The Case of Organic Dairy Conversion in Norway: Assessment of Multivariate Neighbourhood Effects

Tibor A. Marton¹, ² and Hugo Storm³

¹The Norwegian Institute of Bioeconomy Research, Ås, Norway; ²Centre for Agricultural Research, Agricultural Research Institute, H-2462 Martonvásár, Hungary; Correspondence: marton.tibor@atk.hu
³Institute for Food and Resource Economics, University of Bonn, Bonn, Germany; email: hugo.storm@ilr.uni-bonn.de

Keywords: organic dairy conversion, multivariate neighbourhood effect, spatial endogeneity, correlated random effect model, Mundlak-Chamberlain device

Abstract

This study examines the impact of neighbourhood effects and individual farm characteristics on the decision process of organic dairy conversion in Norway, using a unique, spatially explicit farm-level panel set comprising information at the population level from 2003 to 2015. Our results reveal a positive spatial spillover of neighbouring conversion, confirming previous findings. Additionally, we demonstrate that neighbouring organic dairy reversion (i.e. switching back to conventional dairy farming) and organic dairy exits (ceasing to farm altogether) exert notable negative spatial spillovers on organic conversion decisions which have not yet been shown in the literature. If organic dairy production is an important policy goal, such negative spatial spillover requires consideration within policy design and extension.
1. Introduction

In several countries, policymakers are taking action to promote the adoption of organic farming practices as one way to reduce the environmental impacts of farming in addition to addressing growing consumer concerns regarding food safety and health. The example considered in this study is Norway, where policymakers set ambitious goals for the promotion of organic farming, offering a range of subsidies to support conversion. Although the area of organic land and organic farm management has increased in Norway since the beginning of the millennium (Flaten and Lien, 2006; Røsnes, 2010; Norwegian Ministry of Agriculture and Food, 2010), the goal of the government to increase organic production and consumption from 0.5% in 2005 to 15% by 2020 (Norwegian Ministry of Agriculture and Food, 2009) has fallen far short of this goal. In 2018, only 2.2% of the entire food market was organic, and only 4.4% of the total agricultural area was directly under organic cultivation (Landbruksdirektoratet, 2018). Achieving these ambitious goals requires a more effective policy design to promote the adoption of organic farming practices. We should enhance our understanding of farmers’ motives, reservations and goals in terms of organic production to develop more informed policy approaches.

Existing research studies describe organic conversions from different perspectives, encapsulating it as a problem of optimal timing with an uncertain investment that incurs sunk costs (Musshoff and Hirschauer, 2008), analysing the role of moral and social considerations (Mzoughi, 2011). Further studies assume that potential adopters make a discrete choice based on the possibility of maximisation of expected utility subject to prices, profits and inputs, devoting elevated importance to economic and financial concerns (Koesling et al., 2008; Lewis et al., 2011). Some studies categorise farms according to their characteristics (e.g. farmers’ attitudes, age, herd and land sizes, natural resource assets or risk deliberation) (Läppe and van Rensburg, 2011; Läppe and Kelley, 2013), explaining the choice of conversion through individual farm characteristics. Despite the broad range of concepts and approaches in the literature, there is a common understanding regarding the importance of physical localisation and neighbourhood settings as influential to the emergence of organic hubs (i.e. a high density of organic farms in a small region).

Compelling attempts have been made to identify the influence of location factors in the development of organic hubs that are underpinned by the economic and social concept of the ‘neighbourhood effect’ (Lewis et al., 2011; Gosme et al., 2012; Bjørkhaug and Blekesaune,
The conceptual framework is based on the hypothesis that organic farming neighbours or closely spatially related farms can help reduce the uncertainty of organic conversion by lowering the fixed costs of learning about the organic system (Lewis et al., 2011), increasing the probability of conversion to organic farming. Knowledge transfer regarding organic technology development and joint input purchase may further reduce barriers to conversion. Hence, co-operation in general leads to a smoother gateway to the supply chain.

One limitation of existing theory and empirical studies on the neighbourhood effect is that only positive external spatial effects have been covered (e.g. Lewis et al., 2011). In this study, we argue that negative external effects can be similarly influential on farmers’ conversion decisions. Neighbouring farmers’ reversion from organic to conventional farming or neighbouring organic farmers’ exiting farming altogether could serve as a negative example that potentially reduces the likelihood of conversion. Here similar mechanisms of the neighbourhood effect can be expected to act correspondingly to positive external effect. Those negative occurrences could provide knowledge about the disadvantages and challenges of organic production or lead to a weakening of supply chain access in the local neighbourhood.

To our knowledge, this potential deterrence to organic conversion has not yet been studied. For policymakers and extension services that seek to promote the adoption of organic farming, the role of negative examples must be understood to design the right policy strategies and set achievable goals. With the establishment of only positive externality policies, extension services solely focus on promoting conversion by as many farms as possible, irrespective of how many revert at a later stage. However, the existence of potentially negative externalities warrants a more selective approach to the promotion of organic conversion by only farms that have a low likelihood of reversion. Additionally, this approach would justify additional effort and support concentrating on keeping farms within organic production, rather than only focusing on the promotion of adoption as the primary goal.

Although the question of the role of negative examples is relevant more broadly, we restrict our study to Norway and specifically to dairy production as one of the most prominent agricultural activities in Norway. In this case, we can use a unique yearly panel dataset

---

1 Reversion: An organic producer at time $t$ transforms to conventional technology at $t+1$. This is a technical designation of continuing as a conventional farm.
covering the period from 2002 to 2015. The data set covers (almost)\(^2\) all farms in Norway, furnishing information about farmers’ conversion decisions as well as the geographic location of each farm. Using an econometric panel model, we aim to explain the binary decision of whether a conventional dairy farm converts to organic farming during the observation period from 2002 to 2015. To account for neighbour interaction, we leverage the geographic information in the data to derive assorted variables describing conversion, reversion and exit of neighbouring farmers.

The remainder of the paper is structured into five sections: Section 2 introduces the natural and economic environment for dairy production in Norway; Section 3 details the adopted and extended theory; and Section 4 presents the data, the applied method and the potential endogeneity issues. Finally, Section 5 discusses the results, and Section 6 concludes and highlights the policy-relevant findings.

2. Norwegian Case

Norwegian agriculture is characterised by unfavourable natural conditions\(^3\) but enjoys great social and governmental appreciation and support. In 2010, the utilised agricultural area (UAA) was approximately 3.1% of the territory of the country (Eurostat, 2019), measuring about 1 million hectares; one of the smallest ratios within the European Economic Area. Weather conditions, coupled with the peculiar morphology of the territory, limit agricultural production. In 2010, the most common holdings specialise in sheep, goats and other grazing livestock (27%) and dairy (18%), and the rest are specialist cereals, oilseed and protein crops, general field cropping, specialist cattle-rearing and fattening of the total population of farms (Eurostat, 2012). In terms of economic size units, or the sum of the standard outputs (SO) per hectare of crop and per head of livestock, dairy is the most prominent subsector, accounting for 30% of the SO of all Norwegian farms in 2010 (Eurostat, 2012).

Agricultural policy endeavours to promote a diversified agricultural sector delivering a ‘multifunctional agriculture’ (Potter and Tilzey, 2007; Bjørkhaug and Richards, 2008; Forbord et al., 2014). Another goal is to maintain family farming identities (Forbord et al.,

---

\(^2\) Excluding only very small farms that do not qualify for any farm subsidies.

\(^3\) Norway is one of the northernmost countries of the globe (58–71° latitude) covering oceanic and continental type of climates. The grazing season varies from three to nearly 6 months. In the southern regions, the grazing season runs from May to October, whereas further north, it is shorter, from mid-June to mid-September.
2014) and ensure that the current UAA is sustained. To achieve these objectives, government support for agriculture is significantly higher in Norway than in the EU (OECD, 2017). Policies targeting organic agriculture came into effect in 2002 and have been renewed several times with an increase in payment rates\(^4\) and organic conversion grants to encourage farmers to convert to organic production. In 2005, the long-term strategic plan adopted by the government sought to increase organic production and consumption from 0.5% to 15% of overall production and consumption by 2015. That ambition was somewhat reduced in 2009, projecting this desired level by 2020 (Norwegian Ministry of Agriculture and Food, 2009). Organic farming incurs more costs than conventional farming attributable to increased labour intensity, the prohibition of mineral fertiliser and non-organic plant protection and the use of specific technological settings (Flaten et al., 2005). To compensate for these additional costs, organic farms receive significantly higher financial support than conventional producers.

Norwegian agricultural policy divides the country into seven agricultural subsidy zones because of the major differences in longitudinal production conditions. For the organic livestock subsidy, including dairy cows, suckling cows and other cattle, the organic bonus rates vary between regions, with the northern zones receiving more financial support than the southern zones until 2015. For instance, the organic premium for dairy cows in 2003 was 880 NOK\(^5\) in the north and 630 NOK in the south on top of the average 2500 NOK per animal for conventional dairy cows.\(^6\) The geographic differences in such organic bonuses adjusted from almost 30% in 2003 to no difference in 2015. The same trend can be observed for the subsidy adjustments of suckling cows and other cattle. Moreover, organic dairy farmers receive not only livestock-based subsidies but also regional payments. Payments are provided to arable land, including cultivated pastures, corn, potatoes, green manure production and other ecological driven land use, the rates of which are not differentiated by region.

Flaten et al. (2006) explored the conversion motives of individual Norwegian dairy farmers and joint dairy farmers\(^7\) by the year of conversion,\(^8\) finding evidence that improved food quality and potential professional challenges of organic adoption are the most frequently cited

---

\(^4\) Revised in 2007, 2010, 2012, 2013 and 2015.

\(^5\) NOK: Currency of Norway. 1 USD ≈ 9 NOK.

\(^6\) The exact rate of conventional dairy subsidy may differ according to herd size.

\(^7\) Joint dairy farmers merge their dairy cow herds and share the workload, and the joint dairy production activity is regarded as a single farm with respect to payment eligibility and rules.

\(^8\) Flaten et al. (2006) elaborated a questionnaire survey among Norwegian dairy farmers and outlined 10 motives for organic conversion: food quality; professional challenges; soil fertility and pollution problems; ideology and philosophy; health risks (pesticides, etc); animal welfare; profitability; organic farming payments; natural conditions (soil, climate, etc) and income stability.
reasons for all groups (early, mid and late converters). Furthermore, the motivational force of income stability was cited as the least decisive motive. In Norway, since the 1990s, off-farm income generation has rapidly increased (Fleming and Lien, 2009), and dairy farming is generally a secondary engagement for the majority of Norwegian dairy farmers. This explains the numeros cases of ‘hobby’ farms featuring rather small herds. These findings indicate that any analysis from a strictly economic perspective—e.g. coupling potential positive net value to organic conversion—should be expected to have only limited explanatory power in Norway. This dichotomy coincides with Lund and Algés’ (2003) description of Norwegian organic farmers’ motivations consistently being viewed as idealistic and reaching beyond financial concerns.

According to the Norwegian Agriculture Agency (Landbruksdirektoratet, 2018), in 2018, 2.2% of the entire food market was organic, and only 4.4% of the total agricultural area was registered organic. In the same year, the share of organic milk was up to 3.4% of total milk production, whereas Norwegian organic meat production was almost 1%. The government’s ambition of increasing organic production up to 15% by 2020 has remained unsuccessful, despite a massive increase in organic livestock and subsidy payments. In June 2018, Norway announced a new national strategy to promote organic farming until 2030. Support for organic farming has remained constant since 2014, but the organic conversion grants were phased out beginning in 2010 and eliminated altogether in 2016. The government’s justification for terminating organic conversion grants was to advance the simplification of the support scheme for organic farmers (Pekala, 2019).

In our observation period (2002–2015), the number of all dairy farms decreased by almost 60%, but the number of operating organic dairy farms increased by 45% (Table 1). The general annual statistics demonstrate that the Norwegian dairy sector declined, losing almost 60% of its milk producers between 2003 and 2015. This decrease was a result of the reversion of previous organic dairy farms to conventional dairy farms, which is beyond the scope of this paper. Our focus remains on the aspects of neighbouring conformity in operating organic dairy farms (ΣODF in Table 1), which increases in the first 3 years, stagnates until 2011 and later significantly decreases. The first organic policy boost in 2002 results in 172 newly registered organic dairy farms by 2003. This development appears to be the largest over the examined years. During the stagnation, organic entries and organic reversions remain at about the same pace. However, from 2012, the number of farms converting from conventional farming to organic (ΣEDF) is only a single digit, whereas the sum of organic reversals (ΣRDF + ΣExDF, in Table 1) is approximately 20 farms annually.
Considering the subsequent organic policy developments, in 2010, 2012 and 2013, the number of newly established organic dairy farms is even lower at the post-policy time period than prior. Therefore, the first organic governmental intervention seems to have been successful, whereas additional increases to the organic payment rates do not appear to motivate organic conversion.

3. Theory

One theoretical explanation of emerging business trends is often tied to the patterns of the physical localisation of decision-makers; therefore, analysing the influence of regional proximity within the course of micro-behavioural decision factors and the possible inferences between spatially corresponding units is of core interest in agriculture and resource economics literature (Bockstael, 1996; Weiss, 1996; Nelson and Hallerstein, 1997; Brock and Durlauf, 2001, 2007; Anselin, 2001, 2002). Explicitly including the neighbourhood effect in quantifying the social determinants of conversion decisions incorporates the concepts of social learning (Conley and Udry, 2010) and spatial spillover and landscape development (Irwin and Bockstael, 2002). Consequently, spatial processes can be assumed to have a strong influence on farmers’ organic conversion decision. We adopt the theoretical concept of developing neighbourhood relations, relying on the assumption that formerly converted neighbours may be instrumental in swaying the decision of potential converters by reducing the fixed cost of learning and risk, contributing to advanced supply level and in enhancing the competitiveness of the sector. Technology adoption literature explores the causes and effects of wide technological distribution in terms of economic and physical environments, individual characteristics, production uncertainty and spatial spillover (e.g. Lindner, 1980; Feder and O’Mara, 1982; Tsur et al., 1990; Adesina and Baidu-Forson, 1995; Purvis et al., 1995; Koundouri et al., 2006; Oliveira and Martins, 2011). For example, major road networks or locally favourable production conditions may both contribute to spatially clustered behaviour. Economic units may be spatially dependent, as locational attributes influence each other and thus tend to share similar attributes (Goodchild, 1992; Moffitt, 2001). Lewis et al. (2011) examine spatial spillovers of organic dairy farming in southwestern Wisconsin and determine that the presence of neighbouring organic dairy farms is a statistically and economically significant explanatory measure in the decision to convert. They identify a nonlinear relationship in organic conversion between the number of initial organic farms and
the expected number of new conversions that drive the clustered technology diffusion process.

Our key hypothesis in this context is that such diffusion processes are influential in two directions. In previous literature, it is primarily considered that new conversions lead to positive externalities (Lamine and Bellon, 2009; Geniaux et al., 2011; Bouttles et al., 2019). In this study, we hypothesise that reversions (or exits of organic farms) can exert similar negative externalities; an aspect that has yet to be considered in the literature to our knowledge. As shown in Table 1, those reversions and exits imply comparatively large relevance in the Norwegian case, yielding a noteworthy study case. The theoretical motivation of including proxies for bad examples assumes that people may learn from others' mistakes. We hypothesise that such negative examples serve to increase information uncertainty regarding the hurdles and difficulties of organic production, weakening local clusters in terms of the connections to upstream and downstream industries and the possibilities for local knowledge exchange. Overall negative examples are assumed to mirror the positive effects associated with a successful conversion to organic farming.

In our empirical approach, we endeavour to model farmers’ decision quandary on whether to convert a conventional dairy farm to organic dairy at time $t$. We jointly incorporate the effects of positive and negative neighbourhood examples explicitly. For this, we derive the following determinants for each farm at time $t$:

i. the number of neighbouring organic farms (which serve as a proxy of good examples);

ii. the number of neighbouring reverting farms at $t-1$ (which represent bad examples from the organic viewpoint);

iii. the number of neighbouring organic dairy exits at $t-1$ (which represent bad examples and assimilate a meaning of redundant milk production).

The actual numbers of multivariate neighbour vectors depend on the definition of the radius surrounding each individual farm. Defining this radius is relatively arbitrary and can hardly be based on precise information or theoretical knowledge. We intend to keep the focus on face-to-face information transfer, which assumes close proximity and personal discussions about the technology. For this reason, we calculate two small radii within 3 and 5 km. There are collateral arguments for determining two seemingly similar ranges: (i) the coefficients under different radius settings are comparable; (ii) and opens an opportunity for a potential robustness check on the model outcomes.
The applied econometric model is a reduced form discrete choice panel data model with binary probit link to explain the probability of organic dairy conversion. The 13-year dataset creates unbalanced panels of repeated observations of farm-level decisions.

4. Data, Method and Endogeneity Issues

4.1. Data

As noted, our analysis is based on a Norwegian dataset that is unique for two reasons: first, direct payments (DP) are available for virtually any type of crop and animal; second, the Information Act requires full transparency of all beneficiaries of government spending. Hence, the amount of agricultural land used, herd size and farmers’ age are made publicly available for each farm that receives DP. Additionally, geographic information, which is administered by the Norwegian Agriculture Authority, is available for research purposes. The data used in this application is therefore a unique georeferenced farm-level population set of Norwegian dairy holdings that received DP. The 14-year unbalanced panel construction includes more than 179 thousand observations including the annual contributions of 55 thousand dairy farms. We record approximately 4 thousand organic dairy farms in the observed period.

On the basis of the geographic information of each farmstead, we calculate the kilometre distances between the dairies, labelling each dairy farms as either conventional, organic, reverting or exiting in each year, to allow the determination of the dynamic neighbourhood synthesis of individual farms. In this manner, we derive the number of organic, reverting and exiting farms around each conventional dairy (i.e. potential organic convertor) within 3 and 5 km radii. Organic certification is awarded by a Norwegian certifying agency after fulfilling 3-year certification standards for land and 1-year certification standards for a dairy herd. In the estimation, we consider the year that the conversion decision is made and not the certification date. Reversion from organic to conventional is easily identified in the dataset as farms that no longer receive the additional payments for organic production. Table 2 presents the summary statistics of the neighbour variables within 3 and 5 km radii.

9 Commonly, the measure of the radius is arbitrarily determined in the scientific literature. Our motivation in establishing a rather small radius is to reflect the real surrounding neighbours, which may in fact play a significant role in the information flow (Storm et al. 2015).
Additionally, farm characteristics such as herd size, cultivated area and farmers’ age are also available. Table 3 presents the summary statistics of those variables for organic dairy farms. The mean of organic herd size and land is continuously increasing. Both measures nearly doubled over the examination period. However, the slowly increasing but later constant number of organic cows illustrates the lack of organic breakthrough in the Norwegian dairy industry.

4.2. Method

Organic dairy conversion is assumed to be conditional on farm characteristics and on quantified neighbourhood relations. We encode the latter as categorical variables with five levels (0, 1, 2, 3, 4 or more than 4 neighbours) for the number of neighbouring organic farms and neighbouring organic exits and three levels (0, 1, 2 or more than 2) for the number of neighbouring organic reversion. The groups are determined according to the actual number of differentiated neighbours. With the grouped parameter setting, we may correlate the regressors independently and thus hypothesise that

1. as the number of organic neighbours increases, the probability of organic conversion increases;
2. as the number of organic reversions and exiting organic farms increases, the probability of organic conversion decreases.

The response variable is $y_{nt} = 0$ in case a conventional farm $n$ remains conventional in $t$ and $y_{nt} = 1$ in case farm $n$ converts from conventional to organic in time $t$. We use a probit panel model to estimate the probability of conversion conditional on farm characteristics and neighbourhood affiliations as follows:

$$
Pr(y_{nt} = 1 \mid x_n, ORE_{nt}, z_t, z_r, z_{txr}, c_n) = \Phi(x_n'\beta + ORE_{nt}'\delta + z_t'\alpha + z_r'\varphi + z_{txr}'\gamma + c_n), \quad t = 1, \ldots T; r = 1, \ldots 7 \quad Eq. 3
$$

---

10 The number of individuals surrounded by more than four neighbours is insufficiently small (i.e. lack of frequency); therefore, we assign a joint group for limited individuals collectively. The same applies to creating three categorical levels for reversions instead of five.
where the conditional expectation $x_n$ is a set of vectors of individual characteristics (herd and land sizes and farmers’ age$^{11}$); $ORE_{nt}$ is the set of factor variables of organic neighbours, organic reversons and organic exits surrounding farm $n$ at time $t$. $z_t$ is a vector of period $t$-specific dummy variables, which is assumed to absorb all period-specific shocks, e.g. policy change at the major organic milk processor company that are the same for all farms; $z_r$ is a vector of region $r$-specific dummy variables that capture time-invariant regional differences in the conditions for organic production. The regional dummies are identical to the agricultural subsidy zones. Moreover, the interaction terms between regional dummies and year-specific dummy variables are included to control for time-varying effects that are the same for all farms in one region. Finally, $c_n$ denotes the unobserved effect, which is restricted in the applied correlated random effect framework and appears additively inside the standard normal cdf (Papke and Wooldridge, 2008). The inclusion of regional and time fixed effect as well as interaction effects is intended to control for potential endogeneity. The specific identification approach is discussed in the next section.

The applied econometric model is subject to the binary decision of whether a conventional dairy farm converts to organic, where the decision is observed and monitored each year over a 14-year period. The established panel dataset happens to be unbalanced (i.e. differing in the number of observations between groups) because of continuous entries and exits. Therefore, the estimation method has to be shaped for unbalanced panel setting. We follow the technical innovation of Papke and Wooldridge (2008) and use maximum likelihood estimation without the Gaussian quadrature as a pooled probit with bootstrapped standard errors by resampling the cross-sectional units. We use 500 bootstrap replications on the individuals to obtain the bootstrapped cluster-robust standard errors. This treatment of the standard error allows robust inference to any form of heteroscedasticity or temporal correlation across years for each farm (Cameron and Trivedi, 2005; Cameron et al., 2008; Lewis et al., 2011). The theoretical and methodological obstacle of accurately including the effect of social interactions is discussed in detail in the following.

---

$^{11}$ Farmers’ age is considered as a proxy of experience and potential risk-taking capacity. Age can be an important source of farm characteristics, as we hypothesise that the willingness to convert to organic farming is higher for younger farmers who are expected to be more open to adopting new technologies (Flaten et al., 2006).

$^{12}$ ORE is our abbreviation for Organic, Reverting and Exiting organic neighbours.
4.3. The Endogeneity Issue

We endeavour to identify the effects of neighbouring behaviour on the decision of organic conversion, differentiating between positive and negative examples in the neighbourhood. Identification of these effects is challenging because of spatially confounding variables and potential unobservable factors that may cause endogeneity issues (Lewis et al., 2011; Hsieh and Lee, 2016).

The conditions for organic production might differ across space through spatial differences in organic pay price and isomorphic biophysical aptitudes of micro-regions (e.g. valleys or highlands). To control such effects, we include regional fixed effects $z_r$. Conditions for conversion might also vary across time (equally for all farms); for example, due to a change in the subsidy scheme or a change in market prices or regulations. We control for those effects by including time fixed effects, $z_t$. There might also be changes that vary across time and regions. Those effects are controlled for by adding interaction terms between the regional and yearly fixed effects. Although those sets of fixed effects should capture a substantial part of the unobserved confounders, there might still be unobserved effects that vary across space at a smaller spatial scale than those variation captured by the regional fixed effects. To control for those effects, we follow Lewis et al. (2011) considering a Mundlak-Chamberlin (MC) device in a correlated random effects estimation strategy (Mundlak, 1978; Chamberlain, 1982; Papke and Wooldridge, 2008). In this setting, we decompose the unobserved individual characteristics $c_n$ into a mean zero normally distributed random variable and the average of the time-varying explanatory variables:

$$c_n = \psi_n + \frac{1}{r_n} \sum_{t=0}^{r_n} ORE_{nt}^t = \psi_n + ORE_n^t, \psi_n \sim \text{Normal}(0, \sigma) \quad \text{Eq. 4}$$

Here, $ORE_n$ is commonly referred to as an MC device defined as the average of all time-varying explanatory variables. In our specific case, it is the average of all spatial neighbourhood variables capturing average neighbouring farm convergence, reversion and exits of organic farmers. In principle, the MC device is identical to the usual fixed effect estimate in linear cases, but the algebraic equivalence does not hold in nonlinear cases (Papke and Wooldridge, 2008). With this approach, we control for the time-invariant unobserved spatial effects on a smaller spatial scale as captured by the regional fixed effects. For example, we can capture the fact that farms in a certain location are more likely to convert to organic. A specific example is the connection to major road networks as a crucial aspect in optimising the collection routes of dairies. The main dairy cooperative in Norway that
collects organic milk, TINE, employs business agents to urge those farms that are favourably located to the circuit of the collection trucks to convert. Those types of effects are covered with the MC device as long as they are not time-varying. In fact, in terms of the specific example, TINE decided to cease personal marketing in 2011 since the market for organic dairy was saturated; instead, the focus turns toward preserving and strengthening those who had already converted (Skjelvik et al., 2017). This could potentially lead to confounders that are both spatial and time-varying and hence not fully covered by the MC device or the fixed effects potentially leading to some bias and overestimation of the spatial interaction effects that cannot be controlled by the identification strategy. However, we consider those specific types of confounders, which are both time and spatial varying, as a rather specific case and an acceptable limitation of the identification approach.

5. Results

Table 4 presents the parameter estimates for the predictor variables. The set of indicator variables, the annual and zonal dummies, are obtained in the Appendix. The probit model outputs, for both 3 and 5 km radii, show the coefficients, their standard errors and the z-scores, as well as the associated p-values.

Generally, for both radius settings, the results of the factor variables for describing neighbourhood effects and the period-specific variables support the hypothesised tendencies in the decision-making process of organic conversion. Specifically, we find an increasing probability of organic conversion with a higher number of organic neighbours. As the reference level is 0, which implies no organic neighbour, the first contrast predictor vector Organic Neighbour 1 increases the z-score by 0.275 at 3 km and 0.249 at 5 km radius. Organic Neighbours 2, 3 and 4 demonstrate increased positive effects on conversion, confirming the hypothesis that more neighbours increase the likelihood of organic conversion.

In case of considering the 3 km radius, the parameter vector of 4 or more organic neighbours is insignificant because the occurrence of 4 or more than 4 organic neighbours is very small. However, when we increase the observation window from a 3 to 5 km radius, the effect becomes statistically significant.
Furthermore, vectors indicating the number of reverted neighbours show a negative impact on organic conversion, supporting our hypothesis of negative externalities of reversion. In both models, having only one reverting neighbour (Reverted Neighbour 1) has a negative but insignificant effect. When the number of reverted neighbours increases to two, the parameter estimates become statistically significant and show large negative effects on conversion. Interestingly, in absolute terms, the negative effects of reverting neighbours are substantially larger than the positive effects of converting neighbours, indicating that negative examples have a more important effect on conversion compared with the positive effects.

The number of exited organic neighbours shows slightly surprising results. One exited organic farm in the neighbourhood—compared with the zero reference level—shows a positive but insignificant effect on organic conversion. However, in case of more than one organic exit, the parameter estimates become large negative significant numbers in congruence with our hypothesis. Yet (and this is only speculation), we explain the positive effect of one organic exit in the neighbourhood with the likely transmission of organic dairy cows and technology to a conventional dairy farmer in a close surrounding. Furthermore, there may be numerous reasons why organic farmers may decide to shut down their business. Individual reasons may vary between moving, merging, family issues, age, etc, but none of these relates to any system error in the organic dairy industry. However, in case of more than one organic exit at a time, we are entitled to surmise the presence of some unobserved negative external effect that directly makes them exit simultaneously.

Furthermore, as of the farm-specific attributes, our assumption that youth-induced risk-taking ability and potentially higher level of interest in environmental farming promote organic conversion—proxied by farmer’s age—seems to be accurate because of the significant and negative coefficients in both models. It indicates that younger farmers are indeed more likely to convert to organic. We find the coefficients of herd and land sizes very small and consider them marginal in the decision process of organic conversion.

The period-specific dummy predictors show a negative tendency. This confirms that the 2005 and 2009 organic farm policy goal is still far from reach, and the Norwegian organic dairy industry is slowly declining. After 2010, this decrease accelerates in both models, which corresponds to the significant decrease in the summary statistics of organic dairy entries in Table 1. The negative and significant parameter coefficients verify that more organic dairy farms exit organic production than conventional farms decide to convert to organic.

The identical model setting for 3 and 5 km radii allows us to analyse the likely differences between the outcome probabilities when the circumstances of farmers’ neighbourhoods
change. The model outcomes show analogous results, which confirms the robust specification of the functional form regarding close proximities.

6. Conclusion

This article explores the factors of organic dairy technology adoption in Norway during the years 2003–2015. We find that farmers’ age, herd size and agricultural land used are less important elements of potential organic conversion than the neighbouring dairy relations. We demonstrate that spatial spillovers across economic agents are influential in the patterns of technology adoption. Although our model supports the findings of previous studies that the presence of organic dairies in close proximity positively affects organic dairy conversion, more remarkably, we find that neighbouring organic reversions and exits introduce potential negative interaction effects that had not been considered in previous literature.

The results offer important implications for policymakers and extension services that intend to promote organic production. Earlier literature only explored the positive interaction effects of conversion. Based on such results, optimal policy design should promote as much conversion as possible, with each conversion creating positive spillovers. Our results concerning the existence of the negative effects of reversion, however, warrants a more nuanced and strategic policy approach. Given that we demonstrated that the negative effect of neighbouring reversion is potentially stronger than the positive effect of neighbouring conversion in absolute terms, policies should not only be focusing on new adaptors but also ensure that existing organic dairy farms remain active and successful. Correspondingly, policies should increase efforts to improve extension and consultation, supporting farmers that are considering conversion to organic farming and helping them to explore whether converting could be successful in their specific situation. Based on this reasoning, our results support the decision by the Norwegian government to terminate organic conversion grants, which may ease conversion but are ill-suited for sustaining organic production in the long run.

Our result highlighted the critical influence that reversions have in terms of external effects on neighbouring farms. Future research should focus on exploring the root causes underlying the decision to revert from organic to conventional farming. This should help policymakers to design new policies or adjust existing approaches to address the identified causes.
Acknowledgements/Funding

The authors want to thank Thomas Heckelei and Klaus Mittenzwei for their valuable and helpful comments. We acknowledge the support of the Research Council of Norway: Space, land and society: challenges and opportunities for production and innovation in agriculture based value chains; grant no. AGRISPAC/23810 and of the European Regional Development Fund “Investing in your future”; grant no. GINOP-2.3.2-15-2016-00028. The research for this publication by Hugo Storm is partially funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under grant no. STO 1087/1-1, as well as by the German Research foundation under Germany’s Excellence Strategy – EXC 2070 - 390732324. The authors are grateful to Grete Stokstad and Svein Olav Krogli from the Norwegian Forest and Landscape Institute (Skog og Landskap, Ås, Norway) for providing the farm coordinates used in the analysis.
References

Adesina, A. A., & Baidu-Forson, J. (1995). Farmers’ perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Paso and Guinea, West Mrica. Agricultural Economics, 13, 1–9. Retrieved from https://ageconsearch.umn.edu/bitstream/173671/2/agec1995-1996v013i001a001.pdf

Anselin, L. (2001). Spatial Effects in Econometric Practice in Environmental and Resource Economics. American Journal of Agricultural Economics, 83(3), 705–710. Retrieved from https://about.jstor.org/terms

Anselin, L. (2002). Under the hood: Issues in the specification and interpretation of spatial regression models. Agricultural Economics, 27(3), 247–267. https://doi.org/10.1016/S0169-5150(02)00077-4

Bjørkhaug, H., & Blekesaune, A. (2013). Development of organic farming in Norway: A statistical analysis of neighbourhood effects. Geoforum, 45, 201–210. https://doi.org/10.1016/j.geoforum.2012.11.005

Bjørkhaug, H. & Richards C.A. (2008). Multifunctional agriculture in policy and practice? A comparative analysis of Norway and Australia. J. Rural Stud. 24, 98-111.

Bockstael, N. E. (1996). Modeling Economics and Ecology: The Importance of a Spatial Perspective. American Journal of Agricultural Economics, 78(5), 1168–1180. Retrieved from https://about.jstor.org/terms

Bouttles, M. et al. (2019). Conversion to organic farming decreases the vulnerability of dairy farms. Agronomy for Sustainable Development, 39(2), 1–11.

Brock, W. A., & Durlauf, S. N. (2001). Discrete Choice with Social Interactions. The Review of Economic Studies, 68, 235–260. https://doi.org/10.2307/2695928

Brock, W. A., & Durlauf, S. N. (2007). Identification of binary choice models. Journal of Econometrics, 140, 52–75.
Cameron, A. C., & Trivedi, K. P. (2005). Microeconometrics: Methods and Applications. New York: Cambridge University Press.

Cameron, A. C., Gelbach, J. B., & Miller, D. L. (2008). Bootstrap-Based Improvements for Inference with Clustered Errors. Review of Economics and Statistics, 90(3), 414–427. https://doi.org/10.1162/rest.90.3.414

Chamberlain, G. (1982). Multivariate Regression Models for Panel Data. Journal of Econometrics, 18, 5–46.

Conley, T. G., & Udry, C. R. (2010). Learning about a New Technology: Pineapple in Ghana. American Economic Review, 100(1), 35–69. https://doi.org/10.1257/aer.100.1.35

Eurostat. (2012). Agricultural census in Norway - Statistics Explained. Retrieved September 17, 2018, from https://ec.europa.eu/eurostat/statistics-explained/index.php/Agricultural_census_in_Norway

Eurostat. (2019). Share of total organic area (fully converted and under conversion) in total utilised agricultural area (UAA), by country, 2017.

Feder, G., & O’Mara, G. T. (1982). On Information and Innovation Diffusion: A Bayesian Approach. American Journal of Agricultural Economics, 64(1), 145. https://doi.org/10.2307/1241186

Flaten, O., Lien, G., Koersling, M., Valle, P. S., & Ebbesvik, M. (2005). Comparing risk perceptions and risk management in organic and conventional dairy farming: empirical results from Norway. Livestock Production Science, 95(1–2), 11–25. Retrieved from https://www.sciencedirect.com/science/article/pii/S030162260400288X

Flaten, O., & Lien, G. (2006). Organic dairy farming in Norway in relation to the “conventionalisation” debate. In Paper at: Joint Organic Congress. Odensee, Denmark. Retrieved from http://orgprints.org/7232/3/7232_Flaten.pdf
Flaten, O., Lien, G., Ebbesvik, M., Koesling, M., & Valle, P. S. (2006). Do the new organic producers differ from the ‘old guard’? Empirical results from Norwegian dairy farming. Renewable Agriculture and Food Systems, 21(03), 174–182. https://doi.org/10.1079/RAF2005140

Fleming, E., & Lien, G. (2009). Synergies, scope economies and scale diseconomies on farms in Norway. Food Economics - Acta Agriculturae Scandinavica, Section C, 6(1), 21–30.

Forbord, M. et al (2014). Drivers of change in Norwegian agricultural land control and the emergence of rental farming. J. Rural Stud, 33(1), 9-19.

Geniaux, G., Latruffe, L., Lepoutre, J., Nauges, C., Napoleone, C., Sainte-Beuve, J., & Sautereau, N. (2011). The drivers of the conversion in organic farming (OF): a review of the economic literature. In ISOFAR Scientific Conference at the 17. IFOAM Organic World Congress.

Goodchild, M. F. (1992). Geographical information science. Int. J. Geographical Information Systems, 6(1), 31–45. Retrieved from https://www.geog.ucsb.edu/~good/papers/166.pdf

Gosme, M., De Villemandy, M., Bazot, M., & Jeuffroy, M.-H. (2012). Local and neighbourhood effects of organic and conventional wheat management on aphids, weeds, and foliar diseases. Agriculture, Ecosystems and Environment, 161, 121–129. https://doi.org/10.1016/j.agee.2012.07.009

Hsieh, C.-S., & Lee, L. F. (2016). A Social Interactions Model with Endogenous Friendship Formation and Selectivity. Journal of Applied Econometrics, 31(2), 301–319. https://doi.org/10.1002/jae.2426

Irwin, E. G., & Bockstael, N. E. (2002). Interacting agents, spatial externalities and the evolution of residential land use patterns. Journal of Economic Geography, 2(1), 31–54. https://doi.org/10.1093/jeg/2.1.31
Koesling, M., Flaten, O., & Lien, G. (2008). Factors influencing the conversion to organic farming in Norway. International Journal of Agricultural Resources, Governance and Ecology, 7(1–2), 78–95. https://doi.org/10.1504/IJARGE.2008.016981

Koundouri, P., Nauges, C., & Tzouvelekas, V. (2006). Technology Adoption under Production Uncertainty: Theory and Application to Irrigation Technology. American Journal of Agricultural Economics, 88(3), 657–670. https://doi.org/10.1111/j.1467-8276.2006.00886.x

Lamine, C., & Bellon, S. (2009). Conversion to organic farming: a multidimensional research object at the crossroads of agricultural and social sciences. A review. Agronomy for Sustainable Development, 29, 97–112.

Landbruksdirektoratet. (2018). Teknisk Jordbruksavtale 2017-2018.

Läpple, D., & Kelley, H. (2013). Understanding the uptake of organic farming: Accounting for heterogeneities among Irish farmers. Ecological Economics, 88, 11–19. https://doi.org/10.1016/J.ECOLECON.2012.12.025

Läpple, D., & Rensburg, T. Van. (2011). Adoption of organic farming: Are there differences between early and late adoption? Ecological Economics, 70(7), 1406–1414. https://doi.org/10.1016/J.ECOLECON.2011.03.002

Lewis, D. J., Barham, B. L., & Robinson, B. (2011). Are There Spatial Spillovers in the Adoption of Clean Technology? The Case of Organic Dairy Farming. Land Economics, 87(2), 250–267. https://doi.org/10.3368/le.87.2.250

Lindner, R. K. (1980). Farm Size and the Time Lag to Adoption of a Scale Neutral Innovation (Mimeograph). Adelaide, Australia: University of Adelaide.

Lund, V., & Algers, B. (2003). Research on animal health and welfare in organic farming—a literature review. Livestock Production Science, 80(1–2), 55–68. https://doi.org/10.1016/S0301-6226(02)00321-4
Moffitt, Robert A. (2001). Policy interventions, low-level equilibria, and social interactions. Social Dynamics, 4(45–82), 6–17.

Mundlak, Y. (1978). On the Pooling of Time Series and Cross Section Data. Econometrica, 46(1), 69–85. https://doi.org/10.2307/1913646

Musshoff, O., & Hirschauer, N. (2008). Adoption of organic farming in Germany and Austria: an integrative dynamic investment perspective. Agricultural Economics, 39(1), 135–145.

Mzoughi, N. (2011). Farmers adoption of integrated crop protection and organic farming: Do moral and social concerns matter? Ecological Economics, 70(8), 1536–1545. https://doi.org/10.1016/J.ECOLECON.2011.03.016

Nelson, G. C., & Hellerstein, D. (1997). Do Roads Cause Deforestation? Using Satellite Images in Econometric Analysis of Land Use. American Journal of Agricultural Economics, 79(1), 80–88. Retrieved from https://www.jstor.org/stable/pdf/1243944.pdf

Norwegian Ministry of Agriculture and Food. (2009). Handlingsplan for å nå måletom 15 pst. økologiskproduksjonogforbruki 2020. Økonomisk, agronomisk – økologisk!

Norwegian Ministry of Agriculture and Food. (2010). Organic: Increased production in 2009. Oslo. Retrieved from https://www.regjeringen.no/no/dokumentarkiv/stoltenberg-ii/lmd/Nyheter-og-pressemeldinger/nyheter/2010/okologisk-okt-produksjon-i-2009/id597773/

OECD. (2017). Producer support (PSE), % of gross farm receipts, 2000 – 2016. Retrieved from https://data.oecd.org/agrpolicy/agricultural-support.htm

Oliveira, T., & Martins, M. F. (2011). Literature Review of Information Technology Adoption Models at Firm Level. The Electronic Journal Information Systems Evaluation, 14(1), 110–121.
Papke, L. E., & Wooldridge, J. M. (2008). Panel data methods for fractional response variables with an application to test pass rates. Journal of Econometrics, 145, 121–133. https://doi.org/10.1016/j.jeconom.2008.05.009

Pekala, A. (2019). Market Analysis of organic foods in the Nordic and Baltic countries. Nordic Council of Ministers, TemaNord 2019:540. http://dx.doi.org/10.6027/TN2019-540

Potter, C. & Tilzey, M. (2007). Agricultural multifunctionality, environmental sustainability and the WTO: Resistance or accommodation to the neoliberal project for agriculture? Geoforum, 38(1), 1290-1303.

Purvis, A., Boggess, W. G., Moss, C. B., & Holt, J. (1995). Technology Adoption Decisions Under Irreversibility and Uncertainty: An Ex Ante Appproach. American Journal of Agricultural Economics, 77(3), 541–551. Retrieved from http://www.jstor.org/stable/1243223

Røsnes E. (2010). Production and marketing of organic agricultural products Report for 2009, Report number 7/2010, Norwegian Agricultural Authority.

Skjelvik JM, Erlandsen AM, Haavardsholm O. (2017). Environmental impacts and potential of the sharing economy. TemaNord 2017:554. Nordic Council of Ministers.

Storm, H., Mittenzwei, K., & Heckelei, T. (2015). Direct payments, spatial competition and farm survival in Norway. American Journal of Agricultural Economics, 97(4), 1192–1205. Retrieved from http://ageconsearch.umn.edu/bitstream/150022/2/StormEtAl2.pdf

Tsur, Y., Sternberg, M., & Hochman, E. (1990). Dynamic Modelling of Innovation Process Adoption with Risk Aversion and Learning. Oxford Economic Papers. Oxford University Press. https://doi.org/10.2307/2663229

Weiss, M. D. (1996). Precision Farming and Spatial Economic Analysis: Research Challenges and Opportunities. American Journal of Agricultural Economics, 78(5), 1275–1280. Retrieved from https://about.jstor.org/terms
Wollni, M., & Andersson, C. (2014). Spatial patterns of organic agriculture adoption: Evidence from Honduras. Ecological Economics, 97, 120–128. https://doi.org/10.1016/j.ecolecon.2013.11.010
Table 1 Annual conformation of the Norwegian Dairy Industry

| Years | Number of dairy farms (ΣDF) | Number of operating organic dairy farms (ΣODF) | Number of organic entries (ΣEDF) | Number of organic reversions (ΣRDF) | Number of organic exits (ΣExDF) |
|-------|-----------------------------|-----------------------------------------------|---------------------------------|----------------------------------|-------------------------------|
| 2002  | 18782                       | 185                                           | -                              | 3                                | 3                             |
| 2003  | 17521                       | 179                                           | 172                            | 24                               | 20                            |
| 2004  | 16673                       | 307                                           | 37                             | 17                               | 22                            |
| 2005  | 15948                       | 305                                           | 28                             | 13                               | 23                            |
| 2006  | 14556                       | 297                                           | 24                             | 15                               | 23                            |
| 2007  | 13545                       | 283                                           | 30                             | 10                               | 16                            |
| 2008  | 12725                       | 287                                           | 39                             | 9                                | 10                            |
| 2009  | 11751                       | 307                                           | 35                             | 6                                | 15                            |
| 2010  | 11022                       | 321                                           | 34                             | 13                               | 13                            |
| 2011  | 10424                       | 329                                           | 19                             | 10                               | 24                            |
| 2012  | 9761                        | 314                                           | 7                              | 5                                | 12                            |
| 2013  | 9250                        | 304                                           | 8                              | 12                               | 10                            |
| 2014  | 8817                        | 290                                           | 2                              | 10                               | 15                            |
| 2015  | 8310                        | 267                                           | 7                              | 15                               | -                             |

Source: Own calculation based on Norwegian Agricultural Authority, 2016
### Table 2 Summary statistics of Independent Variables

| Years | Number of organic neighbours within 3 km radius | Number of organic neighbours within 5 km radius | Number of reversions within 3 km radius | Number of reversions within 5 km radius | Number of organic exits within 3 km radius | Number of organic exits within 5 km radius |
|-------|-----------------------------------------------|-----------------------------------------------|----------------------------------------|----------------------------------------|-------------------------------------------|-------------------------------------------|
|       | Min  Mean  Std. Dev. Max | Min  Mean  Std. Dev. Max | Min  Mean  Std. Dev. Max | Min  Mean  Std. Dev. Max | Min  Mean  Std. Dev. Max | Min  Mean  Std. Dev. Max |
| 2003  | 0   0.08  0.336  5 | 0   0.169  0.507  5 | 0   0.001  0.026  1 | 0   0.002  0.045  1 | 0   0.001  0.030  1 | 0   0.002  0.043  1 |
| 2004  | 0   0.17  0.478  5 | 0   0.334  0.711  7 | 0   0.023  0.151  2 | 0   0.036  0.189  2 | 0   0.006  0.080  1 | 0   0.013  0.112  1 |
| 2005  | 0   0.19  0.513  5 | 0   0.356  0.738  6 | 0   0.006  0.074  1 | 0   0.010  0.098  1 | 0   0.009  0.095  1 | 0   0.021  0.144  1 |
| 2006  | 0   0.17  0.475  4 | 0   0.332  0.723  6 | 0   0.009  0.094  1 | 0   0.015  0.123  1 | 0   0.011  0.132  3 | 0   0.020  0.171  3 |
| 2007  | 0   0.16  0.469  4 | 0   0.318  0.710  6 | 0   0.011  0.103  1 | 0   0.019  0.137  1 | 0   0.010  0.140  5 | 0   0.022  0.235  5 |
| 2008  | 0   0.16  0.482  5 | 0   0.328  0.724  6 | 0   0.005  0.073  1 | 0   0.013  0.112  1 | 0   0.008  0.092  1 | 0   0.018  0.138  2 |
| 2009  | 0   0.18  0.526  5 | 0   0.365  0.794  7 | 0   0.004  0.062  1 | 0   0.007  0.081  1 | 0   0.005  0.069  1 | 0   0.010  0.101  1 |
| 2010  | 0   0.20  0.553  6 | 0   0.393  0.838  7 | 0   0.003  0.055  1 | 0   0.004  0.063  1 | 0   0.009  0.114  4 | 0   0.016  0.168  4 |
| 2011  | 0   0.20  0.563  6 | 0   0.385  0.841  8 | 0   0.012  0.109  1 | 0   0.023  0.148  1 | 0   0.005  0.074  1 | 0   0.010  0.101  1 |
| 2012  | 0   0.18  0.523  4 | 0   0.354  0.774  8 | 0   0.006  0.078  1 | 0   0.015  0.121  1 | 0   0.013  0.124  2 | 0   0.030  0.184  2 |
| 2013  | 0   0.17  0.495  4 | 0   0.338  0.732  7 | 0   0.002  0.049  1 | 0   0.004  0.063  1 | 0   0.015  0.120  1 | 0   0.030  0.171  1 |
| 2014  | 0   0.17  0.481  4 | 0   0.341  0.734  7 | 0   0.008  0.092  2 | 0   0.012  0.116  2 | 0   0.005  0.067  1 | 0   0.008  0.087  1 |
| 2015  | 0   0.15  0.450  4 | 0   0.306  0.680  6 | 0   0.009  0.096  1 | 0   0.021  0.144  1 | 0   0.008  0.098  2 | 0   0.015  0.141  2 |

Source: Norwegian Dairy Population Data 2003-2015 (NIBIO).

### Table 3 Summary statistics of Individual Characteristics of organic dairy farms

| Years | Farmer's Age | Number of Organic Cows | Number of Utilized Organic Land in daa |
|-------|--------------|------------------------|----------------------------------------|
|       | Min  Mean  Std. Dev. Max | Min  Mean  Std. Dev. Max | Min  Mean  Std. Dev. Max |
| 2003  | 16   47.34  10.40  86 | 0.5  15.33  7.36  143 | 0  19.89  74.35  2017 |
| 2004  | 17   47.71  10.25  89 | 0.5  15.72  7.60  140 | 0  21.08  80.04  1988 |
| 2005  | 18   47.98  10.21  90 | 0.5  15.83  7.66  145 | 0  21.47  81.38  2058 |
| 2006  | 19   48.25  10.12  90 | 0.5  16.44  8.26  152 | 0  21.12  80.99  2065 |
| 2007  | 20   48.44  10.05  87 | 0.3  17.00  8.73  141 | 0  21.27  84.03  2010 |
| 2008  | 19   48.91  10.01  88 | 0.5  17.70  9.60  136 | 0  21.20  85.13  1749 |
| 2009  | 19   49.29  10.04  88 | 0.5  18.12  9.88  121 | 0  22.49  89.79  2193 |
| 2010  | 20   49.59  10.06  89 | 0.5  18.95  10.42  113 | 0  23.19  92.18  2319 |
| 2011  | 19   49.83  10.10  87 | 0.5  19.61  10.98  117 | 0  23.48  99.35  2500 |
| 2012  | 19   49.94  10.17  89 | 0.5  20.59  11.82  121 | 0  23.69  102.29  2501 |
| 2013  | 19   50.21  10.26  90 | 0.5  21.52  12.44  132 | 0  22.46  103.04  2340 |
| 2014  | 19   50.08  10.33  91 | 0.5  21.94  12.77  128 | 0  22.89  105.43  2544 |
| 2015  | 20   50.18  10.33  92 | 0.5  23.39  13.87  124 | 0  23.64  107.61  2850 |
Table 4 Econometric Parameter Estimates for 3 and 5 km radii

| Variables                  | 3 kilometer radius | 5 kilometer radius |
|----------------------------|--------------------|--------------------|
|                            | Estimate           | Std. Error         | z-score | Pr(>|z|) | Estimate           | Std. Error         | z-score | Pr(>|z|) |
| Constant                   | -1.7357            | 0.13               | -13.79  | 0.0000  | -1.7053            | 0.11               | -15.37  | 0.0000  |
| Organic Neighbour 1        | 0.2755             | 0.08               | 3.62    | 0.0003  | 0.2496             | 0.06               | 3.91    | 0.0001  |
| Organic Neighbour 2        | 0.5565             | 0.15               | 3.72    | 0.0002  | 0.4865             | 0.10               | 4.78    | 0.0000  |
| Organic Neighbour 3        | 0.9786             | 0.25               | 3.92    | 0.0001  | 0.5455             | 0.20               | 2.77    | 0.0056  |
| Organic Neighbour ≥ 4      | 1.0413             | 1.46               | 0.71    | 0.4762  | 1.2459             | 0.21               | 5.87    | 0.0000  |
| Avg. Organic Farms         | -0.2236            | 0.07               | -3.02   | 0.0025  | -0.1763            | 0.05               | -3.22   | 0.0013  |
| Reverted Neighbour 1       | -1.6709            | 1.40               | -1.20   | 0.2312  | -1.2817            | 1.13               | -1.13   | 0.2568  |
| Reverted Neighbour 2       | -2.8675            | 1.01               | -2.85   | 0.0044  | -4.2790            | 0.35               | -12.30  | 0.0000  |
| Avg. Reverted Farms        | -4.6968            | 0.36               | -13.21  | 0.0000  | 3.6867             | 0.29               | 12.83   | 0.0000  |
| Exited Neighbour 1         | 0.2936             | 0.23               | 1.29    | 0.1966  | 0.2858             | 0.13               | 2.20    | 0.0277  |
| Exited Neighbour 2         | -3.8392            | 0.23               | -16.78  | 0.0000  | -3.6282            | 0.20               | -18.51  | 0.0000  |
| Exited Neighbour 3         | -3.5506            | 0.31               | -11.34  | 0.0000  | -3.2626            | 0.20               | -16.22  | 0.0000  |
| Exited Neighbour ≥ 4       | -3.8187            | 0.79               | -4.83   | 0.0000  | -3.2525            | 0.35               | -9.27   | 0.0000  |
| Avg. Exited Farms          | 0.3375             | 0.72               | 0.47    | 0.6399  | -0.7291            | 0.58               | -1.27   | 0.2048  |
| Age                        | -0.0067            | 0.00               | -4.13   | 0.0000  | -0.0069            | 0.00               | -4.45   | 0.0000  |
| Herd size                  | 0.0030             | 0.00               | 1.56    | 0.1181  | 0.0025             | 0.00               | 1.34    | 0.1811  |
| Land size                  | 0.0004             | 0.00               | 3.33    | 0.0009  | 0.0004             | 0.00               | 2.95    | 0.0032  |

Note: The standard errors are bootstrapped with 500 replications and clustered by farm.
## Appendix

| Variable | estimate | Std. Error | z-score | Pr(>|z|) estimate | Std. Error | z-score | Pr(>|z|) |
|----------|----------|------------|---------|------------------|------------|---------|---------|
| Year 2014 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2013 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2012 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2011 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2010 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2009 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2008 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2007 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2006 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2005 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2004 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2003 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2002 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2001 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 2000 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1999 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1998 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1997 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1996 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1995 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1994 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1993 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1992 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1991 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1990 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1989 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1988 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1987 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1986 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1985 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1984 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1983 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1982 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1981 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1980 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |
| Year 1979 | -0.240 | 0.16 | -1.49 | 0.14 | -0.240 | 0.16 | -1.49 | 0.14 |

**Note:** The table shows the estimates and standard errors for different years, with the z-scores and p-values indicating the significance of the estimates.