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CLIMATE VARIABILITY AND AGRICULTURAL PRODUCTION IN ARGENTINA: THE ROLE OF RISK-TRANSFER MECHANISMS

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Summary

Research related to climate variability is particularly important in the current conditions faced by Argentine agriculture. These include (a) increased specialization in soybeans, with resulting reduced possibilities of risk-reduction though "portfolio" effects, (b) increased importance of agriculture in "non-traditional" areas, generally characterized by lower yields, higher yield variability and higher production and transport costs, (c) macroeconomic instability resulting in severe contraction and increased interest rates of credit and (d) upward trend in input use and per-acre production costs with consequent increase in break-even crop yields. This paper summarize recent research related to production variability in Argentine agriculture, as well as the consequences of this variability on efficiency and resource allocation and present an overview of strategies for coping with climate variability. We estimate possible benefits to agricultural producers of improved risk-transfer mechanisms. In particular, we obtain estimates of Willingness-to-Pay (WTP) of selected index-type insurance mechanisms for soybean and milk production and outline the requirements for the development of a risk-transfer market for agricultural producers.

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CLIMATE VARIABILITY AND AGRICULTURAL PRODUCTION IN ARGENTINA: THE ROLE OF RISK-TRANSFER MECHANISMS

I. INTRODUCTION AND OBJECTIVES

Argentina is an important producer and exporter of agricultural products. Grain and oilseeds, in particular, constitute the backbone of the counties´ agricultural sector. The fact that most of these crops are planted under dryland conditions implies that production variability is relatively large. For example, research done in the late 1970´s reports coefficients of variation (CV) of Argentine wheat yields of 18 percent, similar to those of Australia, a country well known to suffer important variation in climate. These are substantially higher than those the US (6.7 percent) the EU (6.1 percent) and Canada (10.7 percent) (Anderson, 1979). For corn, yield variations relative to trend are 12 percent in Argentina, as compared to 9 percent in the US.

Additional factors increase production risk in Argentina as compared to other major exporters. In particular, limited development of futures markets result in the Argentine farmer being more exposed to risk than would otherwise be the case. It is in these conditions that risk management practices are of particular relevance.

Recent research (Murphy, 2010) suggests a significant increase in rainfall in selected areas of the *pradera pampeana*. This factor, coupled with the availability of improved production technologies has resulted in a shift in land use from pastures to crops in an important portion of the area. Whether rainfall will fall back to the earlier pattern is a moot point, however some evidence suggests that the impact of climate variability on production systems in Argentina is currently greater than was the case two or three decades ago. The fact that variable input use (in particular fertilizer) has increased dramatically in the last decades puts additional value on alternatives to manage risk and thus stabilize farm net income.[1]

During the last decade a considerable amount of research has been done on the impacts of climate variability and climate change on agricultural production in Argentina and

[1] In the 1990 – 2006 period fertilizer use increased more than ten-fold (Reca, 2010).

neighboring countries (see, e.g. Baethgen, Meinke and Gimenez [2004], Travassso and others [2009], Podestá and others [1999]). Access to meteorological data-bases as well as improved plant-growth modeling have been important factors in this type of research. While agronomic research is a necessary condition for understanding the impact of climate variability, other aspects of the problem also deserve attention: for example, the interaction between the biological and economic aspects in farm-level decision-making, as well as the market-wide impacts of variation in climate.

Producers use a wide array of tactics to cope with production variability. Among others these include diversification in the use of farm and household resources, conservative input levels, drought-tolerant plant varieties, tenancy and sharing arrangements, "wait and see" in technology adoption and the use of selected insurance arrangements. Recent improvements in short- and medium term weather forecasts have also allowed farmers adaptive input allocation. For example, fertilizer use may be profitably increased when a forecast of "adequate" rainfall during the growing period is received. Similar adaptive behavior may involve planting dates, ag-chemical applications and other aspects.

Research related to climate variability is particularly important in the current conditions faced by Argentine agriculture. These include (a) increased specialization in soybeans, with resulting reduced possibilities of risk-reduction though "portfolio" effects, (b) increased importance of agriculture in "non-traditional" areas, generally characterized by lower yields, higher yield variability and higher production and transport costs, (c) macroeconomic instability resulting in severe contraction and increased interest rates of credit and (d) upward trend in input use and per-acre production costs with consequent increase in break-even crop yields.

This paper has the following objectives:

1. Summarize recent research related to production variability in Argentine agriculture, as well as the consequences of this variability on efficiency and resource allocation.

2. Present an overview of strategies for coping with climate variability

3. Estimate possible benefits to agricultural producers of improved risk-transfer mechanisms. In particular estimate Willingness-to-Pay (WTP) of selected index-type insurance mechanisms.

4. Outline the requirements for the development of a risk-transfer market for Argentine agricultural producers.

In recent years, climate variability in agriculture is frequently discussed in the context of the problem of *climate change* (CC). The latter phenomenon refers changes in weather patterns occurring in decades- or centuries-long periods, resulting from human processes and/or the Earth´s natural activity. In this report we will focus on production variability and associated economic risk per-se, in general abstracting from the CC considerations. Our approach emphasizes adaptation to risk in agriculture under "current" (i.e. the next 2 - 3 decades) weather patterns. Possible medium-term (i.e. 5 + decade horizon) scenarios under CC have been the subject of considerable research that will be mentioned only tangentially here, and always in relation to the main focus of our study.

Adaptation to climate variability under "current" (next 2-3 decades) weather patterns appears to be first step for understanding adaptation under alternative CC scenarios. Further, it can be argued focusing on adaptation under present conditions will help "put on the agenda" important research necessary for understanding longer-term adjustments (in relation to this topic see e.g. Washington *et al*., 2006).

II. CLIMATE VARIABILITY AND AGRICULTURAL PRODUCTION

II.1 Overview

Agricultural modernization has resulted in higher output per unit of land. In many cases, the ratio between output and an index of all inputs ("Total Factor Productivity") has also increased. However, recent research has shown that in some important production areas increases in productivity have been accompanied by increases in vulnerability to variations in weather conditions. For example, in the U.S. Midwest corn and soybean yields (1995-2012) period show growing sensitivity to drought as well as to temperature-induced stress. These changes have occurred despite improvements in agronomic practices and crop yield potential (Lobell *et.al.*, 2014). Higher planting density observed in many crops, as well as increased use of nitrogen fertilizer has resulted in larger output variability: under "favorable" conditions output response to input use is large, but if conditions are "unfavorable" output response is small or even negative. Increased output variability resulting from higher input use, coupled with higher per-hectare costs result in substantial increase in financial risk.

Anderson (1979) provides an early but still important review of the issues related to the impacts of climatic variability on Australian agriculture, a country characterized by mostly dryland agriculture, subject to frequent water stress induced by low-rainfall conditions. As shown by Anderson (p.160) Argentine, Australian and the ex-URSS variability of wheat yields (measured as CV) are similar (0.16 – 0.17) but considerably higher than other important producing countries (0.06-0.07 for the U.S. and the EU, and 0.10 for Canada). Anderson focuses not only on variability per-se, but on the economic consequences of variability both at the micro (farm) as well as macro (economy-wide) levels. Significant aspects to be taken into account for understanding the impacts of risk on agriculture include:

1. The impact of variability on the well-being of farmers and farm communities. This "behavioral" aspect is poorly understood, as individual response to variability depends on variables such as net wealth, possibilities of "income smoothing" through credit markets and other aspects.

2. The possibility of adapting i.e. of changing resource use patterns and thus stochastic distribution of results in response to perceived future climatic conditions. Forecast time horizon, forecast accuracy, as well as possibilities for resource re-allocation in response to forecast signals determine the economic value of climate predictions.

At least two approaches can be used to study the impact of climate variability on agriculture. The first is based on historical data: in general, if output is considered a function of a vector of decision inputs ($\boldsymbol{x}$ = land, labor, fertilizer) and time ($\boldsymbol{t}$): $y = g(\boldsymbol{x}, t)$ variability may be estimated comparing actual output in a given year (y_t) with predicted output given function $g(.)$ above. Note that variability thus defined requires an estimate of the functional relationship between non-random inputs $\boldsymbol{x}$ and $\boldsymbol{t}$ and output y.

An alternative (and complementary) approach is to use crop-growth models. Once calibrated, models such as CERES provide a powerful tool to analyze the impact of climate variability: output predictions may be obtained for a range of input values of both random climates as well controlled input variables. Crop models can thus adumbrate not only on "how much" crop output will vary, but on alternative management alternatives (e.g. fertilizer levels, planting dates, crop variety) to cope with climate scenarios (for a review of issues related to crop models see Challinor *et al*., 2009).

The impact of climate variability on output will be a function of (a) how "large" is the variation in relevant climate variables (temperature, rainfall) and (b) the nature of the response function of crop (or animal) production to changing climate input variables. In particular, convexity of the response function to variable climate will in general result in output under "average" climate conditions being higher *than the average* of the output of "unfavorable" and “favorable” conditions. In symbols, let O(U), O(F) and O(A) be respectively output under “unfavorable”, “favorable” and “average” climate conditions where A = ½ U + ½ F. Then, convexity of the response function results in: O (A) > [½ O (U) + ½ O (F)]. In practical terms this implies that (neglecting the possibility of adaptation) inter-annual variation in (say) rainfall will result in reduced welfare for producers because fall in output in “below average” rainfall years is not outweighed by increases in output in “above average” years. [2]

II.2 Changes in Argentine agriculture

During the last half-century grain crop production (the most important activity) expanded from less than 15 million hectares in the early 1970’s to more than 30 million hectares in 2010. In the same period, the index of crop output increased six-fold. Argentine agriculture can be divided into two main sectors: the *region pampeana* (RP) and the *region extra-pampeana* (REP). The first represents some 80 percent of total output and takes place mostly under rainfall conditions. Corn, wheat, sunflower and (particularly) soybeans are the most important crop activities. The region also accounts for more than 85 percent of beef and milk production of the country. Production risk in this large area is caused, in particular, by variability in both quantity as well as timeliness of rainfall: land productivity though high is frequently constrained by deficit in critical crop stages. Murphy (2010) reports more than 50 – 60 percent probability of (December) drought in the central crop production area of the *pradera pampeana*, in the more “marginal” areas of the west-south-west probability of drought increases to 80 – 90 percent. Clearly, rainfall variability has an important impact on crop production, in particular those crops with critical water demands in the late spring-early summer (corn, soybeans and sunflower).

Variability of rainfall is an important but not the only cause of production risk. Hail damage is also relevant, in particular in some localized areas of the provinces of Buenos Aires and Córdoba. Hail frequencies of 0.8 – 1.2 days/year (Murphy, 2010) do not appear (to the “non

[2] Observe that in “marginal” environments output response to climate variables may be of a non-convex type (i.e. increasing marginal response to rainfall or temperature). If this is the case, O(A) < [½ O(U) + ½ O(F)], thus variability around the mean is desirable.

specialist" at least) high; however if the hail event occurs during a critical crop period considerable (or total) damage may occur. The fact that practically all agricultural insurance in Argentina revolves around coverage for hail damage attests to the importance of this source of uncertainty. Late and early frosts, winds, excess moisture (in particular at harvest time) are additional random events affecting production variability.

The production specialization of Argentine agriculture has changed markedly during the last decades. In the early 1980´s soybean represented less than 20 percent of planted area, in 2009 it accounts for more than 60 percent. The shift towards an increasingly "soybean dependent" production system suggests that unforeseen events affecting this crop could have serious consequences on agricultural output. For example, soybean rust outbreaks ("roya de la soja") are an additional factor determining yield variability.[3] Indeed, although the threat posed by a rust outbreak may be countered by the use of fungicides, this results in increased costs for the farmer. As such, it is equivalent to a reduction in output caused, for example, by hail or drought.

As reported by Parellada in the REP grain and oilseed production has grown from 1 million hectares in 1987/1988 to 3.9 million hectares in 2007/2008 (cereals = 1 million, oilseeds = 2.9 million). This region thus account for some 13 – 15 percent of grain and oilseed production of the country. Production variability of dryland crops in the REP is greater than in the RP. For example, coefficient of variation (CV) of soybean yields in the province of Buenos Aires is 14 percent, versus 22 percent in Chaco. Relatively high CV´s exist also for cotton in Chaco (17 percent) and dry beans in Salta (20 percent).[4] The fact that average yields are generally lower in the REP as compared to the RP is an additional factor to be considered: two regions with "similar" yield variability (as measured by yield CV´s) may nevertheless pose different financial risks if one has lower average land productivity than the other.

[3]See e.g. Begenisic, Plopper and Ivancovich (2004)

[4] Standard Deviations used to compute CV´s were calculated from the sum of squared residuals around trend-corrected yields.

Growth in planted area has resulted from a shift from pastures to crops both in the RP as well as in the REP areas. In the case of soybeans area in the REP represented less than 1 percent of total soybean area in the early 1970´s, increasing to more than 20 percent of national area in 2010 - a substantial shift in resource use. In general crop production in “newer” areas is subject to higher production risk, not necessarily because production variability per-se is higher(as measured, for example b*y* yield σ or yield CV), but because, in general average yields are lower or production costs are higher due to increased distance to markets or other considerations.

II.3 Variability in Argentine grain production

Despite the importance of the topic, not much is known about variability of Argentine agricultural production. At the aggregate level, the recent (2008/09) crop shortfall illustrates the possible magnitude of inter-annual variation in yields: the yield index of the four main crops (corn, wheat, sunflower and soybeans) fell more than 30 percent (2008/2009 yield with respect to average of five previous crop years). Percentage fall in export volume was of course even greater. Partially as a result of this shortfall, harvester and no-till planter sales fell by respectively 60, 70 and 70 percent (Agromercado, February 2010).

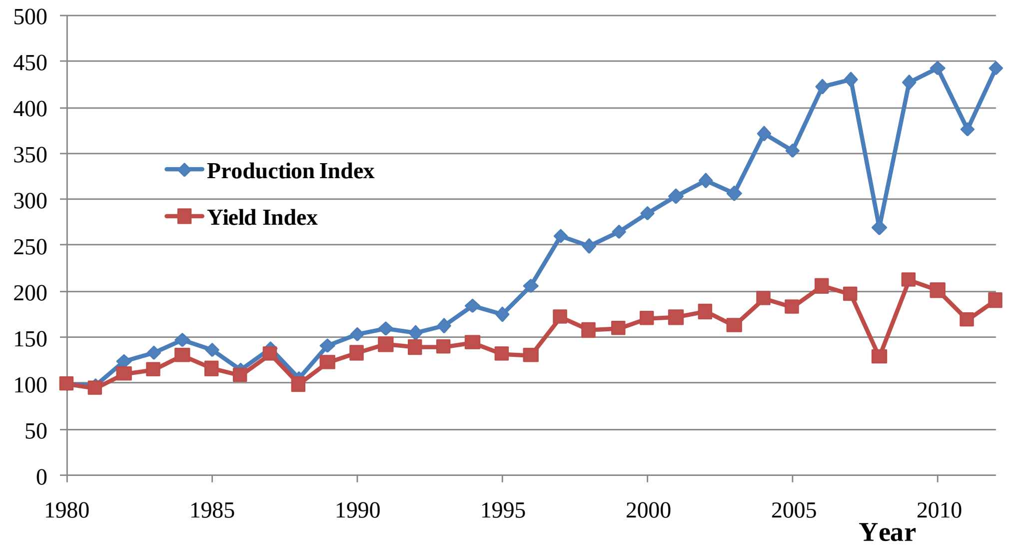
The extent to which production is affected by (random) climatic events varies across production regions and crops. Other factors are also important. For example, the increased use of fertilizer inputs which occurred in Argentina since the late 1980`s results in output increases that are contingent upon growing season conditions: in “above average” conditions output response to additional fertilizer inputs will be greater than when drought or other events result in low crop yields. Yield variability is therefore greater under higher as compared to lower fertilizer input use.[5] This higher yield variability, coupled with higher (per hectare) costs results in increased financial exposure.

Figure II.1 shows a (price - weighted) index of output and yields for the four major crops produced in Argentina (wheat, maize, sunflowers and soybeans). Variability analyzed

[5]Formally, if V(Y) is variance of yields per unit of land area and x is variable input use, dV(y)/dx >0.

here corresponds to a crop mix, and not to a single crop. While this index underestimates variability for individual production activities, it is a "reasonable" proxy of variability: most producers (and the country as a whole) diversify, and the relevant measure of "risk" is variability of the whole production portfolio and not that of a single crop.

Figure II.1
Production and Yield Indexes (1980 = 100)
(Maize, Wheat, Sunflower and Soybeans)



As shown, in the more than 3 decades included in the series, one crop year (2008/9) shows a "very significant" (30 – 40 percent) drop in output, in this case due to generalized water stress. [6]The next important output shortfall occurs in 2011 (15 percent reduction in output). The rest of the series shows approximately 6 years with small (< 10 percent) output drops. If this 33-year long period can be considered a representative sample of what can be expected in the next two decades or so, "large" (> 15 percent) output drops would appear to have a probability of occurrence of less than 10 percent (2/33). Output drops in the "moderate" category (< 10 percent) appear to occur in 6 of the 33 years, than is with a probability of some 20 percent (6/33). Thus, output drops including and above the "moderate" class occur in ¼ of all years.

[6]In all cases we refer to "drops" as output shortfalls from the rough-and-ready "trend" adjusted by eye to the data points.

Of course, a “big if” in the above is whether the 33-year period considered here is “representative” of what can happen in the next few decades. An important “warning sign” to be taken into account is the production variability appears to have increased in the last as compared to the first decade of the period included in the figure.

Data discussed above refer to country-wide production variability. A disaggregated analysis focusing on specific production areas allows additional insights. A first approximation to the impact of climatic variability can be obtained by focusing on grain production in the *pradera pampeana* region which accounts for a significant portion for total agricultural output of the country. Table II.1 reports an index of output variability for different *partidos* of this region. Reported variability corresponds to a constant price-weighted yield measure of the principal grain crops.

Table II.1: Production Variability - *Pradera Pampeana*							
Risk Area	**Output CV (%)**	**"Partidos"**		**Crop Area (2008-2009)**		**Average Product of Land (t/ha)**	**Representative "partidos"**
		Number	**%**	**Hectares**	**%**		
VI	> 50	2	1.3	0	0.2	1.1	Bahía Blanca (Bs As)
V	40 - 49	6	3.8	0	2.0	2.1	Puan and Tornquist (Bs As)
IV	30 - 39	14	9.0	0	2.6	2.4	Villarino (Bs As), 9 de Julio and Vera (Sta Fe)
III	20 - 29	55	35.3	0	30.9	3.3	Concordia, Villaguay and Federal (Entre Rios) Dolores and Rauch (Bs As), San Justo (Sta Fe)
II	10 - 19	75	48.1	0	55.0	3.8	Azul, Rojas, 9 de Julio, Chacabuco and Junin (Bs As) Tercero Arriba and La Capital (Cba), Castelllanos (Sta Fe)
I	< 10	4	2.6	0	9.4	4.6	General Alvarado (Bs As), General Lopez (Sta Fe)
	TOTAL:	156	100.0	0	100.0		

Source: own calculations

As shown, production risk varies widely across areas. In an important portion of the *pradera*, variability is quite low: in risk areas I and II outputs CV's are not greater than 20 percent. As a rough simplification, in this area risk is probably not a significant problem as land productivity is high and production variability low. This area represents approximately 2/3 of total area of the *pradera pampeana* region, and one-half of total area planted to grain in the country.[7]Risk-prone areas in Argentina are thus represented by areas III to VI (some 8 million hectares planted to grain, or 35 percent of the total of this region). To this must be added the area planted outside the *pradera pampeana.* Thus, of the 28 million hectares planted to grain in the country, some 45 percent deserve particular attention as relates to production risk, the remaining 55 percent characterized by yields well above variable costs of production, and by relatively low yield variability.

Estimates presented above are based on aggregate (*partido*) yields. However, a relevant question to be asked is how much higher variability is *at the farm* as compared to *partido* level. In an early paper Eisgruber and Schuman (1963) analyze the relationship between aggregate (e.g. or "county" level) yields and farm-level yields. For the central US corn belt the authors´ report standard deviation (SD) of soybean yields at the farm level are more than twice those at the aggregate (county) level. Similar results obtain for corn and wheat. This issue has considerable importance both for understanding risk faced by the individual farmer, as well as for designing insurance contrasts based on farm- of aggregate-level yields.

A typical *partido* includes several hundred farms and thousands of hectares of land in crop production. If Q_j represents output of the j-th partido, and q_{ij} represents output of the i-th farm in this *partido*:

$$(1) E(Q_j) = E(q_{1j}+q_{2j} \dots + q_{nj}) = E(q_{1j})+\mathrm{E}(q_{2j}) \dots + E(q_{nj})$$

Where "n" is the number of farms in the *partido*. Variance of *partido* output is then:

[7]In the 2008/2009 crop year, total area planted to these crops was 28 million hectares.

$$(2) V(Q_j) = V(q_{1j} + q_{2j} \ldots + q_{nj})$$

We are interested in deriving $V(q_{ij})$ from the available information: $V(Q_i)$. Simplifying assumptions are necessary in order to make some progress. We assume: (1) $V(q_{ij}) = V(q_{kj})$ for all i and k and (2) $E(q_{ij}) = E(q_{kj})$ for all i and k, i.e. all farms in the partido are identical and (3) a single correlation coefficient ρ between yields of all possible pairs of farms in the partido. These assumptions are useful as a starting point in order to get a grasp of possible values of $V(q_{ij})$ given $V(Q_j)$. If a *partido* contains "n" identical farms:

$$(3) V(Q_j) = \sum_{i=1}^{n} V(q_{ij}) + \sum_{i=1}^{n-1} \sum_{k=i+1}^{n} 2\rho \left[V(q_{ij}) V(q_{kj})\right]^{1/2}$$

or (assuming all farms have identical production variances):

$$(4) V(Q_j) = nV(q_j) + \rho V(q_j) n(n-1) = nV(q_j)(1 - \rho(n-1))$$

The variance of output per farm is $V(Q_j/n) = (1/n)^2 V(Q_j)$:

$$(5) V\left(\frac{Q_j}{n}\right) = \frac{V(q_j)}{n} + \rho V(q_j)(n-1)/n$$

For "large" enough n (e.g. n > 300):

$$(6) V\left(\frac{Q_j}{n}\right) = \frac{V(q)}{n} + \rho V(q_j) = V(q_j)(\frac{1}{n} + \rho)$$

Or approximately $V(Q_j/n) = V(q_j)\ \rho$. Thus for a farm belonging to the j-th partido, $V(q_j) = V(Qj/n)/\rho$. Standard deviation of farm-level yields thus results $SD(q_j) = SD(Q_j)/\rho^{1/2}$

As a first approximation we can assume $\rho = 0.7$. Column these conditions CV´s reported in Table II.1 should be adjusted upwards by a factor of 1.4 (1.42 = 1/.7). Note that even with this adjustment, output variability (as measured by yield CVs) of regions I and II remain well below 30 percent. In these areas, the probability of farm income falling below variable production costs (excluding land rent) is extremely low: for example, “direct costs” (excluding land rent but including harvest) for planting soybeans in regions I and II average (as of mid 2014) some US$ 400 per hectare, only a substantial crop failure would result in these costs not being covered.

Of course, the probability of not covering costs greatly increases if land rent is included in costs. However, the value farmers pay for land is “endogenous” depending on profit expectations, and including discounts for the risks involved in the investment of funds. The high values of rent that are paid for the use of agricultural land in most regions of Argentina indeed attests to potential profits to be earned, and also to the existence of (often subtle) risk management and risk-transfer possibilities.

II.4 Adjustment to climatic variability

As pointed out more than half a century ago by Heady (1952) adjustment of the farm-firm to production uncertainty may take many forms. Some of these involve tradeoffs between income or costs and risk. Diversification, limits on farm size, over-investment in machinery, the use of “general” as opposed to “specialized” equipment, drought-resistant (but lower-yielding varieties), “wait and see” in technology adoption, allocation of labor to non-farm enterprises may all result in increased security of income, but at the cost of lower overall efficiency. Risk may also be transferred using insurance. Insurance may not have an impact on production, but may nevertheless be desirable as it allows households to better match income with consumption patterns.

The impacts of climatic variability may be roughly classified in the following categories:

1. Output-reducing. Shortfalls in production from "average" conditions result in direct economic loss. For example, the 2008/9 drought than occurred in Argentina resulted in a lost output of some 30 million tons of grain, for a total of approximately 12.000 million US$. The relevant issue, however, is not the absolute magnitude of this loss, but what measures (if any) could have been taken in order to reduce the loss incurred. Of course, costs and potential benefits of these measures have to be taken into account.

2. Errors in resource allocation. Climate variability results in losses due to input miss-allocation. This miss-allocation can be estimated as the difference in profits resulting from a "perfect foresight" input allocation (i.e. input allocation that maximizes profits given the climate conditions that ultimately prevailed) and the "actual" input allocation (allocation decided before growing-season climate conditions were known). Errors in forecasting climate conditions result in an economic loss proportional to: (i) the magnitude of the forecast error and (ii) the extent to which profits fall when input use deviates from the "optimal" (perfect foresight) level.

3. Profit loss due to risk aversion: If farmers are risk-averse, resource allocation will not maximize profits, but "expected utility" of profits (see e.g. Anderson, Dillon and Hardaker, 1977). Maximization of utility may result in diversification, lower (or in some cases higher) than profit-maximizing input use, risk-transfer through insurance or other mechanisms. Utility maximization is optimal at the individual level, however it implies (at the aggregate) loss of net output. This loss of output is an additional cost (to society) of climate variability.

In relation to item (3) above an important question to be answered is the extent to which risk aversion affects resource allocation at the farm level. The "traditional" view of risk in the agricultural economics literature of 1950´s, 60´s and 70¨s was associated with production and price variability at the farm level (for a summary as of the mid-1970´s see e.g. Anderson, Dillon and Hardaker, 1977).

However, research in finance carried out since the 1960´s (in particular, that resulting from capital-asset pricing models) change somewhat the "traditional" view held by agricultural economist on this topic. In particular, it is now accepted that investor risk depends on co-variation in returns between the "market" portfolio and returns in a given investment project. *Thus, farm production may be "risky" for an investor not having outside opportunities, but may be "safe" for one with a diversified portfolio if farm profits are weakly correlated with non-farm asset returns*. This has important implications for the agricultural sector: the extent toich risk is an issue depends on the extent to which investment capital can flow – in response to differential in returns - from the non-agricultural to the agricultural sector.

The "permanent income" concept can be used to shed additional light on this issue. If farm households can borrow against future income streams, output shortfalls should not necessarily have an impact in any given time period.

A simple model showing an "intertemporal budget constraint" makes this clear. In particular, farm production results in period *t* in an income ofI_t. Consumption in the period is C_t. The budget constraint faced by the household is:

$$(14) \sum_{t=1}^{n} \frac{I_t}{(1+r)^t} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t}$$

Due to production variability, income streams I_t are random. However, of this production variability does not necessarily affect the *present value of consumption*: in a "bad" year ($I_t<C_t$) borrowing is used to supplement farm income in order for desired consumption to be achieved. The above holds even if the household is "risk averse": in an inter-temporal

framework, risk is not an issue as it does not affect consumption patterns: as mentioned, lower than expected income in a given period triggers borrowing in order to align income to desired consumption. Production decisions can be expected in this case to lead to maximization of the present value of income streams, as this allows maximum present value of consumption streams.

Of course, the above assumes the existence of a "perfect" capital market for borrowing (and saving). If borrowing is not possible, or if a sharply increasing supply of funds schedule exists for the household, "risk mitigation" measures will be put into place. These mitigation measures will, in general, result in a reduction in the present value of income and thus of consumption streams. Risk-management strategies are now necessary.

But it also can be pointed out that if borrowing for a given household is limited, but that land, labor and capital services markets operate efficiently, income shortfalls from production can be made up by selling labor, land and capital service inputs in the market.

For example, a small farmer faced with a drought can for example rent his land and capital inputs (providing machinery services) to another producer. In practice this will be easier the more integrated the agricultural production sector in a given area is with producers in other areas and with financial and managerial resources in other sectors of the economy.

"Risk" is therefore a problem in direct proportion to the extent to which financial, land, labor and capital input markets operate with frictions. These considerations deserve of course more rigorous formalization; however they point out that income variability per-se may be less of a problem than superficial examination suggests.

II.5 Longer-term perspective: Climate Change (CC) impacts on production risk

The focus of this report is on insurance and risk management in the "short-run" (i.e. private management and public policies alternatives for the next 5 – 10 years). CC, in contrast, relates to changes in distribution of climate variables (rainfall, temperature, wind) over several decades, centuries or longer periods. This section includes a brief description of issues related to the possible impact of CC on agriculture in the area under study.

While the issue of CC is certainly important for agricultural and general environmental policy, it has been argued that the impact of CC on agriculture, at least up to the middle of the XXIst century is likely to be minor (Crosson, 1997). In fact, CC may benefit agriculture in developed economies, and have a very small impact on those of the developing world. "Small" is interpreted here in relation to other problems such as environmental degradation or slow productivity gains resulting from insufficient investment in R&D (Crosson, p.7).

The "optimistic" above scenario is not shared by all. Other papers (e.g. Adams and others, 1998) point out that increases in temperature will have negative effects in many areas. Increases in CO2 or precipitation levels, by contrast, will have positive effects. Impact of CC remains in part speculative because of the difficulty of predicting response not only of farmers but also of providers of new technology for farmers. For example, biotechnology may negate or even take advantage of apparently negative CC impacts. Furthermore, and as pointed out by Adams, reductions in supply caused by CC may increase incomes of farmers: inelastic demand for agricultural products results in a higher "price times quantity" when less is produced at each price. For Argentine farmers, CC even when reducing domestic growth rates of production, may well have a positive effect if world prices rise sufficiently so as to offset this lower growth in output.

A comprehensive analysis of the impact of CC on US agriculture concludes that "over the next 100 years and beyond, human-induced climate change is unlikely to seriously imperil aggregate food and fiber production in the US, nor will it greatly increase aggregate cost of agricultural production" (Reilly and others, 2001). However regional effects are to be expected. In general, northern (cooler) areas will benefit, and those to the south will lose. This finding is in general agreement with the papers by Crosson and Adams mentioned previously.

Podestá and others (2009) analyze the impact of relatively "short-run" (i.e. 25 years from the present) climate trends in two localities of the Argentine *pampa* region. Their focus is not on CC proper, but on the possible impact of reduction in precipitation following the apparent increase that has occurred since the 1960's. The two localities analyzed in their study (Pergamino, in the province of Buenos Aires and Pilar in Córdoba) correspond respectively to the highly productive and "drier" regions of the *pampas*. They find evidence of increasing (over the next 25 years) probability of negative production incomes in the latter, and no change (or very small change) in the former. Of particular importance is the analysis performed on the impact of farmer adaptation to changing weather patterns. In particular, the authors find that in Pergamino (the highly productive, "low risk" area) difference in returns between the "no adaptation" and the "clairvoyant" or "instant adaptation" strategies is low. In contrast, in Pilar (higher risk, lower productivity) differences in farmer adaptability result in large differences increase substantially.

Previous results have significant implications for agricultural research in general, and for farm management in particular. Increased returns to "adaptive ability" in response to changing climate may result, for example, in lower-educated farmers, or farmers with limited access to management and technical know-how losing ground to farmers better endowed with these decision-making inputs. One consequence could be a trend toward larger and more "professionally" managed farms in response to increased demand for decision-making abilities: as pointed out by Schultz the "ability to deal with disequilibrium" will be particularly important under changing, as opposed to static conditions (Schultz, 1975).

A topic of considerable importance in relation to risk management is the possibility of predicting – even approximately - climate patterns 3-4 months in advance. The well-known "Niño/Niña" phenomenon links ocean circulation in the South Pacific with weather patterns in surrounding continents. Research has shown (e.g. Podestá and others, 1999; Fraisse and others, 2008) that "Niño" and "Niña" years are associated with above and below average precipitation levels in eastern South America. The impact of "Niño" effects is larger for corn and sorghum than for soybeans and sunflower. Wheat (a winter crop) appears to be unaffected by these phenomena. In the case of soybeans, below-average rainfall reduces, but above-average rainfall does not increase yields.

The fact that “leading indicators” relative to Niño/Niña events can be obtained in late winter/early spring (before the plantings of most summer crops) has the potential for allowing certain degree of “fine tuning” in crop management. For example, if an “above-average” rainfall pattern is expected, fertilizer levels may be increased in order to make the most of improved conditions.

III. <u>THE CASE OF SOYBEANS AND DAIRY</u>

We focus attention here on two important activities. For crop production we choose soybeans, by far the most important crop en terms of value of production and export contribution. In turn, dairy farming is chosen as a case-study for the animal sector. This activity is the second most important of the livestock sector, accounting for some 3.000 - 3.500 million dollars annual output (this represents approximately half of the output value of the beef sector). Second, climate variation has possibly a greater impact on dairy than on beef production: excess rainfall and temperatures in particular have a significant impact on the productivity of the dairy herd.

III.1 Soybeans

A. General

Soybean yield potential in Argentina is conditioned by rainfall patterns occurring during the crop cycle. In general, a “water deficit” condition occurs during late spring and summer, thus limiting yields. In the case of Argentina estimates presented by Murphy (2010) indicate a 50 – 60 percent probability of drought (December) in the central production area, increasing to percent more than 80-90 percent in the more “marginal” areas of the west and southwest of the *pradera pampeana*. Notwithstanding the above, the relation between rainfall and crop yields is far from clear. Aspects such as water retention capacity of the soil, water storage prior to planting, distribution of rainfall during the crop season, as well as temperature play a significant part. Excess rainfall in particular during the harvest period may have an important negative impact on output. Lastly, some weather conditions may result in increased losses due to plant disease: soybean rust is an important example of these (Begenicich, Plopper and Ivancovich, 2004). Potential damage from disease implies that is some cases a moderate water deficit may result in higher yields than when no deficit occurs, but when diseases are present (Andrade and Sadras, 2000). Note that although diseases may be controlled by the use of fungicides, this does not eliminate risk as control is done at a cost and thus reduces (in comparison with the no disease benchmark) farm profits.

The impact of climatic variability agricultural production in Argentina has been subject to considerable attention by crop physiologists and agronomists (see in particular Calviño, Andrade and Sadras, 2003, Caviglia, Sadras and Andrade 2004, Andrade and Sadras, 2000, Baethgen, Meinke and Gimenez, 2004). A full review of this and related work will not be attempted here. However, this literature is clearly important for understanding risk-management decisions by farmers.

As relates to soybeans, several conclusions emerge. First this crop is considerably less susceptible to short periods of water deficit than corn. Second, the critical period for soybeans occurs (in the *pradera pampeana*) in February, when probability of water deficit is somewhat lower than mid-December, the critical period for corn. Thus, risk of yield loss is lower for soybeans than corn. Third, evidence suggests that farmers may reduce their exposure to weather risk by choosing planting dates, crop varieties, cropping systems and other aspects. The exposure to risk, it should also be noted, may vary considerably from one farm to another due to variations in soil depth – and thus capacity to store water.

Peñalba, Bettoli and Vargas (2007) analyze soybean yield variability in 58 departments of the main production area of Argentina (1973-1999). Variations in yields and in seasonal rainfall were calculated as differences from linear trend, standardized by dividing by the standard deviation of the series (resulting thus in "z-values"). As expected, both yield levels as well as yield variability change across geographical locations. The authors are able to graph iso-yield and iso-variability contours that show maximum yields and minimum variability in the traditional "North of Buenos Aires -South of Santa Fé" (NBA-SSFe) area, with yields decreasing and variability increasing when moving to west through north. For example, in the

27-year period (1973-1999) yield reductions greater than 1 SD occurred 5 times in Marcos Juarez and 6 times in Rosario. It is important to note that these yield variations refer to aggregate department yields, and as discussed previously yield variation at the farm level can be expected to be considerably larger. In summarizing their results, the authors conclude that:

> In general, a higher maximum temperature during summer months and rainfall excesses in the maturity harvest-period normally result in lower yield, while a higher minimum temperature during the growing season increase soybean yield (…) the crop's negative dependence on atmospheric humidity is shown significantly during summer months at stations located in the north. The most significant spatial coherence with the yield was shown by seasonal precipitation, which can be considered a proper yield indicator (Peñalba and others, p. 12).

Crop modeling has been used to study farm-level yields, and in particular the impact of management practices on both yield levels as well as variability in response to changing random factors. For example, Mercau and others (2007) use the CROPGRO-soybean model to predict farm-level soybean yields in the Argentine *pampa* region. Most importantly, model results were validated using extensive farm-level data produced by the CREA groups. Farm-level production risk derived from their model shows (p.207) a Cumulative Density Funcion (CDF) for the locality of Oliveros (Cordoba). The 0.16 and 0.84 fractiles (corresponding respectively to the mean yields minus/plus one SD of yields) are approximately 2750 and 5250 kg/ha. This results in a SD of 1250 kg/ha. or 31 percent of the "mean" yield of 4000 kg/ha. As way of comparison, results obtained by Gallacher in (2011) from subjective evaluations of soybean yield variation show considerably greater yield CV (these range from 40 to 56 percent). These higher yield CV's are probably a result of farmer estimates of "most probable" yields (1900 – 2300 kg/ha) being much lower than the 4000 kg/ha resulting from the soybean CROPGRO model.

Other studies (e.g. Andrade and Sadras, 2000, Aiken, Lamm and Aboukheira, 2011) confirm the general results presented previously. In general “yield response” to water use is linear over a wide range of values of water use, yield increasing some 8 – 10 kg/ha additional mm of water use of the crop. An additional 100 mm of rainfall occurring during the growing season would therefore result in an additional 800 – 1000 kg of grain per hectare.

B. Response to growing-season rainfall

Partido level data allows estimation of the linkages between yield and rainfall. A Cobb-Douglas production function provides a starting point for analyzing this issue:

$$(10) y_{it} = A e^{\gamma t + \sum \alpha_j d_j} \prod_{i}^{n} x_i^{\beta_i}$$

Were y_{it} is the yield of the *i*-th *partido* in period *t*, the x_i ´s are growing season rainfall inputs, d_i´s production-area specific dummies and *t* in a time trend. α, β and γ are parameters to be estimated.

A data set of 28*partidos* of the *pradera pampeana*, spanning 31 crop years (for some partidos fewer years are available) was used for estimation. The dependent variable is soybean yield in kg/hectare. Independent variables include partido-specific dummies. These capture site-specific differences between. Three regression results are presented: (a) the whole dataset, (b) the “North” (traditional soybean and maize producing areas) and (c) the “south”(south-east, south and south west of the province of Buenos Aires). Independent variables also include rainfall in four monthly periods. These are chosen so as to coincide with “critical” period for the crop. For most *partidos* these correspond to December, January, February and March, for a smaller subset the months are January, February, March and April.[8]

Table III.1 reports regression results. All rainfall variables for the first three periods are significant (p = .10), the rainfall variable of the last period (generally corresponding to pre-harvest or harvest time) is not significant at p = 0.10 but has a positive sign. Given the logarithmic form used, parameter estimates for rainfall variables are interpreted as partial elasticity: i.e. the percentage increase in output resulting from a 1-percent increase in rainfall. Result show that December rainfall has the highest impact on output: for the whole dataset, the elasticity value is 0.14. This implies that an increase in rainfall from (say) 80 to 120 mm (50 percent increase) would increase output from a "base" of 3 t/ha to 3.2 t/ha. If rainfall in the 3-period considered here increases by one percent, output will increase by approximately 0.32 percent.

When predicted values from the model are compared with actual yield values it is apparent that the regression model does a poor job in predicting both "very bad" as well as "very good" years. Further, the predictive accuracy varies according to production area (even though zone-specific dummies were included in the model). For example, the model mimics yields better in Castellanos (province of Santa Fé) than in Pergamino (province of Buenos Aires) even though in the case of Castellanos observed yield variations appear considerably greater than yield variations predicted by the model. This finding is probably related to the increased importance (in explaining yields) of water-induced stress in Castellanos as compared to Pergamino.

Summarizing: interactions between climate variables and crop yields are complex. Average monthly rainfall shows for the case of soybeans a "not too strong" ($R^2 < 35$ %) linkage with crop yield. Of course, this does not preclude drastic output reductions in years with severe water shortages (e.g. 2008/2009).

[8] A soybean is planted somewhat later in the *partidos* in the southern part of Buenos Aires province.

Table III.1: Soybean Yields as a Function of Growing-Season Rainfall

Estimated Equation for Soybeans Yields

Panel Data: 28 *Partidos* - 1980-2010 (*Partido* fixed-effects)

Dependent Variable: lnyield	Equation 1 Total (28 *Partidos*)	Equation 2 North (14 *Partidos*)	Equation 3 South (14 *Partidos*)
lnrain_1	0.142*** (7.18)	0.089*** (6.20)	0.202*** (7.07)
lnrain_2	0.105*** (6.64)	0.106*** (6.45)	0.109*** (3.5)
lnrain_3	0.073*** (5.60)	0.078*** (5.1)	0.052** (2.2)
lnrain_4	0.003 (0.120)	0.054 (1.02)	-0.034*(-2.36)
trend	0.012*** (6.130)	0.015*** (6.39)	0.008** (2.57)
constant	-18.521*** (-4.68)	-24.172*** (-5.34)	-10.879 (-1.66)
Estimation Method	Fixed Effects	Fixed Effects	Fixed Effects
F test (5,27)	58.24	111.07	19.03
R square:			
Within	0.24	0.31	0.21
Between	0.22	0.24	0.48
Overall	0.21	0.22	0.22
Number of Observations	767	428	339

Notes:

t statistics in parenthesis

Robust standard errors (adjusted for 28 clusters in id)

* p<.05; ** p<.01; *** p<.001

C. Estimating subjective yield distributions

Two approaches can be used to obtain estimates of average yields and variation of yields caused by random climatic factors. The first is to use "objective" measurements with farm-level data. This is an excellent approach if resources are available for data collection. In Argentina, for example, the CREA groups routinely gather data on yields and agronomic practices on an individual field-level basis. In a typical CREA group comprised of 10 farms, each with 8-10 crop fields, some 80 – 100 observations will be collected annually. In the overall CREA movement (some 200 groups, or a total of 2000 farms) approximately 1600 – 2000 annual crop observations will gathered. Several of the research papers mentioned in the reference section of this report use the analysis of a wide variety of agronomic problems.

The difficulty involved in gathering field-level data such as described above is apparent in the fact that in Argentina only the CREA groups have been able to carry out this type of effort in a continuous fashion. INTA, the main governmental research organization, undertakes experimental work, and sometimes gathers farm-level data, however no continuous and wide-coverage data base on farmer yields is available in this institution. The point made then is that farm-level yield data is not generally available. Further, farm-level data has to be carefully analyzed in order to take into account changes in input use, climate and other factors.

The other alternative is to use subjective yield estimates of farmers themselves. Subjective yields, it may be argued, are the relevant yields at least from the perspective of the farmer decision-process.

Biases involved in the "elicitation" of subjective probability distributions have long been recognized by psychologists. The volume by Kahneman, Slovic and Tversky (1982) presents a detailed discussion on these topics. In agricultural economics, Anderson and others (1977), discuss the relevance of these biases for applied research. One conclusion of this line of work is that subjective probability distributions may underestimate "true" variability – in particular if attempt is not made to estimate the range of possible outcomes before estimating probabilities of "in between" outcomes. A preliminary study made by Gallacher in Argentina

(1989) found that estimates of *mean* yields made by farm advisors were unbiased; however *variability of yields* (corn, soybeans and wheat) was systematically underestimated.

We report here results from farm-level surveys carried out in Argentina for the purpose of estimating farmer perceptions on soybean yield variability. Soybean yield distributions were estimated for Argentina using the *triangular distribution*. This distribution is convenient for farmer interviews, as it is defined by only three parameters: minimum ("a"), most probable ("b") and maximum yield ("c"). It allows for possible skewness (if any).

For the triangular distribution Expected Value (EV) and Standard Deviation (SD) of yields are defined as:

$$(10)EV(y) = \frac{(a+b+c)}{3}$$

$$(11)DS(y) = \sqrt{(a^2+b^2+c^2-ab-ac-bc)/18}$$

Table III.2 shows the yield distribution averages (over all responding farmers) in the study area. Subjective estimates of yields for early season soybeans range between 2.8 and 3.4 t/ha (in Trenque Lauquen yields are lower). Yield risks, as measured by yield CVs do not appear different between the early and late season crops. Note that with the exception of Trenque Lauquen, "yield risks" as measured by yield CV´s are less than 25 percent. These figures are consistent with the estimates of yields CVs discussed previously in Table III.1, obtained on the basis of *partido* data.

Table III.2: Soybeans - Subjective Yield Estimates

Partido/Departamento	Province		Early Season				Late Season			
			EV	SD	EV - SD	CV	EV	SD	EV - SD	CV
		n obs	t/ha	t/ha	t/ha	%	t/ha	t/ha	t/ha	%
LN Alem	Buenos Aires	37	2.9	0.6	2.3	20.5	2.3	0.5	1.7	23.3
Lincoln	Buenos Aires	15	2.9	0.6	2.3	20.8	2.2	0.5	1.7	22.9
Chacabuco	Buenos Aires	15	3.2	0.6	2.5	20.2	2.4	0.5	1.9	20.4
Junin	Buenos Aires	14	3.1	0.5	2.6	17.9	2.4	0.5	2.0	18.8
Trenque Lauquen	Buenos Aires	40	2.3	0.7	1.6	29.4	1.6	0.5	1.2	28.0
Pergamino	Buenos Aires	35	3.5	0.8	2.7	23.1	2.3	0.6	1.7	25.2
Rojas	Buenos Aires	15	3.4	0.7	2.6	21.3	2.5	0.6	1.9	22.9
General Lopez	Santa Fe	29	2.9	0.6	2.3	20.9	2.2	0.5	1.7	22.1
All		396	2.8	0.6	2.2	21.3	2.2	0.5	1.7	22.1

Source: Farm Survey Results, 2011

The previous discussion may be summarized as follows. First, moisture deficit is an important but by no means exclusive determinant of crop yield. This is particularly true in a large portion of the *pradera pampeana*, less so in the *zonas extra-pampeana*s where water deficit may play a more important role. Second, and related to the above, other climate-induced stress factors such as excess water (which compromises planting or harvest) or humidity (resulting in increased incidence of diseases) can be extremely important. Third, with the exception of "catastrophic" yield reductions, output variability in soybean production appears to be manageable. Indeed, estimated CV´s of 20-25 percent in most production areas suggest that the probability of output falling below than necessary to cover production costs (excluding land rent) are quite small. Of course, the previous statement is conditional on soybean prices not falling substantially in price (say, below US$ 250 per ton).

III.2 Dairy

In this section we discuss the nature of risk in dairy production, in particular resulting from variability of climate or extreme weather events. First, the geographic distribution of milk production in Argentina is presented. Then, we discuss the weather patterns of the most important dairy basins, in terms of rainfall, humidity and other parameters. Finally, we deal with the relationship between weather and milk production.

A. Dairy production systems in Argentina

Argentina produces about 11,400 million liters of milk (provisional data for 2013), with the provinces of Córdoba, Santa Fe and Buenos Aires accounting for more than 95 % of the total. Milk production was typically run on pasture-based production systems, but in latest year's farms have changed toward a process which is popularly regarded as "intensification". TableIII.3 shows data from typical dairy farms from the central production basin of Argentina, in the provinces of Santa Fe and Córdoba.

Table III.3: Evolution of representative dairy production systems in central Santa Fe, Argentina

Year	Herd size (milking cows)	Milk production (lt/day)	Stocking rate (cow/ha)	Concentrates usage (g/lt)	Productivity (lt/cow/day)	Productivity (lt/ha/yr)
1996	110	1400	0.90	130	13.00	3300
1998	115	1670	0.98	180	14.50	4100
1999	120	1800	1.05	200	15.00	4600
2006	140	2450	1.20	250	17.50	6000
2008	140	2520	1.30	325	18.00	6500
2009	140	2590	1.35	400	18.50	7000
2010	145	2750	1.40	450	19.00	7600
2011	150	2900	1.40	500	19.50	8100

Source: own elaboration based on Galetto, 1996; Zehnder and Pelosi, 1997 and Sancor

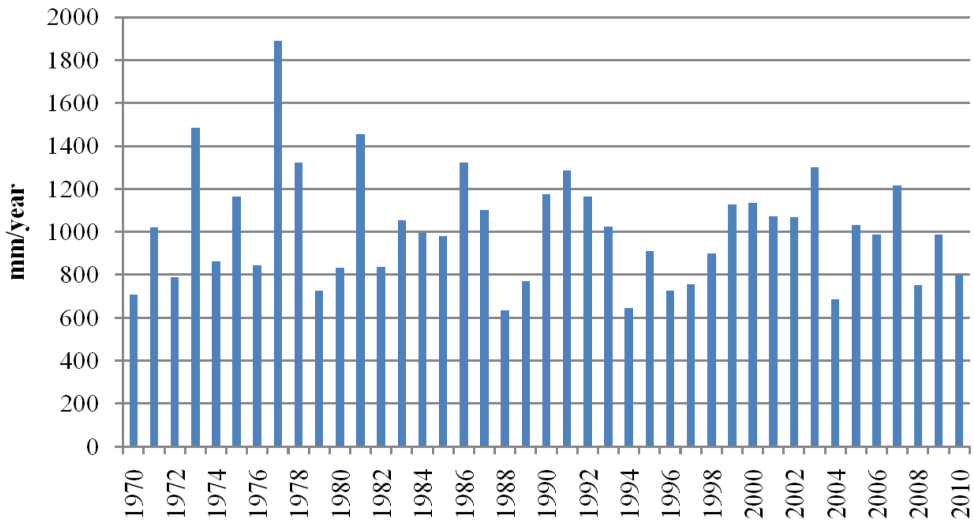
In the early 90´s the typical diet for the dairy cow was made up of grazed alfalfa pastures (60 – 70 % of ingested dry matter), and the rest was provided by grains (corn or sorghum) or commercial concentrates and conserved pasture in the form of hay. Silage was not very important. The picture started to change in the mid 90´s with the widespread diffusion of corn silage and in the last decade, with a sharp increase in the usage of energy concentrates. In today´s dairy production systems at least 50 % of the dairy cow requirements come from concentrates and silage. As a result of this change in the feeding patterns, the relationship between weather and milk production has also changed, as will be shown below.

B. Climatic variability in the region

The largest and more representative dairy basin in Argentina is known as "Central Production Basin" (Cuenca Lechera Central) and covers the central departments of the Santa Fe province (Castellanos, Las Colonias and San Cristóbal, mainly) and San Justo department in eastern Córdoba. The city of Rafaela (Santa Fe) is located in the geographic center of that region, and the main factor explaining climate variability there is rainfall (Figure III.1). In this locality, average rainfall is 1014 mm/yr (1970-2010), the minimum 637 mm/yr (1988) and the maximum

1889 mm/yr (1977). In addition to the important degree of inter-year variation of precipitation, there is also high intra-year variation, typically with severe excesses in fall and extended droughts in late winter and early spring. One example of these extreme variability in the amount of rainfall in the city of Rafaela was in March 2007, with more than 500 mm in the whole month and 358 mm in just two days, the 28th and 29th,

Figure III.1. Rainfall distribution for Rafaela, Santa Fe, 1970-2010 (mm/yr)



Source: INTA Rafaela

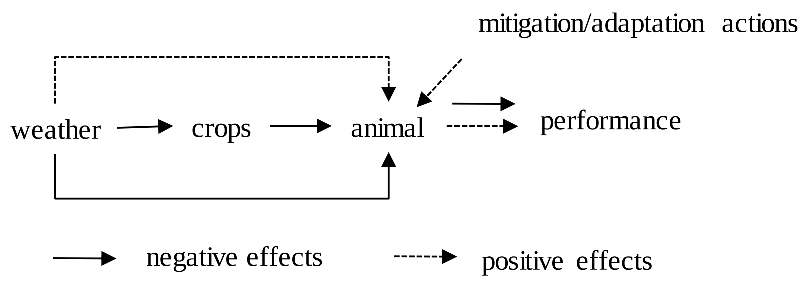
The second factor explaining climatic variability from the perspective of dairy production is temperature and humidity. The breed of dairy cows used in Argentina is mostly of the American Holstein type, particularly sensitive to high temperatures and humidity (known as "heat stress") which occur between the months of November and March. In fact, and as shown in a later section, the combination of both high temperature and humidity is what causes severe production problems to the dairy cows. In the central region of Santa Fe and Córdoba it is common to observe these problems of high temperatures and humidity, particularly concentrated in the period between mid-December to late February.

Although of lesser importance in comparison with rainfall and the combination of high temperatures and humidity, dairy production systems suffer the occurrence of hail which can produce severe losses in annual and perennial crops which constitute the basis of the feed supply in the pastoral dairy producing systems. In the region of Argentina where milk production is located, there is an average of 0.7 (Ceres, Santa Fe) to 1.8 (Laboulaye, Córdoba) hail events per year, with maximum probability of occurrence being in the months of September to December (Instituto Clima y Agua, 2008).

C. Impact of climatic variability on dairy production

The impact of climate change and variability on livestock, particularly on dairy, is more complex than the impact on crops, were most of the studies have concentrated so far (Reilly and others, 2001). This complexity can be observed in Figure III.2, which shows the different type of effects which add up together to influence the performance (yield) of the dairy cow.

Figure III.2: Relationship between climate and milk production



We first observe a typical negative effect of climate on crops (for example, drought) which translates into a negative effect on the animal and performance. At the same time however, the same adverse weather for crops can have a positive effect on the animal, for example, dry weather associated with drought results in a better environment for the dairy cow. Other events, such as excess rainfall, could produce negative effects directly on the dairy cow, particularly in pastoral systems. To make things more complex, in dairy production there are a large number of management possibilities which can alter the effect of weather with direct and positive influence on the animal (mitigation measures), such as cooling, for example, making it possible that the combined effect of all these events could be on the positive or the negative side, as indicated by the two arrows defining animal performance.

All factors mentioned in the paragraph above make the relationship between weather and milk production quite complex. With this in mind, we´ll present the main impacts of rainfall and the combination of temperature and humidity on milk production. Starting with rainfall, note first that the main forage crop in Argentina is alfalfa, which is tolerant to relatively long dry periods, but suffers the excess of precipitation. In an trial conducted in Rafaela (Romero and others, 2011), the effect of rainfall and the level of underground water on alfalfa yield was measured, showing positive effects for rainfall up to levels of 201 mm/month (and thereafter the effects are negative) and similarly, when the level of underground water is 2.68 or closer to the surface, the effect on alfalfa yield is negative.

As already mentioned, rainfall variability has direct effects on animal welfare and production: dry weather - associated with droughts - creates a favorable environment for the dairy cow, which can show all its genetic potential (if adequately fed), while excess rainfall, particularly in the pastoral production systems of Argentina, many of them with poor infrastructure (Baudracco *et al.*, 2014), can have negative effects on animal welfare and production, because of the excess of mud and the general animal discomfort associated with it.

The impact of rainfall variability upon milk production was studied with a sample of 303 dairy farms with data spanning from July 2000 to July 2010. The original data available was not milk production but milk deliveries, which was transformed into daily milk production, which was the dependent variable of the model, estimated as a function of the standardized precipitation index – SPI (Mc Kee *et al.*, 1993). Table III.4 shows the results obtained, with the dependent variable expressed in logarithmic form, and therefore the coefficients can be regarded as the percentage change in milk production as a result of a unit change in the independent variable (the climatic index).

Table III.4: Rainfall impact over milk production. Dependent variables: ln (milk production in lt/month).

Variable	Coeff	St Error	P>|t|
Tendence	0.0021 ***	0.0003	0.00
D_Autumn	-0.118 ***	0.0052	0.00
D_Winter	-0.0206 **	0.0087	0.02
D_Spring	0.0911 ***	0.0067	0.00
SPI 9	-0.1297 ***	0.0116	0.00
D_SPI 9 negative	-0.0022	0.0104	0.83
SPI 9 x D_SPI negative	0.1706 ***	0.0158	0.00
SPI 9 x D_Autumn	-0.0319 ***	0.0046	0.00
SPI 9 x D_Winter	0.0118 *	0.0069	0.09
SPI 9 x D_Spring	0.0624 ***	0.0067	0.00
Constant	10.5278 ***	0.0218	0.00
		Within Effects	
Nro observations		34148	
Nro groups (i)		303	
Obs per group	min:12	max:120	mean:113
sigma_u		0.7076	
sigma_e		0.319	
Rho		0.8311	
R^2	within=0.1198	between=0.0257	overall=0.0289
F(11,302) =	218	Prob > F=0	

The overall coefficient of determination (R^2) is low, showing that the model has a partial explanatory power of the behavior of milk production at the farm level. The R^2 for the temporal variation of milk production was higher (12 %). Moreover, the explanatory power of the model increased when the estimation was done with sub-samples of farms located within smaller geographic areas.

The coefficients of the trend and seasonal variables have the expected signs and are statistically significant. In the fall (March, April and May) and winter (June, July and August) seasons, milk production is lower than in summer, with the highest level of milk production (in relation the climatic index) being observed in spring.

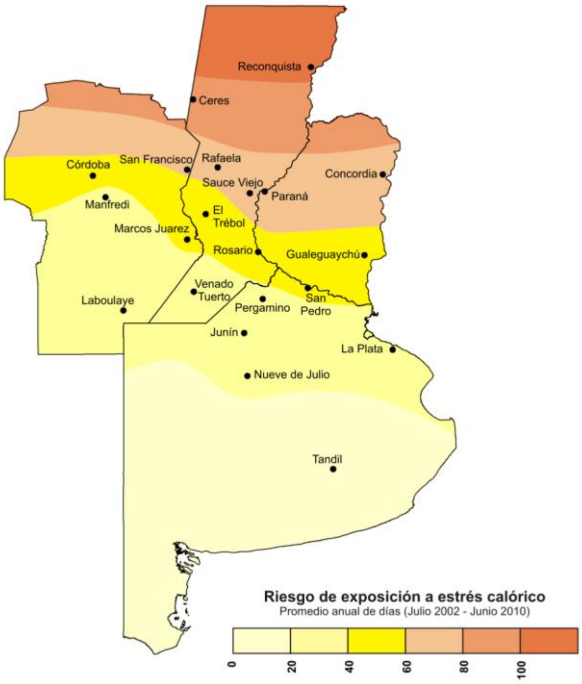
The auxiliary variable "D_SPI 9 negative" represents the months in which the SPI9 index is negative, showing that precipitation is below normal. It was included in the model in order to create interactions which may allow us to differentiate the effects on milk production of excess rainfall (SPI positive) and deficit rainfall (SPI negative). Other variables included in the model were the interactions between the SPI index and the seasons of the year, under the assumption that the same SPI index causes differential impacts in the different seasons (due to the typical length of the day).

The adverse precipitation events do not have the same intensity in the whole region and thus the average coefficient underestimates the production losses due to the more extreme events. For example, the highest precipitation effect in the SPI9 index scale was observed in April 2009, in the town of Ñanducita (San Cristobal department, Santa Fe province), with accumulated rainfall of 1681 mm in the 9 months up to April 2003, which translated into a SPI9 index of 2.56. If we multiply the value of the index by the loss coefficient for the fall season [100*exp (-0.13-0.03)-1]=14.92 %, gives a loss in milk (produced or sold) of -38.2 % for April 2009, which is higher than the loss estimation calculated using the average SPI coefficient for April 2003, which was 1.42 (the lower was 0.175 and the highest, in Ñanducita, 2.56). Following this reasoning, one alternative to produce more realistic loss estimates would be through the uses of the extreme coefficients of the confidence interval of the parameter (in this example, the SPI9).

Summarizing the evidence, there are differential effects according with the type of event (precipitation deficit or excess) and the season of the year in which they occur. Generally, droughts produce lower losses than excess rainfall (a 73 % relationship), which also agrees with the perception of farmers (59 % relationship). If we focus now in the seasonal effects, fall is the most critical season due to the occurrence of excess rainfall while the spring season suffers most the effects of droughts, measured in SPI9 scale.

As was mentioned above, the second most important factor of weather on milk production are the combined effects of high temperatures and humidity, also called “heat stress”, which has detrimental effects on milk production and reproduction of dairy cows, particularly for the production systems located in the northern areas of the milk production region of Argentina (Map III.1 shows regions of the country with different incidence of heat stress measured as days with THI of 72 or higher).

Map III.1: Areas of Argentina with the same incidence of heat stress (THI≥72) for dairy cattle



The impact of heat stress on the Holstein dairy cows is a sudden decrease in milk production. As shown in Table III.5 the incidence of a day of heat stress (October 30th, 2009) on three subsequent days results in a decrease in milk production for a 226-cow herd of almost 3000 liters. Although not shown in the data, heat stress also causes other type of effects on milk production. One of them is a medium term impact: the cow which suffers a reduction in milk production due to the combination of high temperatures and humidity will not recover the full production potential. The other, long term effect is through the reproduction of the dairy cow, affecting pregnancy and the survival rate of new-born cattle.

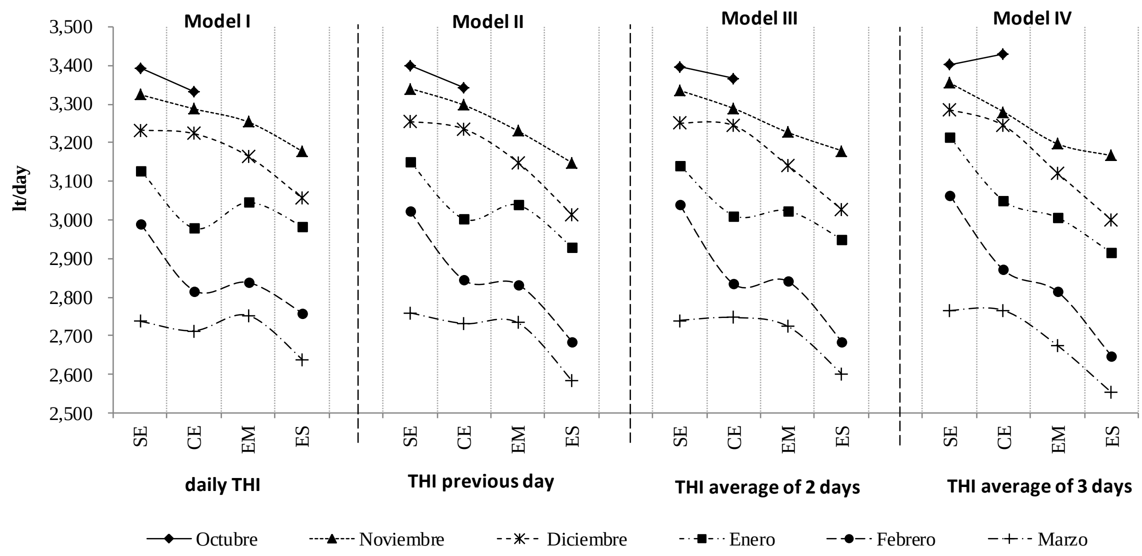
Table III.5: The impact of heat stress on milk production in Rafaela, Sta Fe

Period	Milk production (lt/cow/day)	Difference in milk production (lt/cow/day)	Difference in milk production (lt/herd/day)	Accumulated difference in milk production (lt/herd)
Previous days	27.8	0	0	0
30-10-2009	26.3	1.5	340	340
1/11/2009	25.1	2.7	612	952
2/11/2009	23.3	4.7	1067	2019
3/11/2009	24.3	3.5	794	2813

Source: Taverna and others (2011)

We also estimated the impact of heat stress on milk production using a sample of daily milk sales of 577 dairy farms, together with temperature and humidity records of 20 meteorological stations, for two time periods: October 2010 – March 2011 and October 2011 – March 2012. The daily THI (temperature and humidity index) was calculated for each station, and it was extrapolated to each dairy farm with the help of kriging techniques. Four types of heat stress events were defined: no stress (THI < 68), low stress (68≤THI≤72), moderate stress (72≤THI≤76) and severe stress (THI >76). The impact of the heat stress events was measured through an ANOVA test on the "daily milk deliveries" in relation with "heat stress events", "month" (control variable for forage availability and herd composition) and their interaction. Two other control variables were included: i) amount of milk delivered the first day of each period (to account for the size of the farm) and ii) successive days with THI ≥ 72 (to account for the different effects of isolated or accumulated days with heat stress). Four models were estimated, each of them with different criteria for selecting the THI index: Model I (THI of the t day), Model II (THI of the t-1 day), Model III (average THI for t and t-1) and Model IV (average THI for t, t-1 and t-2). The purpose of the last two models was to capture residual effects on milk production. Means were compared with the LSD test at the 0.05 probability level, and Figure III.3 shows the results obtained.

Figure III.3: Monthly milk production regarding heat stress.



Different letters indicate statistically significant differences (p <0.05)

The interaction between "heat stress event" and "month" was significant, with the exception of October for models II and IV, because in that months we did not observe moderate and severe events. The highest frequency of severe events was in January, but the intensity was a little higher in February. The heat stress events produced a decrease in milk production in the same day (Model I) and also in the following day (Model II), but the impact was even higher when measured with Models III and IV, indicating the importance of the negative residual effects. Also, milk production losses were higher with the intensity of the event. Considering the parameters estimated with Model IV, for a 150 milking cows dairy herd, daily milk production was reduced by 0.11 and 0.23 liters per cow per day for each additional unit of THI between moderate and severe thresholds.

IV. OPPORTUNITIES FOR RISK-TRANSFER: INDEX-TYPE INSURANCE

IV.1 Risk transfer

In Argentina, as in many Latin American countries, poor functioning of financial markets limit the possibilities of smoothing farmer's inter-year income variability due to climate shocks. Futures and options markets - of major importance both for price forecasting as well as for the transfer of risk - are insufficiently developed. If export demand for agricultural products is perfectly elastic (as is the case for a small open economy) the impact of "bad" years due to climate is not dampened by price increases and variability of agricultural production translates directly into farm-level income variability. This contrasts with large countries, like the US, where national production shortfalls can be expected to result - at least partially – in some price increases.

If individuals have limited opportunities to adapt to climate variability, production risk can have different types of consequences on the farmers, rural areas and the country as a whole. For farmers it can result first, in a decrease in welfare due to the need to adapt to inter-year fluctuations in net incomes. Consumption patterns may be affected, in particular if capital markets do not allow (or allow at a high cost) borrowing in times of financial stress. This of course is more significant for limited-resource producers, where net income levels are not much higher than yearly household consumption. Restrictions in opportunities to cope with production risk can also result in allocative inefficiency: for example a "safety first" (e.g. see Anderson, Dillon and Hardaker, 1977) behavioral pattern may sacrifice profits in order to reduce the probability that profits fall below a certain threshold. In other cases, "conservative" behavior may imply using input levels such that marginal costs are below output prices thus resulting in a loss of net surplus. Alternatively, risk may push farmers into using "excessive" input amounts: for example, under grazing production systems livestock producers may choose "low" stocking rates (low cattle/land ratios) in order to protect themselves against shortfalls in forage production due to drought or excessive rainfall. Or they may invest in forage reserves in the form of silage or hay inventories "in case" pasture production is insufficient. Such inventories, of course, carry a cost.

Production risk, income and consumption variability may have impacts beyond the farm gates. The fortunes of rural areas are partially "tied" to what happens in farms. Although caution has to be used in using "multiplier" type of concepts (double counting is a possible error) it appears reasonable to expect "ripple" effects of farm shorfalls on the communities in which farms rely on. Input and credit suppliers, output processors as well as consumer goods retailers are affected by reduced farm incomes. In some cases severe output shorfalls may also result in increased opportunism and moral hazard: for example, non-payment of debt may be chosen by some even when objectively, payments could be met. This results in an increased difficulty in separating opportunists from those who face real difficulties. Reduced trust among community members may thus result, with a corresponding reduction in exchange and thus efficiency.

These effects are perceived as "an important" issue by informed observers, however no clear-cut evidence exists on the implications of this risk at the micro or aggregate levels or how to develop institutions able to transfer the production risk in an efficient manner. An important challenge for both public policy as well as private insurance firms is how to expand "non-traditional" insurance products, and in particular how to develop multi-risk coverage for agricultural producers. In Argentina, hail and hail plus "additional" insurance premiums account for more than 95 percent of total premiums, with multi-risk premiums totaling less than 2 percent. Existing multi-risk insurance schemes are tailor-made for individual (in general relatively large) farms. These schemes result in an indemnity if yields fall below certain threshold, indemnity being the difference between the threshold and the observed yield at the farm. Insurance schemes such as these have very high costs, further costs per unit of land increase substantially for smaller as compared to larger producing units.

The principle of insurance as a risk-transfer instrument is that, by accepting appropriate premiums from a large number of clients, the insurance company is able to pool the risks. Using information about the frequency and level of claims, the company set the premiums at levels that will enable it to pay all the indemnities (pure premium) plus a margin for operating costs and profit. This means that the expected value of the insurance contract is negative from the point of view of the farmer. In consequence, commercial insurance is purchased only for risk averters: individuals that are willing to pay a premium greater than the expected loss (actual loss times probability).

A key question is how large is the difference between the pure premium and the commercial premium. Asymmetric information problems increase the costs of providing commercial insurance and limit the application of traditional crop insurance in rural areas, particularly in developing countries. Informational asymmetry occurs when one of the parties of the contract has more or better information about a risky outcome than the other. Two main problems of asymmetric information are pervasive in agricultural insurance markets: *adverse selection and moral hazard*. Adverse selection occurs when potential insurance clients have hidden information about their risk exposure that is not available to the insurance company, who then becomes more likely to erroneously assess the risk. Adverse selection problems increase the costs, and insurance companies must set a higher premium if informational asymmetry makes it impossible to identify the clients with higher risk. Moral hazard occurs when one of the parties engage in hidden actions that increase their exposure to risk. Moral hazard is a form of post-contractual opportunism that can leave the insurer exposed to higher levels of risk than had been anticipated when premiums were set. For example, a farmer with multi-risk crop insurance may choose to neglect a poor crop, knowing that the insurer will pay for a shortfall in yields. Monitoring behavior to totally control moral hazard is impossible or very costly and therefore increases the insurance premiums.

IV.2 Index insurance: Characteristics, advantages and disadvantages

In recent years, weather index (or parametric) insurance products have received increased attention. With index insurance products payment of an indemnity depends on an objective index based, for example, on observations of rainfall, temperature or average area yields, rather than actual loss. If the index falls below (or rises above) a previously agreed threshold value, then the indemnities are paid by the insurance company. One important condition is that the index should be independent, reliable and beyond the control of both the insurer and the insured. Because there is an objective index, easy to measure at low cost, it is relatively easy to calculate the probability that indemnities are due. It is important to remark that the indemnity is calculated on the results of the weather index (or average area yields) measured in the area where the farm is located, not on the actual farm results on weather or yields.

For economic agents exposed to weather-related financial losses, weather index insurance provide a mechanism for coping with risk efficiently. The benefits to such a contract design are several and appropriate to rural areas where covariate risk, asymmetric information and high transactions costs implies that conventional insurance is extremely costly or not available. Under an index contract insurance companies and insured clients need only monitor the index to know when a claim is due and indemnity payments must be made. They do not need to verify claims of individual losses at the farm, which can substantially reduce the transactions costs of monitoring and verification of the insurance contracts. These gains come at the cost of basis risk, which refers to the imperfect correlation between an insured's potential loss experience and the behavior of the underlying index on which the index insurance payout is based. A contract holder may experience the type of losses insured against, but fail to receive a payout if the overall index is not triggered. Conversely, while the aggregate experience may result in a triggered contract, some insured individuals may not have experienced losses yet still receive payouts. The tradeoff between basis risk and reductions in incentive problems and costs is thus a critical determinant of the effectiveness of index insurance products. The lower the basis risk the higher the effectiveness and the efficiency of the risk transfer. The key point here is if the disadvantage of the basis risk may be more than compensated for by the cost advantages of index insurance in terms of lower premiums and administration costs. Agricultural applications of such products are increasingly being discussed since many agricultural production enterprises are highly sensitive to extreme weather conditions (Richards *et al*., 2004;

Vedenov and Barnett, 2004; Chen *et al*., 2004; Varangis *et al*., 2002; Mahul, 2001; Martin *et al*., 2001; Skees *et al*., 2001; Turvey, 2001, Deng *et al*. 2007, Chantarat *et al*. 2009).

Index (or "parametric) based insurance schemes allow reduction in delivery costs including in these moral hazard and adverse selection costs. However, they require substantial set-up costs in the form of (i) information on weather, yields and economic impacts, and (ii) potential impact of contract design alternatives. Also, as a new product it can be difficult for stakeholders to understand and time and resources must be invested in explaining how it works. Finally the most important problem is the potential low correlation between the index and farm results, or in other terms when insurance payouts do not match the actual losses – either there are losses but not payout, or a payout is triggered even though there are no losses. This "basis risk" for the insured remains a significant problem.

Our research focuses on the possibility of obtaining welfare or production efficiency gains via public policy measures aimed at increasing the use of transfer of risk in agricultural production. We point out that in Argentina there is a considerable potential for some index insurance alternatives. For reasons to be discussed in other sections of this paper, public intervention (e.g. in the form of improving the availability of farm-level yields, or site-specific climate information) may help the decision process of both suppliers and demanders of insurance. If this occurs, efficiency gains could result.

The design of index products and the estimation of benefits derived from index insurance is a necessary first step in order to decide whether publicly-sponsored projects such as mentioned should be undertaken. These benefits can be gauged by different methods. Among these willingness-to-pay (WTP) is a convenient and well-tried alternative that allows inferences to be made on aspects such as quantity demanded at different prices, consumer (or producer) surplus and other aspects (see, e.g. Hanemann, 1984; Kealy, Montgomery and Dovidio, 1990; Mitchell and Carson, 1989). WTP for insurance will vary substantially among productive regions and farm types. This occurs because, as mentioned in previous sections, alternatives open to the farmer for risk reduction include not only insurance but production diversification, access to the non-farm labor market, renting out machinery or land and others. Following sections discuss the design of index insurance products and WTP for two study cases (soybeans and milk) in argentine agriculture.

V. <u>CASE STUDIES OF RISK-TRANSFER USING INDEX-TYPE INSURANCE SCHEMES</u>

V.1 Index insurance in soybean production

A. Rainfall index insurance: Pergamino case study

This section explores the design of index insurance for soybean production in the central region of Argentina. The insurance coverage was designed according rainfall measure in the Meteorological Station of the National Institute for Agricultural Technology (INTA) in Pergamino (province of Buenos Aires) between July 1931 and June 2010. The choice of this location is based on the importance of the soybeans crop (57% of total area), the availability of information and the fact that according to farmers, the risk associated with changes in the amount and frequency of rainfall is perceived as a major problem in this zone for the coming next 10 years (Cabrini and Calcaterra, 2008). Also, this is an area where there is a high willingness to take crop insurance. For example, in 2006/2007 95% of the soybean acreage was insured against hail. The average coverage yield was 2.5 ton/ha (Cabrini and Calcaterra, 2008), and the observed average yield was 3.2 ton/ha (SAGPyA).

For the design of the insurance coverage the following parameters were considered:

• Climate Event: rainfall deficit.

• Reference weather station: We used rainfall data from the weather station of INTA-Pergamino. The data cover the period July 1931 - June 2010 and presented the following distribution: i) median: 943.10 mm per year; ii) quartile 1: 802.3 mm; iii) quartile 3: 1134.10 mm; iv) maximum: 2014.6 mm for the period July 2006-June 2007; v) minimum: 511.9 mm from 1949 to 1050.

• Coverage Period (pc): Measured in days. During the pc period the event is liable to be compensated. The proposed coverage period - 21 December to 20 February - was specified considering the critical period of rainfall deficit for the crop.

• Climate Index: Cumulative daily rainfall during the coverage period, expressed in millimeters (mmpc).

• Trigger Index (mmd): The value of accumulated rainfall during the period of coverage, which activates compensatory mechanism. The 130 mm value was selected, so the insurance guarantees between 20 and 30% of water requirements of soybeans.

• Exit Index (mms): Below this index value the compensation is 100%. Selected considering the minimum historical rainfall (50 mm).

• Insured amount: The capital on which compensation is calculated.

• Right to compensation: When mmpc< mmd

• Amount of compensation (i)

If mmpc ≥ mmd	*compensation = 0%*
If mmd >mmpc> mms	*compensation = (mmd - mmpc) / (mmd – mms)*
If mmpc ≤ mms	*compensation = 100%*

• Frequency of compensation

Total years / number of compensations

• Likelihood of compensation

Number of compensations (years)/ Total years analyzed

Table V.1 presents a synthesis of the insurance principal features. The trigger value was defined based on soybean water requirements in Pergamino. According to Andriani (2000) these values vary between 450 to 650 mm. The insurance thus guarantees 20% of soybean rainfall needs during coverage period. If the measured rainfall level is lower, company insurance should pay. The proposal considers two ways to estimate indemnity: progressive (PP) and occurrence-severity (POS). The first indemnity mechanism (PP) is used in Ethiopia and other countries and indemnity vary between 0% (accumulated rainfall ≥ 130 mm) to 100% of sum insured (accumulated rainfall < 50 mm). The second mechanism was proponed in Gastaldi and others

(2009). This mechanism has a fixed percentage to compensate event occurrence and a variable percentage to compensate event severity.

Table V.1: Insurance Characteristics and Definitions

Concept	Parameters
Crop	Soybeans (first occupation)
Insured capital	Yield (ton)
Contract duration	Yearly
Risk insurance	Drought
Sowing date	1st Week of November
Coverage period (p_c)	21 December to 20 February
Harvest date	Last Week of March
Climate index	Acumulated rainfall (mm)
Weather Station	Pergamino – INTA
Trigger index (mm_d)	130 mm
Exit index (mm_s)	50 mm

Historically, the proposed insurance should have paid 13 of 79 agricultural years and average payment probability was one every six years (see Table V.2). The maximum payout would have been in 1942/1943, followed by 1961/1962. In the last 20 years (since 1980/1981), hypothetical insurance should have paid in 1982/1983 and 2008/2009, both periods with severe droughts and with yield loses as measured by the Ministry of Agriculture. Also, insurance would have triggered in periods as 1984/1985, 1987/1988 and 2007/2008 when yield were been normal. These “false strikes” or incorrect payouts are associated with soybean plasticity and adaptation to rainfall variability. The result is that insurance indemnities are paid in some periods despite yield being normal. In contrast, insurance did not result in indemnity in 1993/1994 and 1996/1997, periods when in fact there were yield losses. But, these losses were produced not by insufficient rainfall but by soybean stem canker (Wrather and others, 1997 and 1999b).

The coverage assessment was done following the method proposed by Osgood and others (2007). The proposed methodology is a correlation analysis between the time series of hypothetical insurance claims with a series of yield losses of soybean crop.

Simulated data for yields were obtained for the period 1931-2010 using the software "Weather Index Insurance Educational Tool" (WIIET), developed by the International Research Institute for Climate and Society (IRI). This software contains a module to estimate crop water requirements (WRSI) and the results were used as a proxy for yields.

Estimated premium was 5.9% of insured capital for PP insurance and 8.5% for POS insurance. These premium rates are minimum values and were estimated based on historical rainfall since 1931 to 2010. However, taking into account that climate change has increased rainfall variability, it would be important to include additional climate information, climate forecasts and multivariate climate scenarios to assess the sensibility of estimated premium rates.

Results from the analysis are promising, although as pointed out in some years rainfall levels may exceed the trigger level and yields can be nevertheless low due to diseases. In other years the scheme results in indemnity payments even when yields – due to the plasticity of the soybean plant - were normal. The basic problem then is the "basis risk" resulting from less than perfect correlation between the parameter used in the insurance contract (in this case rainfall) and farmer yields.

Table V.2: Rainfall index in Pergamino
Premiums and Payouts under different scenarios

	Scenarios for Rainfall				
Scenario	**1**	**2**	**3**	**4**	**5**
First year	1931/'32	1960/'61	1980/'81	1990/'91	2000/'01
Last year	2009/'10	2009/'10	2009/'10	2009/'10	2009/'10
N° of agricultural years	79	50	30	20	10
Average rainfall 21 December-20 February *(mmp $_c$)*	217	227	236	245	255
Rainfall CV	45%	44%	43%	42%	52%
N° of payouts (years)	13	7	5	2	2
Average rainfall in payout years (mm)	101	103	116	117	117
Probability of payout	16%	14%	17%	10%	20%
Frequency of payout (years)	6.1	7.1	6.0	10.0	5.0
Progressive payout scheme					
Maximum indemnity (% of insured capital)	100%	76%	37%	17%	17%
Agricultural year	1942/'43	1961/'62	1982/'83	2007/'08	2007/'08
Average indemnity (% of insured capital)	35.8%	33.7%	17.4%	15.9%	15.9%
Pure premium (% of insured capital)	5.9%	4.7%	2.9%	1.6%	3.2%
Occurrence-severity payout scheme					
Maximum indemnity (% of insured capital)	100%	82%	53%	38%	38%
Agricultural year	1942/'43	1961/'62	1982/'83	2007/'08	2007/'08
Average indemnity (% of insured capital)	51.8%	50.3%	38.1%	36.9%	36.9%
Pure premium (% of insured capital)	8.5%	7.0%	6.3%	3.7%	7.4%

B. Climate index and crop yields

Considerable potential exists for improving insurance contracts such as the one presented in this section. For example, correlation between model predictions and regional or sub-area yields can be expected to be higher than correlation between simple meteorological data and yields. Indeed, models "build-in" the relevant production function relating multiple weather inputs and yields. Model output could thus be used in agricultural insurance contract: instead of the "trigger" for indemnity payment being calculated on (say) growing season rainfall, it could be based on yields predicted from a crop growth model which takes into account not only the rainfall variable but several other variables determining yield. Constraints have to overcome, however, for this potential to be realized: models have to be developed and calibrated and (most importantly) institutional and legal issues have to be ironed out before contracts can incorporate model results as indemnity trigger mechanisms.

The final objective of a climate index is to reflect as accurately as possible the "input" of climate variables to plant growth and ultimately yield. Note that as in any production process, climate input variables (z1, z2, …zn) result in output y, given decision input levels (x1, x2, …xn) chosen by the producer. As in any production process, climate inputs zi substitute among themselves, and substitute with decision input xj. Note that the insurance contract can be based on individual climate inputs zi (e.g. rainfall, temperature) or may be based on a function of climate inputs: z = f (z1, z2, …zn). As an example of the latter, a "days of water stress" index may be constructed on the basis of daily observations of rainfall, temperature and wind. If carefully designed correlation between this index and crop growth or yield should be higher than correlation between an individual variable (rainfall) and temperature.

The "ultimate" climate index result from a full-blown crop growth simulation model that maps climate input variables (z1, z2, …zn) and decision input levels (x1, x2, …xn) to predicted yields y. Models of this type exists and have been used to predict crop yields. Conceptually, the insurance contract could be based on these predicted yields instead of on "raw" climate data. The predicted yield is basically an "aggregate input" of climate variables, where aggregation has been made taking into account the nature of the transformation process (production function) of climate inputs (z1, z2, …zn) to output. For example, an indemnity could result if predicted yield yp is below some threshold yT – that is if growing conditions are sufficiently "unfavorable" so as to result in a "low" yield of yp.

While the above is conceptually feasible, "practical" constraints may limit applicability. The production model is in the last instance opaque to interested parties -- crop physiologists are the only ones who understand "what is going on" in calculations. Opaqueness may ultimately result in contractual failure between suppliers and demanders of insurance.

The difficulty basing contracts on "high quality but opaque" indexes may force parties to settle for simple but crude climate indexes. For example, as discussed before, a soybean insurance contract may be based on growing-season rainfall. The relevant issue here is whether this contract results in risk-reduction for the producer: that is, given that unfavorable conditions result in a yield drop Δy, the contract triggers and indemnity I in order to (partially or totally) offset the loss incurred.

We analyze here the applicability of the rainfall insurance scheme of to soybean production in 32 partidos of the main production area of Argentina. Yield data for the 1980/81 – 2009/10 period (30 years) is used to analyze: (i) yield losses in "drought" years and (ii) indemnity payments that would result – under the specified contract – in these years.

Agronomic research has found – below some threshold - a linear response of soybean yield to water availability (see e.g. Andrade and Sadras, 2000; Aiken and others, 2011). Insurance contracts have been designed based on this finding (Gastaldi and others, 2011). The insurance contract proposed below is based on three variables: growing-season rainfall (RG), "trigger" rainfall below which indemnity is paid (RT), and a "catastrophe" rainfall level below which indemnity is 100 percent of insured value (RC). The contract is of the following type (Indemnity expressed as percentage of insured crop yield):

(1) $R^G \geq R^T$ → Indemnity = 0

(2) $R^C < R^G < R^T$ → Indemnity = $100*[(R^T – R^G) /(R^T - R^C)]$

(3) $R^G \leq R^C$ → Indemnity = 100 %

Note that (2) implies a linear "loss" of yield when rainfall falls below RT. For the analysis we fix RT = 140 mm and RC = 50 mm. We calculate RG for each *partido* as (2/3) of cumulative rainfall between December and February. We use a 30-year time series of yield history of 32 *partidos*. Some 873 observations result.

Table V.3 and Figure V.1 presents summary statistics. The total number of observations (*partidos* x years) is 873 – resulting roughly from the 30-year period for the 32 *partidos* (no soybean was planted for some *partidos* and years, no rainfall data is available for others). We focus attention here on years where yield losses were equal or greater that 20 percent.[9] The insurance policy represented by equations (1) – (3) above would have triggered insurance payments in 57 out of the total 142 "incidents" where yield losses were greater than 20 percent. Average yield loss in these 142 "incidents" was 38 percent, and average indemnity payment only 14 percent. Some specific considerations on data follow:

a. Table V.3: From the total of 873 yield-rainfall observations, 142 (or 16 percent) correspond to a yield drop of 20 percent or more. Somewhat arbitrarily, this output drop is taken as the "threshold" above which negative impact on farm finance begins to kick in.

b. Table V.3: The insurance contract presented in the previous paragraph would have resulted in an indemnity payment in 57 of these 142 cases with yield drops. Indemnity is paid out in 7 percent of the total 873 observations, less than half of the 142 where a drop in yield (> 20 percent) occurs.

c. Table V.3: Average indemnity payment (where the average is calculated only for years where indemnity is paid) corresponds closely to average losses in these years (respectively 36 vs 38 percent). However, the fact that indemnity is triggered in less than half of the years where yield drop occurs, results in an indemnity well below average yield loss (14 vs 38 percent).

d. Table V.3: If no drought occurs, probability of a drop in yields is low. However, if a drought (as defined here i.e. rainfall equal or less than 140 mm during the growing season) occurs, probability of drop of yields being no greater than 20 percent is 62 percent. That is, in "dry" years a relatively high probability exists that yields not be much below average.

e. Figure V.1: Higher yield losses are associated with higher indemnity payments. However, and as mentioned before, in many years where yield losses occurs, no indemnity is triggered (data points on x-axis). Moreover, an increase in the severity of yield drop is

[9] "Yield loss" for the i-th *partido* in year t is defined as $(y_{it} - y^{av}_i)/ y^{av}_i$, were y_{it} is the (trend) corrected yield and y^{av}_i is the (trend corrected) average 30-year yield for the *partido*. Yearly trend increase was assumed equal for all *partidos* (1.3 percent per year) – this figure is the average trend for all observations.

associated with an increased dispersion of indemnity payments: "average" payment may correspond quite well to "average" damage", however the difference between these two magnitudes may be substantial, in particular when damages are relatively high.

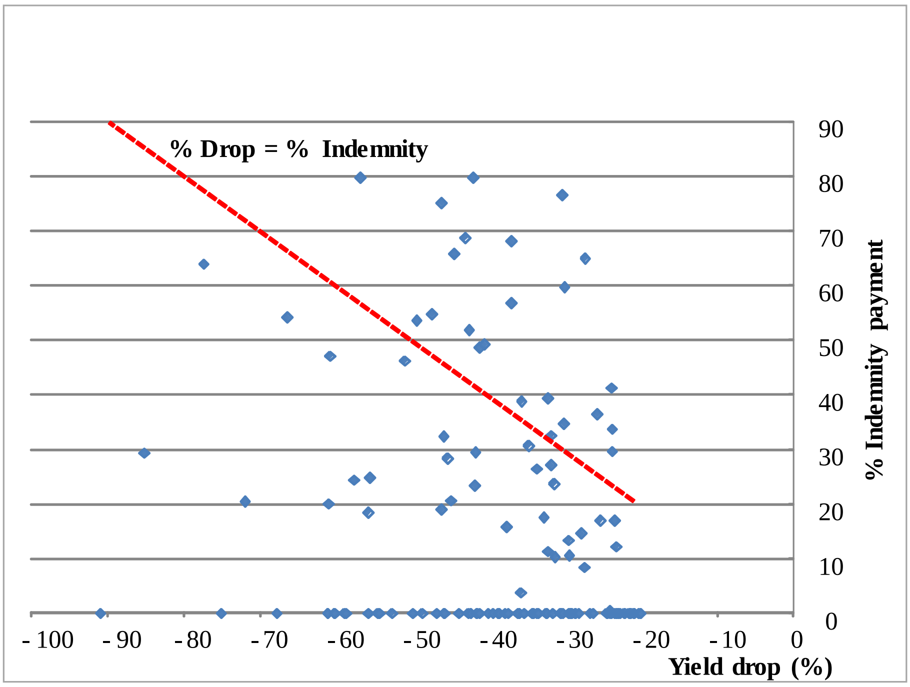
The example shown here represents a case where (i) an important number of years with losses do not result in indemnity payment and (ii) indemnity paid averaged only over years actually paid (36 percent) is quite similar to overall average losses (38 percent). However, (i) and (ii) taken together imply (iii) average indemnity over all years (14 percent) is considerably lower than average losses over these years.

The issue then is that indemnity – when paid – is on average quite similar to average losses, but that many years where losses occur do not trigger indemnity payments. One way of attacking this problem is to raise the threshold RT for indemnity to be triggered – a higher proportion of years would result in payments. However, it is also possible that even when increasing RT, a weak association will emerge between actual losses and indemnity payments. This would result if yield losses are caused by factors other than (conventionally measured) insufficient rainfall.

Table V.3: Rainfall Index Insurance Contract -- 32 *partidos* of the pradera pampeana (1980-2010 data)

	n	**%**
Total Number of Observations (partidos x years)	873	100
Observations with yield loss > 20 %	142	16
Observations where indemnity is triggered	57	7
	Average %	**Maximum %**
Yield Loss	38	91
Indemnity - calculated over all years	14	80
Indemnity - calculated over years actually paid	36	80

Fig V.1: Rainfall Index insurance - Indemnity payment as a function of yield drop (%)



C. Willingness to pay for index insurance

The market analysis of a potential insurance product designed to transfer risk should consider answering the fundamental question: "Are potential buyers willing and able to pay the required premium for an agricultural insurance product?" (Saleem and others, 2008). Obviously, willingness to pay is a function of producer characteristics such as risk aversion, the climate variability, farm size and asset position and the ability to manage risk with other mechanisms.

However, relatively few studies focus on the demand for index-based products. Two approaches have been used in these studies: Revealed Preference (RP) or Stated Preference (SP). The first approach focuses on the observation of consumer behavior at the market to estimate his ex-post willingness to pay. The main assumption is that the information comes from a real fact, a market transaction. The second approach is based on hypothetic data to estimate ex ante willingness to pay for products not available yet in the market.

The RP approach uses revealed preference concept in estimating latent demand for hypothetical insurance. Gautam and others (1994) for example use two-year panel data to examine the efficiency of drought management strategies used by peasants in India. They find evidence of market viable latent demand for drought insurance in the region. The same approach was utilized in Burkina Faso by Sakurai and Reardon (1997), who find that farmer's perceived probabilities of droughts and the size of cultivated area have positive impacts on insurance demand, while off-farm income and availability of public and private assistance have negative impacts on insurance demand.

The SP approach implies application of field survey studies and experiment in eliciting insurance demand. The common approach, which is also widely used to estimate the value of goods and services that are not traded in the marketplace, is the contingent valuation (CV) method, in which survey questions elicit respondents' willingness to pay (Mitchell and Carson 1989, Carson and Hanemann 2005, Alberini and Kahn 2006). A relatively small literature applies CV methods to study WTP for agricultural insurance. Patrick (1988) and Vandeveer and Loehman (1994) use a single dichotomous (yes/no) choice question to study producers' demand for a multiple peril crop insurance, rainfall insurance and other modifications of crop insurance. McCarthy (2003) and Sarris and others (2006) use similar single CV question to study pattern of demand for rainfall insurance in Morocco and Tanzania, respectively. Chantarat, Mude and Barrett (2009) use CV to study index based livestock insurance in Kenya. For the United States, Saalem and others (2008) estimate willingness to pay for different coverage levels in trout production.

The CV method is known as hypothetic method because of the way researchers obtain the economic value individuals assign to a good. The standard procedure consists of designing a survey which describes the good characteristics. It directly gives the good valuation and it is compatible with Hicksian welfare measures. In our case, it is the compensating variation or the willingness to pay (WTP) for a welfare gain.

The dichotomous or discrete choice VC format introduced by Bishop and Heberlein (1979) has great acceptance because it only requires responding yes/no in relation with a given payment “A” instead of an exact estimation of the monetary value consumer would be willing to pay. This format is known as “referendum” or “close ended” question with a given value or bid price. It induces more honestly revelation of preferences. However, CV method introduces issues not easily solved such as the optimal sample size for the valuation experiment, the bid values range and the “right” model specification.

As the dependent variable has a discrete format, it takes 1 value if the individual is willing to pay the price “A” suggested in the survey and it takes zero value if not. The regression errors are generally assumed to be normal or logistic distributed and estimation procedure is probit or logit respectively.

Hanemann (1984) and Cameron and James (1987) developed theoretical frameworks to estimate welfare changes compatible with the CV method. Hanemann´s original idea is known as the indirect utility difference model –supported by McFadden random utility framework- while Cameron’s idea is the expenditure difference model to estimate a random WTP.

The goal of estimating parametric models from dichotomous choice CV responses is to calculate willingness to pay for the good described. In addition, parametric models allow for the incorporation of respondent characteristics into the willingness to pay functions. This allows learning about the influence of individual preferences or characteristics influence on WTP (the covariate effects).

An important methodological question arises from the consistency between statistical and economic assumptions and the choice models selected. Bounds on WTP can be implemented in two ways. One is to estimate an unconstrained model and to truncate the final welfare measure at the calculation stage. The second approach is to estimate a model with the right bounds from the beginning. According with Haab and McConnell (2002), a direct way to achieve this using Cameron’s approach is to specify the following model:

$$WTP_j = G(z_j\gamma + \varepsilon_j)y_j \ (1) \ 0 \le G(z_j\gamma + \varepsilon_j) \le 1; \ G'(z_j\gamma + \varepsilon_j) \ge 0 \text{ and } j = 1,..,n$$

Each j individual WTP is a proportion of income (y) and G is a function of an n dimensional vector (z) of characteristics and choice influences. A recommended version of this formulation is:

$$WTP_j = \frac{y_j}{1+\exp(-z\gamma-\varepsilon)} \quad (2)$$

If the probability that the jth individual responds yes to the question about his willingness to pay \$A for a gain in welfare – a new product - is given for the following expression:

$$\Pr(yes) = 1 - F_{WTP}(A) = \left\{1+\exp\left[(-z_j\gamma - \ln(\frac{y_j - A}{A}))/\sigma\right]\right\}^{-1} \quad (3)$$

The literature has focused on two measures of central tendency (the mean and median of the WTP distribution) to evaluate the change between the initial and final situation for the population. The first is equivalent to apply the Kaldor-Hicks compensating criteria because the mean is positive if the positive values more than compensate the negative values in the distribution. In turn, the median is equivalent to applying the majority criterion: the change is desirable if most of population votes for it.

The dichotomous choice or referendum-style approach represents the usual method for contingent valuation implementation. In order to get an unbiased estimate of WTP it is necessary to know whether an individual does not want to pay a particular premium because of the premium itself or simply because the individual does not want to buy the good at any price. Following the approach of Hite, Hudson, and Intarapapong (2002) our surveys contained a follow-up question. Individuals who refused to pay the stated premium where asked: “Would you pay any positive amount?” This follow up maintains the single bounded nature of the question but allows differentiation between positive WTP responses from zero (or negative) WTP responses.

For the WTP study case we use a single-price contingent valuation instrument to examine mean willingness to pay, as well as the factors that influence individual willingness to pay, for index insurance for soybean production in Argentina. We conducted a survey in the *pradera pampeana* region of Argentina [10]. The survey data contains productive and socioeconomic characteristics of 200 soybean producers. A hypothetical insurance scheme was proposed to the farmers to investigate the WTP. In the soybean case a yield insurance scheme was proposed to the producers. To avoid moral hazard and adverse selection problems the idea is to use some more objectively measured index that is less subject to the influence of the insured. One such index is crop yield assessed over a local area so as to avoid the moral hazards of insuring yields on an individual farm or field basis.

It is not easy to choose between an index based on crop yields (as used in this survey) and one based on a climate (e.g. rainfall) variable. Advantages and disadvantages are associated with both. In section C we analyzed the performance of an (albeit crude) rainfall-index insurance scheme in the *pradera pampeana*, concluding that additional "fine tuning" is necessary for the rainfall index to be reasonably correlated with losses incurred at the farm level. We chose here for the WTP evaluation a yield index, under the assumption that farmers will find it easier to understand a contract based on area yield, than one based on rainfall. Indeed, while farmers have a keen appreciation of the impact of climate on yields, few have had the opportunity to analyze the relationship between specific values of rainfall and resulting yields. That is, it may be difficult for a given farmer to understand the risk-reducing impact of a contract that offers to pay an indemnity of x if rainfall falls below y.

Each respondent of the survey was given an explanation about the proposed yield index insurance scheme and the costs of the hypothetical product. The explanation was as follows:

[10] The survey area is North-west of the province of Buenos Aires (Leandro N. Alem, Lincoln, Chacabuco, Junin, Trenque Lauquen, Pergamino, Rojas) and south-west of the province of Santa Fe (General Lopez).

Suppose that a company offers an insurance product based on an index of local yields with the following characteristics: If at the end of the crop season the soybean index yield in the County (or local area) is less than XX kg / ha, the insurance company pays an indemnity. Compensation shall be calculated as the difference between XX kg / ha and the final average yield obtained in the area. The average yield in the area is measured from an index built with objective information. If the index is below the pre-agreed value insurance is automatically triggered.

It is important to understand that compensation is paid and triggered by the index value without checking the actual damage in the individual field. That is, you can collect the insurance and no loss of production and vice versa.

(the XX value was randomly assigned with variation over an specific interval for each region/zone)

We estimate the WTP for the insurance product using the results of the two survey questions presented below.

Q1: In the above example, would you be willing to purchase the insurance if the premium is XX kg per insured hectare?

(Different pre-specified premiums were randomly asked by region/ zone)

Q2:. If your answer to Q1 is NO, would you be willing to pay any amount for this policy?

An answer to question 1 in the affirmative implies that the pre-specified premium rate is the lower bound of the distribution of the WTP, while infinity marks the upper bound. Question 2 serves as a follow-up question in the event of a negative response to question 1. An affirmative response to question 2 indicates that zero represents the lower bound and the pre-specified premium rate represents the upper bound. However a negative answer to question 3 means the lower bound of the distribution is negative infinity and the upper bound is zero.

Estimation Methodology

We use a probit model with sample selection (Van den Ven and van Praag, 1981) to estimate mean WTP from the survey data. Choosing to pay for a potential index based insurance product (at the specific coverage and asked premium rate) is contingent on whether an individual wants to buy the index insurance in the first place. Given the specific characteristics of the index insurance it is likely that some individuals do not want to buy index based insurance at any price. Thus, individuals who stated that they did not want to buy index insurance at any price (i.e. that responded "No" to the follow-up question) could be classified as non users.

The probit model with selection has the following structure:

$$Y_{1i}^{*} = X_{1i}\beta_1 + \varepsilon_{1i}$$

$$Y_{2i}^{*} = X_{2i}\beta_2 + \varepsilon_{2i}$$

Where Y_{2i}^{*} is the utility function of an individual reflecting one´s overall attitude towards an index based insurance (signified by a "No" response to buying insurance at any price) and Y_{1i}^{*} is the utility difference between buying the index insurance at the suggested price and not buying. X_{1i} and X_{2i} are the respective vectors of covariates for individual (i), β´s are the associated coefficient parameters and ε_j´s are respective error terms. Y_{ji}^{*} and $Y_{ji}$are associated in the following manner:

$$\text{For every individual (i), } Y_{ji} = \left\{ \begin{array}{l} 1 \text{ if } Y^{*}_{ji} \geq 0 \\ \text{for } j = 1, 2 \\ 0 \text{ if } Y^{*}_{ji} < 0 \end{array} \right\}$$

However, $Y_{1i}$is observed only if $Y_{2i} = 1$.

The second probit equation is based on the complete sample and the first probit equation is based on a selected (or censored) sample. The use of the selection model helps to dissociate the types of consumers (potential buyers and non buyers of insurance at any price) and rectify the potential selection bias.

We fit the following joint maximum-likelihood function (Van den Ven and van Praag, 1981) to estimate the model:

$$\prod_{i=1}^{N1}\phi_2(\beta_1^{'}X_{1i},\beta_2^{'}X_{2i};\rho).\prod_{i=N1+1}^{N2}\phi_2(-\beta_1^{'}X_{1i},\beta_2^{'}X_{2i};\rho).\prod_{i=N2+1}^{N3}\phi(-\beta_2^{'}X_{2i})$$

Where observations 1…N1 are respondents willing to pay the stated premium rate, observations N1+1…N2 are respondents not willing to pay the stated premium rate but willing to pay some lower price and observations N2+1…N3 are "No", "No" respondents, *ϕ_2(.) is CDF of a bivariate normal,* ϕ is CDF of univariate normal distribution and ρ correlation between ε_{1i} and ε_{2i}. Estimation was done using the *Heckprob* procedure in Stata version 10. Mean WTP was calculated using the method for a lineal utility function described in Haab and McConnell (2002).

Table V.4 presents definitions and variables used in estimations. Tables V.5 present the estimated coefficients of the probit models with selection correction. Table V.6 presents the mean WTP values based in the estimated coefficients, conditioning by zone and fixing the independent variables at the mean.

Findings of the estimates include the following:

1. Demand for insurance is negatively sloped – higher premium s result in less insurance being demanded. This result is as expected, however in surveys such as this it is not implausible to obtain non-significant results as regards to the price variable.

2. WTP may be expressed as a fraction of "expected yield" (for early-season soybeans: 2.8 t/hectare.

3. WTP varies across production areas. For example, WTP is higher for the partidos of Lincoln and Trenque Lauquen. This is as expected, as these are located in a "mixed" farming area, a-priori riskier than the "central" production area of the country.

4. Production risk, as measured by yield CV has "correct" (and significant) sign.

5. The planted area, age and education variables are not significant.

We can conclude from this case study that insurance is a relevant option for the transfer of risk; however research aimed at analyzing constraints for the development of the insurance market has been practically non-existent. We analyze possible demand for index-insurance products in soybean production in Argentina and our WTP survey and estimation results shows potential for the development of the market. However, market-making will probably require substantial public investment in climate and yield data, as well as improved know-how on the practical aspects of insurance delivery. Close cooperation between the public and the private sector appears to be necessary for growth of the insurance market. In particular, the "heavy artillery" of the public sector as relates to climate and agronomic yield research needs to be combined with the agility and problem identification capacity of private sector firms. Indeed, know-how gained by these firms in marketing conventional insurance products can help the introduction of new, index-type policies. Although insurance has the potential for improving risk management, in the area studied here many other options exist for the reduction or transfer of risk. Multiple cropping systems, improved capital flows into agriculture, non-farm income and other alternatives compete directly with insurance as risk management tools. A "systems" or "holistic" approach to risk analysis therefore seems called for.

Table V.4: Definition of Variables

Variable	Definition
WTP	Dummy variable (Yes=1)
Premium	Premium (kg/ha)
cvsoy	Coefficient of Variability of Soybean yields (from individual subjective assessment)
Age	Age of the farmer (years)
Edu	Education. Maximum level attained 1=primary school; 2=high school;3=college degree
Z1	Dummy Variable (Zone 1=1) Argentina: Pergamino-Chacabuco-Junín-Rojas
Z2	Dummy Variable (Zone 2=1) Argentina: Alem – General Lopez
Z3	Dummy Variable (Zone 3=1) Argentina: Lincoln-Trenque Lauquen
Selection	Dummy Variable (0 if “No” in response to Q1 and “No” in response to Q2. 1 otherwise)
area	Area under soybean cultivation 2009-2010 (thousand of ha)
Risk	Willingness to take financial risks in a 1 to 5 scale. 1=highly unwilling; 5= highly willing
female	Dummy Variable (1 if female and 1 otherwise)
inc	Dummy variable. 1 if 80% or more of total income is from farming activities and 0 otherwise
agins	Dummy variable. 1 if the farmer uses agricultural insurance and 0 otherwise
area	Total area of the farm (thousand of ha)

Table V.5: Coefficient estimates. Probit model with selection Soybean

Variable	Coefficient	Robust Std. Error	P>|z|
WTP			
premium	-0.018***	0.003	0.00
z1	-0.986***	0.256	0.00
z2	-1.575***	0.258	0.00
Cv	-2.550*	1.515	0.09
Areasoy	-0.189	0.119	0.11
Age	-0.001	0.007	0.79
Educ	0.016	0.157	0.91
_cons	4.939***	0.749	0.00
Selection			
z1	0.024	0.339	0.940
z2	-0.455	0.345	0.190
Female	-0.093	0.258	0.720
Age	-0.001	0.008	0.880
Educ	0.163	0.202	0.420
Inc	0.277	0.265	0.300
Agins	1.570***	0.225	0.000
risk	0.193**	0.080	0.020
Area	-0.032*	0.018	0.080
Cv	2.941	2.423	0.230
_cons	-1.711	1.032	0.430
ρ	-1	0.000	
Observations	199		
Censored Obs.	37		
Non Censored Obs.	162		
Log likelihood	-150.82	Wald chi2(7)	Prob > chi2 = 0.00
Wald test (r = 0)		chi2(1) = 35.22	Prob > chi2 = 0.00

***Significant at 1%; **Significant at 5%; *Significant at 10%

Table V.6: WTP (Mean). Soybean yield insurance

Zone	WTP (kg/ha)
Zone 1	184
Zone 2	151
Zone 3	240
Mean (Average Zone)	189

V.2 Index insurance in dairy production

This section presents several proposals for index insurance schemes for milk production. We first review results obtained by Gastaldi, Galetto and Lema (2009) and Galetto, Lema and Gastaldi (2011), who developed single and combined insurance schemes alternatives for milk production in Argentina, for droughts, excess precipitations and heat stress (temperature and humidity). Following this we propose a new variant of the scheme introduced by Galetto, Lema and Gastaldi (2011) which is developed based on daily precipitation data.

A. Index insurance for milk production in Argentina: Previous results

Gastaldi, Galetto and Lema (2009) developed an index insurance scheme to cope with the consequences of climatic variability in dairy production systems in the northern area of the Santa Fe province, in Argentina. They estimated the impact of rainfall variability through the use of the *Standardized Precipitation Index* (SPI), developed by McKee, Doesken and Kleist (1993) to monitor drought conditions in the U.S. This index is regularly published by the National Weather Service (Servicio Meteorológico Nacional – SMN) of Argentina, and this was one of the reasons which justify its use in the construction of the index insurance scheme. The other reason is that the SPI only requires precipitation data, unlike other indexes, such as the one proposed by Palmer (Palmer, 1965) which in addition to rainfall uses information on groundwater depth.

Gastaldi, Galetto and Lema (2009) found that the impact of rainfall variability on milk production was not symmetrical, at least for the conditions of dairy production systems in northern Santa Fe: production problems (reduction in milk production) associated with excess rainfall were more severe than those arising from drought. Moreover, the excess of rainfall was normally a short run phenomenon, best represented by an SPI2, whilst drought were long run, accumulative phenomena, best represented by an SPI6 (Gastaldi and others, 2010).

Based on the work done previously by the same authors, Galetto, Lema and Gastaldi (2011) developed a more comprehensive index insurance scheme for milk production, for a larger area and using more basic information for the estimation of the insurance scheme parameters. Basically, scheme also uses the SPI as trigger, paying for excess precipitation (using SPI2 as criterion) and deficits (using SPI6 as criterion).

The trigger values were defined using monthly precipitation data (1971-2009 periods) for three points in the northern dairy producing area of Santa Fe (Rafaela and Ceres) and Córdoba (San Francisco). The payments are triggered with SPI takes the following values:

- Lack of precipitation: the insurance pays when SPI 6 $\leq$ -1.75
- Excess of precipitation: the insurance pays when SPI 2 $\geq$ 1.75 if and only if SPI 6 $\geq$ 1

For both type of events there is a maximum payment when SPI6 $\leq$ -2.5 or SPI2 $\geq$ 2.5. The use of a combined criterion for excess precipitation (SPI 2$\geq$ 1.75 if and only if SPI 6 $\geq$ 1) is justified on the ground that high rainfall levels may not be damaging to production if the area was suffering a severe drought (that is, when SPI6 $\leq$ 1).

If an adverse rainfall event (wet or dry period) occurs, the farmer would obtain a payment which is a percentage of the insured amount, expressed in liters of milk. The total payment would be the product of the milk price, the amount of milk insured, the observed SPI value and a payment coefficient which was calculated using an econometric model estimated with monthly milk production data from 303 dairy farms for the period July 2000 to June 2010 (see Table V.7 below).

Table V.7: Payment unit rates (%) for adverse precipitation events for milk production in northern Córdoba and Santa Fe

Season	Month	Payment Unit Rate (%)	
		Excess	**Deficit**
Summer	Dec - Jan - Feb	14.10%	6.60%
Fall	Mar - Apr - May	16.80%	3.20%
Winter	Jun - Jul - Aug	13.10%	7.80%
Spring	Sep - Oct - Nov	8.60%	13.40%
Average		*13.20%*	*7.80%*

As mentioned, for the characteristics of the dairy production systems of the region under study, the events with excess precipitation are more harmful than the deficit events, almost doubling the impact on milk production. The greater impacts are for excess precipitation in fall and lack of rainfall in late winter or spring.

In the work of Galetto, Lema and Gastaldi (2011) there is also an insurance scheme for heat stress events, based on the observed behavior of the THI (temperature and humidity index). The design of the scheme was based on an econometric model which found significant evidences of milk production losses when the THI is greater than 72 (or 76 in the larger farms).

Using this evidence, a heat stress index scheme was proposed, in which the insured dairy farm would receive a payment when the THI > 76, and the payment value would be equal to 3.624 % of the daily milk production per unit of THI larger than 76. For example, for a THI of 80, the payment would be equal to (80 – 76) * 3.624 % = 14.49 % of the daily milk production. Additional details of these schemes, which include several variants for single and combined events, can be found in the already mentioned work of Galetto, Lema and Gastaldi (2011).

B. A new drought index insurance proposal based on daily milk production data

The index insurance proposals presented so far have been developed using monthly rainfall data. However, in an extended period without precipitations it may happen that a sudden and significant storm rainfall episode cannot put an end to the consequences of the drought. This may occur because the absorption capacity of the soil makes it difficult to retain the water. For this reason, we introduce here a new alternative for the calculation of the "standardized precipitation index" (SPI), using daily precipitation data, which is used for drought episodes.

The proposal consists on the calculation of the SPI with monthly precipitation data obtained through the accumulation of daily values of "effective rainfall", which is the amount of rain actually available and useful for crops growth. It depends on the soil type (structure, topography) and the intensity of the rain. This variant of the SPI (which may be called "effective SPI") requires daily information of total rainfall (mm/day) and rainfall intensity (mm/h).

This index insurance proposal was developed only for the city of Rafaela, in the province of Santa Fe. The basic information for the construction of the effective SPI were daily rainfall values from 1 January 1971 to 31 December 2009 obtained from the meteorological station located at Rafaela Agricultural Experiment Station from INTA (Argentina´s National Agricultural Research Institute). The "effective rainfall" was calculated with a scale which is used in the same station for the development of predictive crop models (J.Villar, personal communication, 2011).

The scale considers that rainfall up to 50 mm/day are fully utilized by crops, and above this level they are only partially used (70 %). As an example, the use of the scale is as follows:

- 50 mm = 50 mm x 100% = 50 mm effective
- 60 mm = 50 mm x 100% + 10 mm x 70% = 57 mm effective

Another alternative for the calculation of the effective rainfall is through the use of the method known as "direct runoff" (NRCS, 2004) which involves the estimation of the "runoff" level for the site, which is a value obtained from tables, and it depends on soil use, the soil slope and type, and the previous humidity conditions, which then allows for the calculation of the amount of rainfall not available for crop usage.

In our proposal, the daily values of effective rain (using the INTA method) were accumulated to obtain monthly values which were then used to estimate the “effective SPI6”. The next step was to use the effective SPI6 series to estimate payout probabilities and amounts and average premiums for the insurance proposal for milk production farms.

The use of the effective SPI6 as trigger for drought insurance for milk production increased the number of payouts in comparison with the index insurance scheme developed in Galetto, Lema and Gastaldi (2011). Consequently, it also increased the frequency of payments and the cost of the insurance (pure premium), which is now 0.27% of the insured capital, higher than the value obtained in the original proposal (0.15% of the insured capital).

Summarizing, this proposal is an improvement in the sense that incorporates agronomic criteria which contribute with climate to define yield variability. One the other hand, the problems with this proposal is that it requires daily data, which may not be available and, in general, the simplicity of the standard SPI index insurance contract is lost. Despite the above considerations, advancements in technology make it easier to obtain the necessary information. The basic approach would consist of using satellite generated data to complement rainfall data to obtain daily rainfall values, a method which has also been used in several situations in Latin America (Dinku and others, 2008, Ruiz, 2009).

C. An index insurance proposal for heat stress

The effect of heat stress is higher when it comes in the form of “heat waves”, which are defined as events characterized by three or more days with a THI higher than 72. As already mentioned, these events are particularly relevant in one of the main dairy producing region of Argentina that located in the northern areas of Santa Fe and Córdoba. However, the index insurance proposal advanced by Galetto, Lema and Gastaldi (2011) does not take into account whether a dairy heat event is included within a “heat wave” as defined above. That is, it pays for isolated heat stress events. Therefore, we found it valuable to propose an index scheme based on heat waves as the trigger of the payment.

The period of the year covered by the contract is from October to March, and it has two "triggers". Trigger 1, when THI > 76, but it has to be included within trigger 2, when there is a period of three consecutive days with THI > 72. For example:

Day 1: THI 70

Day 2: THI 77 — **Doesn´t trigger,** because it is an isolated event of THI > 76.

Day 3: THI 71

Day 4: THI 74

Day 5: THI 70

Day 6: THI 73

Day 7: ITH 75

Day 8: THI 78

HEAT WAVE, 3 days with THI > 72

Triggers, because it is included within a heat wave

Following this new trigger scheme, and using the same unit coefficients proponed by Galetto, Lema and Gastaldi (2011), which was 3.624 % of daily milk production per unit THI above 76, we recalculate the frequency and amount of payments and the pure premium.

The (pure) premium for the new proposal is reduced in 13 and 17 % for Ceres and Rafaela, due to the lower frequency of payments, which also makes this scheme more interesting since could be sold at a lower cost.

D. Willingness to pay for dairy index insurance

Following the conceptual framework presented in section V.1, we propose the use of the price contingent valuation methodology to assess the willingness to pay for an index insurance product for milk producers. In order to collect the required data for the study we conducted a farm level survey to 165 milk producers, primarily in person using enumerators, in the central region of Argentina (See Map 1). Producers were selected randomly from a population of 500 farmers who are suppliers to a leading milk cooperative industry.

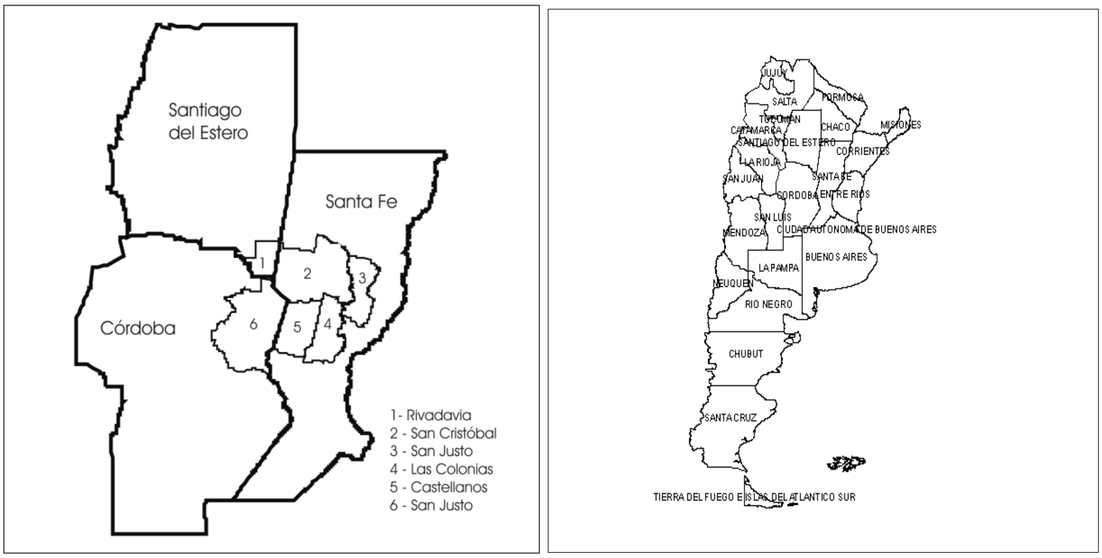
Each respondent was given an explanation about the index insurance and the hypothetical product and was asked questions to confirm understanding. The explanation was as follows:

Suppose that a company offers insurance against drought and excess rainfall events. The capital to ensure (coverage) is 15% of the monthly milk production in case of occurrence of an event. With a fixed component of 10% and 5% variable depending on the intensity of the event calculated from a weather index. That is, the milk producer always takes at least 10% (if the event occurs) and the remaining 5% is calculated based on the intensity of the event of drought or extreme humidity.

The occurrence and intensity of the event (drought or extreme humidity) is measured from an index built with rainfall and temperature information provided by Weather Stations in the area. If the index exceeds a certain pre-agreed value insurance is automatically triggered.

It is important to understand that compensation is paid and triggered by the climate index value without checking the damage. That is, you can collect the insurance and no loss of production and vice versa (because the association between the index and the output is high but not perfect).

Map V.1: WTP Survey Study Zone



We estimate the WTP using the results of the two survey questions presented below:

Q1 In the above example, would you be willing to purchase the insurance if the premium rate is XX percent of the insured milk?

(Four pre-specified premium rates –XX- were randomly asked : 3%, 5%, 7% and 9%)

Q2. If your answer to Q1 is NO, would you be willing to pay any amount for this policy?

An affirmative answer to question 1 implies that the asked premium rate is the lower bound of the distribution of the WTP, while infinity marks the upper bound. Question 2 serves as a follow-up question. An affirmative response to question 2 indicates that zero represents the lower bound and the pre-specified premium rate represents the upper bound. A negative answer to question 3 means the lower bound of the distribution is negative infinity and the upper bound is zero.

The survey generates 165 usable responses. Table V.8 presents the summary statistics of the data collected as well as how each variable was defined.

Table V.8: WTP Survey
Summary statistics and variable descriptions

Variable	**Mean**	**Min**	**Max**	**Std.Dev**
Age (years)	55	23	84	12,56
Education (Maximum level attained - 1=primary school; 2=high school;3=college degree)	1,72	1	3	0,75
Percentage of income derived from milk production (1=+80%; 2=60/80%; 3=40/60%; 4=-40%)	1,61	1	4	0,90
Farm Size (Total Farm Area in Hectares)	194	0	1.425	205,52
Number of cows (heads)	290	10	1.300	223,43
Use of Insurance Market (Yes=1; No=0)	0,47	0	1	0,50
Risk Aversion (Willingness to take financial risks in a 1 to 5 scale. 1=highly unwilling; 5= highly willing)	2,86	1	5	1,31
Milk Producción (year 2009-10 in thousand liters/year)	685,35	47,95	2.325,18	405,85
Zone 1 (Castellanos and San Justo County – Santa Fe Province)	0,40	0	1	0,49
Zone 2 (San Justo County – Córdoba Province)	0,27	0	1	0,45
Zone 3 (Rivadavia County –Santiago del Estero Province- and San Cristóbal County –Santa Fe Province)	0,33	0	1	0,47
Willingness to Pay (Index insurance at 3%, 5%, 7% or 9% premium rates) (Yes=1; No=0)	0,50	0	1	0,50
Willingness to pay any amount (Yes=1, No=0)	0,71	0	1	0,45
Number of respondents: 165 Date: November-December 2010				

Econometric Estimation Methods

We follow the approach presented in section V.1C, a probit model with sample selection (van de Ven and van Praag, 1981) to estimate mean WTP.

Model specification is as follows: the selection model contained the variables *age*, *edu*, *production and risk* (See Table V.9 for definition of variables).

Table V.9: Definition of Variables.

Variable	**Definition**
WTP	Dummy variable (Yes=1)
Premium	Premium (%)
Cows	Number of cows (thousand of heads)
Age	Age of the farmer (years)
Edu	Education
Z1	Dummy Variable (Zone 1=1)
Z2	Dummy Variable (Zone 2=1)
Z3	Dummy Variable (Zone 3=1)
Selection	Dummy Variable (0 if “No” in response to Q1 and “No” in response to Q2. 1 otherwise)
Production	Milk Producción 2009-2010 (thousand of liters/year)
Risk	Risk Aversion

The production variable is included in the selection model under the assumption that preferences for insurance contracts vary with the size of the farm. The WTP model includes variables *premium, age, education, cows, z2 and z3*. The premium variable identifies the price of insurance, cow is a proxy variable of wealth. The variables age, education, z1 and z2 are controls for individual characteristics and location of the farm.

Estimation was done using the Heckprob procedure in Stata version 10. Mean WTP was calculated using the method for a lineal utility function described in Haab and McConnell (2002). To provide some additional information on the distribution of WTP we also calculated the Turnbull distribution-free mean estimator (Haab and McConnell, 2002).

Estimation Results

Table V10 contains the estimated coefficients and standard errors for both the selection and WTP equation. For the selection equation production has a positive and significant effect. For the WTP equation results indicate a positive and significant sign on the zone variables. The positive sign indicates that producers located in the more risky zones (2 and 3) are willing to pay a higher premium. The education variable is negative and significant in both equations, indicating that more educated people are less willing to pay for insurance. This unexpected result may follow from the fact that the more educated milk producers have more sources of off-farm income and, in consequence, their potential demand of insurance can be lower.

Table V.10: Coefficient estimates - Probit model with selection

Variable	Coefficient	Std. Error	P>|z|
WTP			
Premium	-0.141***	0.047	0.00
Cows	0.503	0.508	0.32
Age	-0.016*	0.009	0.08
Edu	0.052	0.163	0.75
Z2	0.445*	0.254	0.08
Z3	0.825***	0.245	0.00
Constant	1.522*	0.802	0.06
Selection			
Production	0.001*	0.000	0.10
Age	-0.003	0.011	0.77
Edu	-0.303*	0.189	0.10
Riks	0.006	0.120	0.96
Constant	0.072	0.092	0.43
□	-0.999	0.076	
Observations	161		
Censored Obs.	25		
Non Censores Obs.	136		
Log likelihood	-146.22	Wald chi2(5) = 24.01	Prob > chi2 = 0.0005
LR test (ρ = 0)		chi2(1) = 1.88	Prob > chi2 = 0.17

***Significant at 1%; **Significant at 5%; *Significant at 10%

Table V.11 presents the estimated WTP values based in the estimated coefficients, conditioning by zone and fixing the independent variables at the mean.

Table V.11: WTP (Mean) by Zone

Zone	WTP (%)
Zone 1 (Rafaela County)	6,09
Zona 2 (San Francisco County)	9,25
Zone 3 (Ceres County)	11,94
Mean (Average Zone)	8,91

Mean WTP is increasing from 6% in Zone 1 to 12% in Zone 3 a result that is consistent with the fact that the more risky the location the more is the WTP. On average respondents appear ready to pay a premium rate of 8.9% for the insurance.

Table V.12 presents the relative frequencies used to calculate the Turnbull estimator. Table V.13 presents the Turnbull lower bound estimate that results in a premium rate of 10.8% for the proposed insurance policy.

Table V.12: Turnbull Estimator – Relative Response Frequencies

Premium (tj)	**Negative Responses (Nj)**	**Total Responses (Tj)**	**F*j (Nj/Tj)**	**f*j (Fj+1-Fj)**
3	13	44	0,2955	0,2955
5	20	41	0,4878	0,1924
7	24	40	0,6000	0,1122
9	25	39	0,6410	0,0410
9+			1	0,3590

Table V.13: WTP (Mean) –Turnbull Estimator

	Mean (Lower Limit)	**Std. Dev**	**Confidence Interval 95%**	
WTP	10,78	0,34	10,12	11,45

VI. CONCLUSIONS AND RECOMMENDATIONS

Agricultural production is of primary importance in Argentina, not only does it contribute to a major part of export earnings, it also supplies practically the total food consumed by the population of these countries. The agricultural and agribusiness sector, moreover, accounts for a significant portion of total employment. Our research focuses on the possibility of obtaining welfare or production efficiency gains via public policy measures aimed at increasing the use of risk transfer mechanisms insurance in agricultural production.

In many Latin American countries poor functioning of financial markets limit the possibilities of smoothing inter-year income variability. Futures and options markets - of major importance both for price forecasting as well as for the transfer of risk - are insufficiently developed. In these countries production variability of grain and oilseeds translates directly into farm-level income variability. Production risk may have impacts beyond the farm gates. The fortunes of rural areas are partially "tied" to what happens in farms.

This paper has shown that production risk is a factor to be taken into account when analyzing the agricultural sector. Despite its importance, not much is known about risk and its impacts on resource allocation, efficiency and welfare in rural areas. Insurance is an important mechanism for risk-transfer that has grown significantly during the last years; however the majority of insurance policies base indemnity payments on damage assessment at the individual farm level. Index or "parametric" insurance is non-existent.

The research shows evidence that insurance policies based on area-wide indexes are valued by farmers: WTP results from questionnaires are in principle sufficiently high so as to merit further attention on the part of policy makers, producer organizations and researchers. WTP derived from questionnaires have obviously to be taken with a "grain of salt" as they result from answers to hypothetical questions and not actual choices revealed in the market.

Our results suggest that milk producers apparently have an "effective" interest in insurance, i.e. they are willing to pay for the product. Using survey data and standard willingness to pay techniques we assessed the premium rates milk producers are willing to pay for an index based insurance. In general, milk producers in Argentina appear willing to pay premium rates of 6 to

12 percent for insurance. Estimates of the pure (actuarial) premiums for this type of index insurance are on average 2.5 percent. Insurance companies usually increases this figures from 25% to 50% to cover administrative costs and other expenses. In consequence, the estimated WTP values are well above the estimated pure premiums, indicating that an index based insurance market could be possible and profitable for insurance companies.

For the soybean study case a yield insurance scheme was proposed to the producers. To avoid moral hazard and adverse selection problems the idea is to use some more objectively measured index that is less subject to the influence of the insured. One such index is crop yield assessed over a local area so as to avoid the moral hazards of insuring yields on an individual farm or field basis. WTP may be expressed as a fraction of "expected yield": for early-season soybeans our estimates are 2.8 t/hectare. WTP, varies across production areas; for example is higher for the partidos of Lincoln and Trenque Lauquen. This is as expected, as these are located in a "mixed" farming area, a-priori riskier than the "central" production area of the country (also, in these partidos expected indemnities are higher). Summarizing our soybean results, a comparison of WTP and expected indemnities suggests possible opportunities for risk-transfer via insurance. Our data base allows additional analysis that will further illuminate this issue.

Most of the existing agricultural insurance systems in the world are heavily subsidized. Abundant research exists on this topic in many countries. The challenge of course is to provide some guidelines for an insurance program to cope with agricultural risk that is able to "stand on its own" in the sense that public participation is limited to aspects such:

1. Producing basic information used for insurance contracts (weather and yield data, soil types, farm numbers, planted area etc)
2. Providing specialized scientific and technical support
3. Acting as a facilitator or coordinator of activities of different parties,
4. Acting as a liaison with institution in other countries that can transfer their experience. For example, the FAO, the World Bank, USDA, IFPRI, Agriculture Canada and others.

5. Providing know-how for the setting up of private mechanisms for mediation and conflict resolution

6. Proposing changes in legislation related to agricultural insurance

7. In limited cases, helping insurance companies to reach agreements with reinsurers

We discuss below some of the issues that need to be addressed for viable index insurance to develop.

VI.1 Legal issues

In the case of Argentina the insurance industry is regulated by a specific law (N° 17418/1967) which requires an "in-situ" verification of the damages. Therefore, in the view of insurance regulators, index insurance schemes cannot be introduced in Argentina. However, this view is "extreme", typical of the standard government agency which shows prudent behavior before an innovation (such as index insurance) can be approved. Other government agencies as well as private companies are actively exploring alternatives. In particular, industry participants consider that sooner or later a wider interpretation of the law will prevail.

VI.2. Availability of weather data

There is widespread agreement that a prerequisite for the successful development of a weather-based index insurance contract is the availability of abundant and reliable weather data. It may happen that in addition of the "official" weather network there are other private or cuasi-official networks. This is the case of Argentina, with many weather stations operating outside the network of the National Weather Service (Servicio Meteorológico Nacional – SMN), such as those belonging to INTA or the Rosario Board of Trade. Therefore, in order to have a solid base with climate data, there should be a national effort to coordinate the various networks so that their results share the same standards.

VI.3 Availability of yield data

Considerable progress can be made in Argentina in relation to yield forecasting and yield estimation. Currently, agricultural yields are reported at the level of the basic political-administrative unit (partido or departamento). These political units frequently cover many thousands of hectares. In Argentina, and as relates to soybeans, many partidos cover 150.000 – 200.000 planted hectares to the crop. The departamento of General Lopez (Santa Fe province in Argentina) is even larger, covering more than 600.000 hectares of soybeans.

Yield estimation suffers not only because of the coarse grid in which yields are estimated, but also because of (i) lack of timeliness, (ii) crude estimation methods, (iii) no cross-checking. Improved estimation of yields, both during the growing season (yield forecasts) as well as during the harvest period is an important input for many purposes. Crop insurance programs based on area-yield indexes require accurate and timely yield information. A high-quality yield estimation program requires substantial resources, however a-priori it would appear that these resources are well within the capacity of the country. In particular, public-private partnerships provide an excellent alternative for yield estimation to be carried out at very reasonable costs. Sampling methods for objective yields surveys reduce the costs of obtaining field-level information. Telephone and internet-based "subjective yield" information gathering provides an important complement. In Argentina, private NGO´s such as the CREA (Consorcios regionales de Experimentación Agropecuaria) groups and AAPRESID (Asociación Argentina de Productores de Siembra Directa) may be interested in this kind of project.

Honesty in reporting is undoubtedly a problem to be solved. An index-based insurance program results in decisions potentially involving substantial amounts in payments. The possibility of interested parties attempting to influence the direction or magnitude of these payments is always present. Note that in the case of a conventional insurance policy, damages are assessed in-situ. Adverse selection and moral hazard are certainly problems to be reckoned with, however settlement of payment takes place with the interested parties (insurance company representative, the insured party and possibly independent damage assessor) meeting face to face. In the case of the index-insurance information necessary for damage assessment is gathered indirectly y a third party. How this information is gathered and analyzed may be quite opaque to interested parties – in any case these may set up some kind of supervision or cross-checking procedures.

An important aspect to be taken into account in relation to yield (or for that matter weather-based) indexes is what "conflict resolution" procedures are put in place, and whether these are binding or not for settlement without recourse to formal the legal process. The "Camaras Arbitrales" (grain trading bourses) in Argentina have private (and binding) conflict resolution practices in place that could serve as models for an index insurance scheme.

VI.4 Remote sensing

Remote sensing technologies are advancing at a rapid pace and need to be explored as a complement or a substitute of traditional weather stations. Relatively low cost data, "objectivity" and low risks of tampering make data generated with remote sensing technologies particularly interesting for index-based insurance schemes. Research is needed in order to explore applications of these technologies for insurance purposes. A multidisciplinary approach involving crop and animal production specialists, climatologists, remote sensing scientists and agricultural economists is called for.

VI.5 Basis risk

One of the problems of implementation related with index insurance is the existence of basis risk, that is, the fact that farm risks (in our case the variability of milk production) are not well correlated with the behavior of the index used in the contract. One of the key issues to reduce basis risk is the availability of weather data but there are other alternatives which could be explored. For example, in the case of dairy farming, instead of using milk production as the "risk variable" it is possible to decompose the milk production process into the different sub-processes and then design a separate contract for each of these (e.g. maize, sorghum production for feed, alfalfa for grazing). A separate contract can also be designed for the direct weather impacts on the animal. This would result in a "chained multirisk contract".

VI.6 Climate and dairy production systems

In the case of dairy production systems there is a link between the intensification of the production process, the increase in the herd size and the impact of weather related problems, particularly excess rain and heat stress events. "Intensification" means that a growing portion of feed comes from outside the farm, thus weakening the link between climate and production. On the other hand, the growth of the dairy herd makes increases its vulnerability to the direct impacts of weather on the animal (heat stress in particular). Therefore, an important line for further research is to explore the links between weather, pasture, costs, animals and production for the type of large dairy farms which likely to develop in the future, allowing too for considerations of animal welfare.

VI.7 Index insurance and disaster relief program

Many countries operate "disaster relief programs", which are based on assessments of damages in large areas. They therefore carry an important degree of "basis risk", particularly for livestock (beef and dairy) farms. A properly designed weather-index insurance scheme is a superior alternative for the traditional disaster relief programs. These programs are costly, difficult to understand by farmers and subject to different kinds of political interference. Insurance programs, in contrast, fit naturally with the overall risk-strategy used by the producer. Studies need to address the issue of replacing disaster relief programs with index insurance schemes.

VI.8 Aggregation

Many insurance industry officers consider that index insurance is only be viable if there is some form of "aggregation", in the sense that all (or most) farms in a given region purchase the insurance. Therefore, there is scope here for the development of programs which include provincial governments (subsidizing partially the premium) or dairy companies, facilitating the provision of insurance for their farmers. In the case of dairy processors, they could use these schemes to insure their own losses when a disaster occurs, in the same fashion that an energy company uses and indexed contract. In the case of the government, whether be at the provincial or national level, the provision of this type of contract could also be a part of a dairy development program, particularly when the expansion of the production frontier is a national priority.

VI.9 Climate Change and adaptation to climate

Adaptation to weather patterns and to climate change is a very important issue for agricultural producers. Some headway has been done in recent years (for example, developing strategies for making use of "Niño/Niña" forecasts), however much progress can still be made. Research on how producers cope with weather variability, on multiple-cropping systems, on crop improvement to meet weather variability should be high in the research agenda.

VI.10 Pilot project

A "pilot project" carried jointly by governments (national, provincial), insurance companies and farmers appears as an important first step for progress to be made in relation to index insurance schemes. Much is learnt by "learning by doing". In particular, a pilot project should focus attention on deriving usable indexes, data gathering procedures, drafting contract models to be used, and designing mechanisms for settling payments and resolving disputes.

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