LITERATURE REVIEW

SCALING AGRICULTURAL TECHNOLOGIES AND INNOVATION DIFFUSION

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SCALING AGRICULTURAL TECHNOLOGIES AND INNOVATION DIFFUSION

Management Systems International
Corporate Offices
200 12th Street, South
Arlington, VA 22202 USA
Tel: + 1 703 979 7100

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E3 Analytics and Evaluation Project

Prepared by:

Marco Johnson (dTS)

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ACRONYMS AND ABBREVIATIONS

ADOPT	Adoption and Diffusion Outcome Prediction Tool
BDM	Bass diffusion model
BFS	Bureau of Food Security (USAID)
bST	Bovine Somatotropin
CA	Conservation agriculture
dTS	Development & Training Services
E3	Bureau for Economic Growth, Education and Environment (USAID)
FTF	Feed the Future
MNC	Multi-national corporation
MPI	Markets, Partnerships and Innovations Office (of USAID/BFS)
MSI	Management Systems International
PA	Precision agriculture
PICS	Purdue Improved Cowpea Storage
PPP	Public-private partnerships
USAID	United States Agency for International Development
VAS	Value Added Services
ZOI	Zone of Influence

EXECUTIVE SUMMARY

Introduction

USAID's Bureau for Food Security (USAID/BFS) commissioned this literature review to identify evidence or evidence gaps on innovation diffusion and the related field of market strategy for scaling up new technologies, particularly in the context of agriculture markets in relevant developing countries. The review is expected to inform the design of future BFS programming related to the scaling of agricultural innovations. The review draws on a range of documents but is not intended to be a comprehensive search of all materials relating to these topics.

The first part of this review provides an overview of innovation diffusion modeling and the primary models associated with that field of study, along with a definition of relevant terms. Part II discusses the relevant findings based on a review of literature, organized into six sub-sections. The third and final part summarizes the most relevant topics and conclusions derived from the findings that are of relevance for BFS.

Finding 1: Diffusion Models – Commonalities, Limitations and Criticism

Diffusion of innovations theory is the most widely-accepted categorization of how innovative technologies and ideas spread through cultures and markets. Innovations are incrementally adopted in order to trigger a takeoff point when it rapidly reaches mass adoption and becomes self-sustaining. Innovation diffusion models help estimate the potential for adoption of a technology as well as the speed with which it will be adopted.

Theoretical diffusion models seek to explain or predict the diffusion and adoption of innovations. Influential case studies and diffusion frameworks were developed in the second half of the twentieth century as a result of agricultural gains. These "classical" works, furthered in large part by Everett Rogers and Frank Bass, laid the groundwork for diffusion theory and instigated a decades-long period of diffusion modeling. The Bass Diffusion Model (BDM) is often the starting point for experts who propose modifications. Over time, the classical frameworks were expanded upon and modified based on evolving socio-economic and academic trends. Beyond academia, managers and marketing professionals use diffusion innovation models as an integral part of product life cycle design, while extension agents use the models as a foundation for their outreach methods. Criticism of innovation diffusion theory has often been leveled directly at Rogers and his contributions. In recognition of these criticisms, he proposes solutions such as working directly with smaller farmers and involving them in the design and development of technologies that are appropriate for their circumstances.

Finding 2: Practical *Ex Ante* Model Useful for Development Context

While countless models of the adoption and diffusion of innovations exist, designing, calculating and interpreting results remains inaccessible for many people. Nevertheless, the need for estimates on the rate and timing of adoption are increasingly in demand by technology promoters. The Adoption and Diffusion Outcome Prediction Tool (ADOPT) was created as a solution to this problem, and has three primary functions: (1) predicting an innovation's likely peak extent of adoption and likely time for reaching that peak, (2) encouraging users to consider the influence of a structured set of factors affecting adoption, and (3) engaging research, development and extension managers and practitioners by making adoptability knowledge and considerations more transparent and understandable.

Finding 3: Factors Affecting Adoption and Diffusion of Innovations

It is vital to understand the characteristics of adopters (how, how often and when they adopt) as well as the innovation itself to be able to more accurately estimate an innovation's time to takeoff. Equally important is to consider the technologies that were not adopted. Rogers, corroborated by numerous other researchers in the innovation diffusion literature, has identified five attributes most likely to affect the speed and extent of the adoption and diffusion process: relative advantage, compatibility, complexity, trialability and observability. An estimated two-thirds of innovations released globally fail to reach scale. Diffusion studies have identified other major constraints involving factors such as a lack of credit, limited access to information, aversion to risk, inadequate farm size, inadequate incentives associated with farm tenure arrangements, insufficient human capital, absence of equipment to relieve labor shortages, chaotic supply of complementary inputs and inadequate infrastructure.

Finding 4: Adapting to Local Conditions & Immature Technology

Quick and widespread adoption of an innovation is facilitated when the technology or service is properly adjusted to local tastes, needs and preferences. Input and feedback is often required from a variety of stakeholders, including farmers, engineers, scientists, manufacturers and marketing specialists. Case studies reveal the importance of large, well-funded research institutions with the mandate to facilitate changes to the benefit of farmers and others in the agricultural sector. Innovations designed to be bundled and used together must be equally accessible, understandable and affordable. Some technologies meant to be out-of-the-box may undergo multiple iterations before appropriately conforming to the needs and preferences of farmers. Immature technologies – those not properly adapted to the market – are unlikely to be adopted. Studies show that farmers prefer having the flexibility to purchase components independently rather than being forced to buy bundle packages of technologies.

Finding 5: Product Takeoff

Product takeoff occurs when a critical mass of innovators combined with early adopters become powerful enough to affect the majority of the potential market. Predicting the takeoff point for an innovation is key to facilitating its adoption and diffusion within a market. The early market stage of an innovative product is characterized by initial slow growth immediately after commercialization followed by a sharp increase in sales, which indicates the takeoff phase. Takeoff times tend to be shorter in developed countries and longer in middle-income and developing countries. The average penetration potential for developing countries is about one-third that for developed countries, while it takes developing countries on average 17.9 percent longer to achieve peak sales.

Finding 6: Developing Country Market Entry

Market entry is a critically-important facet of the business development cycle. Due to the limited number of commercially-scaled product launches in developing countries, firms will need to maintain flexibility and be willing to depart from predetermined marketing strategies. This theme of trial and error is common in the literature concerning market entry in developing countries. The Agri VAS Toolkit features best practices based on past experience and offers practical advice on marketing information and communications technologies to smallholders in developing countries. Its marketing tools resemble those used in developed markets but consider the preferences of consumers and smallholders in developing countries. Finally, the success of mobile money provider M-PESA in Kenya, and later in other countries, is largely due to the company's ability to offer a range of financial products and services that are in high demand among many who do not engage in the traditional financial sector. M-PESA's success lies in its ability to listen to and understand the evolving needs of their customer base.

INTRODUCTION

Background

Scaling up access to and adoption of agricultural technologies and innovations that impact nutrition, stunting and wasting rates in developing countries is a critical component of ongoing efforts by the United States Agency for International Development (USAID) and other donor agencies to eradicate poverty. The U.S. government's Feed the Future (FTF) initiative, which is being implemented by USAID in 19 countries, has emphasized the role of the private sector in achieving these goals, and USAID's FTF programming recognizes the importance of scaling pathways via commercialization through the private sector in addition to strategic partnerships with the public sector and civil society.

A key challenge for efforts to take new technologies to scale is to estimate the potential market demand of such innovations and determine the portion of a population that represents the early majority adopters, after which take-off may occur. This information is essential to estimating USAID program targets, investments/costs, direct and indirect beneficiaries, and impact monitoring and evaluation.

To inform these efforts, USAID's Bureau of Food Security (USAID/BFS) commissioned this literature review to identify evidence or evidence gaps on innovation diffusion and the related field of market strategy for scaling up new technologies. The review focuses on the literature in the marketing and technology diffusion field related to how innovations scale up through forms of diffusion and places it in the context of agriculture markets relevant to development in select countries. The review was conducted over a period of three weeks and examined a range of documents relevant to scaling innovations via commercial pathways, including as many agriculture-specific sources as possible. While most of the literature included lacked specific metrics that would be applicable to future programming, the last section of this review does provide some initial conclusions relevant for BFS as it continues to promote the successful scaling of these technologies.

Purpose and Audience of the Literature Review

The purpose of this literature review is to identify and synthesize existing research, literature and evidence or evidence gaps on innovation diffusion and the related market strategy field, as well as assess its possible application to agricultural development including BFS' future programming. Findings from the literature review are expected to inform upcoming project design activities in BFS relating to the rapid scaling of agricultural technologies using commercial pathways.

The primary audience for this review is USAID/BFS staff involved in the scaling of agricultural innovations (including the Markets, Partnerships and Innovations Office [BFS/MPI]). Additional potential audiences for this study may include overseas Mission staff in the FTF Zones of Influence (ZOIs), and other units within the Agency examining scaling such as the Bureau for Economic Growth, Education and Environment (E3) and the Global Development Lab.

Methodology

The literature review drew on a range of documents, including academic articles, professional studies, working papers, discussion papers, book chapters, books case studies and relevant grey literature. The review was not intended to be a comprehensive search of all materials relating to the topics, but instead was based upon a selection of documents that were expected to be helpful for BFS in formulating its strategy on scaling agricultural innovations in FTF countries and elsewhere.

The following search terms were used to identify materials for potential inclusion in this review:

- Market entry
- Marketing
- Market penetration
- Technology diffusion models
- Takeoff
- Agriculture
- Adoption
- Immature technology
- Metrics
- Product life cycles
- Scale
- Scalable innovations
- Sustainability
- Farmers
- Information communication technologies (ICT)
- Pioneer advantage
- Forecasting
- Middle-income
- Developing countries

The criteria used for selecting documents to be examined in the review included whether the document addressed issues relating to scaling agricultural innovations as well as more generally on the topic of product marketing. This review was not intended to comprehensively investigate the range of literature relating to innovation diffusion.

Annex A provides an annotated bibliography (in alphabetical order) of the literature that was used in this review including a summary description of the source. References to this literature are made throughout in the text.

Organization of the Literature Review

The findings from the literature review are organized into six sub-sections. **Finding 1** discusses the most influential models in the wide-ranging adoption and diffusion universe and which models have been successfully deployed in the agricultural context, as well as advantages, disadvantages and extensions of the models. **Finding 2** identifies a diffusion model designed for ease of use and simplicity, allowing results (peak adoption level and time to peak adoption) to be inputted and generated by experts and laypersons alike. **Finding 3** details the necessary components in the diffusion of innovations, including characteristics of innovations and innovators. **Finding 4** is a mostly theoretical discussion on innovation takeoff points, due to a lack of empirical research in the literature. **Finding 5** synthesizes perspectives on adapting agricultural products to local contexts and discusses immature technologies. **Finding 6** explores market entry approaches and provides examples of successful marketing strategies in middle-income and developing countries.

The **Conclusions** section of this review revisits the major themes from each of the findings sub-sections and poses questions left unanswered by the literature for further follow-up and discussion by those working to scale access to, and adoption of, agriculture technologies in developing countries.

Definitions of Relevant Terms

- **Adoption**: a process involving an *individual* that includes the series of stages one undergoes from first hearing about a product to finally accepting or using it; also, the moment at which the decision maker acts to make the spread of the technology happen.
- **Bass Diffusion Model (BDM):** describes the process of how new products get adopted in a population; classifies adopters as innovators or imitators, where the speed and timing of adoption depends on their degree of innovativeness and the degree of imitation among adopters.
- **Commercialization:** the diffusion pathway by which a value chain is sufficiently resourced and organized to bring an innovation or product to a market (typically a mass market).
- **Communication channels**: means by which messages are spread, including via mass media, interpersonal channels and electronic communications.
- **Diffusion**: the process by which an innovation penetrates markets over time within a group driven by social influences, which include all interdependencies among consumers that affect various market players – with or without their explicit knowledge (Peres et al, 2009).
- **Diffusion modeling**: the process of understanding the spread of innovations throughout their life cycle.
- **Innovation**: any thought, behavior or thing that is new because it is qualitatively different from existing forms (Jones, 1967).
- **Institutionalization:** incorporation of the program into the routines of an organization or broader policy and legislation.
- **Maturity:** the period from a product's slowdown until sales begin a steady decline.
- **Peak sales:** the point at which sales of a product reach their highest rate before plateauing or declining.
- **Rate of adoption**: the relative speed with which members of a social system adopt an innovation. It is usually measured by the length of time required for a certain percentage of the members of a social system to adopt an innovation.
- **S-curve (aka logistic curve)**: innovations typically diffuse over time in a pattern that resembles an S-shaped curve, indicating that an innovation goes through a period of slow, gradual growth before experiencing a period of relatively dramatic and rapid growth.
- **Saddle**: a sudden, sustained and deep drop in sales of a new product after a period of rapid growth following takeoff, followed by a gradual recovery to the former peak.
- **Scale**: having a significant impact on its goals at the population level. The FTF definition adds "in the target ZOI in each country."
- **Slowdown:** the point of transition from the growth stage to the maturity stage of the product life cycle. The slowdown signals the beginning of a period of level, slowly increasing or temporarily decreasing product category sales.
- **Social system:** the combination of external influences (mass media, organizational or governmental mandates) and internal influences (strong and weak social relationships, distance from opinion leaders). There are many roles in a social system, and their combination represents the total influences on a potential adopter.
- **Sustainability**: the degree to which an innovation or program of change is continued after initial resources are expended.
- **Take-off point (aka critical mass or tipping point)**: the time at which a rapid increase in sales occurs that distinguishes the cutoff point between the introduction and growth stage of the product lifecycle.

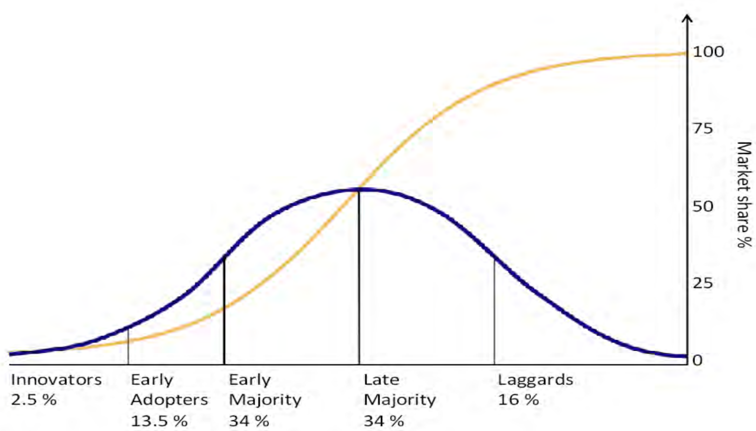
DIFFUSION MODELS

Classical Models: Rogers and Bass

Diffusion modeling is at the core of efforts to scale agricultural technologies. Once diffusion models and their application in successfully scaled commercial examples are understood, they may be adapted and applied to developing country contexts. Diffusion research seeks to understand the spread of innovations by modeling their entire life cycle from the perspective of communications and consumer interactions (Peres at al., 2010). The diffusion of innovations theory posits that an innovation is communicated through certain channels over time among the members of a social system. The two seminal diffusion theories that underlie most research on the topic were pioneered by Everett Rogers and Frank Bass, and together are referred to as the "classical" diffusion models. Rogers' model can only be applied after adoption is complete; it has no predictive capability. By contrast, the Bass model estimates the probability that adoption will occur in response to exposure to the innovation (*external influence*) and the social interaction effect (*internal influence*), which is then applied to the total that have adopted by some point in time (Wright, 2011).

Figure 1 represents the diffusion of innovations according to Rogers. With successive groups of consumers adopting the new technology (shown in blue), its market share (yellow) will eventually reach the saturation level. The blue bell curve is known as the diffusion curve and indicates adoption categories; the yellow S-shaped curve is known as the logistic function and is broken into sections of adopters. Early work by Rogers on the adoption and diffusion of innovations focused on farmers and identified various categories of technology adopters including innovators, early adopters, the early majority, the late majority and laggards, with the percent of adopters indicated at each phase. Understanding the S-curve is imperative to diffusion modeling.

FIGURE 1: DIFFUSION OF INNOVATIONS AS DESCRIBED BY ROGERS



Lowenberg-DeBoer (1998) describes three phases generally associated with technology adoption:

1. Innovators who try out a new technology while it is still unknown and untested
2. Rapid adoption when the profitability and other aspects of the new technology are well known
3. The plateau when most of those who will use the technology have adopted it

Lowenberg-DeBoer then identifies the factors that influence the speed of adoption and thus the shape of the S-curve:

- **Age**: younger farmers are generally more quick to adopt innovations
- **Education**: higher levels of education are correlated with technology adoption, in large part due to the greater likelihood of access to information and inherent understanding of the benefits of technologies
- **Risk aversion/risk bearing utility**: risk takers and those who have a financial margin of error are more likely to be innovators
- **Adjustment costs (aka switching cost)**: the costs associated with changing from the current technology to a new one
- **Learning curve**: the length of time it takes to learn how to effectively use the technology
- **Peer pressure**: this can act for or against the decision to adopt, depending on whether a society or group thinks new technology adoption is a status symbol, or whether there is pressure to preserve traditional ways

The early market success of consumer and industrial product innovation is generally characterized by an initial period of slow growth immediately after commercialization followed by a sharp increase (Rogers, 2003). For most new products, the takeoff point is clear since it corresponds to the first large increase in sales. According to Rogers (1995), the rate of adoption – the speed with which new ideas and innovations are embraced by individuals and groups – is to a major extent predicated on five factors: (1) relative advantage, (2) compatibility, (3) level of competency, (4) trialability, and (5) observability. The various stages in the multistep diffusion process include innovation development, dissemination, adoption, implementation, maintenance, sustainability and institutionalization.

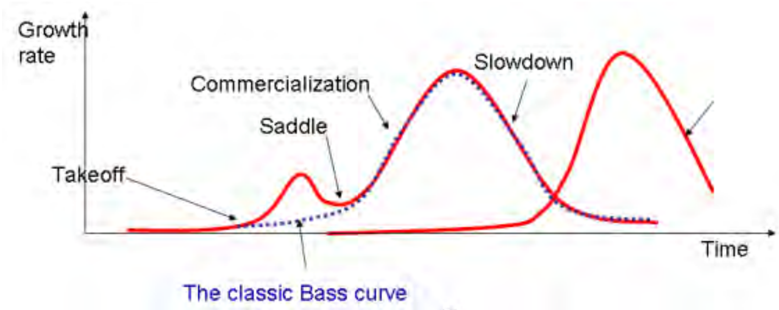
Extensions of the Classical Models

The advent of the Internet and proliferation of social media, combined with macro-level factors such as globalization and increased competition, have instigated widely-adopted extensions of the classical models beyond those that explore scenarios of a single market monopoly of durable goods in a homogenous, fully-connected social system. The nature of diffusion processes in a world of increasingly powerful technology and greater access to information by consumers requires broadening the scope to include more sophisticated social interactions among adopters.

Some of the most influential expansions of the classical diffusion models involve product life cycles, by examining points in product life cycles that are not accounted for in Rogers' "smooth-adoption" curve. As reflected in Figure 2, these extensions account for three notable modifications:

- **Product takeoff**: the typical Bass model indicates spontaneous adoption from an initial group but does not account for how adoption takes place. Takeoff studies explore market behavior around this initial stage of adoption.
- **Saddle**: updated diffusion models also account for a saddle in which an initial peak precedes a trough of substantial depth and duration, followed by increased sales that eventually exceed the initial peak (Peres et al, 2008).
- **Technological substitution**: classical models foresee termination of the diffusion process as a technology reaches market saturation. In reality, new products enter the market (introduced either by the pioneering company or imitators) that offer adaptations and varying price points, which introduce additional S-curves.

FIGURE 2: TURNING POINTS IN THE PRODUCT LIFE CYCLE



Defining Adoption and Diffusion

Understanding the meaning of “adoption” and “diffusion” is important for measuring success. The literature provides few conclusive definitions of these terms. Rogers (1962) defined adoption as "the mental process an individual passes from first hearing about an innovation to final adoption." This definition is a starting point but is incomplete. Feder et al (1985) provided definitions that are applicable to any technology. They insist that, for rigorous theoretical and empirical analysis, a precise quantitative definition of adoption is needed. Such a definition must distinguish between individual (farm-level) adoption and aggregate adoption.

- Final adoption at the level of the individual farmer is defined as the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential.
- The diffusion process is defined as the spreading of a new technology within a region.

Scandizzo and Savastano (2010, p.7) noted that, according to Rogers, diffusion is characterized by three stages, culminating in adoption. According to their interpretation, adoption is part of the decision-making process, “i.e., not only is it merely a component of diffusion, but it also characterizes the moment at which the decision maker acts to make the spread of technology happen.” They go on to clarify that adoption and diffusion are two related processes referring to collective spread and individual choice. Their study uses the adoption and diffusion of genetically modified crops in the U.S. to illustrate distinctive characteristics in adoption-diffusion stages.

According to Spielman et al (2009), an innovation can have an important socioeconomic impact only when it is part of a *sustained process* involving many actors with different capabilities and resources. Innovators may try new things, but few of these yield practices that improve what is already in use. Thus, adoption involves incorporating a trial element into a long and complex process by many actors.

FINDINGS

Finding 1: Diffusion Models – Commonalities, Limitations and Criticism

Diffusion models have practical application for businesses, academics and extension agents. Seed companies and artificial insemination labs must estimate whether there is demand for a new technology, project sales, consider market penetration and determine price points before launch in order to develop a marketing strategy. Academics and development practitioners use diffusion models to study the effects that socio-economic variables have on market dynamics. Stephenson (2003) relates that innovation diffusion theory is the foundation of extension agriculture outreach methods.

This review considered various models that consider adoption and diffusion generally as well as in the agricultural context. While these models may be helpful in analyzing past events or predicting future ones, there are still limitations to what they can do. This section outlines some of these limitations, as well as identified adaptations and solutions. Finally, this section summarizes wide-ranging criticism of diffusion theory, including assertions of bias against smallholder farmers. Annex B provides tables from Peres et al (2009) that condense the vast subject of adoption and diffusion models by summarizing the more notable subjects of study (research trends, turning points in product life cycles and multi-national takeoff models) and prominent researchers.

While several theories (e.g., the two-step hypothesis, the trickle-down effect, technology-driven models) attempt to explain the mechanics of diffusion, the diffusion of innovations theory (largely credited to Rogers) is the dominant model for analyzing diffusion in the agricultural context. The theory predicts that an innovation will initially be adopted by a small group of innovative farmers and then later diffused to other farmers. The importance of diffusion models to predict adoption behavior (*ex ante*) and account for past performance (*ex post*) is important both for understanding past behavior and applying lessons learned as well as generating useful information and guidelines for decision makers. The models can be applied to predict penetration potential, innovation takeoff point, timeline for diffusion, etc.

Under Rogers' larger construct, a variety of models exist that are used to explain adoption and diffusion. One of the best known is Bass Diffusion Model (BDM; Bass, 1969), which is classified as a penetration model.[1] Together, Rogers' and Bass' contributions are referred to as the "classical" diffusion model. The BDM has been broadly used as a predictive (*ex ante*) model of the product diffusion process in marketing. The BDM assumes that the social network into which it diffuses is fully connected and homogenous (Peres et al, 2010), the market potential of new products/innovations remains constant over time, the nature of the innovation does not change, the diffusion of new innovations is independent of other innovations, and the diffusion process is not influenced by marketing/promotion strategies such as changing product prices or changes in advertisements (Mahajan et al., 1990). Meade and Islam (2006) indicated that the primary applications of diffusion models are for consumer durables and telecommunications, although as discussed later, applications for agricultural are plentiful.

There are important differences to keep in mind between diffusion models and adoption models. In general, diffusion models describe the behavior of adopters in aggregate and have limited capacity to explain technical change, because they only describe successful innovations *ex post* and fail to describe innovations that failed in the market. Furthermore, they cannot explain why some users adopt an innovation more quickly than others. Adoption models, on the other hand, model the time of adoption of an individual (firm, farm, entity) depending on firm and innovation characteristics. The diffusion curve is then calculated by aggregating all the dates of adoption.

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[1] Other models include: trial/repeat, deterministic and stochastic.

Applications

The BDM can be applied in a variety of ways. Pratt (2008) applies the BDM to earnings of firms that introduced innovative products. His results show that earnings streams often grow slowly, then accelerate rapidly, and finally plateau at a constant rate; as such, the BDM is useful in describing them. Estimating future earnings using the BDM may assist entrepreneurs and early stage investors in estimating the future value of their investments and in timing their exit strategies.

Zepeda (1990) explains that diffusion modeling is useful for predicting adoption rates before a new technology is available. Results permit the identification of potential gainers and losers, which can allow for anticipation of policy implications.

Bivariate probit models, which employ a joint model for two possible binary outcomes and produce a probability of adoption accounting for the two binary variables, are prevalent throughout literature on innovation adoption. These types of models use qualitative data based on interviews with identified innovators and adopters, and work best when innovations are close to commercialization and are already known to farmers. For example, a binary probit model could measure farmers' decisions on whether to use marketing contracts *and* whether to use environmental contracts. One of the most noteworthy and influential examples of this model was a series of studies by numerous academics and extension agents to test hypotheses on factors influencing the adoption of bovine somatotropin (bST) into the U.S. dairy industry (see for example Stephanides and Tauer, 1998 and Zepeda, 1990). The studies compare probabilities of bST adoption for different individuals and to make predictions of adoption. Based on analysis from surveys of dairy farmers in California, Zepeda's model (which segregated subjects into five adopter categories) predicted that potential adoption of bST would be 44 percent of potential users. Actual results show that adoption peaked at 30 percent before declining to 18 percent by 2008,[2] far below expectations predicted by the model (An and Butler, 2009). Not only did the actual adoption of bST not meet expectations, but many early adopters ultimately eschewed the technology for a variety of reasons that were not considered in *ex ante* models, such as fluctuations in the market price of milk and feed. This example illustrates that predictive modeling can be useful for identifying trends, but that users should have solid survey data taken from the population of target adopters.

Limitations and Model Extensions

Academic works on technology diffusion are plentiful and generate a wide variety of approaches and conclusions. However, there is no consensus among theorists and academics on approaches or even definitions.[3] In their 2006 review of the modeling and diffusion literature, Meade and Islam establish that most post-1970 models (after Rogers and Bass) were modifications and expansions of the classical approaches. Their source review identified the primary categories of these modifications as "the introduction of marketing variables in the parameterization of the models; generalizing the models to consider innovations at different stages of diffusions in different countries; and generalizing the models to consider the diffusion of successive generations of technology."

Rogers' S-curve is a simplified construct that helps describe technology diffusion *ex post*, but rarely describes the actual detailed process in practice, regardless of the context in which it is applied. For example, the adoption of hybrid corn in the U.S. was famously explained by the S-curve (Grilliches, 1957), but it was actually more complicated and lumpy than the smooth S-curve indicated in graphical

[2] The model failed to account for factors that ultimately affected adoption, such as increased management requirements and an overestimation of increased yields and farmer profitability (see Gillespie et al., 2010, for further discussion).
[3] The meanings of "adoption" and "diffusion" generate different definitions depending on the author (see Rogers, 2003 and Peres, Muller and Mahajan, 2010).

form – particularly because the speed of adoption varied by state, with Corn Belt states adopting more quickly than southern states (Lowenberger-DeBoer, 1998). The same general limitation will hold true regardless of geographic location or technology, and Rogers' diffusion model has been widely criticized for supposing that all probable adopters are homogeneous (Tidd and Bessant, 2009).

Mahajan et al explain that the BDM recognizes two sources of technological innovations: internal and external. In the agricultural context, the adoption of innovations through external factors is initiated by factors outside the farming community, for instance by extension agents or mass media promotion, while internal factors stem from inter-personal communication between farmers. Farmers adopting an innovation through external factors are sometimes referred to as (real) innovators, while those adopting through internal factors are described as imitators. However, the BDM's distinction between adoption through external or internal factors may not reflect the reality of how farmers decide to adopt or reject an innovation. In response to this, Peres et al (2010) relate that recent contributions to diffusion modeling literature have re-examined this interpretation in order to identify and discuss all types of social interactions, namely by taking into account network externalities and social signals.

One major challenge identified by Peres et al (2009) in diffusion modeling is revolutionizing the approach to data and sources of information. The vast majority of data used for modeling is aggregate (mostly annual), category-level sales or usage data of durable goods in Western countries. Less emphasis has historically been placed on collecting data from middle-income and developing countries. A 2002 study by Talukdar et al attempted to rectify this by capturing the diffusion of 6 products in 31 developed and developing countries across Europe, Asia and North and South America – including China, India, Brazil and Thailand – representing 60 percent of the world's population. The authors identify gaps in the literature on adoption patterns in the developing world, since it is difficult to locate examples of quick adoption and high diffusion rates of agricultural technologies released through commercial pathways in developing countries. Several studies exist on the adoption and diffusion of agricultural technologies in developing countries, but these focus on examples of innovations supported by governments and/or development initiatives.

In his 2004 study, Albers analyzes numerous models for forecasting the diffusion of an innovation prior to launch and proposes a solution for durable goods,[4] which includes many agricultural technologies that have utility over time (such as machinery and other long-use inputs, but not seeds or fertilizer). His model and its accessibility were widely referenced in the reviewed literature that focused on *ex ante* adoption models, and its strength lies in its consolidation of lessons learned from previous models. In order to implement forecasting, companies depend on subjective judgment based on available information of analogous products. This works because the diffusion of nearly all innovations follows the S-curve. However, often there is no direct analogous product to reference, so he proposes to combine several semi-analogous products to a weighted average.

Since the coefficients of the BDM depend on each other and cannot be combined independently, Albers describes the diffusion curve by the period in which sales peak and the ratio of sales in the peak period to cumulative sales. For simplicity's sake, he assumes that penetration in the peak period is 50 percent (although this can be altered if more is known about the penetration of similar technologies during the peak period). It has been shown that this method reproduces the respective diffusion curves of 34 products (mostly white and brown goods, but he does include hybrid corn) accurately up to the peak period. His findings also imply that predictions should focus on diffusion up to the peak period, since the rest is of minor importance to companies.

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[4] A durable good is defined as one that yields utility over time rather than being completely consumed in one use.

In spite of much recent research to consider new ideas to diffusion theory, few research questions have been fully resolved. For example, Meade and Islam (2006) point out that while there is some convergence of ideas on the most appropriate way to include marketing mix-variables into the BDM, there are several viable alternative models. They predict that the future direction of research is likely to include forecasting new product diffusion with little or no data, forecasting with multinational models and forecasting with multi-generation models.

Criticism

Despite its strengths and strong appeal, the BDM suffers from several limitations. Ruttan (1996) reported on criticism of classical diffusion theory that began to surface when the theory was applied to international development. In each updated version of his book, Diffusions of Innovations, Rogers addresses such criticisms and acknowledges that these critiques come to the fore earlier, it may have been possible to correct these shortcomings. Rogers (1995) concedes four major themes of critique:

1. **Pro-innovation bias**: the implication that innovation should be adopted by all farmers; the act of adopting is considered positive while the act of rejecting is considered negative
2. **Individual-blame bias**: the development agency is not blamed for its lack of response to the needs of farmers; instead, individuals who do not adopt the innovation are blamed for their lack of response
3. **Issue of equality**: what negative effects could diffusion of the innovation bring about (i.e. unemployment, migration of rural people, equitable distribution of incomes)
4. **Bias in favor of larger and wealthier farmers**: The assistance provided by development agencies tends to focus on their innovative, wealthy, educated, and information-seeking clients, leading to less equality[5]

Stephenson's article details changes that Rogers (1995) has developed in the application of diffusion theory in order to address these types of criticisms:

1. Tailor communications to all categories of farmers in order to promote awareness and information.
2. Involve less financially-advantaged farms in developing technologies and practices that are appropriate for their farm and financial scale. A good strategy is to form organizations such as cooperatives to enhance access to financial resources. Furthermore, Brown (1981) recommends that in order to be successful, change programs should have a financial support infrastructure for farmers.
3. Be aware that the shift in focus from working with wealthy innovative farmers to working with less financially-advantaged farmers may require some fundamental changes, as these farmers "tend to place less credibility in professional change agents, and they seldom actively search for information from them".

Finding 2: Practical *Ex Ante* Model Useful for Development Context

An abundance of literature discusses the adoption and diffusion of agricultural innovations, yet few sources seek to simplify this knowledge into a construct that is accessible to decision makers who wish

[5] Stephenson (2003) provides an example that illustrates the critique that diffusion theory favors large wealthy farmers and increases the inequities in rural areas. He cites a 1972 case study by Jim Hightower that focused on the tomato industry in California. A project developed a mechanical tomato harvester and the breeding of a tomato that could be mechanically harvested. The tomato harvester was large and expensive, and its purchase was limited to large farmers who had the necessary financial means. Ultimately, several years after its release, 600 large growers controlled tomato production where previously there had been 4,000. Furthermore, the machines displaced thousands of U.S. farm workers.

to generate quantitative predictions across a wide array of agricultural contexts. Although adoption and diffusion are very difficult to forecast, owing to complex economic, social and psychological disciplinary boundaries, there is an ongoing demand for estimates to be made. Based on this need for a tool that can not only predict adoption and diffusion outcomes but also inform users about influences on those outcomes and engage them in the actual modeling process, the Adoption and Diffusion Outcome Prediction Tool (ADOPT) was created.

Created by Kuehne et al (2011), ADOPT was designed for three primary functions: (1) predict an innovation's likely peak extent of adoption and likely time for reaching that peak, (2) encourage users to consider the influence of a structured set of factors affecting adoption, and (3) engage research, development and extension managers and practitioners by making adoptability knowledge and considerations more transparent and understandable. The tool is structured around four aspects of adoption: (1) characteristics of the innovation, (2) characteristics of the population, (3) actual advantage of using the innovation, and (4) learning of the actual advantage of the innovation. The tool does not claim to be a panacea or generate extremely accurate predictions, but rather is intended to create a framework for making reasonable estimates and provide a usable framework for analyzing an inherently complex subject.[6]

Annex C shows the ADOPT conceptual framework in graphic form. The tool aims to operationalize a framework that is based on well-established adoption theory and literature (Feder & Umali, 1993; Lindner, 1987; Pannell, et al., 2006; Rogers, 2003). Using a standardized Excel spreadsheet for data collection, users input values from pull-down lists, which are used in calculations that predict the interaction among included variables. Calculations programmed by the creators take into account the strength, direction and nature of influence of the variables. The output of the tool is a value in years for Time to Peak Adoption and a percentage value for Peak Adoption Level. The tool also graphically calculates the expected performance in an S-curve format.

The advantages of this tool, beyond its simplicity and usability, are that it will work in any location and with any agricultural innovation. However, it has the disadvantages of not being able to alter the influence of the variables as well as the relative newness of the tool since it has received limited real-world testing. Three examples were identified in the literature of ADOPT being used, including one that was referenced in the study itself. ADOPT was created in Australia and it remains to be seen whether the tool will be useful outside of that country as intended.

Finding 3: Factors Affecting Adoption and Diffusion of Innovations

Understanding the characteristics of both innovations and adopters is critical to understanding and forecasting diffusion. Rogers describes five key attributes, widely adopted in diffusion-related literature, that determine the speed and extent to which an innovation is adopted. These attributes are outlined in this section and considered in detail as part of a case study involving mechanical cassava graters in Africa.

Factors in Successful Diffusion of Innovation

The 2009 report from the Meridian Institute on the transfer of technologies to smallholder farmers points out that it is difficult to locate consensus on what comprises "innovation success" in the literature. Rogers and other experts (Wenjert, 2002; Scandizzo and Savasanto, 2010) comprehensively reviewed the attributes of innovations that are most likely to affect the speed and extent of the adoption and diffusion process, and determined five core attributes:

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[6] In order to simplify the model and support accuracy, two variables – age and education – were not included. Age commonly appears in adoption studies but shows inconsistent results. Education was excluded because of variances in education levels and presents challenges in the data collection process.

1. **Relative advantage**: whether the innovation is better than what was previously available
2. **Compatibility**: whether the innovation fits with the intended audience
3. **Complexity**: whether the innovation is easy to use
4. **Trialability**: whether the innovation can be tried before making a decision to adopt
5. **Observability**: whether the results of the innovation are visible and easily measurable

The Meridian report goes on to describe some noteworthy innovations in the context of sub-Saharan Africa, both in the commercial and development program contexts. Holding other factors constant (such as relative advantage or cost), these technologies are less complex and easily observable commodity-based object innovations that are targeted for relatively simple application. Examples include the Purdue Improved Cowpea Storage (PICS) bags in Western Africa (Moussa et al., 2009), the cassava grater in West Africa, tissue culture banana in East Africa and milk pasteurization across the continent.

Price (or profitability) is another important factor for adoption. One of the rationales used is that a lower price places the product within the budgetary limitations of a greater number of buyers, thus increasing the market potential (Mahajan & Peterson, 1978). Thus, a beneficial price of an innovation compared to the product it supersedes (part of the relative advantage attribute) is also identified as the dominant economic determinant of adoption.

The Meridian report describes the case of Tropical Manioc Selection, an improved variety of cassava in West Africa, as an example of an innovation in a developing country context that demonstrates the five characteristics for innovation success. Traditionally, *gari* (processed cassava) was made with a mortar and pestle; later, artisans developed a hand grater that made the process slightly more efficient but required an increase in labor. In the 1930s, the French introduced a mechanical grater that was modified over time by farmers. The adoption of the mechanical grinder was slow at first; by 1969, it had been adopted by approximately 25 percent of villages in Nigeria involved with cassava production. However, by 2009 mechanical graters of one variety or another could be found in virtually all cassava-producing villages in Nigeria and throughout west and central Africa. In terms of each of the five attributes:

- **Relative advantage**: replacement of hand grating with the mechanized grater cut the cost of gari production in half; 51 days of labor were needed to prepare a ton of *gari* by hand versus 24 days by mechanized grater. In terms of price, the mechanical grater was available in many forms; farmers could purchase an off-the-shelf unit or buy individual components and construct one. It is also important to note that while the proliferation of different types of mechanical graters on the market drove prices down over time, the key to its success was its simplistic nature, which made even early-generation machines cost effective.
- **Compatibility**: the simplicity of the mechanical grater meant that there was only a small switching cost involved, but it produced results equal to or better than hand graters at a lower cost and in less time.
- **Complexity**: mechanized graters are simple and easily compatible with local knowledge in terms of design, repair and maintenance. Graters can also take on many different forms and be purchased off-the-shelf or improvised by farmers.
- **Trialability**: due to the low technical demands of the grater, interested adopters did not require special training to operate them, enabling easy access to trials in shops or by a neighbor.
- **Observability**: results of the mechanical grater are immediate.

Explaining the Decision of Whether and When to Adopt

One of the foundations of understanding adoption and diffusion is explaining the timing of when someone adopts an innovation, as well as whether and why they decide to adopt at all. An innovation may have superior characteristics to a previous technology, but use must translate into economic benefits – which are dependent upon the adopter's structural characteristics. For farmers, these differences include farm size, market share, market structure, input prices, labor relations, firm ownership and current technology. Farm size and market share are the two variables that appear most often in the diffusion models (Diederen et al., 2003; Feder et al., 1985; Scandizzo and Savastano, 2010) and the usual hypotheses are that large (but not the largest) farms with substantial (but not too much) market power are the most innovative (Diederen et al 2003). However, it should be noted that other studies point out a negative relationship between farm size and technology adoption, mostly due to farmers' risk aversion and their tendency to follow a technological ladder in adoption (Scandizzo and Savastano, 2010).

Categorizing adopters is not as straightforward as presented in Rogers' diffusion (bell) curve. His model identifies innovators as the first 2.5 percent of adopters, early adopters as the next 13.5 percent, the early majority as the next 34 percent, the late majority as 34 percent and finally laggards as the remaining 16 percent. Yet it is also important to account for the non-adopters in a population, as this indicates the total rate of adoption in a market or population (the height of the bell curve). Diederen et al (2003) sampled Dutch farmers and their adoption behavior (on a variety of innovations rather than a specific one) and found that innovators made up 3 percent, early adopters 10 percent, late adopters 24 percent and non-adopters the remaining 63 percent. Their results indicated that larger farms that produce for heterogeneous markets are more likely to adopt early, while those with a higher solvency ratio were less likely to adopt. This may seem counterintuitive, but they posit that instead of using funds to invest in new innovations, farmers with higher solvency ratios may be more risk averse and "sit on their money," while innovators and early adopters are more likely to finance innovative purchases with debt financing. Finally, innovators and early adopters are generally younger than late adopters.

The study by Diederen et al also searched for differences between innovators and early adopters, and found that while they were indistinguishable in terms of farm structure attributes, innovators are generally younger than early adopters and value external information sources more than early adopters. Also noteworthy in the Diederen et al 2002 study was that adoption behavior shows some recurrences in time: being an innovator (or a late adopter) in the past increases the probability of being an innovator in the current period. However, since their study period was over two years, it is fair to assume that over time some innovators and early adopters may lose the will to stay at the cutting edge; numerous studies demonstrate that adopters become more risk averse as they age (Moussa, 2009; Scandizzo and Savasanto, 2010).

Weimann & Brosius (1994) suggest that personal characteristics such as self-confidence and independence or "psychological strength" have relevance on the adoption of innovations, since they likely modulate the extent to which an actor adopts an innovation without waiting for the security of knowing that others have so acted. Wejnert (2002) relates that "psychologically strong actors select the most important innovations from the abundance of information covered by the media, rapidly adopt those innovations, and using their own social networks, create a public agenda that significantly promotes adoption. Conversely, psychologically weak actors depend on the opinions of stronger actors who relay media information." Wejnert also points out that not enough research has been done to investigate personal characteristics of individual actors as modulators of adoption of innovations.

The literature reinforces the importance of surveying potential innovators down to the regional and/or tribal level, since adoption characteristics vary depending on a variety of factors including whether groups are nomadic, traditionally conservative, have significant non-agricultural sources of income, etc.[7] These studies suggest that development programs aimed at supporting commercial diffusion of innovations should ensure that companies have done their due diligence on target demographics.

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7 See the example of Moussa et al (2009) in Burkina Faso, "where farmers from the Mossi ethnic group were more likely to adopt compared to those from the Peulh ethnic group."

Constraints to Adoption

While some innovations make large impacts and are widely referenced in the literature, it is equally important to consider technologies that were not as widely adopted. Chukwuma-Nwuba (2013) informs that two-thirds of innovations released globally ultimately fail to diffuse, while Golder and Tellis (1996) reveal that market pioneers account for 47 percent of the failure rate. The Meridian Institute reports that activity-based process innovations that are knowledge-intensive and require group action to overcome high transaction costs linked to major institutional gaps have a higher likelihood of failing. Examples include soil fertility enhancement practices, integrated pest management and watershed conservation.[8]

Additionally, as previously noted, the characteristics of adopters themselves – including age, farm size, financial position and psychological factors – significantly influence the timing and rate of adoption. Constraints to the rapid adoption of innovations include factors such as the lack of credit, limited access to information, aversion to risk, inadequate farm size, inadequate incentives associated with farm tenure arrangements, insufficient human capital, absence of equipment to relieve labor shortages (thus preventing timeliness of operations), chaotic or unavailable supply of complementary inputs (such as seed, chemicals, and water), and inappropriate transportation infrastructure (Feder et al, 1985).

International development initiatives seek to address these constraints in order to create the conditions necessary to facilitate the adoption of improved practices that may lead to higher incomes (Feder et al., 1985). The lack of notable scaled agricultural innovations in developing countries indicates that success has only been partially realized, and generally in limited geographic areas, or zones. As Feder et al write, "…immediate and uniform adoption of innovations in agriculture is quite rare. In most cases, adoption behavior differs across socioeconomic groups and over time. Some innovations have been well received, while other improvements have been adopted by only a very small group of farmers." A better understanding of the attributes of successful technologies and adopter behavior can help shape investments designed to rapidly scale to reach smallholders.

Finding 4: Adapting to Local Conditions & Immature Technology

Adjusting agricultural technologies to local conditions is mandatory to ensure adoption. Technologies rarely emerge from laboratories ready to be utilized on farms. Instead, a period of adaptation is required with a variety of stakeholders including farmers, engineers, scientists, manufacturers and marketing specialists all contributing to the effort. Even when this happens, the technology often needs further adjustments after use on farms. Also, farmers sometimes have the option to adopt several distinct technologies, either adopting the complete package of innovations introduced, or subsets of the package. These cases may result in several adoption and diffusion processes occurring simultaneously or staggered in time.[9]

The examples in this section from the literature illustrate technologies and innovations that were successful due to their adaptability to local markets. Innovations must sometimes go through iterations before higher rates of adoption occur, and few innovations follow a classical S-curve adoption path since adoption dynamics are affected by fits and starts as products are adapted to the market. Key issues highlighted by these examples include:

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[8] With the exception of the PICS bag example, case studies for all of these technologies can be found in the report Science and Innovation for African Agricultural Value Chains: Lessons learned in transfer of technologies to smallholder farmers in sub-Saharan Africa (2009).

[9] Feder et al (1985) write that in most cases, "agricultural technologies are introduced in packages that include several components, for example, high yielding varieties, fertilizers, and corresponding land preparation practices. While the components of a package may complement each other, some of them can be adopted independently."

- The adaptation of technology packages and partial adoption
- The adaptation of technologies to meet the specific needs of farmers (depending on agro-ecological zone, farm size, or cropping style)
- External price factors

Griliches' (1957) work on the diffusion of hybrid corn in the U.S. illustrates that technological distance in agriculture could be overcome through local adaptations of technologies. His study showed that farmers in the southern U.S. would adopt hybrid corn seed only after southern research institutions applied knowledge acquired in the Corn Belt states. Farmers in the south had to wait for appropriate adaptations in corn breeding to fit the southern climate (Lowenberg-DeBoer, 1998). It took farmers in the Corn Belt roughly 20 years to adopt hybrid seed once it was developed, while it took southern farmers roughly another 20 years. Adoption in both regions and throughout the U.S. is now at or near 100 percent. A similar example is that of rice threshing technology developed in Japan, which adapted to the tropical conditions of the Philippines through bioengineering carried out by the International Rice Research Institute (Akkonyulu, 2013). These cases also illustrate the important role of large-scale research institutions in making costly but necessary investments in adapting technologies.

Using the correct underlying technology is also crucial for adoption. Lowenberg-DeBoer (1998) gives the example of tractor adoption in the U.S. The first designed tractors were steam-powered, but only suited for a tiny fraction of farms. It was only when gas-powered tractors were developed that the switch from animal to mechanical traction occurred. Due to the mechanical nature of the tractors, many farmers were able to make modifications on their own, and manufacturers also received information on farmer preferences. Over time, through formal and informal processes, tractors came to be indispensable on most medium- and large-sized U.S. farms.

Lowenberg-DeBoer hypothesizes that in the late 1990s, precision agriculture (PA) showed many of the same adoption dynamics as motorized mechanization a century before. PA came on the market in an incomplete fashion and there were questions as to its profitability. The costs of high-technology implements used in PA (e.g., GPS systems, yield monitors, variable rate technologies) initially did not make up for savings on the farm. Yet over time, farmers modified the inputs and by 2003 there was significant uptake of some implements of PA.[10] U.S. farmers modified their needs by adopting only those inputs in the suite of PA tools that they felt would benefit their productivity and sales.

The Cerrados region of central Brazil provides a similar example. As Griffin and Lowenberg-DeBoer (2005) explain, "due to the characteristics of much of Brazilian agriculture; i.e. low land prices, modest labor costs, low management induced soil variability, relatively low on-farm computer use, production of relatively low price commodities and the relatively high cost of imported high tech equipment suggest that Brazilian growers as a whole may lag in PA adoption, particularly the classic PA concepts of yield monitor data analysis for fine tuning crop management and variable rate application." Similar to the U.S., the PA inputs most favorable to large-scale Brazilian farmers tend to be GPS guidance technologies, automation of recordkeeping, employee supervision and quality control. The authors point out that a different marketing mix would appeal to farmers in different regions of Brazil where higher value-added crops are grown. Higher sales per hectare would favor adoption of a wider range of classic PA technologies. Depending on the price of fertilizers and energy prices, the authors note that larger-scale commodity farmers may find it economical to adapt variable rate applications, ideally with targeted assistance from public or private research institutions.

Conservation agriculture (CA, meaning low tillage or no tillage) provides an example of an innovation that came to the market in an immature state. Initially in the U.S., a complete CA system for use by

[10] Yield monitor penetration reached 36 percent, while geo-referenced soil maps and yield maps reached 25 percent and 13.7 percent, respectively.

farmers was not available. It was not until innovations in chemical weed control and planting equipment were developed in the 1970s that it became cost effective for farmers to adopt them. By 1997, no tillage was used on roughly 24 percent of soybean and corn farms (Lowenberger-DeBoer, 1998) and the rate as of 2009 was 35.5 percent, or 88 million acres (Horowitz et al, 2009).

Ernstein et al (2008) detail the efforts of the International Maize and Wheat Improvement Center to adapt no tillage agriculture to local conditions for smallholders in South Asia, Mexico, and southern Africa. Their research supports the idea that, as in developed countries, farmers, researchers, service providers and machinery manufacturers in middle-income and developing countries need to be linked within an innovation system that fine-tunes equipment and crop management while strengthening local institutions.

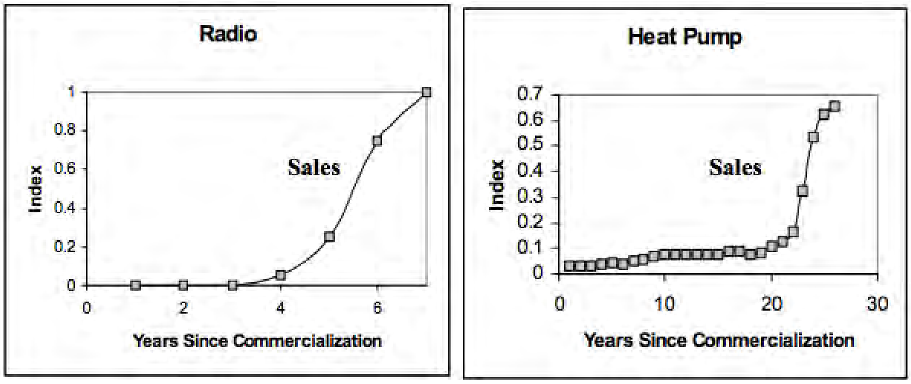
The literature highlights that in all agricultural markets around the globe, successful innovations are those that are either out-of-the-box – since they do not require much additional capital or intellectual investment by farmers – or can be adapted over time to the needs and preferences of farmers. These studies also reinforce that companies should be prepared to capture the feedback of customers to ensure that modifications conform to the needs of users. Large and influential research institutions, funded publicly or privately, play a crucial role in furthering the adaptation process, while the presence of other agricultural stakeholders supports this process.

Finding 5: Product Takeoff

Accurately predicting the likely takeoff point for an innovation is key to successfully supporting its adoption and diffusion within a market. Within a company, understanding the time to takeoff is crucial to ensuring that sufficient resources are allocated (and how they are allocated) so that support is not prematurely withdrawn before the technology has a chance to diffuse in the market. Externally, it is imperative to manage investors' expectations for time to takeoff so they do not lose patience. The time to takeoff varies depending on a market's level of economic development. Generally speaking, takeoff times are shorter in developed countries and longer in middle-income and developing countries. There is a dearth of data in the literature relating specifically to product takeoff for agricultural innovations, meaning that the figures generated by the studies described in this section can only be general guides. Furthermore, studies are lacking on tracking takeoff in middle-income and developing countries.

As described by Peres et al (2010), "the buildup to takeoff does not require any consumer interaction; rather, takeoff is a result of heterogeneity in price sensitivity and risk avoidance. Specifically, as the innovation price decreases and becomes associated with less risk, the product takes off." Product takeoffs occur when a critical mass of innovators combined with early adopters become powerful enough to affect the majority of the potential market. According to Agarwal and Bayus (2002), the early market stage of an innovative product is characterized by initial slow growth immediately after commercialization followed by a sharp increase in sales (400 percent on average, Golder and Tellis, 1997). Figure 3 illustrates product takeoff points for different products in Europe; the typical "hockey stick" shape of the sales curve is indicative of takeoff when sales rapidly and dramatically increase. Agarwal and Bayus point out that the concept of takeoff is critically important for managers and industry analysts, due to its implications on short-term and long-term research and development, marketing and manufacturing.

FIGURE 3: THE GRAPHIC REPRESENTATION OF SALES TAKEOFF POINT OF PRODUCT INNOVATIONS



Golder and Tellis (1997) were among the first to apply a model for the takeoff event, and they successfully used a hazard model due to its accuracy in measuring time-related events. They use three primary independent variables: (1) price, which is the single most important factor, (2) year of introduction, and (3) market penetration. Their model provides generalizations for price reduction, nominal price, the penetration rate at takeoff and the time to takeoff. Analyzing data from 31 successful innovations, they found that the average time to takeoff in developed markets was 6 years in the U.S. and Europe[11] (with variances by product type and location), the price at takeoff was 63 percent of the introductory price, and the average market penetration rate at takeoff was 1.7 percent of market potential. Every 1 percent decrease in price led to a 4.2 percent increase in the probability of takeoff. Additionally, takeoff in the number of firms in the market precedes product takeoff by at least three years (Agarwal and Bayus, 2002). Furthermore, the Golder and Tellis model can be used to predict takeoff 1 year ahead, with an average error of 1.2 years, and it predicts takeoff from the point of product introduction with an expected average error of approximately 2 years. Despite its accuracy, the authors freely admit to the model's limitations, including endogeneity bias and effects from other variables.

Agarwal and Bayus analyzed the role of price decreases and new firm entry at the takeoff stage for a variety of industrial and consumer product innovations launched over a 150-year period in the U.S. They applied a proportional hazards analysis and determined that price reductions and new firm entry are significant explanatory variables. Their research showed that price reduction effects should not be overstated. Whereas price reductions account for less than 5 percent of the variance in sales takeoff times, new firm entry accounts for almost 50 percent of this same variance. The authors found no evidence of price mediating effects of firm entry on sales takeoff times. Finally, they found that price reductions have a greater effect that can be improved with low R&D costs. These results support their hypothesis that non-price, demand-side shifts during early market entry stages are the key driver for sales takeoff.

The 2002 study by Talukdar et al included six products in 31 developed, middle-income and developing countries across Europe, Asia and the Americas. Their findings show clear differences between takeoff in developed countries and other less-developed markets, and therefore provide key information for firms seeking to expand into emerging international markets. They found that the average penetration potential for developing countries is about one-third (0.17 versus 0.52) that for developed countries. This means that with the large populations (and high population density) found in many developing

[11] The average is six years after launch in America. White goods, such as kitchen and laundry appliances, have generally taken longer, but brown goods, such as TVs and CD players, often took off faster. The average new-product takeoff point in Europe is also about six years, although national differences within Europe vary greatly.

countries, a penetration potential of 0.17 represents significant market opportunities in surveyed emerging markets. Furthermore, their results indicate that it takes developing countries on average 17.9 percent longer (19.25 versus 16.33 years) to achieve peak sales. Finally, they found that developing countries experience a slower adoption rate compared to developed countries, despite the positive effect of product introduction delays on diffusion speed. Figure 4 shows time to takeoff for a basket of products in select developed and middle income countries.

FIGURE 4: THE SALES TAKEOFF POINT OF PRODUCT INNOVATIONS IN SELECT COUNTRIES

Country	Median Years to Takeoff	Products Studied
Japan	5.4	14
United States	6.2	14
Germany	7.1	15
United Kingdom	8.0	14
Brazil	9.3	11
India	12.4	14
China	13.9	6

Source: Tellis et al., 2013.

Their study also accounted for macro-environmental variables on penetration potential and speed. For example, their model predicts that a 1 percent change in the level of international trade can change the penetration potential by around 0.5 percent (these are positively correlated, so an increase in trade has a positive effect on penetration potential), while a 1 percent increase in urbanization could increase penetration potential by about 0.2 percent. These are two important variables that are likely to be dynamic in the coming years in developing countries. Although managers will have no control over such macro variables, these findings can serve as a valuable empirical tool for deciding what variables they should consider in evaluating diverse international markets and in performing sensitivity analysis with respect to their projected trends. Notwithstanding the useful information generated for developing versus developed countries, the authors admit to limitations in their approach and that a wider range of products and countries should be included in subsequent research.

The time to sales takeoff varies depending on the innovation; some quickly achieve sales takeoff after commercialization, whereas others exhibit poor performance for years with low sales (Agarwal and Bayus, 2002; Golder and Tellis, 1997). Achieving takeoff is generally explained by conventional economic supply theory, which states that as supply of a good increases, it puts downward pressure on prices. In this case, increased capacity as a result of new firm entry into a market would tend to lower prices. At the point that prices decrease and pass a threshold of affordability, there is a significant increase in sales. However, Agarwal and Bayus argue that this explanation is incomplete. In addition to affecting supply, firm entry also creates additional demand through product improvements, expanded distribution and increased consumer awareness of brand quality through promotional activities.

While there is a sizeable amount of literature on takeoff relating to durable goods, research on takeoff in the context of agricultural innovations is lacking. Studies by Golder and Tellis as well as Agarwal and Bayus comment on the unavailability of data. Finding appropriate data sources is complicated, since information on most products is reported only once products reach a threshold sales level, making it even more difficult to study innovations that failed to reach critical mass. This literature review did not discover any agriculture-specific innovations that were the subject of takeoff analysis.

Anecdotal evidence (Lowenberger-DeBoer) suggests that percent adoption may not always be a good predictor for takeoff, but it appears to be a strong indicator. The generally-accepted rule for consumer products holds that takeoff occurs when the adoption rate reaches 16.6 percent (a ratio of 1:6). In the case of agricultural technologies, the ratio may be as high as 1:4 up to 1:3, although it is difficult to substantiate this based on the lack of empirical evidence. The takeoff for seeds, for example, appears to happen at a much higher rate, in the range of 30 to 35 percent for some varieties (Lowenberger-DeBoer). In correspondence with Lowenberger-DeBoer in April 2015, he suggested that instead of percent adoption, the business case for adoption may be a better indicator. If an innovator determines that benefits of adopting are clear (increased sales or quality, decreased costs), he or she will be more likely to adopt. Lowenberger-DeBoer offers the example of when GPS guidance was gaining traction in the U.S. in the early 2000s; his informal economic study predicted rapid adoption because the benefits were very clear and quick, which was accurate for a certain segment of farmers for whom the technology was a cost savings.

Griliches (1957) also emphasizes the role of economic factors such as expected profits and scale in determining the variation in diffusion rates. Doss et al (2006) define profit as the value of the output minus the cost of production, including the opportunity cost of the farmer's time. Their study of farmers in four East African countries found that farmers rarely talk about their adoption decisions in these terms. Instead, farmers focus on only one aspect of the equation: the price of inputs. In reality, price may be a constraint because farmers cannot purchase inputs due to limited credit markets or if the marginal levels of output from improved varieties do not justify the use of improved inputs. However, as Doss et al reinforce that some farmers in developing countries lack the necessary information about an innovation to fully calculate and weigh the costs and benefits of potential adoption. Market entry strategies may require some level of support for efforts of extension agents, media campaigns and even agricultural lenders that explain how to undertake a simplistic cost-benefit analysis. This review did not identify metrics used to define marginal economic value, although this is a subject that would yield useful information on whether adopting an innovation makes sense from a financial perspective (the 'business case' for the farmer). Innovation-specific information on the percent increase in margin or decrease in cost would certainly be central in terms of adoption criteria, and is worth pursuing in subsequent academic exercises and capturing on surveys.

Finding 6: Developing Country Market Entry

Market pioneers (first movers) often face higher degrees of marketing and technological uncertainty as compared with early followers and late entrants. This uncertainty is a result of the difficulty in forecasting consumer response to a pioneering innovation. Emerging markets present specific challenges compared to developed markets, such as consumer spending power and brand awareness, as well as logistical and infrastructural inadequacies compared to developed markets. This serves to emphasize the importance of finding the correct approach to entering new emerging markets. Many companies pursue a trial-and-error approach to market entry in developing countries, since there are few examples of highly successful product launches in these countries – particularly from multi-national companies (MNCs), around which much of the literature is centered.

One issue with the available theoretical literature is that most of it is focused on product launches in developed markets and the articles are quite dated (primarily from the 1980s and 90s). Nevertheless, the literature summarized here describes why it is usually worth the risk for a company to be a pioneer in the market. First, a review of the Sorgenfry and Munch article discusses market entry into middle-income countries. While it is focused on a fast-moving consumer good, there are lessons to be learned for entry into developing countries as well. The Agri Value Added Services (VAS) Toolkit is then described, which is oriented specifically to agricultural markets in developing countries but with a strong focus on mobile network operators. The Agri VAS overview highlights market entry experiences to generate a list of lessons learned for market entry into developing markets.

Sorgenfry and Munch's analysis looks at MNCs entering the middle-income markets (termed "emerging markets" in the article[12]) of Russia, India and China, using Carlsberg beer as a product that is present in all three markets. The entry strategies of Carlsberg into each of these markets are described along with reasons for their success or failure. Key takeaways include that the strategy used when entering emerging markets is dependent upon factors relevant to each specific market, and that even though studies and theories recommend one entry mode, the actual entry is often different. The adaptation and design of a uniquely-crafted entry strategy is more important than following prescribed or previously-tested modes. The authors compared actual company results with a paradigm by Buckley and Casson (1998), and found their framework to be too rigid for the context of middle-income countries – although the authors acknowledged the model's success for market entry in western China. Finally, Sorgenfry and Munch comment on the need to adapt entry strategies and timing to each specific market. So far, there is not one model that is applicable across middle-income countries. This study has obvious limitations, including that beer is a very specific fast-moving consumer good with which consumers display a lot of brand loyalty. In addition, their research included only three countries that are at the upper spectrum of "emerging markets," so some of the specific entry decisions would not be appropriate for less-developed economies.

The Agri VAS Toolkit, written by members of the GSMA mAgri Program[13], provides information for those wishing to design agricultural VAS deployments based on the initiative's past experiences in Asia and Africa. It draws on market entry experience to generate a list of lessons learned for market entry into developing markets. The manual is divided into four sections, including information on assessing customers, marketing techniques, service design and the business model.

The Toolkit proclaims that "those Agri VAS deployments that have achieved success have often done so through clever adaptation to their environment. Replicating them elsewhere would be to remove a crucial piece of the jigsaw." This sentiment mirrors anecdotal evidence from marketing managers who try to develop a marketing plan that encompasses all contingencies, as well as carefully observe conditions and nimbly respond to issues as they arise. The Toolkit is useful to see some of the marketing aspects that are specific to market entry in developing countries, such as marketing strategies in places where brand awareness and understanding of value propositions are low, there are low levels of media consumption and low literacy rates (particularly in rural areas where the service is targeted). Many of the marketing tools are similar to those used by firms in developed markets. The manual stresses the importance of understanding the actual needs of smallholder farmers. This is complicated by the fact that smallholders and others at the base of the economic pyramid tend not to be heavily surveyed, meaning there is a dearth of relevant marketing information. Before launching, the authors recommend that prospective service providers focus their efforts on three key activities:

1. **Consumer market segments**: segmentation of the market is a crucial keystone of product design. Each demarcation may well have unique problems and needs. Identifying these is a logical first step.
2. **Market research**: once segmentation has occurred, methodical market research and analysis need to be conducted for each.
3. **Agriculture cycle consideration** should be given to the fact that a farmer's activities are almost entirely governed by the overarching super-structure of the agricultural cycle. At different points in this cycle (planning, planting, growing, harvesting or selling) the

[12] The authors selected countries by assessing GDP per capita and GDP growth rates. Russia, India and China are all in the upper third in the list of 23 so-called "emerging markets." These were selected also due to the large global population represented as well as the global market.

[13] In partnership with USAID and the Bill and Melinda Gates Foundation, the GSMA has recently launched the mFarmer Initiative to support mobile operators and agricultural partners in sub-Saharan Africa and India and create commercially viable and scalable mobile information services to benefit over two million smallholder farmers.

farmer will have a uniquely different set of information needs that the Agri VAS must fulfill.

These three activities are further broken out into sub-categories, and present a useful list of characteristics that should be considered for any company considering marketing to smallholder farmers and similar demographics.

It is clear that M-PESA, the mobile money provider based in Kenya and operating throughout sub-Saharan Africa, implements many of these marketing practices. Since 2007, M-PESA – in partnership with Kenya's largest mobile provider, Safaricom – has grown to 6 million subscribers (nearly half of Safricom's subscriber base as of 2009) (Mas and Morawczynski, 2009). Person-to-person money transfers reached $1.6 million by the same period. Latent demand for money-transfer services encouraged rapid growth, driven by the flow of rural-to-urban migration in Kenya. The success of the mobile money service is due in large part to it offering a range of financial and related services that are in high demand. Systems designed to gauge customer feedback help keep the service relevant. M-PESA launched in Tanzania in 2008, but had only reached 100,000 subscribers the following year. The International Finance Corporation worked closely with M-PESA and Vodafone Tanzania to rework their marketing strategy, including a simpler pricing model, a more targeted education-based marketing campaign and the introduction of an aggregator model to better manage and support its distribution network (IFC, 2009). The modifications were a success and, as of 2013, M-PESA has over 5 million subscribers in Tanzania. This underlies the importance of thoroughly researching a market to determine potential weaknesses prior to launch. M-PESA managers likely assumed many of the operating realities in Tanzania would be similar to neighboring Kenya, but this assumption delayed growth. This case also illustrates the successful partnership between a private company and an international development finance institution.

M-PESA has since expanded into other developing markets, with mixed success. Poor performance in Afghanistan and South Africa is counterbalanced with stronger performance in India and Romania. In fact, M-PESA, in partnership with Vodafone, has plans to further expand into other eastern European countries where there are a high number of unbanked (Reuters, 2014). This would be an exceptional example of impressive expansion by an indigenous African technology brand.

The decision on the timing of market entry must balance the risks of premature entry and the problems of missed opportunities; the analysis requires both quantitative and qualitative data. The qualitative decision is whether a product should be a pioneer or a follower, while the quantitative decision involves the timing of market entry (Lilien and Yoon, 1990). Lilien and Yoon's research used data from France that encompassed 112 new industrial products from 52 French firms. Their statistical results support the following guidelines on market entry timing: "(1) enter earlier when the expected return is higher, (2) enter later when the market is evolving more rapidly: the first entrant sees high returns if he is successful, but bears the risk of lower likelihood of success than later entrants."

Even with these supported guidelines, there remains a psychological element on the decision by firms in determining market entry. Robinson and Min (2002) relate that first movers often face the greatest market and technological uncertainties, due to the unpredictability of forecasting consumer response to an innovation and because an innovative product may not function well. Furthermore, memorable phrases such as "the first to market is the first to fail" and "the pioneer is the one with arrows in his back" are well known throughout the world of marketing. Thus, many firms choose to be early followers, thereby reducing risk by learning from the mistakes (and successes) of the pioneer. On the other hand, survival rates for market pioneers are often enhanced by their temporary monopoly, and after their monopoly has ended they benefit from customer loyalty, setting the product standard, superior distribution and the possibility of building a broad product line. Robinson and Min compared survival rates for 167 first entrant pioneers with those of 267 early followers. Their results support Lilien and Yoon's research by suggesting that for industrial goods businesses, the first mover advantages of pioneers more than offset technological uncertainties. Results also indicate that the longer a first mover's monopoly, the better the chance of long-term survival.

CONCLUSIONS

Finding 1: Diffusion Models – Commonalities, Limitations and Criticism

The classical models for innovation diffusion have spawned many critiques regarding the models' use in non-Western contexts. While countless academics have offered suggestions and improvements to the models, there does not appear to be one modified model or framework that is accepted across multiple disciplines. The most accurate models are usually those that build off of previous studies, taking into account lessons learned and applying novel approaches. A clearer understanding of diffusion modeling, including its uses, criticisms and suggested fixes, will ensure that they are applied correctly to technology introduction and promotion in the agricultural context of emerging markets.

Finding 2: Practical *Ex Ante* Model Useful for Development Context

While there is ample literature on models that analyze the adoption and diffusion of new agricultural technologies, most require a highly technical understanding. Yet technology promoters need to be able to estimate the rate and timing of adoption. To address this gap, researchers in Australia developed ADOPT to not only deliver the desired information, but also respond to the needs and abilities of its intended users. In addition to predicting an innovation's likely peak extent of adoption and estimated time for reaching the sales peak, ADOPT encourages users to consider the influence of a structured set of factors affecting adoption and engages managers and practitioners by helping adoptability knowledge and considerations to be more understandable and transparent.

Finding 3: Factors Affecting Adoption and Diffusion of Innovations

Launching a new innovation, either commercially or as part of a development project, is a risky venture. By one account, two-thirds of innovations fail to diffuse and hit takeoff. Successful innovations tend to have a shared set of general characteristics, specifically those that are less complex and more easily observable commodity-based object innovations targeted for relatively simple application. While specific interventions may vary by location due to different characteristics of groups and ecosystems, this basic rule of thumb is likely to hold true for many emerging market country contexts. This information could represent a starting point on technologies and value chains in FTF countries that should be prioritized for successful adoption. Furthermore, the literature suggests that more research is needed regarding the personal characteristics of individual actors as modulators of the adoption of innovations.

Finding 4: Adapting to Local Conditions & Immature Technology

Adjusting agricultural technologies to local needs and preferences is essential to adoption, and may require inputs from a variety of stakeholders. It may also only happen over time and use. The literature also highlights the importance of large, well-funded research institutions devoted to such projects. Utilizing the correct underlying technology that is suitable for the local environment is also imperative for adoption. Evidence shows that out-of-the-box solutions must often undergo multiple iterations before they are found acceptable, meaning that companies must provide formalized ways to collect feedback from customers in order to make modifications. Bringing immature technologies to the market prematurely hinders the chances of adoption, as does packaging bundles of services that cannot be purchased separately.

Finding 5: Product Takeoff

Understanding an innovation's time to takeoff is key to determining the resources needed to get it to that point. Knowledge about the takeoff point for an innovation is crucial for managers to make decisions to maintain, increase or withdraw support for new products. Price is the single most important factor in determining takeoff, followed by year of introduction and then market penetration.

The vast majority of data pertaining to innovation takeoff is drawn from durable goods in developed economies; much less information exists on takeoff dynamics in middle-income and developing countries. In addition, no agriculture-specific literature has been identified on this subject and is well worth further study.

Innovators and early/late adopters must somehow calculate the marginal economic value of innovations in order to make a determination on adoption. However, many smallholders lack the skills to properly carry out a cost-benefit analysis based on metrics and instead focus only on the price of an innovation without taking into consideration the potential increased yields or decreased costs that come with adoption. This is an important gap in the literature worth further research given its impact on adoption.

Finding 6: Developing Country Market Entry

The literature confirms that a trial-and-error approach is generally pursued for market entry into developing countries, due to the lack of data on previous successful product launches – especially for agricultural products. Evidence in the literature overwhelmingly concurs that it is generally advantageous to be a first mover (rather than an early follower), as it allows companies to build brand loyalty, establish market share and make iterative product improvements.

The Agri VAS Toolkit, created for designing agricultural VAS deployments, is a manual of best practices based on past experience in Asia and sub-Saharan Africa. It stresses the importance of understanding the actual needs of smallholder farmers, although it recognizes that this is complicated by the lack of marketing data for this demographic since they tend not to be widely surveyed (with the exception of development initiatives).

The success of M-PESA in Kenya, and later in other countries, is largely due to the company's ability to offer a range of financial products and services that are in extremely high demand among many who do not engage in the traditional financial sector. Due to its success and replicable model, it may be the first African high-tech brand to successfully expand into middle-income countries.

ANNEX A: ANNOTATED BIBLIOGRAPHY

Akkoyunlu, Şule. (2013). Agricultural Innovations in Turkey. Swiss National Centre of Competence in Research: Working Paper (2013/30).
The article identifies the characteristics of innovative farmers and suggests policy strategies to encourage agricultural innovations. The analysis shows that agricultural innovations are taking place in Turkey and various public and private stakeholders contribute to the development and adoption of innovation in agriculture. Agricultural enterprises and cooperatives, clusters of innovation, non-governmental organizations, research institutes, government and international institutions play an important part in the collaborative effort to create and disseminate innovation.

Albers, Sönke. (2004). Forecasting the Diffusion of an Innovation Prior to Launch. Cross-functional Innovation Management-Perspectives from Different Disciplines. 243-258.
In order to help managers with forecasts this article provides the values of the three descriptors for 34 different product categories. Any person who wants to derive analogous products can use this database and combine the products such that the weighted average of the descriptors of these products is as similar to the category for which the forecast is needed. This is a method that is easy to apply, uses all the experience of the past and shows high face validity.

Agarwal, Rajshree., Bayus Barry L. (2002). The Market Evolution and Sales Takeoff of Product Innovations. *Management Science,* 48 (8), 1024-1041.
In contrast to the prevailing supply-side explanation that price decreases are the key driver of a sales take-off, we argue that outward shifting supply and demand curves lead to market take-off. Our fundamental idea is that sales in new markets are initially low since the first commercialized forms of new innovations are primitive. Then, as new firms enter, actual and perceived product quality improves (and prices possibly drop) which leads to a take-off in sales.

Armstrong, J. (2001). *Principles of Forecasting: A Handbook for Researchers and Practitioners*. Boston, MA: Kluwer Academic.
This book summarizes knowledge from experts and from empirical studies. It provides guidelines that can be applied in fields such as economics, sociology and psychology. It applies to problems such as those in finance (how much is this company worth?), marketing (will a new product be successful?), personnel (how can we identify the best job candidates?) and production (what level of inventories should be kept?).

Assefa, S.; Alemneh, D. G.; Rorissa, A. (2015). Diffusion of Scientific Knowledge in Agriculture: The case for Africa. *Agricultural Information Worldwide,* 6, 34-47.
This article investigates existing knowledge diffusion models and their limitations, available best practices, and the potential to infuse translational research as a way to augment extension service programs in SSA agricultural practices.

Bass, F. M. (1969). A New Product Growth Model for Consumer Durables. *Management Science,* 15, 215–227.
A growth model for the timing of initial purchases of new products is developed and tested empirically against data for 11 consumer durables. The basic assumption of the model is that the timing of a consumer's initial purchase is related to the number of previous buyers. The model yields good predictions on the sales and the timing of the peak when applied to historical data. A long-range forecast is developed for the sales of color television sets.

Beise, M. (2001). Country Specific Success Factors of the Global Diffusion of Innovations. *Lead Markets*, 14. Springer Science & Business Media.

This book intends to answer three questions: What are lead markets? What constitutes a lead market? And how can companies harness lead markets to generate global innovations? It also explores production adoption and diffusion in an international context and explains why innovative products are adopted faster in some places than others.

Bikhchandani, Sushil; Hirshleifer, David; Welch, Ivo. (1992). A Theory of Fads, Fashion, Custom and Cultural Change as Information Cascades. *Journal of Political Economy*, 100(5), 992-1026.
This article introduces the concept of information cascades: an integral concept in the product life cycle. Analysis was conducted by Golder and Tellis. An informational cascade occurs when a person observes the actions of others and then—despite possible contradictions in his/her own private information signals—engages in the same acts.

Brown, L. A. (1981). *Innovation diffusion: A new perspective*. New York: Methuen.
Supporting Stephenson's desire to make extension services more equitable, he cites Brown who said that change programs must have a financial support infrastructure for farmers in order to be successful.

Butler, L. J. (2009). Update on rBST use in the California Dairy Industry. *Agricultural and Resource Economics Update,* 12(5), 5-7.
Discusses adoption of BST in California and reasons for disadoption; useful for comparing actual adoption to estimates of adoption based on ex ante prediction models.

Caswell, M. F.; Fuglie, K. O.; Klotz, C. A. (2003). *Agricultural Biotechnology: An economic Perspective*. Nova Publishers.
Their review of economic factors affecting adoption of BST by US dairy farmers features predicted adoption rates using ex ante adoption models, which in the literature review are ultimately used in comparison to actual adoption rates.

Chandrasekaran, D.; Tellis, G. J. (2007). A Critical Review of Marketing Research on Diffusion of New Products. *Review of Marketing Research*, 3(1). 39-80.
This article critically examines alternate models of diffusion of new products and the turning points of the diffusion curve. On each of these topics, it focuses on the drivers, specifications and estimation methods researched in the literature. We discover important generalizations about the shape, parameters and turning points of the diffusion curve and the characteristics of diffusion across early stages of the product life cycle. Future research opportunities are identified.

Chandrasekaran, Deepa; Tellis, Gerard J. (2008). Global Takeoff of New Products: Culture, Wealth, or Vanishing Differences? *Marketing Science*, 27(5). 844-860.
The authors study the takeoff of 16 new products across 31 countries (430 categories) to analyze how and why takeoff varies across products and countries. They test the effect of 12 hypothesized drivers of takeoff using a parametric hazard model. The authors find that the average time to takeoff varies substantially between developed and developing countries, between work and fun products, across cultural clusters and over time. Products take off fastest in Japan and Norway, followed by other Nordic countries, the United States, and some countries of Midwestern Europe. Takeoff is driven by culture and wealth; As well as product class, product vintage and prior takeoff. Most importantly, time to takeoff is shortening over time and takeoff is converging across countries. The authors discuss the implications of these findings.

Chandy, L.; Hosono, A.; Kharas, H. J.; Linn, J. F. (Eds.). (2013). *Getting to Scale: How to Bring Development Solutions to Millions of Poor People*. Brookings Institution Press.
The global development community is teeming with different ideas and interventions to improve the lives of the world's poorest people. Whether these interventions succeed in having a transformative impact depends not just

on the idea's brilliance but on whether it can be brought to a scale where they reach millions of poor people. "Getting to Scale" explores what it takes to expand the reach of development solutions beyond an individual village or pilot program so they serve poor people everywhere.

Chirwa, Ephraim W. (2005). Adoption of Fertilizer and Hybrid Seeds by Smallholder Maize Farmers in Southern Malawi. *Development Southern Africa,* 22(1), 1-12.
Despite decades of agricultural policies that promoted the adoption of fertilizer and hybrid seed technologies as ways of improving productivity in maize fanning, smallholder farmers in Malawi have been relatively slow to adopt the new technology. Using bivariate probit analysis and controlling for technology acquisition through grants, the article found that fertilizer adoption was positively associated with higher levels of education, larger plot sizes and higher non-farm incomes, but negatively associated with households headed by women and distance from input markets.

Chukwuma-Nwuba, E. O. (2013). The Failure of Most Entrepreneurial Technological Innovations to Diffuse: What the Literature Say. *International Journal of Management Sciences*, 1(11), 463-470.
This article focuses on three industries: the automobile; food and the computer/electronic industry. The article has the aim of identifying technologically sound products that have failed to diffuse and why. Specific reference is given to when the products get to the market.

Cobert, B.; Helms, B.; Parker, D. (2012). *Mobile Money: Getting to Scale in Emerging Markets*. McKinsey & Company.
The article's research reveals the three most critical success factors to implement after a provider has launched its deployment and starts to face execution problems: (1) pay close attention to managing the agent network; (2) create a compelling product offering; and (3) maintain corporate commitment.

Dearing, J. W.; Meyer, G. (1994). An Exploratory Tool for Predicting Adoption Decisions. *Science Communication*, 16(1), 43-57.
The authors propose methods for comparing the likelihood of the diffusion of differing developing innovations. They define and examine eleven attributes: Economic Advantage, effectiveness, observability, trialability, complexity, compatibility, reliability, divisibility, applicability, commutuality, and radicalness.

Dekimpe, M.G.; P.M. Parker; M. Sarvary. (1998). Globalization: Modeling Technology Adoption Timing Across Countries. *Technological Forecasting and Social Change,* 63, 25-42.
The paper proposes a new methodology called the "coupled-hazard approach" to study the global diffusion of technological innovations. This coupled approach addresses several methodological challenges arising from the global nature of the considered diffusion process and the intricacies of the type of innovations studied.

Derpsch, R.; Friedrich, T.; Kassam, A.; Li, H. (2010). Current Status of Adoption of No-till Farming in the World and Some of its Main Benefits. *International Journal of Agricultural and Biological Engineering*, 3(1), 1-25.
Opposite to countries like the USA where fields under no-tillage farming are tilled every now and then, more than two thirds of the area under no-tillage systems in South America is permanently not tilled; in other words once adopted, the soil is never tilled again. The spread of no-tillage systems on more than 110 million ha world-wide shows the great adaptability of the systems to all kinds of climates, soils and cropping conditions.

De Souza Filho, H. M.; Young, T.; Burton, M. P. (1999). Factors Influencing the Adoption of Sustainable Agricultural Technologies: Evidence from the State of Espírito Santo, Brazil. *Technological Forecasting and Social Change*, 60(2), 97-112.
A dynamic econometric framework (duration analysis) is used to analyze the determinants of farmers' decisions on whether or not to adopt low-external-input and sustainable agriculture (LEISA) technology. A wide range of

potential determinants (both economic and non-economic) are considered. Our results suggest that the probability of a farmer adopting this technology increased if the farmer was more integrated with farmers' organizations, had contacts with nongovernmental organizations, was aware of the negative effect of chemicals on health and the environment, could rely on family labor, and had a farm located in an area with better soil conditions.

Diederen, P.; Van Meijl, H.; Wolters, A. (2002). *Modernization in Agriculture: What Makes a Farmer Adopt an Innovation?* Wageningen University and Research Centre: Agricultural Economics Research Institute (LEI).
This paper addresses the question which factors influence a farmer in deciding to adopt an innovation. The authors differentiate between innovations that are new to the farmer, but already well established in the sector, innovations that are early in their process of diffusion and innovations that are new to the farmer's sector. The authors use an ordered probit approach to relate adoption behavior to variables that capture characteristics of the farm (labor and financial resources and market position), of the business environment of the farm (type of production and market, degree of regulation) and of the farmer (access to information, capabilities, preferences). Data on 865 Dutch farms is used and the paper finds that innovation adoption is positively related to labor resources, market position, access to information and past adoption behavior, and negatively to solvency and the degree of market regulation.

Diederen, P.; Van Meijl, H.; Wolters, A.; Bijak, K. (2003). Innovation Adoption in Agriculture: Innovators, Early Adopters and Laggards. Wageningen University and Research Centre: Agricultural Economics Research Institute (LEI).
This paper analyses the choice of a farmer to be an innovator, an early adopter or a laggard (an adopter of mature technologies or a non-adopter) in the adoption of innovations that are available on the market. The authors estimate a nested logit model with data from a large sample of Dutch farmers. They found that structural characteristics (farm size, market position, solvency, age of the farmer) explain the difference in adoption behavior between innovators and early adopters on the one hand and laggards on the other. They also found that early adopters and innovators do not differ from each other regarding these structural characteristics. However, they appear to differ in behavioral characteristics: innovators make more use of external sources of information and they are more involved in the actual development of innovations.

Doss, Cheryl R. (2006). Analyzing Technology Adoption Using Microstudies: Limitations, Challenges, and Opportunities for Improvement. *Agricultural Economics*, 34(3), 207–219.
Policy makers and interest groups have many questions about the use of improved technologies in developing country agriculture. These include the roles of policies, institutions and infrastructure in the adoption of improved technologies and their impact on productivity and welfare. Most micro-level adoption studies; however, cannot address these important policy issues. Drawing on an extensive review of the literature on the adoption of agricultural technologies, this article suggests alternative approaches for designing technology adoption studies to make them useful for policy makers. It explores the generic limitations of cross-sectional adoption studies carried out in small numbers of communities and discusses some problems faced in conducting such studies. Recommendations include the use of sampling approaches that allow data from microstudies to be generalized to higher levels of aggregation, adherence to clearly defined terms that are standardized across studies and careful examination of the assumptions that often underlie such studies.

Doss, C.; W. Mwangi; H. Verkuijl; de Groote, H. (2003). Adoption of Maize and Wheat Technologies in Eastern Africa: A Synthesis of the Findings of 22 Case Studies. CIMMYT Economics Working Paper 03-01. Mexico, D.F.: CIMMYT.
This paper synthesizes the findings of 22 micro-level studies on technology adoption carried out by the International Maize and Wheat Improvement Center (CIMMYT) with national agricultural research systems in Ethiopia, Kenya, Tanzania and Uganda from 1996-1999. The authors found that technology adoption is taking

place across Eastern Africa but considerable scope remains to improve the productivity of smallholder agriculture in higher potential regions with high levels of adoption.

Erenstein, O.; Sayre, K.; Wall, P.; Dixon, J.; Hellin, J. (2008). Adapting No-tillage Agriculture to the Conditions of Smallholder Maize and Wheat Farmers in the Tropics and Sub-tropics. *No-till Farming Systems,* 253-278.
The paper summarizes CIMMYT's experiences with the adaptation of no tillage to smallholder conditions in the tropics and sub-tropics, focusing on three contrasting cases: 1) irrigated rice-wheat systems in South Asia; 2) rainfed maize and irrigated wheat systems in Mexico; and 3) rainfed maize in Southern Africa. The term 'Conservation Agriculture' is preferable to 'No-Till agriculture' whenever the three underlying principles - minimal soil disturbance, surface residue retention and crop rotation - are followed.

Feder G.; Just, R.E.; Zilberman D. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. *Economic Development and Cultural Change*, 33(2), 255-298.
The purpose of this paper is to survey various studies that have attempted to explain patterns of adoption behavior either theoretically or empirically. Because the volume of such published research is overwhelming, the paper attempts to review representative works rather than to present an exhaustive discussion of all work to date. Section II introduces a general conceptual framework for analyzing adoption and diffusion processes and then proceeds to survey the existing conceptual and theoretical literature regarding adoption patterns of agricultural innovations in LDCs within this framework. Section III reviews empirical studies that have attempted to clarify and validate various aspects of adoption processes in the light of the theoretical literature. Section IV provides a critique of methodologies and models used in the empirical literature and suggests new approaches and directions. The implications of the survey are indicated in the last section.

Fliegel, FC; Kivlin, JE. (1966). Attributes of Innovations as Factors in Diffusion. *American Journal of Sociology*, 72, 235–248.
Discussion on the characteristics of an innovation and how that relates to its adoption and eventual diffusion, specifically on the economic and social costs and benefits of adoption.

Fountas, S.; Pedersen, S. M.; Blackmore, S. (2005). ICT in Precision Agriculture–Diffusion of Technology. Gelb, E.; Offer, A. (eds). *ICT in agriculture: perspective of technological innovation.*
Precision Agriculture (PA) is the management of spatial and temporal variability of the fields. This management concept incorporates a range of management as well as ICT tools to assess and treat the variability within the field. PA has been practiced over the last 15 years mostly in North America and Northern Europe. Despite its promises, PA has not yet managed to be adopted widely by farmers. This chapter's results are based on the findings of six mail surveys, focus groups and personal interviews with PA practitioners in the UK, Denmark and the USA over six years (1998-2003). The information related to ICT adoption in PA is presented, including software and hardware aspects, data ownership, data handling, data interpretation, internet and e-mail use, as well as information preferences to invest and practice in PA.

Fowler, Ben and White, Dan. (2015). Scaling Impact: Extending Input Delivery to Smallholder Farmers at Scale. Leveraging Economic Opportunities (LEO) Report No. 7.
This paper strives to inform the development of market systems that improve smallholder access and adoption of commercial inputs. Previous studies have focused primarily on cases where donor funding has facilitated market change. This report, on the other hand, considers a diversity of models but focuses particularly on those that have reached significant scale.

Franco, J. A.; Calatrava, J. (2008). Adoption and Diffusion of No-tillage Practices in Southern Spain Olive Groves. 12th Congress of the European Association of Agricultural Economists (EAAE).

This paper analyses the process of adoption of no-tillage in southern Spain's olive groves using data from a survey carried out in 2006 among 215 olive tree farmers from the Granada Province in Southern Spain regarding the adoption of soil conservation and management practices. The authors modeled the diffusion process of no-tillage practices using three different specifications (logistic, Gompertz and exponential) and estimated an ordered probit model to analyze which factors determine the adoption of no-tillage.

Friedrich, T.; Derpsch, R.; Kassam, A. (2012). Overview of the Global Spread of Conservation Agriculture. *Field Actions Science Reports: The Journal of Field Actions*, Special Issue 6.
Global empirical evidence shows that farmer-led transformation of agricultural production systems based on Conservation Agriculture (CA) principles is already occurring and gathering momentum worldwide as a new paradigm for the 21st century. The data presented in this paper, mainly based on estimates made by farmer organizations, agro-industry, and well-informed individuals, provide an overview of CA adoption and spread by country, as well as the extent of CA adoption by continent.

Gabre-Madhin, E.Z; Haggblade, S. (2001). *Successes in African Agriculture: Results of an Expert Survey. International Food Policy Research Center, Markets and Structural Studies Division, Discussion Paper 53*. Washington, D.C.
This source provided guidance on demarcating successful innovations that adhere to certain criteria. This was useful as part of the larger task of developing a clear cut definition of what a "successful" innovation looks like in context.

Gatignon, H.; Eliashberg, J.; Robertson, T. S. (1989). Modeling Multinational Diffusion Patterns: An Efficient Methodology. *Marketing Science*, 8(3), 231-247.
The objective of this study is to develop an econometric model for the diffusion of innovations at the individual country level, but which also allows the parameters of the process to differ systematically across countries. The conceptualization rests on behavioral and spatial theories of diffusion and extends the domain to international markets. The cross-national model of innovation diffusion highlights substantive differences and similarities among international markets. It also provides estimates for diffusion parameters, even for countries where sales data are not available, thereby yielding some insights into the nature of the expected diffusion pattern in these countries prior to market entry.

Gillespie, J.; Nehring, R.; Hallahan, C.; Sandretto, C.; Tauer, L. (2010). *Adoption of Recombinant Bovine Somatotropin and Farm Profitability: Does Farm Size Matter?.*
Excellent overview of the path of adoption of bST in the US, representing the largest dairy producing regions in the US. Also discusses the reasons for disadoption after usage peaked around the year 2000 and has leveled off since then at about 15% of potential adopters.

Greve, HR. (1998). Performance, Aspirations, and Risky Organizational Change. *Administrative Science Quarterly,* 43(1), 58–86.
Discussion on the characteristics of an innovation and how that relates to its adoption and eventual diffusion, specifically on the economic and social costs and benefits of adoption. The study reported here uses learning theory to examine how performance feedback affects the probability of risky organizational changes that are consequential to an organization's performance. The theory predicts how decision makers interpret organizational performance by comparing it with historical and social aspiration levels. Empirical analysis of the consequences of performance shortfalls on the probability of strategic change in the radio broadcasting industry shows clear sensitivity to social and historical aspiration levels. It also shows that changes seen or done by the station predict future change, suggesting that the recent experiences of organizations cause differences in capabilities and perceived opportunities, leading to differences in organizational inertia.

Griffin, T.W.; Lowenberg-DeBoer, J.; Lambert, D.M.; Peone, J.; Payne, T.; Daberkow, S.G. (2004). *Adoption, Profitability, and Making Better Use of Precision Farming Data*. Department of Agricultural Economics. Purdue University.
Precision agriculture (PA) technology has been on the market for almost 15 years. Global Positioning Systems (GPS), Geographic Information Systems (GIS), yield monitors, variable rate technologies (VRT) and other spatial management technologies are being used by farmers worldwide, but questions remain about the profitability of the technology and its future. This paper summarizes: 1) data on worldwide adoption of PA technology, 2) review of PA economics studies and 3) implications for Brazil. Worldwide adoption estimates are based on reports by an international network of collaborators.

Golder, P. N.; Tellis, G. J. (1993). Pioneer Advantage: Marketing Logic or Marketing Legend?. *Journal of Marketing Research*, 30(2), 158–170.
Studies show that pioneers have long lived market share advantages and are likely to be market leaders in their category. However, that research has potential limitations, namely the reliance on a few established databases, the exclusion of non-survivors, and the use of single-informant self-reports for data collection. The authors' results show that almost half of market pioneers fail and their mean market share is much lower than that found in other market studies.

Golder, P. N.; Tellis, G. J. (1997). Will it Ever Fly? Modeling the Takeoff of Really New Consumer Durables. *Marketing Science*, 16(3), 256–270.
This article makes observations regarding early takeoff points in new consumer durables. Takeoff appears as an elbow-shaped discontinuity in the sales curve showing an average sales increase of over 400%. In contrast, most marketing textbooks and diffusion models generally depict the growth of new consumer durables as a smooth sales curve. Results from the study are intended for managers to make decisions about resource allocation to support new products for an appropriate amount of time so they have time to reach takeoff.

Golder, P. N., & Tellis, G. J. (2004). Growing, Growing, Gone: Cascades, Diffusion, and Turning Points in the Product Life Cycle. *Marketing Science*, 23(2), 207–218.
The product life cycle (PLC) is the result of multiple supply and demand forces. However, past research has focused primarily on the role of diffusion in driving the PLC. This study takes a step toward a broader theoretical perspective on the PLC by incorporating informational cascades and developing and testing many new hypotheses based on this theory. The authors use a hazard model of the duration of the growth stage as well as many descriptive results to evaluate their hypotheses.

Griliches, Z. (1957). Hybrid Corn: An Exploration in the Economics of Technological Change. Econometrica, *Journal of the Econometric Society,* 501-522.
Seminal work on diffusion adoption theory and application of S-curves to explain hybrid corn adoption in the US. The work presented in this paper is an attempt to understand a body of data: the percentage of corn acreage planted with hybrid corn by state and by year. By concentrating on a single, major, well defined, and reasonably well recorded development – hybrid corn – may hope to learn something about the ways in which technological change is generated and propagated in US agriculture.

Gruber, Harald. (2001). Competition and Innovation: The diffusion of Mobile Telecommunications in Central and Eastern Europe. *Information Economics and Policy*, 13(1), 19-34.
The paper tackles the issue of rapid diffusion of mobile telecommunications in Central and Eastern Europe. Results show that the later a country has adopted mobile telecommunications the faster the diffusion speed. There is a convergence in adoption levels across countries at 20 per cent of the population. Competition variables are important: the speed of diffusion increases with the number of firms and simultaneous entry is more effective than sequential entry in accelerating the diffusion speed. Diffusion speed increases with the size of the fixed

telecommunications network and the length of the waiting list. It is concluded that the development of mobile communications networks has significant welfare effects and a set of policy recommendations are provided.

Gudlavalleti, S.; Gupta, S.; Narayanan, A. (2013). Developing Winning Products for Emerging Markets. *McKinsey Quarterly*, 2, 98-103.
To master the extremes of a fast-changing competitive landscape, the paper challenges ones company's assumptions about designing, developing and manufacturing products for emerging regions. This article reviews the challenges of designing, developing, and manufacturing products for fast-changing emerging markets— environments where customers are both extremely price conscious and demanding. Against this backdrop, a growing number of companies find that they must reexamine their traditional approaches to product development and tailor them to these realities.

Hightower, J. (1972). *Hard Tomatoes, Hard Times: The Failure of the Land Grant and College Complex*. Schenkman: Cambridge, Massachusetts.
There is no doubt that American agriculture is enormously productive and that agriculture's surge in productivity is largely the result of mechanical, chemical, genetic and managerial research conducted through the land grant college complex. But the question is whether the achievements outweigh the failures, whether benefits are overwhelmed by costs.

Horowitz, J. (2011). *No-till Farming is a Growing Practice*.
Most U.S. farmers prepare their soil for seeding and weed and pest control through tillage – plowing operations that disturb the soil. Tillage practices affect soil carbon, water pollution, and farmers' energy and pesticide use, and therefore data on tillage can be valuable for understanding the practice's role in reaching climate and other environmental goals. In order to help policymakers and other interested parties better understand U.S. tillage practices and, especially, those practices' potential contribution to climate-change efforts, this report showed that approximately 35.5% of U.S. cropland planted to eight major crops, or 88 million acres, had no tillage operations in 2009.

M-Money Channel Distribution Case: Tanzania. (2010). International Finance Corporation.
This paper discusses the original strategic tactics that Vodacom Tanzania employed during the launch of M-PESA in April 2008 and describes how those tactics have evolved since to improve delivery and penetration of the system in Tanzania.

Jadhav, Amol, et al. (2011). Agricultural Value Added Services (Agri VAS): Market Entry Toolkit. GSMA — mAgri Programme.
The purpose of this document is to help key players recognize, understand and act upon opportunities in the mobile agriculture sector.

James J. (1993). New Technologies, Employment and Labor Markets in Developing Countries. Dev. Change, 24, 405–37.
Discussion on the characteristics of an innovation and how that relates to its adoption and eventual diffusion, specifically on the economic and social costs and benefits of adoption. This article is concerned with the impact of new technologies - especially, but not entirely, those that are related to microelectronics - on employment and labor markets in developing countries. Taking the form of a literature survey it looks at those impacts that have already occurred as well as effects that seem likely to occur in the future. Both sets of issues are addressed within an analytical framework that views the impact of technical change as the end result of a process which begins with the generation and proceeds via the diffusion of new technologies. The need for so broad an approach is shown to stem from the multiplicity of ways in which the generation and diffusion of new technologies influence each other and condition the ultimate impact of these technologies on employment and

labor markets. Because many such mechanisms have not yet received much attention in the literature, there appears to be substantial scope for further research.

Kelsey, Jack B. (2013). *Constraints on the Adoption of Agricultural Technologies in Developing Countries: Literature Review.* Agricultural Technology Adoption Initiative. J-Pal (MIT) and CEGA (UC Berkeley).
Considerable agro-ecological heterogeneity across locations in Sub-Saharan Africa means that technologies vary across relatively small areas. Agro-ecological heterogeneity is a consequence of the high dependence on rain-fed agriculture and microclimates that require specific farming practices. Technologies may be disproportionately suited to the growing conditions faced by the wealthiest farmers, resulting in selective unavailability of appropriate technologies for other farmer types. Adoption will not occur where technologies are unavailable, yet selective availability is largely a supply side, technology development challenge less suited to targeted interventions to encourage take up.

Knowler, D.; Bradshaw, B.; Gordon, D. (2001). The Economics of Conservation Agriculture. Natural Resources Management and Environment Department. Food and Agriculture Organization (FAO) of the United Nations.
Policy is important to CA adoption. Successful policies require a thorough understanding of farm-level conditions and site-specific programs that utilize various policy tools. More uniform policies could help develop social capital and promote conditions for collective action. Developing sustainability indicators that evidence the benefits of CA can help meet the need for improved analysis and information. A whole-farm approach may be the most appropriate basis for financial analyses as it can capture the full range of farmers' responses and incorporate the options available.

Koh, et al. *From Blueprint to Scale: The Case for Philanthropy in Impact Investing*,10–19.
This report springs from a point of view shared by Monitor and Acumen Fund—that philanthropy is the essential but often overlooked catalyst that unlocks the impact potential of inclusive business and impact investing. The key themes discussed here are based on the sum of Monitor's extensive research into more than 700 inclusive businesses in Africa and India, and Acumen Fund's decade of experience as a pioneering impact investor. They also draw together the experiences and observations of dozens of impact investors, grant funders, academics and other experts who were generous enough to share their thoughts with us.

Krammer, S. M. (2009). Drivers of National Innovation in Transition: Evidence from a Panel of Eastern European Countries. *Research Policy*, 38(5), 845-860.
Innovation plays a crucial role in determining today's economic growth patterns. But what enables some countries to innovate more than others? This study attempts to answer this question by analyzing in premiere a panel of sixteen Eastern European transition countries. It provides a detailed description of innovation identifying regional differences in terms of historical heritage, technological specialization, commitments and main actors involved in this process, before and after the fall of communism. Secondly, it explores empirically the main drivers of their innovative output, proxied by patents, using a variety of econometric techniques and control variables. The results confirm the crucial role of universities and existing national knowledge base complemented by R&D commitments from both public and private sources. Policy measures, such as intellectual property rights protection or a favorable business climate, increase significantly the propensity to patent, while measures of transitional downturn and industrial restructuring diminish it. Finally, globalization contributes to developing new innovations in these countries through inflows of foreign investment and trade.

Kuehne, G.; Llewellyn, R.; Pannell, D.; Wilkinson, R.; Dolling, P.; Ewing, M. (2011). *ADOPT: A Tool for Predicting Adoption of Agricultural Innovations.* AARES 55th Annual Conference, Crown Conference Centre, Melbourne.
A wealth of evidence exists about the adoption of new practices and technologies in agriculture but there does not appear to have been any attempt to simplify this vast body of research knowledge into a model to make

quantitative predictions across a broad range of contexts. This is despite increasing demand from research, development and extension agencies for estimates of likely extent of adoption and the likely timeframes for project impacts. This paper reports on the reasoning underpinning the development of ADOPT (Adoption and Diffusion Outcome Prediction Tool). The tool has been designed to: 1) predict an innovation's likely peak extent of adoption and likely time for reaching that peak; 2) encourage users to consider the influence of a structured set of factors affecting adoption; and 3) engage R, D & E managers and practitioners by making adoptability knowledge and considerations more transparent and understandable. The tool is structured around four aspects of adoption: 1) characteristics of the innovation, 2) characteristics of the population, 3) actual advantage of using the innovation, and 4) learning of the actual advantage of the innovation. The conceptual framework used for developing ADOPT is described.

Lichtenberg, E. (1989). Land Quality, Irrigation Development and Cropping Patterns in the Northern High Plains. *American Journal of Agricultural Economics*, 71(1), 187-194.
Water scarcity is likely to increase in the coming years, making improvements in irrigation efficiency increasingly important. An emerging technology that promises to increase irrigation efficiency substantially is a wireless irrigation sensor network that uploads sensor data into irrigation management software, creating an integrated system that allows real-time monitoring and control of moisture status that has been shown in experimental settings to reduce irrigation costs, lower plant loss rates, shorten production times, decrease pesticide application, and increase yield, quality and profit. The author uses an original survey to investigate likely initial acceptance, ceiling adoption rates and profitability of this new sensor network technology in the nursery and greenhouse industry.

Lilien, G. L.; Yoon, E. (1990). The Timing of Competitive Market Entry: An Exploratory Study of New Industrial Products. *Management Science*, 36(5), 568-585.
In a dynamic, competitive environment, the decision to enter the market should be timed to balance the risks of premature entry against the missed opportunity of late entry. Previous research has mainly focused on the strategic aspects of the entry-time decision. In this paper we review the literature and develop a set of propositions about the timing of new product entry. Then we empirically test the relationship between the market-entry time and the likelihood of success for new industrial products.

Lin, J. Y. (1991). Education and Innovation Adoption in Agriculture: Evidence From Hybrid Rice in China. *American Journal of Agricultural Economics*, 73(3), 713-723.

Linder, J.R.; Dolly, D. (2012). Extension and Outreach: Not a Question of if, but How. *Journal of International Agricultural and Extension Education*, 19(3), 1-9.
This article offers ten ideas to create an effective extension and outreach service in developing countries. Based on experiences and research and those of leading scholars and practitioners in the field, effective extension systems must: be institutionalized, well-defined and well-funded; address important/contemporary issues/problems; be sufficiently nimble and flexible in order to address emerging issues; be a credible and unbiased source for information/education and solutions/research; understand the needs of its customers; embrace participatory and integrated approaches; recognize that little happens in isolation and create regional/global sustainable partnership/linkages with governments, NGOs, researchers and educators; be excellent stewards of resources acquired; recognize that return on investment (ROI) from its research and outreach must be well-documented; and allow for decentralized decision-making and action when warranted.

Lowenberg-DoBoer, J. (1998). *Adoption Patterns for Precision Agriculture, No. 982041*. Society of Automotive Engineers.
Early experience with precision farming technology suggests that some hardware and software may follow a rapid S-curve adoption path, but that the use of integrated precision farming systems may take longer to develop and be subject to false starts and periods of stagnation. Yield monitors appear to be following a classic S-curve

adoption path. Precision farming adoption is like that of hybrid corn because changes in organizations will be required to use it effectively. It is like motorized mechanization because it is coming on the market in an immature form and lends itself to farmer tinkering.

Lowenberg-DoBoer, J.; Griffin, T.W. (2005). Worldwide Adoption and Profitability of Precision Agriculture: Implications for Brazil. *Revista de Politica Agricola*. 14(4).

Mahajan, V.; Muller, E.; Bass, F. M. (1991). New Product Diffusion Models in Marketing: A Review and Directions for Research. *Diffusion of Technologies and Social Behavior*. Berlin, Heidelberg, Springer. 125-177
This article reexamines the structural and conceptual assumptions and estimation issues underlying the diffusion models of new product acceptance. The authors evaluate these developments for the previous two decades and conclude with a research agenda to make diffusion models theoretically more sound and practically more effective and realistic.

Mahajan, V.; Peterson, R. A. (1978). Innovation Diffusion in a Dynamic Potential Adapter Population. *Management Science* 24, 1589–1597.

Mas, Ignacio; Morawczynski, Olga. (2009). Designing Mobile Money Services Lessons from M-PESA. *Innovations.* MIT Press Journals, 4(2), 77-91.
This article explores why M-PESA has grown so rapidly within the Kenyan context and explains its cross-border appeal. M-PESA is not the only mobile money service to be launched in Africa, but it is the most successful. For example, South Africa's WIZZIT has managed to attract 250,000 customers in four years of operation. Neighboring Tanzania launched its own version of M-PESA in April 2008, but it has only recently crossed the 100,000-customer mark.

McRoberts, Neil; Franke, A. C. (2008). *A Diffusion Model for the Adoption of Agricultural Innovations in Structured Adopting Populations,* No. 61117.
The authors introduce a new model for examining the dynamics of uptake of technological innovations in agricultural systems, using the adoption of zero-till wheat in the rice-wheat system in Haryana state, India, as a case study. A new equation is derived which describes the dynamics of adoption over time and takes into account the effect of aggregation (e.g. on a spatial and/or cultural basis) in the adopting population on the rate of adoption. The model extends previous phenomenological models by removing the assumption of homogeneity in the non-adopting fraction of the population. We show how factors affecting the per capita rate of adoption can be captured using cognitive mapping and simulate the dynamics of the adoption process.

Meade, N., & Islam, T. (2006). Modeling and Forecasting the Diffusion of Innovation-A 25-year review. *International Journal of Forecasting*, 22(3), 519-545.
The wealth of research into modeling and forecasting the diffusion of innovations is impressive and confirms its continuing importance as a research topic. The main models of innovation diffusion were established by 1970. (Although the title implies that 1980 is the starting point of the review, we allowed ourselves to relax this constraint when necessary.) Modeling developments in the period 1970 onwards have been in modifying the existing models by adding greater flexibility in various ways. The objective here is to review the research in these different directions, with an emphasis on their contribution to improving on forecasting accuracy, or adding insight to the problem of forecasting.

Moser, Christine; Barrett, M.; Christopher, B. (2006). The Complex Dynamics of Smallholder Technology Adoption: the Case of SRI in Madagascar. *Agricultural Economics*, 35(3), 373-388.
This article explores the dynamics of smallholder technology adoption, with particular reference to a high-yielding, low external input rice production method in Madagascar. The authors present a simple model of technology

adoption by farm households in an environment of incomplete financial and land markets. The authors use a probit model and symmetrically censored least squares estimation of a dynamic tobit model to analyze the decisions to adopt, expand, and disadopt the method. We find that seasonal liquidity constraints discourage adoption by poorer farmers. Learning effects—both from extension agents and from other farmers—exert significant influence over adoption decisions.

Moussa, B.; Otoo, M.; Fulton, J.; Lowenberg-DeBoer, J. (2009). Evaluating the Effectiveness of Alternative Extension Methods: Triple-Bag Storage of Cowpeas by Small-Scale Farmers in West Africa. Selected Paper prepared for presentation at the Agricultural & Applied Economics Association.
This study examined two questions related to the adoption of triple-bag storage technology for farmers storing cowpeas in West Africa. First the effect of an extension program, focused on village demonstrations, on adoption was considered. Second, the effect of radio messages to augment this extension program was analyzed. The results indicate that adoption was positively affected by the extension program and radio messages do augment the effectiveness.

Moussa, B.; Abdoulaye, T.; Coulibaly, O.; Baributsa, D.; Lowenberg-DeBoer, J. (2014). Adoption of On-farm Hermetic Storage for Cowpea in West and Central Africa in 2012. *Journal of Stored Products Research*.
This study is based on interviews with 3456 randomly selected cowpea farmers in 322 villages in ten countries in West and Central Africa in 2010 and 2012. It uses descriptive statistics to track the trends in adoption of cowpea storage technology compared to previous studies and Firth logistic regression to identify important factors in adoption. The interviews indicate that regionally about 46% of respondents use some type of hermetic storage for their cowpeas and about 44% of the quantity of cowpea stored on farms is in hermetic containers. Both the percentage of respondents and the percentage of stored quantity fall slightly short of the 50% benchmark hypothesized. The 2010–2012 estimates compare to about 30% of cowpea quantity stored in hermetic containers in 2003–2004. Regionally, the most commonly used hermetic storage container is the triple layer Purdue Improved Cowpea Storage (PICS) bag.

Meyer, JW; Rowan, B. (1977). Institutionalized Organizations: Formal Structure as Myth and Ceremony. *American Journal of Sociology*, 83, 440–463.
This article argues that the formal structure of many organizations in post-industrial society dramatically reflect the myths of their institutional environment instead of the demands of their work activities. The authors review prevailing theories of the origins of formal structures and the main problem which those theories confront. Namely, that their assumption of successful coordination and control of activities are responsible for the rise of modern formal organization are not substantiated by empirical evidence. Rather, there is a great gap between the formal structure and the informal practices that govern actual work activities. The authors present an alternative source for formal structures by suggesting that myths embedded in the institutional environment help to explain the adoption of formal structures. Earlier sources understood bureaucratization as emanating from the rationalization of the workplace. Nevertheless, the observation that some formal practices are not followed in favor of other unofficial ones indicates that not all formal structures advance efficiency as a rationalized system would require. Therefore another source of legitimacy is required. This is found in conforming the organization's structure to that of the powerful myths that institutionalized products, services, techniques, policies and programs become.

Negassa, A.; Hellin, J.; Shiferaw, B. (2012). *Determinants of Adoption and Spatial Diversity of Wheat Varieties on Household Farms in Turkey.* CIMMYT.
Explores the determinants behind adoption of wheat varieties in Turkey, household size, the number of owned cattle, the number of buildings on farm, farm size, farm land fragmentation, the percentage of irrigable farm plots and regional variations are the important factors in determining the farmers' first-stage choice of wheat variety types.

New Growth International. (2009). *Science and Innovation for African Agricultural Value Chains: Lessons Learned in Transfer of Technologies to Smallholder Farmers in Sub-Saharan Africa*. Meridian Institute.
This report was prepared by New Growth International (NGI) for the Meridian Institute under an initiative that aims to identify out-of-the-box innovative technology options that add significant value for smallholder farmers by reducing inefficiencies in the cassava, dairy and maize value chains in sub-Saharan Africa. The report reviews lessons learned from historical attempts (successful and unsuccessful) to implement technologies in selected commodity value chains in African agriculture.

Padel, S. (2001). Conversion to Organic Farming: A Typical Example of the Diffusion of an Innovation? *Sociologia Ruralis*, 41(1), 40-61.
This paper reviews a large number of studies of organic farmers carried out in several countries over a period of about twenty years, and critically assesses whether or not the results appear to fit the framework of the adoption/diffusion model. After a summary of the adoption/diffusion model and a short description of organic farming and its development in Europe, the personal and social characteristics of early adopters of other innovations are compared with the conversion process to organic farming. Most of the studies reviewed, particularly the earlier ones, were carried out at a time when the organic sector was small and the diffusion of organic farming was at the so-called innovation stage. The first organic farmers showed similar characteristics to innovators of other environmental innovations and faced problems that were typically associated with this stage, such as opposition in the farming community and social isolation. Several similarities between the studied organic farmers and early adopters of other innovations were identified and the overall conclusion appears therefore justified that the model can be used to gain some further understanding of the diffusion processes of organic farming and the individual adoption or conversion decision.

Pannell, A; Marshall, D. J.; Barr, B, G. R.; Curtis, C, N.; Vanclay, D, A.; Wilkinson C, R. (2006). Understanding and Promoting Adoption of Conservation Practices by Rural Landholders. *Australian Journal of Experimental Agriculture*, 46, 1407-1424.
Research on the adoption of rural innovations is reviewed and interpreted through a cross-disciplinary lens to provide practical guidance for research, extension and policy relating to conservation practices. Adoption of innovations by landholders is presented as a dynamic learning process. Adoption depends on a range of personal, social, cultural and economic factors, as well as on characteristics of the innovation itself. Adoption occurs when the landholder perceives that the innovation in question will enhance the achievement of their personal goals. A range of goals is identifiable among landholders, including economic, social and environmental goals.

Perez-Aleman, Paola. (2011). Collective Learning in Global Diffusion: Spreading Quality Standards in a Developing Country Cluster. *Organization Science*, 22,(1), 173-189.
This research analyzes how foreign organizational practices diffuse among indigenous enterprises in a developing economy. It highlights the collective knowledge-building process as central for understanding diffusion. Based on a longitudinal case study of a cluster of dairy producers in Nicaragua, a representative low-income country, it looks at cross-border diffusion in conditions that differ significantly from advanced economies. The current literature that highlights institutional pressures driving global spread of practices has limits for capturing a significant dynamic caused by increased integration of markets and production.

Peres, Renana, et al. (2010). Innovation Diffusion and New Product Growth Models: A Critical Review and Research Directions. *Research in Marketing*, 27, 91-106.
In this paper, diffusion modeling literature is reviewed from the early 1990s and analyzed for how diffusion research has broadened its scope to describe the richness and phenomena related to new product growth. We focus on studies that explore six questions related to (1) the drivers of growth, (2) the shape of the product life-cycle curve, (3) the relationships between individual adoptions and aggregate growth, (4) marketing mix influences, (5) cross-country influences, and (6) the effect of competition on growth.

Prahalad, C.K. (2012). Bottom of the Pyramid as a Source of Breakthrough Innovations. *Journal of Product Innovation Management*, 29(1), 6–12.
In this paper, the author identifies the bottom of the pyramid (BOP) markets as a new source of radical innovation. By focusing managerial attention on creating awareness, access, affordability, and availability (4As), managers can create an exciting environment for innovation. He suggests that external constraints can be utilized to build an innovation sandbox within which new products and business models can be created. Using a live example of such an innovation—the development of the biomass stove for the rural poor in India—he illustrates the process and the usefulness of the approach. Increasingly, global firms are recognizing the implications of innovations at the BOP for developed markets as well.

Ratt, Jon D. (2008). Applying the Bass Adoption Curve to Innovative New Venture Earnings. *American Journal of Entrepreneurship*, 21-44.
The S-shaped innovation adoption curve described by the Bass (1969) model is applied to earnings of firms, which introduce new innovative products. These earnings streams often grow slowly, then accelerate rapidly, and finally, plateau at a constant rate so that the Bass model is useful in describing them. Examples of firms whose earnings can be fitted to this S-shaped pattern during new product introductions are identified. Estimating future earnings using the Bass model may assist founding entrepreneurs and other early stage investors in estimating the future value of their investments and in timing their exit strategies.

Robinson, William T., and Min, Sungwook. (2002). Is the First to Market the First to Fail? Empirical Evidence for Industrial Goods. *Journal of Marketing Research*, 39, 120-128.
Research estimates the market pioneer's survival rate, the typical pioneer's survival rate has not been compared with that of early followers. The authors' study compares survival rates for 167 first-entrant market pioneers versus 267 early followers. The main conclusion is that pioneers' temporary monopoly over the early followers plus its first mover advantages typically offset the survival risks associated with market and technological uncertainties.

Rogers, E.M. (1976). New Product Adoption and Diffusion. *Journal of Consumer Research*, 2, 290 -301.
This paper summarizes what we have learned from research on the diffusion of innovations that contributes to understanding new product adoption, discusses how the background of diffusion research affected its contributions and shortcomings, and indicates future research priorities. Diffusion research has played an important role in helping put social structure back in the communication process. Network analysis and field experiments are promising tools in diffusion studies. The diffusion model has aided our understandings of the consumption of new products.

Rogers, E.M. (1995). *Diffusion of innovations (4th edition).* The Free Press. New York.
In this fourth edition, Rogers presents the culmination of more than thirty years of research that will set a new standard for analysis and inquiry. The fourth edition is (1) a revision of the theoretical framework and the research evidence supporting this model of diffusion, and (2) a new intellectual venture, in that new concepts and new theoretical viewpoints are introduced. This edition differs from its predecessors in that it takes a much more critical stance in its review and synthesis of 5,000 diffusion publications. During the past thirty years or so, diffusion research has grown to be widely recognized, applied and admired, but it has also been subjected to both constructive and destructive criticism. This criticism is due in large part to the stereotyped and limited ways in which many diffusion scholars have defined the scope and method of their field of study. Rogers analyzes the limitations of previous diffusion studies, showing, for example, that the convergence model, by which participants create and share information to reach a mutual understanding, more accurately describes diffusion in most cases than the linear model.

Rogers, M.E. (2003), *Diffusion and Innovations, 5th ed.*, Simon and Schuster. ISBN 978-0-7432-5823-4.
Rogers explains how new ideas spread via communication channels over time. Such innovations are initially perceived as uncertain and even risky. To overcome this uncertainty, most people seek out others like themselves who have already adopted the new idea. Thus the diffusion process consists of a few individuals who first adopt an innovation, then spread the word among their circle of acquaintances—a process which typically takes months or years. But there are exceptions: use of the Internet in the 1990s, for example, may have spread more rapidly than any other innovation in the history of humankind. Furthermore, the Internet is changing the very nature of diffusion by decreasing the importance of physical distance between people. The fifth edition addresses the spread of the Internet, and how it has transformed the way human beings communicate and adopt new ideas.

Ruttan, V. (1996). What happened to technology adoption diffusion research? *Sociologia Ruralis* 36, 51-73.
This article discusses the diffusion of technology, culture, and knowledge in a social change context and explains why adoption-diffusion almost disappeared from the sociology research agenda.

Satoyama, Takanori, et al. (2014). Getting to Scale with Successful Experiences in Rice Sector Development in Africa: Best Practices and Scalability Assessments. *Coalition for African Rice Development (CARD) Secretariat Report.*
With the financial support of the International Fund for Agricultural Development (IFAD), the CARD secretariat decided to take stock of such successful experiences, and examined their applicability to other African countries. In this stocktaking exercise, models were collected from eight countries. Though not exhaustive, these models cover almost the entire rice value chain from policy formulation to provision of inputs and extension services, production, land management, marketing, financing, and irrigation management. Although each of these models relates to only one or two segments of the value chain, the models as a set provide implications in quite comprehensive domains.

Scandizzo, P. L.; Savastano, S. (2010). The Adoption and Diffusion of GM Crops in United States: A Real Option Approach.
This article aims at modeling adoption and diffusion decisions of farmers towards genetically modified crops under a real option framework. Modern GM crops help farmers to resolve two main sources of uncertainty: output uncertainty and input uncertainty. Those crops represent a revolutionary form of farming compared to the technology adoption studied in the literature in the late 1970s and early 1980s.

Schmitz, A., & Seckler, D. (1970). Mechanized Agriculture and Social Welfare: The Case of the Tomato Harvester. *American Journal of Agricultural Economics*, 52, 569-577.
An integrated public-private approach to mechanical harvesting of tomatoes for canning has sharply reduced producers' labor requirements. Gross social returns to aggregate research and development expenditures are in the vicinity of 1,000%. Even if displaced labor had been compensated for wage loss, net social returns are still highly favorable. Since tomato pickers were unorganized, no compensation was demanded or paid. The analysis indicates a need for policies designed to distribute the benefits and costs of technological change more equitably. Social scientists could properly be concerned with developing institutional means of achieving this goal.

Sorgenfry, Mark; Munch, Lasse. (2009). *Strategies for Market Entry: Fast Moving Consumer Goods Companies in Emerging Markets.* Aarhus School of Business.
This thesis takes a look at how MNEs in the FMCG industry enter new emerging markets. In order to gain an understanding of this the paper looks at three specific markets, namely Russia, India and China.

Spielman, David J.; Ekobir, Javier; Davis, Kristin. (2009). *The Art and Science of Innovation System Inquiry: Applications to Sub-Saharan African Agriculture.* International Food Policy Research Institute.
Agricultural education, research and extension can contribute substantially to enhancing agricultural production

and reducing rural poverty in many parts of the developing world. However, evidence suggests that their contributions are falling short of expectations when it comes to Sub-Saharan Africa; where agriculture continues as the region's primary source of livelihood. The entry of new actors, technologies, and market forces, when combined with new economic and demographic pressures, suggests the need for more innovative and less linear approaches to exploiting new opportunities and overcoming constraints.

Steele, James. (2007). *Innovation Diffusion and Travelling Waves. Pattern and Process in Cultural Evolution. This paper examines the dynamics of innovation diffusion by illustrating the difficulty of using changing frequency distributions to diagnose a particular social learning process. It begins by discussing an influential model of new product diffusion taken from the marketing science literature. The model described estimates the importance of social imitation (or contagion) in the temporal evolution of frequencies of adopters for new consumer durables.*

Stefanides, Zdenko; Tauer, Loren W. (1999). The Empirical Impact of Bovine Somatotrapin on a group of New York Dairy Farms.
Data from a panel of New York Dairy farms were used to estimate rbST adoption functions, and to measure the impact of rbST on milk output and profitability per cow. Adoption results are consistent with previous rbST adoption studies. Farm size, productivity and education of the principal operator are the most important explanatory variables influencing adoption. The use of rbST was found to significantly increase milk output per cow net of other explanatory variables, correcting for self-selection with respect to rbST use. The impact on profits, was, however, not statistically different from zero at any conventional statistical significance level.

Stephenson, G. (2003). The Somewhat Flawed Theoretical Foundation of the Extension Service. *Journal of Extension*, 41(4), 1-7.
In this article written by a US extension practitioner, Stephenson poses tough questions about utilizing innovation diffusion theory, and whether having extension agents cause harm to the population they serve due to the model's favoring large wealthy farmers and increasing the inequities in rural areas. He recommends change by realizing that methods can influence which farmers succeed and which farmers are excluded from success.

Strang D.; Meyer JW. (1993). Institutional Conditions for Diffusion. *Theory Soc*., 22, 487–511.
Discussion on the characteristics of an innovation to determine its adoption and diffusion, specifically the study of public versus private consequences of adoption. Most sociological analysis treats diffusion as a primarily, or even exclusively, relational phenomenon. When diffusing practices and adopter identities are rich in social and cultural meaning, however, connectedness seems an insufficient explanatory principle. Our aim is to suggest how institutional conditions operating in wider social systems affect the rate and form of diffusion. We argue that diffusion is importantly shaped and accelerated by culturally analyzed similarities among actors, and by theorized accounts of actors and practices. These institutional conditions are argued to be especially rife in "modern" social systems, and help to account for the intimate connections between social-scientific interest in diffusion and its empirical prevalence.

Sunding, David; Zilberman, David. (2000). *The Agricultural Innovation Process: Research and Technology Adoption in a Changing Agricultural Sector*. Department of Agricultural and Resource Economics, University of California at Berkeley.
The chapter reviews the generation and adoption of new technologies in the agricultural sector. The first section describes models of induced innovation and experimentation, considers the political economy of public investments in agricultural research and addresses institutions and public policies for managing innovation activity. The second section reviews the economics of technology adoption in agriculture. Threshold models, diffusion models, and the influence of risk, uncertainty, and dynamic factors on adoption are considered. The section also describes the influence of institutions and government interventions on adoption. The third section outlines future research and policy challenges.

Swinton, S. M.; Lowenberg-DeBoer, J. (2001). Global Adoption of Precision Agriculture Technologies: Who, When and Why. Proceedings of the 3rd European Conference on Precision Agriculture, 557-562.
The adoption of precision agriculture technologies has been uneven, both geographically and temporally. The economic theory of induced innovation predicts that new technologies will be developed and adopted where they make more efficient use of the scarcest productive resources. Indeed, adoption of precision agriculture technologies has been fastest where labor is costly but land and capital are relatively less costly. Where precision agriculture is being adopted, the uneven adoption rate is tied to normal cycles for replacing the expensive machinery in which many precision agriculture technologies are embodied.

Talukdar, D.; Sudhir, K.; Ainslie, A. (2002). Investigating New Product Diffusion Across Products and Countries. *Marketing Science*, 21(1), 97-114.
As firms jockey to position themselves in emerging markets, they need to evaluate the relative attractiveness of market expansion in different countries. Since the attractiveness of a market is a function of the eventual market potential and the speed at which the product diffuses through the market, a better understanding of the determinants of market potential and diffusion speed across different countries is of particular relevance to firms deliberating their market expansion strategies. Despite a recent spurt in research on multinational diffusion, there exist significant gaps in the literature. First, existing studies tend to limit their analysis to industrialized countries, thus reducing the ability to generalize the insights to many emerging markets. Second, these studies tend to focus on the coefficients of external and internal influence in the Bass diffusion model but do not analyze the determinants of market potential. Third, the choice of variables that affect the parameters of the Bass diffusion model has been rather limited.

Tam, Vikki, et al. (2014). *Growing Prosperity: Developing Repeatable Models to Scale the Adoption of Agricultural Innovations.* Bain & Company with Acumen.
This overview introduces the challenges facing the developing world's smallholder farmers who rely on agriculture for their livelihood. By adopting products and services from pioneer firms, these customer farmers could improve their lives and the lives of future generations.

Tellis, G. J. (2012). *Unrelenting Innovation: How to Create a Culture for Market Dominance*. John Wiley & Sons.
Tellis informs on how the culture of a firm is the crucial driver of an organization's innovativeness and describes the three traits and three practices necessary to create a culture of relentless innovation. Organizations must be willing to cannibalize successful products, embrace risk, and focus on the future. Organizations build these traits by providing incentives for enterprise, empowering product champions and encouraging internal markets. Spelling out the critical role of culture, the author provides illustrative examples of organizations with winning cultures and explores the theory and evidence for each of the six components of culture. The book concludes with a discussion of why culture is superior to alternate theories for fostering innovation.

Tellis, Gerard J.; Stremersch, Stefan; Yin, Eden. (2003). The International Takeoff of New Products: The Role of Economics, Culture and Country Innovativeness. *Marketing Science*, 22(2), 188-208.
Sales takeoff is vitally important for the management of new products. Limited prior research on this phenomenon covers only the United States. This study addresses the following questions about takeoff in Europe: 1) Does takeoff occur as distinctly in other countries, as it does in the United States? 2) Do different categories and countries have consistently different times-to-takeoff? 3) What economic and cultural factors explain the intercountry differences? 4) Should managers use a sprinkler or waterfall strategy for the introduction of new products across countries? The authors adapted the threshold rule for identifying takeoff (Golder and Tellis 1997) to this multinational context.

Tellis, G. J.; Johnson, J. (2007). The Value of Quality. *Marketing Science*, 26(6), 758–773.
Product quality is probably undervalued by firms because there is little consensus about appropriate measures and methods to research quality. We suggest that published ratings of a product's quality are a valid source of quality information with important strategic and financial impact. We test this thesis by an event analysis of abnormal returns to stock prices of firms whose new products are evaluated in The Wall Street Journal. Quality has a strong immediate effect on abnormal returns, which is substantially higher than that for other marketing events assessed in prior studies. Moreover, there are some important asymmetries in the effect. We discuss the research, managerial, investing, and policy implications.

Tellis, G., Schneider, J., Hall, J. (2013). "The Long Road to Takeoff."
Online. http://thebuildnetwork.com/innovation/product-adoption/

Trigo, Eduardo J; Cap, Eugenio J. (2003). The Impact of the Introduction of Transgenic Crops in Argentinean Agriculture. *AgBioForum*, 6(3), 87-94.
Since the early 1990s, Argentinean grain production underwent a dramatic increase in grains production (from 26 million tons in 1988/89 to over 75 million tons in 2002/2003). Several factors contributed to this "revolution," but probably one of the most important was the introduction of new genetic modification (GM) technologies, specifically herbicide-tolerant soybeans. This article analyses this process, reporting on the economic benefits accruing to producers and other participating actors as well as some of the environmental and social impacts that could be associated with the introduction of the new technologies.

Van Everdingen, Y.; Fok, D.; Stremersch, S. (2009). Modeling Global Spillover of New Product Takeoff. *Journal of Marketing Research*, 46(5), 637-652.
This article examines the global spillover of foreign product introductions and takeoffs on a focal country's time to takeoff, using a data set of penetration data for eight high-tech products across 55 countries. It shows how foreign clout, the susceptibility to foreign influences, and inter-country distances affect global spillover patterns. The authors find that foreign takeoffs, but not foreign introductions, accelerate a focal country's time to takeoff. The larger the country, the higher its economic wealth, and the more it exports, the more clout it has in the global spillover process. In contrast, the poorer the country, the more tourists it receives, and the higher its population density, the more susceptible it is to global spillover effects. Cross-country spillover effects are stronger the closer the countries are to one another, both geographically and economically, but not necessarily in terms of culture. The model the authors develop also quantifies the spillover between each country pair, allowing it to be asymmetric.

Vodafone Brings Africa's M-Pesa Mobile Money to Europe. (2014). Reuters.
This article describes M-Pesa's expansion into Romania and mentions further expansion plans into other middle-income countries in Eastern Europe.

Weimann G, Hans-Bernd B. (1994). Is There a Two-step Flow of Agenda-setting? *Int. J. Publ. Opin. Res*, 6, 323–341
This article discusses the personal characteristics that have relevance to the adoption of innovations, including self-confidence and independence or psychological strength.

Wejnert, Barbara. (2002). Integrating Models of Diffusion of Innovations: A Conceptual Framework. *Annual Review of Sociology,* 297-326.
This source provides a conceptual framework for integrating the array of variables defined in diffusion research to explicate their influence on an actor's decision to adopt an innovation. The framework groups the variables into three major components. The first component includes characteristics of the innovation itself. A second component involves the characteristics of innovators (actors) that influence the probability of adoption of an

innovation. The third component involves characteristics of the environmental context that modulate diffusion via structural characteristics of the modern world.

Wollni, M.; Andersson, C. (2013). *Spatial Effects in Organic Agriculture Adoption in Honduras: the Role of Social Conformity, Positive Externalities, and Information.* 2013 Annual Meeting, August 4-6, 2013, Washington, DC (No. 149911). Agricultural and Applied Economics Association.
In this article we test various potential explanations, including the availability of information in the farmer's neighborhood, social conformity concerns and perceived positive external effects of the adoption decision, in a spatially explicit adoption model. We find that farmers who believe to act in accordance with their neighbors' expectations and with greater availability of information in their neighborhood network are more likely to adopt organic agriculture. Furthermore, perceived positive productivity spillovers to neighboring plots decrease the probability of adoption. We discuss the implications of our findings for the dissemination of sustainable agricultural technologies in low-potential agricultural areas in developing countries.

Wright, V. (2011). Rates of Adoption: The Diffusion of Agricultural Innovations. Victorian Government Department of Primary Industries.
Predicting rates of adoption, and how they might be influenced, requires an in-depth, detailed understanding of the adoption process; more so than is the case in regard to predicting the extent of adoption. The question arises as to how to characterize the adoption process of farmers.

Zepeda, L. (1990) Predicting Bovine Somatotropin Use by California Dairy Farmers. *Western Journal of Agricultural Economics*, 55-62.
An ex ante adoption model of bovine somatotropin is estimated with survey data of California milk producers. Theoretical justification is developed for incorporation of socioeconomic explanatory variables in a technology-adoption model. The advantages of a multinomial over a binomial ex ante are also presented.

ANNEX B: INNOVATION DIFFUSION AND NEW PRODUCT GROWTH MODELS

Taken from Peres et al., 2009.

Table 1: Major research trends

	Subject	Research up to 1990	Research since 1990	Directions for further research
Growth mechanisms	What drives growth?	Homogenous social network Word of mouth communications as the main growth driver	Consumer heterogeneity (such as adopter categories and price sensitivity) as an alternative driver, especially during early growth Additional growth drivers: informational cascade and network externalities	A unified framework for heterogeneity and diffusion Variety of growth drivers: communications, signals, network externalities Shadow diffusion processes
	What is the shape of the life cycle curve?	Antecedents and estimation of inflection points and maximum sales in the Bass model	Other turning points: commercialization takeoff, saddles, and slowdown The shape of the growth curve of successive technology generations Acceleration of diffusion processes over time	Takeoff as an integral part of diffusion modeling A comprehensive model for technological substitution
	How do individual adoption decisions affect aggregate growth?	Mainly aggregate-level modeling	Aggregate- and individual-level modeling; use of agent-based modeling and social network concepts	Individual-level and social network models becoming a major trend Networks with partial connectivity Disentangle the hierarchy of effects in adoption Multi-user adoption units
Implementation	What are the marketing mix influences on growth?	Type of products: durables Marketing mix variables are not included in the model. Marketing mix variables: mainly price and advertising	Type of products: durables and services; intensive research on entertainment diffusion Integrated models with marketing mix variables Marketing mix variables: mainly price	Type of products: services, online services Marketing mix variables: product and distribution channels (place)
	How do cross-country interactions influence growth?	Mainly single-market in Western countries	International aspects: differences in growth patterns between countries; cross-country effects Optimal global entry strategies Diffusion of innovations in the developing world	Marketing mix decisions under global awareness Marketing mix decisions under the demographic changes caused by mass immigration waves
	What is the effect of competition on growth?	Category-level models	Models on competitive diffusion and brand-level analysis The effect of disadoption and churn	Do firms compete for the same market potential? Complex competitive structure along the distribution chain The mechanisms of brand choice (1-step vs. 2-step process)

Table 2: Turning points in the product life cycle

Stage in life cycle	Main research focus	Paper	Data	Results
Takeoff	Sources that influence time to takeoff	Golder and Tellis 1997	31 US innovations launched 1898-1990	Price Market penetration
		Agarwal and Bayus 2002	30 US innovations launched 1849-1984	Entry of firms (a proxy for demand side) Price decline Demand-side explanation dominant
		Tellis, Stremersch, and Yin 2003	10 durables in 16 European countries	Region (Scandinavia faster than Mediterranean) Product type (brown goods (CD, TV) take off faster) Cultural factors (uncertainty avoidance and masculinity) Later entry time (leads to shorter takeoffs)
		Foster, Golder, and Tellis 2004	40 US innovations	Time frame (WWII, 1965, 1980) Category Price
		Goldenberg, Libai, and Muller 2007	Fax machines, CB radios, CD players, and DVD players in the US	Network externalities
Saddle	Saddle occurrence and its explanation as a dual-market phenomenon	Goldenberg, Libai, and Muller 2002	32 US consumer electronic innovations launched 1950-1985	A saddle exists in between 1/3 and ½ of the cases. Average relative depth is 25%, with duration of four years. Saddle is created by cross-market communication gap.
		Muller and Yogev 2006	35 US consumer electronic innovations launched 1950	Dual markets (early and main market) were reported in 26 of the 35 cases. Average adoption at time wherein early and main market curves intersect is 16%.
		Van den Bulte and Joshi 2007	33 data sets of three categories: antibiotics; music CDs; high-tech products.	A dual-market model can predict saddles.
Other turning points	Incubation time (the time between invention and launch)	Kohli, Lehmann, and Pae 1999	32 US durables in three categories, USA, 1922-1992	Incubation time has a chilling effect on the p and q of the category.
	Commercialization, takeoff, and slowdown	Golder and Tellis 2004	30 US innovations launched 1929-1990	Both diffusion and informational cascade were found to be significant. In the average sales figures, a saddle was observed.

Table 5: Multinational Diffusion – Cross country influences*

Research focus	Paper	Description / Model	Data	Results
Existence of cross-country influences	Elberse and Eliashberg 2003	An econometric model testing the connection between a film's performance in the domestic market and its performance in foreign markets	164 films. Domestic: US; foreign: France, Germany, Spain	1. Domestic performance influences foreign availability and revenues. 2. This influence decreases with the time lag between domestic and foreign launches.
Multinational diffusion models	Eliashberg and Helsen 1996	$\frac{dx_i}{dt} = (1 - x_i)(p_i + q_i x_i + \delta x_j)$	VCRs in 13 European countries; sales data of a single firm	1. Mostly $\delta < q$, might be negative. 2. There is a flow from big countries to small countries.
	Ganesh and Kumar 1996	$\frac{dx_i}{dt} = (1 - x_i)(p_i + q_i x_i + \delta x_j)$	B2B durables: supermarket scanners in US, Japan, and eight European countries	Cross-country influence δ is positive and significant.
	Ganesh, Kumar, and Subramanian 1997	What influences Ganesh and Kumar's (1996) δ? Test empirically geographical proximity; cultural similarity; economic similarity; continuous / radical innovation; existence of standards; entry time lag.	Four durables, 15 European countries tested in pairs	The learning effect is influenced by cultural similarity; economic similarity; continuous / radical innovation; existence of standards; and entry time lag. It is not affected by geographic proximity!
	Kumar and Krishnan 2002	$\frac{dx_i}{dt} = (1 - x_i)(p_i + q_i x_i) \cdot \sum_{j \neq i}^{N} (1 + \delta_{ij} \frac{dx_j}{dt})$	Case studies of three durables in six European countries, tested in pairs	Influences exist in all directions: lead <> lag, lag <> lead, and simultaneous.
	Putsis et al. 1997	$\frac{dx_i}{dt} = (1 - x_i)(p_i + q_i x_i + \sum_{j \neq i} \delta_{ij} x_j)$	Four durables in products 10 European countries	Countries with strong external connections affect other countries. Therefore they should be the first to begin with.
	Van Everdingen, Aghina, Fok, 2005	Use the same model as Putsis et al., but with dynamic parameters	Internet access, landline, and cellular telephony in 15 EC countries	Using dynamic parameters provides better fit and forecast.
Entry Strategy	Kalish, Mahajan, and Muller 1995	A game theoretic optimization model for a monopoly and a competitive scenario, to study which entry strategy is better: simultaneous, or sequential		When conditions in foreign markets are unfavorable (slow growth or low innovativeness), competitive pressure is low, and fixed entry costs are high, then sequential entry is preferable.
	Libai, Muller, and Peres 2005	Compare three types of dynamically allocated budgets		Dispersing marketing efforts (as in support-the-strong and uniform) Moderators: entry costs, level of responsiveness to advertising

* Mathematical expressions are based on Equation (1) formulation: x_i = cumulative adoption proportion in country i; δ_{ij} – influence parameter of country i on country j; p_i, q_i = external and internal influence parameters for country i.

ANNEX C: "ADOPT" CONCEPTUAL FRAMEWORK

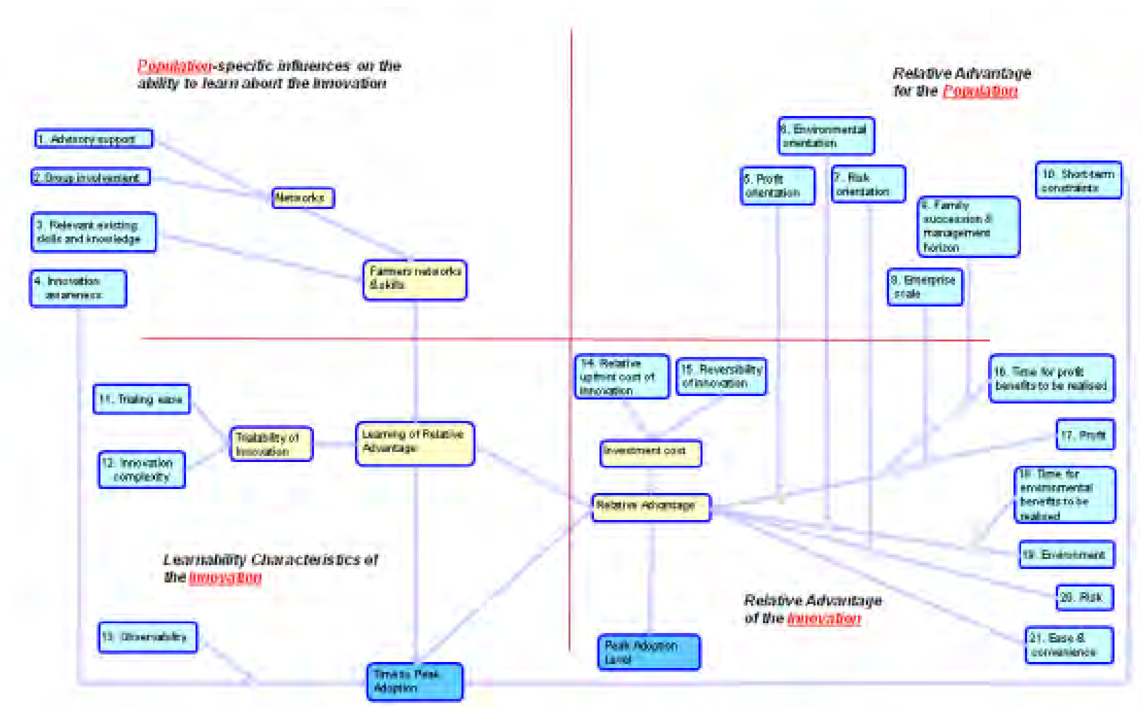
All text and information below was copied directly from the ADOPT manual: Kuehne, G., Llewellyn, R., Pannell, D., Wilkinson, R., Dolling, P., & Ewing, M. (2011). ADOPT: a tool for predicting adoption of agricultural innovations. In *AARES 55th Annual Conference, Crown Conference Centre, Melbourne*.

Adoption Influences Conceptualized as a Quadrant

Population-specific influences on the ability to learn about the innovation	Relative advantage for the population
Learnability characteristics of the innovation	Relative advantage of the innovation

This quadrant is designed as a summary of how the conceptual framework works; it is a simple description of the ambiguity that is an adoption decision.

Conceptual Framework



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The Conceptual Framework shows that the two left-hand quadrants (population-specific influences on the ability to learn about the innovation and the learnability characteristics of the innovation) only influence the time taken to reach peak adoption; they do not influence the peak adoption level (Griliches, 1957). The relative advantage for the population and the relative advantage of the innovation influence both the time taken to reach peak adoption and the peak adoption level. They influence the time taken to reach peak adoption in two ways: short-term constraints have a direct impact while the other variables have a more filtered effect, in that relative advantage also affects the l*earning of relative advantage* node (Griliches, 1957).

ANNEX D: LITERATURE REVIEW STATEMENT OF WORK

Statement of Work (SOW)

Literature Review on Scaling Technologies

Evidence and Lessons for Feed the Future

1. Task Description

This Statement of Work (SOW) outlines the requirements for a review of literature for USAID's Bureau for Food Security (USAID/BFS) addressing the evidence or evidence gaps on innovation diffusion and the related field of market strategy for scaling up new technologies. The E3 Analytics and Evaluation Project, led by Management Systems International (MSI) along with team members Development & Training Services (dTS) and NORC at the University of Chicago, has been requested by USAID/BFS to carry out this literature review.

The review will focus on literature in the marketing and technology diffusion field related to how innovations scale up through forms of diffusion, and will place it in the context of agriculture markets relevant to development in select countries. This review will inform the design of future USAID/BFS' programming related to the scaling of agricultural innovations.

2. Background

The Feed the Future (FTF) initiative is the U.S. government's flagship program in promoting food security in selected developing countries. This Presidential Initiative was created by President Obama in 2009 and is being implemented by USAID in 19 countries: 12 in Africa, 4 in Asia and 3 in the Caribbean and Central America. The goals of FTF are to improve nutrition and reduce poverty, stunting and wasting among the poorest of the poor in target zones known as Zones of Influence (ZOI) in each country. The ZOIs were selected in collaboration with host country governments and are based on contiguous geographic areas characterized by high levels of poverty, stunting and/or wasting.

The principal modalities of FTF have been to identify and prove the cost effectiveness of agricultural innovations that would impact the program's goals. These innovations are of two types: (1) those directly affecting farmers' production and incomes, such as new, high-yielding varieties of staple cereals or better utilization of other inputs like fertilizer and irrigation, and (2) indirectly through interventions to strengthen specific product value chains upstream and downstream from small, poor producers. All FTF programs use a value chain approach, concentrating their efforts on only a few products, and often combine one or more technical innovations with multiple activities to address gaps in the value chain.

From the outset, FTF-supported technical innovations, once proven effective, were expected to be scaled up[14] sustainably. This involves the technology reaching a critical mass of adopters as well as continued access and utilization of the technology by the adopter over the medium-term.[15] Achieving population scale, or at least reaching a "tipping point" (also known in the literature as the "takeoff point") where scaling could continue on its own, is a goal of the FTF programs.

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[14] Scale is defined by FTF as having a significant impact on its goals at the population level in the target ZOI in each country.
[15] Over the longer-term, newer technologies may emerge to take the place of the innovations introduced. Each technology is anticipated to have a lifecycle where after maturity, it is likely to be less relevant as new technologies are identified and introduced.

A key challenge for FTF efforts to scale new technologies is to estimate the potential market demand of an innovation and determine the number of a population that represents the early majority adopters. This information is key to estimating program targets, costs, direct and indirect beneficiaries, and impact monitoring and evaluation.

Scaling pathways relevant to agricultural value chains include specific approaches to pursue secondary adoption and spontaneous diffusion, commercialization and/or strategic partnerships. Secondary adoption and spontaneous diffusion occur once a critical mass of adopters is reached; further adoption continues to grow organically ("go viral"). FTF has emphasized the role of the private sector wherever possible in achieving its goals, and commercialization through the private sector is the preferred pathway for scaling. At the same time, FTF recognizes that strategic partnerships with the public sector or civil society (e.g. NGOs, universities) may need to play an important role. Scaling access and adoption in the FTF ZOIs often includes a combination of the above, where a critical mass of adoption is reached with the appropriate supporting value chain spaces for continued self-generated scaling without additional external support.

3. Purpose, Audience and Intended Uses

The purpose of this literature review is to identify and synthesize existing research, literature and evidence or evidence gaps on innovation diffusion and the related market strategy field, and assess its possible application to agricultural development including USAID/BFS' future programming. In particular, this review may inform USAID's future modeling of S-curves on new agricultural technology adoption in order to better inform planning, budgeting and monitoring and evaluation (M&E) systems. The review will also explore the possibility of developing an innovation diffusion model[16] from the discipline's state-of-the-art experience.

The scope of this review is broad, and it is not anticipated that it will be based upon a comprehensive search of all materials relating to the topic. This literature review instead will be based upon a curated selection of documents that will be most helpful for USAID's understanding of the key relevant literature on the diffusion of innovation.

The primary audience for this review is USAID/BFS staff designing future programming related to the scaling of agricultural innovations (including the Markets, Partnerships and Innovations Office [BFS/MPI]). Additional potential audiences for this study may include overseas Mission staff in the FTF ZOIs, and other units within the Agency examining scaling such as the E3 Bureau and the Global Development Lab.

4. Data Sources

Previous studies on innovation diffusion have largely focused on developed or middle-income countries and on industries outside of agriculture. To ensure that the lessons from this review are relevant for FTF purposes, the literature review will focus on documents relevant to marketing agriculture technologies to maximize adoption and diffusion (e.g., early market entry, market penetration, diffusion forecasting, quantifying the market takeoff point), including experiences in middle and lower middle income countries (and low income countries where possible). The review will seek to identify key conclusions related to market sizing, adoption and diffusion models, takeoff points and any other notable characteristics of innovation markets and marketing.

The review will draw on a range of documents, including academic articles, working papers, discussion papers, book chapters and books and case studies as appropriate. The research team should document all search criteria/terms and databases used to identify relevant literature so that the review can be duplicated.

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[16] "Diffusion modeling" seeks to understand the spread of innovations throughout their life cycle.

5. Gender

In line with USAID's Gender Policy, the literature review will seek to identify any gender-specific and differential effects of scaling experiences identified in the documents being examined. This may include using gender-specific keyword search terms as part of the literature identification process. Any gender-specific and differential effects that are discussed in the literature will be highlighted in the summary analysis.

6. Deliverables

The following deliverables are anticipated under this task:

Deliverable	Estimated Due Date
Draft Literature Review	o/a April 23, 2015
Annotated Bibliography of Key Documents	o/a April 23, 2015
Final Literature Review	o/a two weeks following receipt of USAID comments on the Draft Literature Review

The literature review will identify, consolidate and synthesize the literature on scaling innovations from a marketing perspective. The synthesis and categorization of conclusions in the review will reflect relevance for FTF countries and target adopters.

The Final Literature Review is expected to be up to 15 pages (excluding the executive summary and annexes) and should include the following sections:

- Executive Summary
- Introduction
- Findings
- Conclusions
- Annex: SOW for the Literature Review
- Annex: Annotated Bibliography

7. Team Composition

The literature review is expected to be primarily conducted by two team members: a Team Leader and a Primary Researcher. Additional research support, technical oversight and expertise will provided by the E3 Analytics and Evaluation Project home office team.

Team Leader

A Team Leader will serve as the technical lead on this review, and will have primary responsibility for coordinating the review team's efforts to ensure successful completion of the required deliverables. The Team Lead will serve as a primary technical point of contact for BFS. They should have familiarity with the relevant literature in scaling up and demonstrated knowledge in the scaling of agricultural technologies. The Team Lead should hold at least a master's degree with at least 10 years of experience in their technical sector.

Primary Researcher

A Primary Researcher will carry out the majority of the desk research and synthesis tasks for this review, overseen by the Team Leader. The Researcher should have knowledge of diffusion modeling, agricultural development in developing countries, and USAID's FTF strategy. The expert should hold at least a master's degree with no less than five years of relevant experience.