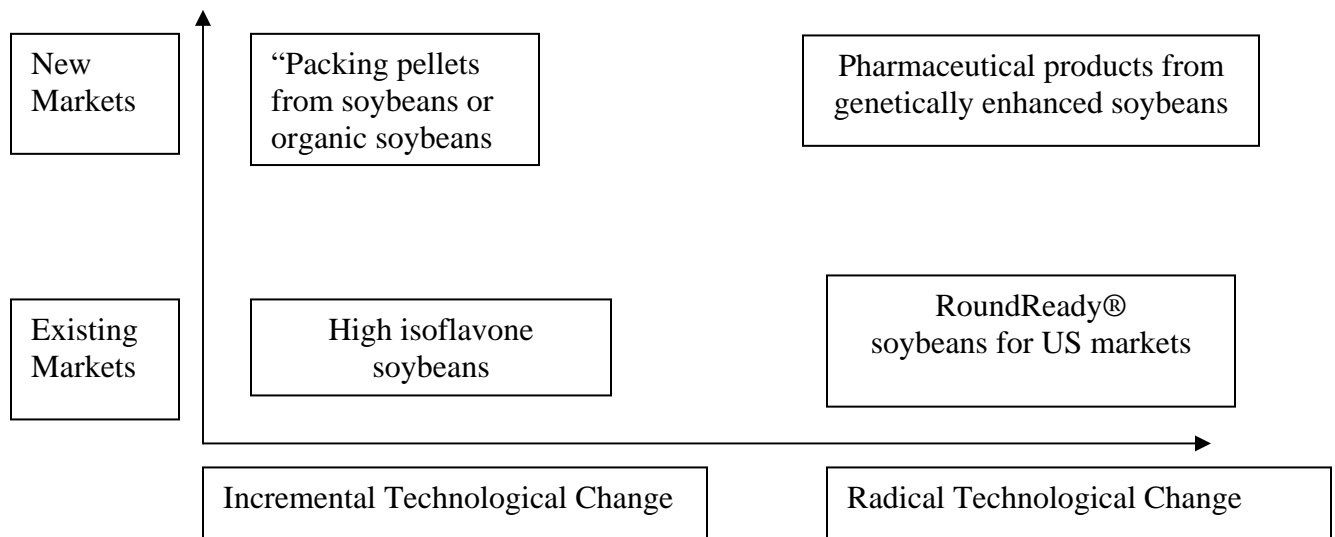


Investigation of Policy and Strategic Implications of Biotechnology Development and Adoption
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The objective of the proposed study is to develop strategic and analytical tools that will inform public and private decision makers regarding the impact of risk and uncertainty associated with disruptive technological change. Because the confluence of nano, bio and information technology represents a dramatic shift in the competitive environment facing the soybean sector, the purpose of the proposed research is to study how best to anticipate endogenous and exogenous uncertainty, and to deal with the impact of technological uncertainty.

Technological change may be either incremental or radical; and these technological changes may result either in changes in existing markets, or be disruptive and result in the creation of new markets altogether (Benner and Tushman, 2003). In Figure 1, we illustrate how the soybean sector can be affected when the dimensions of technological change and market impact are taken into account. The impact of incremental technological change in existing markets represents the least degree of risk and uncertainty, because existing supply chain relationships are maintained in this context. For example, in the mid 1990s, a group of farmers in central Illinois entered into a relationship with a food processor to deliver soybeans produced from varieties shown to have the potential to have higher isoflavone levels. This was a low risk venture for both the producers and their customer, but provided the opportunity for slightly higher profits.

Figure 1: Technological Change and Markets Served in the Soybean Production Industry



As technological change becomes more disruptive, or makes it possible to serve new markets, there is an increasing impact on the task environment faced by the firms in the focal industry (Christensen, 1997). For Roundup Ready soybeans, the technology was disruptive in terms of its impact on the genetic and agricultural chemical industries, however, caused minimal disruption for existing domestic commodity markets. In other cases, alternative supply chain relationships need to be developed. Organic soybeans need to be separated from commodity

soybeans if their full potential value is to be achieved. Doing so is inconsistent with the dominant commodity marketing channel.

The change in both technological factors and demand dimensions may result in uncertainty due to a shift in what resources and capabilities become more relevant to the changing market (Agarwal and Bayus, 2002). The hypothetical example of producing pharmaceutical products from genetically enhanced soybeans illustrates the increase in sector risk as new supply chain relationships and societal guarantees of performance have to be established while more normal production and marketing risks also need to be overcome.

Thus, movements to the right and upward from the origin in Figure 1 imply higher levels of risk and uncertainty that in turn impact decision making of the key players in the industry today. To deal with this uncertainty, it is important that decision makers in industry, universities and government use appropriate strategic analysis that takes into account both exogenous and endogenous sources of risk and uncertainty (Barney, 2001).

Strategic risk can emerge from either exogenous or endogenous sources. When there is uncertainty related to whether the underlying technological breakthroughs will occur, or if there will be market acceptance of the technological change, the source can be characterized as exogenous, or outside of the direct control of sector decision makers. Exogenous technological uncertainty for instance, is likely to be associated with scientific and research based innovations. Exogenous market uncertainty may result from differences in adoption rates or levels of demand that need to be penetrated. Thus, decision makers need to use decision theoretic tools such as real options analysis or scenario analysis to deal with these sources of risk and uncertainty (Bowman and Hurry, 1993).

When there is uncertainty related to responses of key players to the technological change, the source of uncertainty is characterized as endogenous, or related to strategic interactions among the relevant players in the task environment affected by the technological change. Evolution of both existing and emerging industries can either be fueled, or constrained, by the reactions of the key stakeholders that are affected by the technological change. For example, a buy-in of the technological change by all players in the supply chain would result in more efficient dissemination, because coordination and anticipation of changes at all parts of the supply chain are essential to unlocking the power of disruptive changes. Alternatively, resistance at any level may constrain growth. In turn, the degree to which a strategic decision is met with resistance depends on how well the current resources and capabilities of the related players are positioned to take advantage of the change, and the alignment of incentives that affect their motivation (Hagedoorn, 1993; Dyer and Singh, 1998; Agarwal, Croson and Mahoney, 2004). Thus, decision makers need to be cognizant of reactions of key players that represent complementary assets (supply chain; complementary products) or competitive threats (rivals in the focal industry). Game theoretic tools are needed to analyze and understand these sources of risk and uncertainty (Khanna, Gulati and Nohria, 1998; Agarwal, Croson and Mahoney, 2004).

We propose to analyze the application of biotechnology, in conjunction with developments in information and nanotechnology to the soybean production and marketing sector. The change represented by the confluence of these technologies is clearly disruptive (Benner and Tushman, 2003; Christensen, 1997), and decision makers are grappling with whether to make strategic commitments early, or to retain flexibility and the option to wait (Barney, 2001). Our research design proposes to combine fieldwork and analytical models that would inform strategic decisions, and model the effects of these decisions under various potential scenarios. We will conduct an iterative design that will allow us to capture the temporal effects

of key strategies, as they evolve under the manifestations of subsequent resolutions of important uncertainties. We will employ both decision theoretic and game theoretic techniques to analyze the actions and strategic reactions of key players, and by repeating these over time, we will be able to model how decisions change over time. We highlight below some of the important aspects of our research design:

We will focus on the soybean production / marketing sector, and gather data on its current status, while identifying key historical trends that may have caused the current state of the industry. This will require developing a database on the focal firms, for non-profit institutions that affect the supply chain and relevant complementary and substitute industries. In particular, at the end of this stage, we will have identified the key decision makers whose actions may have an impact on both technological and market outcomes. Three specific levels of the sector will be emphasized in the analysis; genetics, farm production, and soybean processing. These levels are of particular interest as they contain many of the key activities that can be affected by technological change, especially biotechnologically-based innovation.

We will then survey the key players to identify key technological developments in bio and information technology as they affect the soybean production / marketing sector and their likely time of occurrence. These data will allow us to structure the strategic environment facing the key players, and allow us to identify both the type of technological change and the demand characteristics as per Figure 1.

Input will be solicited from private sector participants at the three sector levels of emphasis and in other parts of the sector that complement and connect the three levels of focal interest. Interviews also will be conducted with public sector representatives who have relevant insights and observations. At least 100 sector decision makers will be interviewed.

Using decision theoretic and game theoretic models as our baseline, we will develop strategic models that will allow “sense making” by the key decision players in the soybean production industry, where the general parameter values are informed by the data gathered in Stages 1 and 2. A key aspect of our study will require interaction with the key players in the industry, whose actions depend on both their abilities (resources and capabilities) and their motivation (incentive alignment). We will use structured interviews and survey designs to assess the likely actions and reactions of key players, and the resulting outcomes.

Interviews regarding intentions and outcomes will be iterated over time to develop an inter-temporal analysis of how strategic decisions are made, and their impact over time. These efforts likely will not include all the interviewees participating in Stages 1 and 2. However, enough understanding will be obtained in those stages so that a broad understanding of potential responses can be obtained.