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The evolution of farm size: an exploratory study by configural frequency analysis

Investment support measures in agriculture can have differentiated effects on the strategic reorganisation and the performance of farms. In this paper, we study the patterns of technical change of a sample of farms in the Lombardy region, Italy, that invested in structural modernisation benefiting from the financial incentives provided under the measure 121. We find evidence relating the modernisation of farms under the umbrella of the measure 121 to limited positive changes in farmland and more substantial positive changes in other inputs. The results are not conclusive regarding a causal relationship between the measure 121 and the structural change of farms. Nonetheless, the paper describes a situation in which patterns of farmland reduction are relatively less frequent in farms that make use of this policy instrument.

1. Introduction

A decrease in the number of operating farms characterised the recent evolution of the agricultural sector in western countries, and in particular in Europe (Breustedt and Glauben, 2007). This general trend also appears in the Eurostat figures according to which the aggregate number of farms decreased by approximately 26% during the period 2000-2010 (Eurostat, 2013). The phenomenon is considerable also in Italy, where the fall in the same period is about 24%. According to Uthes et al. (2011), this decline in the number of farms, that is highly correlated with the increase in the average farm size, is part of a more general structural change process implying a redistribution of land from the dropping-out to the remaining farms is implicit in this process. Dynamics external to the agricultural sector connected to the changes in the economy and the society as well also relate to the documented decline in the number of agricultural farms. On the economic side, the most productive sectors of the economy now employ production factors to the largest extent, subtracting resources to the agricultural sector. On the social side, lifestyles and expectations are rapidly changing, espe-

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cially for young generations, shaping the different characters of the agricultural sector as a whole.

The productivity growth that the agricultural sector exhibited during the last century also majorly contributed to this structural change in agriculture, and will likely continue to be influential. The productivity trend is expected to last for at least the first half of the current century, perhaps in the majority of the agricultural areas (Rabbinge et al., 2000). The growth in productivity, towed by the mechanisation of agriculture and the spreading of more managerial approaches to farming, sides the (re)distribution of resources to farmers in regions and, consequently, the efficiency of agriculture, and ultimately the overall welfare of the agricultural communities (Breustedt and Glauben, 2007).

Structural change in agriculture, inefficient farms drop-off and modernisation of surviving farms are all aspects of attention for the policymakers in the EU. In particular, farm modernisation is the objective of one of the most relevant structural measures of the EU farm investment policy, the measure 121, with the longest history of implementation, ranging over four decades (Travnikar and Juvancic, 2015). Objective of this measure is "to modernise agricultural holdings, to improve their economic performance through better use of the production factors including the introduction of new technologies and innovation, targeting quality, organic products and on/off-farm diversification, including non-food sectors and energy crops, as well as improving the environmental, occupational safety, hygiene and animal welfare status of agricultural holdings" (EC, 2005). The ultimate goal of promoting modernisation through investment support is to increase the productivity and the income of the individual economic unit, but there are also significant benefits related to the increased co-operation. (Zasada et al., 2015)

Few facts contribute to highlight the prominence of the measure 121 during the programming period 2007-2014. First, 87 out of 88 Rural Development Programs (RDPs) across the EU programmed this measure. Second, more than 198,000 farm holdings in Europe received support for their modernisation and the total volume of investments realised by 2012 accounts to almost €34 billion (ERDN, 2014a; 2014b). Italy that is the geographical framework of reference in this case study, allocated to the measure 121 a significant amount, about €4.9 billion, second only to Germany (€5.6 billion) (ERDN, 2014a; 2014b).

The present study aims at exploring the structural change in farms that applied for the measure 121 in the Lombardy region, Italy. Our goal is to describe the results generated by measure 121 in the farms that joined it, without determining any cause-effect relations between the measure and change in the farm's structure.

In line with EU CAP objectives, the RDP of the Lombardy region in the period 2007-2013 targeted the competitiveness of the agricultural sector and the measure 121 represented the most prominent instrument of financial support to the first axis, providing incentives for the modernisation of farms and ultimately for the evolution of farming techniques and management practices. Thanks to the measure, benefiting farmers could invest to reorganise the production rebalancing the input factors and joining significant benefits regarding costs cut-down and production frontier improvement, sometimes conditions not to leave the market. Previous research demonstrated the investment support benefits on business (GVA) expansion and productivity (GVA/labour costs) improvements (Ratinger et al., 2012). In the 2014-2020 programming period, the RDP planned a significant share of the loans to contribute to the modernisation and performance improvement of agricultural holdings. In the Lombardy region, the 2014-2020 RDP budgeted 409 out of 1,157 billion Euros to promote investments for the profitability, competitiveness and sustainability of farms

So far, and to the authors knowledge, the empirical literature investigated the relationship between the farmers' participation in RDP measures and the territorial factors such as the local institutions (Bertoni et al., 2008), the profit-maximising farm behaviour (Barreiro-Hurlé et al 2008), and the socio-economic and geographic characters of the farm (Pascucci et al., 2011). In the specific of measure 121, some recent studies pointed attention to the geographical differences between regions where the measure applies (Caruso et al., 2015), the effects of the measure on local development (Bednaříková, 2015), and the leverage effect through private co-financing involvement (Sin and Nowak, 2014) but none has dealt instead with the effects of voluntary participation to policy measures on production factors composition.

With this paper, we contribute to the existing literature exploring how the participation to the measure 121 relates to the farmers' choice of production technique, and in particular the choice to expand the farm size (in terms of Usable Agricultural Area – UAA) in relation to the use of other production factors, namely labour and capital. As known, the reduction (or the expansion) of the agricultural area is the results of several different strengths, including urban development, farm abandonment, different structural change in the agriculture and food system, farmers' strategies, the combined adoption of RD measures, and it cannot be imputed to the measure 121 only.

Farmers choose simultaneously the amount of land and other inputs to employ for production, causing the dynamics of these quantities to be related intrinsically (Kislev and Peterson, 1982) but looking at the effects of increasing UAA and hence of expanding farm size, we can disentangle two very frequent patterns. The first observable pattern is a decrease in both labour and capital and is coherent with an agricultural production technique that becomes less land-intensive (Kristensen, 1999). The stability or increase in one or both inputs characterises the second pattern, that is more typical when the farm expansion is the consequence of an improved professionalisation of the agricultural activity. By studying systematically how the combination of factors responds to an investment for modernisation strategy, as that supported by the measure 121, we seek to explore the possible effects of this policy instrument for the development of the regional agriculture.

For a sample of farms that required and obtained access to the measure 121 in the Lombardy region for co-financing structural interventions, we observe the variation in the production technique, that is the composition of production factors land, labour, and capital, over the period 2000-2010. We construct statistical tests for the hypothesis that the observed variations in production factors are not independent and we study the specific characters of the patterns of variations that occur more frequently than expected. In the remaining of the paper: the next Section briefly introduced the study area; Section 3 describes the data and illustrates the empirical approach; Section 4 summarises the results of the empirical analysis; in Section 5 some policy reflections conclude the work. with

2. The case study

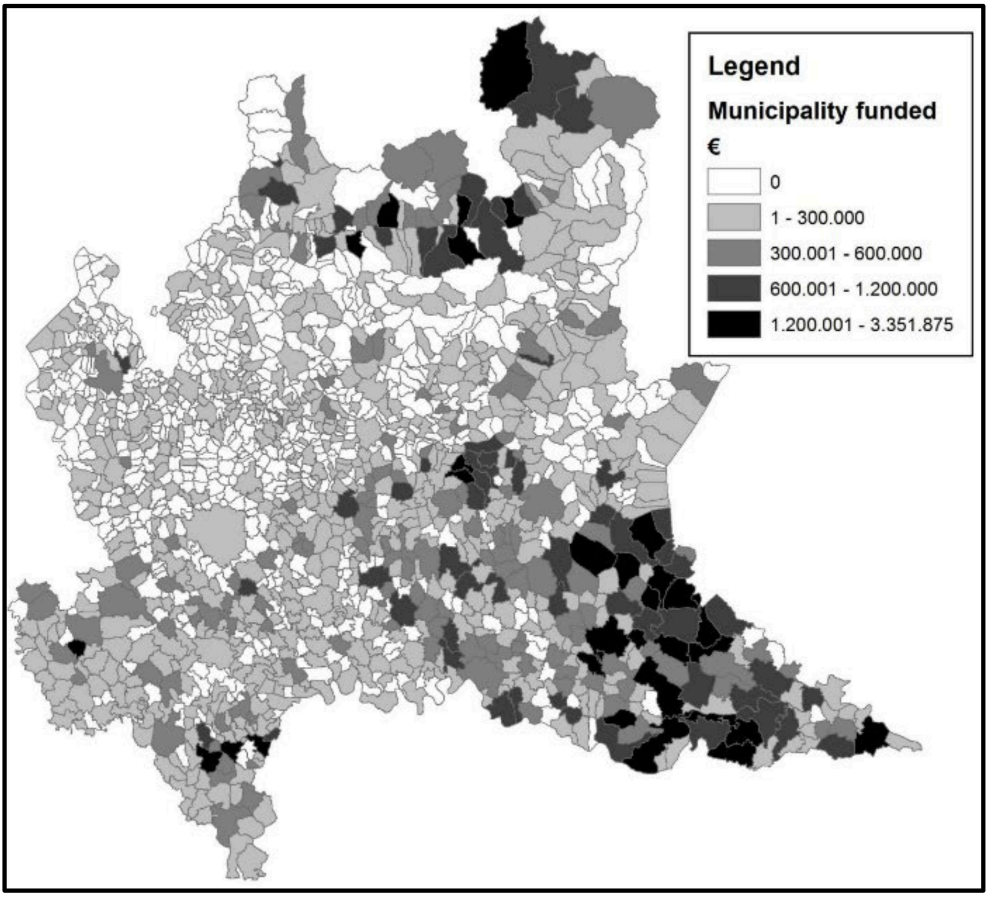
The Lombardy region experienced, in the last decade, the declining trend in the number of existing farms that, with different modes and intensities, characterised the other geographical areas in the country and Europe as well. Based on the data collected during the last census of agriculture by the national institute of statistics (ISTAT), there were, in Lombardy, as much as 53,313 farms in 2010, substantially less (-24%) compared to the 71,000 farms in the last (2000) census. During the same period, the UAA decreased from 1,039,592 to 984,871 ha (about 41% of total land in the region). As a consequence, the average farm size increased from 14.6 to 18.4 ha per farm, well above the national average (7.9) that, however, hides prominent disparities among farms locates in the different geographical areas of the country.

Within the region, the farm size growth has been the most significant in the provinces of Milano, Bergamo, Brescia and Monza e Brianza, the most urbanised areas in the region, being Milan itself among the second largest urban agglomeration in the country. Although to a lesser extent, the phenomenon showed up also in the southern part of the region (Pavia, Mantova, and Lodi) where the plain territory encourages the agricultural activity. Oppositely, the mountain areas of the region (Varese, Como, and Lecco) experienced a sharp decrease in the average farm size. By and large, the spatial distribution of the variation in farm size informs that the holding's expansion more likely occurred where the agriculture is both more intensive and more specialized, somehow in contrast to the expectation that farm concentration could prevail in the less productive areas of the regions, where the probability to drop-off is the highest. A closer look at the census data (2000-2010) reveals a decrease in the number of small and medium-sized farms to the benefit of the number of large (more than 50 ha) farms, that now represent only the 10% of total farms, even though their holdings sum up to the 58% of total UAA.

Considering the trends in the other production factors, the evidence in Pieri and Pretolani (2011) tells of a significant fall in the number of agricultural workers in the Lombardy region in the years 2008-2010, which turned from 80,000 to 70,800, consistently with what also happens in Europe according to the official statistics (Eurostat, 2010). Lombardy outperforms the country average when it turns to the stability of workers in the sector, as 54% of the employees are stable against a national average of only 28%, even though the number of hired workers increased by 45%, passing from 23,660 to 34,457. Turning the attention to capital, there is evidence of the decline, by about 23% in the last five years in the new-buy of agricultural machines (Pieri and Pretolani, 2011) although some overall investments did not show significant variations. (Casati and Pieri, 2008). While this figure could evidence the general crisis that is threatening the agricultural sector, it is not possible to exclude at all that the structural reorganisation and the expansion of farms lead to efficiency, possibly achieved through a rationalisation of machinery investments.

Within the context framed by the above figure, actions financed under the measure 121 are intended to improve the use of productive factors, to reduce variable costs, and to reinforce the overall performance of the farms in terms of both income and value added. To this goal, the measure provides monetary incentives to the adoption of innovative processes that qualify the productions stages, even internalising the most productive stages of the value chain, product transformation and sales. Leveraging on the regional financial contributions, in fact, farms have an incentive to invest, uncovering new product development plans, reorganising the production processes, redesigning the competitive strategies to bet-

Figure 1. Distribution of funding of RDP measure 121 (Lombardy region) - Total funds distributed from 2008 to 2011.



ter adapt to the socio-economic and environmental changes and to benefit from the new opportunities generated by these changes (Regione Lombardia, 2010). According to the second intermediate evaluation report (Regione Lombardia, 2010), by 2010 already 1,461 farms applied for the measure 121 determining an overall expenditure of about 228 million, including private contribution, that means an average of 156 thousand euro invested per farm.

Figure 1 maps the distribution of financed interventions at the municipality level for the case study region, darker tones indicating that the municipality has received a relatively larger financial contribution, likely because farms in the municipality are more willing to renew their structures.

3. Data and empirical approach

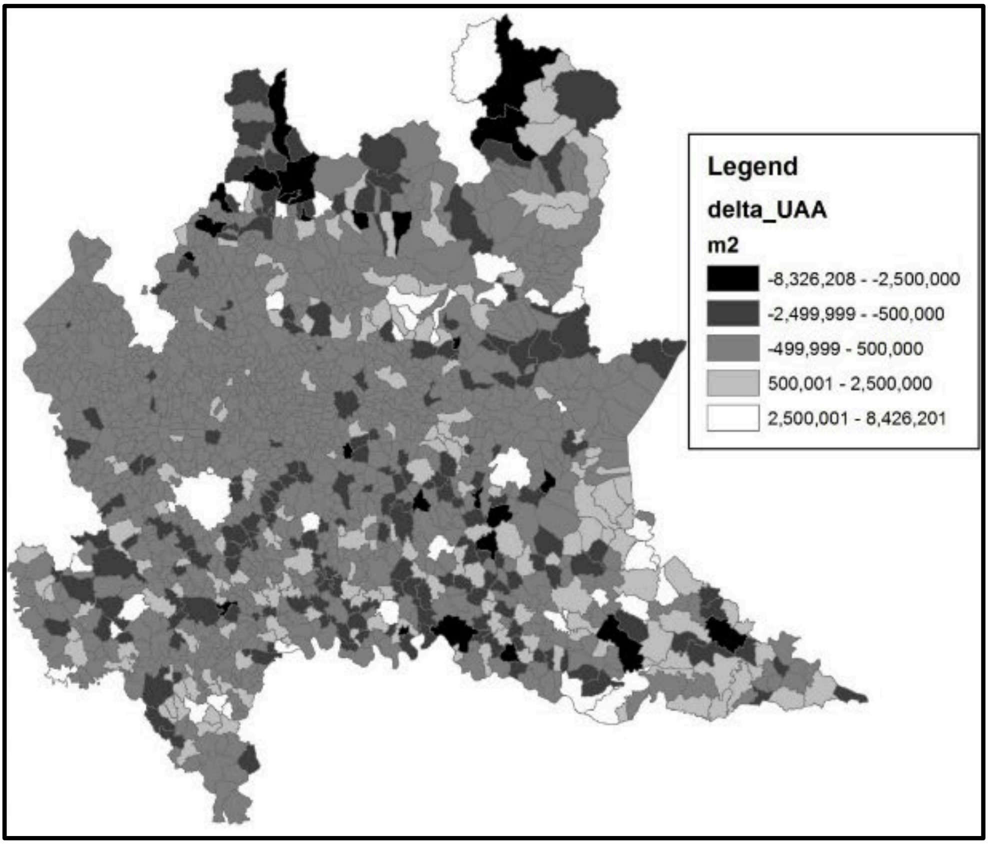
The empirical analysis in this paper employs farm-level data for the Lombardy region (Italy). Being the region among the most competitive in the agri-food sector in Europe and also among the most urbanises and with the highest concentration of tertiary workers, the sample under study adequately represents the characteristics of a modern agricultural system, making the empirical analysis and the policy conclusion sound also for other geographical contexts.

The main source of the data is the SIARL, the Informative System for the Agriculture of the Lombardy Region, which collects data on farmer's applications to the support measures financed under the European Union Common Agricultural Policy (CAP), and specifically the Rural Development Program (RDP). Farmers use the system to manage their applications for support measures, and the system records farmers information that, once anonymised, are transferred into a publicly accessible portal.

The data accessed for the purpose of this research concern the years 2008-2001, by which we measure the differential between the final and the initial year relative to three main variables, land, labour, and capital, which represent the main production inputs. Our measure of land is the total square meters of Usable Agricultural Area owned and rented by the farm. The yearly number of worked hours, including both family and non-family workers, is the measure of labour and the total amount of fuel consumption serves as a proxy for the utilisation of capital in the farming activity. The figures 2 to 4 map the differentials in the three variables in the considered period at the municipality level, hence including all the farms in the database.

The sample used in this analysis includes uniquely the farms that applied to the measure 121 of the RDP, and this justifies the choice of the time span for the empirical analysis. In 2007 the region published the first call relative to the programming period 2007-2013 and applicant farms only received access to funding in 2008. Of the 1416 total applicant farms, 12 updated their information in the informative system up to 2011, reasonably because they also applied for other measures during the period. Because the number of farms with updated information is substantially lower in 2012, we considered the year 2011 the optimal response

Figure 2. Increase/decrease of UAA (m^2).

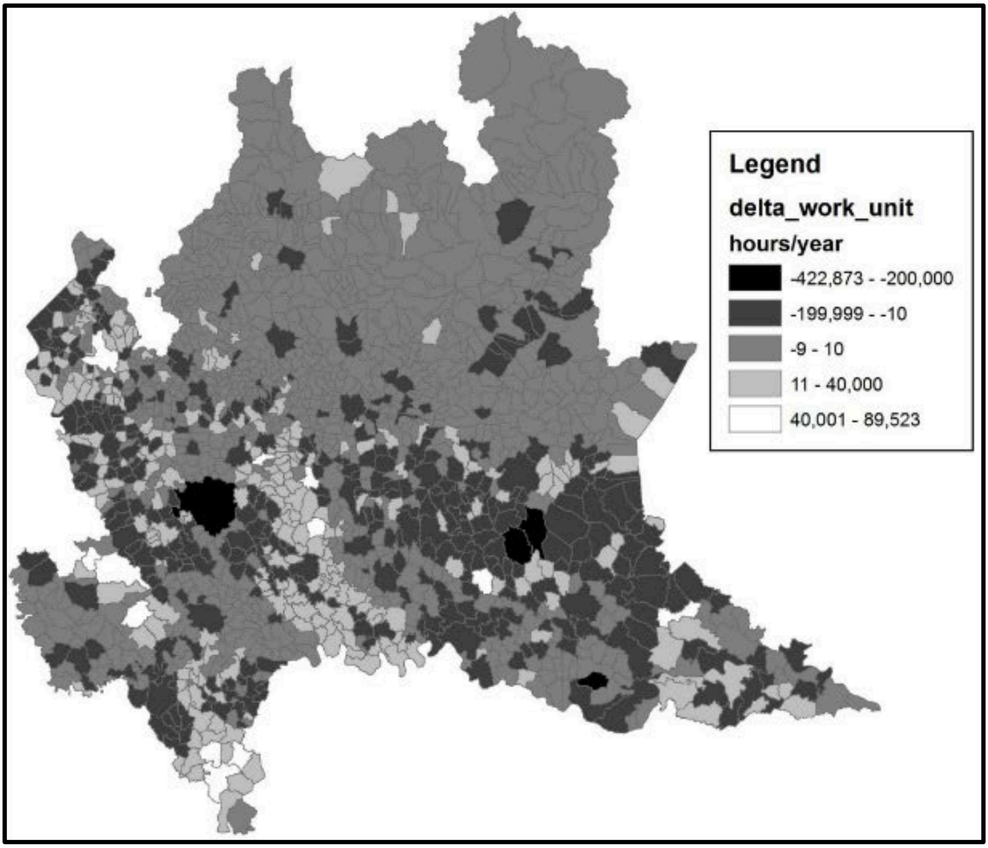


to the trade-off between a very limited time span and an excessively low size of the sample.

We investigated the relationship between the dynamic of the three variables for farms that applied for the measure 121 with Configural Frequency Analysis (CFA), a data analysis tool for assessing the degree of independence of categorical variables in a multivariate framework. Applications of CFA include both exploratory and inferential approaches and found application primarily in psychological studies (Lienert, 1968; Von Eye, 1990; Netter et al., 2000; Von Eye, 2004) and to a minor extent in economics (Mann, 2005). In short, applied in an exploratory fashion, the CFA technique identifies special patterns of factors (variables) in the empirical sample, where special means that the joint distribution associated with that pattern is statistically different from the expected distribution under the hypothesis of independence. Applied for inference, the CFA technique tests the hypothesis of independence in a specific pattern of factors.

The objective of this approach in the context of policy evaluation is to investigate which special patterns occurred in farms applying for the measure. This

Figure 3. Increase/decrease labor force (hours/year).

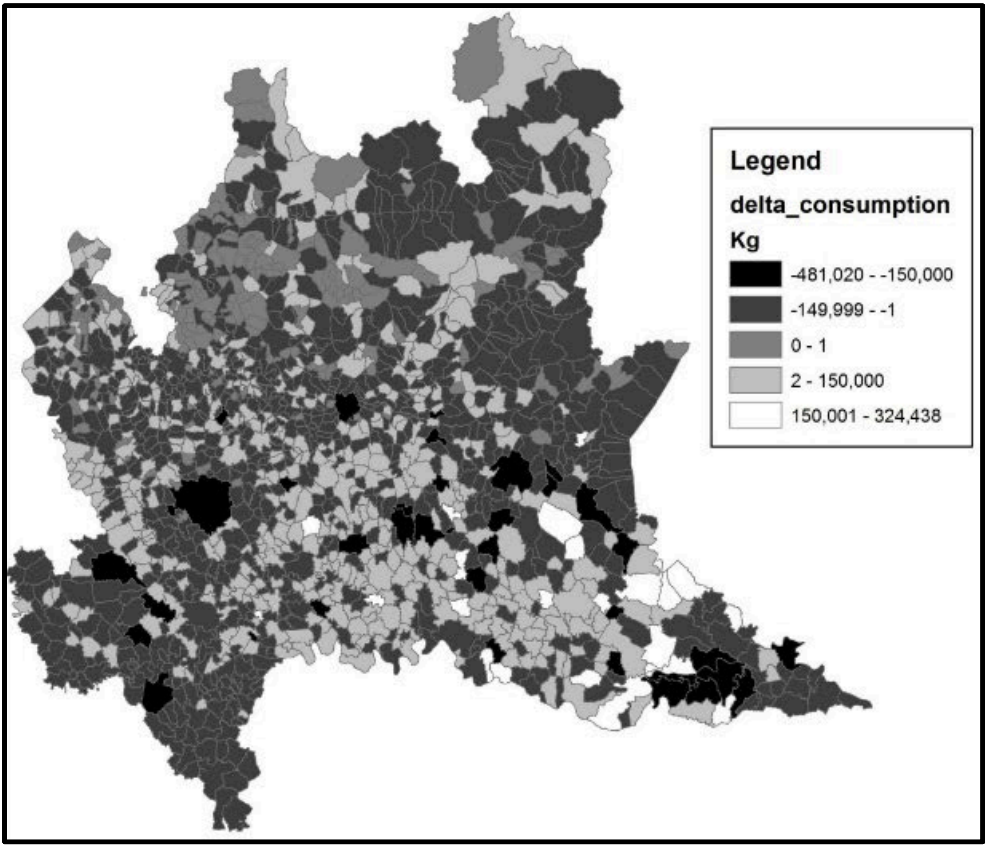


in turn implies that no causality relationship can investigated and then inferred from the empirical analysis. Nonetheless, the considered measure supports farmers in the pathway to restructuring and modernisation, and farmers are requested to participate with substantial investments, and it is interesting to understand how farmers investing in the restructuring and modernisation of their business changed the combination of production factors.

Letting **X = [L, K, A]** denote the vector of percentage changes in, respectively, labour, capital, and agricultural area in the sample farms, we define the vector of categorical variables **x = [l, k, a]** taking values 1,0,-1 if the related change was positive, zero or negative as follows:

$$x_i^s = \begin{cases} 1 & if \quad X_i^s > 0.05 \\ 0 & if \quad -0.05 < X_i^s < 0.05 \quad i = 1, 2, N; s = l, k, a \\ -1 & if \quad X_i^s < -0.05 \end{cases} \quad [1]$$

Figure 4. Increase/decrease of fuel consumption.



In the Equation [1] we allow percentage changes of the variables in the +/-5% interval to be considered normal, meaning that the change does not reflect a substantial variation of the variable and, accordingly, we assign the value of 0 to these changes.

Table 1 presents the marginal distributions of the three factors. The total UAA decreased in a very limited number of farms, less than 20% and the remaining farms are equally shared in the two other categories, hence stable UAA and growing UAA. This evidence, even though based on a very specific sample, is coherent with the figures of the structural change dynamics of the whole region. The distribution differs in the case of the other two variables, emphasising a substantial degree of stability in the case of labour and, in contrast, substantial changes in both directions in the case of capital.

Using the information of the marginal distributions we compute for each possible combination of the values of **a**, **l**, **k** the expected number of observations $E(n^{a,l,k})$ under the hypothesis that the three variables are independent. The

Table 1. Marginal distributions of variables, absolute (and relative %) frequencies.

	Decreasing (d) (-1)	Stable (s) (0)	Growing (g) (1)
a	47 (17.5)	111(41.4)	110 (41.1)
l	43 (16.1)	144 (53.7)	81 (30.2)
k	76 (28.4)	66 (22.7)	131 (48.9)

hypothesis of independence is certainly simplistic and probably unrealistic, but it is useful to remind here that, for the application, this hypothesis only serves as a null hypothesis with respect to which compare the reality. At the same time, among the possible assumptions about the null hypothesis, it is the most neutral, in the sense that it does not require the researcher to formulate apriori assumptions about the relationship between the variables.

Comparing the empirical realisation, that is the absolute frequencies from the cross-tabulation of the variables and the expectations results in the identification of special combinations of factors for which the empirical frequency is statistically different from the expected one. A "type" defines a special combination in which the empirical frequency is larger than the expected, and the opposite holds for the "antitype". The analysis of types and antitypes contributes to the understanding of which structural change pathway occur more (less) frequently in farms investing in business restructuring and modernisation.

We compute the expected number of observation $E(n^{a,l,k})$ as in the Equation [2], where can take any value in the set and $m = \{g,e,d\}$ and $p^s{}_g = p(x^s = 1)$, $p^s{}_e = p(x^s = 0)$, $p^s{}_d = p(x^s = -1)$ and N is the total sample size.

$$E\left(n \mid m_a, m_l, m_k\right) = N \cdot p^a_{m_a} \cdot p^l_{m_l} \cdot p^k_{m_k} \qquad [2]$$

Thus, considering, for instance, the case of farms in which we observe a decrease in all factors, that is $m_a = m_l = m_k = l$, using the estimates in Table 1, $p(a = d) = 0.175$, $p(l = d) = 0.161$, and $p(k = d) = 0.284$, the expected number of observation under the null hypothesis that the factors, and hence the variations of inputs, are not correlated is 2.14.

Having computed the expected number of occurrences for each possible combination, the hypothesis that the difference between the observed (f^o) and the expected (f^e) frequencies can be subject to empirical test. We use the statistics in the Equations [3] and [4].

$$\frac{\left(f^o - f^e\right)^2}{f^e} \sim \chi^2 \qquad [3]$$

$$\frac{f^o - f^e}{\sqrt{f^e\left(1 - \frac{f^e}{m}\right)}} \sim z \qquad [4]$$

4. Results

Table 2 summarises the results of the CFA analysis. The first three columns of the table specify the values of the factors associated with the specific combination in row and column four reports the expected frequencies computed according to the Equation [2]. Comparing the observed (column 5) with the expected frequencies, we define types and antitypes (in column 6) and test the hypothesis that the difference is statistically significant (columns 7 and 9). For each statistic, we also report the associated *p-values*.

Before turning to the analysis of types and antitypes, few considerations are worth. The first is that the highest observed frequencies characterise the groups of farms that i) increased only capital and left labour and land unchanged (26); ii) increased both labour and capital but left land unchanged (28); iii) increased all factors (20). The second is that the incidence of farms in which at least two factors decreased, independently of the change in the third factor is below 10% and the same figure for farms in which at least two factors increased is as three times as large. This evidence is perfectly coherent with the characteristics of the sample, having selected farms that are investing money in their business transformation.

Considering types and antitypes, we find four significant[1] types and two significant antitypes. To the first significant type is associated the increase in both labour and capital and a decrease in the land. We speculate that these farms are undergoing a radical transformation from a production technique based on scale economies to a production technique that shifts the value added to the workforce and the mechanisation of the production. The second significant type considers farms that decreased both labour and capital and left land unchanged. The decrease in both variables inputs indicates that the economic restructuring of the farms is oriented toward a more cost-saving production technique combined with the stabilisation of size. The other two significant types are characterised by a stability of land and the increase in either only labour or both labour and capital, similarly to the first identified type.

Overall, we find no evidence of a correlation between the increase in farm size and the change in other production inputs, as none of the identified types consider positive variations of UAA. This also reflects the results about the antitypes, according to which, a less than expected number of farms increased land, leaving unchanged the amount of labour and either increasing or decreasing the amount of capital.

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[1] We consider significant a type or an antitype is at least one of the two statistics shows an associated p-values lower than the 5% threshold. In the case of the z statistics the test conducted is the one-side test.

Table 2: CFA results.

A	L	K	Expected Frequency	Observed Frequency	Classification	χ^2	(p-value)	*z-stat*	(p-value)
-1	-1	-1	2.138	1	Antitype	0.606	(0.436)	-0.782	(0.217)
-1	-1	0	1.716	2	Type	0.047	(0.829)	0.217	(0.414)
-1	-1	1	3.686	3	Antitype	0.128	(0.721)	-0.360	(0.359)
-1	0	-1	7.161	6	Antitype	0.188	(0.664)	-0.440	(0.330)
-1	0	0	5.748	4	Antitype	0.532	(0.466)	-0.737	(0.231)
-1	0	1	12.344	7	Antitype	2.314	(0.128)	-1.557	(0.060)
-1	1	-1	4.028	5	Type	0.234	(0.628)	0.488	(0.313)
-1	1	0	3.233	3	Antitype	0.017	(0.897)	-0.131	(0.448)
-1	**1**	**1**	**6.943**	**12**	**Type**	**3.682**	**(0.055)**	**1.944**	**(0.026)**
0	**-1**	**-1**	**5.050**	**13**	**Type**	**12.512**	**(0.000)**	**3.571**	**(0.000)**
0	-1	0	4.054	3	Antitype	0.274	(0.601)	-0.527	(0.299)
0	-1	1	8.705	12	Type	1.247	(0.264)	1.135	(0.128)
0	0	-1	16.913	17	Type	0.000	(0.983)	0.022	(0.491)
0	0	0	13.575	18	Type	1.442	(0.230)	1.233	(0.109)
0	0	1	29.153	26	Antitype	0.341	(0.559)	-0.619	(0.268)
0	1	-1	9.5137	13	Type	1.278	(0.258)	1.151	(0.125)
0	**1**	**0**	**7.636**	**14**	**Type**	**5.304**	**(0.021)**	**2.337**	**(0.010)**
0	**1**	**1**	**16.399**	**28**	**Type**	**8.207**	**(0.004)**	**2.957**	**(0.002)**
1	-1	-1	5.005	5	Antitype	0.000	(0.998)	-0.002	(0.499)
1	-1	0	4.017	3	Antitype	0.258	(0.612)	-0.511	(0.305)
1	-1	1	8.627	5	Antitype	1.525	(0.217)	-1.255	(0.105)
1	**0**	**-1**	**16.761**	**8**	**Antitype**	**4.579**	**(0.032)**	**-2.210**	**(0.014)**
1	0	0	13.453	8	Antitype	2.210	(0.137)	-1.525	(0.064)
1	**0**	**1**	**28.891**	**17**	**Antitype**	**4.894**	**(0.027)**	**-2.342**	**(0.010)**
1	1	-1	9.4280	7	Antitype	0.625	(0.429)	-0.805	(0.210)
1	1	0	7.5672	8	Type	0.025	(0.875)	0.160	(0.437)
1	1	1	16.251	20	Type	0.865	(0.352)	0.960	(0.169)

5. Concluding remarks

In conclusion, we can affirm that in three on four of the significant Types the decision to adhere to the Measure 121 seems to foster good performance as at least one, but often both of the productive factors increase. And at the same time in three on four the surface doesn't decrease. In other terms, the Measure 121 can contribute to the enhancement of farm productivity and to the preservation of farmland, which is the most important farm asset and a fundamental natural resource.

This work is a first attempt to apply CFA methods to the analysis of the relationships between variables at the farm level. Preliminary results, however, suggest that the exploratory approach of this method, although not very common in economic studies, can, in fact, be fruitfully employed to study farm dynamics. In support of the CFA approach, there is the adaptation to samples of varying size. For this work, the sample under study is relatively small but previous studies have also employed much larger samples (Mann 2005). In his work, Mann uses a sample of 57,747 farms in Switzerland which have pasture land in their assets.

Finally, the most significant result of the analysis concerns the varying outcomes linked to the voluntary decision to apply for the measure 121 of the RDP of the Lombardy region, both regarding change in farmland and of changes in the levels of other production factors. The propensity to increase (or better not to decrease) farmland seems the first characterising feature, even considering that farmland conditions, in fact, the use of the other factors of production, although in varying manners. In other words, the measure 121, aimed at supporting the structural modernisation of the farms, proves more efficient if the farm increases the level of UAA. If not, the measure looks more like an occasion for benefiting farmers to increase the likelihood of survival.

However, some limitations of the applied method and the possible future development of the research must be briefly listed. First of all, CFA cannot analyse rival hypotheses and thus excludes any deterministic finding. Secondly, CFA doesn't define the cause-effect relations which could be highlighted by other more stringent approaches. Moreover, the further analysis including counterfactual sample could enrich and strengthen our results. Finally, the results of the combined adoption of different measure can better underexplain the structural change of farms.

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