properties of the ADII. First, actual ADII scores for this sample tend to be clustered within a range (2.47 to 6.15) that is narrower than the index's possible range (1.00 to 10.00). Second, the ADII subindex scores show somewhat greater variance than the actual ADII scores, suggesting that they hold a degree of analytical interest that is independent of the aggregate ADII. (See Appendix C for individual domain scores by country and Appendix D for individual indicator scores by country.)

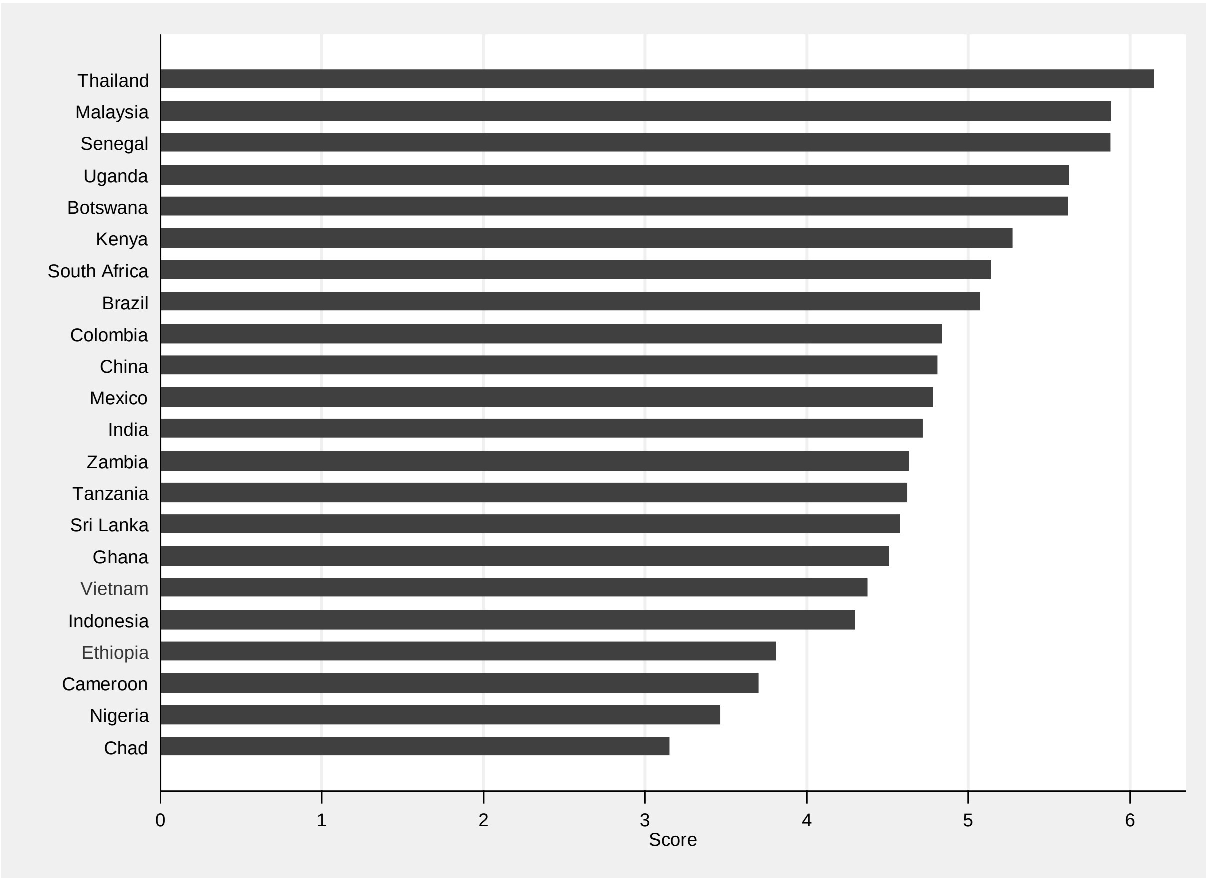
Table 1. ADII and ADII subindexes, descriptive statistics

Index/domain	No. of indicators	No. of observations (countries)	Mean	S.D.	Min	Max
Aggregate ADII	41	35	4.5241	0.7997	2.4798	6.1507
Knowledge and education domain	11	35	4.0514	0.9009	2.1406	6.7590
Bridging institutions domain	3	35	3.5435	1.4600	1.0000	7.0000
Business and enterprise domain	12	35	4.2282	0.8482	1.1618	5.6101
Enabling environment domain	15	35	6.2732	1.0083	3.0904	7.8747

Source: Authors.
Notes: ADII and ADII domain scores are scaled from 1 to 10. S.D. denotes standard deviation.

Figure 2 provides a ranking of aggregate ADII scores for 22 countries selected from the 35-country sample used in this paper, ranging from highest to lowest. Overall, Thailand emerges as a leader in innovation, with an ADII score greater than 6, followed by Malaysia and Senegal, Uganda and Botswana, Kenya, and South Africa and Brazil, all with ADII scores greater than 5. Overall, Ethiopia, Nepal, Cameroon, Nigeria, Zimbabwe, Chad, and Myanmar have the lowest ADII scores, representing the bottom 20 percent interval of scores from the 35-country sample. The mean ADII score (4.5241) falls between Sri Lanka and Ghana. A breakdown of countries by scoring quintile is provided in Appendix C.

Figure 2. Aggregate ADII scores, selected countries



Source: Authors.

To better illustrate the composition—and variations in the composition—of these ADII scores, we examine here the scores for domains that comprise the agricultural innovation system, as described in Figure 1. We begin with Figure 3, which maps each country's subindex score for its knowledge and education domain against the corresponding score for its business and enterprise domain. This mapping is a useful way of classifying countries according to different innovation system properties.

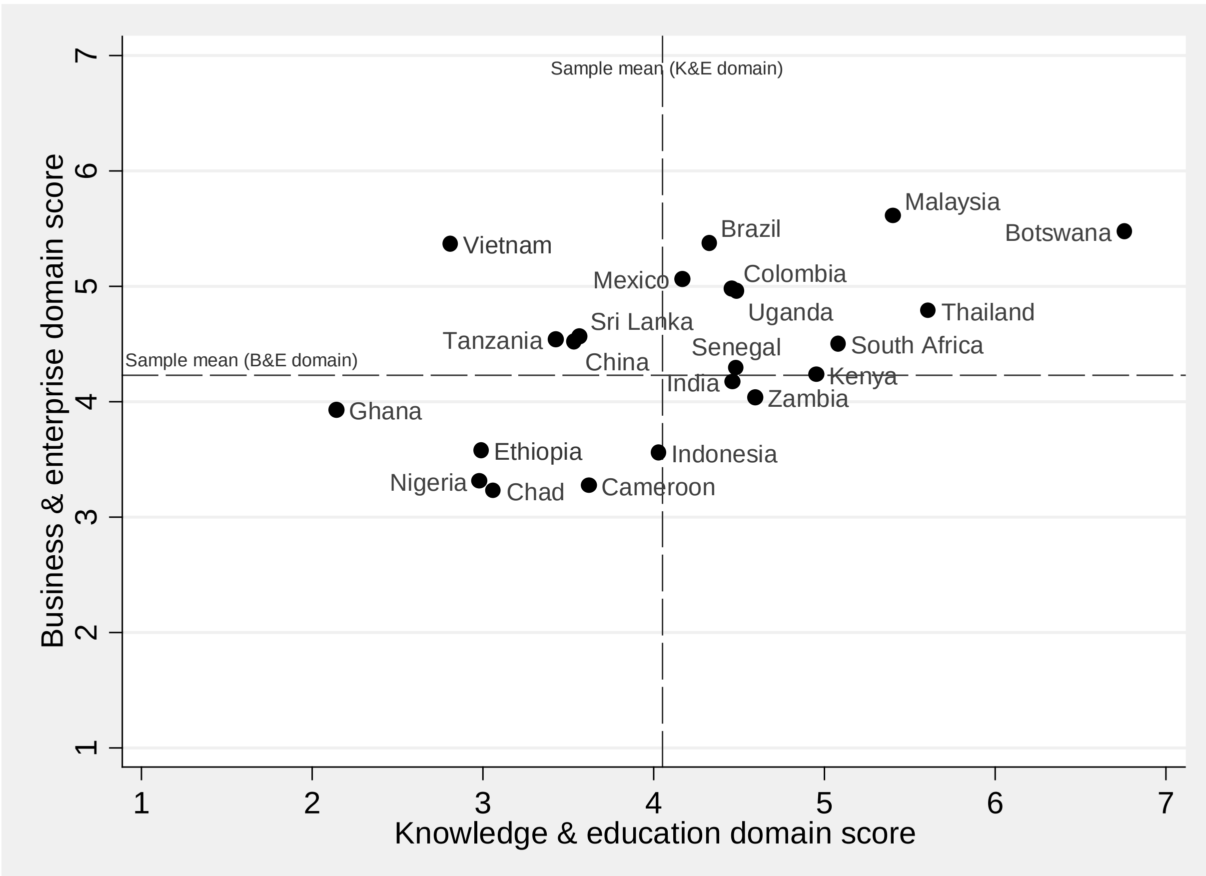
The first type of country might be described as having a strong knowledge and education domain and a weak business and enterprise domain. This describes a country where investments in innovative capabilities—in research institutes, universities, technical training, and other formal knowledge sources—exceed investments in knowledge-based commerce and enterprise. Here, the drivers of innovative performance are more "supply oriented," that is, more developed in the fields of science and education relative to business. Agricultural innovation systems in India, Kenya, and Zambia may fit into this category relative to the other countries studied in the 35-country sample presented here. This might also describe the former Soviet Union and the transitional Eastern European economies that emerged from its collapse, all of which are known for their prowess in science, technology, and education but are regarded as rudimentary performers in the fields of business and enterprise.

The second type of country might be described as having a strong business and enterprise domain and a weak knowledge and education domain. This could describe the more "demand-oriented" countries where technological leapfrogging and imitation in the commercial sector are drivers of innovation performance, and where scientific and education performance lags. Agricultural innovation systems in

China, Tanzania, and Vietnam may fit into this category relative to the other countries studied in the 35-country sample presented here.

The third and fourth types of countries might be described as “leaders” and “followers,” respectively. For example, leaders in the sample—countries such as Botswana, Malaysia, and Thailand—are characterized by relatively strong scores in both the knowledge and education domain and business and enterprise domain. Necessarily, followers in the sample—countries such as Cameroon, Chad, Ethiopia, Ghana, and Nigeria—are characterized by relatively low scores in these domains.

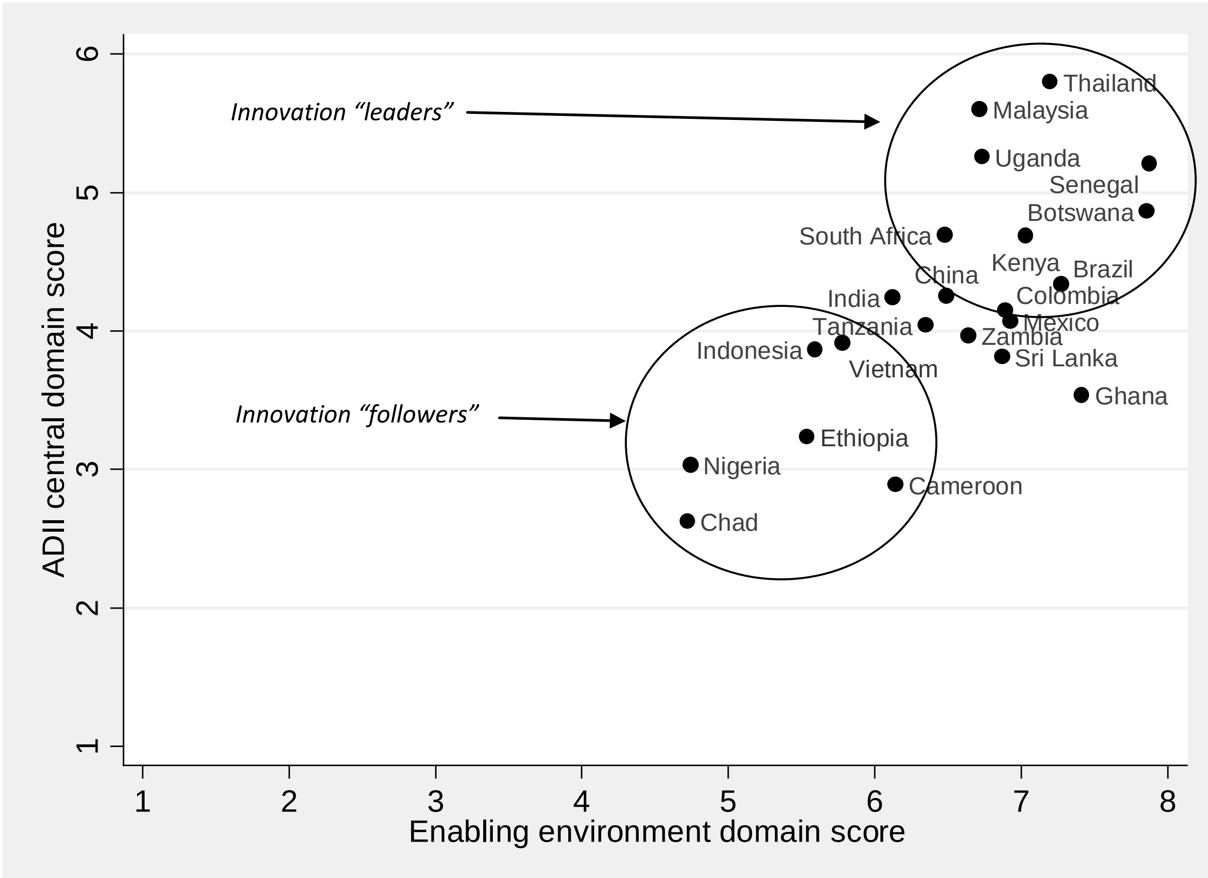
Figure 3. Science and commerce: Key ADII domain scores



Source: Authors.

Another classification maps the performance of the innovation system’s enabling environment domain against the mean of the other “central” components—the knowledge and education, bridging institutions, and business and enterprise domains (Figure 4). Again, leader and follower countries emerge from this characterization, as does a positive relationship between an enabling environment and performance of a system’s principle component. Further econometric analysis of this relationship is clearly warranted.

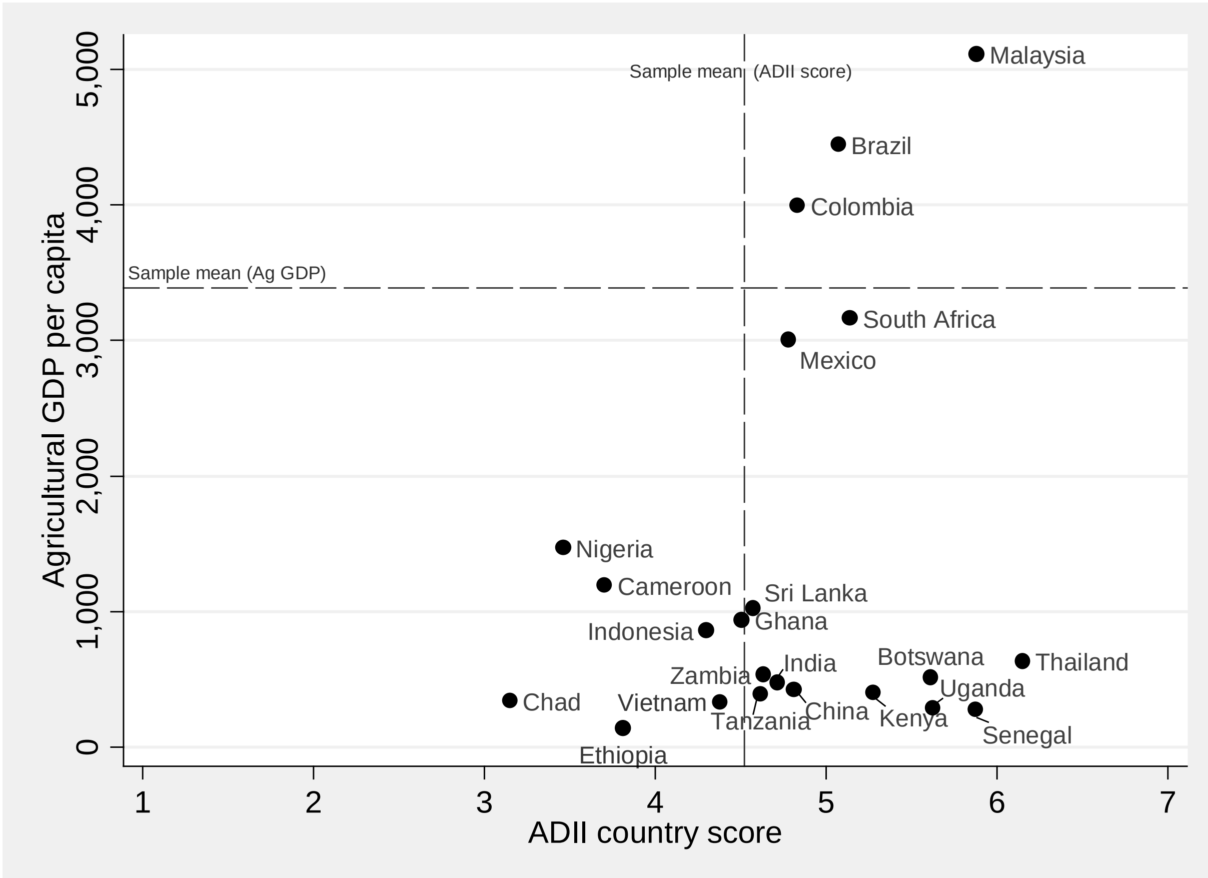
Figure 4. Enabling environment and central domains: Key ADII scores[a]



Source: Authors.
Notes: [a] "Central domain score" refers to the mean value of the three ADII subindexes that measure the following "central" domains: (1) knowledge and education, (2) bridging institutions, and (3) business and enterprise.

To illustrate the potential impact of innovation system performance on agriculture, we map the ADII scores against agricultural GDP per capita (measured in constant 2005 US dollars) in Figure 5. Despite the close clustering of countries with low ADII scores and low agricultural GDP per capita, there is some evidence of a positive relationship between the two. Key comparators such as Brazil, Colombia, Malaysia, Mexico, and South Africa perform well on both counts, suggesting that innovation contributes to agricultural productivity. However, other comparators such as China and India do not exhibit a clear relationship between agricultural innovation and productivity. Moreover, our two countries of interest—Ethiopia and Vietnam—score fairly low against both variables of interest, thus providing limited evidence of a clear relationship.

Figure 5. Agricultural GDP per capita and ADII country scores



Source: Authors.

A more complete model of the relationship between innovation system performance and agricultural sector performance requires further statistical exploration. Attempts to regress the ADII and the individual domain scores suggest these variables are only weakly associated with most of the indicators chosen to describe the outcomes of an innovation system. This suggests that there is still room for further exploration of these relationships with more complete models and alternative estimation techniques.

In fact, while the ADII provides some insights into national innovation performance and comparisons against other developing countries, it should be noted again that index and domain values are sensitive to data availability and data quality. For example, in Figure 3, Ghana is characterized by a knowledge and education domain that falls well below the 35-country sample mean and well below its regional comparators. But close observers of Ghana’s economic and agricultural performance might take issue with these scores.

A closer look at the ADII data suggests that 3 of the 11 variables used to calculate the knowledge and education domain score are, in the case of Ghana, missing variables. However, since missing values are simply dropped from calculations of a given country’s ADII score, the missing values do not completely explain Ghana’s performance in this domain. Moreover, missing values for the same indicators are found for several other countries (Bhutan, Laos, and Myanmar, not shown in Figure 3), all of which score at or above the 35-country sample mean for the knowledge and education domain.

A more likely explanation for Ghana’s paradoxical performance might be its relatively low values for indicators including agricultural journal publications, agricultural research intensity, official development assistance for agricultural education and training, and official development assistance for agricultural research and development. With respect to the latter two indicators, an argument could be made that low levels of official development assistance may indicate greater investment from national budgetary resources (and thus greater independence from international donors), and that this may be positively related to performance in the knowledge and education domain. However, we prefer here to assume that greater resources, from whatever source, are preferable to fewer resources, and thus construe Ghana's relatively low levels of official development assistance as a constraining factor in the knowledge and education domain. Moreover, a closer look at the indicators for Ghana shows that the country scores below the 35-country sample means for 6 of the 8 available indicators in the knowledge and education domain, resulting in the low x-axis value illustrated in Figure 3.

These paradoxes notwithstanding, the findings presented above illustrate how a conceptual modeling of an agricultural innovation system can be quantified and illustrated with data from a range of secondary sources. To be sure, the ADII can be further improved by incorporating more up-to-date information, introducing additional or alternative indicators, expanding the sample of countries, and subjecting the underlying relationships to further econometric and statistical testing. However, as a first demonstration, the ADII goes some distance in showing the feasibility of measuring innovation system properties and performance.

4. TOWARD A MORE "SYSTEMS-ORIENTED" ADII

In this paper, we are also interested in moving beyond the measurement of system properties and performance, using secondary data sources, to the introduction of indicators that are more "systems-oriented." These types of indicators are meant to capture attributes such as heterogeneity, integration, and responsiveness of actors and networks, all of which are critical characteristics of a performant innovation system (see Giuliani 2007; Giuliani and Bell 2005). Conceptually, these attributes are fairly simple to understand: an innovation system is likely to be more productive when a diversity of actors brings new ideas to the innovation process ("heterogeneity"), provided that they are supported by integrative processes of communication, exchange, and learning ("integration"), and provided that sufficient incentives exist—profits, status, or recognition—to stimulate their participation ("responsiveness").

Several of the secondary data sources used above—namely, WEF (2007) and IFAD (2005)—incorporate systems-oriented indicators into their indexes. Prime examples include the WEF's measure of "university–industry research collaboration" or IFAD's measure of "dialogue between government and rural organizations." Moreover, they measure these indicators using tools such as expert opinion polls (in the case of WEF) and consultative processes (in the case of IFAD). But apart from these examples, conventional data from conventional sources are limited in their ability to describe the underlying properties of an agricultural innovation system and their influence on innovation performance.

Thus, we propose here an integrated, multistep toolkit for improving the measurement of innovation system properties and performance. This toolkit focuses on measuring and analyzing underlying systems-oriented properties such as the linkages, relationships, and influences among heterogeneous actors. While there are many different ways of examining such properties, our toolkit combines participatory data collection tools with expert opinion surveys and organization/firm-level surveys to obtain relational data that better characterize an innovation system. Data generated by this toolkit can be introduced into the index described above as a means of capturing relational data or used as a separate means altogether of measuring indicators and establishing benchmarks. We illustrate these tools with applications to Ethiopia and Vietnam.

Choosing Units of Analysis within the Agricultural Sector

The first step in measuring and analyzing more systems-oriented indicators is to define the primary unit of analysis. Here, we choose to define this as the main subsectors of a given country's agricultural economy, grouped into three main categories: food staple (FS), high value/traditional exports (HV/TE), and livestock (LV). Arguably, each subsector is host to its own innovation subsystems and can thus be examined as a separate unit.

The choice of exactly which subsectors might be examined is determined by the resources available to the researcher. With unlimited resources, the ambitious researcher may choose to examine all subsectors within each of the four main categories, thereby covering the entire agricultural economy. The resource-constrained researcher may choose to examine "representative" subsectors from each category, based on criteria such as the sector having (1) a relatively high share of the subsector as a proportion of agricultural GDP; (2) a relatively high importance to food security; (3) relatively high importance to economic growth and development; (4) a relatively high real or potential growth rate; or (5) any combination of these criteria.

For example, the representative subsectors in Ethiopia's agricultural economy that we chose to study were maize (a major food staple with a high growth rate in terms of production), coffee (a traditional export with significant importance to the economy), and poultry (a small but rapidly growing commodity in the livestock subsector). In Vietnam, similar criteria might suggest that emphasis be placed on rice (the food staple crop), cashews or coffee (high value crops), and pigs (a key livestock commodity). Of course, other choices of crops and commodities could be made, but so long as they maintain some degree of representativeness, they can usefully inform the measurement and analysis of an innovation system.

Diagnosing the Innovation System: Influence Network Mapping

The second step in measuring and analyzing systems-oriented indicators is to generate a diagnosis of the innovation subsystems in question. To do this, participatory or consultative tools are useful ways of identifying key actors, their salient characteristics, the nature of their relationships and interactions, and their influence or power within a system.

Here, we use a participatory analysis tool known as Influence Network Mapping or "Net-Map" (Schiffer and Waale 2008; Schiffer 2007). Net-Map is useful because it can be used to study the formal and informal networks that link actors involved in innovation processes and to assess the influence these actors have on such processes. More important, Net-Map generates relational data that are absent in the largely attributional data from secondary sources presented earlier.

In the context of this paper, Net-Map was used in Ethiopia as a diagnostic tool to map the innovation landscape relating to the poultry subsector and to identify and describe (1) key innovation actors by sector (public, private, civil society), and by domain (knowledge, enterprise, and so forth); (2) their respective roles in the sector (input supply, knowledge and information, finance and credit, for example); (3) the nature of their relationships (command/administration, collaborative/cooperative, financial, other); and (4) their influence or power in the system. For a complete description of the Net-Map process, see Appendix E.

Collecting Data: Expert Opinion and Organizational Surveys

The third step is to obtain data on specific properties and performance from each innovation subsystem. Here, the findings of the Net-Map exercise can provide useful information on the key actors to interview as a means of obtaining such data. Once key actors are identified, tools such as expert opinion surveys can be used to collect a range of soft data types.

In this paper, expert opinion surveys were used to obtain information on the following characteristics of specific subsystems: effectiveness of organizations and organizational collaborations; responsiveness of organizations to technological, market, and other opportunities; accountability of organizations to different types of stakeholders; accessibility of organizations to different types of stakeholders; and the innovativeness of organizations in terms of introducing new efficiency-improving products and processes.

For example, in the case of Ethiopia, this was done by asking expert respondents to identify their key collaborators and then asking a series of questions about their collaborators relating to each of these four topics. Responses were scaled from 1 (the lowest possible response) to 4 (the highest possible response), with provisions for "does not apply" and "do not know" responses. To elicit the most accurate answers possible, questions were typically asked in a semi-structured and open-ended format, with respondents being asked to quantify their answers only after having considered and discussed the question fully.

Thus, experts were asked to respond to questions such as "how effective are your key collaborators (in the maize/poultry/coffee subsector) at…" promoting innovation among farmers, increasing agricultural productivity, responding to new market opportunities, responding to new scientific and technological opportunities, and responding to input from your organization on strategic planning and priority setting. Similar questions were posed with respect to organizational responsiveness, accountability, and accessibility.[7]

A total of 22 experts in Ethiopia were interviewed in person in mid 2008: 9 from the maize subsector, 8 from the poultry subsector, and 5 from the coffee subsector. To avoid weighting of their aggregated responses in favor of one subsector over another, responses were averaged first by individual subsector and then across all subsectors.

[7] See http://www.surveymonkey.com/s.aspx?sm=1Rg41mJ7cBkhMnjHIjE0pQ_3d_3d for an online version of the survey (for reference purposes only).

An alternative to this approach was used in the case of Vietnam, where experts were chosen from secondary sources Stads and Hai 2006) and without the benefit of a Net-Map exercise. A total of 24 experts responded to the survey by email or on paper in late 2007 and early 2008. Respondents included experts from public agricultural research organizations (7), public agricultural extension services (4), private agribusinesses (3), agricultural education and training institutions (6), and relevant government ministries and agencies (4) in Vietnam.[8]

These experts were queried on many of these same topics, although responses elicited were of a more reflective nature with respect to the characteristics of the respondents' own organizations, not their collaborators' characteristics. While this approach presented certain problems (for example, a tendency for respondents to bias their responses to represent their organizations in a favorable light), it did generate some useful data. Moreover, these questions were included as an add-on to a more comprehensive organizational survey (described below) that aimed at collecting more basic data on organizational/firm-level resources and expenditures—data that are equally important to the design of an ADII-type index.

Illustrations from Ethiopia and Vietnam

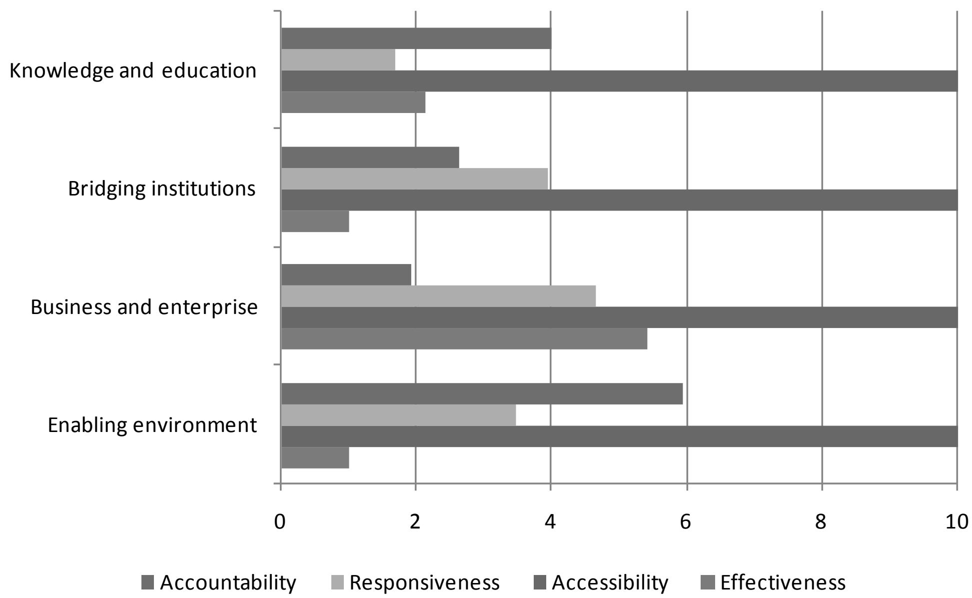
Here, we present indicators that capture some of the more systems-oriented characteristics of agriculture in Ethiopia and Vietnam, based on the expert opinion surveys described above. Ideally, if these indicators were integrated with the secondary data presented in the ADII earlier, we would be able to paint a more detailed and nuanced picture of the properties and performance of an agricultural innovation system.

First, we examine opinions on key systems characteristics based on responses from experts representing selected subsectors of Ethiopia's innovation systems. Figure 6 shows expert opinions from the 22 experts in the maize, coffee, and poultry subsectors surveyed in mid 2008. These results provide some interesting insights into key innovation systems properties—accountability, responsiveness, accessibility, and effectiveness—for each of the four system domains.

For instance, while the surveyed experts found that their respective collaborators were overwhelmingly accessible, actual responsiveness and accountability to other stakeholders and opportunities were relatively limited. Overall, these surveyed experts also found the system, particularly the domains that capture bridging institutions and the enabling environment, to be minimally effective in promoting innovation.

[8] See http://www.surveymonkey.com/s.aspx?sm=FhZTQlvx019s5rNDSJ_2fLtg_3d_3d for an online version of one of the surveys used in Vietnam (for reference purposes only).

Figure 6. Expert opinions: Innovation system properties, by domain, Ethiopia



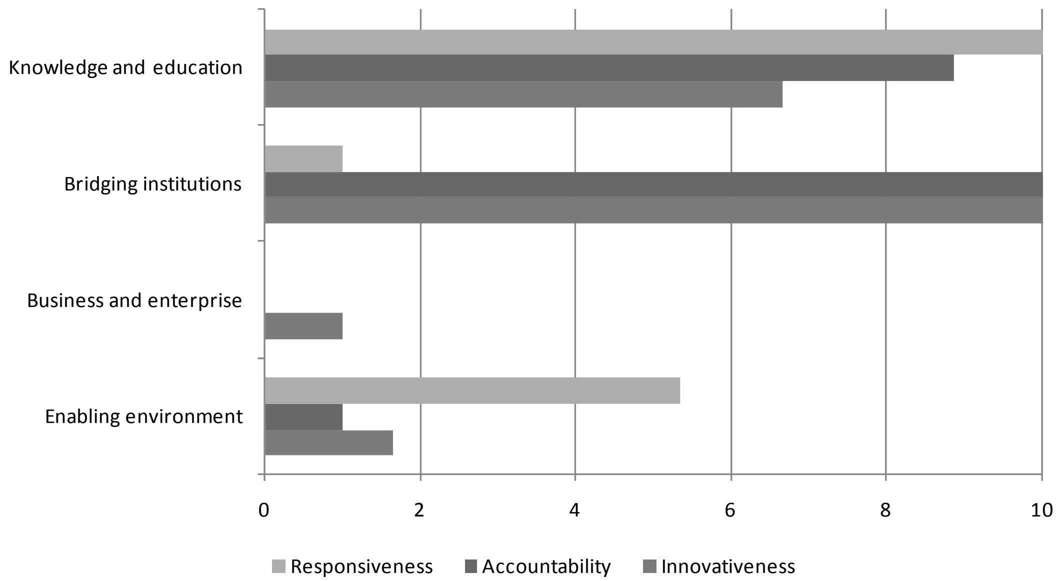
Source: Authors.
Note: Scores range from 1 to 10.

Figure 7 provides a similar measure of expert opinions from Vietnam based on reflective responses from the 24 respondents. Owing to the different survey tools tested in Vietnam, these results are not immediately comparable to those from Ethiopia. However, they do illustrate the fact that variations exist in expert opinions on innovation system properties such as responsiveness, accountability, and innovativeness among key innovation actors.

For example, while respondents indicated that educational, research, and extension organizations (represented in the knowledge and education domain and bridging institutions domain) were strongly innovative, the business community and enabling policy environment (key ministries and public agencies) were both less so. Similarly, while educational and research organizations were viewed as strongly responsive to different and emerging innovation opportunities, the corresponding organizations involved in extension were viewed as being weakly responsive.

This exercise shows how an expert opinion survey approach can provide an entirely new set of indicators—measures of accountability, responsiveness, accessibility, effectiveness, and innovativeness—that can significantly improve on the secondary data used in the ADII.

Figure 7. Expert opinions: Innovation system properties, by domain, Vietnam



Source: Authors.
Note: Scores range from 1 to 10. Expert opinions from business and enterprise domain respondents on responsiveness and accountability were not available.

This exercise also shows how the expert opinion survey approach can be used to generate relational data—a form of data that captures the essence of "systems-oriented" properties by measuring phenomena beyond the straightforward attributes of an actor. For example, the surveys conducted in Ethiopia and Vietnam collected data on both the main types of linkages between key system actors and the effectiveness or importance of these linkages.

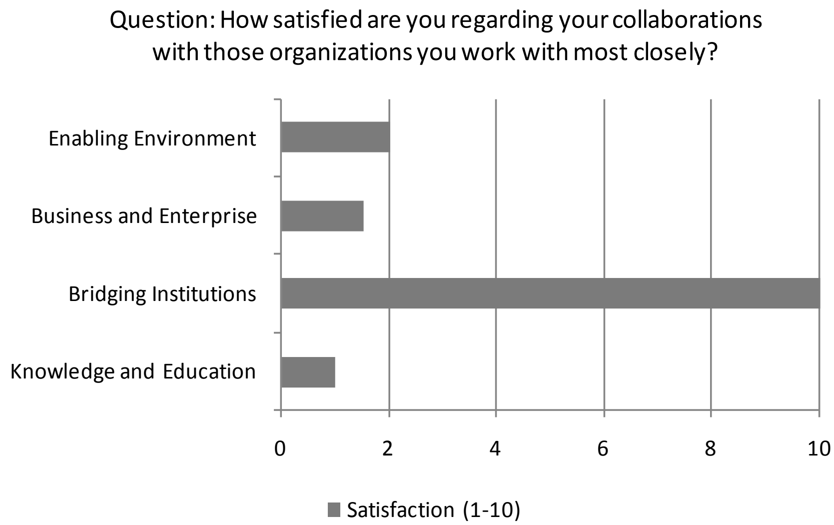
Respondents' assessments of these linkages are based on a large amount of relational data. In Ethiopia, respondents were asked to list their organizations' collaborations with other organizations with regard to maize, poultry, or coffee innovation. Table 2 summarizes the number of collaborations that were provided by respondents, classified according to the collaborator's domain. Respondents then answered questions relating to their satisfaction with the identified collaborators (Figure 8). Results show that while respondents from all domains were satisfied with linkages with bridging institutions (in this case, linkages with public extension services), they were largely dissatisfied with their linkages with collaborators in all other domains, particularly the knowledge and education domain (in this case, public research organizations and institutes of higher learning).

Table 2. Number of collaborations assessed by respondents, by domain, Ethiopia

Respondent (by domain)	Number of collaborations (by collaborator's domain)				
	KE	BI	BE	EE	Total
Knowledge and education (KE) (8)	12	7	16	6	41
Bridging institutions (BI) (3)	3	5	6	3	17
Business and enterprise (BE) (8)	3	9	17	10	39
Enabling environment (EE)(3)	0	1	9	7	17
Total (22)	18	22	48	26	114

Source: Authors.

Figure 8. Organizational collaborations and satisfaction, by domain, Ethiopia



Source: Authors.
Note: The four domains given on the vertical axis refer to the types of collaborating organizations that respondents were asked to comment on.

Respondents in Vietnam were asked a slightly different question: "How do you rate the importance of your cooperation with..." the private sector, extension service providers, higher learning institutes, and so on. Table 3 shows that a total of 22 respondents from various innovation system domains provided assessments of 244 collaborations. Note, however, that the question was framed in a way that asked respondents to comment on different *types* of collaborators, not on specific organizations as was the case in the Ethiopia survey. This framing provides less detailed information than the Ethiopia survey but still offers some insight into the strengths and weaknesses of relations within an innovation system.

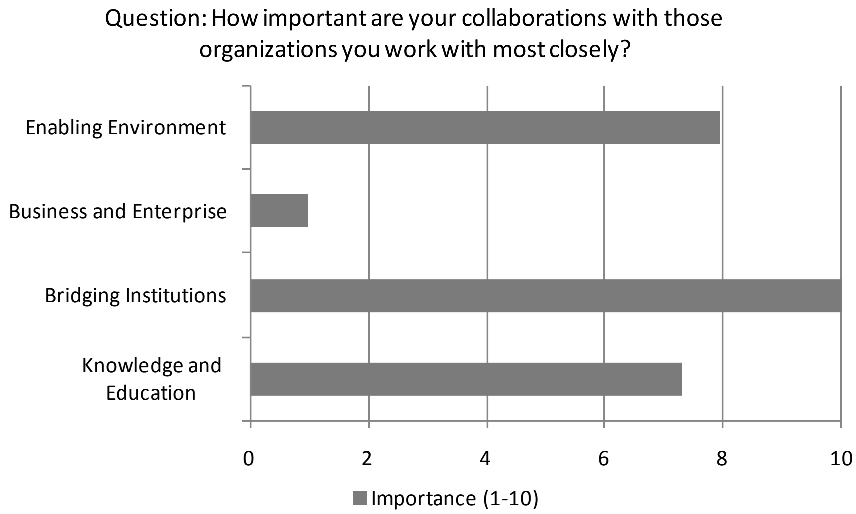
Respondents in Vietnam also answered questions relating to the importance of their linkages with their collaborators (Figure 9). Results show that limited importance is placed on linkages with collaborators in the business and enterprise domain relative to all other domains, possibly suggesting a discontinuity between public and private sector innovation activities, or a general absence of public–private collaboration in the agricultural sector.

Table 3. Number of collaborations assessed by respondents, by domain, Vietnam

Respondent (by domain)	Number of collaborations (by collaborator's domain)				
	KE	BI	BE	EE	Total
Knowledge and education (KE) (12)	56	12	13	48	129
Bridging institutions (BI) (5)	23	5	8	24	60
Business and enterprise (BE) (1)	4	1	2	2	9
Enabling environment (EE) (4)	20	3	2	21	46
Total (22)[a]	103	21	25	95	244

Note: [a] Note that although there were a total of 24 respondents to the Vietnam survey, only 22 responded to questions on collaborations and linkages.

Figure 9. Organizational linkages and importance of the linkage, by domain, Vietnam



Source: Authors.
Note: The four domains given on the vertical axis refer to the types of collaborating organizations that respondents were asked to comment on.

As a next step, we introduce these systems-oriented indicators into the ADII scores for Ethiopia and Vietnam presented earlier. For Ethiopia, a total of 20 new variables (each the simple average of domain-specific scores for accountability, responsiveness, accessibility, effectiveness, and satisfaction) were introduced to the existing ADII calculations. For Vietnam, 16 new variables (each the simple average of domain-specific scores for responsiveness, accountability, innovativeness, and importance) were similarly introduced. Revised index scores (ADII′) are given in Table 4.

Table 4. ADII scores using systems-oriented indicators, by domain, Ethiopia and Vietnam

	ADII: Original scores						ADII′: Revised scores					
Country	ADII	KE	BI	BE	EE	No. of indicators	ADII′	KE	BI	BE	EE	No. of indicators
Ethiopia	3.81	2.99	3.14	3.58	5.54	41[a]	4.23	3.26	4.63	3.93	5.13	61
Vietnam	4.38	2.81	3.56	5.37	5.78	35[a]	5.08	4.39	5.95	4.70	5.27	51

Source: Authors.
Note: [a] Number of indicators totals less than 41 for both countries due to missing values.

Again, because of the differences in survey design, note that ADII′ scores are not immediately comparable across these two countries. But the within-country differences between the ADII and ADII′ scores appear to be substantial and positive. Moreover, there is some variation in the domain-specific differences in scores resulting from the introduction of these systems-oriented variables. For example, while inclusion of data from the expert assessments of the knowledge and education and bridging institutions domains result in increases for the respective domain scores in both countries, the scores for both countries' enabling environment domains actually decrease. This is consistent with findings discussed earlier, and it demonstrates how these systems-oriented properties can be used to create a more detailed picture of the innovation system without a particular bias in any direction.

In summary, although the contribution of these measures depends acutely on the way the survey questions are framed, they do generate an important set of data that is useful in measuring relational elements of an innovation system. These are precisely the types of “systems-oriented” indicators that are difficult to obtain from secondary sources but are nonetheless critical to quantifying system properties and performance. And importantly, while the data presented above are highly sensitive to the different survey methods used, they demonstrate the feasibility of collecting more systems-oriented indicators. Provided that a consistent and rigorous methodology is pursued across a large set of countries and system actors, these data can strengthen the ADII by adding indicators that capture organizational/firm attributes such as accountability, responsiveness, accessibility, effectiveness, and innovativeness, and indicators that capture organizational/firm relations such as satisfaction, importance, or effectiveness of collaboration. Ultimately, these types of indicators can be valuable to future ADII-type exercises that seek to convey a more accurate and more nuanced characterization of innovation system properties and performance.

We add here an important caveat. Despite the need for the systems-oriented data argued for above, there is also a fundamental need for more, and more detailed, *hard* data. For example, basic indicators such as farmer-to-extension agent ratios or expenditures on agricultural extension are presently unavailable for most of the countries studied here from any source or are prohibitively costly to obtain. Similarly, basic indicators such as business expenditure on research and development, or the value of private investments in agriculture more generally, are similarly difficult to secure. But without these types of hard data, an ADII-type exercise must rely on proxies that are often poor substitutes for data that should be of interest to policymakers, donors, investors, and other stakeholders.

It is for this reason that expert opinion surveys must be complemented by other data collection efforts such as organizational/firm-level surveys that provide *hard* data on organizational/firm capabilities and resources. For example, the surveys used in Vietnam were meant to identify (1) activities undertaken by key innovation system actors, (2) tools and methods used in conducting these activities, (3) human resource and financial resources, (4) recent organizational innovations undertaken to improve the conduct of these activities, and (5) organizational linkages that support these activities. These surveys were designed and implemented along lines similar to surveys conducted by ASTI (2005), which are, in turn, designed in general accordance with internationally accepted statistical procedures and definitions for compiling R&D statistics. In short, future efforts to develop innovation indicators and benchmarks must invest heavily in the collection and analysis of both hard and soft data to develop comprehensive, comparable, and replicable statistics on innovation system properties and performance in developing-country agriculture.

5. CONCLUSION

The rapidly changing nature of both global and local food and agricultural systems suggests the need to rethink how innovation can contribute to improving agricltural productivity and poverty reduction in developing countries. While breakthroughs in communications, microbiology, genomics, and other scientific fields can help foster technological change, their contributions are incomplete without commensurate changes in the wider system within which they operate. A better understanding of how this integrated system functions is critical to promoting dynamism, responsiveness, and competitiveness in developing-country agricuture to enhance productivity and reduce poverty.

But our efforts to develop a better understanding require us to recognize that we do not know how to measure the abstract concept of innovation, particularly with respect to developing-country agriculture. Without such measurements, policymakers, investors, donors, and practitioners cannot make informed decisions that consciously support the development of responsive, dynamic, and competitive agriculture.

This paper attempts to bridge that knowledge gap by providing a "proof of concept" that innovativeness in developing-country agriculture can be measured. We do so first by identifying a set of indicators from secondary data sources that measure key elements of an agricultural innovation system. Several hundred indicators were reviewed, validated, and quantified, ultimately resulting in 41 key indicators used to develop the Agriculture, Development, and Innovation Index (ADII) presented earlier.

We then design and test the elements of a toolkit for collecting and analyzing "systems-oriented" indicators that add more process-oriented nuances to ADII with both attributional and relational data. The results of this exercise, and the tools used in the exercise, are presented with reference to expert opinion survey data collected in Ethiopia and Vietnam in 2007–08. Throughout this process, we also design a toolkit with which to measure agricultural innovativeness in a way that extends beyond the "black box" of input–output matrixes and models by adding elements that describe the underlying processes that contribute to building innovative capabilities in the agricultural sector.

This paper demonstrates how the broad area of "innovation policy" can be subdivided into more tractable areas to which policy and investment choices can be targeted. In Ethiopia, for instance, the findings from this paper might suggest that challenges facing the business and enterprise domain require relatively more emphasis than those facing the knowledge and education domain, thus suggesting that pro-agribusiness policies and investments are as important as new investments in agricultural universities and research centers. In Vietnam, on the other hand, findings might suggest the need for accelerating investment in technical and scientific education relative to the commercial sector. And in both countries, findings might suggest that bridging institutions—both their nature and their performance—are insufficient to the needs of their wider agriculture innovation systems.

But ultimately, the aim of this paper is to design a combined qualitative/quantitative toolkit for measuring innovation systems' properties and performance and an analytical approach that emphasizes not only inputs and outputs, but also systems properties that are more difficult to measure. While there is scope for more work on developing appropriate indicators and the tools to measure them, it is hoped that this paper will lay the groundwork for future efforts in this field of inquiry. And as better information and analysis emerge from such efforts, it is hoped that policymakers, investors, donors, and other development actors will be able to make decisions that strengthen innovation systems in developing-country agriculture and, ultimately, support national and global efforts to foster agricultural development, economic growth, and poverty reduction.

APPENDIX A: INDICATOR DESCRIPTION

Descriptions and sources of the indicators used to compile the ADII are given below. Additional indicators that were ultimately excluded from ADII calculations due to close correlations but incomplete country coverage or a lack of up-to-date data are as follows: market efficiency (WEF 2007); policy uncertainty (World Bank 2008a); investment and trade environment (Zhang et al. 2004); Climate of Political Freedom Index (Zhang et al. 2004); proportion of female public agricultural researchers out of all public agricultural researchers (BA, MA, and PhD levels) (ASTI 2005); and higher education and training as efficiency enhancers for a competitive economy (WEF (2007).

Knowledge and Education Domain

Public researchers per $100 million of agricultural GDP (*Int_agrsrchr*) (ASTI 2005). This indicator is a five-year average (1998–2002) of the number of researchers in the public sector per US$100 million of agricultural GDP, divided by US$100 million agricultural GDP, in constant 2005 US dollars, for 2003. Data for Bangladesh, Bhutan, Cambodia, Laos, Nepal, and Pakistan are for 2003 only; Benin, Botswana, Burkina Faso, Mali, and Senegal, for 2001 only; Nigeria and Zambia, for 2000 only; Brazil, Colombia, and Mexico, for1996 only.

Quality of the educational system (*EdSysQual)* (WEF 2007). This indicator is based on scores from the WEF Executive Opinion Survey question on the quality of a given country's education system. Scores range from 1 (does not meet the needs of a competitive economy) to 7 (meets the needs of a competitive economy).

Quality of scientific research institutions (*SciQual)* (WEF 2007). This indicator is based on scores from the WEF Executive Opinion Survey question on the quality of scientific research institutions, such as university laboratories and government laboratories, in a given country. Scores range from 1 (nonexistent) to 7 (the best in their fields internationally).

Migration rate of tertiary education holders (*MigrRate)* (Docquier and Marfouk 2004). This indicator measures the proportion of working age individuals (aged 25 and over) with at least tertiary (university) educational attainment in 2000, who were born in a given country but living in another country, taking into account neither their occupation, nor where education took place, nor when they arrived.

Public-sector agricultural R&D intensity (*Int_agrd*) (ASTI 2005). This indicator is a five-year average (1998–2002) of total public spending on agricultural R&D, measured as a percentage of agricultural GDP. Data for Malaysia are for 2002 only; data for Bangladesh, India, Indonesia, Laos, Myanmar, Nepal, Pakistan, and Sri Lanka, are for 2003 only; data for Botswana, Burkina Faso, Mali, and Senegal are for 2001 only; Nigeria and Zambia data are for 2000 only.

Official development assistance to agricultural education/training. (*ODA_AET)* (OECD 2008). This indicator is calculated as a four-year average (2002–05) of gross disbursements of official development assistance to agricultural education/training (measured in constant 2005 US$ million) divided by agricultural GDP (also measured in constant 2005 US$million). This includes official development assistance to agriculture, fishery, and forestry education/training.

Official development assistance to agricultural research (*ODA_Agrd*) (OECD 2008). The indicator is calculated as a four-year average (2002–05) of gross disbursements of official development assistance to agricultural research (measured in constant 2005 US$million) divided by agricultural GDP (also measured in constant 2005 US$million). This includes official development assistance to agriculture, fishery, and forestry research.

Agricultural scientific journal articles (*Journals*) (ISI Web of Science 2008); World Bank 2008a). This indicator is a five-year average (2001–05) that measures the number of scientific journal articles on agriculture per million of agricultural GDP. Figures on scientific journal articles on agriculture were calculated based on a ISI Web of Science database search for (1) articles published on agriculture, livestock, fishery, forestry, and crops and (2) on cases where at least one of the author's addresses corresponded to the selected country.

Membership in regional and international agricultural research system (*Rsrchmmb*)(APAARI 2008; ASARECA 2004; SACCAR 2000; CORAF/WECARD 2008; and CGIAR 2008). The indicator measures a country's membership in regional and international agricultural research systems and networks as of 2007. The indicator is an index ranging from 0 (does not belong either to the regional or international agricultural research system) to 1 (belongs to both).

Access to education in rural areas (*Edaccess*) (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses the extent to which the country has created laws, policies, institutions, and practices that promote equal access for boys and girls to education in rural areas. Country scores range from 1(the lowest possible grade) to 6 (the highest possible grade).

Technological readiness as efficiency enhancers for a competitive economy (*TechReady*). (WEF 2007). This indicator is a composite of seven measures of technological readiness including measures of information and communications technology (ICT) infrastructure, technology transfer, and foreign direct investment, and firm-level technology absorption. Scores are scaled from 1 (technologies are not ready for use by end users) to 7 (technologies are ready for use by end users).

Bridging Institutions Domain

University-industry research collaboration (*UniIndcoll*) (WEF 2007). This indicator is based on scores from the WEF Executive Opinion Survey on the extent to which businesses collaborate with local universities in support of the business's R&D activities. Scores range from 1 (minimal or nonexistent collaboration) to 7 (intensive and ongoing collaboration).

Official development assistance to agricultural extension and cooperatives (*oda_ext_coop*) (OECD 2008; World Bank 2008a). This indicator is calculated as a four-year average (2002–05) of gross disbursements of official development assistance to agricultural extension and agricultural cooperatives (measured in constant 2005 US$million) divided by agricultural GDP (also measured in constant 2005 US$million).

Access to agricultural research and extension services (*AgREaccess*) (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses the extent to which the agricultural research and extension system is accessible to poor farmers, including women farmers, and is responsive to their needs and priorities in a given country, where 1 equals the lowest possible grade and 6 equals the highest possible grade.

Business and Enterprise Domain

Cost of business start-up procedures (*BizCosts*) (World Bank 2008a). This indicator is a three-year average (2003-05) of the cost to register a business as a percentage of gross national income (GNI) per capita.

The status of innovation factors in economic competitiveness (*Innov*) (WEF 2007). This indicator is a composite of measures of the strength of networks and supporting industries, the sophistication of firms' operations and strategies, and other innovation factors. Scores are scaled from 1 (not conducive to a nation's competitiveness) to 7 (conducive to a nation's competitiveness). The indicator itself is a simple average of the scores for (1) Business Sophistication and (2) Innovation. Business Sophistication is a composite measure of 11 variables (local supplier quantity, local supplier quality, state of cluster development, nature of competitive advantage, value chain breadth, control of international distribution, production process sophistication, extent of marketing, willingness to delegate authority, local availability of process machinery, and extent of incentive compensation) and Innovation is a composite measure of 7 variables (capacity for innovation, quality of scientific research institutions, company spending on R&D, university-industry research collaboration, government procurement of advanced technology products, availability of scientists and engineers, and utility patents).

Official development assistance to agricultural financial services (*ODA_AgFin*) (OECD 2008; World Bank 2008a). This indicator is calculated as a four-year average (2002–05) of gross disbursements of official development assistance to agricultural financial services (measured in constant 2005 US$million) divided by agricultural GDP (also measured in constant 2005 US$million).

Official development assistance to agro-industries (*ODA_Agind*) (OECD 2008; World Bank 2008a). This indicator is calculated as a four-year average (2002–05) of gross disbursements of official development assistance to agro-industries (measured in constant 2005 US$ million) divided by agricultural GDP (also measured in constant 2005 US$million).

Roads, total network (*Roads*) (World Bank 2008a). This indicator measures kilometers of road network per capita as of 2003 and includes motorways, highways, and main or national roads, secondary or regional roads, and all other roads in a country. Data for Kenya, South Africa, Thailand, and Vietnam are for 2000; those for Malaysia are 2001; for India and Indonesia, 2002.

Investment climate for rural businesses *(RuralInvest)* (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses whether government has adopted an appropriate policy, legal, and regulatory framework to support the emergence and development of private rural businesses in a given country, where 1 equals the lowest possible grade and 6 equals the highest possible grade.

Access to agricultural input and produce markets (*MktAccess*) (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses whether the policy and institutional framework supports the development of commercially based agricultural markets that are rooted in the private sector and are efficient, equitable, and accessible to small farmers in a given country, where 1 equals the lowest possible grade and 6 equals the highest possible grade.

Enabling conditions for rural financial services development (*Ruralfin*) (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses the extent to which the policy and institutional framework supports the development of a commercially based rural finance market that is rooted in the private sector and is efficient, equitable, and accessible to low-income populations in rural areas in a given country, where 1 equals the lowest possible grade and 6 equals the highest possible grade.

Fertilizer consumption (*Fertlzr*) (World Bank 2008a). This indicator is a five-year average (1998-2002) of the quantity of plant nutrients used per unit of arable land, measured in terms of 100 grams per hectare of arable land. Fertilizer products cover nitrogenous, potash, and phosphate fertilizers (including ground rock phosphate), but traditional nutrients—animal and plant manures—are not included. The time reference for fertilizer consumption is the crop year (July through June).

Agricultural machinery (*Machine*) (World Bank 2008a). This indicator is a five-year average (1999-2003) of tractors in use per 100 square meters of arable land and refers to wheel and crawler tractors (excluding garden tractors) in use in agriculture at the end of the calendar year specified or during the first quarter of the following year.

Foreign direct investment inflows (FDI) (World Bank 2008a). This indicator is a five-year average (2000–04) of the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor and is measured as a percent of GDP. Net inflows of investment are calculated from the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital, as shown in the balance of payments.

Information and communication technology expenditure (*ICTexp*) (World Bank 2008a). This indicator is a five-year average (2000–04) of information and communications technology expenditures and is measured as a percent of GDP. Expenditures include computer hardware (computers, storage devices, printers, and other peripherals); computer software (operating systems, programming tools, utilities, applications, and internal software development); computer services (information technology consulting, computer and network systems integration, Web hosting, data processing services, and other services); and communications services (voice and data communications services) and wired and wireless communications equipment.

Enabling Environment Domain

Centralization of economic policymaking (*Central*) (WEF 2007). This indicator measures the extent to which economic policymaking in the country is centralized and is measured within a range of 1 (highly centralized—national government controls almost all important decisions) to 7 (highly decentralized—states and cities have important decision rights affecting economic development).

Number of years with conflicts killing at least 1,000 people (*Conflict*) (Zhang et al. 2004). This indicator shows the number of years a country has been engaged in war killing at least 1,000 people in the 24-year period between 1970 and 2004. Thus, the variable takes a maximum value of 24 and a minimum value of 0. The data in Zhang et al. (2004) were drawn from the Centre for the Study of Civil War at the International Peace Research Institute.

Property rights index (*Property*) (Heritage Foundation 2008). This indicator measures the strength of property rights in a given country. Countries are graded between 0 and 100, where scores of 100 represent the highest level of the property rights index, scores greater than 80 represent “free,” 70–79.9 represent “mostly free,” 60–69.9 represent “moderately free,” 50–59.9 represent “mostly unfree,” and 0–49.9 represent “repressed.”

Quality of governance (*Govern*) (Kaufmann, Kraay, and Mastruzzi 2006). This indicator is calculated as a simple average of six components of governance: voice and accountability, political stability, government effectiveness, regulatory quality, rule of law, and control of corruption.

Level of corruption (*Corrupt*) (World Bank 2008a). This indicator measures the share of senior managers who ranked corruption as a major or very severe constraint in 2003. Data for Indonesia, South Africa, and Thailand are for 2004; data for Ethiopia are for 2002.

Cash crop volatility (*Volatile*) (Zhang et al. 2004). This indicator is the weighted average of the volatility of groundnuts, coffee (green), cocoa beans, cotton lint, sugar, tea, and tobacco prices weighted by their share in total value of cash crop earnings over the period 1996-2005. Volatility is the coefficient of variation and it is calculated using the export unit value. Groundnuts are defined as shelled groundnuts, groundnuts with shells, and groundnut oil. Sugar is defined as confectionary sugar, raw centrifugal sugar, syrups, and others. Tobacco is unmanufactured tobacco.

International policy regime membership index (*Ipregmmb*) (CPB 2006; ITPGRFA 2008; UPOV 2007; WTO 2008; WIPO 2008). This indicator is a composite that measures whether a given country is a member of major international policy regimes, agreements, or conventions that govern agriculture. The major regimes included in this indicator are the Convention on Biological Diversity's Cartegeña Protocol on Biosafety (CPD), the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA), the International Union for the Protection of New Varieties of Plants (UPOV), and the World Trade Organization (WTO). A score of 0 implies that the country does not belong to any international policy regimes; a score of 1 implies that the country belongs to all international policy regimes mentioned here.

External assistance to agriculture (*ODA*) (FAO 2006; World Bank 2008a). This indicator is a five-year average (1999–2003) that measures external assistance to agriculture as a percent of agricultural GDP, where both external assistance to agriculture and agricultural GDP are calculated using constant 2005 US dollars. External assistance to agriculture covers concessional and nonconcessional commitments made by bilateral and multilateral donors to developing countries and countries in transition for the development of agriculture in a broad sense, which includes land and water; research, training and extension; inputs; agricultural services; crop production; livestock; fisheries; forestry; agriculture (other, not elsewhere specified); environmental protection; rural development/infrastructure; manufacturing of inputs; regional and river development; and agro-industries.

Policy and legal framework for rural organizations (*PolicyFrame*) (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses the extent to which an enabling policy and legal environment is present for the rural poor to organize into autonomous groups, associations, or other forms of collective action. Country scores range from 1 (the lowest possible grade) to 6 (the highest possible grade).

Dialogue between government and rural organizations (*Dialogue*) (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses the extent to which the rural poor are able to enter into dialogue with government or to lobby government representatives and express their concerns and priorities with regard to issues crucial to their livelihoods. This indicator looks at whether the government is responsive to rural poor people; whether it takes into consideration their views in developing the policy, strategic, and investment framework for the sector; and whether it provides a conducive environment for such exchange. Country scores range from 1 (the lowest possible grade) to 6 (the highest possible grade).

Allocation and management of public resources for rural development (*PubRsrce*) (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses government policy, strategy, and investment programs for the agricultural and rural development sector, and on the efficiency, consistency, and transparency with which resources are allocated and managed and their use reported on. The indicator assesses if government (1) gives adequate emphasis to the sector in its planning and budgeting and has in place policies, strategies, and investment programs that are appropriate and consistent with each other; (2) has in place effective financial management systems to ensure that expenditures are consistent with the approved budget and provides timely and accurate financial reporting and auditing; and (3) allocates and makes available appropriate proportions of the sectoral budget to the different levels of government (national, state, provincial, district and below, as relevant). Country scores range from 1 (the lowest possible grade) to 6 (the highest possible grade).

Accountability, transparency, and corruption in rural areas (*Account*) (IFAD 2005). This indicator is based on grades assigned through a consultative process managed by IFAD in 2004 that assesses the extent to which, at the local level, (1) government (at both the executive level, such as the ministry of agriculture, and the legislative level, such as the district council) can be held accountable to rural poor people for its use of funds and the results of its actions; and (2) public employees and elected officials are required to account for the use of resources, administrative decisions, and results obtained. Both levels of accountability are enhanced by decentralization of authority and responsibility for public functions and by transparency in decisionmaking and disclosure of information. A high degree of accountability and transparency is likely to discourage corruption or the abuse of office for public gain. Country scores range from 1 (the lowest possible grade) to 6 (the highest possible grade).

Patent rights index (*Patents*) (Park and Wagh 2002; Ginarte and Park 1997).This indicator measures the regime strength of intellectual property rights for 2000 and includes such issues as the coverage, duration, and enforcement of patent rights, as well as membership in international treaties and protection from restrictions on patent rights.

Governance and legal institutions index (*Legal*) (Zhang et al. 2004). This indicator is a factor that captures government effectiveness, regulatory quality, rule of law, control of corruption, and protection of property rights, calculated from analysis conducted by Zhang et al. (2004).

Physical infrastructure index (*Infra*) (Zhang et al. 2004). This indicator is a factor that captures percent of total roads paved (1997-99 average) and density of roads (1995), calculated from analysis conducted by Zhang et al. (2004).

Innovation Outcomes

Agricultural total factor productivity change (*TFP*) (Coelli and Rao 2003). This indicator measures the average annual change in total factor productivity for the period 1980–2002. Calculations are based on a Malmquist index estimation of total factor productivity.

Cereal yield (*Yield*) (World Bank 2008a). This indicator is a five-year average (2001–05) of cereal yields, measured in kilograms per hectare of harvested land, including wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains. Production data on cereals refer to crops harvested for dry grain only. Cereal crops harvested for hay or harvested green for food, feed, or silage, and those used for grazing, are excluded.

Agriculture value added per worker (*AgGDPpw*) (World Bank 2008a). This indicator is a five-year average (1999–2003) of the ratio of agricultural value added, measured in constant 2000 US dollars, to the number of workers in agriculture.

Per capita agricultural production index (*Agprdind*) (FAO 2006). This indicator indexes per capita agricultural production in 2003–04 against an average for the base years 1999–2001.

APPENDIX B: TECHNICAL NOTES

This appendix details technical aspects of the ADII design, including treatment of missing values, standardization of variables, and weighting.

Missing Values

Missing values are not a trivial issue in the design of the ADII. The following countries and indicators had missing values.

Myanmar: *ICTexp*,*FDI*, and *Corrupt* from World Bank (2008a); all official development assistance (ODA) indicators from OECD (2008) and World Bank (2008a); *Patents* from Park and Wagh (2002) and Ginarte and Park (1997); all WEF (2006) data; all Zhang et al. (2004) data; and all ASTI data.

Bhutan: *ICTexp* and *Corrupt* from World Bank (2008a); all WEF (2007) data; Property from Heritage Foundation; all Zhang et al. (2004) data; and all ASTI data.

Laos: *ICTexp* and *Corrupt* from World Bank (2008a); Patents from Park and Wagh (2002) and Ginarte and Park (1997); all WEF (2007) data; and all Zhang et al. (2004) data.

Ghana: All WEF (2007) data and all ASTI data.

Thailand: All Zhang et al. (2004) data and all ASTI data.

Weighting and Principal Component Analysis (PCA)

Principal component analysis (PCA), a special form of factor analysis that serves to condense information, is employed to determine whether the use of equal weights in the calculation of the ADII is empirically warranted (see Wiesmann 2006). Given the design of the ADII (specifically, the use of four domains or subindexes to structure the composite index), we chose to employ a weighted PCA approach, as suggested by De Silva, Thattil, and Gamini (2000).

Factor analysis methods use the correlation structure of the variables (otherwise referred to as indicators in this study) or the covariance structure *(Σ)*. By using the covariance matrix, we can manually rescale variables *(X_i)* by dividing their respective standard deviations *(σ_i)*, making analysis based on covariance similar to the use of correlation. By using this rescaling method, we can also assign specified weights to the factor structure of the model. To apply a weight of ω_i to the variable X_i, we rescale the variable as

$$X_i^* = \frac{X_i}{\sigma_i \omega_i} \tag{B1}$$

and apply factor analysis to variable X_i^* instead of X_i.

When there are domains, groups, or sets of variables in the data, as is the case here, it is necessary to maintain a balance between the sets of variables in forming the factors (since the normal factor method yields factors with equal weighting for variables). In order to balance the sets we adopt the following technique. Let the variables in the k^{th} set be described as

$$x_{1k}, x_{2k}, \dots \dots \dots \dots x_{nk} \quad for\ k = 1,2, \dots \dots .p \tag{B2}$$

Let the PCA using the variables in the k^{th} set yield the Eigen value structure of the principal components (PCs):

$$\lambda_{1k} > \lambda_{1k}, \dots \dots \dots \dots > \lambda_{1k} > 0 \tag{B3}$$

The first PC has an Eigen value λ_{1k}. We use the reciprocal of the square root of this Eigen value to represent the weight ω_k for the set *k;* that is,

$$\omega_k = {}^{1}\!/\!\sqrt{\lambda_{1k}} \tag{B4}$$

We then rescale the variables to

$$X_{ik}^{-} = \frac{X_{ik}}{\sigma_i \omega_k} \quad for\ i = 1,2, \dots \dots n_k \tag{B5}$$

After rescaling all the variables (within sets), we perform factor analysis using the covariance option to apply the weights to the factors. This method can be called the "weighted PC-based factor analysis." The rescaling done in this manner will maintain the balance between the sets of variables, rather than between individual variables, thus eliminating the effect of differences on the number of variables in each set. The joint correlation effect for each set is determined by the first Eigen value of the PCA performed on each set. Since the basic grouping is done based on correlations (factor method), the first Eigen value will account for most of the correlation between variables in the set, thus increasing the efficiency of the selected model.

After the factors are derived, the next step is to identify, label, and interpret the factors. Once this is done, the factors are combined to obtain a composite index, the Agricultural Development and Innovation Index based on PCA-determined weights ($ADII^{pca}$).

$$[(ADII]^{pca})_j = \sum_{i=1}^{m} F_{ij} v_i \tag{B6}$$

i = i…….. m, the number of common factors,

j = 1 … . n, the number of variables.

Here, F_{ij} is the factor score of the i^{th} factor for the j^{th} variable, and v_i is the variance explained by the i^{th} factor in the model. The $ADII^{pca}$ is then used to rank the countries according to the innovativeness of their agriculture. An analysis based on the factors, composite index, and their rankings follows.

While employing PCA within each set or domain of the ADII, we used the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy to evaluate the model as a whole and a measure based on the values of the diagonal and off-diagonal elements of the anti-image correlation matrix to similarly evaluate the sampling adequacy of the individual variables in the model. Critical values for both the KMO and each diagonal anti-image correlation matrix element are as follows. Values greater than 0.8 are termed "commendable," values greater than 0.7 are "middling," and values greater than 0.6 are "mediocre." Values less than 0.5 require remedial action, either dropping the offending variables or including other variables related to the offending variables. Critical values for the off-diagonal elements of the matrix should be as close to zero as possible. See Wiesmann (2006) for a more detailed discussion of this evaluation method.

As a result of the PCA process, many of the original variables set forth in the equally weighted ADII (and presented earlier in this paper) were dropped due to missing values or linear interdependence among rescaled variables generated by the PCA process. And although the variables with missing values can be reinstated after mean substitution, many were found to be unsuitable for factor analysis because the values of the diagonal elements of the anti-image correlation matrix were less than 0.5. At this point, 10 variables were dropped along with five countries (Bhutan, Ghana, Laos, Myanmar, and Nepal, thus improving the KMO measure significantly. The variables for inclusion and the weights for each domain were then calculated and are as follows.

> *Knowledge and education domain*: Variables: *Sciqual, edacacess, techready, rsrchmmb, int_agrd, oda_aet, oda_agrd,* and *edsysqual*; Eigen value of the first PC = 3.26; corresponding weight = 0.55.
>
> *Bridging institutions domain*: Variables: *Uniindcoll* and *oda-ext-coop*; Eigen value of the first PC = 1.23; corresponding weight = 0.9.
>
> *Business and enterprise domain:* Variables: *innov, ruralinv, mktaccess, ruralfin, bizcost, fertlzr, machine, ictexp,* and *roads*; Eigen value of the first PC = 3.02; corresponding weight = 0.57.
>
> *Enabling environment domain*: Variables: *central, property, govern, policyfr, dialogue, pubrsrce, account, patents, ipregmmb, legal,* and *corrupt*; Eigen value of the first PC = 4.10; corresponding weight = 0.5.

Variables in each domain were then rescaled using the corresponding weights and the standard deviation of the variable, according to the formula shown in Equation B5. The rescaled variables were then pooled back to perform a factor analysis of the entire composite index. In this process, variables for which the value of the diagonal element of the anti-image correlation matrix was less than 0.5 were dropped. Ultimately, only 17 variables were suitable for factor analysis and thus retained.

Table B.1. Factor statistics

Factor	Eigenvalue	Percent of variance	Cumulative percentage
Factor 1[a]	6.3	36.8	36.8
Factor 2	2.8	16.6	53.4
Factor 3	2.5	15.0	68.4
Factor 4	1.1	4.4	72.8

Source: Authors.
Notes: [a] Four factors were extracted by factor analysis (criterion: Eigenvalue > 1).

Table B.1 shows the results of the factor analysis. Four factors explain 73 percent of the variation in the variables involved in the process. This is consistent with the conceptual framework used to describe an agricultural innovation system in this paper (see Figure 1).

Table B.2 shows that the communality (the percentage of variance of a given variable explained by the four factors retained and shown in Table B.1) of most of the variables is of an acceptably high level. However, this is not the case for three variables (*bizcosts, fertlzr,* and *ictexp*), where there is still a substantial amount of variance (more than 50 percent) that is not sufficiently explained by these four factors. The communalities also show that these four factors explain 60 to 70 percent of the variance in several other variables (*ruralinv, property,* and *pubrsce*), while they explain 75 to 95 percent of the variance for the remaining 11 variables. The factor scores in Table B.2 can be interpreted as the regression coefficients of each variable that is used to obtain the latent factors.

Table B.2. Factor score coefficient matrix

Variable	Communality	Factor 1	Factor 2	Factor 3	Factor 4	Derived Weight
Sciqual	0.785	0.082	-0.108	-0.005	0.236	0.039
int_agrd	0.755	-0.031	-0.083	0.251	0.023	0.025
Techread	0.946	0.411	0.048	0.084	-0.389	0.277
Uniindco	0.827	0.133	-0.025	-0.020	-0.041	0.071
Innov	0.940	0.411	-0.221	-0.157	0.247	0.183
Ruralinv	0.609	-0.002	0.165	-0.035	-0.078	0.032
Mktacces	0.802	-0.021	0.391	0.051	-0.385	0.086
Bizcosts	0.468	0.015	0.039	0.019	-0.038	0.024
Roads	0.809	-0.004	-0.245	0.324	0.031	0.014
Fertlzr	0.499	0.039	0.045	-0.027	-0.114	0.023
Ictexp	0.450	0.020	-0.098	0.024	-0.021	-0.011
Dialogue	0.787	-0.073	0.019	0.029	0.605	0.013
Govern	0.794	0.004	0.074	0.185	-0.039	0.071
Policyfr	0.781	-0.017	0.165	-0.081	0.283	0.039
Property	0.687	-0.006	0.008	0.128	0.050	0.037
Pubrsrce	0.640	-0.029	0.148	-0.012	0.067	0.027
Legal	0.798	-0.085	0.134	0.244	0.007	0.050

Source: Authors
Notes: Extraction method: Maximum likelihood. Rotation method: Varimax with Kaiser normalization.
Factor scores method: Regression.

Note that in Table B.2, the formula for derived weights is

$$\text{Weight of variable } x = \frac{\sum_{i=1}^{4} F_{ij} v_j}{\sum_{i=1}^{15} \sum_{i=1}^{4} F_{ij} v_j}, \tag{B7}$$

where F_{ij} is the factor score of variable X_i to factor j, and V_j is the variance explained by factor j.

In this study, the suitability of the model based on 17 variables yields a KMO measure of 0.802, which, according to the criteria discussed earlier, is “commendable” for factor analysis. Moreover, the measure of sampling adequacy for almost all of the variables is either “commendable” or “middling” based on the values of the diagonal elements of the anti-image correlation matrix, as shown in Table B.3. The low values of the off-diagonal elements of the anti-image correlation matrix also meet the criteria for sampling adequacy.

Table B.3. Anti-image correlation matrix

Variable	sciqual	int_agrd	techread	uniindco	innov	ruralinv	mktacces	bizcosts	roads	fertlzr	ictexp	dialogue	govern	policyfr	property	pubrsrce	Legal
sciqual	0.805	0.209	0.161	-0.427	-0.430	0.303	0.148	-0.174	0.040	-0.010	0.148	-0.225	0.095	0.214	-0.284	-0.154	-0.186
int_agrd	0.209	0.698	0.237	-0.163	-0.218	0.057	-0.038	0.131	-0.255	-0.122	0.074	-0.290	-0.298	0.396	-0.153	0.150	-0.373
techread	0.161	0.237	0.841	-0.291	-0.601	-0.001	-0.256	-0.055	-0.224	-0.345	-0.023	-0.065	-0.126	0.065	-0.234	0.130	-0.044
uniindco	-0.427	-0.163	-0.291	0.830	-0.177	-0.275	-0.301	-0.036	-0.162	-0.003	-0.355	-0.062	0.106	0.016	0.306	-0.061	0.183
innov	-0.430	-0.218	-0.601	-0.177	0.776	0.054	0.361	0.051	0.274	0.074	0.114	0.287	-0.177	-0.336	0.016	0.002	0.196
ruralinv	0.303	0.057	-0.001	-0.275	0.054	0.788	-0.032	-0.274	0.352	-0.111	0.157	0.024	0.118	-0.015	-0.492	-0.274	0.007
mktacces	0.148	-0.038	-0.256	-0.301	0.361	-0.032	0.784	0.024	0.242	-0.038	0.261	0.263	-0.351	-0.231	0.093	-0.100	-0.295
bizcosts	-0.174	0.131	-0.055	-0.036	0.051	-0.274	0.024	0.925	-0.239	-0.083	0.149	0.103	-0.089	-0.045	0.030	0.018	-0.076
roads	0.040	-0.255	-0.224	-0.162	0.274	0.352	0.242	-0.239	0.697	-0.025	-0.150	-0.061	-0.083	0.106	-0.223	0.197	-0.290
fertlzr	-0.010	-0.122	-0.345	-0.003	0.074	-0.111	-0.038	-0.083	-0.025	0.860	-0.116	0.183	0.117	-0.152	0.233	-0.150	0.065
Ictexp	0.148	0.074	-0.023	-0.355	0.114	0.157	0.261	0.149	-0.150	-0.116	0.800	0.003	-0.113	0.127	0.076	0.082	-0.036
Dialogue	-0.225	-0.290	-0.065	-0.062	0.287	0.024	0.263	0.103	-0.061	0.183	0.003	0.674	-0.050	-0.724	-0.014	-0.366	0.125
Govern	0.095	-0.298	-0.126	0.106	-0.177	0.118	-0.351	-0.089	-0.083	0.117	-0.113	-0.050	0.890	0.005	-0.309	-0.255	0.061
Policyfr	0.214	0.396	0.065	0.016	-0.336	-0.015	-0.231	-0.045	0.106	-0.152	0.127	-0.724	0.005	0.755	-0.042	0.161	-0.251
Property	-0.284	-0.153	-0.234	0.306	0.016	-0.492	0.093	0.030	-0.223	0.233	0.076	-0.014	-0.309	-0.042	0.815	0.207	-0.156
Pubrsrce	-0.154	0.150	0.130	-0.061	0.002	-0.274	-0.100	0.018	0.197	-0.150	0.082	-0.366	-0.255	0.161	0.207	0.816	-0.348
Legal	-0.186	-0.373	-0.044	0.183	0.196	0.007	-0.295	-0.076	-0.290	0.065	-0.036	0.125	0.061	-0.251	-0.156	-0.348	0.791

Source: Authors.

Table B.4 shows the rotated factor matrix based on a Varimax rotation of the original factors that maximizes the separation of high and low loadings of variables on each factor. This helps to explain the factor to which a variable has close affinity and also helps to better interpret the factors. The bold figures in Table B.4 denote the factor to which the variable loads highest (that is, the factor with which the variable has the highest correlation), and is hence assigned to.

Factor 1 can be described as representing the knowledge and education domain of the agricultural innovation system as many of the variables in this domain load high on the factor. Most of the variables in the knowledge and education domain whose variances are well explained in the model (as shown by high communality) load high on Factor 1. Factor 2 appears to describe the business and enterprise domain, as most variables in this domain load high on the factor. Likewise, Factor 3 can be taken to represent the enabling environment domain. Though largely consistent with our initial conceptual framework of an agricultural innovation system (Figure 1), the assignment of variables to different factors based on rotated factor loading is not exactly similar.

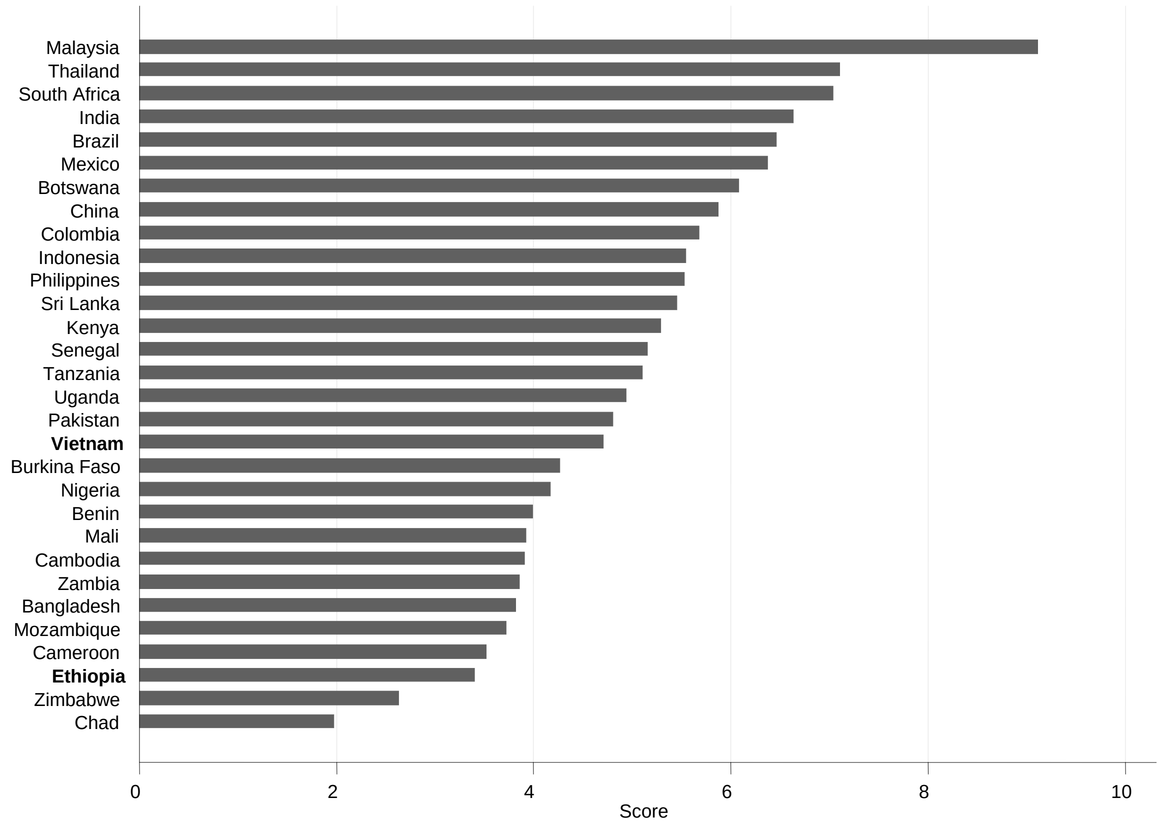
Table B.4. Rotated factor matrix[a]

Variable	Factor 1	Factor 2	Factor 3	Factor 4
Sciqual	**.818**	.039	.126	.314
int_agrd	.019	-.075	**.865**	.028
Techread	**.925**	.189	.232	.012
Uniindco	**.894**	.119	.103	.059
Innov	**.954**	.072	.024	.157
Ruralinv	.304	**.717**	-.015	.036
Mktacces	.236	**.787**	.315	-.168
Bizcosts	**.529**	.329	.282	.019
Roads	.061	-.377	**.813**	-.035
Fertlzr	**.641**	.224	-.071	-.180
Ictexp	.012	-.638	.062	-.197
Dialogue	.113	.435	.225	**.731**
Govern	.454	.349	**.677**	.085
Policyfr	.385	**.640**	-.051	.470
Property	.370	.249	**.677**	.171
Pubrsrce	.154	**.720**	.110	.292
Legal	-.069	.426	**.774**	.112

Source: Authors.
Notes: Extraction method: Maximum likelihood. Rotation method: Varimax with Kaiser normalization.
[a] Rotation converged in five iterations.

Ultimately, the PCA-weighted Agricultural Development and Innovation Index ($ADII^{pca}$) is calculated by using the average of the variables in the model according to their corresponding weight (shown in the last column of Appendix Table B.2). The resulting $ADII^{pca}$ for the countries involved is presented in Figure B1.

Figure B.1. Aggregate ADII^{pca} scores (with weightings based on principal component analysis), selected countries



Source: Authors.

Further analysis is needed to determine the composite innovation index's robustness against measurement error and moderate changes in the aggregation function such as changes in the weights of variables used in the process. To this end, we conduct an analysis of the Spearman rank correlation coefficients for the various version of the index presented in this study. The rank correlations are used to assess whether the index versions are "redundant," that is, whether the country scores for (1) the ADII^{pca} , (2) an equally weighted ADII made up of the same 17 variables (denoted ADII^{prn}), and (3) the initial ADII made up of 41 variables, which is presented in this paper. Thresholds for redundancy are as follows: a rank correlation coefficient that is not significantly less than 0.90 is considered a "Level 1" redundancy, and a rank correlation coefficient that is not significantly less than 0.70 is considered a "Level 2" redundancy (see Wiesmann 2006).

Table B.5 shows the rank correlation coefficients for these three versions of the composite index. The correlation coefficient for the ADII^{pca} and ADII^{prn} obtains a Level 1 redundancy with a value of 0.95 (significant at the 1 percent level). This suggests that the ADII^{pca} is not very sensitive to moderate changes in weighting factors. When we consider the initial ADII set forth earlier in this paper, both the ADII^{pca} and ADII^{prn} obtain a Level 2 redundancy with correlation coefficients of 0.73 and 0.79, respectively. Again, this suggests that we can reject any alternative to equal weighting. However, we do recognize that the number of countries in these indexes differs, suggesting opportunities for further analysis with a larger sample of countries.

Table B.5. Spearman's rank correlation coefficient

Index name	$ADII^{pca}$ 18 variables with PCA-determined weights	$ADII^{prn}$ 18 variables with equal weighting	ADII 41 variables with equal weighting
$ADII^{pca}$	1	0.95***	0.73***
$ADII^{prn}$	0.95***	1	0.79***
ADII	0.73***	0.79***	1

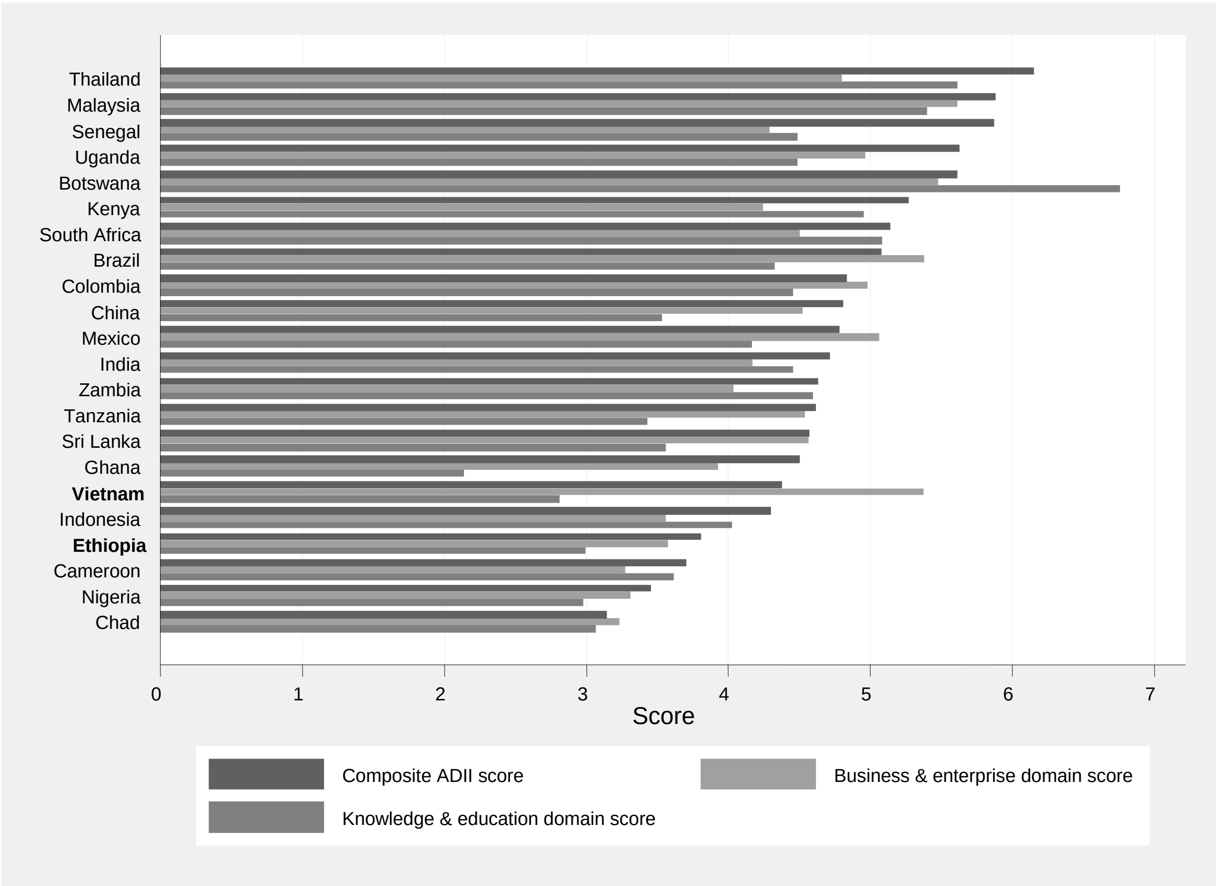
Note: *** Statistically significant at the 1 percent level.

In summary, we chose to retain the original ADII described in this paper on both technical and conceptual grounds. The technical grounds for this choice are based on the finding that a PCA-weighted version of the composite index based on 17 innovation indicators (nor an equally weighted version for the composite index, using the same set of indicators) is significantly different from the original composite index. The conceptual grounds for this choice are based on the fact that PCA simply discerns interdependence among a set of variables, and does not make inferences about relationships that are explained by the conceptual framework articulated in this paper.

APPENDIX C: ADII DOMAIN SCORES

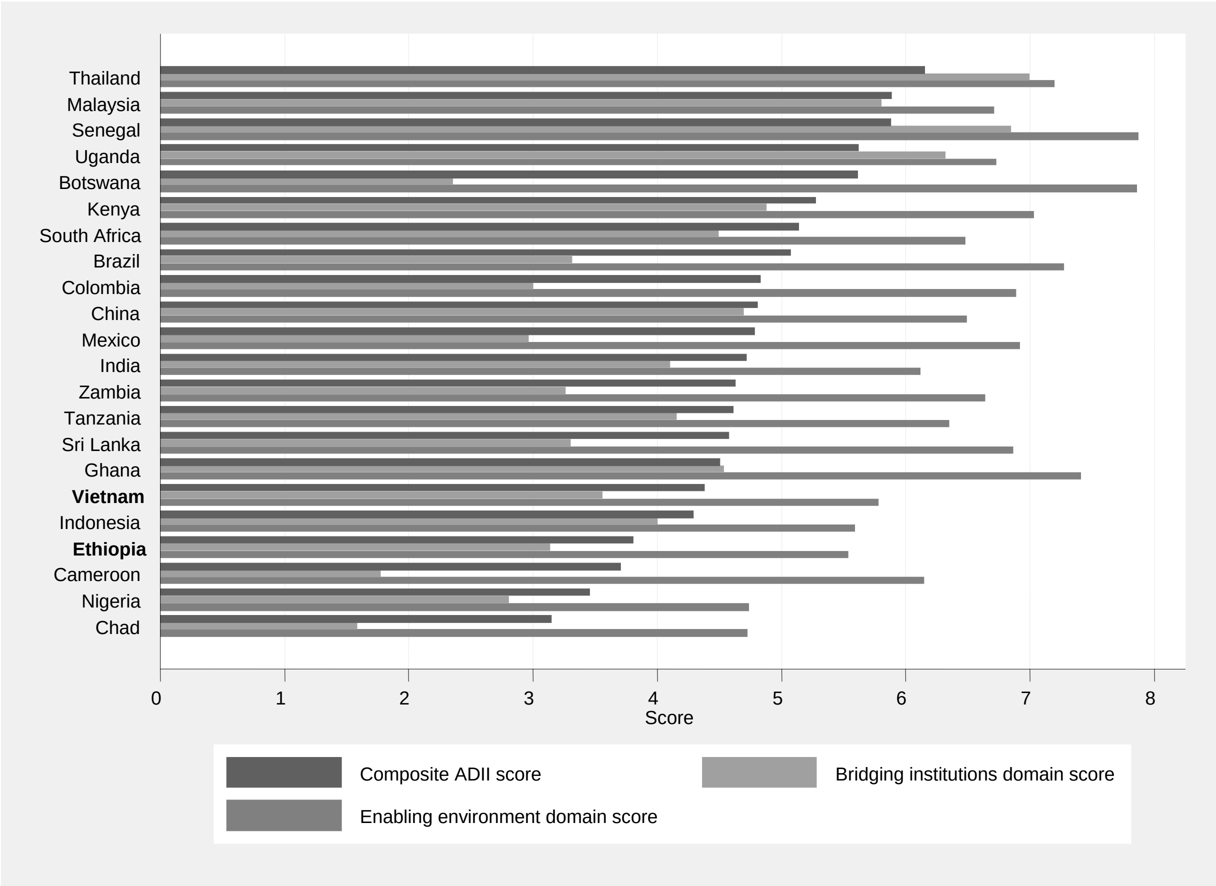
This appendix provides additional data on the Agriculture, Development, and Innovation Index (ADII) and its component subindexes or domains.

Figure C.1. ADII scores, knowledge and education domain scores, and Business and Enterprise domain scores, by country



Source: Authors.
Note: Possible scores range from 1 to 10.

Figure C.2. ADII scores, bridging institutions domain scores, and enabling environment domain scores, by country



Source: Authors.
Note: Possible scores range from 1 to 10.

Figure C.3. ADII domain scores, selected countries (radar diagrams)

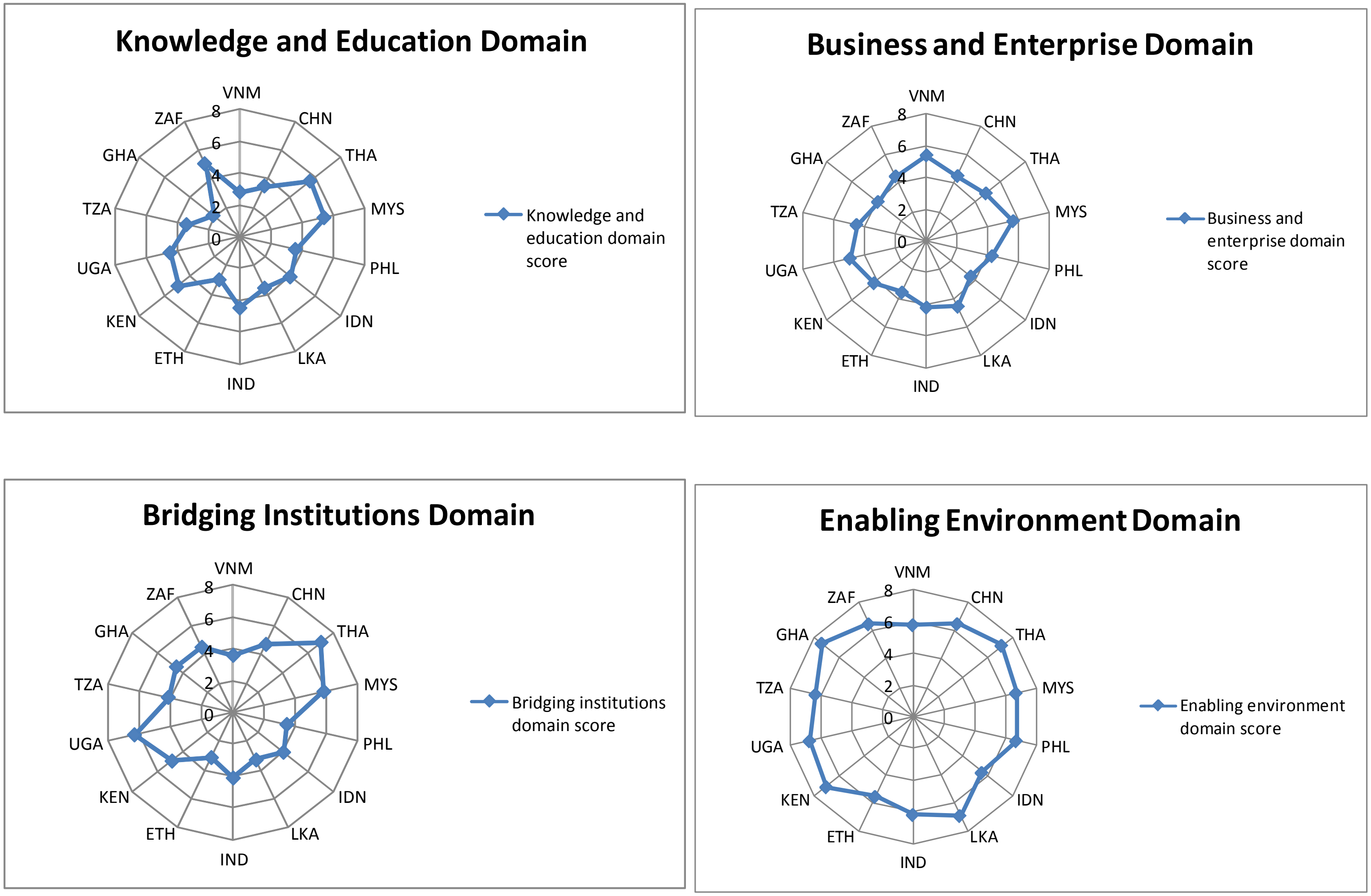


Table C.1. ADII scores and individual domain scores, by country and quintiles

Country	Country Code	Quintile	ADII Score	AgGDPpw	BI	BE	EE	KE
Thailand	THA	1	6.1507	633.5256	7.0000	4.7940	7.1994	5.6096
Malaysia	MYS	1	5.8827	5111.8194	5.8017	5.6101	6.7156	5.4035
Senegal	SEN	1	5.8756	275.3396	6.8500	4.2937	7.8747	4.4841
Uganda	UGA	1	5.6251	289.7993	6.3214	4.9601	6.7319	4.4872
Botswana	BWA	1	5.6120	512.8179	2.3500	5.4810	7.8580	6.7590
Kenya	KEN	2	5.2757	399.5257	4.8815	4.2395	7.0299	4.9518
South Africa	ZAF	2	5.1409	3166.4679	4.5006	4.5038	6.4768	5.0825
Brazil	BRA	2	5.0739	4447.4988	3.3183	5.3752	7.2745	4.3276
Burkina Faso	BFA	2	4.8497	189.7382	3.2478	4.2581	7.3912	4.5019
Cambodia	KHM	2	4.8406	343.3743	5.0952	3.6662	5.9380	4.6630
Colombia	COL	2	4.8346	3996.9119	3.0075	4.9830	6.8884	4.4594
China	CHN	2	4.8118	420.9657	4.7003	4.5250	6.4883	3.5337
Mexico	MEX	2	4.7808	3008.0131	2.9650	5.0657	6.9235	4.1688
India	IND	2	4.7152	478.4857	4.1028	4.1740	6.1222	4.4617
Zambia	ZMB	3	4.6348	538.6798	3.2644	4.0391	6.6409	4.5950
Tanzania	TZA	3	4.6184	391.2279	4.1623	4.5396	6.3454	3.4261
Sri Lanka	LKA	3	4.5754	1026.4621	3.3000	4.5696	6.8677	3.5643
Ghana	GHA	3	4.5067	936.4677	4.5410	3.9315	7.4139	2.1406
Mali	MLI	3	4.5059	267.4764	3.1704	4.1023	6.9006	3.8502
Philippines	PHL	3	4.4900	1128.7998	3.4316	4.2389	6.7325	3.5571
Pakistan	PAK	3	4.4540	824.2196	3.5014	4.6375	6.0307	3.6462
Bhutan	BTN	3	4.3889	175.3659	1.0000	5.2797	7.1362	4.1396
Vietnam	VNM	3	4.3796	333.5595	3.5574	5.3715	5.7809	2.8085
Benin	BEN	3	4.2990	643.1609	2.6957	3.8707	6.2383	4.3912
Indonesia	IDN	3	4.2966	861.3068	4.0063	3.5615	5.5899	4.0289
Lao PDR	LAO	3	4.0440	752.0116	2.4761	3.9371	5.6004	4.1624
Mozambique	MOZ	3	3.9929	261.0029	3.3451	4.2405	5.6339	2.7519
Bangladesh	BDG	3	3.9609	362.0826	2.4148	3.9181	5.5827	3.9278
Ethiopia	ETH	4	3.8119	142.6071	3.1415	3.5787	5.5374	2.9899
Nepal	NPL	4	3.7259	252.6973	2.5032	3.8410	5.3022	3.2571
Cameroon	CMR	4	3.7044	1195.9037	1.7787	3.2750	6.1432	3.6207
Nigeria	NGA	4	3.4605	1470.4197	2.8057	3.3158	4.7402	2.9803
Zimbabwe	ZWE	4	3.3934	82713.1801	1.5858	3.4181	4.6200	3.9495
Chad	TCD	5	3.1500	341.9748	1.5854	3.2313	4.7207	3.0625
Myanmar	MMR	5	2.4798	586.4631	1.6120	1.1618	3.0904	4.0550

Source: Authors.
Notes: AgGDPpw is agriculture value added per worker; BI is the bridging institutions domain; BE is the business and enterprise domain; EE is the enabling environment domain; and KE is the knowledge and education domain.

APPENDIX D: A LIST OF STANDARDIZED INDICATOR VALUES FOR ALL COUNTRIES

Table D.1. Standardized indicator values, 35-country sample

Variable	BDG	BEN	BFA	BRA	BTN	BWA	CHN	CMR	COL	ETH	GHA	IDN	IND	KEN
Rsrchmmb	10.0000	5.5000	5.5000	10.0000	1.0000	5.5000	5.5000	5.5000	10.0000	5.5000	5.5000	5.5000	10.0000	10.0000
Int_agrsrchr	2.4140	2.5287	4.6115	2.5860	…	10.0000	…	…	2.6815	1.5541	1.5732	…	…	4.1146
Int_agrd	1.3529	…	1.5176	…	…	10.0000	1.3647	…	…	1.3059	1.5059	1.1882	1.3176	3.4353
MigrRate	9.2446	8.6403	9.5468	9.5468	10.0000	9.8058	9.3525	7.1079	7.8849	6.5899	1.0000	9.8273	9.3525	4.5827
Edaccess	4.7575	3.2500	1.4500	4.7575	3.9925	7.7500	3.9925	3.2500	5.5000	2.5075	2.5750	3.9925	3.2500	5.5000
Journals	1.3459	2.9904	2.5214	3.5370	1.9294	8.6451	1.4036	2.2514	1.6576	2.2654	1.7875	1.2258	1.6105	4.5855
ODA_AET	1.0347	4.5059	10.0000	1.1315	1.0000	1.0000	1.0082	1.4138	1.0886	1.7721	1.2069	1.1228	1.1761	1.6355
ODA_Agrd	2.4007	4.3142	2.8700	1.1619	6.9157	2.3300	1.0480	1.8215	1.3626	2.0140	1.9766	1.1744	1.0870	3.1128
EdSysQual	2.8000	3.4000	2.5000	1.9000	…	5.8000	4.6000	4.0000	5.5000	3.4000	…	8.2000	7.9000	7.6000
SciQual	3.5714	3.2500	4.5357	6.7857	…	5.1786	5.8214	2.2857	4.2143	4.5357	…	8.0714	9.3571	7.7500
TechReady	2.4264	2.4604	2.9358	6.1283	…	4.2604	4.6679	2.4264	5.2453	1.9170	…	5.0075	6.1962	4.1245
KE Index	*3.9278*	*4.3912*	*4.5019*	*4.3276*	*4.1396*	*6.7590*	*3.5337*	*3.6207*	*4.4594*	*2.9899*	*2.1406*	*4.0289*	*4.4617*	*4.9518*
AgREaccess	4.6000	…	…	…	…	…	5.5000	…	…	5.5000	6.4000	6.4000	5.5000	7.3000
ODA_Ext_Coop	1.0443	2.8913	3.3956	1.1365	1.0000	1.0000	1.0010	1.6574	1.1151	1.4244	2.6820	1.0189	1.0084	1.8445
UniIndcoll	1.6000	2.5000	3.1000	5.5000	…	3.7000	7.6000	1.9000	4.9000	2.5000	…	4.6000	5.8000	5.5000
BI Index	*2.4148*	*2.6957*	*3.2478*	*3.3183*	*1.0000*	*2.3500*	*4.7003*	*1.7787*	*3.0075*	*3.1415*	*4.5410*	*4.0063*	*4.1028*	*4.8815*
RuralInvest	7.0000	7.0000	7.0000	5.8900	7.0000	7.0000	8.5000	4.0000	10.0000	7.0000	7.0000	6.2500	8.5000	7.7500
MktAccess	8.0000	7.0000	7.0000	6.5200	8.0000	9.0000	9.0000	7.0000	7.0000	6.0000	5.8000	6.0000	5.0000	6.0000
Ruralfin	7.5455	7.5455	7.5455	8.7891	7.5455	3.4545	7.5455	7.5455	5.9091	10.0000	7.5455	5.9091	6.7273	10.0000
ODA_AgFin	1.0000	1.7591	1.2309	1.0184	1.0000	1.0000	1.0000	1.0956	1.0118	1.1569	1.0006	1.0000	1.0215	1.0248
ODA_Agind	3.6646	2.7127	7.7469	1.0217	2.2218	2.6260	1.1121	1.0893	1.0249	1.0982	3.5647	1.3133	1.0743	4.0909
BizCosts	7.8522	6.1292	6.9486	9.8805	9.6967	9.8883	9.7943	6.2586	9.5595	5.6994	8.2035	7.5192	8.9664	9.0441
Roads	1.8232	2.2475	1.4820	6.9517	9.2551	10.0000	1.5965	2.7553	2.3494	1.0000	2.1516	1.8153	3.0812	2.0408
Fertlzr	3.1659	1.2129	1.0708	2.4517	…	1.1411	4.4432	1.0819	4.2781	1.1844	1.0526	2.7291	2.3631	1.3954
Machine	1.3868	1.0409	1.2567	8.8020	1.4530	10.0000	1.0352	1.0458	5.8778	1.0000	1.0034	1.0253	1.0726	1.0138
ICTexp	1.0000	…	…	3.4975	…	…	2.0044	2.1740	4.4090	…	…	1.2248	1.7590	1.3392
FDI	1.4740	2.0269	1.5093	2.6560	1.3449	2.5682	2.4791	2.0037	2.3315	3.1749	1.9929	1.0000	1.6474	1.4575
Innov	3.1048	3.9032	4.0484	7.0242	….	3.6129	5.7903	3.2500	6.0444	2.0524	…	6.9516	8.8750	5.7177
BE Index	*3.9181*	*3.8707*	*4.2581*	*5.3752*	*5.2797*	*5.4810*	*4.5250*	*3.2750*	*4.9830*	*3.5787*	*3.9315*	*3.5615*	*4.1740*	*4.2395*
Govern	3.2847	5.6899	5.8165	6.7207	7.9324	10.0000	4.9605	3.7729	5.1474	3.2666	6.8413	4.4240	6.2987	4.3938
ODA	2.4546	5.2624	8.2570	1.3497	9.4954	4.0664	1.1781	1.5910	1.1477	4.6166	5.0464	1.9816	1.2916	2.3833
Property	…	4.0000	4.0000	7.0000	…	10.0000	2.5000	4.0000	5.5000	4.0000	7.0000	4.0000	7.0000	4.7500

Table D.1.Continued

Variable	BDG	BEN	BFA	BRA	BTN	BWA	CHN	CMR	COL	ETH	GHA	IDN	IND	KEN
PolicyFrame	*7.6000*	*7.0000*	*7.0000*	*10.0000*	*7.0000*	*6.4000*	*8.8000*	*7.0000*	*7.6000*	*7.0000*	*6.4000*	*7.0000*	*8.2000*	*8.8000*
Dialogue	*4.0000*	*7.0000*	*7.0000*	*10.0000*	*6.2500*	*10.0000*	*8.5000*	*4.0000*	*4.7500*	*7.0000*	*7.0000*	*7.0000*	*6.2500*	*9.2500*
PubRsrce	*4.8571*	*6.0657*	*6.5800*	*7.2229*	*7.8657*	*7.4286*	*8.3029*	*4.0086*	*6.5800*	*10.0000*	*6.5800*	*7.4286*	*6.1429*	*6.5800*
Account	*2.3770*	*7.3934*	*8.3770*	*8.0820*	*10.0000*	*8.9180*	*9.4590*	*3.4590*	*8.9180*	*8.9180*	*8.3770*	*5.6230*	*6.2131*	*8.3770*
Patents	*6.9111*	...	...	*7.7778*	*1.0000*	*5.9778*	*6.5111*	…	*8.2000*	*3.2222*	…	*6.0444*	*5.8444*	*7.7778*
Corrupt	*3.7438*	*1.0000*	*9.7232*	*2.6861*	…	*9.3974*	*7.1937*	*9.7050*	*10.0000*	*5.8622*	…	*5.5777*	*6.0443*	*1.9020*
Ipregmmb	*7.0000*	*7.0000*	*7.0000*	*10.0000*	*4.0000*	*4.0000*	*7.0000*	*7.0000*	*10.0000*	*4.0000*	*7.0000*	*7.0000*	*7.0000*	*10.0000*
Central	*9.1818*	*4.8182*	*5.3636*	*6.4545*	*7.8182*	*7.8182*	*3.4545*	*9.1818*	*4.8182*	*4.0000*	…	*1.0000*	*3.1818*	*7.5455*
Conflict	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*1.0000*	*10.0000*	*10.0000*	*10.0000*	*10.0000*
Volatile	…	*9.6294*	*9.5765*	...	…	*8.1471*	…	*10.0000*	…	*9.1000*	*9.8941*	…	…	*9.6294*
Legal	…	*3.1600*	*3.4092*	.	…	*10.0000*	…	*4.3785*	…	*4.3508*	*5.6523*	…	…	*3.4646*
Infra	…	*4.8842*	*5.1211*	…	…	*9.9289*	…	*3.7237*	…	*3.7474*	*5.9500*	…	…	*3.3447*
EE Index	*5.5827*	*6.2383*	*7.3912*	*7.2745*	*7.1362*	*7.8580*	*6.4883*	*6.1432*	*6.8884*	*5.5374*	*7.4139*	*5.5899*	*6.1222*	*7.0299*
TFP	*6.7273*	…	*5.0909*	*6.7273*	…	…	*10.0000*	*5.9091*	*5.9091*	…	*6.8909*	*3.5364*	*6.2364*	*5.5000*
Agprdind	*6.3834*	*7.7552*	*8.7321*	*10.0000*	*3.7021*	*6.1132*	*8.9088*	*6.3002*	*7.3811*	*6.5081*	*8.3164*	*9.2621*	*6.3418*	*6.5808*
Yield	*7.0102*	*2.3261*	*2.0620*	*6.2742*	*3.2766*	*1.0000*	*10.0000*	*3.5648*	*7.0602*	*2.6726*	*2.8759*	*8.4934*	*4.8764*	*3.0762*
AgGDPpw	*1.3762*	*1.9132*	*1.0897*	*6.6536*	*1.0237*	*1.5975*	*1.4949*	*2.9742*	*6.8585*	*1.0000*	*1.4438*	*1.8793*	*1.5714*	*1.4104*
ADII	*3.9609*	*4.2990*	*4.8497*	*5.0739*	*4.3889*	*5.6120*	*4.8118*	*3.7044*	*4.8346*	*3.8119*	*4.5067*	*4.2966*	*4.7152*	*5.2757*

Table D.1.Continued

Variable	KHM	LAO	LKA	MEX	MLI	MMR	MOZ	MYS	NGA	NPL	PAK	PHL	SEN
Rsrchmmb	*5.5000*	*5.5000*	*5.5000*	*10.0000*	*5.5000*	*5.5000*	*5.5000*	*10.0000*	*10.0000*	*1.0000*	*10.0000*	*5.5000*	*5.5000*
Int_agrsrchr	*2.4331*	*2.8153*	…	*3.1975*	*4.4968*	…	…	…	*2.0127*	*4.3057*	*3.9809*	*1.0000*	*1.1338*
Int_agrd	…	*1.2118*	*1.3529*	…	*2.1412*	*1.0000*	…	*3.1882*	*1.3765*	*1.1882*	*1.2118*	*1.3882*	*2.0000*
MigrRate	*8.7914*	*7.2806*	*4.3237*	*7.1727*	*7.7770*	*9.5252*	*1.1942*	*8.0144*	*2.4676*	*9.6763*	*8.2734*	*7.0647*	*5.0576*
Edaccess	*10.0000*	*3.9925*	*5.5000*	*3.9925*	*2.1250*	*3.2500*	*1.7425*	*7.7500*	*2.5750*	*2.5075*	*2.3500*	*7.0075*	*1.0000*
Journals	*1.2572*	*1.5144*	*2.3439*	*3.4035*	*1.6796*	…	*1.7916*	*2.1748*	*1.4499*	*1.8753*	*1.0000*	*1.6431*	*3.7871*
ODA_AET	*2.3375*	*7.0039*	*2.5353*	*1.0078*	*1.9926*	*1.0000*	*5.0265*	*1.0550*	*1.0263*	*3.2324*	*1.0000*	*1.1968*	*7.5784*
ODA_Agrd	*3.5845*	*3.9806*	*1.1587*	*1.1762*	*6.1392*	…	*1.8082*	*1.0458*	*1.0148*	*2.4285*	*1.0000*	*1.4137*	*10.0000*
EdSysQual	*3.4000*	…	*5.8000*	*3.4000*	*2.8000*	…	*2.2000*	*10.0000*	*4.9000*	*3.1000*	*4.0000*	*5.8000*	*4.3000*
SciQual	*1.9643*	…	*6.7857*	*5.1786*	*4.2143*	…	*2.9286*	*10.0000*	*5.5000*	*3.2500*	*4.8571*	*4.2143*	*5.5000*
TechReady	*2.9358*	…	*3.9887*	*6.1623*	*2.3245*	…	*1.9509*	*10.0000*	*3.7170*	*2.3585*	*3.6491*	*5.5170*	…
KE Index	*4.6630*	*4.1624*	*3.5643*	*4.1688*	*3.8502*	*4.0550*	*2.7519*	*5.4035*	*2.9803*	*3.2571*	*3.6462*	*3.5571*	*4.4841*
AgREaccess	*3.7000*	*3.7000*	*2.8000*	…	…	*1.6120*	…	*6.4000*	…	*4.6000*	*4.6000*	*4.6000*	…
ODA_Ext_Coop	*8.1856*	*1.2522*	*1.0000*	*1.0301*	*3.8407*	…	*3.5903*	*1.0052*	*1.0115*	*1.0097*	*1.0042*	*1.0947*	*10.0000*
UniIndcoll	*3.4000*	…	*6.1000*	*4.9000*	*2.5000*	…	*3.1000*	*10.0000*	*4.6000*	*1.9000*	*4.9000*	*4.6000*	*3.7000*
BI Index	*5.0952*	*2.4761*	*3.3000*	*2.9650*	*3.1704*	*1.6120*	*3.3451*	*5.8017*	*2.8057*	*2.5032*	*3.5014*	*3.4316*	*6.8500*
RuralInvest	*7.0000*	*4.7500*	*8.5000*	*9.2500*	*6.1000*	*1.0000*	*7.0000*	*7.9900*	*6.2500*	*7.7500*	*7.0000*	*7.0000*	*7.0000*
MktAccess	*8.0000*	*8.0000*	*7.0000*	*10.0000*	*7.0000*	*1.0000*	*7.0000*	*10.0000*	*4.2000*	*8.0000*	*6.0000*	*7.0000*	*6.2000*
Ruralfin	*7.5455*	*5.9091*	*5.9091*	*6.7273*	*7.5455*	*1.0000*	*6.7273*	*7.5455*	*5.0909*	*5.9091*	*6.7273*	*9.1818*	*5.9091*
ODA_AgFin	*1.1481*	*1.0620*	*1.7029*	*1.0000*	*5.7712*	…	*2.0804*	*1.0000*	*1.0000*	*1.6677*	*1.0000*	*1.0325*	*1.0354*
ODA_Agind	*5.0447*	*1.0801*	*2.4361*	*1.0113*	*2.1569*	…	*5.2099*	*1.5233*	*1.0344*	*1.3961*	*1.0000*	*1.1418*	*10.0000*
BizCosts	*1.0000*	*9.7434*	*9.8918*	*9.7745*	*6.0097*	…	*8.0027*	*9.6196*	*8.2962*	*8.5577*	*9.4683*	*9.6811*	*7.6952*
Roads	*2.5277*	*4.2860*	*3.9845*	*2.8619*	*1.6386*	*1.0471*	*1.7215*	*2.6780*	*1.6814*	*1.0766*	*1.7989*	*2.3104*	*1.4762*
Fertlzr	*1.0116*	*1.1014*	*4.6785*	*1.9273*	*1.1079*	*1.1892*	*1.0364*	*10.0000*	*1.0671*	*1.4867*	*2.7220*	*2.6502*	*1.1660*
Machine	*1.3580*	*1.6681*	*1.0579*	*8.4075*	*1.3126*	*1.5808*	*1.7968*	*1.1338*	*1.5817*	*2.3498*	*9.4541*	*1.0098*	*1.1579*
ICTexp	…	…	*2.6586*	*1.4165*	…	…	…	*3.4654*	*1.9368*	...	*3.4160*	*2.7185*	*3.8740*
FDI	*2.4432*	*1.7705*	*1.7334*	*2.4408*	*2.7975*	*1.3157*	*3.5104*	*2.3655*	*2.4046*	*1.3522*	*1.5999*	*1.7858*	*1.7169*
Innov	*3.2500*	...	*5.2823*	*5.9718*	*3.6855*	…	*2.5605*	*10.0000*	*5.2460*	*2.7056*	*5.4637*	*5.3548*	…
BE Index	*3.6662*	*3.9371*	*4.5696*	*5.0657*	*4.1023*	*1.1618*	*4.2405*	*5.6101*	*3.3158*	*3.8410*	*4.6375*	*4.2389*	*4.2937*
Govern	*3.8754*	*3.1882*	*5.5874*	*6.6604*	*6.4977*	*1.0000*	*5.5814*	*8.4749*	*2.7904*	*3.0074*	*3.4715*	*5.6236*	*6.5760*
ODA	*6.6034*	*5.5400*	*4.1270*	*2.0398*	*8.0686*	…	*10.0000*	*1.0000*	*1.3064*	*4.6929*	*1.6860*	*3.5442*	*8.1444*
Property	*4.0000*	*1.0000*	*7.0000*	*7.0000*	*4.0000*	*1.0000*	*4.0000*	*7.0000*	*4.0000*	*4.0000*	*4.0000*	*4.0000*	*7.0000*

Table D.1. Continued

Variable	KHM	LAO	LKA	MEX	MLI	MMR	MOZ	MYS	NGA	NPL	PAK	PHL	SEN
PolicyFrame	*7.0000*	*5.8000*	*7.0000*	*6.7000*	*7.0000*	*1.0000*	*5.8000*	*9.2500*	*5.2000*	*5.2000*	*8.2000*	*8.8000*	*8.5000*
Dialogue	*7.0000*	*7.0000*	*7.0000*	*7.0000*	*7.0000*	*1.0000*	*5.5000*	*7.9900*	*6.4000*	*4.0000*	*7.7500*	*8.5000*	*10.0000*
PubRsrce	*6.1429*	*6.5800*	*6.5800*	*7.8657*	*5.8086*	*2.7229*	*8.3029*	*7.8657*	*4.5229*	*5.7314*	*7.0171*	*5.7314*	*6.5800*
Account	*6.2131*	*7.2951*	*8.3770*	*8.9180*	*8.3770*	*1.0000*	*7.2951*	*3.4590*	*4.4426*	*6.7541*	*7.8361*	*7.8361*	*7.1475*
Patents	…	…	*9.0000*	*7.3556*	…	…	*1.0000*	…	…	…	*5.4222*	…	*7.4444*
Corrupt	*4.0289*	…	*8.3772*	*8.2702*	*4.7583*	…	…	*8.6503*	…	…	*5.7130*	*6.2947*	*5.8266*
Ipregmmb	*7.0000*	*4.0000*	*4.0000*	*7.0000*	*7.0000*	*7.0000*	*4.0000*	*7.0000*	*7.0000*	*1.0000*	*4.0000*	*7.0000*	*7.0000*
Central	*3.4545*	…	*5.3636*	*4.2727*	*5.0909*	…	*5.6364*	*3.1818*	*5.9091*	*8.6364*	*7.2727*	*6.7273*	*8.3636*
Conflict	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*10.0000*	*4.8571*	*10.0000*	*9.5714*	*10.0000*	*10.0000*	*10.0000*	*10.0000*
Volatile	…	…	…	…	*9.2059*	…	…	…	*1.0000*	…	…	…	*9.7882*
Legal	…	…	…	…	*2.6615*	…	*4.5169*	…	*1.5538*	…	…	…	*5.5969*
Infra	…	…	…	…	*3.0368*	…	*3.4158*	…	*6.5895*	…	…	…	*6.7079*
EE Index	*5.9380*	*5.6004*	*6.8677*	*6.9235*	*6.9006*	*3.0904*	*5.6339*	*6.7156*	*4.7402*	*5.3022*	*6.0307*	*6.7325*	*7.8747*
TFP	*10.0000*	*7.5455*	*5.2545*	*6.7273*	*3.4545*	*6.7273*	*6.7273*	*5.4182*	*8.3636*	*5.9091*	*6.7273*	*5.7455*	*6.7273*
Agprdind	*7.0173*	*7.2875*	*6.0612*	*6.7679*	*7.0797*	*9.4596*	*6.5185*	*8.1917*	*5.4065*	*7.0589*	*6.1651*	*7.8383*	*1.8418*
Yield	*4.2015*	*6.3770*	*6.9358*	*5.8605*	*1.9067*	*6.7891*	*1.9144*	*6.5966*	*2.2446*	*4.5976*	*4.8369*	*5.7982*	*1.9579*
AgGDPpw	*1.3631*	*1.6943*	*2.3053*	*5.2782*	*1.2135*	*1.2143*	*1.0622*	*10.0000*	*2.2026*	*1.1792*	*2.0110*	*2.7928*	*1.2644*
ADII	*4.8406*	*4.0440*	*4.5754*	*4.7808*	*4.5059*	*2.4798*	*3.9929*	*5.8827*	*3.4605*	*3.7259*	*4.4540*	*4.4900*	*5.8756*

Table D.1. Continued

Variable	TCD	THA	TZA	UGA	VNM	ZAF	ZMB	ZWE
Rsrchmmb	5.5000	10.0000	5.5000	10.0000	5.5000	10.0000	5.5000	5.5000
Int_agrsrchr	…	…	2.4713	1.3631	2.1059	2.5096	3.5605	…
Int_agrd	…	…	1.2588	1.4118	1.1020	4.4353	1.5765	…
MigrRate	8.7698	9.7842	6.8489	5.5971	1.8417	9.0935	8.1007	8.6187
Edaccess	2.1250	3.9925	4.7575	7.7500	5.5000	3.9925	4.7575	1.0000
Journals	1.0706	2.1807	2.0477	3.5220	1.4456	10.0000	2.1784	2.8041
ODA_AET	1.0622	1.0000	1.2465	3.3474	2.9094	1.2605	8.8169	1.3697
ODA_Agrd	1.9102	…	2.7038	2.7933	2.3719	1.6515	1.3641	1.3541
EdSysQual	1.0000	6.7000	4.0000	4.6000	2.5000	2.8000	5.5000	7.0000
SciQual	1.0000	6.4643	6.1429	6.7857	3.8929	8.0714	3.5714	4.5357
TechReady	1.0000	6.7057	3.9887	3.3094	3.9208	6.8755	3.3094	2.6642
KE Index	3.0625	5.6096	3.4261	4.4872	2.8085	5.0825	4.5950	3.9495
AgREaccess	…	6.4000	6.4000	10.0000	5.5000	3.7000	…	…
ODA_Ext_Coop	2.1708	…	1.1870	4.0643	1.1721	1.9017	3.7287	1.5858
UniIndcoll	1.0000	7.6000	4.9000	4.9000	4.0000	7.9000	2.8000	…
BI Index	1.5854	7.0000	4.1623	6.3214	3.5574	4.5006	3.2644	1.5858
RuralInvest	5.5000	10.0000	7.0000	7.0000	7.0000	5.5000	7.0000	2.5000
MktAccess	3.0000	9.6800	8.0000	9.0000	8.0000	8.0000	7.0000	2.0000
Ruralfin	5.9091	6.4655	10.0000	10.0000	6.7273	3.4545	6.7273	2.6364
ODA_AgFin	1.0000	1.0000	1.9311	1.0001	10.0000	1.0257	1.0000	1.0000
ODA_Agind	1.0258	…	5.3038	9.2635	2.4500	3.3162	1.0416	1.0394
BizCosts	2.6013	9.9901	6.2494	7.3304	9.1544	10.0000	9.4542	4.2918
Roads	3.0707	1.2886	2.0757	2.4005	2.4745	6.0638	5.9780	5.6267
Fertlzr	1.0484	2.3524	1.0451	1.0000	5.1922	1.6948	1.0855	1.6212
Machine	1.0259	1.0787	1.0092	1.0036	1.1388	1.0253	1.6435	5.2141
ICTexp	…	1.6609	…	…	…	4.0815	…	10.0000
FDI	10.0000	1.9757	2.4741	2.4054	2.7193	1.9156	2.5002	1.3665
Innov	1.3629	7.2419	4.8468	4.1573	4.2298	7.9677	1.0000	3.7218
BE Index	3.2313	4.7940	4.5396	4.9601	5.3715	4.5038	4.0391	3.4181
Govern	2.7180	7.1005	5.3403	4.5988	4.9424	8.7401	4.9967	1.2411
ODA	6.9444	1.6478	3.1178	6.5354	1.6838	1.1866	7.8274	2.5982
Property	2.5000	7.0000	4.0000	4.0000	1.0000	7.0000	5.5000	1.0000

Variable	TCD	THA	TZA	UGA	VNM	ZAF	ZMB	ZWE
PolicyFrame	4.0000	10.0000	8.8000	8.2000	7.0000	4.6000	5.8000	2.2000
Dialogue	4.0000	6.2500	7.7500	9.2500	4.7500	2.5000	5.5000	1.7500
PubRsrce	4.0086	7.0171	6.5800	7.8657	7.4286	5.7314	4.8571	1.0000
Account	3.4590	10.0000	7.8361	9.4590	9.4590	6.2131	4.5410	2.3770
Patents	7.7778	5.9778	…	…	…	10.0000	...	8.2000
Corrupt	***…***	***8.2179***	***4.4852***	***5.9533***	***…***	***8.4682***	***5.0777***	***…***
Ipregmmb	7.0000	7.0000	4.0000	7.0000	7.0000	7.0000	7.0000	7.0000
Central	8.0909	6.1818	4.8182	4.5455	4.5455	6.1818	8.9091	10.0000
Conflict	1.4286	10.0000	10.0000	4.8571	10.0000	7.0000	10.0000	8.2857
Volatile	…	…	9.4176	8.5176	…	9.5765	9.6824	9.7882
Legal	3.1600	…	5.0708	5.7077	…	5.2923	5.2646	1.0000
Infra	1.2842	…	1.0000	2.5158	…	4.8605	2.8000	10.0000
EE Index	4.7207	7.1994	6.3454	6.7319	5.7809	6.4768	6.6409	4.6200
TFP	1.0000	4.6818	5.3364	4.8455	7.0545	8.1182	…	5.9091
Agprdind	6.1963	7.1420	6.2171	5.5208	9.4492	7.0485	6.3522	1.0000
Yield	1.5283	5.5497	3.1127	3.4554	9.0897	5.6625	3.1909	1.6209
AgGDPpw	1.2051	1.9199	1.3194	1.2155	1.3377	5.5606	1.1863	1.3101
ADII	3.1500	6.1507	4.6184	5.6251	4.3796	5.1409	4.6348	3.3934

APPENDIX E: INFLUENCE NETWORK MAPPING: AN APPLICATION TO ETHIOPIA

Although poultry production in Ethiopia represents just a fraction of the country's total agricultural output, it is a traditional component of livelihoods for many rural households and, typically, for the women in these households. As such, the transformation of Ethiopia's poultry sector from small-scale subsistence production to more commercial production levels can potentially contribute to the country's efforts to promote economic growth, agricultural development, and poverty reduction.

There is evidence to suggest that several poultry clusters are emerging in Ethiopia where rapid innovation is occurring in the application of new production technologies, organizational structure, and marketing strategies, all of which may expand the sector's potential contribution to growth, development, and poverty reduction. This brief study provides a descriptive analysis of the poultry sector in Ethiopia, with specific emphasis on the role of innovation in promoting the growth and development of poultry enterprises among small-scale, resource-poor farmers in the country.

To do so, the study examines both the wider poultry sector in Ethiopia and a specific poultry innovation cluster. The aim of this activity is twofold: (1) to analyze innovation processes and systems in developing-country agriculture and (2) to demonstrate the utility of a new field research method (Net-Map). Focus is specifically placed on the small-scale commercial production systems because of their relative importance to poverty reduction and rural livelihood improvement.

Net-Map was used with two sets of individuals in April 2008. The first exercise, held in Addis Ababa, was conducted with an international expert in poultry genetics. The exercise provided a descriptive analysis of the key characteristics and interactions in Ethiopia's poultry sector at the national level. The second exercise was conducted primarily with the manager of a farmers' cooperative involved in a poultry development project, with input from several other cooperative members and two public-sector researchers involved in the project. This exercise was held near the project's coverage area, approximately 125 kilometers from Addis Ababa, in an area referred to as the poultry innovation cluster in the Debre Zeit-Mojo corridor of the Addis Ababa market shed. Background interviews were also conducted with two farmers (one male, one female) participating in the project on their farms in the cluster area.

In each exercise, participants were first asked to list all the actors that they believed to be important to promoting or facilitating farmer innovation in the poultry sector, including actors from the private sector, the public sector, nongovernmental organizations (NGOs), civil society organizations (CSOs), cooperatives, farmer organizations, and others. The interview team wrote down the names of actors on different colored pieces of paper to denote different categories of actors (public, private, and other nongovernment actors, such as NGOs, CSOs, cooperatives, and farmers' organizations). These actor cards were distributed on a large empty sheet of paper.

Second, participants were asked to identify the important linkages existing among the different actors in the network. Linkages were categorized according to the flow of (1) production inputs and equipment (embodied knowledge), (2) knowledge and information (disembodied knowledge), (3) credit and financial services, (4) regulatory oversight, and (5) coordination and cooperation. These linkages were then drawn between the actor cards, with a different color used to denote each type of linkage and arrows to indicate the direction of the linkage.

Third, participants were asked to evaluate the level of influence that each actor has in promoting or facilitating farmer innovation in the poultry sector. Participants were asked to build "towers" of round disks, with higher towers denoting relatively greater influence of a given actor. The size of each tower was chosen by the interviewee, with no limit on height. Each tower was placed on top of the corresponding actor card on the map, giving the exercise a three-dimensional visualization.

Fourth, the participants were asked to rate whether each actor's influence on farmer innovation processes was positive or negative. Their assessment of each actor's influence was based on a scale of five possible responses: greatly positive (++), somewhat positive (+), neutral (0), somewhat negative (-), or greatly negative (—). Each assessment rating was written beside the actor on the map.

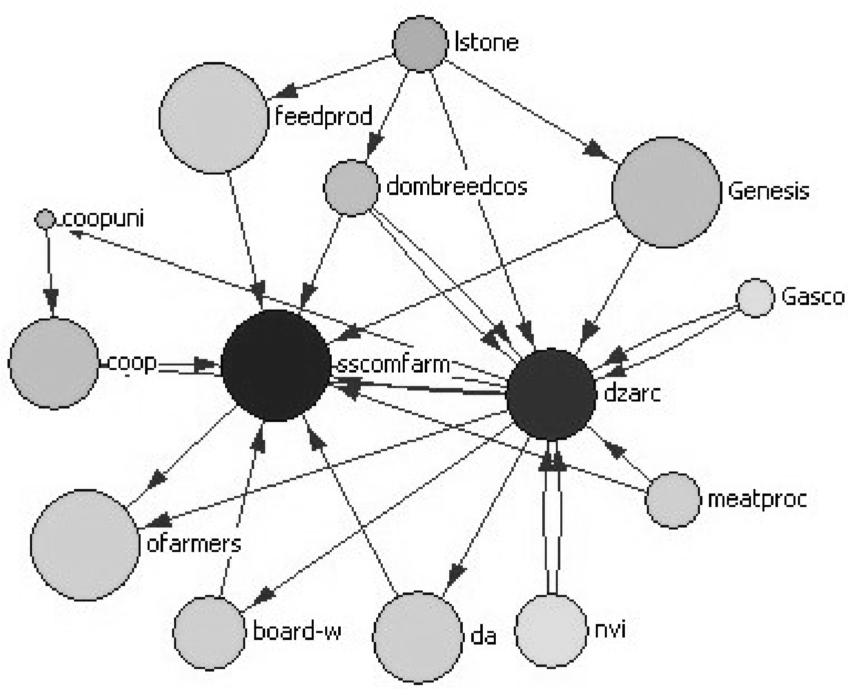
Fifth, the participants were asked to reflect on the information presented in the resulting map and to comment on the major constraints, challenges, and opportunities in the poultry sector. These discussions built on information revealed during interactions between the participants and interviewers during the previous four steps. However, this fifth step also allowed participants to modify the map and their responses by drawing on both the visualization, with the purpose of increasing the accuracy and validity of their own analysis.

Finally, the qualitative and quantitative data generated through the net-mapping exercise were used for social network and descriptive analyses to characterize innovation processes in the poultry sector among small-scale farmers.

Findings demonstrated how the innovation potential of poultry production systems in Ethiopia were realized through a combination of the platform-building efforts of the public research system, production capabilities of the private sector, and collective action among farmers. More specifically, the innovation process was driven by a combination of the network-based transmission of both embodied knowledge (new technologies embodied in the hybrid/exotic poultry breeds and new production inputs), and disembodied knowledge (production techniques, collaboration procedures between the public and private sector, market information). An illustration of these relationships is provided in Figure E1.

The model's viability and replicability in other parts of the country depends acutely on the identification of specific actors that can support these knowledge flows. The model's viability and replicability also depend on better identification of the market dynamics such as demand growth, competition, and price volatility. This suggests that the promotion of similar poultry innovation clusters needs to be driven not only by new technologies and production techniques, but also by the calculus of effective supply responses to market opportunities by small-scale commercial poultry farmers.

Figure E.1. The poultry innovation cluster in the Debre Zeit-Mojo corridor



Notes: *board-w* is the *woreda* (district) Bureau of Agriculture and Rural Development; *coop* is farmers' cooperative; *coopuni* is cooperative union; *csscomfarm* is small-scale commercial farmers; *da* is development agent; *dombreedcos* is domestic breeding companies; *dzarc* is the Debre Zeit Agricultural Research Center; *feedprod* is feed producers; *Gasco* is Gasco private limited company (PLC); *Genesis* is Genesis Farms, a PLC; *lstone* is limestone suppliers; *meatproc* is meat and bone meal processors; and *nvi* is the national veterinary institute; *ofarmers* isother small-scale commercial farmers.

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