

It All Makes Cents: the Economics of Conservation Tillage

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Introduction

Economics has been a very important motivator in the development and adoption of conservation tillage (CT) technologies. This paper takes a retrospective look at how the economics of conservation tillage has changed over time, and how economic incentives were integrally entwined with the producer adoption and the development of CT. In describing the economics of CT it focuses on the innovation system and the dynamics of a process that brought so many actors together to successfully launch this revolution in farming systems.

The analysis of the innovation system for conservation tillage is a key to understanding some of the essential processes and linkages that drove the development and adoption of CT. The systems approach helps to interpret the role that producers, engineers, agronomists, organizations played in the process, and in turn, how these groups were influenced and had influence on external markets and policies. The perspective of an innovation system helps to highlight the role that communication, information flows and knowledge stocks played in the innovation process. Finally, greater understanding of this very successful innovation system can provide some additional insights into policies that can better foster future innovation.

This brief paper does not analyze two other important economic aspects of the CT innovation. The economic incentives of on-farm adoption are not examined in detail. While these are a critical aspect of the adoption process, these on-farm economics are self evident given the high rates of adoption, and as such are left for another paper. Second, the economic impacts of the CT revolution are not measured. Given the scale of adoption, the profound impact on farming systems, and the environmental impacts, the economic impacts should be measured and described in a cost/benefit framework. Unfortunately a cost/benefit analysis is well beyond the scope of this paper, which specifically focuses on the innovation system.

The remainder of this paper is organized in three parts. Section 2 is used to introduce a simple economic framework to examine the farm level viability of the technology. In Section 3 this framework is applied to four periods of development to identify how the viability and the perceptions of viability changed over time. Section 4 concludes the document with a discussion of the role of internal and external economic forces with some discussion about future viability, and the lessons that can be learned from this amazing transformation.

2.0 The Economic Forces For on Farm Adoption

In adopting a cropping system, producers compare the expected net returns from the new cropping system to their existing system. In the case of conservation tillage systems, the changes in expected returns include short run cash income and expenses, perceived machinery costs, perceived changes in labour management costs, as well as the perceived value changes to soil quality, and perhaps some adjustment for perceived changes in risk. According to economic theory, producers adopting the CT must have perceived a net benefit from the adoption.

Changes in the net benefits of CT did not spontaneously occur. Many forces combined and evolved over a long period to improve the viability and to drive the increased adoption of CT technology over time. Some of the key drivers include, 1) improved agronomic knowledge, 2) improved machinery technology, 3) changes in soil quality, 4) improved herbicides, 5) better pulse and Canola varieties, 6) lower market prices for key crop inputs, 7) less constraining agricultural policies and institutions, and, 8) the accumulation of capital on farms. Each of these drivers changed the perceived benefit for producers making their adoption decisions. A brief chronological description of these forces gives us some insight into the nature of the innovation system.

The earliest drivers for CT were the episodic periods of drought and wind erosion. In particular, the dust bowl of the 1930s and the severe drought of 1961, showed the value of maintaining crop cover. Without sufficient crop cover, severe wind erosion could take place, often with severe impacts on soil quality and many offsite affects as well. In response to the extensive wind erosion in the 1930's, governments established the PFRA and introduced many measures to reduce soil erosion including, reestablishing permanent forage cover on fragile soils and the active promotion of strip farming. Research also began on tillage implements such as the Noble Blade, heavy duty cultivators, and the rod weeder to better conserve surface crop residue. By the late 1960s there was some move away from one way "Discers" towards hoe drills as seeding and tillage equipment because of their propensity to bury trash which left fields more vulnerable to erosion. During the 1960's there was also some push toward direct seeding but the inability to control grass weeds severely limited the adoption of zero tillage prior to the 1970s.

From 1968 to 1972, there was a severe glut on the world grain markets. The United States had accumulated large government stockpiles, while Canada, also a signatory to the International Wheat Agreement, severely restricted export sales in an effort to maintain wheat prices. As a result there were very restrictive delivery quotas for wheat on the Canadian prairies, with a large accumulations of on-farm stocks and very low local grain prices. These on-farm stocks were particularly burdensome in the black soil, which produced more crop per improved acre. The result was a strong economic encouragement to summerfallow, which was exacerbated by the "Lower Inventories For Tomorrow" program that paid case incentives to reduce future grain output. Some "double" summerfallowing and wind erosion took place as result of these programs. During these

“Dark Ages” there was very little interest in intensifying production or in adopting CT technologies, although hoe drills and cultivators continued to replace discers.

Following the “Great Russian Grain Robbery” in 1973, grain prices were dramatically higher and delivery quotas were no longer binding. The result was a seven fold increase in the price of a marginal bushel of wheat, increasing from about 60 cents per bushel for wheat to over \$4.00 bushel. The outlook for agriculture became very bright, with farmers looking for ways to intensify production. Farmers, particularly in the black soil zone, were increasing stubble cropping and were experimenting with larger amounts of nitrogen fertilizer which given the seeding equipment had to be broadcast on the soil surface. Seeding stubble with hoe drills also required a good deal of pre seeding tillage to cope with straw.

In 1975 the Saskatchewan Guide to Farm Practice first highlighted the long-term decline in soil organic matter in Saskatchewan soils. Don Rennie, a soil scientist who would become the Dean of Agriculture at the University of Saskatchewan, gained a great deal of public attention for his research. He indicated that the current system was not sustainable and that producers should reduce tillage and summerfallow to conserve soil organic matter. While he was not the first to identify the issue, this was the first time where a large number of producers became aware of the issue. This desire to reduce summerfallow and the economic drive to intensify production, forced farmers to rethink their tillage and seeding systems.

By the late 1970’s there was a growing interest in air seeders, which were cultivators, with an air delivery system for seed. This move was predated by important innovations in heavy duty cultivator technology including the size of cultivators and the four wheel drive tractors to pull them, rock trip mechanisms, articulated frames, and their trash clearance, gave producers the mechanical ability to seed in heavy trash conditions. These early “air seeders” tended to use wide sweeps with high soil disturbance, followed by harrow packers to firm the seed bed. These early units, also tended to be combine seed and fertilizer in a “single shoot” air delivery system, which limited the amount of nitrogen that could be applied at seeding.

By the mid 1980s, there was great deal of interest in air seeders with many firms producing and refining the technology. They became a major feature at the Western Farm Progress Show held in Regina each summer. Significant improvements in air seeders included in row packers that precisely controlled seeding depth, variable packing pressure, separate (side band or mid band) fertilizer placement, and narrow knife type openers that minimized soil disturbance. These innovations were developed and adopted by several small Saskatchewan companies, such as Prasco, Flexicoil, Bourgot, Morris, and ConservaPac. Many of these mechanical innovations were tested at the Prairie Farm Machinery Institute. ConservaPac worked extensively with Agriculture and Agri-food Canada (AAFC) and the Indian Head Agricultural Research Foundation, to test mechanical and agronomic concepts. Interestingly, during this whole period of development, ideas and technical improvements were quickly adopted by much of the industry with very little cross licensing of the technology, suggesting that effective

intellectual property protection was very limited. The result was an industry that remained competitive despite substantial innovation.

Once the air seeder technology was refined it became a major driver in CT. Although these seeders did cause some soil disturbance at seeding, they allowed for higher quality one-pass seeding with nutrient optimization, saving producers labour, time and fuel. This technology combined with the other drivers, made the CT economically desirable, not only in Saskatchewan but across the region and internationally. Of particular note was the decrease in the price of glyphosate after 1990. During the late 1980's and 1990's conservation tillage field days were very popular and well attended by producers, allowing them to make an adoption decision and also allowing them to refine the application of the technology over time.

The adoption of CT has become very wide spread in western Canada. (see chapter XX). This adoption is consistent with positive farm level economics. Zentner et al. (2002) conclude that minimum tillage and zero tillage (both forms of CT) provide both short run economic benefits and long run environmental benefits in most soil-climatic regions in Western Canada. They found that that Brown and Dark Brown soil zone may favour conventional tillage at lower prices while producers in Black soil zone and to some extent the Gray soil zone favour zero till (ZT) because of a yield advantage despite similar costs.

The Innovation Process

There are several standard models of innovation in the economics and business literature. The simplest is a linear model of product innovation as shown in Figure 1. In this model, a new discovery leads to applied science and the development of new products which are marketed and adopted by the final users. This is very much a “push” model, where new ideas are the source with the adoption/commercialization being the end product.

Figure 1: The Linear Model of Innovation



Rogers (1962) introduced the concept that adoption was not a passive process but rather a sociological process where early adopters influenced later adopters. The implication was that the successful marketing involved reaching the early adopters. In CT the discovery of some ideas, such as side banding of fertilizer eventually led to the development of commercial products, but this does not account for the pent up demand for better tillage technology.

Griliches (1958) introduced the concept of induced innovation to the economic literature. As shown in figure 2 the idea behind models of induced innovation, is that the circumstances for an industry change creating either a severe problem or a real economic opportunity that did not exist previously. This new circumstance changes relative prices, which creates a demand for a new technology. The demand for new technology in turn drives product development and the demand for applied science.

In the case of CT it is clear there were aspects of induced innovation at work. The high grain prices combined with knowledge of organic matter depletion, sparked an interest in direct seeding technologies. In effect, the demand for new technology pulls the knowledge through to adoption. However this induced innovation model is not rich enough to capture the influence of new knowledge on innovation and adoption.

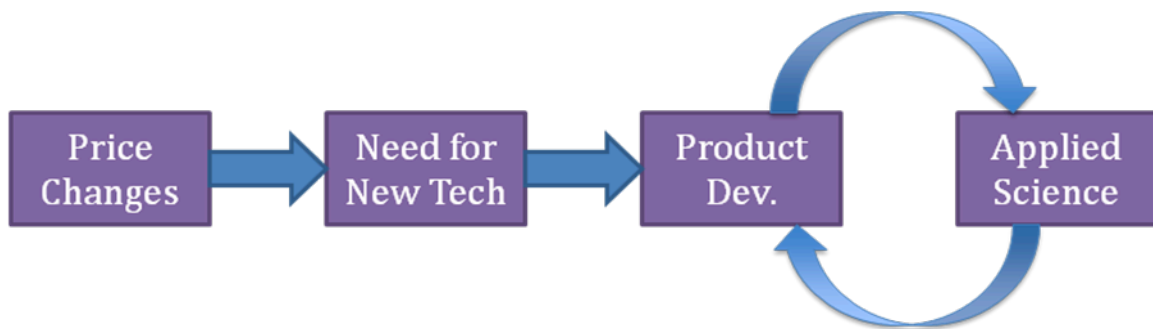


Figure 2: Induced Innovation (Griliches, 1958)

A somewhat richer innovation model where both push and pull drivers of innovation and two directions of influence are incorporated are known generally as chain models of innovation. Kline and Rosenberg (1986) argue that innovation is not a single event or product but is more often involves many new products and processes governed by a change set of relationships. As depicted in figure 3 these models recognize that there are many points of interface in innovation, each with two-way flows of information and influence. For instance, marketing affects adoption, yet technologies that are adopted influence product marketing. Applied science affects the types of products that are developed but the products that are developed in turn affect the applied science agenda. These two-way flows of knowledge and influence have been central to the models that recognize that extension activities are really engagement mechanisms where knowledge flows in two directions between science and industries.

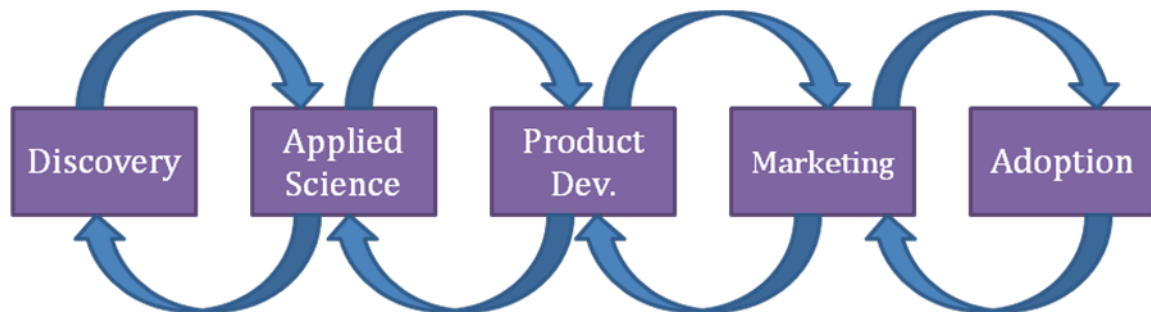


Figure 3: Chain models of Innovation (Kline and Rosenberg,1986)

The chain models of innovation fit CT well. Evidence of two-way flows of knowledge with both a push and pull for innovation abound in the case of CT. Clearly producers, and producer organizations, were directly involved in the innovation process, both as sources of knowledge drivers of innovations and as customers for innovative products. Similarly, science and scientists played a significant role in creating the conditions for innovation, solving some applied science problems, testing product and process efficacy and communicating the results to large numbers of producers. While this chain model is very rich and captures the two-way flows of information, it does not capture the role of external drivers on CT innovation.

A modern and more complex view of innovation recognizes innovation as a complex process that takes place within a regional, national or global innovation system. As shown is Figure 4, CT chain innovation can be depicted as being driven by external drivers.

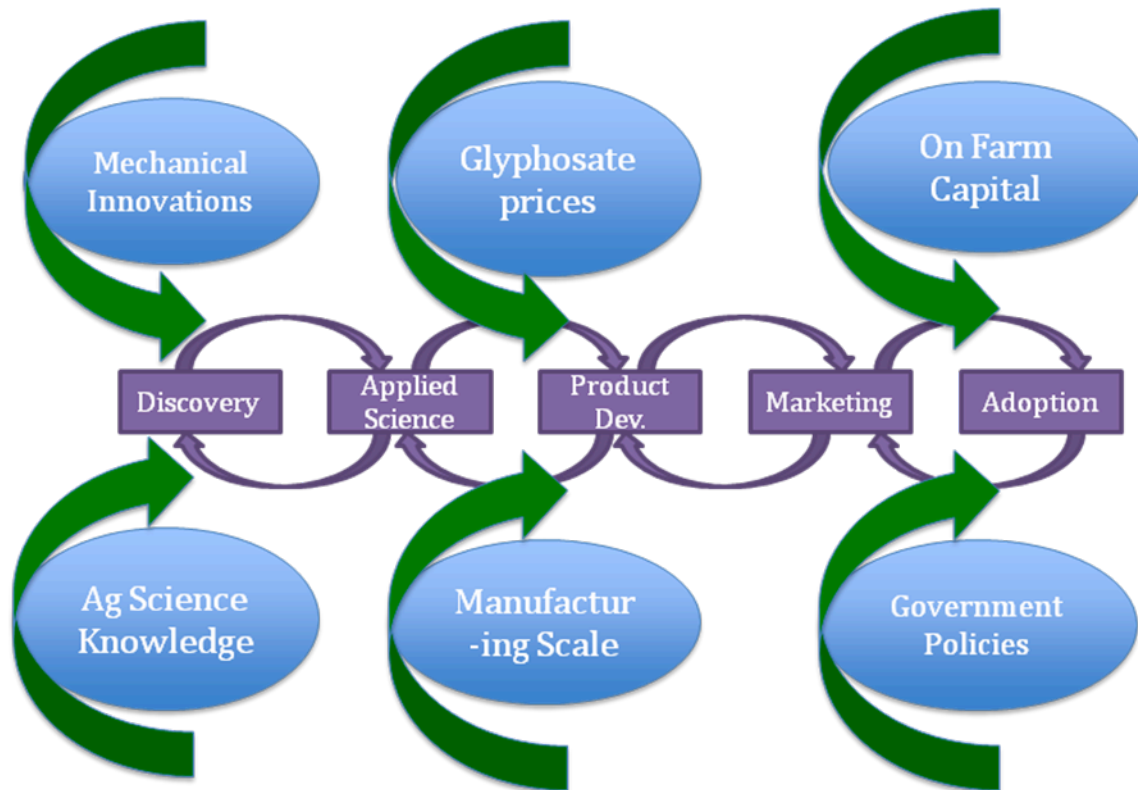


Figure 4: External Drivers of the CT Innovation Chain

In the model shown in figure 4 there are six drivers that accelerated or intensified the innovation process. As drawn, these are external drivers which influenced CT innovation. While the addition of drivers can help explain the development path for CT, this model misses two key aspects of the innovation system. First of all, some of these drivers are stocks, which accumulate over time. Second, these drivers are not all external to the system. The development, growth and adoption of CT had a profound effect on many of these drivers. Some of the drivers are therefore part of the CT innovation system, and cannot be viewed as external system.

The incorporation of six drivers as part of the CT innovation is shown in Figure 5. As depicted each of these drivers receive positive feedback from the innovation process, which in turn, makes them stronger drivers for CT innovation.

The adoption of CT added to the stock of mechanical innovation through continued research and product development effort that intensified to take advantage of the growing market. As this knowledge stock increased, the quality of these machines improved, thus reducing costs and increasing crop yields. The adoption also led to an expansion of the scale of manufacturing, enabling these companies to take advantage of economies of scale, further augmenting machine quality while reducing manufacturing costs.

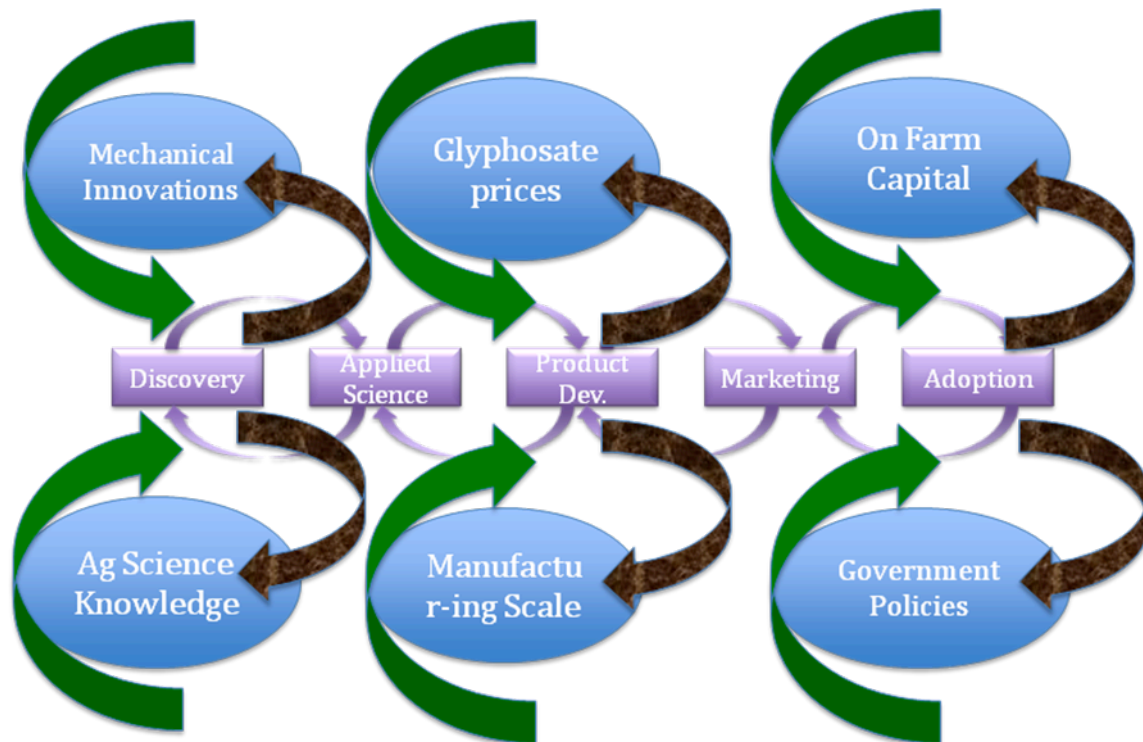


Figure 5: Drivers and positive feedbacks in the Innovation system.

The adoption of earlier CT technologies contributed to increases in CT related capital stocks on farms. Not only did farmers accumulate machinery that would complement CT, many adjusted farm size to better fit the technology. Perhaps most importantly, their own stock of human capital and knowledge increased as they learned more about CT. All of these on-farm stocks contributed to and strengthened the adoption of CT.

Government policies were also influenced by the adoption of CT technologies. As cropping intensified, delivery quota rules were changed to reflect production rather than acres. As these CT technologies became more popular, cropping became more diverse. These created political pressure to modify crop insurance and farm safety net programs to better reflect new crops and cropping systems. As CT became more mainstream, government policies rather than being external were influenced by CT.

CT innovation also influenced the stock of agronomic knowledge. As producers and CT machinery firms tried new practices, applied scientists examined and worked with these new systems, enhancing their knowledge about what was possible and economically feasible. A good example of an increase in the stock of agronomic knowledge, is how fertilizer recommendations changed over a short period of time. As shown in Table 1, the Nitrogen fertilizer recommendations for cereal crops virtually doubled between 1972 and 1984. These increases were no doubt driven by producer desire to crop more intensively. As a result of higher recommendations, more farmers were able to see higher yield and potential benefits from CT.

Table 1: Guide to Farm Practice Recommended N Range for Cereals 1972,1978,1984

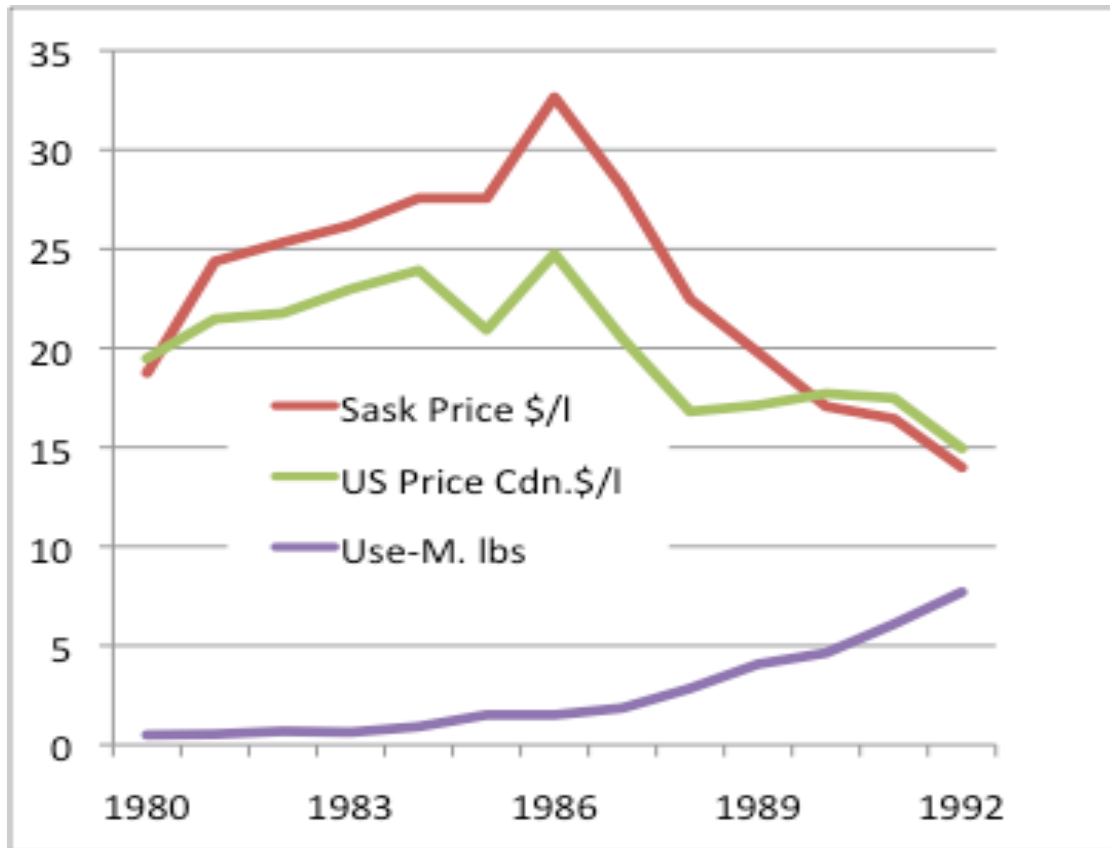
Year	Brown Soil Zone Recommended Rates	Dk.Brown Soil Zone Rates pounds of N per acre	Black Soil Zone
1972	0-30	15-40	15-50
1978	10-35	25-50	40-60
1984	10-40	25-65	50-95

Source: Saskatchewan Guide To Farm Practice (Various)

Perhaps the most interesting positive feed back from an economic perspective was the relationship between CT adoption and the pricing of RoundUp, Monsanto’s patented glyphosate herbicide. As shown in Figure 6, the Canadian price of RoundUp was decreased by 50% between 1986 and 1992. This price decrease occurred at time when demand was decreasing and Monsanto had more than a decade to patent expiry in 2001.

A potential explanation for this pricing behavior is shown in Table 2. Looking at revenue in 1986 versus 1992, revenue more than doubled despite the 50% price drop. The quantity of sales increased more than five-fold when Roundup became priced more competitively with the cost of tillage. A further calculation shows that increases in sales would have contributed positively to Monsanto’s profits as long as their production cost were less than \$9 per litre. If the adoption CT was responsible for creating demand conditions responsible for Monsanto’s reduction in RoundUp pricing, this important driver of innovation must be viewed as internal rather than external to the adoption of CT.

Figure 6: RoundUp Prices and Canadian Use 1980-1990



Source: Kowal (1993)

Table 2: Saskatchewan and US RoundUp Prices and Sales Quantity 1980-1992

year	Sask Price \$/l	US Price Cdn.\$/l	Canadian Use-M. lbs	Cdn. Revenue \$M
1980	\$18.75	\$19.48	0.496	9.30
1981	\$24.37	\$21.47	0.534	13.01
1982	\$25.33	\$21.76	0.683	17.30
1983	\$26.20	\$22.98	0.633	16.58
1984	\$27.56	\$23.92	0.913	25.16
1985	\$27.56	\$20.92	1.506	41.51
1986	\$32.65	\$24.75	1.506	49.17
1987	\$28.14	\$20.49	1.851	52.09
1988	\$22.46	\$16.80	2.843	63.85
1989	\$19.77	\$17.12	4.067	80.40
1990	\$17.06	\$17.71	4.628	78.95
1991	\$16.44	\$17.48	6.085	100.04
1992	\$13.98	\$14.94	7.7	107.65

Source: Calculated from Kowal (1993)

Clearly there are a number of drivers for CT innovation that received positive feedback from adoption. These positive feedbacks have implications for the nature of the innovation process and how it can be managed. Before leaving the discussion of drivers, it is important to point out that some drivers such as the price of oil are external to the innovation process and are unaffected by the extent of adoption. Still other drivers become less important over time as negative feedback from adoption renders them less important. For example, soil erosion was an important motivator that largely disappeared as CT took hold.

Policy Implications

The CT innovation and the adoption process is a rich and wonderfully complex story. The grass root need to intensify production and conserve soils combined with public sources of knowledge and other economic forces to bring about a transformative change in farming systems.

A closer examination of the forces at work reveals that CT innovation was a complex system with many drivers and many positive feedbacks. These positive feedbacks reveal the need to develop institutions and resources to support early innovators who will in turn help drive subsequent innovation.

In this success story, the interaction with science, which helped identify issues of sustainability, and the ability of producers and small firms to do engineering to address their own mechanical issues, were important factors. With the support of public and producer organizations, these ideas were tested and communicated widely. As the technology developed, the positive feedbacks from commercialization strengthened the innovation forces resulting in widespread adoption and transformation of farming systems. The existence of positive feedbacks makes the path of development extremely hard to predict and manage. In the case of CT it was clearly a success.

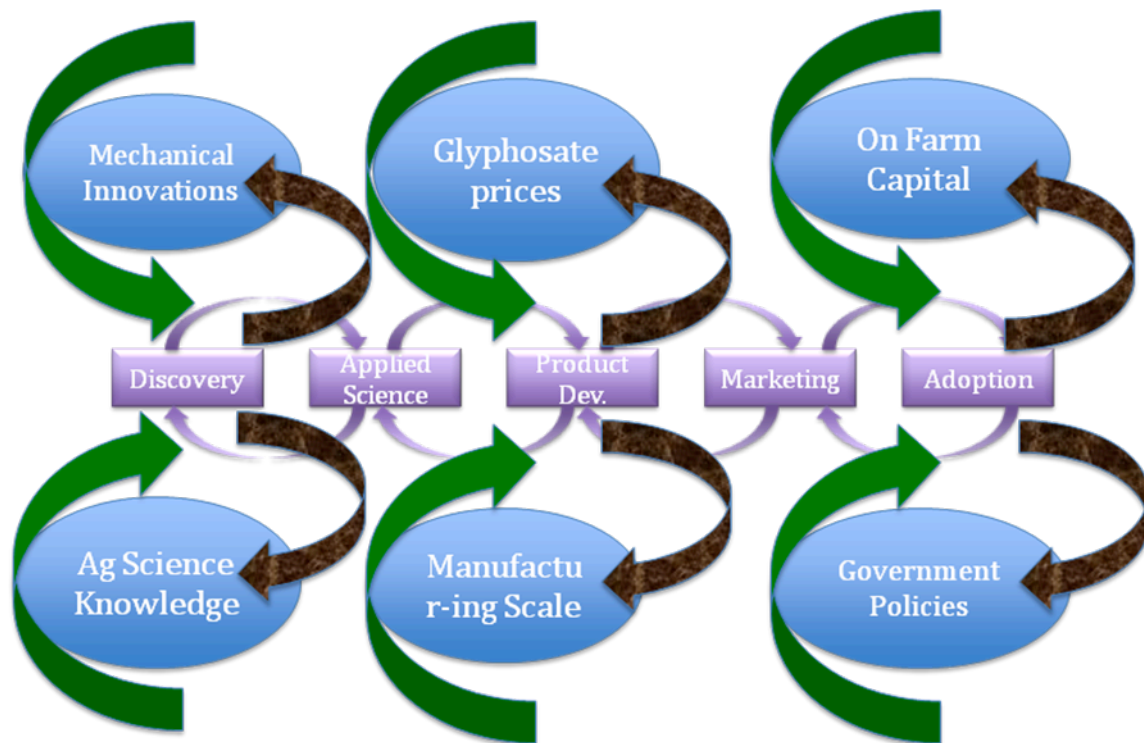
There are number policy implications of this success story.

First, there are some types of valuable research that can take place on the scale of very small firms, indicating a need to support entrepreneurial research. Critical support included interaction and advice from scientists, product testing and concept verification, public trade shows, and support for producer organizations where likeminded individuals can meet and share ideas. In agriculture research involving agronomic systems, engineering, and perhaps small crop breeding could fall into this category.

Second, CT did not result from a directed research project. It developed over many years, with the public sector undertaking some high risk research in order to identify issues and potential technologies.

Producer organizations played a critical role in the development of conservation tillage.

Initially these organizations were small and provided a supportive meeting place for early innovators. As adoption increased, these organizations rapidly grew and played a very significant role in the acceleration of adoption. Despite their past record of success, these soil conservation organizations do not have a stable funding bases as they do not fit well in the Canadian system of producer levy collection. Given the long run nature of the problems, and the past successes of industry driven research, perhaps viable funding models for these organizations needs to be explored.



References:

Kaufmann, Alexander and Tödting, Franz. (2001). "Science–industry interaction in the process of innovation: the importance of boundary-crossing between systems."

Research Policy 30 (2001) pp. 791–804.

Guide to farm practice in Saskatchewan (Various Years) Saskatchewan Agricultural Services Co-ordinating Committee, Regina Saskatchewan.

Kowal, Tracy (1994) *Herbicide Pricing in North America*, M.Sc. Thesis, University of Saskatchewan.

Griliches, Zvi. (1958), "The Demand for Fertilizer: An Economic Interpretation of a Technical Change", *Journal of Farm Economics*, Vol. 40, No. 3 (Aug., 1958), pp. 591-606.

Kline, S. and N. Rosenberg. (1986). "An Overview of Innovation." In Landau, R. and Rosenberg, N. (eds) *The Positive Sum Strategy: Harnessing Technology for Economic Growth*. Washington, D.C.: National Academy Press. pp.275-306.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.