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In-farm diversity stabilizes return on capital in Argentine agro-ecosystems

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ABSTRACT

Agricultural production faces risks of various kinds caused by weather, pests, markets, and policy changes. Minimizing these risks is an ongoing objective of farmers. The diversification of activities and the selection of the most stable activities are frequently mentioned as potential stabilizing factors. The aim of this study is to determine the impact of diversification and selection of activities on economic stability over time in a set of farms located in the southwest of the Pampa Region, Argentina. We use the coefficient of variation of return on capital as indicator of economic stability. These farms routinely evaluate their economic performance through a shared methodology. We compiled a data set that included 366 annual productive and economic results for 82 farms in 7 years between 2000 and 2008. We analyzed the economic and yield results of these farms and of a set of simulated farms that differentially combined various activities. We found that a greater diversification of activities was associated with an increase of stability, measured by a reduction of the coefficient of variation of return on capital as diversification increased. This effect resulted from a significant increase of mean return on capital without changing the standard deviation as diversification increased. We also found significant differences in this indicator of economic stability of individual activities as a result of different combinations of variability in yields, prices and costs. Birth to slaughter livestock operation was much more economically stable than either cow-calf or fattening operations. Wheat was the most stable crop, corn was the least stable crop, and sunflower and soybean showed intermediate stability. Overall, livestock activities were more stable than agricultural crops. Simulated farms showed that more diversified combinations were economically more stable. The stability of the average real farm was very similar to the most stable farm simulation. This suggests that farmers in the study area have found in the diversification and selection of activities useful tools to reduce the economic risks they face.

1. Introduction

The success of agricultural production is strongly determined by many environmental and economic factors beyond the control of the farmer. Environmental factors such as floods, droughts, winds, and hail cause serious economic losses (Warrick, 1980). In the case of livestock grazing, long-lasting drought or floods may push farmers to the difficult choice between raising their costs to levels of bankruptcy or watching their animals die of starvation (Díaz-Solís et al., 2009). Economic factors, such as the sharp fluctuations in prices of inputs and outputs may also create instability in the economy of a farmer (Timmer, 1997). Epidemics of foot-and-mouth disease or the emergence of bovine spongiform encephalopathy may close markets in a matter of days. Political decisions, whether domestic, such as devaluations and changing export taxes, or international, such as suspending purchases of agricultural products may change the economy of farmers overnight.

Farmers deploy a variety of strategies to cope with these environmental and economic variations, stabilize farm income performance and reduce risks. For example, Vavra and Colman (2003) found that farmers in the United Kingdom chose their crops based not only on optimal benefit, but also on risk avoidance. Often, farmers buy insurance against weather-related disasters such as hail, fire, frost, wind and drought. They also trade both input and output products in futures markets, and carefully negotiate the conditions for purchases and sales. They often lower production costs, even giving up expectations of higher revenues (Ellis, 1993). All these strategies are common to any agricultural region, but they become critical and more expensive as the environmental conditions are less favorable (Di Falco et al., 2010a), and thus, the stability of each crop is lower, the insurance premiums are higher, and farmers seek other ways to ensure the survival of their businesses.

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Two strategies to stabilize farm income are diversification and selection of agricultural activities that are more secure and stable, yet not necessarily the most profitable (Berzsenyi et al., 2000). The stabilizing effect of the first strategy, diversification, is based on the assumption that different activities depend on different markets and are affected by the weather to varying degrees. Poor farmers in Africa and Asia look for different revenue sources to reduce risk (Ellis, 2000). Ethiopian farmers increased total production through crop diversification, particularly in drier areas (Di Falco et al., 2010a). Zentner et al. (2002), based on experimental plots, showed that a certain degree of crop diversification reduced economic risk for farmers in Western Canada. Viglizzo and Roberto (1998) showed that production of a set of farms in Argentina was more stable in those that carried out many activities (up to 6), including beef cattle and annual crops. Iiyama et al. (2007) found that some combinations of livestock and crops improved the income of farmers in a semiarid region of Kenya, and suggested that it might also increase their stability. This effect of diversification is comparable to the "portfolio effect" (Sharpe, 1970; Tilman et al., 1998), and it is more likely to act positively on stability as the response of different activities to the environment or the market is more contrasting. For example, in the Pampas region a year with a very dry and cold winter may be simultaneously unfavorable for wheat and livestock grazing, but it may be very favorable for corn and soybean if rainfall is abundant in summer. An increase in the cost of fertilizer could decrease the income of wheat and maize, but barely affect sunflower and soybean, and not affect livestock breeding at all. A sharp price fall in international oil markets may affect the returns of sunflower and soybean, but not alter the income of cereals and meat.

The second stabilizing strategy, the selection of activities inherently more stable, could be based on factors such as the higher drought tolerance of sunflower with respect to corn and soybean, or the relatively low variable costs in seeds and herbicides of wheat crop compared to corn and sunflower, which means less capital put at risk. It could also result from other more complex reasons, as in the case of livestock grazing (Viglizzo, 1986), which involves primary production and secondary processing of feed into meat or milk. This is an ongoing process throughout the year, which can absorb and compensate for relatively long periods of scarce resources through transfers of forage resources in time and space, or through the use of animal body reserves of energy and protein (Viglizzo and Roberto, 1998).

In the Southwest of the Pampas, Argentina, farm diversification is common. Crop yields and forage production for livestock are very unstable due to soil and climatic constraints. Economic conditions are also unstable due to the lack of consistent economic policies (Alesina et al., 1996). Thus, it is interesting to investigate whether farm diversification is a mechanism that stabilizes economic performance in the face of environmental and economic instability. Van Keulen (2006) emphasized the need for comparative studies to better understand the most important factors in complex agricultural systems and thus generate appropriate policies. In general, farm-level studies have focused on diversification as a means of increasing economic performance rather than on stabilizing it (Di Falco et al., 2010b; Iiyama et al., 2007; Villano et al., 2010). On the other hand, the few studies that focused on stability mostly concerned product yields and left aside the economic features that determine the stability of farms, such as the product prices, the costs, the resulting farm income, and the capital invested (Viglizzo and Roberto, 1998).

This paper analyzes the relationship between diversification and stability of yield and economic performance, based on information from real farms. The specific objectives are (1) to determine whether the different degree of diversification of activities carried out by a sample of farmers of Southwestern Pampa is related with the stability of return on capital, and (2) to determine if the selection of activities affects the stability of return on capital. We will test two hypotheses: (1) diversification of activities tends to offset climate and market fluctuations, so that production and return on capital is more stable in more diversified farms. (2) Some activities have more stable return on capital than others, which influences the stability of whole-farm return on capital.

2. Materials and methods

2.1. Study area

The study was based on information from farms located in the General La Madrid and Laprida Depression (SAGyP-INTA, 1990; Soriano, 1992), Southwest of Buenos Aires province and the Argentine Pampa. The area covers approximately 2 M ha between the Tandilia and Ventania hill systems. It is a vast flat plain between 130 and 200 m above sea level, part of the high basins of the Salado and Quequén rivers. Mean annual rainfall is 800 mm and mean annual temperature is 14 °C. At the landscape scale, there is a matrix of lowlands, with alkaline and poorly drained soils (typical natracuols), interspersed with small uplands, with better drained soils (typical argiudols and tapto-artic soils). These two landscape elements have contrasting agronomic capabilities, which limit both the productivity and feasibility of activities. Lowlands are always used for cow-calf operations on either natural grasslands or sown pastures of forage species best adapted to these soils. Uplands have been cropped since the beginning of the 20th century as part of a rotation with perennial pastures used for livestock fattening operations (Paruelo et al., 2006). The proximity between cow-calf lowlands and upland-based fattening livestock often fosters the implementation of birth to slaughter operations within a single farm. Thus, at the landscape scale, crops and livestock production coexist because lowlands are restricted to livestock and uplands are under either livestock or cropping production according to a rotation plan. Due to landscape structure and farm size, some farms are exclusively or nearly exclusively constituted by lowlands, but no farm is entirely constituted by uplands.

2.2. Data collection

We compiled a database of 366 yearly productive and economic results from 82 individual farms over 7 annual financial cycles between 2000–2001 and 2007–2008. The farms were members of a non-governmental organization, the Argentine Association of Consortia for Regional Agricultural Experimentation (AACREA). The database included, for each farm and each year, crop and livestock activities, area occupied by each activity, production, product prices, direct and indirect costs of each activity, farm income (revenues minus total costs), and total capital invested, which included land, all categories of livestock, and the capital required to carry out all annual activities. Fattening livestock and the capital required to carry out annual activities were included because the farms need to immobilize those resources for a year or more before they generate an income. In addition, that is how the farmers themselves consider the capital invested in their annual financial reports. Return on capital was calculated as the ratio between annual net farm income and capital invested. Economic data for different years were transformed to constant currency values (March 2009 Argentine pesos) according to the domestic wholesale price index published monthly by the National Statistics and Censuses Institute (INDEC, 2012).

The original database did not discriminate between birth to slaughter, cow-calf and fattening operations in terms of cost and production. Thus, we reached such discrimination through the following procedure. The lowlands of all farms were assigned productivity, costs and product prices equal to those of the farms entirely composed of lowlands, whose sole activity was cow-calf operation. Upland area not occupied by crops in each farm was assigned the difference between the production, price and cost of the whole farm and the corresponding values previously assigned to lowlands. Similarly, the value of the land for lowlands was assumed to be equal to the average land value of farms entirely consisting of lowlands, whereas the land value of uplands was estimated as the difference between the market value of the whole farm and the value of its lowlands. The production price was differently calculated for cropping and livestock. In the case of crops, it was simply the market price of total annual production, whereas in the case of livestock, a continuous process, production price was calculated as $S - B + SD$, where S is the total amount of annual income from selling meat, B is the procurement cost, from buying feeder calves, cows or bulls, and SD is the difference between the price of cattle stock at the end and the start of the annual period, both valued with the price at the end of the period.

2.3. Data analysis

2.3.1. Diversification and return on capital

Regarding the first objective (to determine whether the different degree of diversification of activities carried out by a population of farmers of Southwestern Pampa is related with the stability of the return on capital of their farms), we worked with a subset of the database just described. We selected the 211 annual financial records from 35 farms that had at least four years of data.

The coefficient of variation (CV) of the return on capital of each farm over time was calculated from the available database of 7 annual periods, and adopted as the only indicator of its economic stability (lower CV denoting greater stability). We focused on return on capital instead of other commonly used variables, e.g. farm income, because the farms under study are businesses run with a business rationale. Owners are regularly weighing their investment alternatives, even outside of agriculture, and paying more attention to return on capital than to income. In addition, return on capital is a relative measure that allows comparing farms of different size (land), and other types of capital, such as livestock and infrastructure. We correlated the interannual CV of farm return on capital with Shannon's H index (Shannon and Weaver, 1949), a diversity index that takes into consideration not only the number of activities but also their proportion (relative area in our case): $H = -\sum p_i \ln p_i$ (from $i = 1$ to n), where p_i is the proportion of area assigned to the ith activity. We also investigated the relationship between each component of the CV, mean or standard deviation, and this H diversification index. In addition, we tested through multiple linear regressions if other variables explained part of the variation unexplained by the diversity of activities. These other variables were: proportion of owned land, farm size (which ranged between 929 and 10,715 ha) to account for the possible effect of economies of scale, number and mean date of the analyzed financial cycles (the latter to account for possible bias due to technological progress), and number of years under systematic technical advice (measured by years as members of AACREA).

2.3.2. Activities and their stability

Regarding the second objective (to determine if some activities have more stable return on capital than others, which influences the stability of the whole farm return on capital), we used the complete database to evaluate the regional-level variability of each activity. For each activity (cow-calf, fattening and birth to slaughter livestock, and crops of wheat, sunflower, soybean and corn) and year, we averaged the production, product prices, costs, gross margin (considering only direct costs) and farm income of all farms. Then, we calculated the 7-year mean, standard deviation and CV of each variable for each activity over time. These measures of variability of each activity do not reflect the average variability at the farm level.

2.3.3. Selection of activities and farm stability

Integrating the two objectives, in order to combine diversification and selection of activities, we designed ten simulated farms with size, upland/lowland proportion and other characteristics equivalent to the mean of the complete database. For each of these simulated farms, we assigned a different area to each of the activities carried out in the region. All the resulting simulated farms allocate their lowlands to similar cow-calf operations. The uplands use was as follows:

1. Average. Each activity in the same proportion as the database average in the 2000–2008 period
2. Fattening: The fattening operation consists of a birth to slaughter operation of all calves produced plus the fattening of imported calves.
3. Wheat.
4. Sunflower.
5. Corn.
6. Soybean.
7. Mixed cropping: wheat, sunflower, corn and soybean on the uplands, in the database average proportions.
8. Mixed cropping, 20% fattening: 20% pastures for cattle fattening and the remaining area destined to crops in database average proportions.
9. Mixed cropping, 33% fattening: 33.3% pastures for cattle fattening and the remaining area destined to crops in database average proportions.
10. Mixed cropping, 50% fattening: 50% pastures for cattle fattening and the remaining area destined to crops in database average proportions.

Each of these simulated farms was subjected to the "wind tunnel" of environmental and economic conditions (costs, prices and yields) between 2000 and 2008. We assigned to each simulated farm and each activity the regional-average capital investment, yields, prices, direct costs and indirect costs. We then calculated farm income and return on capital for each case and each year. We correlated the interannual CV of farm return on capital with Shannon's H (Shannon and Weaver, 1949) diversity index described previously for the five possible activities: livestock fattening, wheat, sunflower, corn and soybean. Notice that the variability of these simulated farms is based on regional average data. Thus, the variability does not necessarily reflect the variability of an individual farm. The simulated farms were built for comparative purposes only.

2.4. Statistical procedures

Data analysis was performed by means of simple and multiple stepwise regressions (Infostat, Cordoba University).

3. Results

3.1. Diversification and return on capital

The coefficient of variation of return on capital decreased with increasing diversification (Fig. 1-A). The decrease in variability with diversification was more pronounced in the lower range of diversification. Due to the landscape structure of the region, the least diversified farms were dominated by lowlands with cow-calf

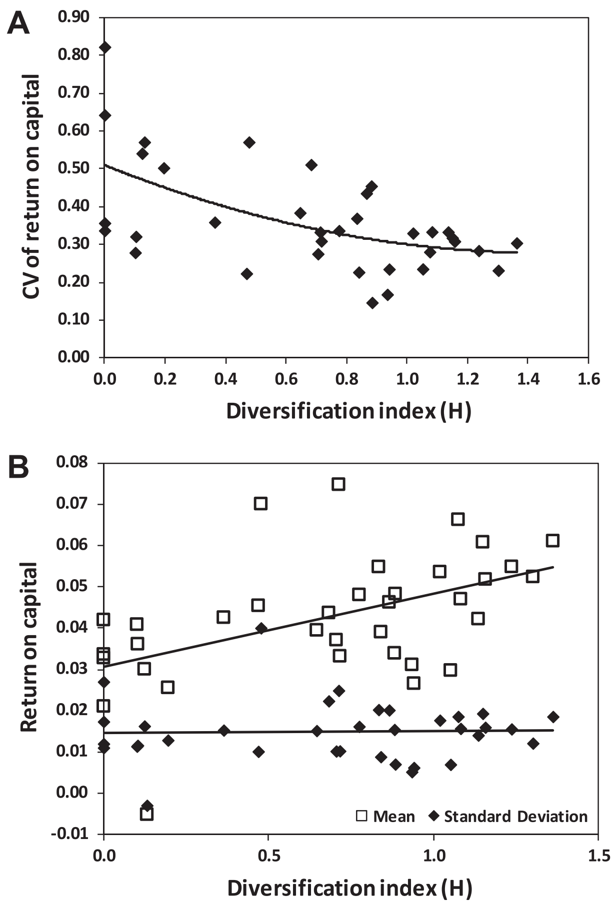

Fig. 1. Relationship between the diversification index (*H*) and the coefficient of variation over time of the return on capital (A) and its components (B): mean (white squares) and standard deviation (black rhombi). The standard deviation is indifferent to more diversification, while the mean tends to increase, with the consequent reduction of CV. The model in 1-A is: $CV = 0.10H^2 - 0.31H + 0.51$; ($n = 35$, $R^2 = 0.33$, $P < 0.0018$). The models in 1-B are: Mean = 0.018H + 0.03; ($n = 35$, $R^2 = 0.24$, $P < 0.0026$); and SD = 0.00037H + 0.015; ($n = 35$, $R^2 = 0.0005$, $P > 0.63$).

operations, whereas as diversification increased a growing proportion of uplands, and thus crops, was added. The lower CV of return on capital in more diverse farming operations was due to higher mean rather than lower standard deviation of return on capital (Fig. 1-B).

Diversification explained just 33% of the variability in the CV of return on capital (Fig. 1-A); a high proportion of the variation remained unexplained, particularly at the lower range of diversification. An important part of the remaining variability of the CV of return on capital was associated with the number of years a farm was member of AACREA and with the proportion of owned land (Table 1, Fig. 2). The number of years within AACREA, possibly a reflection of maturity and technological level of the productive system, was negatively related with the CV of return on capital. The proportion of owned land also was negatively associated with the CV of return on capital and accounted for 33%. No significant association was found between the CV of return on capital and farm size, mean date of the financial cycle or the number of financial cycles analyzed for each farm.

Due to their large dispersion around the model of Fig. 1-A, the farms with a low degree of diversification ($n = 7$) were separately analyzed. The CV of farm return on capital within this group was largely ($R^2 = 54\%$) explained by the CV of total beef production, as both variables were positively related (Fig. 3). Other variables explored, as beef production/ha, beef production costs, beef price, or indirect costs/ha did not explain differences between farms in CV of return on capital.

Table 1
Stepwise regression model of the coefficient of variation over time of return on capital among 35 farms members of the Southwestern AACREA zone, in Southwestern Pampas, Argentina. $R^2 = 0.49$; Adj. $R^2 = 0.44$.

Variable	Coefficient	Std. error	*P*
Intercept	0.79	0.102	0.001
Diversity index	−0.16	0.043	0.001
Land ownership	−0.29	0.109	0.012
Years in AACREA	−0.003	0.002	0.064

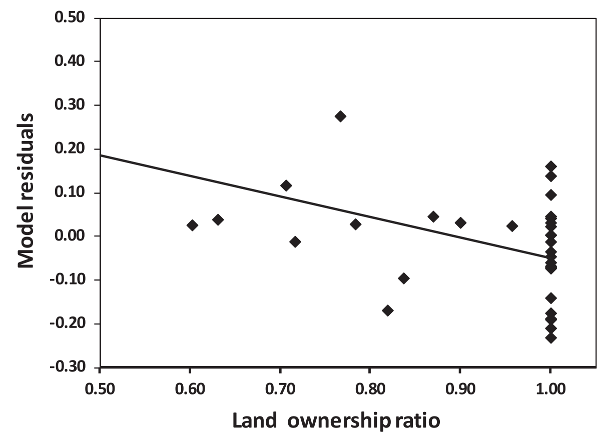

Fig. 2. Relationships between the residual of the function relating coefficient of variability over time of return on capital with the diversification index (*H*), and the proportion of owned land. The model (Land ownership = L) is: model residual = −0.47L + 0.42; ($n = 35$, $R^2 = 0.33$, $P < 0.0003$).

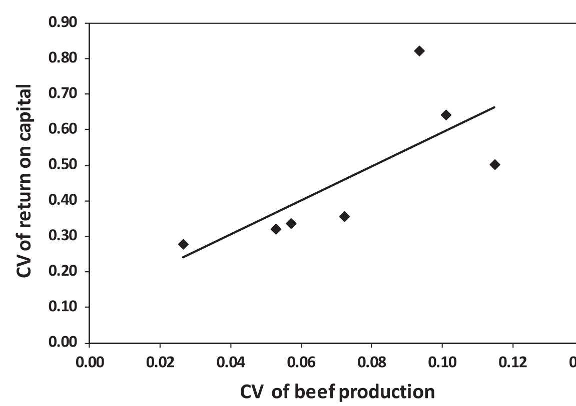

Fig. 3. Relationship between the CV of historical return on capital and the CV of beef production in non-diversified livestock operations. Within no diversified operations, production stability is positively associated with economic stability. The model (where CV Roc = CV of return on capital and CV B = CV of beef production) is: CV Roc = 5.12CV B + 0.09; ($n = 7$, $R^2 = 0.54$, $P < 0.06$).

3.2. Activities and their stability

The coefficient of variation of production differed among activities (Table 2). Across crops, sunflower showed a production less variable than soybean, corn and wheat, in that order. Across livestock activities, cow-calf and birth to slaughter operations were less variable than fattening. This was due to the fact that mean production in a fattening operation was four times greater than in the

Table 2
Productive and economic variables of 82 farms members of the Southwestern AACREA zone (Southwest of Pampas, Argentina) for the 2000–2008 period: coefficient of variation, mean values, and standard deviation. Economic data for different years were transformed to constant currency values (March 2009 Argentine pesos). The number of farms included in each analysis varied among years and ranged between 34–55 for birth to slaughter and fattening, 40–63 for cow-calf, 36–54 for wheat, 30–45 for sunflower, 23–50 for soybean, and 7–38 for corn.

Variable	Type of activity	Activity	CV	Mean	SD
Production (kg/ha)	Livestock	Birth to slaughter	0.045	188	8
		Cow-calf	0.043	155	7
		Fattening	0.113	621	70
	Cropping	Wheat	0.168	2769	465
		Sunflower	0.103	1733	179
		Soybean	0.137	1868	255
		Corn	0.151	4651	704
Product price ($/kg)	Livestock	Birth to slaughter	0.059	2.709	0.159
		Cow-calf	0.032	2.674	0.085
		Fattening	0.107	2.740	0.293
	Cropping	Wheat	0.226	0.441	0.100
		Sunflower	0.175	0.732	0.128
		Soybean	0.148	0.649	0.096
		Corn	0.272	0.348	0.094
Production cost ($/ha)	Livestock	Birth to slaughter	0.173	225	39
		Cow-calf	0.198	155	31
		Fattening	0.251	891	223
	Cropping	Wheat	0.123	549	67
		Sunflower	0.120	566	68
		Soybean	0.125	537	67
		Corn	0.111	799	88
Gross margin ($/ha)	Livestock	Birth to slaughter	0.088	284	25
		Cow-calf	0.130	260	34
		Fattening	0.248	817	203
	Cropping	Wheat	0.196	642	126
		Sunflower	0.282	705	199
		Soybean	0.280	672	188
		Corn	0.310	773	239

other two activities, but its standard deviation was ten times higher. In terms of production, livestock was less variable than any crop.

The coefficient of variation of the product prices also differed among activities (Table 2). Among crops, the CV of the price of oil seeds, sunflower and soybean, was about a third less than that of wheat and maize. Among livestock activities, the CV of the product price in cow-calf operation was a half than in birth to slaughter operation and a 25% of the CV of product prices in fattening operation. This was due to the fact that the average price of the meat produced was similar for all these activities, but the standard deviation was much higher in fattening operations. The variability of livestock production prices was nearly 33% of the variability of crop production prices.

The coefficient of variation of production costs also varied among activities, particularly between crops and livestock (Table 2). Relative variability was similar for all crops, but the average cost per unit area of maize and its absolute variability (standard deviation) were more than 40% higher than for the others. Cost variability was similar between cow-calf and fattening operations and slightly less in the case of birth to slaughter production systems, but the average cost of meat production was 43% higher in a fattening than in a cow-calf operation (Table 2). Crop costs were in general less variable than livestock costs.

Regarding gross margin variation, wheat was less variable than maize and both of them were less variable than sunflower and soybean (Table 2). The average gross margin of maize exceeded by 10–20% the one of the other three crops. Within livestock production, cow-calf operations and birth to slaughter production systems had smaller gross margins per unit area than the fattening operation. The gross margin of birth to slaughter production systems and of cow-calf operations was two to three times less variable than those of the agricultural crops. The margin of the fattening operations was as variable as that of the cropping systems.

The combination of these determinant factors resulted in numerically different mean and interannual variation of return on capital among activities (Table 3). The return on capital of livestock activities was less variable than that of the individual crops. However, the return on capital of the four crops combined in the same proportion as the average farm was as stable as any of the livestock activities. Among livestock activities, the birth to slaughter production system was less variable than each of its components: cow-calf and fattening operations. Cropping activities were 20% more profitable than livestock activities. Among crops, there were few differences in mean return on capital, as the ones with higher average gross margin (Table 2, corn, for example) demanded more capital investment. Among livestock activities, the birth to slaughter production system, with similar mean return on capital as that of cow-calf and fattening operations, was the least variable. The mean and the variability of capital investment

Table 3
Capital investment and return on capital of different activities carried out by 82 farms members of the Southwestern AACREA zone (Southwest of Pampas, Argentina): coefficient of variation, mean values, and standard deviation. Economic data for different years were transformed to constant currency values (March 2009 Argentine pesos). Number of farms per activity and year are as in Table 2.

Activity	Capital ($/ha)			Return on capital		
	CV	Mean	SD	CV	Mean	SD
Livestock						
Birth to slaughter	0.21	6001	1267	0.20	0.0508	0.0103
Cow-calf	0.23	5673	1322	0.24	0.0494	0.0119
Fattening	0.18	16,395	2879	0.26	0.0528	0.0140
Cropping						
Wheat	0.16	11,264	1759	0.37	0.0605	0.0226
Sunflower	0.14	11,026	1495	0.28	0.0627	0.0176
Soybean	0.14	10,994	1540	0.27	0.0603	0.0160
Corn	0.15	11,341	1668	0.24	0.0668	0.0158
Mixed cropping	0.15	11,139	1618	0.22	0.0619	0.0135

Table 4
Farm income and return on capital for the conditions of the 2000–2008 period, for the database average of real farms and nine simulated farms. Economic data for different years were transformed to constant currency values (March 2009 Argentine pesos).

	Return on capital			Farm income		
	Mean	Standard deviation	Coefficient of variation	Mean ($/ha)	Coefficient of variation	Minimum ($/ha)
Database average	0.056	0.012	0.22	312	0.18	208
Fattening	0.052	0.012	0.23	370	0.24	283
Wheat	0.055	0.023	0.41	280	0.26	173
Sunflower	0.057	0.019	0.32	312	0.33	110
Corn	0.062	0.016	0.26	347	0.32	127
Soybean	0.055	0.016	0.30	296	0.34	152
Mixed cropping	0.056	0.014	0.25	298	0.21	190
Mixed cropping, 20% fattening	0.056	0.011	0.19	322	0.20	190
Mixed cropping, 33% fattening	0.055	0.012	0.22	323	0.17	230
Mixed cropping, 50% fattening	0.054	0.012	0.21	335	0.18	244

per unit area were similar for all crops. On the other hand, fattening operations required on average three times more capital than cow- calf operations and birth to slaughter production systems and 50% more than cropping.

3.3. Selection of activities and farm stability

The economic stability of the nine simulated farms and the average of the real farms showed significant numerical differences (Table 4). The variability of return on capital was 30% to 50% lower in the simulated farms whose upland area combined cropping and livestock compared to those with a single crop on all uplands. The combination of activities of the average farm proved very stable, almost as stable as the most stable simulated farms, whose uplands included several combinations of crops and fattening or only fattening. The numerically most unstable simulated farm was the Wheat one (Table 4). In contrast to the variability of return on capital, mean return on capital was very similar for all simulated farms, the highest being the Corn farm (10% higher than the simulated average farm) and the lowest the Fattening farm (7% less than the simulated average farm, Table 4). On the other hand, the standard deviation of return on capital varied markedly between simulated farms. The most unstable farm (Wheat) doubled the standard deviation of the most stable one (Mixed cropping, 20% fattening) (Table 4).

The average farm income per unit area was numerically different among the simulated farms (Table 4). The Corn farm had a 20% higher mean farm income than the other simulations, but had one of the lowest minimum farm incomes. The Soybean farm showed a low and unstable average farm income. The farm devoted to wheat generated the lowest average farm income, but its minimum (173 $/ha) was higher than the minimum of farms with any other crop monoculture in the uplands. The Sunflower one showed a high average farm income, but was unstable and had the lowest minimum farm income. The Fattening farm gave the highest average farm income and was more stable than any crop activity. The simulated farm with the combination of activities in the database average proportion, "Database average", had intermediate farm income and was more stable than any other option. The three different mixed cropping-fattening simulations had similar average farm income and the same stability than the Region average (Table 4).

For the simulated farms, the CV of return on capital decreased with diversification (considering livestock and the four crops as potential activities, Fig. 4). Considering both uplands and lowlands, the relationship was curvilinear: Livestock-only operations with $H = 0$, had a low CV of return on capital. The CV of return on capital reached its maximum value at intermediate H values, corresponding to all cropping monoculture models, and decreased in those schemes that combine several different activities on uplands. The CV of the database average return on capital was similar to the

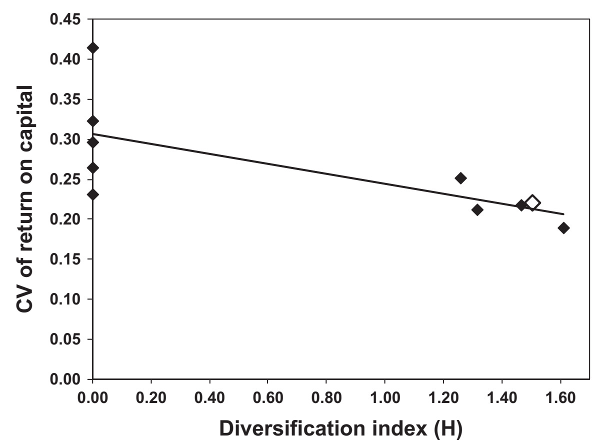

Fig. 4. Relationship between the diversification index (H) and the stability of return on capital over time for soils only suitable for agriculture for simulated farms. White rhombus corresponds to the average of all real farms. The cases with $H = 0$ are the monocultures of each crop and fattening, while the other points correspond to the more diversified simulated farms. The model is: CV roc = −0.06H + 0.30; ($n = 10$, $R^2 = 0.49$, $P < 0.024$).

one of the simulated farms with analogous degree of diversification (Table 4). When the analysis was restricted to the farm area suitable for crops (uplands), excluding the lowlands that can only be used for cow-calf operations, we found a negative association between activity diversification and the CV of return on capital. The CV of return on capital was similar to the simulated database average scenario with similar degree of diversification (Fig. 4).

4. Discussion

4.1. Diversification and return on capital

Three factors associated with farm stability of return on capital over time were identified: diversification of activities, land ownership, and time with systematic technical advice. In relation to the first factor, it has been shown before that diversification increased farm total income (McIntire et al., 1992; Parsons et al., 2011a). This could be related with the complementary nature of animal husbandry and cropping for nutrient recycling (Delve et al., 2001; Holling, 1995) and distribution (Parsons et al., 2011b). However, the relationship between diversification of activities and stability of farm income over time has been less studied, and mostly from a productive point of view, as Roncoli et al. (2001) in Burkina Faso.

From an economic outlook more similar to ours, Herrero et al. (2010) emphasized the buffer role of livestock production in bad years. Villano et al. (2010) found synergism in Australian diversified farms, while Biswas et al. (2006) compared in India economic stability over time of different crop sequences using experimental and estimated data. Recently, with approaches convergent with ours, Bell and Moore (2012) analyzed the risk mitigation effects of diversification of activities in Australia by modeling regional data. Lawes and Kingwell (2012), in Australia's severe droughts, found evidences of better performances in more diversified farms.

In this study, we found that diversification of activities stabilized return on capital by increasing mean return on capital without increasing its deviation, resulting in a smaller coefficient of variation. In our study region, the gradient of farm diversification is also a gradient of landscape heterogeneity. Low-diversity farms are dominated by lowlands devoted entirely to livestock operations. In contrast, farms with uplands imbedded in the matrix of lowlands devote a greater proportion of area to crops, which are more profitable but more unstable than livestock. As expected, more cropping-diversified farms are more profitable, but interestingly the portfolio effect generated by the diverse activities neutralizes the destabilizing effect that could be added by the more variable cropping activities. By raising the average return on capital without altering its standard deviation, these farms have lower coefficient of variation of return on capital.

While this way of economic stabilization through diversification proved useful in the place and time analyzed, it does not rule out other alternatives for improvement, such as focusing in activities not particularly stable but with average returns significantly higher than any current combination.

The variability of return on capital decreased as land ownership increased. The pattern may be explained on the basis of a decrease of fixed costs as land is owned rather than leased. As fixed costs decrease, farm income becomes more stable. Additionally, as a higher proportion of land is owned by the farm, the capital involved is much higher. As farm income and capital are the terms of the ratio used to calculate return on capital, any variation in farm income has a large impact on the return on capital of leased lands.

Regarding the effect of the number of years as member of AACREA, knowledge acquisition and development of working routines likely generated a maturing effect on the farms that made them more effective in problem-solving and in reducing the incidence of environment and market variation. In that sense, Kingwell and Pannell (2005) argued that the complexity of diversified farms in Western Australia required greater entrepreneurial skills or better technical advice. Van Keulen and Schiere (2004) also pointed out that mixed farming systems are complex, which implies a higher management challenge. The wide diversity of return on capital stability in livestock-only farms was linked to the stability of the production as a possible consequence of the above-mentioned maturity of the productive system. In contrast to the findings of other authors (Morrison Paul and Nehring, 2005; Van Keulen and Schiere, 2004), we found no evidence that the loss of economies of scale that brings diversification is reflected in the economic outcome.

4.2. Activities and their stability

Comparing the economic stability of various farming activities and identifying its determinant variables is of great interest to farmers (Bell and Moore, 2012; Helmers et al., 1986; Roberts and Swinton, 1996). Production was more variable for crops than for livestock probably because in the event of unfavorable climate conditions it is easier to find alternative feed for animals than to rescue a rain-fed crop from stress conditions. Additionally, year round livestock production has more chances to compensate for a period of unfavorable conditions than crops. Sunflower had the least variable productivity, probably as a result of its summer drought tolerance (Andrade and Sadras, 2000) in an area where this is common because of low rainfall and shallow soils. Productivity of the fattening operation was more variable than that of the cow-calf operation and the birth to slaughter production system, likely because in unfavorable years, cow-calf operations are prioritized by farmers, who are willing to incur higher costs in order to stabilize calf production (Short, 2001). In contrast, fattening operations had flexibility to opt to sell animals at lower weights rather than incurring in higher costs (Cevger et al., 2003).

The livestock product prices were more stable than crop product prices possibly because in Argentina meat is mainly sold in national currency in the domestic market, while grains are mainly sold in the international market (SIIA MAGyP, 2010), which adds variability due to exchange rate variations. The product price of fattening operations was more variable than the other livestock operations because is affected both by the sale value, which depends on consumer price, and by the procurement cost, which depends on the price of feeder calves. Thus, the production price of fattening suffers from the variability of two markets. Among agricultural products, oilseeds were more stable than cereals, probably because they are mostly exported (SIIA MAGyP, 2010).

An inverse and complementary phenomenon was evident in production costs: livestock production costs were more variable than cropping costs. Livestock production can sustain the level of production in adverse environmental conditions (Short, 2001) through an increase in input costs, while rain-fed cropping has more or less fixed cost *ex ante* and very little chance to adapt to further problems through higher costs. No differences among crops were found.

We confirmed the presumption that livestock operations including cow-calf provide stability not only as one more activity in a diversified portfolio, but also as an activity with high inherent stability. A possible explanation for the slightly more stable wheat crop could be that is largely consumed domestically (SIIA MAGyP, 2010). During years of poor harvest and internal shortage, price variations lead to an income stabilizing mechanism that does not exist for other grains, whose prices will depend on global scarcity or abundance rather than national ones.

The return on capital of birth to slaughter production systems was more stable than its components cow-calf or fattening operations, possibly because some of the interannual costs and revenues variations tend to compensate. Mean return on capital was similar among all crops separately, but variability was lower in mixed-cropping systems. This result is similar to that reported by Di Falco and Perrings (2003) when analyzing a period of 23 years in southern Italy. This pattern suggests that farmers prudently diversify crops obtaining stability without affecting farm income. The relative independence of each crop market and the different timing of their critical periods (Andrade and Sadras, 2000; Di Falco and Perrings, 2003) could have been the reason why it was economically better to have various crops instead of only one. Zentner et al. (2002) arrives at similar conclusions in studies in semi-arid regions of Canada.

4.3. Selection of activities and farm stability

Simulated farms built with the real data for individual activities were also more stable as diversification increased. Livestock-only farms proved very stable despite the lack of diversification, while farms that used the uplands as crop monocultures were very unstable. Farms that combined several crops were more stable than farms that only cropped a single species, in what appears to be another demonstration that the expected portfolio effect really operated in this case. When livestock fattening was added to a combination of several crops, both the mean and the stability of the result were higher. Likely, this positive effect of the addition of fattening comes not only from a simple portfolio effect, but also from the stabilizing effect of a synergism between cow-calf and fattening operations coexisting in the same farm conforming a birth to slaughter system: they absorb the variation of the calf market and are only subjected to the variation of the beef market, which is more stable.

Why farmers do not move to a livestock-only production system instead of implementing such a complex matrix of activities, when they can expect similar return on capital and stability results with livestock as a single activity? The answer may rest in the higher amount of capital (including feeder calves and total costs) required for a livestock operation than for cropping. The data on farm income and return on capital of Table 4 indicate that livestock-only production requires 1440 $/ha more capital (capital = farm income/return on capital) than the average farm to obtain an income just 58 $/ha higher. The marginal return for the required capital for this production model is very low, in the order of 4%/year, lower than the financial market cost of money. Similar arguments have been discussed by Van Keulen and Schiere (2004) analyzing the gradual rediscovery of the benefits of mixed farming under both high and low input systems.

5. Conclusions

In conclusion, we provide evidence for the existence of two different, powerful and non-exclusive tools to reduce the variability of farm income in the studied region: livestock production and diversification of activities. Both seem to be common among present farmers. The combination of activities that resembled the average real farm had a return on capital and stability similar to the best of the proposed hypothetical combinations. The production model followed by these farmers seems to arise from a tradeoff between return on capital, stability, and working capital requirements. This can be interpreted as the result of a successful adaptation to an unstable environment, in which farms have found a survival mechanism in livestock production and the implementation of a complex cropping system with various crops in rotation with pastures. This process is the antithesis of what has happened during the last decades in the parts of the country with more favorable environmental conditions for crops, where livestock production has disappeared and soybean cropping covers more than 70% of total area (Viglizzo et al., 2010).

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