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Does the future of a farm depend on its neighbourhood? Evidence on intra-family succession among fruit and vegetable farms in Italy

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Abstract

The transfer of farm activity over time occurs through different pathways, among which the more frequent is intra-family farm succession. Thus, better information on farm succession determinants is crucial for understanding farm succession and informing appropriate sectoral policies. To date, substantial research has focused on the effect of farm, farmer and potential heir features on farm succession, while the role played by socio-economic conditions around a farm has been relatively less examined. Building on previous contributions, the present paper considers farm succession as the opposite of labour migration out of the agricultural sector. Thus, the effect of the labour market and surrounding conditions (LMSC) around a farm on its succession probability is explored. The aim of this paper is therefore to explore whether and to what extent the inclusion of LMSC variables may contribute to a better understanding of farm succession. Using data from a sample of 266 fruit and vegetable farms (gathered for informative purposes by a producers' organization consortium), empirical evidence that LMSC variables play an important role in explaining the succession probability in these types of farms is provided. Specifically, the results show that (*i*) including LMSC variables in a farm succession analysis increases the explanatory power and robustness of the model estimates; (*ii*) LMSC variables have a non-linear effect on succession; and (*iii*) some explanatory variables (farmer education and farm age, specialization and dimension) are significant across various specifications, while other variables (farmer age, territorial location and distance of a farm from its producer organization) change their sign and/or significance when LMSC variables are included in the model. As a consequence, our findings suggest that LMSC variables should be included in farm succession and labour market analysis to provide a better estimate of farm succession probability.

Keywords: Farm transfer, Local labour market, Out-farm migration, Occupational choice theory

JEL classification codes: J62, J43, Q12, R12

Background

Agriculture in Italy and Europe involves farms that are predominantly family-owned (Graeub et al. 2016). For this reason, intra-family succession is the preferred mechanism to transfer farm management to future generations (Lobley et al., 2010; Leonard et al. 2017; Chiswell 2018). Even if evidence of farm performance after intra-family succession is not univocal (Bertoni et al. 2017; Carillo et al. 2013), generational turnover and renewal in agriculture is still largely assured by this process. Thus, an in-depth analysis of the mechanisms and determinants of intra-family succession is relevant to addressing the multiple challenges that Italian and European agriculture will face in future decades.

The relevance of this issue is based on at least three important issues that are widely debated in the literature: (i) the capacity of intra-family farm succession to ensure an adequate turnover in agriculture and to address the ageing population of farmers, (ii) the consequences of high/low rates of farm succession, and finally, (iii) the relationship between farm succession and rural migration.

The first issue pertains to the progressive ageing of the farmer population, particularly in developed countries where there is a shortage of young farmers, or even a farm succession crisis (Zagata and Sutherland 2015; Burton and Fischer 2015). This problem is evident in Italy, where according to Eurostat data from 2016, 41% of farms, representing 27% of the total agricultural area, are managed by farmers aged 65 years or over (65% of farms and 50% of the agricultural area managed farmers aged 55 years or over). Whether a succession crisis is taking place in the agricultural sector is debatable, considering that official statistics do not record information on farm succession. Based on information from ad hoc surveys, the FARMSTRANSFER project (Errington 1998; Uchiyama et al. 2008; Lobley et al., 2010; Chiswell and Lobley 2015) indicates that succession rates are satisfactory. Nevertheless, in particular contexts such as marginal areas or areas with a high incidence of small farms, more critical situations may emerge. Similarly, Zagata and Sutherland (2015) examined young farmer shortages in Europe using Eurostat data.

Another topic of debate in terms of succession in agriculture pertains to the potential consequences of the lack of successors in agriculture and for ageing farmers. Opinions differ on this point. Some believe that low succession rates should not necessarily be considered a negative phenomenon, as in more productive areas, farms without successors can be absorbed by farms that are maintained, favouring economies of scale (Chiswell and Lobley 2015; Glauben et al. 2006). Other authors argue that, especially in marginal areas, the lack of succession can translate into abandonment of territory and loss of farm-specific knowledge and human capital accumulated and transmitted by previous generations, with a risk of environmental and territorial degradation (MacDonald et al. 2000; Corsi 2009; Raggi et al. 2013; Demartini et al. 2015).

However, several authors agree that young farmers are more inclined towards entrepreneurship (Vesala and Vesala 2010; McDonald et al. 2014; Stenholm and Hytti 2014), farm business diversification (McElwee and Bosworth 2010; Grubbström et al. 2014; Suess-Reyes and Fuetsch 2016; Ohe 2018) and adoption of eco-sustainable farming practices (Van Passel et al. 2007; Bertoni et al. 2011; Paracchini et al. 2015; Hamilton et al. 2015; Suess-Reyes and Fuetsch 2016).

Finally, the issue of farm succession clearly intersects with the wider abandonment of rural areas by younger people. Although the two phenomena do not completely overlap, they are connected, and farm succession trajectories can be considered a part of this larger phenomenon, especially in areas characterized by high agricultural employment (Bertoni and Cavicchioli 2016b). Several studies analysed the motivations behind the intentions of potential heirs to abandon agricultural activity and/or rural areas (Morais et al. 2017, 2018; Bednaříková et al. 2016; Chen et al. 2014; Bjarnason and Thorlindsson 2006). In particular, this trend seems to be strengthened among young people with a higher level of education (Bednaríková et al., 2016) and, other things being equal, women (Leibert 2016; Johansson 2016).

For the above-mentioned reasons, understanding the mechanisms and determinants of farm succession is relevant for assuring continuity in agricultural activities. A large part of the literature on farm succession is devoted to analysing the process of farm succession using both qualitative and quantitative approaches (Bertoni and Cavicchioli 2016b). Quantitative papers on farm succession rely on estimating the timing of succession, the effect of succession on farm assets/performance and mainly the probability and determinants of farm succession. Specifically, this last type of literature focuses on isolating the factors affecting the probability of farm transfer. Such analyses exploit limited dependent variable regression (probit or logit) using the event of farm succession as a dependent variable (1, succession takes place; 0, succession does not take place). This type of event may be observed directly (following a sample or a population of farms over a long time span, Stiglbauer and Weiss 2000) or may be inferred by asking a farmer his/her expectations about farm transfer (Glauben et al., 2004). In the former case, the information is more reliable, while data based on farmer statements may be inconsistent with respect to the actual event of succession (Väre et al. 2010). Most of the analyses have been carried out at the farm level, while few have focused on the probability that each potential heir in a family farm will take over the farm (Simeone 2006; Mann 2007; Aldanondo Ochoa et al. 2007).

The main part of farm succession literature focuses on the effect of farm, farmer and potential heirs features on the probability that succession takes place (Stiglbauer and Weiss 2000; Kimhi and Nachlieli 2001; Simeone 2006; Glauben et al. 2009; Cavicchioli et al. 2015), paying less attention to the effect exerted by socio-economic conditions around the farms examined, with some notable exceptions (Glauben et al., 2004, Aldanondo Ochoa et al. 2007; Corsi 2009; Kerbler 2008). To account more explicitly for the effect of the economic environment around the farm, some recent contributions (Bertoni and Cavicchioli 2016a; Cavicchioli et al. 2018) have treated the phenomenon of farm succession as the opposite choice with respect to searching for alternative employment outside of the farm sector. This decision has been previously modelled within the occupational choice theory (OCT—Todaro 1969; Harris and Todaro 1970; Mundlak, 1978; Barkley 1990 and Larson and Mundlak 1997). According to this theory, the probability of searching and finding a job in another sector is (linearly) fostered by the income gap between sectors: the larger the spread between the sectors (e.g., agriculture and non-agricultural activities) is, the higher the incentive for an individual to migrate out of the sector of origin. OCT also states that the income gap between sectors is a necessary but not sufficient condition for labour mobility, as other variables may increase or decrease the transaction costs for finding employment outside of the original sector. Such variables are population density, employment rate, and the relative dimensions (in labour size) of the economic sectors where the migration takes place. Considering, for example, labour migration from agricultural to non-agricultural sectors, such a process, according to OCT, is favoured in areas with higher population densities that offer more occasions to find a job. Similarly, the higher the employment rate in the local labour market, the higher the probability that agricultural workers will find jobs in non-agricultural sectors. Finally, the smaller the relative labour size of the agricultural sector (intended as the number of agricultural workers with respect to non-agricultural workers), the higher the employment opportunities will be in non-agricultural sectors for labourers coming from farming activities.

A recent analysis of the effect of agricultural payments on off-farm labour migration was based on OCT (Olper et al. 2014), with results consistent with theoretical expectations. Treating farm succession as an alternative to off-farm migration allows a bridge between a traditional farm succession analysis and OCT. Because farm transfer represents the opposite choice with respect to finding a job outside of the agricultural sector, the expected effect of local labour market variables (income gap, population density, employment and relative labour size of an agricultural sector) on farm transfer should be the opposite of those predicted by OCT. Thus, if OCT predicts a positive effect of income gap, population density, employment rate and relative labour size of the farm sector on agricultural labour migration, then increasing values of these variables are expected to discourage farm succession. The use of the variables suggested by OCT in farm succession analyses has yielded some unexpected results; according to OCT, local labour market variables should exert a linear effect on labour migration, but the effect of these variables in farm succession analyses were non-linear (Bertoni and Cavicchioli 2016a; Cavicchioli et al. 2018). The authors explained such unexpected outcomes as a combination of pro-succession and anti-succession effects for increasing values of local labour market variables.

The aim of this paper is therefore to better understand whether and to what extent the inclusion of LMSC variables may contribute to a better understanding of farm succession. This paper is based on a traditional farm succession analysis, as it uses farm and farmer features to explain farm transfer; furthermore, in continuity with recent studies (Bertoni and Cavicchioli 2016a; Cavicchioli et al. 2018), it contributes to the literature by accounting explicitly for the interaction between farm and farmer characteristics with labour market and surrounding conditions (LMSC) on farm succession predictions. By including the latter group of variables, intra-family farm succession was modelled as an alternative to searching for employment in non-agricultural sectors. With respect to previous studies that used OCT in farm succession analyses, in this study, the empirical exercise was carried out on a larger sample of fruit and vegetable farms. An additional contribution of this study, in comparison to similar previous analysis, is to assess whether and to what extent the inclusion of LMSC variables improves the prediction of farm succession in terms of estimation accuracy.

This analysis explores the following factors: (*i*) whether LMSC variables affect farm succession, (*ii*) whether their effect is linear or non-linear, and (*iii*) whether and to what extent the inclusion of such variables improves the prediction of farm succession in comparison to a traditional farm succession analysis, based mainly on farm and farmer features.

The remainder of the paper is organized as follows: the "Data and methodology" section shows the sample data and methodology used to carry out the empirical exercise, presenting the different models (with and without LMSC variables) and explaining the post-estimation tests for model comparison. The "Results and discussion" section presents and discusses the results of the different models used to predict farm succession, in addition with post-estimation comparisons. The "Concluding remarks" section outlines the main conclusions.

Data and methodology

Data and variables

As mentioned in the introduction, detecting farm succession is difficult, considering the lack of official data on this process. Thus, the present analysis focused on a group of farms for which such information was available.

The empirical exercise to test the above-mentioned hypotheses was carried out using data from a 2010 survey of fruit and vegetable farms belonging to a consortium of producers' organizations (POs). It is worth noting that such a survey was originally designed by the PO consortium for informative purposes and not for research aims. Therefore, the survey was intended to provide a detailed picture of farms belonging to the consortium, with detailed questions on crop mix and production. Researchers have been involved only in designing the part of the questionnaire devoted to human capital and farm succession perspectives. The pilot questionnaire was pre-tested and validated at the beginning of 2010 on a limited number of farms representing the main typologies of the entire population. The validated questionnaire was administered to all farms over 2010. Both the pilot and final questionnaires were administered face-to-face by technicians of the consortium to farm holders. The information on farm succession perspectives allowed us to infer farm succession probabilities. Unfortunately, as the questionnaire was mainly designed for informative purposes for the PO consortium, some explanatory variables, usually employed in farm succession analysis literature, were not collected. Thus, these missing variables have been replaced by other available proxies in the subsequent analysis.

Furthermore, the database from which data have been drawn covered all the farms that were members of the PO consortium (603 farms); as farm-level data on farm membership in producers organizations (and their consortia) are not publicly available, it is difficult to establish to what extent the collected data may be representative of all fruit and vegetable farms that are members of POs in Italy. For the same reason, the extendibility of the results is not straightforward.

From all the surveyed members of the PO consortium (603), a sample of 266 farms with farm-holders older than 45 years old with at least one child aged 15 years or older was selected. Such criteria were adopted to ensure that farms that have considered and/or are planning on farm succession were selected. Thus, we excluded farms without potential successors or siblings that were too young on the family farm.

The event of family business transfer in the sample was treated as a dichotomous variable, inferred from farm-holder expectation on whether farm succession would take place in the future. It is worth remembering that such expectations may not result in actual behaviour (Väre et al. 2010). As the aim of the analysis was to explore the improvement in farm succession estimations brought by labour market and surrounding conditions (LMSC) variables, in comparison to farm and farmer features, both the former and the latter have been selected as explanatory variables. The description of the variables is included in Table 1 in addition to the justification for their inclusion in the analysis, which was based on previous literature.

The explanatory variables in Table 1 are classified as belonging to the farm, farmer or LMSC variables. Farm and farmer variables have been selected as a compromise between evidence from previous literature on farm succession (listed in the last column of Table 1) and data availability. As the survey from which the dataset was developed was not designed for research purposes, it was necessary to select some proxy variables that were as similar as possible to those suggested by the literature. In particular, among farm-level information, available data on farm size, both in economic (*Turnover_250*, expressed as a dummy variable) and in structural terms (*Workdays*), have been selected. Furthermore, two dummy variables (*RPFV farm* and *Fruit farm*) were selected to capture the heterogeneity in farm production within the sample.

Labour market and surrounding conditions (LMSC) variables (income gap, population density, employment rate and share of agricultural labour) were calculated at the local labour system level. According to the Italian Institute for Statistics (ISTAT), a local labour system is an area (groups of municipalities) with homogeneous features in terms of supply and demand of labour (for further information, see www.istat.it/en/archive/142790). Therefore, LMSC variables have been calculated and associated with the local labour system of each farm in the sample. Notably, in Table 1, variables not suggested by occupational choice theory, such as *Distance* (the distance of the farm from the headquarter of the producer organization) and various territorial locations of the farm (*Hills*, *Mountain* and regional dummies), are classified as LMSC variables. The inclusion of such variables is suggested by the literature and is necessary to capture site-specific characteristics of the areas surrounding a farm. Even if the present contribution takes advantage of the theoretical insights from occupational choice theory, there is not yet a unifying theoretical framework suggesting which variables should be included or excluded in the empirical exercise to test farm succession determinants. Thus, among the variables available in the dataset, we selected those that were relevant in previous literature under different specifications. In so doing, it was possible to test the three research questions mentioned above and to isolate farm succession determinants with effects that are more stable across various specifications.

The sample contains 266 farms of which 113 with farmers that declared succession and 153 with farmers that did not expect an intra-family succession of the farm business. Table 2 reports descriptive statistics for each variable of the sample and is split into farms with and without (expected) succession.

Methodology

As described in the background section, the main contribution and emphasis of the present paper is to explore whether and to what extent labour market variables and surrounding conditions (LMSC) around a farm affect succession probability and improve its estimation. These research questions informed the empirical strategy that was

Table 1 Definition of variables used in the analysis

Variable category	Variable	Definition	Unit of measure	Previous studies using similar variables (effect on succession)[1]
Dep. variable	Succession	Farmer thinks that the next generation will take over the farm	1 = yes; 0 = no	
Farmer	Farmer age	Age of the farm-holder	Age	Corsi 2009 (BS); Glauben et al., 2004 (BS); Aldanondo Ochoa et al. 2007 (US); Kimhi and Nachlieli 2001 (BS); Stiglbauer and Weiss 2000 (BS)
	Farmer degree	Farmer has a degree	1 = yes; 0 = no	Simeone 2006 (+); Corsi 2009 (−); Mishra et al. 2010 (−) Bertoni and Cavicchioli 2016a (−)
	Farmer children	Number of farmers' children > 15 years old in the farm	Number of children	Aldanondo Ochoa et al. 2007 (−); Cavicchioli et al. 2015 (−); Mann 2007 (+)
Farm	Turnover_250	The farm annual turnover is over 250,000 EUR	1 = turnover > 250,000 EUR;0 = otherwise	Corsi 2009 (+); Mishra and El-Osta 2008 (+); Aldanondo Ochoa et al. 2007 (+); Kerbler 2008 (+)
	Farm duration	Years since the farm began	Years	Bertoni and Cavicchioli 2016a (+)
	RPFV farm	Farm type: ready prepared fresh vegetables (RPFV)	1 = yes; 0 = no	Kimhi and Nachlieli 2001 (−); Bertoni and Cavicchioli 2016a (+)
	Fruit farm	Farm type: fruit production	1 = yes; 0 = no	
	Emplwork	Share of employed worked days on total annual worked days in the farm	%	Kerbler 2008 (−)
	Workdays	The annual worked days in the farm both by holder family and employees	Days	Aldanondo Ochoa et al. 2007 (+); Glauben et al., 2004 (+); Kimhi and Nachlieli 2001 (−)
Labour market and surrounding conditions (LMSC)	Distance	Distance from the headquarters of the producer organization	Kilometres	Aldanondo Ochoa et al. 2007 (−)
	Popdens	Population density at the local labour systems level	Inhabitants per square kilometre	Alasia et al. 2009 (+); Olper et al. 2014 (−); Bertoni and Cavicchioli 2016a (US)
	Empl	Employment rate at the local labour systems level	%	Corsi 2009 (−); Barkley 1990 (+); Alasia et al., 2009 (−); Olper et al. 2014 (+); Cavicchioli et al. 2018 (BS)
	Agrshare	Share of agricultural employment on total employment at the local labour systems level	%	Barkley 1990 (−); Larson and Mundlak 1997 (−); Corsi 2009 (+); Olper et al. 2014 (+)
	Incgap	Income gap between non-agricultural sectors and agricultural sector in each province (NUTS 3)	Thousands EUR (GVA/worker)	Barkley 1990 (−); Larson and Mundlak 1997 (−); Olper et al. 2014 (−); Bertoni and Cavicchioli 2016a (BS)

Table 1 Definition of variables used in the analysis *(Continued)*

Variable category	Variable	Definition	Unit of measure	Previous studies using similar variables (effect on succession)[1]
	Hills	Farm is located in the hills	1 = yes; 0 = no	Corsi 2009
	Mountain	Farm is located on the mountains	1 = yes; 0 = no	Glauben et al., 2004 (–)
	Regional dummies	Farm location in a NUTS 2 region (omitted: Lombardy)	1 = yes; 0 = no	

[1]*(+)* a linear positive effect, *(–)* a linear negative effect, *(BS)* a bell-shaped non-linear effect, *(US)* a u-shaped non-linear effect

Table 2 Descriptive statistics of the sample

Variable	Total farms in the sample (*n* = 266)		Farms with succession (*n* = 113)		Farms without succession (*n* = 153)	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
Succession	0.42	0.50				
Farmer age	56.04	9.56	55.76	10.63	56.29	8.68
Farmer degree	0.05	0.21	0.04	0.19	0.05	0.22
Farmer children	2.55	1.56	2.93	1.76	2.30	1.34
Turnover_250	0.30	0.46	0.17	0.38	0.40	0.49
Farm duration	32.85	22.71	35.68	23.39	29.68	21.24
RPFV farm	0.23	0.42	0.38	0.49	0.12	0.33
Fruit farm	0.38	0.49	0.22	0.42	0.52	0.50
Emplwork	25.73	32.93	33.71	34.14	20.00	31.04
Workdays	966.5	1206.1	1332.4	1407.6	696.3	965.6
Distance	55.29	138.31	66.61	149.29	49.43	132.98
Popdens	298.2	429.8	365.4	403.9	242.4	420.2
Empl	47.64	4.09	46.89	5.00	48.07	3.28
Agrshare	5.85	3.29	5.53	2.92	6.04	3.53
Incgap	29.68	9.27	27.22	8.99	31.70	9.15
Hills	0.04	0.21	0.09	0.29	0.01	0.11
Mountain	0.38	0.49	0.24	0.43	0.50	0.50
Regional dummies						
Campania	0.13	0.33	0.22	0.42	0.07	0.25
Piemonte	0.06	0.24	0.03	0.16	0.09	0.29
Veneto	0.03	0.17	0.05	0.23	0.01	0.11
Emilia-Romagna	0.03	0.18	0.04	0.21	0.03	0.16

based on a limited dependent variable (probit) regression. This type of regression analysis yields estimated coefficients (odds ratios) that measure the effect of each explanatory variable on the succession probability. Therefore, three different specifications have been estimated:

- First specification (models 1, 2 and 3), including only farm and farm variables
- Second specification (model 4), including farm and farm variables and LMSC variables in linear form, as suggested by occupational choice theory
- Third specification (models 5, 6 and 7), including farm and farm variables and LMSC variables in non-linear form

The six models estimated in the first and third specifications differ for the introduction of squared terms in some continuous variables to test their possible non-linear effects. Overall, seven models have been estimated. For brevity purposes, the results of only three models (models 3, 4 and 7) are presented, one for each specification, in addition to post-estimation statistics. For the first and third specifications, the models that perform better in terms of prediction accuracy (pseudo R-square and share of correctly classified) were selected. The comparison of all seven models, in addition to their post-estimation statistics, is available as Additional file 1.

In the first specification (models 1–3), we tested the effects of farm and farmer characteristics and of farm location in the hills or in the mountains (also defined as altimetry) and regional dummies. The effect of altimetry dummies was measured compared to the excluded altimetric band (plane). For instance, a positive and significant coefficient of "Hill" indicates a higher succession probability for farms located in hilly areas with respect to those in plain areas. The same reasoning applies to regional dummies, whose effect was compared to the excluded region (Lombardy).

As in the literature, some continuous variables (such as farmer age) are found to exert a non-linear effect on succession, which was tested both in models 1–3 and in models 4–6 for some continuous variables. In the second specification (model 4), LMSC variables—*Popdens*, *Empl*, *Agrshare* and *Incgap*—are entered in linear form, as suggested by occupational choice theory. In models 5–7, the same variables are tested in polynomial (non-linear) form. This process is justified by previous findings (Bertoni and Cavicchioli 2016a, 2016b; Cavicchioli et al. 2018).

To compare different models, some statistical criteria that are widely used in the context of model selection are considered. Specifically, the pseudo *R*-square (see McFadden (1973), which is based on the likelihood ratio test, the scoring function (see Akaike 1974 and Schwarz 1978) and finally some classification results from the confusion matrix are used (Provost et al. 1998).

The pseudo *R*-square used in this analysis is McFadden's test. This test is based on a comparison between the log-likelihoods of two specifications: the full-model with predictors and the intercept model. Therefore, McFadden's *R*-squared measure can be defined as follows:

$$R^2_{\text{McFadden}} = 1 - \frac{\ln \hat{L}(M_{\text{full-model}})}{\ln \hat{L}(M_{\text{intercept}})} \tag{1}$$

where $\hat{L}$ denotes the maximized estimated likelihood value, while $M_{\text{full - model}}$ and $M_{\text{intercept}}$ denote the full-model predictors and the model with only an intercept, respectively. Thus, the ratio of the log-likelihoods suggests the level of improvement over the intercept model offered by the full model. Moreover, a small ratio of the likelihoods indicates that the full model provides a better fit than the intercept model, implying that McFadden's measure is higher for the model with the greater estimate of likelihood function.

The Akaike information criterion (AIC) and the Bayesian information criterion (BIC) represent alternative model selection tools. They are defined as follows:

$$\text{AIC} = -2\ \ln\left(\hat{L}\right) + 2k \tag{2}$$

$$\text{BIC} = -2\ \ln\left(\hat{L}\right) + 2\ \ln(Nk) \tag{3}$$

where $\ln\left(\hat{L}\right)$ denotes the maximized estimated log-likelihood value related to the full-model predictors, and k and N are the total number of estimated parameters and observations, respectively. Both the AIC and the BIC indicators represent badness of fit measures; therefore, the optimal model is selected based on the minimum AIC and/or BIC. It is important to highlight that the BIC shows a larger penalty term to address the issue of the overfitting model.

Finally, the confusion matrix consists of a predictive classification table, with the representation shown in Table 3:

Given the context of our analysis, we define an "event" as r farm succession occurring or not occurring. If farm succession takes place, then the event is equal to 1. If farm succession does not take place, then the event is equal to 0. Therefore, the entries of the matrix, A, B, C and D have different meanings. Specifically, A is the number of correct predictions that farm succession takes place, B is the number of incorrect predictions that farm succession takes place, C is the number of incorrect predictions that farm succession does not take place, and D is the number of correct predictions that farm succession does not take place.

Thus, the representation of the confusion matrix allows us to compute, for each estimated model, three types of conditional probabilities:

1. The sensitivity, which is defined as the A/(A + C) proportion of events
2. The specificity, which is the (D/(B + D)) proportion of non-events
3. The accuracy (also known as the share of correctly classified), which is the ((A + D)/ N) proportion of events correctly predicted by the model

Given the context of our analysis, the above-mentioned conditional probabilities (sensitivity, specificity and accuracy) in addition to the pseudo R-square and the information criteria (AIC and BIC) provide an intuitive measure of comparison among the models.

Results and discussion

The main results of the model estimates of farm succession are presented in Table 4, based on the estimation strategy presented in the "Methodology" section. Table 4 reports only three of the seven models estimated, which are presented in Additional file 1: Annex 1, as a robustness check. Parameter estimates in bold denote those variables with a stable effect, in terms of sign and significance, across the models.

There are some variables that had an effect on intra-family farm succession robust across various specifications in terms of sign and significance. The graduation of farm-holders exerts a negative effect on the probability of farm succession, in contrast to the results of Simeone (2006), who examined a sample of 100 farmers in central Italy but in line with some studies that used a similar proxy, considering parents with at least a high school diploma (Corsi 2009; Mishra et al. 2010). Different effects of the same variable may be explained by the specificity of the contexts examined. More generally, a possible explanation of the present results relies on a higher probability that a graduate farmer pushes his/her children to graduate, and graduation, especially in non-agricultural subjects, would increase their propensity to abandon agricultural activity.

The probability of farm succession is higher for older farms (coefficient positive and linear, consistent with Bertoni and Cavicchioli 2016a). Specialization in fruit or ready-prepared fresh vegetables results in the probability of having successors negative or positive, respectively. The coefficient of the share of hired work is negative and consistent with Kerbler (2008), who tested the same variable on a sample of 789 Slovenian farmers. Additionally, farm size had a stable effect on succession, even if divergent in financial and structural terms. Succession probability is lower in farms

Table 3 Theoretical confusion matrix comparing the number of events observed and predicted by an estimated model

Predicted/observed farm succession events		Observed farm succession events		
		Farm succession takes place	Farm succession does not take place	Total observed farm succession events
Predicted farm succession events	Farm succession takes place	A	B	A + B
	Farm succession does not take place	C	D	C + D
	Total predicted farm succession events	A + C	B + D	*N*

Table 4 Results of probit regression

	Farm and farmer variables; no labour market and surrounding condition (LMSC) variables (model 3)	Farm and farmer variables; LMSC variables in linear form (model 4)	Farm and farmer variables; LMSC variables in non-linear form (model 7)
Farmer age	0.0121	0.0118	− 0.1481*
Farmer age_sq	–	–	0.0013*
Farmer degree	*− 0.9126****	*− 0.9698****	*− 0.8957****
Farmer children	0.0372	0.092	0.1379**
Turnover_250	− 0.3030*	− 0.3309*	− 0.3785**
Farm duration	*0.0116****	*0.0108****	*0.01****
RPFV farm	*0.8196***	0.4348	*0.8985****
Fruit farm	*− 1.3773****	*− 1.2117***	*− 1.1348***
Emplwork	*− 0.0108****	*− 0.0113***	*− 0.0104**
Workdays	*0.0007***	*0.0006***	*0.0007***
Workdays_sq	*0.0000***	*0.0000**	*0.0000***
Distance	0.0080**	−0.0004	− 0.0008***
Distance_sq	0.0000**	–	–
Popdens	–	0.0000	− 0.0036***
Popdens_sq	–	–	0.0000***
Empl	–	0.0164	2.7195***
Empl_sq	–	–	− 0.025***
Agrshare	–	− 11.2887***	− 4.8662
Incgap	–	0.1382***	− 1.3349***
Incgap_sq	–		0.0335***
Hills	0.7892	*1.9286****	*2.3695****
Mountain	1.4278***	− 1.1795	− 10.8799***
Campania	0.6311*	1.0965	7.0349***
Piemonte	*−1.291****	*− 2.2433****	*− 7.041****
Veneto	0.1133	2.6116***	1.6324**
Emilia-Romagna	− 0.0911	0.5548	− 0.9747
Constant	− 1.8808***	− 5.0828	− 57.2248**
N obs	259	259	259
Pseudo R^2	23%	26%	30%

*, ** and ***, denote significance at 10%, 5% and 1%, respectively
The table reports three of seven different model specifications. The complete version with all the models is presented in Additional file 1: Annex 1
The parameter estimates whose sign and significance are stable across different specifications are presented in italics (those not presented in Table 3 are available as supplemental material)

with turnover beyond 250,000 euros, which is not consistent with previous findings (Mishra and El-Osta 2008; Aldanondo Ochoa et al. 2007). On the other hand, a stable positive effect of the structural dimensions of a farm, approximated by the number of workdays, is observable.

As occupational choice theory suggests a linear effect of LMSC variables on labour migration (and then, in the opposite manner, on succession), LMSC variables have been entered in linear terms (model 4), finding a positive linear role of income gap (between agricultural and non-agricultural sectors), negative linear role of share of agricultural employment and non-significant effect of employment rate and population density. According to the second research question (and in line with Bertoni and Cavicchioli 2016a and Cavicchioli et al. 2018), the non-linear effects of such variables have been explored. Thus, three (income gap, employment rate and population density) of the four LMSC variables were significant both in linear and in squared terms, while the share of agricultural employment was not significant (neither linear nor squared). In line with similar previous findings (Bertoni and Cavicchioli 2016a; Cavicchioli et al. 2018), the explanation of such results relies on a combination of pro-succession and anti-succession effects due to the specific features of such farms. The pro-succession effects of LMSC variables rely on increased market opportunities for fruit and vegetable farms nearer to densely populated and wealthier areas (having higher employment rates and larger income gaps compared to agricultural areas). Another possible explanation of pro-succession effects relies on better services for the family farm that would be encouraged to continue its activity. The anti-succession effects exerted by LMSC variables are those predicted by the occupational choice theory: if increasing values of *Popdens*, *Empl* and *Incgap* favor out-farm migration, then for the same reason, they will discourage farm succession. Interestingly, the introduction of LMSC variables restored the significance of some farm and farmer variables: farmer age (non-linear u shaped, even if significant at 10%), number of children in the family farm (positive, in line with Mann 2007 but in contrast to Aldanondo Ochoa et al. 2007 and Cavicchioli et al. 2015), distance of the farm from the producers organization where the product is delivered (negative, in line with Aldanondo Ochoa et al. 2007) and farm location in hilly areas (positive, in line with Corsi 2009, in contrast to Glauben et al. 2004). The same effect occurred with the regional dummy Campania, whose magnitude and significance increase consistently. Furthermore, farm location in mountainous areas changed sign (from positive to negative, increasing its magnitude) after the inclusion of contextual variables. The results presented point to a non-linear effect of LMSC variables on farm succession, as in the linear specification (model 4) where only two of the four LMSC variables were significant.

To compare the different models presented and to explore the contribution of the LMSC variables in improving farm succession predictions, some post-estimation statistics for model comparisons have been carried out. The statistics are presented in Table 5 for models 3, 4 and 7, while the same statistics for all the estimated models are available in Additional file 1: Annex 2. An explanation description of the statistics presented in Table 5 is included in the last part of the "Methodology" section.

The model evaluation and comparison criteria provide three main results.

Table 5 Post-estimation statistics for model comparison

	Farm and farmer variables; no labour market and surrounding conditions (LMSC) variables (model 3)	Farm and farmer variables; LMSC variables in linear form (model 4)	Farm and farmer variables; LMSC variables in non-linear form (model 7)
Pseudo R^2	23%	26%	30%
Sensitivity	65%	62%	65%
Specificity	82%	83%	87%
Correctly classified	75%	74%	77%
AIC	312	306	295
BIC	379	384	380

Post-estimation statistics for models 1, 2 5 and 6 are available in Additional file 1: Annex 2

First, for each of the McFadden's *R*-squared measures reported in Table 5 and Additional file 1: Annex 2, there is substantial agreement that model 7 fits the outcome data better than the other models.

Second, the AIC and BIC are minimized in models 7 and 1, respectively. This outcome is not surprising because BIC penalizes model complexity more heavily, which is consistent with the larger number of estimated parameters involved in model 7 (having LMSC variables in level and squared) than in model 1.

Third, the results from the confusion matrix allow us to compare the sensitivity, specificity and accuracy for each model at a 0.5 cut-off value. These three indicators have the advantage of assessing the performance of each model in terms of actual and predicted classifications without being affected by the proportion of farms with succession. Table 5 shows that despite models 1 and 7 providing the same percentage of sensitivity (65%), the inclusion of the LMSC variables improves the specificity and the accuracy of the outcome variable.

Overall, for this analysis, model 7 offers the best fit among the set of candidate models, and therefore, the inclusion of LMSC variables offers better farm succession predictions.

Concluding remarks

The aim of this paper was to explore whether and to what extent the inclusion of labour market and surrounding conditions (LMSC) variables may improve a farm succession analysis. The reason for including such a category of determinants relies on the already identified intuition that family business transfer may be viewed as an alternative decision of potential heir(s) compared to finding employment outside of the agricultural sector.

According to OCT, the latter decision is affected by LMSC variables. The above-mentioned research question has been addressed empirically by estimating various models that predict farm succession probability. One model was estimated that included only farm and farmer features (and without LMSC variables), while in the second and third models, LMSC variables were included in linear and non-linear form, respectively. In the second model (linear), only two LMSC variables were significant, while in the third model (non-linear), three of the LMSC variables were significant, suggesting that the relationship between farm succession and LMSC variables may be better modelled in a non-linear fashion rather than as a linear relationship. From the model comparison, a block of variables emerged (*Farmer children*, *Farm duration*, *Fruit farm*, *Emplwork* and *Workdays*) whose effect was robust across specification, while the introduction of LMSC variables restored the significant effect of some other variables (*Hills*) and changed the sign of some others (*Mountain*). To investigate and compare the accuracy of different model specifications (excluding and including LMSC variables), some post-estimation and model fitting tests were performed. The model including LMSC variables in a non-linear form emerged as a better fit in terms of the actual event of farm succession in terms of pseudo R-squared, specificity, share of correct predictions and one of two information criteria (AIC). For this reason, the present empirical findings suggest that farm succession analyses are improved by including LMSC variables.

As stated in the data description, given the specific composition of the sample (fruit and vegetable farms belonging to a PO consortium) and the lack of data on PO affiliations in the underlying population of these farms, both sample representativeness and result extendibility are not straightforward. Thus, the present analysis should be repeated on different types of farms and in different areas to obtain a better picture of the effect of LMSC variables on farm succession. However, the contribution of the present findings goes beyond the underlying population of our sample (farms members of POs or fruit and vegetable farms) as it may provide various implications for farm succession analyses and potentially for farm labour migration studies. First, contextual variables (LMSC variables) play a role when analyzing the probability of intra-family farm succession, improving model fit and predictions; second, in specific cases, such as those examined, the effect of LMSC variables on intra-family transfer is non-linear, unlike those expected by occupational choice theory; third, the inclusion of contextual variables may change the significance and/or sign of some farm and farmer variables on succession probability. These implications suggest considering intra-family farm transfer as part of a wider problem of labour allocation choice in the agricultural sector that cannot be examined in isolation with respect to labour, population and economic patterns of other sectors. Furthermore, potential non-linear effects of labour market and contextual variables should be explored and taken into account not only in farm succession analysis but also in empirical estimations based on occupational choice theory, for instance, in the assessment of the labour effect of agricultural policy. Finally, the present study indirectly points to the lack of a clear and unifying theoretical framework underpinning the empirical analysis of family farm features affecting succession (child, farmer and farm features). Such an in-farm theoretical framework of succession should be clearly defined to match the out-farm migration framework suggested by occupational choice theory.

Additional file

Additional file 1: Annex 1 -Robustness Check across different specifications. Annex 2 - Post-estimation statistics for comparison of the 7 estimated models. (DOCX 23 kb)

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Availability of data and materials

The datasets generated during and/or analysed during the current study are not publicly available due to a confidentiality agreement with subjects involved in the survey.

Authors' contributions
The research design was conceived by DC and DB. Data gathering has been carried out by DGF and RP. The "Background" section has been written by DC and DB, the "Data and variables" section by DB, the "Methodology" section by DC, the "Results and discussion" section by DC and the "Concluding remarks" by DC, DB, DGF and RP. All the authors read and approved the final manuscript.

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