# To Invest or to Sell? The Impacts of Ontario's Greenbelt on Farm Exit and Investment Decisions

Na Li[1], Richard J. Vyn[2] and Ken McEwan[2]

[1]University of Toronto; [2]University of Guelph, Ridgetown Campus

**Abstract**

*This paper examines the impact of Ontario's Greenbelt legislation, a land use policy that permanently protects over 1.8 million acres of land from non-agricultural development, on farmers' exit and investment decisions. A farm-level panel data set for 32,512 farms in Ontario is used to perform two econometric estimations: a correlated random effects Probit model of farm exit and a dynamic unobserved effects Tobit model of farm investment. The Greenbelt policy is found to have influenced both farm exit and farm investment decisions, with the impact varying depending on location within the Greenbelt. In particular, the results indicate evidence of a negative impact on farm investment, which is contrary to one of the objectives of the Greenbelt policy.*

## 1. Introduction

Ontario's Greenbelt (see Figure 1), a farmland preservation program implemented in 2005, permanently protects over 1.8 million acres of farmland and environmentally sensitive lands surrounding the Greater Golden Horseshoe – one of the most populous and fastest growing regions in North America – from urban development. This policy was implemented primarily in response to the significant loss of prime farmland that had been occurring in this area due to continually advancing urban sprawl[1]. In addition to protecting farmland, the goals of the Greenbelt included providing protection and support to the local agriculture industry in order to foster long-term investment in the industry and to contribute to its economic viability. Proponents of the Greenbelt argue that the permanent protection of farmland can serve as a commitment to the agricultural industry and stimulate farmers to invest and to be successful rather than waiting to "sell out" to developers, where farmland tends not to be used optimally for agricultural production.

On the other hand, contrary to other public land preservation policies, the Greenbelt protection applies to primarily private lands. Hence, this policy may influence decision-making by private landowners. For example, the protection of farmland may encourage farmers to invest in their operation and expand production, while concerns regarding potential declines in farmland values due to the loss of development potential may encourage them to sell their farmland. In addition, even with this protection, prior loss of local agriculture infrastructure due to encroaching urban development may reduce the likelihood that farms will invest or even stay in business. As a result, the impact of the Greenbelt legislation on farm structure, particularly farm exit and investment, remains unclear. On a broader level, while numerous farmland preservation policies have been enacted across North America, it is unclear whether the benefits of these policies extend beyond preservation itself to actually enhance the local agriculture industry.

---

[1] According to the Ontario Farmland Trust, 600,000 acres of farmland in this area was lost to urban development between 1996 and 2006.

The purpose of this study is to assess empirically the impact of the Greenbelt protection on farmers' decisions to expand production and to exit from agriculture. Although in recent years there have been a number of studies identifying factors contributing to farmers' exit and investment decisions (e.g., Goetz and Debertin, 2001; Benjamin and Phimister, 2002; Ahearn et al., 2005; Dong et al., 2010), limited attention has been paid to the influence of land use policies on these decisions. In examining the effect of a dairy price floor policy on farm exit, Foltz (2004) also found that the number of acres of land preserved by the purchase of development rights (PDR) program in Connecticut had no significant effect on dairy farm entry or exit decisions or on dairy farm sizes. Foltz (2004) also highlights land use policies as an important avenue for future research. This paper builds on previous empirical studies that examined government policies and farm structure by focusing explicitly on the influence of a land use policy, i.e., the Greenbelt, on farm exit and investment decisions. Given the prevalence of land use policies that have been implemented to protect farmland, it is important to determine whether such protection impacts the agriculture industry and, in particular, whether it influences farm-level decisions.

Generally, empirical models of farm exit and farm investment have been estimated using state- or county-level aggregate data. The models estimated in this paper take advantage of unique unbalanced panel data on individual Ontario farms for the period 2003-2011, which allows for controlling for many factors that could affect farmers' production and management decisions in order to identify the effect of the policy change. Similar to Kazukauskas et al. (2013), we use a correlated random-effects (CRE) specification in a Probit model of farm exit to control for unobserved heterogeneity in identifying the impact of Greenbelt policy. Though rarely reported in non-linear "difference-in-differences" models, treatment effects have more direct economic relevance than the coefficient of a treatment interaction term. We apply a method recently proposed by Puhani (2012) to identify the average treatment effects of the Greenbelt policy on the treated (ATT).

Another advance made in this paper is that we employ a dynamic panel Tobit model with unobserved individual-specific effects to identify the impact of the Greenbelt policy on farm investment decisions. A dynamic panel setting is appropriate to capture investment dynamics at the farm level, since disaggregated investment decisions are often observed to be largely persistent. We apply an innovative approach to disentangle the effect of the Greenbelt policy from investment persistence due to unobserved heterogeneity or state dependence. In addition, by relaxing the strong assumption of independence between initial conditions and unobserved heterogeneity, this approach facilitates a simple estimation of policy treatment effects averaged across the distribution of the unobserved heterogeneity.

## 2. A Theoretical Model of Farm Exit and Investment Decisions and Strict Zoning Policies

Following Goetz and Debertin (2001) and Ahearn et al. (2005), we view the exit decisions of farm operators as an outcome of comparing the present value of expected future utility derived from continuing farming ($V_{tf}$) and expected utility of quitting ($V_{tq}$), with the present value of expected future utility defined by:

$$V_t = \int U_t \left(c, I, h, R; \boldsymbol{z}\right) e^{-\delta t} \mathrm{d}t, \tag{1}$$

where $\delta$ is the continuously compounded discount rate, and $R$ is the rental rate for farmland. In this model, the one period household utility ($U_t$) depends on goods and services consumed by the household ($c$), the investment of the accumulated savings ($I$), the labor hours ($h$), the decision whether to sell or continue renting the farmland ($R$), as well as a vector of other household characteristics ($\boldsymbol{z}$). Expected utility ($V_t$) is maximized subject to standard constraints, such as existing production technology, intertemporal budget constraint and time allocations. Farm proprietors will continue in farming as long as $V_{tf} \geq V_{tq}$.

The Greenbelt policy could potentially affect farm household decisions in different ways. First, it impacts the expected utility associated with discontinuing the farm operation by directly affecting the sale price of farmland. If agricultural zoning has a negative effect on farmland sale price, as shown empirically in Lynch et al. (2007) and Deaton and Vyn (2010), among others, then it directly decreases the expected return from selling a farm. On the other hand, decreasing farmland value may lower the entry cost and therefore raise the number of potential entrants. Absent of zoning, the high cost of farmland represents a barrier to entry that may help to reduce competition from potential entrants and therefore sustain low productivity farms. In this regard, if strict zoning reduces farmland value and, subsequently, reduces entry costs of farming as well as marginal utility of farm work and farm investment, then it can assist in “crowding out” less efficient farms.

Second, the Greenbelt policy could either stimulate or discourage investment for existing farmers. Farmland in this area has generally appreciated steadily over time, mainly due to urban development pressure. The Greenbelt policy, however, precludes the possibility for the zoned agricultural lands to be developed for non-agricultural uses in the future. The resulting increased certainty for the agriculture industry in this area may encourage farmers to make a strategic commitment to farming, rather than waiting to sell out to developers, and invest more in capital, machinery and long-term conservation improvements in order to improve farm productivity in the long run.

There are also factors that could cause a negative effect of the Greenbelt policy on farm-level investment. First, the timing of zoning policies is critical to the adjustment process. The agriculture infrastructure (i.e., farm services, input suppliers, etc.) in rural areas adjacent to large, growing urban centers may have deteriorated considerably prior to the implementation of the land protection policy. Such deterioration may substantially reduce the marginal return of additional investment in farming. Second, farmers’ expectations may play a role in diminishing the “incentive” effect of the Greenbelt policy. While reduced farmland prices in the Greenbelt may make it less enticing to sell their farms, farmers may remain inactive in investment with the expectation of selling their farms when land prices go back up in the future.

## 3. Empirical Model

We capture the effect of the Greenbelt through a difference-in-differences (DD) approach. This approach hinges on the “common trend" assumption, i.e. the difference in the average outcome between the treatment and the control groups (farms within and outside of the Greenbelt) remains constant over time without treatment. The policy effect of the Greenbelt protection is then identified by the difference in the expected potential outcomes conditional on treatment, defined as the *average treatment effect on the treated* (ATT):

$$ATT = \mathrm{E}\left[Y^1|d=1,X\right] - \mathrm{E}\left[Y^0|d=1,X\right],$$

where $Y$ denotes the outcome of interest, with superscript 1 indicating participation in the treatment; $X$ denotes a vector of control variables; $d$ indicates the treatment status, which is equal to 1 if the treatment is received and 0 otherwise. Note that the counterfactual outcome $\mathrm{E}\left[Y^0|d=1,X\right]$ is unobserved but can be derived.

Using this approach, we first use a panel Probit model to examine the impact of the Greenbelt on the decisions of farmers to sell their farm and exit the industry. Next, we compare the investment patterns before and after the implementation of the Greenbelt policy across individual farms located in southern Ontario, both within and outside of the Greenbelt, utilizing a dynamic panel Tobit model.

Unlike the linear DD model, the treatment effects in nonlinear models like Probit or Tobit cannot be constant across the treated population (Athey and Imbens, 2006). To address this issue, we follow Puhani (2012) by calculating the treatment effects on the treated as the incremental effect of the coefficient of the treatment interaction term $\theta$, assuming a constant difference between groups across time in the unobserved latent variable (rather than the observed limited dependent variable itself).

The issue of endogeneity can arise with land use policies such as the Greenbelt, which can bias the estimated impacts of such policies. However, as discussed in Deaton and Vyn

(2010), endogeneity is unlikely to be an issue in the case of the Greenbelt due to the manner in which it was implemented. Specifically, the Greenbelt boundary was delineated without direct input or influence from individual landowners or from municipalities. As a result, neither landowners nor municipalities were able to self-select in or out of the Greenbelt. This substantially reduces the likelihood of endogeneity, which was confirmed through testing procedures in Deaton and Vyn (2010). Similarly, we anticipate exogenous assignment to the treatment and control groups.

### *3.1. Modeling the Probability of Exit*

To explore the potential impact of the Greenbelt on farm exit decisions, we use panel data to estimate a random effects Probit model as follows:

$$Exit^*_{it} = \tau_t + \kappa GB_i + \theta \left( Y05_t \times GB_i \right) + \boldsymbol{\gamma} \boldsymbol{x}_{it} + u_i + v_{it}, \tag{2}$$

where $Exit^*_{it}$ is a latent variable denoting the unobservable value of selling farm $i = 1, \ldots, N$ in year $t = 1, \ldots, T$, and the actual farm exit variable $Exit_{it}$=1 if $Exit^*_{it} > 0$ and 0 otherwise. $GB_i$ is a policy treatment variable indicating whether a farm is located in the Greenbelt area; $Y05_t$ is a time dummy for post-Greenbelt years; $\tau_t$ is a time dummy; $\boldsymbol{x}_{it}$ is a vector of control variables; and $u_i$ denotes a time-invariant component capturing farm-specific unobserved heterogeneity.

As the standard random-effects model requires a restrictive assumption that the random effects ($u_i$) are not correlated with explanatory variables, we use the correlated random-effects (CRE) model, following Mundlak (1978). More specifically, the unobserved heterogeneity is modeled in the following function:

$$u_i = \alpha_0 + \lambda \bar{\boldsymbol{x}}_i + \varepsilon_i, \tag{3}$$

where $\alpha_0$ is a constant term and $\bar{\boldsymbol{x}}_i \equiv \sum_{t=1}^{T} \bar{\boldsymbol{x}}_{it}/T_i$. The time invariant disturbance term $\varepsilon_i$

is assumed to be independent and identically distributed with variance $\sigma_\varepsilon^2$ and zero mean, and independent of of $\boldsymbol{x}_{it}$ and $v_{it}$.

Therefore, the full model may be written as:

$$\begin{aligned}\Pr\left(Exit_{it}=1|\boldsymbol{x}_{it},\bar{\boldsymbol{x}}_i,\tau_t,GB_i,\varepsilon_i\right) = \Phi&\left(\tau_t+\kappa GB_i+\theta\left(Y05_t\times GB_i\right)\right.\\ &\left.+\boldsymbol{\gamma}\boldsymbol{x}_{it}+\alpha_0+\lambda\bar{\boldsymbol{x}}_i+\varepsilon_i\right). \qquad (4)\end{aligned}$$

We apply a recent method proposed by Puhani (2012) to identify the average treatment effects of the policy intervention on the treated (ATT). Following Wooldridge (2010, p. 488-489), we calculate the corresponding conditional expectation of potential outcomes $Y^1$ and $Y^0$, by integrating equation 4 with respect to the density of the unobserved heterogeneity $u_i$, so the treatment effect on the treated (TT) can be expressed as:

$$\begin{aligned}TT = &\Phi\left(\left(\widehat{\tau}_t\mathbf{1}\left(t\geq 2005\right)+\widehat{\kappa}+\widehat{\theta}+\widehat{\boldsymbol{\gamma}}\boldsymbol{x}_{it}+\widehat{\alpha}_0+\widehat{\lambda}\bar{\boldsymbol{x}}_{\boldsymbol{i}}\right)\left(1+\widehat{\sigma}_\varepsilon^2\right)^{-1/2}\right)\\ &-\Phi\left(\left(\widehat{\tau}_t\mathbf{1}\left(t\geq 2005\right)+\widehat{\kappa}+\widehat{\boldsymbol{\gamma}}\boldsymbol{x}_{it}+\widehat{\alpha}_0+\widehat{\lambda}\bar{\boldsymbol{x}}_{\boldsymbol{i}}\right)\left(1+\widehat{\sigma}_\varepsilon^2\right)^{-1/2}\right), \qquad (5)\end{aligned}$$

where $\mathbf{1}(\cdot)$ is an indicator function. ATT would be readily computable by averaging TT across $i$ and $t$.

In order to assess the fit of the binary choice model, we employ the expected Percentage of Correct Predictions (ePCP) statistic proposed by Herron (1999), which essentially measures the average of the probabilities the hypothetical model assigns to the correct outcome category. The traditional model fit statistic, "percentage correctly predicted" (PCP), which reports percentage correctly classified by a model based on a classification rule – any observation with a predicted probability $\widehat{\mathrm{Pr}_\mathrm{j}}\geq 0.5$ are classified as 1, 0 otherwise – suffers the problem of overstated precision. For example, an observation with the predicted probability $\widehat{\mathrm{Pr}_\mathrm{j}}=0.51$ is treated equally precise as an observation with $\widehat{\mathrm{Pr}_\mathrm{j}}=0.99$ when the actual outcome $Y_j$ is 1. In contrast, ePCP distinguishes between large and small values of predicted probabilities $\widehat{\mathrm{Pr_j}}$ by employing the following formula:

$$ePCP = \frac{1}{n}\left(\sum_{Y_j=1}\widehat{\mathrm{Pr_j}} + \sum_{Y_j=0}\left(1-\widehat{\mathrm{Pr_j}}\right)\right).$$

Obviously, models with high ePCP values are preferred, where only relatively small differences exist between observed outcomes and predicted probabilities.

### *3.2. Modeling the Level of Investment*

There is well-documented evidence that physical capital investments are "irreversible" (e.g., Hill, 2010); as a result, farm investment decisions are made cautiously as well as infrequently. Accordingly, farm-level data tends to contain a substantial number of zero observations for investment. We therefore treat investment as a corner response variable bounded below at zero and utilize a Tobit model to estimate the effect of the Greenbelt policy on the level of farm investment.

It is often observed that disaggregated investment decisions are largely persistent (e.g., Sakellaris, 2004). To capture investment dynamics at the farm level, we employ a dynamic panel model. For dynamic nonlinear models with unobserved individual-specific effects, special attention must be paid to the treatment of the initial conditions. One possibility is to treat the initial conditions $I_{i0}^*$ as exogenous, i.e., a non-random starting value for each cross-sectional unit, implying a strong assumption of independence between initial $I_{i0}^*$ and unobserved heterogeneity $u_i$. In the case of farm investment, for example, this amounts to assuming that unobserved individual specific characteristics such as "farm management skill" and "risk preference" are independent of initial farm investment. Wooldridge (2005) provided a simple, easily applicable solution to treat the initial conditions as endogenous by specifying an auxiliary distribution for the unobserved heterogeneity conditional on the initial outcome variable and explanatory variables. While Wooldridge's model includes values of the time-varying explanatory variables at each period (except the initial period), subsequent empirical work often uses a more constrained specification that includes the within-means of the time-varying explanatory variables. Rabe-Hesketh and Skrondal (2013) showed that the constrained model that includes within-means of time-varying explanatory variables across all periods can lead to severe bias for short panels and proposed several corrections.

In our work, we adopt the following version of Wooldbridge's dynamic Tobit model proposed by Rabe-Hesketh and Skrondal (2013):

$$\begin{aligned} I_{it}^{*} &= \boldsymbol{\rho g}\left(I_{i,t-1}\right) + \tau_t + \kappa GB_i + \theta\left(Y05_t \times GB_i\right) \\ &+ \boldsymbol{\gamma x}_{it} + u_i + v_{it}, \\ I_{it} &= \max\left\{I_{it}^{*}, 0\right\}, \end{aligned} \tag{6}$$

where $I_{it}^{*}$ is a latent variable that underlies the observed investment $I_{it}$; and the unobserved heterogeneity is defined as $u_i = \alpha_0 + \alpha_{\mathbf{1}} I_{i,1} + \lambda \bar{\boldsymbol{x}}_{\boldsymbol{i}}^{+} + \varepsilon_i$, with $\bar{\boldsymbol{x}}_{\boldsymbol{i}}^{+} \equiv \sum_{t=2}^{T} \bar{\boldsymbol{x}}_{\boldsymbol{it}}/(T_i - 1)$. To allow for the possibility that the effect of lagged investment varies depending on whether it was a corner solution (zero) or an interior solution, we use two transformed variables to capture these effects, i.e.:

$$\mathbf{g}\left(I_{i,t-1}\right) = \left(\mathbf{1}\left(I_{i,t-1} = 0\right), \mathbf{1}\left(I_{i,t-1} > 0\right) \ln\left(I_{i,t-1}\right)\right).$$

Among other advantages, as pointed out by Wooldridge (2005), specifying a distribution of heterogeneity conditional on initial conditions facilitates easy identification of partial effects on the mean outcome, averaged across the distribution of unobserved heterogeneity. With $\boldsymbol{\beta w}_{it} = \boldsymbol{\rho g}\left(I_{i,t-1}\right) + \boldsymbol{\gamma x}_{it} + \alpha_0 + \alpha_1 I_{i,1} + \lambda \bar{\boldsymbol{x}}_{\boldsymbol{i}}^{+}$, the treatment effect on the treated (TT) can be easily computed as:

$$
\begin{aligned}
TT = {} & \Phi\left(\left(\tau_t \mathbf{1}\left(t \geq 2005\right) + \kappa + \theta + \boldsymbol{\beta}\boldsymbol{w}_{it}\right)\left(\sigma_v^2 + \sigma_\varepsilon^2\right)^{-1/2}\right)\left(\tau_t \mathbf{1}\left(t \geq 2005\right) + \kappa + \theta + \boldsymbol{\beta}\boldsymbol{w}_{it}\right) \\
& + \left(\sigma_v^2 + \sigma_\varepsilon^2\right)^{-1/2} \phi\left(\left(\tau_t \mathbf{1}\left(t \geq 2005\right) + \kappa + \theta + \boldsymbol{\beta}\boldsymbol{w}_{it}\right)\left(\sigma_v^2 + \sigma_\varepsilon^2\right)^{-1/2}\right) \\
& - \Phi\left(\left(\tau_t \mathbf{1}\left(t \geq 2005\right) + \kappa + \boldsymbol{\beta}\boldsymbol{w}_{it}\right)\left(\sigma_v^2 + \sigma_\varepsilon^2\right)^{-1/2}\right)\left(\tau_t \mathbf{1}\left(t \geq 2005\right) + \kappa + \boldsymbol{\beta}\boldsymbol{w}_{it}\right) \\
& - \left(\sigma_v^2 + \sigma_\varepsilon^2\right)^{-1/2} \phi\left(\left(\tau_t \mathbf{1}\left(t \geq 2005\right) + \kappa + \boldsymbol{\beta}\boldsymbol{w}_{it}\right)\left(\sigma_v^2 + \sigma_\varepsilon^2\right)^{-1/2}\right).
\end{aligned}
\tag{7}
$$

## 4. Data and Variable Descriptions

We use farm-level data for 32,512 farms from the Ontario Farm Income Database (OFID) provided by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), which is compiled from Ontario farm tax filing records for the 2003-2011 period. New entrants are assigned a new farm-level identifier, therefore missing records (i.e., where identifiers no longer appear in the data in subsequent years) can serve as a proxy for farm exits. Comparative statistics for the treatment and control groups for both dependent variables are presented in Table 1. It is evident from this table that the share of exiting farms increased in the control group in the post-treatment period but decreased (statistically insignificant) in the treatment group. Also of note is that, while investment increased in both the control and treatment groups between the pre- and post-treatment period, the increase was insignificant for the treated farms.

In Canada, capital expenditures on depreciable property such as buildings, machinery and equipment are deducted over a period of several years instead of in full in the year of purchase. This yearly deduction is called a capital cost allowance (CCA). Since we do not have data for net investment, we construct the investment variable based on a five-year leading moving average of CCA, that is

$$I_{it} = \left(CCA_{i,t} + CCA_{i,t+1} + \cdots + CCA_{i,t+4}\right)/5.$$

Using the moving average instead of the original level of CCA helps alleviate the effect of arbitrary manipulation of CCA for tax-saving purposes. As shown in Table 1, while both groups increased investment in the post-Greenbelt period, the average farm investment is larger in the treatment group both before and after the implementation of the Greenbelt policy.

Table 2 presents the descriptive statistics for all variables used for the empirical analysis. The key explanatory variables of interest are the Greenbelt policy variables. As evident in Figure 1, the Greenbelt consists of three distinct areas: the Protected Countryside (PC) area, the Oak Ridges Moraine Conservation Plan (ORM) area, and the Niagara Escarpment Plan (NEP) area. The latter two of these zones, the ORM and the NEP, had previously been protected (though less restrictively) by specific provincial regulations prior to the implementation of the Greenbelt. For this reason, we consider the disaggregated effects of PC, ORM, and NEP. As we do not have the physical address of farms in the data set, the way in which we identify whether a farm is within or outside of the Greenbelt boundary is based on the postal codes on record[2]. Geographic information systems (GIS) software was used to identify the percentage of land for each postal code area that is within the Greenbelt boundary. For postal code areas that are not fully within the Greenbelt, the assumption is that the higher the percentage of area within the boundary the greater the likelihood that the farm is located in the Greenbelt. However, to reduce the likelihood of incorrect identification of farm locations with respect to the Greenbelt boundary, we exclude observations whose postal code areas have a proportion of 25%–75% of land located in the Greenbelt boundary (we further address this issue through robustness checks). The remaining lower end and higher

---

[2] There are just over 10,000 distinct postal codes that overlap in whole or in part with the Greenbelt, for which the average area is 1.7 square kilometers.

end observations are assigned to 0 and 1, respectively, for the Greenbelt dummy variables. A similar approach is used to assign farms to the three areas within the Greenbelt. Under this classification, 1,153 (3.5%) farms are identified as inside the PC area, while only 27 and 19 farms are located inside the ORM and NEP areas, respectively. Evidently, the majority of Greenbelt farms are in the PC. Next, we define post-treatment variables ($GB\_post$, $PC\_post$, $ORM\_post$, and $NEP\_post$) for farms located within the Greenbelt boundary in post-policy years (i.e., 2005 onward). We conduct joint Wald tests for both components of the analysis to determine whether the estimated Greenbelt effect should be disaggregated for the three zones.

We control for a variety of farm-level factors that we expect will influence farm decisions. These include profitability as measured by operating profit margin ratio[3], operating efficiency as measured by operating expense ratio[4], farm size categorized by total operating revenue (the omitted size is that of farms with revenues between $10,000 and $49,999)[5], the number of family employees indicated by the number of taxfilers associated with the farm operation, farm type based on the percentage of the sales of the major commodity or commodity group (the omitted type is field crop farms), whether the farm is incorporated, and whether the farm uses credit. To account for the effect of specialization/diversification, we control for the proportion of revenue contributed by the major commodity. We also include interest expense, as a proxy for the amount of farm debt, and rent expense variables.

Farm management decisions may be influenced not only by farm-level factors but also by the location of the farm. Specifically, the proximity of a farm to urban areas may influence these decisions. To account for this potential influence, we include the distances from the postal code area centroid (since we do not have farm addresses) to the city of Toronto and to the nearest urban area with population greater than 50,000.

---

[3] Operating profit margin ratio is calculated by dividing the farm's net operating income (before interest and taxes) by total operating revenue.

[4] Operating expense ratio is calculated as total operating expenses divided by total operating revenue.

[5] The smallest revenue category (under $10,000) is not used as the reference group since farms in this category are excluded for one of the robustness checks.

In addition to the Greenbelt policy, Ontario has a number of other programs intended to strengthen the viability of farm operations and to support investment in farm operations: for example, business risk management (BRM) programs such as AgriStability and AgriInvest. In order to capture the effects of these programs we include a variable to measure total government payments. Government program payments have also been used as a determinant of farm exit by Kazukauskas et al. (2013) and by Goetz and Debertin (2001).

Finally, to account for unobserved heterogeneity, we include year-averaged variables for profitability, operating efficiency, interest, rent, and government payments.

## 5. Results

In this section we present and discuss the empirical results. We begin by discussing the parameter estimates for variables that affect the probability that a farmer exits farming, including the Greenbelt variables. Subsequently, we discuss the effects of the Greenbelt variables on farm investment. The tables of results for both components of the empirical analysis include parameter estimates for the primary models as well as for alternate model specifications used for robustness checks, which are described below.

### *5.1. Estimation Results for Probability of Exit*

Table 3 summarizes the results of the random effects Probit estimates of the probability that a farm goes out of business. Note that since the value of the dependent variable is observed based on the following year (i.e., if the farm is no longer in business in the following year), all explanatory variables are actually lagged by one period, with the lag sign suppressed. Due to this specification of the farm exit variable, all observations for 2011 are omitted from the analysis as we are unable to observe if a farm exits in 2012.

A likelihood-ratio (LR) test which formally compares the pooled estimator with the panel estimator is included at the bottom of Table 3. This test statistic is significant, implying that the random effects model is preferred to a pooled model. The expected percentage of correct predictions (ePCP) is 89.0%, which suggests that the model fits the data well. A joint Wald test of equality of the coefficients *PC_post*, *ORM_post*, and *NEP_post* failed to reject the hypothesis that the policy effect is the same across the three Greenbelt zones. As a result, the Greenbelt policy effect is estimated using a single variable ($GB$), following Equation 4.

Most of the time-averaged control variables are statistically significant, suggesting that the CRE specification is appropriate. The signs of the year-averaged variables indicate that higher levels of debt (i.e., interest expense) and lower operating profit margins are associated with a higher probability of exit, which is consistent with expectations. One interesting finding is that the sign of lagged interest expense is the opposite of the corresponding time-averaged variable. The interpretation of this finding is that taking on more debt in the previous year may help farms temporarily stay in business; however, in the long run, farms relying on high levels of debt have a higher probability of going out of business.

As for other control variables, the results suggest the likelihood of exit is higher for farms that are less diversified, unincorporated, and smaller-sized (lower revenue class), as well as for farms hiring fewer family members. Conversely, usage of credit, higher government payments, and higher rent expenses are found to decrease the probability of exit. Differences in the probability of exit are found to exist across farm types, where, relative to field crop farms, the probability is significantly higher for all other farm types except for beef, tender fruits, and other crops. The location of the farm with respect to urban areas is also found to influence the likelihood of farm exit, where farms in closer proximity to urban areas are more likely to exit. This is consistent with the effects of urban development pressure on surrounding farmland.

The results for a number of these control variables are consistent with those of previous studies. For example, Goetz and Debertin (2001) found that government payments reduced the probability of farm exit and that significant differences in exit existed between various farm types, while Ahearn et al. (2005) and Dong et al. (2010) each found inverse relationships between farm size and exit rate.

We now turn to the effects of the Greenbelt policy variables. We find that the implementation of the Greenbelt has had a negative and significant effect (though only at the 10% level) on the probability of exit. This suggests that the protection for the agriculture industry provided by the Greenbelt policy may have reduced farm exit in the Greenbelt relative to areas outside the Greenbelt. The corresponding treatment effect, calculated based on Equation 5, indicates that, on average, farmers in the Greenbelt area have a 2.1% lower probability of going out of business following the implementation of the Greenbelt zoning policy, relative to farmers outside the Greenbelt boundary (see Table 5)[6].

As a robustness check, we use an alternate, more restrictive threshold to specify whether a farm is located within or outside the Greenbelt boundary. Instead of omitting farms in postal code areas that are between 25% and 75% within the Greenbelt, we use 10% and 90% as the cut-off percentiles for the treatment and control groups, where farms in postal code areas that are greater than 90% within the Greenbelt are assigned to 1 for the Greenbelt dummy variables. Column 2 of Table 3 reports the results of this model specification, which are qualitatively the same as those of the primary model.

Next, to reduce the potential influence of outliers, we estimate the model using a reduced sample. Since small farms with very low operating income may have a substantially different production function and may benefit from off-farm income, their decision-making processes may not be consistent with those of typical farming operations. As a result, we exclude unincorporated farms with total operating revenues below $10,000. The results of this specification, provided in column 3 of Table 3, indicate that the impact of the Greenbelt policy remains qualitatively unchanged relative to the primary model. Hence, overall, these results imply that the Greenbelt policy has influenced farm exit decisions in a manner that appears to be consistent with the goals of the Greenbelt policy.

---

[6] We also considered the interactions of the treatment variable with farm characteristics (e.g., farm type) but did not find anything of significance.

### *5.2. Estimation Results for Level of Investment*

The dynamic Tobit estimates for farm investment are provided in Table 4. Both lagged investment variables are significant, which suggests that high levels of persistence exist in agricultural investment. The effect of $I_{i1}$ is significant at the 5% level, which implies endogeneity of the initial conditions. The LR test statistic suggests that the random effects model is more appropriate than a pooled model. A joint Wald test of equality of the coefficients $PC\_post$, $ORM\_post$, and $NEP\_post$ rejects (at the 10% level) the hypothesis that the policy effects of the three Greenbelt zones are the same. This implies that the unrestricted model that explicitly estimates the effects of the Greenbelt in each of the three zones is more appropriate. Hence, for the estimation of this model, the variable $GB$ in Equation 6 is broken down into three variables that correspond with the three areas of the Greenbelt.

The results for the time-averaged control variables indicate that farms with higher rent expenses and lower government payments tend to invest more. Similar to the farm exit model, opposing effects are found for lagged interest expense and the corresponding time-averaged variable. The interpretation of this finding is that more debt in the previous year may discourage farm investment temporarily; however, in the long run, a high level of debt is associated with a higher level of investment.

The signs of other control variables indicate that less diversified farms and unincorporated farms have higher levels of investment, while farms with more family employees and usage of credit have lower investment. A number of significant differences in investment exist across farm types, where, relative to field crop farms, investment is significantly lower for dairy, floriculture, nursery, tobacco, other fruits and vegetables, and other animal farms. Finally, investment is not significantly influenced by profitability or operating efficiency[7].

The effects of the Greenbelt policy are found to vary by zone (see Table 4), with a significantly negative effect in the PC and a significantly positive effect (though only at

---

[7] Variables accounting for the distances to the nearest urban areas are not included in this model, as they were not found to significantly impact investment.

the 10% level) in the ORM. Calculation of the corresponding treatment effects, based on Equation 7, indicates that relative to areas outside the Greenbelt the average investment of farms in the ORM would be \$3,406 higher following the implementation of the Greenbelt zoning policy while the average investment of farms in the PC would be \$1,067 lower (see Table 5). This negative effect may be due to farmers' inactivity in investment with the expectation of selling their farms after the implementation of Greenbelt policy.

As with the farm exit model, we perform robustness checks to examine whether our results are robust to alternate thresholds (10% and 90%) for the specification of the treatment and control groups and to a reduced sample specification in which unincorporated farms with revenues below \$10,000 are excluded. As evident in Table 4, the results of these specifications indicate that the policy effect in the PC is consistent with the result of the primary model while the effect in the ORM is not significant across all models.

In addition, we perform a third robustness check in which we use an alternate specification of the dependent variable, where the level of investment is specified based on a four-year instead of a five-year leading moving average of the CCA. As shown in column 4 of Table 4, the results of this specification are qualitatively the same as those of the other two robustness checks for the PC, while the effect in the ORM is not significant. Overall, these results provide evidence that the implementation of the Greenbelt has negatively impacted the level of farm investment in the PC, an outcome that is contrary to the goals of the Greenbelt. Conversely, given the results of the robustness checks as well as the very low number of observations in the ORM and the relatively low level of statistical significance, the positive impact in the ORM observed in the primary model should be viewed with caution.

## 6. Conclusions

Economic theory suggests competing hypotheses regarding the effects of zoning policies on farm exit and investment decisions. This paper examines empirically the impact of the Greenbelt policy on the Ontario agriculture industry using farm-level panel data. This paper adds to the literature on factors that influence farm exit and investment decisions, but is, to our knowledge, the first study to explicitly examine the impacts on farm exit and investment of a land use policy that was implemented to protect the agriculture industry. This study may have application for areas with other farmland preservation programs, such as purchase or transfer of development rights (PDR/TDR) programs.

We use a difference-in-differences approach to estimate the effects of the Greenbelt policy on farmers' exit and investment decisions. We find evidence that the Greenbelt policy has influenced both exit and investment decisions. The probability of farm exit is found to have decreased among farms in the Greenbelt relative to farms outside the Greenbelt, which suggests that the protection for the agriculture industry provided by the Greenbelt has reduced farm exit. However, the level of farm investment in the Protected Countryside area of the Greenbelt has been negatively impacted relative to areas outside the Greenbelt, a finding that is supported by the robustness checks. This impact is contrary to one of the stated objectives of the Greenbelt policy, as the protection provided by the Greenbelt does not appear to have enhanced investment in the local agriculture industry. While these results with respect to the impacts on farm exit and on investment appear to be conflicting, the reduction in farm exit may have occurred due to the decrease in farmland values caused by the Greenbelt policy (see Deaton and Vyn (2010)), which may have delayed farm exit decisions in the hope that prices would recover, during which period no major farm investments are made.

There are limitations inherent in this study that should be acknowledged. There are potential limitations associated with the specifications of the dependent variables for both components of the analysis. Farm-level investment is not specifically observed; as a result, capital cost allowance is used as a proxy for the level of investment. However, since capital expenditures are typically depreciated over a number of years, there is likely a high degree of correlation between investment and capital cost allowance, which enhances the suitability of the use of CCA as a proxy for investment. Nonetheless, the inability to observe actual investment levels remains a potential shortcoming of this study. In addition, this variable would not capture alternate forms of investment such as long-term investment in soil quality through production practices such as reduced tillage. Farm exit is determined by the discontinuation of farm identifiers in subsequent years of the data. However, farm restructuring (i.e., incorporating the farm) or ownership changes (i.e., transferring ownership from father to son), where the farm does not actually go out of business, would result in a new identifier being assigned to the farm. Since the original identifier is discontinued, this would be interpreted as a farm exit. Such cases likely comprise only a small proportion of farm exit observations, but the possibility remains that this could influence the results. Finally, the method for identifying whether farms are located in the Greenbelt (i.e., farms in postal code areas that are at least 75% within the Greenbelt area are identified as being located in the Greenbelt) allows for the possibility of incorrect identification, which could bias the results. However, the results of the robustness checks in which 90% is used as the threshold for identification within the Greenbelt are qualitatively consistent with the results of the primary model.

The implications of the results of this study are notable. The finding of decreased investment in the PC suggests that the Greenbelt policy has not achieved the objective of enhancing long-term investment in the local agriculture industry. This finding also contradicts the argument of Greenbelt proponents that permanent protection of farmland can stimulate investment in the agriculture industry. It may be the case that the infrastructure (i.e., farm services, input suppliers, etc.) necessary to support the agriculture industry in the Greenbelt area had already deteriorated considerably prior to the implementation of the Greenbelt. Such deterioration, which can often occur in rural areas adjacent to large, growing urban centers, may discourage additional investment in agriculture despite the protection of the agriculture industry from encroaching urban influence that was provided by this policy. This suggests that the timing of land use policies to protect the agriculture industry in near-urban areas is critical. A more in-depth examination of agriculture in the

Greenbelt could assess the degree to which deterioration of agricultural infrastructure may have occurred prior to the implementation of the Greenbelt.

## References

Ahearn, M. C., Yee, J., Korb, P., 2005. Effects of differing farm policies on farm structure and dynamics. American Journal of Agricultural Economics 87 (5), 1182–1189.

Athey, S., Imbens, G. W., 2006. Identification and inference in nonlinear difference-in-differences models. Econometrica 74 (2), 431–497.

Benjamin, C., Phimister, E., 2002. Does capital market structure affect farm investment? a comparison using french and british farm-level panel data. American Journal of Agricultural Economics 84 (4), 1115–1129.

Deaton, B. J., Vyn, R. J., 2010. The effect of strict agricultural zoning on agricultural land values: The case of ontario's greenbelt. American Journal of Agricultural Economics 92 (4), 941–955.

Dong, F., Hennessy, D. A., Jensen, H. H., 2010. Contract and exit decisions in finisher hog production. American Journal of Agricultural Economics 92 (3), 667–684.

Foltz, J. D., 2004. Entry, exit, and farm size: assessing an experiment in dairy price policy. American Journal of Agricultural Economics 86 (3), 594–604.

Goetz, S. J., Debertin, D. L., 2001. Why farmers quit: A county-level analysis. American Journal of Agricultural Economics 83 (4), 1010–1023.

Herron, M. C., 1999. Postestimation uncertainty in limited dependent variable models. Political Analysis 8 (1), 83–98.

Hill, R. V., 2010. Investment and abandonment behavior of rural households: An empirical investigation. American Journal of Agricultural Economics 92 (4), 1065–1086.

Kazukauskas, A., Newman, C., Clancy, D., Sauer, J., 2013. Disinvestment, farm size, and gradual farm exit: The impact of subsidy decoupling in a european context. American Journal of Agricultural Economics 95 (5), 1068–1087.

Lynch, L., Gray, W., Geoghegan, J., 2007. Are farmland preservation program easement restrictions capitalized into farmland prices? what can a propensity score matching analysis tell us? Applied Economic Perspectives and Policy 29 (3), 502–509.

Mundlak, Y., 1978. On the pooling of time series and cross section data. Econometrica: Journal of the Econometric Society, 69–85.

Puhani, P. A., 2012. The treatment effect, the cross difference, and the interaction term in nonlinear "difference-in-differences" models. Economics Letters 115 (1), 85–87.

Rabe-Hesketh, S., Skrondal, A., 2013. Avoiding biased versions of wooldridge's simple solution to the initial conditions problem. Economics Letters 120 (2), 346–349.

Sakellaris, P., 2004. Patterns of plant adjustment. Journal of Monetary Economics 51 (2), 425–450.

Wooldridge, J. M., 2005. Simple solutions to the initial conditions problem in dynamic, nonlinear panel data models with unobserved heterogeneity. Journal of Applied Econometrics 20 (1), 39–54.

Wooldridge, J. M., 2010. Econometric analysis of cross section and panel data. MIT press.

## Table 1. Dynamics of farm exit and investment proxy variables by control and treatment group

| | Control | Treatment |
|---|---|---|
| **Exit rate** | | |
| Pre-greenbelt | 0.072 | 0.086 |
| | (0.259) | (0.280) |
| Post-greenbelt | 0.079 | 0.074 |
| | (0.269) | (0.262) |
| P-value | 0.000 | 0.129 |
| **Investment ($ 000s)** | | |
| Pre-greenbelt | 29.788 | 42.099 |
| | (79.137) | (76.875) |
| Post-greenbelt | 33.196 | 47.034 |
| | (85.871) | (103.538) |
| P-value | 0.000 | 0.138 |

Standard deviation in parentheses

## Table 2. Descriptive statistics for variables used in the farm exit and investment models

| Variable | Definition | Mean | S.D. | Min | Max |
|---|---|---|---|---|---|
| **Dependent variables** | | | | | |
| Exit | = 1 if farm is out of business in the following year | 0.078 | 0.267 | 0 | 1 |
| I | Five-year leading moving average of capital cost allowance ($ 000s) | 32.332 | 83.687 | 0 | 4,464 |
| **Greenbelt and location variables** | | | | | |
| GB | = 1 if farm is located in the Greenbelt | 0.040 | 0.195 | 0 | 1 |
| PC | = 1 if farm is located in the Protected Countryside area | 0.036 | 0.186 | 0 | 1 |
| ORM | = 1 if farm is located in the Oak Ridges Moraine area | 0.003 | 0.050 | 0 | 1 |
| NEP | = 1 if farm is located in the Niagara Escarpment Plan area | 0.001 | 0.036 | 0 | 1 |
| GB_post | = 1 if farm is located in the Greenbelt and the Greenbelt policy is in effect | 0.031 | 0.173 | 0 | 1 |
| PC_post | = 1 if farm is located in the PC and the Greenbelt policy is in effect | 0.028 | 0.164 | 0 | 1 |
| ORM_post | = 1 if farm is located in the ORM and the Greenbelt policy is in effect | 0.002 | 0.045 | 0 | 1 |
| NEP_post | = 1 if farm is located in the NEP and the Greenbelt policy is in effect | 0.001 | 0.031 | 0 | 1 |

Continued on next page

**Table 2 – continued from previous page**

| Variable | Definition | Mean | S.D. | Min | Max |
|---|---|---|---|---|---|
| Toronto_dis | Distance to the city of Toronto, in kilometers | 136.22 | 86.386 | 0 | 402.778 |
| Urban_dis | Distance to the nearest urban area with a population of 50,000 or more, in kilometers | 32.491 | 25.35 | 0 | 145.958 |
| **Farm structural variables** | | | | | |
| Credit | = 1 if farm uses credit | 0.812 | 0.391 | 0 | 1 |
| Incorp | = 1 if farm is incorporated | 0.213 | 0.409 | 0 | 1 |
| Interest | Interest expense ($ 000s) | 17.691 | 53.104 | 0 | 6,624 |
| Profitability | Operating profit margin ratio | -7.819 | 965.479 | -275,248 | 195,749 |
| Efficiency | Operating expense ratio | 5.930 | 714.366 | 0 | 253,426 |
| Govern | Government payments ($ 000s) | 11.848 | 64.179 | 0 | 4,408 |
| Opcount | Number of operators (taxfilers) associated with the farm | 1.304 | 0.526 | 1 | 7 |
| Rent | Rent expenses ($ 000s) | 14.361 | 67.31 | 0 | 6,400 |
| Sect_pct | Share of revenue from primary farm sector | 0.897 | 0.154 | 0.220 | 1 |
| **Farm type variables** | | | | | |
| Beef | = 1 if farm is a beef farm | 0.203 | 0.402 | 0 | 1 |
| Dairy | = 1 if farm is a dairy farm | 0.072 | 0.258 | 0 | 1 |
| Field crops | = 1 if farm is a field crops farm (benchmark farm type) | 0.487 | 0.500 | 0 | 1 |
| Floriculture | = 1 if farm is a floriculture farm | 0.010 | 0.097 | 0 | 1 |
| Grapes | = 1 if farm is a vineyard | 0.008 | 0.090 | 0 | 1 |
| Mixed | = 1 if farm is a mixed farm | 0.015 | 0.123 | 0 | 1 |
| Nursery | = 1 if farm is a nursery | 0.009 | 0.096 | 0 | 1 |
| Other animal production | = 1 if farm specializes in production of other animals | 0.096 | 0.295 | 0 | 1 |
| Other crops | = 1 if farm specializes in production of other crops | 0.006 | 0.077 | 0 | 1 |
| Other fruits & vegetables | = 1 if farm specializes in production of other fruits and vegetables | 0.013 | 0.113 | 0 | 1 |
| Tender fruits | = 1 if farm is a tender fruit farm | 0.006 | 0.077 | 0 | 1 |
| Tobacco | = 1 if farm is a tobacco farm | 0.024 | 0.152 | 0 | 1 |
| **Farm size variables, categorized by total operating revenues** | | | | | |
| Size 1 | Under $10,000 | 0.077 | 0.267 | 0 | 1 |
| Size 2 | $10,000 - $49,999 | 0.286 | 0.452 | 0 | 1 |
| Size 3 | $50,000 - $99,999 | 0.163 | 0.369 | 0 | 1 |
| Size 4 | $100,000 - $249,999 | 0.198 | 0.398 | 0 | 1 |
| Size 5 | $250,000 - $499,999 | 0.133 | 0.339 | 0 | 1 |
| Size 6 | $500,000 and over | 0.144 | 0.351 | 0 | 1 |

## Table 3. Regression results for farm exit

| | Primary | Alternate Threshold | Reduced Sample |
|---|---|---|---|
| **Greenbelt policy variable** | | | |
| GB_post | −0.196* | −0.181* | −0.234* |
| | (0.102) | (0.105) | (0.135) |
| **Location variables** | | | |
| Toronto_dis | −0.001** | −0.001** | −0.002** |
| | (0.0002) | (0.0002) | (0.0002) |
| Urban_dis | −0.003** | −0.003** | −0.006** |
| | (0.001) | (0.001) | (0.001) |
| GB | 0.013 | −0.014 | −0.043 |
| | (0.116) | (0.120) | (0.159) |
| **Farm structural variables** | | | |
| Interest | −0.002** | −0.002** | −0.002** |
| | (0.0005) | (0.0005) | (0.0006) |
| Profitability | 0.0000002 | 0.000001 | 0.0002 |
| | (0.00002) | (0.00002) | (0.0002) |
| Efficiency | −0.000008 | −0.000007 | 0.0009 |
| | (0.00002) | (0.00002) | (0.0008) |
| Govern | −0.0009** | −0.0009** | −0.0009** |
| | (0.0002) | (0.0002) | (0.0002) |
| Sect_pct | 1.063** | 1.067** | 1.188** |
| | (0.081) | (0.082) | (0.106) |
| Rent | −0.001** | −0.001** | −0.001** |
| | (0.0005) | (0.0005) | (0.0005) |
| Credit | −0.476** | −0.474** | −0.605** |
| | (0.027) | (0.028) | (0.039) |
| Opcount | −0.103** | −0.099** | −0.152** |
| | (0.027) | (0.028) | (0.036) |
| Incorp | −0.116** | −0.115** | −0.229** |
| | (0.044) | (0.044) | (0.053) |
| **Time-averaged farm structural variables** | | | |
| MInterest | 0.003** | 0.003** | 0.005** |
| | (0.0006) | (0.0006) | (0.0007) |
| MProfitability | −0.0001** | −0.0001** | −0.00001 |
| | (0.00005) | (0.00005) | (0.0003) |
| MEfficiency | −0.0001** | −0.0001** | −0.0004 |
| | (0.00006) | (0.00006) | (0.0006) |
| MRent | −0.0004 | −0.0005 | −0.001 |
| | (0.0006) | (0.0006) | (0.0007) |
| MGovern | −0.0003 | −0.0003 | −0.0007 |
| | (0.0004) | (0.0004) | (0.0005) |
| **Farm type variables** | | | |
| Beef | −0.003 | −0.004 | 0.181** |
| | (0.033) | (0.033) | (0.048) |
| Dairy | 1.221** | 1.218** | 1.421** |
| | (0.052) | (0.053) | (0.064) |
| Floriculture | 0.502** | 0.486** | 0.597** |
| | (0.144) | (0.146) | (0.180) |
| Grapes | 0.532** | 0.540** | 0.754** |
| | (0.150) | (0.152) | (0.207) |

Continued on next page

**Table 3 – continued from previous page**

| | Primary | Alternate Threshold | Reduced Sample |
|---|---|---|---|
| Mixed | 0.476$^{**}$ | 0.459$^{**}$ | 0.619$^{**}$ |
| | (0.090) | (0.092) | (0.113) |
| Nursery | 0.464$^{**}$ | 0.462$^{**}$ | 0.615$^{**}$ |
| | (0.131) | (0.134) | (0.175) |
| Other animal production | 0.595$^{**}$ | 0.593$^{**}$ | 0.862$^{**}$ |
| | (0.044) | (0.045) | (0.061) |
| Other crops | 0.181 | 0.166 | 0.257 |
| | (0.147) | (0.151) | (0.217) |
| Other fruits & vegetables | 0.460$^{**}$ | 0.488$^{**}$ | 0.585$^{**}$ |
| | (0.113) | (0.116) | (0.146) |
| Tender fruits | 0.127 | 0.122 | 0.346 |
| | (0.181) | (0.183) | (0.238) |
| Tobacco | 0.459$^{**}$ | 0.460$^{**}$ | 0.511$^{**}$ |
| | (0.076) | (0.077) | (0.104) |
| **Farm size variables** | | | |
| Size 1 | 0.751$^{**}$ | 0.750$^{**}$ | |
| | (0.030) | (0.030) | |
| Size 3 | −0.607$^{**}$ | −0.613$^{**}$ | −0.730$^{**}$ |
| | (0.029) | (0.030) | (0.035) |
| Size 4 | −0.996$^{**}$ | −1.004$^{**}$ | −1.223$^{**}$ |
| | (0.034) | (0.035) | (0.041) |
| Size 5 | −1.245$^{**}$ | −1.257$^{**}$ | −1.574$^{**}$ |
| | (0.044) | (0.045) | (0.052) |
| Size 6 | −1.581$^{**}$ | −1.598$^{**}$ | −1.980$^{**}$ |
| | (0.057) | (0.058) | (0.066) |
| **Year variables** | | | |
| Year=2004 | 0.119$^{**}$ | 0.131$^{**}$ | 0.350$^{**}$ |
| | (0.036) | (0.036) | (0.047) |
| Year=2005 | 0.502$^{**}$ | 0.509$^{**}$ | 0.769$^{**}$ |
| | (0.039) | (0.040) | (0.053) |
| Year=2006 | 0.681$^{**}$ | 0.686$^{**}$ | 1.023$^{**}$ |
| | (0.044) | (0.045) | (0.059) |
| Year=2007 | 0.978$^{**}$ | 0.983$^{**}$ | 1.408$^{**}$ |
| | (0.047) | (0.048) | (0.063) |
| Year=2008 | 1.496$^{**}$ | 1.506$^{**}$ | 2.030$^{**}$ |
| | (0.051) | (0.052) | (0.067) |
| Year=2009 | 1.485$^{**}$ | 1.496$^{**}$ | 2.078$^{**}$ |
| | (0.056) | (0.057) | (0.073) |
| Year=2010 | 1.738$^{**}$ | 1.753$^{**}$ | 2.367$^{**}$ |
| | (0.061) | (0.062) | (0.078) |
| **Constant term** | | | |
| Constant | −2.875$^{**}$ | −2.898$^{**}$ | −3.504$^{**}$ |
| | (0.105) | (0.107) | (0.141) |
| Observations | 163,449 | 160,185 | 133,661 |
| ePCP | 0.890 | 0.890 | 0.918 |
| Log lik. | −39,571 | −39,690 | −29,440 |
| LR test [p-value] | 3,084 | 3,038 | 3,123 |
| | [0.000] | [0.000] | [0.000] |

Standard errors in parentheses.
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < .01$.

## Table 4. Regression results for farm investment

| | Primary | Alternate Threshold | Reduced Sample | Four-Year MA |
|---|---|---|---|---|
| **Greenbelt policy variables** | | | | |
| PC_post | $-1.413^{**}$ | $-1.877^{**}$ | $-1.540^{**}$ | $-2.003^{**}$ |
| | (0.672) | (0.916) | (0.766) | (0.825) |
| ORM_post | $4.413^{*}$ | $4.426^{*}$ | 4.496 | 5.066 |
| | (2.547) | (2.618) | (2.819) | (3.133) |
| NEP_post | −1.440 | −4.157 | −0.969 | −2.293 |
| | (3.675) | (5.114) | (4.382) | (4.532) |
| **Greenbelt location variables** | | | | |
| PC | 0.188 | 0.615 | 0.0189 | 1.027 |
| | (1.034) | (1.295) | (1.195) | (1.238) |
| ORM | 0.817 | 1.312 | 1.237 | 0.309 |
| | (3.503) | (3.587) | (3.952) | (4.270) |
| NEP | −2.714 | −2.151 | −3.445 | −1.852 |
| | (5.205) | (7.240) | (6.370) | (6.170) |
| **Lagged investment variables** | | | | |
| $\mathbf{1}\left(I_{t-1}=0\right)$ | $-12.57^{**}$ | $-12.47^{**}$ | $-11.57^{**}$ | $-14.79^{**}$ |
| | (0.772) | (0.789) | (1.010) | (0.711) |
| $\mathbf{1}\left(I_{t-1}>0\right)\ln\left(I_{t-1}\right)$ | $3.359^{**}$ | $3.272^{**}$ | $4.201^{**}$ | $4.933^{**}$ |
| | (0.109) | (0.111) | (0.136) | (0.111) |
| **Initial condition** | | | | |
| I_0 | $0.992^{**}$ | $0.994^{**}$ | $0.988^{**}$ | $0.947^{**}$ |
| | (0.003) | (0.003) | (0.004) | (0.003) |
| **Lagged farm structural variables** | | | | |
| LInterest | $-0.077^{**}$ | $-0.079^{**}$ | $-0.076^{**}$ | $-0.077^{**}$ |
| | (0.003) | (0.004) | (0.004) | (0.003) |
| LProfitability | −0.00002 | −0.00002 | −0.000006 | −0.00008 |
| | (0.0002) | (0.0002) | (0.0003) | (0.0001) |
| LEfficiency | −0.00005 | −0.00007 | −0.0001 | −0.0002 |
| | (0.0005) | (0.0005) | (0.0008) | (0.0003) |
| LGovern | $-0.014^{**}$ | $-0.015^{**}$ | $-0.015^{**}$ | $-0.021^{**}$ |
| | (0.001) | (0.001) | (0.001) | (0.001) |
| LRent | $0.012^{**}$ | $0.012^{**}$ | $0.012^{**}$ | $0.019^{**}$ |
| | (0.002) | (0.002) | (0.002) | (0.003) |
| **Farm structural variables** | | | | |
| Sect_pct | $1.475^{**}$ | $1.712^{**}$ | $1.947^{**}$ | $1.504^{**}$ |
| | (0.665) | (0.679) | (0.786) | (0.732) |
| Credit | $-0.511^{*}$ | $-0.587^{**}$ | $-0.621^{*}$ | $-0.795^{**}$ |
| | (0.279) | (0.286) | (0.347) | (0.307) |
| Opcount | $-1.471^{**}$ | $-1.458^{**}$ | $-1.528^{**}$ | $-2.168^{**}$ |
| | (0.296) | (0.300) | (0.343) | (0.340) |
| Incorp | $-1.899^{**}$ | $-1.851^{**}$ | $-2.082^{**}$ | $-3.425^{**}$ |
| | (0.446) | (0.452) | (0.500) | (0.516) |
| **Time-averaged farm structural variables** | | | | |
| MInterest | $0.202^{**}$ | $0.207^{**}$ | $0.201^{**}$ | $0.282^{**}$ |
| | (0.005) | (0.005) | (0.005) | (0.005) |
| MProfitability | 0.0002 | 0.0001 | −0.0001 | 0.00005 |

Continued on next page

**Table 4 – continued from previous page**

| | Primary | Alternate Threshold | Reduced Sample | Four-Year MA |
|---|---|---|---|---|
| | (0.0008) | (0.0008) | (0.003) | (0.001) |
| MEfficiency | −0.0004 | −0.0003 | −1.558** | −0.0002 |
| | (0.002) | (0.002) | (0.777) | (0.002) |
| MRent | 0.018** | 0.017** | 0.017** | 0.004 |
| | (0.003) | (0.003) | (0.003) | (0.003) |
| MGovern | −0.103** | −0.107** | −0.101** | −0.090** |
| | (0.004) | (0.004) | (0.004) | (0.005) |
| **Farm type variables** | | | | |
| Beef | 0.027 | 0.077 | 0.387 | −0.124 |
| | (0.298) | (0.305) | (0.381) | (0.336) |
| Dairy | −1.685** | −1.721** | −2.030** | −3.360** |
| | (0.554) | (0.560) | (0.615) | (0.608) |
| Floriculture | −9.170** | −7.991** | −9.207** | −9.375** |
| | (1.378) | (1.484) | (1.509) | (1.585) |
| Grapes | 2.098 | 1.336 | 2.047 | 2.243 |
| | (1.518) | (2.112) | (1.756) | (1.750) |
| Mixed | −0.585 | −0.552 | −0.483 | −0.840 |
| | (0.598) | (0.610) | (0.682) | (0.666) |
| Nursery | −2.173* | −1.993 | −2.629* | −2.781* |
| | (1.291) | (1.383) | (1.523) | (1.476) |
| Other animal production | −2.791** | −2.796** | −2.892** | −3.931** |
| | (0.412) | (0.416) | (0.488) | (0.461) |
| Other crops | −0.175 | −0.066 | 0.068 | 0.043 |
| | (1.545) | (1.576) | (1.923) | (1.734) |
| Other fruits & vegetables | −2.046* | −2.308** | −2.574** | −2.194* |
| | (1.087) | (1.113) | (1.254) | (1.241) |
| Tobacco | −3.382** | −3.367** | −3.793** | −2.088** |
| | (0.726) | (0.727) | (0.868) | (0.801) |
| Tender fruits | 0.255 | 0.665 | 0.416 | 0.433 |
| | (1.606) | (2.325) | (1.888) | (1.849) |
| **Farm size variables** | | | | |
| Size 1 | 0.745** | 0.729* | | 1.034** |
| | (0.368) | (0.377) | | (0.407) |
| Size 3 | −0.840** | −0.822** | −0.935** | −1.625** |
| | (0.250) | (0.256) | (0.288) | (0.274) |
| Size 4 | −1.281** | −1.236** | −1.537** | −2.549** |
| | (0.306) | (0.313) | (0.353) | (0.334) |
| Size 5 | −1.293** | −1.283** | −1.744** | −2.245** |
| | (0.395) | (0.404) | (0.449) | (0.431) |
| Size 6 | 1.121** | 1.075** | 0.383 | 2.047** |
| | (0.499) | (0.510) | (0.561) | (0.542) |
| **Year variables** | | | | |
| Year=2005 | 0.598** | 0.575** | 0.736** | 0.739** |
| | (0.152) | (0.156) | (0.177) | (0.192) |
| Year=2006 | 1.456** | 1.452** | 1.733** | 1.151** |
| | (0.155) | (0.158) | (0.179) | (0.195) |
| Year=2007 | 3.029** | 3.064** | 3.571** | 2.506** |
| | (0.159) | (0.163) | (0.184) | (0.199) |
| Year=2008 | | | | 4.079** |
| | | | | (0.204) |

Continued on next page

**Table 4 – continued from previous page**

| | Primary | Alternate Threshold | Reduced Sample | Four-Year MA |
|---|---|---|---|---|
| **Constant term** | | | | |
| Constant | $-6.067^{**}$ | $-6.126^{**}$ | $-7.724^{**}$ | $-8.006^{**}$ |
| | (0.820) | (0.835) | (1.069) | (0.916) |
| Observations | 62,685 | 60,542 | 53,398 | 82,672 |
| Log lik. | −261,751 | −253,166 | −227,799 | −360,541 |
| LR test [p-value] | 28,000 | 27,000 | 25,000 | 41,000 |
| | [0.000] | [0.000] | [0.000] | [0.000] |
| Ward test [p-value] | 4.93 | 5.51 | 4.29 | 4.81 |
| | [0.085] | [0.064] | [0.117] | [0.090] |

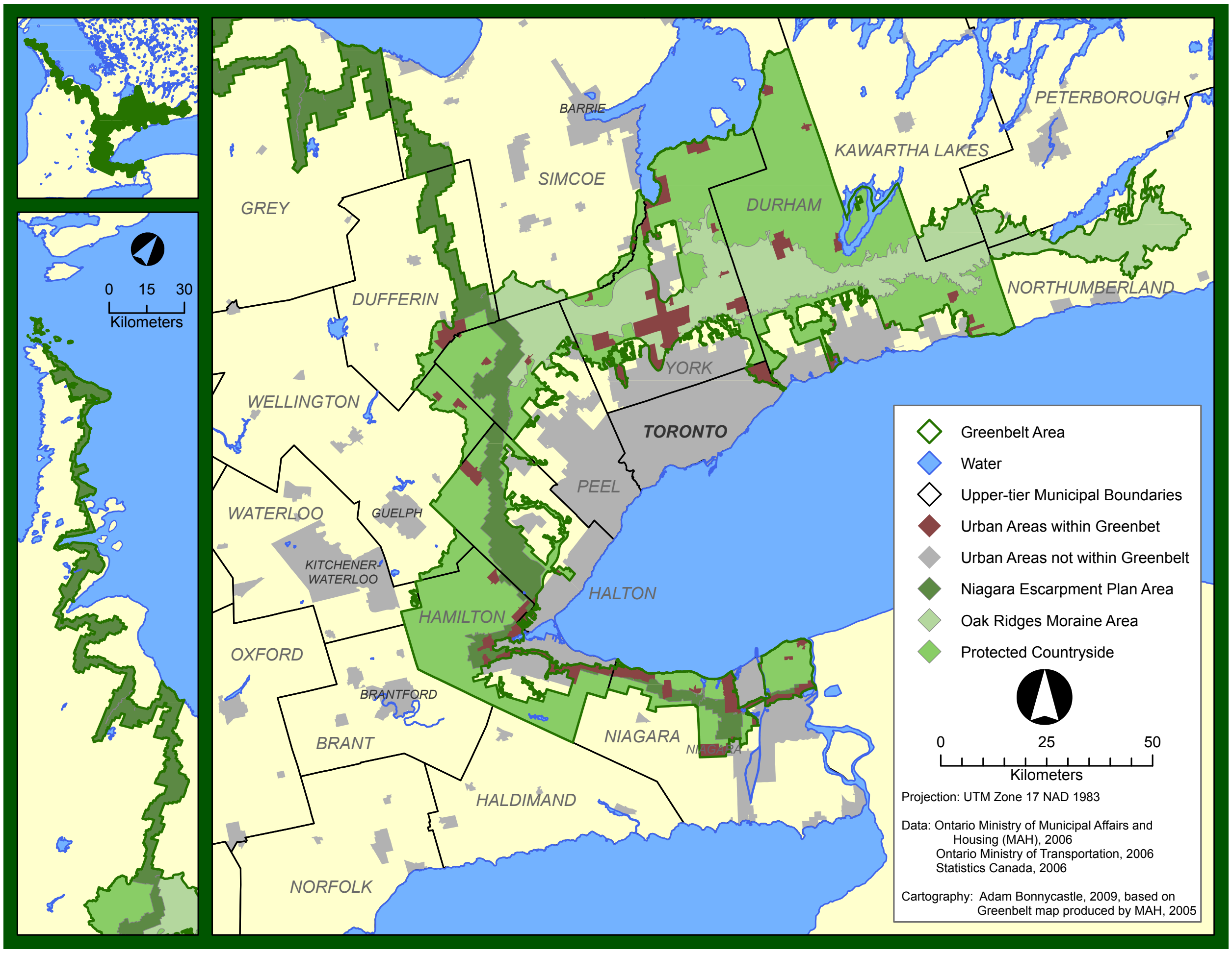
Standard errors in parentheses.
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < .01$.

## Table 5. Comparison of the policy effects of the Greenbelt variables

| | Primary | Alternate Threshold | Reduced Sample | Four-Year MA |
|---|---|---|---|---|
| **ATT on Farm Exit** | | | | |
| GB_post | -0.021* | −0.019* | −0.019* | |
| | (0.011) | (0.011) | (0.011) | |
| **ATT on Farm Investment** | | | | |
| PC_post | $-1.067^{**}$ | $-1.383^{**}$ | $-1.183^{**}$ | $-1.460^{**}$ |
| | (0.505) | (0.671) | (0.586) | (0.598) |
| ORM_post | $3.406^{*}$ | $3.457^{*}$ | 3.477 | 3.677 |
| | (2.001) | (2.078) | (2.215) | (2.307) |
| NEP_post | -0.962 | −2.939 | −0.674 | −1.469 |
| | (2.443) | (3.571) | (3.037) | (2.882) |

Standard errors in parentheses are calculated using the delta method.
$^{*}$ $p < 0.10$, $^{**}$ $p < 0.05$, $^{***}$ $p < .01$

Figure 1. Map of the Greenbelt in southern Ontario



Projection: UTM Zone 17 NAD 1983

Data: Ontario Ministry of Municipal Affairs and Housing (MAH), 2006
Ontario Ministry of Transportation, 2006
Statistics Canada, 2006

Cartography: Adam Bonnycastle, 2009, based on Greenbelt map produced by MAH, 2005