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# An Agent-Based Model of Regional Structural Change: A Focus on Saskatchewan Agriculture

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## 1.0 Background and Objectives

Over the past four decades, Saskatchewan agriculture has undergone many changes, including farm consolidation and other structural adjustments. Declining farm population is a major contributor to current economic difficulties in many rural areas. Structural change[1] is an important issue for the farm and for rural regions in general, but the process and underlying drivers of change are not well understood. Improving the understanding of the structural dynamics of the farm sector could lead to the development of policies to help mitigate some of the negative impacts of such changes on the rural Saskatchewan economy.

Changes in agricultural structure mean that farming activities and farm policy should have considerable flexibility. Policy may be implemented both to meet short-term objectives and to have a net positive effect on the long-term sustainability of the industry.

Agent based modeling (ABS) is a dynamic simulation framework used in this research to analyze structural change at the regional level. In our ABS model, individual farmer agents with differing demographic financial characteristics and entrepreneurial attitudes compete for farmland through both leasing and ownership markets. Ultimately, our research has the following objectives: 1) to replicate historical structural shifts that have occurred in Saskatchewan agriculture during the period from 1960-2000, assuming that technology and farming practices remain constant and 2) to estimate the structural evolution of the region under the assumption of zero government stabilization transfers.

### 1.1 Model drivers and structural change

Recently there has been much debate concerning the forces driving structural adjustment in agriculture. The primary drivers of this adjustment considered in this study are; 1) entrepreneurial behaviour and farm household expectations, 2) cost of production and production efficiency, 3) path dependency and the farm life-cycle and 4) government transfers.

[1] Structural change includes changes in characteristics which describe the number and size of farm units, demographic and economic characteristics of farm operators, methods of production and the mix of products produced by industry participants.

### 1.2 Aggregate models of structural change

Earlier research describing the dynamics of farm structural change has been largely inconclusive. The interactions between these factors are complex and difficult to incorporate into general modelling approaches. This has almost certainly led to significant inconsistency in policy recommendations.

## 2.0 Agent-Based Models

Agent-based economic modeling is a micro-level or 'ground up' simulation modeling approach that uses precise specifications of individual actions and interactions to generate aggregate outcomes. In contrast, current farm level policy tools are 'top down' approaches that focus on aggregate outcomes without detailed consideration of the individual actions that generated the aggregate outcome.

The base scenario constructed in this analysis simulated farm financial progress and growth of a synthetic farm population representing a typical rural municipality (RM) in Saskatchewan, Canada. The farm population was constructed based on the 1960 Census profile of farm size, wealth and operator ages. In addition, farms were randomly assigned a location within the RM and one of three distinct managerial types. Our model incorporated a series of individual equations that replicate the business environment of price and yield expectations, which along with risk attitude and financial constraints, form the basis for individual valuation of farmland. Agents expand their operations by buying farmland or obtaining leases if they "win" a farmland auction. In addition, agents are assumed to disregard government program payments in forming their expectations. In the simulation, agents stop farming either through forced exits or through retirement, while new agents enter as children of existing or exiting farmers. Our simulated farmers farm under risk and uncertainty but to better capture reality, prices and yields are based on actual yields, prices and government programs applicable to the study region. In this manner, the simulated farm population and associated individual characteristics are tracked over the period 1960 to 2000.

We examine two scenarios. The first (or base) scenario simulates this farm economy with actual government transfer payments applicable to the region, including payments from stabilization and ad-hoc farm programs. However, in order to assess the impact of government transfer payments on regional farm structure, a second scenario is delineated. In this scenario, all government program transfer programs are removed and agents receive zero transfer payments.

### 2.1 Comparison between simulated results and historical data

#### 2.11 Base Scenario

The base simulation results closely mirrored historical trends in overall Saskatchewan farm structure, including variables such as farm size, numbers and debt as well as farmland values over the 40-year period between 1960 and 2000. The simulated decrease in farm numbers was 1.72% per year while the historical rate was 1.53%. Simulated mean farm size increased annually at a rate of 1.61-1.76% as compared to the historical rate of 1.58%. However, these changes were not quite as smooth as the historical record, where the latter is based on a much larger area (Figure 1). This effect is likely due to the relatively small population associated with an individual RM.

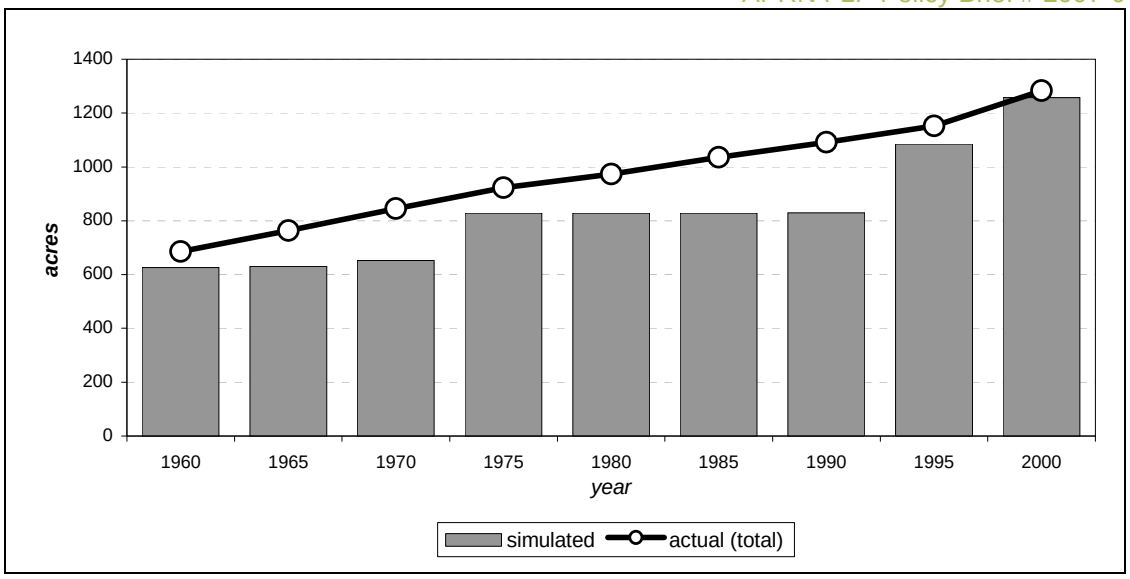


**Figure 1**. Simulation Results (base scenario) – Mean Farm Size (total acres).

The distribution of farms also provides insight as to the nature of structural changes. Our simulated distribution in farm size after 40 years is displayed in Figure 2. These results match the historical distribution of most farm sizes, with the notable exception of the less than 400 acre class. Our inability to correctly estimate this farm size class is likely caused by the omission of off-farm labour markets because in the model, off-farm income is fixed.

While the base simulations revealed certain limitations of the modeling environment, we generally found a good statistical match between the model and the distribution of the observed data over the 40-year study period. The simulated output matches the historical data closely enough to give us confidence that our agent based simulation is capturing many aspects of individual farm level behaviour in the study region.

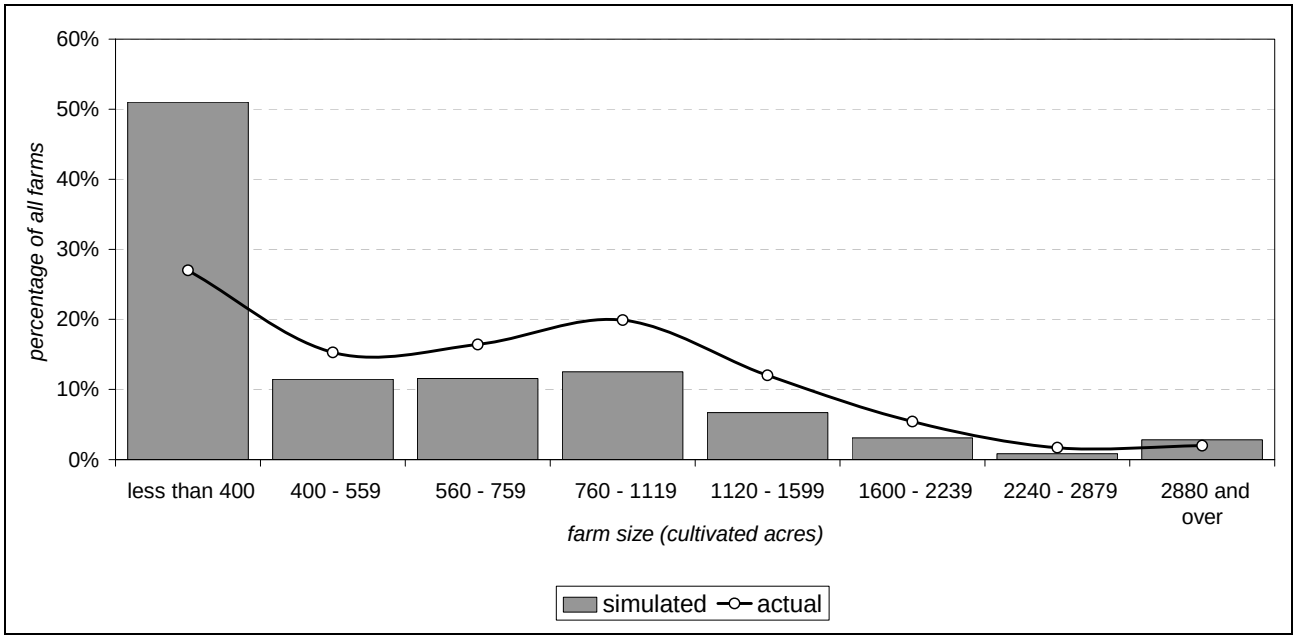


**Figure 4**. Simulated Distribution of Farm Size, base scenario, 2000 (year 40)

### 2.2 Zero transfer scenario

In the zero transfer government payment scenario, the characteristics of the same 1960 farm population are tracked over time using the same prices and yields as the base scenario but farm agents receive no government transfers - ie. no stabilization programs or ad-hoc stabilization program payments. Every 5 years, farm numbers, as well as size and farmland values were compiled and compared to the base scenario.

There were few government payments prior to 1987 and hence, there was no difference between the two scenarios up to that point. In the post-1987 time period, the base and zero transfer scenarios began to diverge considerably due to transfer payments. Under the zero payment scenario, simulated farm numbers decreased significantly while mean farm size increased significantly. Interestingly, small farms were affected more - small farms continued to exist in this scenario, but the overall size distribution shifted towards an increasing proportion of larger farms.

### 2.3 Insights

We observed several interesting phenomena within the simulations. The first is that the elimination of government transfers resulted in slightly decreased farmland prices even though government payments were not explicitly included in gross margin expectations. We speculate that this is likely due to the deterioration of free cash and/or increased debt over the economically depressed years of the 1980's. The result would suggest that even if programs are decoupled so they do not directly influence farmers' expectations, programs can indirectly affect farmland prices. A second and related phenomenon is that the elimination of government payments encouraged farmer agents to lease rather than purchase additional farmland.

In reality by 1991, government transfers diminished considerably. Thus, by the end of 2000, farm structure across the two scenarios started to converge. This suggests that the impact of government program payments on farm structure might not persist for long unless the programs are maintained.

## 3.0 Policy Implications

The base simulation model closely matched farm sector structural adjustments that occurred in Saskatchewan over the study period. This suggests at least a 'proof of concept' for this type of modeling. We believe that agent based modeling could yield a framework for future research focusing on structural dynamics and policy analysis.

Even with government transfer payments included, farm structure was still characterized by an evolution towards more large farms with fewer farms overall. While we found that government payments reduced the rate of change in farm structure, when government transfers were removed, farm structure tended to rapidly catch up with the no transfer payment scenario. In addition, we found that government stabilization programs and ad-hoc payments may have had unanticipated consequences on farming in the region by encouraging expansion through farmland purchases rather than leasing and driving an increase in farmland prices.

Finally, we note that farming is an inherently complex system generating large-scale effects that are difficult to predict using traditional aggregate models. It has been difficult to predict structural outcomes in agriculture based on the analysis of individual system components. However, agent based farm level models may be superior in this respect to traditional models in assessing long run structural change because they incorporate individual agent interaction through markets,

while also allowing individual heterogeneity in location, demographics and behavior. Because of this heterogeneity and complex individual interaction, they can help identify emergent (or inherently unpredictable) farm level behaviour.

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