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Risk in Investment Decision Making and Greenhouse Tomato Production Expansion in Florida

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Abstract

The outcomes of agricultural investment decisions are affected by the risk in price, cost, and yield outcomes. To examine those risks, net present value models with Monte Carlo simulation are used to analyze the viability of greenhouse tomato investment decisions. The analysis is further extended by utilizing a real options approach. The results indicate that a grower would choose to continue field-grown tomato production due to high option values and risk aversion. Moreover, some policies or market conditions which increase credit availability, decrease energy prices, reduce tomato price fluctuation and/or facilitate effective risk management strategies would make the greenhouse production preferable.

Keywords: risk in investment, greenhouse tomato, real option approach, stochastic dominance and efficiency

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Introduction

The severity of international competition, new trade agreements, change in government policies, weather conditions, and fluctuations in yield and price have significant impacts on the agricultural entities (Harwood et al. 1999). All these factors are combined in the notions of risk and uncertainty. Decision making under risk is a critical component in agricultural management. Growers make decisions by selecting one among many alternatives to diminish the negative economic effects of risky conditions. Additional information about uncertain factors and effective risk management strategies helps producers make better decisions. Risk management tools include enterprise diversification, vertical integration, contracts, hedging, options, liquidity, insurance, and off-farm employment (Harwood et al. 1999). The use of alternative risk management strategies depends on the grower's risk perception, information availability, and the availability and impact of government farm programs.

The risk-based model is widely used by academics and business consultants to explore investment decisions made by growers. Studies in this topic generally focus on (a) decision-making under risk and uncertainty, (b) application of stochastic dominance, and (c) the real option approach for investing in a new technology.

The risk analysis methodologies proposed in the studies can be summarized chronologically as follows. Initially, risk programming was applied by Hazell (1971) to examine risky decisions; later, Anderson, Dillon, and Hardaker (1977) focused on the role of producers' risk attitudes; further, an empirical analysis of effective educational programs to facilitate risky decision-making was provided by Nelson and Harris (1978). Then, Young (1984) improved the methods of measuring risk. More general efficiency criteria for ordering risky choices were introduced by King and Robison (1981), and stochastic simulation was proposed by Mapp and Helmers (1984). More applications of risk analysis in production, marketing, and finance are also published by various researchers (Robison and Brake 1979; Sonka and Patrick 1984). Collins and Barry (1986) evaluated a single-index model using two separate approaches in portfolio analysis for agricultural firms. In addition, Williams, Llewelyn, and Barbany (1990) examined risk-based decisions in the context of stochastic dominance between two systems and for five crop rotations. They provided results focused on the preference of risk-averse managers.

Simulation is a widely covered subject; however, most of the existing studies are not written for agricultural economists and do not relate to agricultural firm-level models. The earliest simulation as a tool for analyzing risky decisions was suggested by an agricultural economist goes back to the 1970s (Richardson and Mapp 1976, Anderson, Dillon, and Hardaker 1977). These studies used various types of equations and identities to construct the Farm Level Income and Policy Simulation Model (Richardson and Nixon 1982). Recently, Richardson, Klose, and Gray (2000) developed a procedure for estimating and simulating probability distributions in farm-level risk assessment and clearly described the procedure on how to analyze risk by this method. This methodology is used widely in the literature (Richardson, Lemmer, and Outlaw 2007; Palma et al. 2011). One of the rare studies on greenhouse production by Uva et al. (2000) investigates risk for adopting any of four commonly used zero runoff sub-irrigation systems in greenhouse operations described in different crop categories with a Monte Carlo simulation approach. Last, Iwai and Emerson (2008) combined risk analysis with a Monte Carlo simulation by calculating NPV and the real options approach to assess sugarcane mechanization investment in Florida.

In lieu of previous studies, the goal and the strength of this paper is to examine possible tomato production alternatives for Florida producers by using different risk analysis tools and incorporating various risks into the decision making analysis. Thus, this study develops a comprehensive investment decision model that implements Monte Carlo simulation and the real option approach to look at the decision to invest in greenhouse production systems. The results indicate that a grower would choose to continue with field-grown tomato production due to high option value and risk aversion. These results are consistent with what has been witnessed in tomato production in Florida. However, policies or market conditions such as an increase in credit availability, decreased energy prices, reduced tomato price fluctuation, and/or facilitating effective risk management strategies would make greenhouse production preferable for Florida producers.

Overview of the Fresh Tomato Market in the United States

Among all the vegetable crops in the United States, the total value of production is the highest for tomato production (USDA-ERS 2013a). Tomato demand in the U.S. is high during all 12 months of the year (USDA-ERS 2013b). Fresh tomatoes are harvested in California during all seasons except winter. In Florida, tomatoes are harvested from October to June, with peak production from November to January. Most of Florida's tomato production is shipped to the eastern United States while Mexico provides fresh tomatoes for the western United States (VanSickle, Evans, and Emerson 2003). Overall, almost one-third of the fresh tomatoes consumed in the United States is imported from Mexico and Canada during the off-season period. Around 40% of the Mexican and the large majority of Canadian tomatoes imported to the United States are produced in greenhouses (USDA-FAS 2013). Other countries like the Netherlands and Spain also export greenhouse tomatoes to the United States, but in smaller quantities.

Florida field-grown production supplies tomatoes largely for the winter market in the eastern US markets while northern and western US field-grown production supplies the summer markets. California supplies its tomatoes mostly west of the Mississippi River in spring and summer. Florida producers get higher prices for their product because they produce when lower winter supplies result in higher prices (USDA-ERS 2012b). Tomato production in Florida fell from 22,250 hectares (55,000 acres) in 1990 to 12,140 hectares (30,000 acres) in 2012 (USDA-ERS 2013b). Overall, competition with Mexican producers affects the profits of Florida tomato producers that have traditionally benefited from higher prices in the winter market. Figure 1 demonstrates the last 10 years of domestic and import tomatoes in the U.S. market. Domestic fresh tomatoes supply went down 25% from the peak level in 2005. The supply of fresh tomatoes imported from Mexico almost doubled in ten years, from 2002 to 2011, surpassing US domestic tomatoes after 2010.

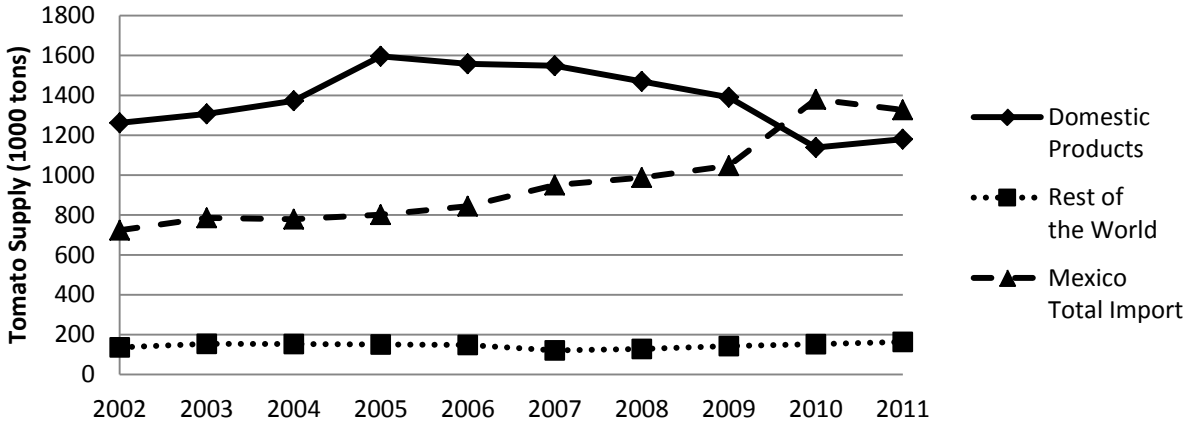

Figure 1. Fresh tomato supply in the U.S. market

Most U.S. states, except Florida, and Mexico and Canada produce tomatoes during the summer season so supplies are generally high and prices are relatively low. However, the dynamics are different during the winter season when the main tomato suppliers are the state of Florida and Mexico. Florida produces mainly field-grown tomatoes. Every year, Mexico is shipping more and more greenhouse/screen-house tomatoes to the United States. Figure 2 shows the disaggregation of tomato imports from Mexico by field-grown and greenhouse tomatoes. The composition of Mexican imports has been significantly enhanced by greenhouse production, and it has been observed that the increase in Mexican tomato imports is associated with the increase in greenhouse tomato imports specifically.

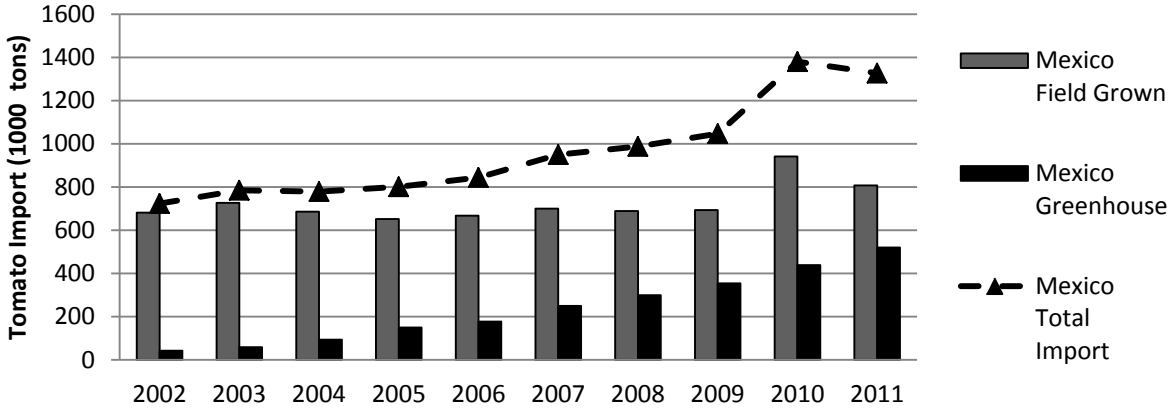

Figure 2. Tomato imports from Mexico by technology

The increase in Mexican tomato imports has coincided with a trade conflict between imported and U.S. domestic fresh winter tomatoes. International competition has been an issue in the industry since the early 1970s (Bredahl, Schmitz, and Hillman 1987; VanSickle, Evans,and Emerson 2003). Given that tomatoes are the highest valued fresh vegetable crop, the U.S. fresh tomato market is favored by importers and domestic producers alike. While importers have increased their shares with lower prices, domestic producers have attempted to keep their share in the tomato market without any costly investment in production practices. However, due to the demand for high quality tomatoes by U.S. consumers and the minimum reference price applied

to Mexican tomato imports (USDOC 2013), Mexican producers have increasingly shipped larger quantities of greenhouse tomatoes with higher quality to compete with Florida field-grown winter tomatoes. Mexico greenhouse production acreage increased to 12,000 hectares in 2012, and 70% of this acreage was devoted to tomato production (SAGARPA 2013). Competition with Mexican greenhouse tomato producers pushed winter tomato producers (particularly in Florida) to consider new investment opportunities like greenhouse tomato production.

Since 2000, U.S. greenhouse tomato production increased two-fold (from 122 thousand tons in 2000 to 244 thousand tons in 2011), although its share in the total fresh tomato market is still relatively low at approximately 15% (Figure 3). However, for the retail market specifically, more than 40% of domestic tomatoes are produced using greenhouse technologies (USDA-ERS 2013b). California and Arizona have become the key states for greenhouse production since the competition with Mexican greenhouse tomato producers drove them to switch to this niche market during the winter season when the tomato price is at the peak level. Moreover, recent studies also show that greenhouse tomato production in the U.S. market is in the boom phase and will continue to grow.

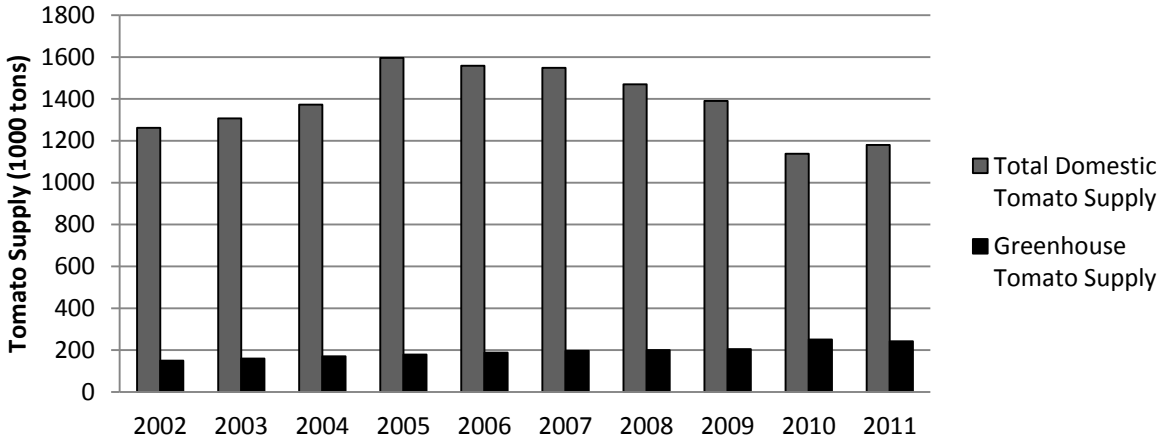

Figure 3. Domestic fresh tomato market in the United States

Fresh tomato prices are known to be sensitive to the instabilities of supply that lead to price volatility. Florida's biggest winter tomato competitor, Mexican greenhouse production, has between three- and twenty-fold more yield (on per-square meter basis) than Florida field-grown production. Although greenhouse production cost is high, its competitiveness in revenue and quality can be better than that of field-grown tomatoes. Hence, imported greenhouse tomatoes have opportunities to increase their market share in the United States (Cantliffe and VanSickle 2003). Overall, the increased interest in greenhouse tomato production in the southwestern U.S. states, as well as increasing competition from imported Mexican greenhouse tomatoes have subsequently decreased winter tomato prices, and hence the profits of Florida producers.

There are advantages and disadvantages to greenhouse production. The controlled environment of greenhouse production gives high and stable yields. It also enables growers to perfect crop timing and to supply winter markets when fresh market prices are at a premium. In contrast, the disadvantages are high initial investment costs, high operating costs, and energy-intensive production practices. Aforementioned, investment and operating costs for greenhouse tomato

production are higher than those of field production, and as a result, greenhouse production is often perceived by Florida producers as more risky (Cook and Calvin 2005). The main risk factors for tomato production can be identified as yield, price, and cost risks (Table 1).

Table 1. Risk identification for greenhouse and field-grown tomato productions

Risk parameters	Risk source	Greenhouse	Field-grown
Yield Risk	Weather	Low	High
Price Risk	Supply/ Demand relationship	Relatively low	High
Cost Risk	Input – Energy – Labor expense variability	High	Relatively low

Source. Compiled by author based on the literature (Harwood et al. 1999; Roberts, Osteen, and Soule 2004).

Controlled atmosphere almost eliminates much of the yield risk in greenhouse production whereas yield risk is high for field grown production. An industry survey indicates that tomato yields vary from 9 to 14.5 kg (20–32 lbs) per plant per year in a regular greenhouse while yield can range from 21 to 23 kg (46–50 lbs) per plant under the best greenhouse technology (Pena 2005). Furthermore, a field-grown trial showed that per plant tomato yield generally ranges from 3 to 7 kg (6–15 lbs) per plant in Florida (Santos et al. 2013).

The source of price risk lies in the supply and demand relationship. Stabilized greenhouse production (i.e., the ability to target harvesting time to the periods when prices are high) reduces this price risk. Moreover, low-priced imported tomatoes increase price risk for domestic greenhouse and field-grown producers. Finally, cost risk comes from inputs like energy and labor expenses. High operating costs and energy intensive production processes increase the chances of negative profits for greenhouse production although there are some technological improvements to reduce this risk. However, cost risk is relatively low in field-grown production. Nevertheless, the investment in greenhouse production systems may be a viable option for growers in Florida, since this technology results in greater yields, higher quality products, and a more stable market demand and/or prices than current field-grown production technologies.

This paper incorporates risk into the net present value and real option analysis to investigate the potential benefits of Florida tomato producers investing in greenhouse production methods. The feasibility of the greenhouse investment opportunity is evaluated given the decision maker's risk aversion and the different revenue and cost structures of tomato production technologies. Therefore, the study also investigates whether the investment in greenhouse technology allows Florida producers to increase their per unit revenue or reduce their production costs to keep their market share.

Data and Models

The financial models to analyze tomato production in Florida are built on three different production budgets. The first budget set is called the patriot model based on the high technology greenhouse tomato production system (Greenhouse-HT) which has higher costs and higher yield than the typical Florida greenhouse production (VanSickle 2011). The second set is for the typical greenhouse tomato production in Florida (Greenhouse-FL); this set relies on the enterprise budget information from the University of Florida's Small Farm and Alternative

Enterprises project team (Smith et al. 2009). This budget was updated to 2013 by UF extension agents. The last budget contains the field-grown tomato production budget provided as interactive budget tables for Florida field-grown tomato by University of Florida, Food and Resource Economics Department (Smith and VanSickle 2009). The first two sets use different greenhouse sizes (the patriot model is based on 120,000 square meters [29.7 acres] greenhouse area and the Florida greenhouse budget is based on 335 square meters). According to the agricultural census, the average tomato farm size is 28 hectares taken as a base to construct a budget for field-grown tomatoes in Florida (Agcensus 2012). For this analysis, all the budget sets are adjusted to a 4047 square meters basis (one acre) to make relevant comparisons between field-grown and greenhouse production systems. Therefore, we assume that the producer will decide based on comparing the technologies at the same scale and allocate land according to the chosen technology. Since the budgets are chosen at the average investment size for these technologies, the producer would invest in the feasible size when the decision is made.

The budget data are inserted into pro-forma financial statements, namely the income statement, cash flow statement, and balance sheet, for each production technology. The financial model is constructed in Excel add-in Simetar©, a simulation and risk analysis software (Richardson, Schumann, and Feldman 2008). The data include expected yield, expected unit price, variable cost, fixed cost, construction cost, and durables expense. The initial equity (IE) requirement for field-grown production (fg) is assumed to be zero while it is set to $8.65/square meter ($35,000.00/acre) for greenhouse production. This value is calculated from the financial model as a minimum requirement to ensure that the cash balance never falls below zero at the mean for a rational investment decision.

Working capital loans are provided for 90% of the annual variable production cost at an interest rate of 5%. It is further assumed that 80% of the equipment and durables costs for greenhouse tomato production are funded with a seven-year loan at 8% interest. The rate of return to investment is assumed to be 10% based on previous literature (Richardson and Mapp 1976), which is used as a discount rate for the Net Present Value (NPV) analysis (Table 2).

Table 2. Key assumptions used in greenhouse tomato financial model*

Variable	Unit	Value
Operating Loan Length	Years	1
Operating Loan Interest Rate	Percent	5.0
Long-term Loan Length	Years	7
Long-term Loan Interest Rate	Percent	8.0
Interest on Equity Invested	Percent	10.0
Corporate Tax Rate	Percent	25.0
Inflation Rate	Percent	2.0
Increase in Energy Prices	Percent	7.0

Note.*The assumptions are constructed based on the data collected from IRS (2012), US-EIA (2013), and USDA-FSA (2014).

Greenhouse production requires approximately from 15 to 30 times more start-up cash than does field-grown production (Table 3). The largest expense for greenhouse production is the growing

cost since the high yield requires higher cost seedlings and chemical expenses (Table 4). Labor cost for Florida greenhouse production accounts for the big portion of total expense. It is observed that the higher yield in greenhouse production leads to lower per-unit sales costs as compared with field-grown production. The budget summaries reveal that greenhouse production is an energy-intense technology because energy cost accounts for a significant portion of the total production cost.

Table 3. Initial investment budget for three production technologies (in dollars per acre*)

	Field-grown	Greenhouse – FL	Greenhouse - HT
Initial Equity	$—	$35,000.00	$35,000.00
Total Liability	$13,150.00	$620,919.07	$1,299,292.49
Start-up Cash	$13,150.00	$196,322.35	$389,055.81
Construction Cost & Durables	$—	$459,596.72	$945,236.68

Note. *1 acre is equal to 4,046.86 square meters.
Source. Based financial model built on three budget sets

Table 4. Annual operational cost for three production technologies (in dollars per acre*)

	Field-grown	Greenhouse – FL	Greenhouse – HT	Shares of Production Cost		
Growing Costs	$7,218.09	$27,043.08	$170,147.20	41.20%	11.48%	33.41%
Energy Costs	$—	$58,040.68	$93,297.17	0.00%	24.64%	18.32%
Labor Costs	$354.92	$74,653.13	$131,167.23	2.03%	31.69%	25.76%
Sales Costs	$5,815.80	$53,005.56	$80,520.31	33.19%	22.50%	15.81%
Administrative	$4,132.85	$22,852.22	$34,151.64	23.59%	9.70%	6.71%
Total Production Cost	$17,521.66	$235,594.67	$509,283.54	100.00%	100.00%	100.00%

Note. *1 acre is equal to 4,046.86 square meters.
Source. Based on three budget sets (see Appendix for details).

The simulated net income statements (NIs) of all three tomato production technologies are computed at the expected level for 2014 (Table 5). The simulation result shows that the break-even production points are 26 kg per square meter (22 lbs per plant and 10,650 plants per acre) and 52 kg per square meter (38 lbs per plant and 12,141 plants per acre) for Florida greenhouse (fl) and high-tech greenhouse (ht), respectively. Therefore, these levels are used for the rest of the analysis. The tax rate on earnings before tax (EBT) is taken as 25%, based on the average tax rate of agricultural production firms as calculated from corporate tax data for the last ten years (IRS 2012). Straight-line depreciation is applied for all equipment. Gross profit, earnings before tax (EBT), and net income are computed as follows:

Table 5. Net income statements for alternative tomato production technologies, 2014 ($/acre)*

	Field-grown	Greenhouse – FL	Greenhouse– HT
Expected Production	18,370 kg	111,107 kg	214,775 kg
Expected Revenue	$19,501.47	$338,458.85	$666,456.25
Energy Cost	$—	$58,040.68	$93,297.17
Other Costs	$7,573.01	$101,696.21	$301,314.43
Gross Profit	$11,928.46	$194,106.46	$289,382.97
Sales and Administrative Cost	$9,948.65	$75,857.79	$114,671.94
Depreciation	$—	$61,121.85	$79,953.60
Interest Payment	$657.06	$40,015.95	$83,412.91
EBT	$1,322.75	$1,726.38	$(6,193.80)
Tax on EBT (%25)	$330.69	$431.60	$—
Net Income	$992.06	$1,294.79	$(6,193.80)

Note.* 1 acre is equal to 4,046.86 square meters.

The net present value (NPV) framework is commonly used to evaluate agricultural investment. In this analysis, free cash flow (FCF) and NI are calculated for the span of ten years and discounted to the starting period. NPV was obtained by subtracting the initial investment amount from the present value of the enterprise.

$$(1) \quad NPV_0 = -(\text{Start} - \text{up Equity Value}) + \sum_{t=1}^{T} \frac{FCF_t}{(1+r)^t} + \frac{\text{Terminal Value}}{(1+r)^T}$$

where start-up equity value is added manually to prevent firms from running out of cash during the financial year, *FCF* is the free cash flow at the time *t* for ten years of analysis, terminal value is the value of the firm at the end of ten years, and *r* is the after tax discount rate.

Simulation Model

This study aims to incorporate yield, price and cost risks into the NPV analysis. This objective is achieved by simulating the risk parameters for 10 years. Since the average depreciation of all infrastructure and durables for greenhouses is about 10 years, this time frame is selected for the analysis. A Monte Carlo simulation model of tomato production is based on the framework presented by Richardson, Lemmer, and Outlaw (2007). Risk parameters are the correlated tomato yield and sales prices used in the financial statement analysis. Data were collected from USDA-ERS (2013b) annual field-grown price and yield data from 1990 to 2012 for Florida, and from USDA-AMS (2013) monthly terminal point greenhouse prices in the eastern U.S. states from January 2004 to December 2012. Time series tomato price/yield data sets are used to assess price/yield correlation and volatility. Specifically, USDA-ERS data are used to analyze the price/yield correlation of field-grown methods; the correlation is used in price simulations, which are then applied to all financial analyses. We assume no fluctuations in greenhouse tomato yield. Moreover, the USDA-AMS data are used to calculate the premium received by greenhouse tomatoes. End-user fuel prices are used for estimating the increase in energy cost. The risk associated with this cost is accounted for in the model by using the fuel/liquid petroleum gas and electricity price relationship. The gas and electricity price data are collected from 1990 to 2012

(US-EIA 2013). The price change in the simulated prices is inserted as the stochastic growth rate for annual fuel and electricity expenses, which is used to generate the stochastic energy cost.

Table 6. Summary statistics for stochastic variables, 1990-2012

Variable	Unit	Mean	Standard Deviation	Minimum	Maximum
Tomato Yield	kg/sq m	3.86	0.32	3.25	4.54
Sale Prices	$/kg	0.83	0.25	0.57	1.60
Electricity Price	$/KW	5.32	0.87	4.43	6.83
Gas/LPG Price	$/liter	0.36	0.19	0.18	0.80

All simulated stochastic components are iterated simultaneously in the model and the key components of the financial model are simulated 500 times for each production technology to estimate the probability density functions (PDF) and cumulative distribution functions (CDF). The distribution of yield, revenue, cost, and net present values (NPV) are presented in Figure 4.

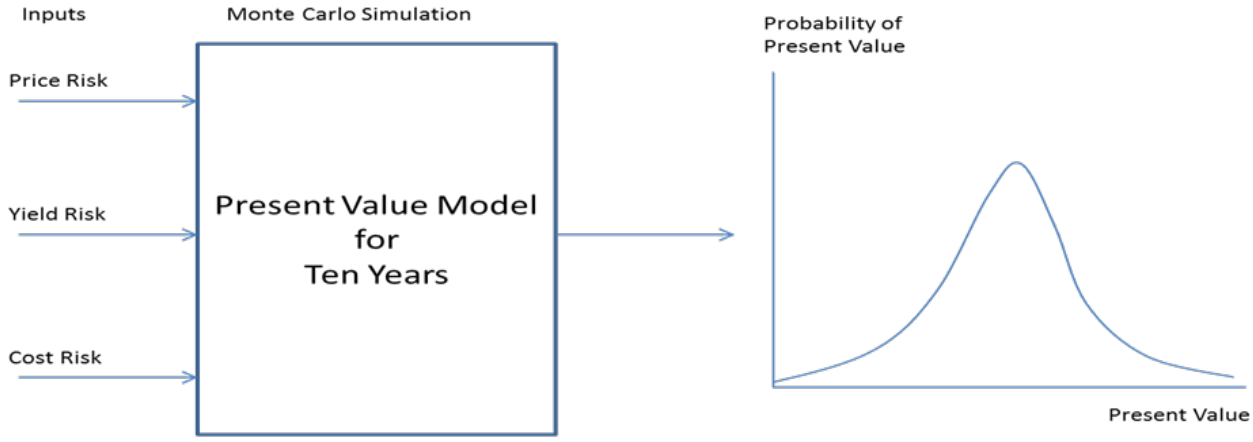

Figure 4. Risk modeling in the net present value analysis
Source. Adapted from Copeland and Antikarov (2003).

The stochastic variables are selected as the tomato yield, sale price, fuel/lpg gas price, and electricity price. The multivariate empirical (MVE) probability distribution is used for the simulation of these variables (Richardson, Klose, and Gray 2000) where yield and sale prices correlation and, gas and electricity price correlation are utilized. MVE distribution ensures that the simulated variables have the same correlation as they were correlated in the past. Each variable is estimated with trend variable to obtain ditrended residuals with which we can calculate fractions of trend (S_i) and cumulative probabilities ($F(S_i)$). The stochastic variables, summarized in Table 7, are inserted into financial models for the iteration of NPV to evaluate the economic risk associated with the tomato investment decision. For each variable, $CUSD_i$ represents the correlated uniform standard deviates calculated to correlate variables appropriately (Richardson, Klose, and Gray 2000).

Table 7. Stochastic variables used in financial model of tomato production investment decision

Variable	Unit	Value
Tomato Yield (Field-Grown)	kg/sq m	Mean Yield^k * [1 + MVE (S_i, $F(S_i)$, $CUSD_1$)]
Sale Prices	\$/kg	Mean Price^k * [1 + MVE (S_i, $F(S_i)$, $CUSD_2$)]
Electricity Price	\$/KW	Mean Price^k * [1 + MVE (S_j, $F(S_j)$, $CUSD_3$)]
Gas/Liquid Petroleum Gas Price	\$/liter	Mean Price^k * [1 + MVE (S_j, $F(S_j)$, $CUSD_4$)]

The NPV distributions are ranked using Simetar© software. Mean variance method, first and second degree stochastic dominance, stochastic dominance with respect to a function (SDRF), and stochastic efficiency with respect to a function (SERF) are applied to rank the risky alternatives (Hardaker et al. 2004). Stochastic dominance with respect to a function (SDRF) and stochastic efficiency with respect to a function (SERF) allow us to incorporate risk aversion in our analysis (Richardson and Outlaw 2008).

Real Option Approach

The NPV analysis has the following limitations: (1) only current information available at the time of the decision is used; (2) after the initial investment decision is made, the future decisions cannot be analyzed; and (3) just a single discount rate is used to calculate NPV (as opposed to allowing the rate to change over time). Hence, the analysis of NPV using criteria discussed above may be incomplete, and it may be insufficient to explain why U.S. growers still do not switch to the greenhouse tomato production. The next step in this research is to use the real options approach (ROA) to evaluate the viability of greenhouse tomato production in Florida. ROA has several advantages. First, ROA allows including the future value of agricultural investment into the current investment decision analysis. Second, ROA controls for the irreversibility of investment in the analysis. Third, ROA allows modeling a dynamic decision-making process while NPV models for the current decision. Fourth, ROA allows for the flexibility of agricultural investment by including the non-linear distribution of the cash flow or the eventual risk profile changes. The main difference in the concept of NPV and ROA could be shown as follows:

$$(2)\quad NPV : MAX(at \quad t = 0)[0, E_0(V_t - X)]$$

$$(3)\quad ROA : E_0 MAX(at \quad t = T)[0, V_t - X]$$

where $V_t - X$ represents the comparison of the possible values to choose the best among the possible alternatives (Copeland and Antikarov 2003). ROA uses expectation of maximum values where the decision is made after the information is revealed (maximize at t=T). In contrast, NPV assigns the decision for today by looking at the maximum of the expectations (maximize at t=0). Real option value is calculated by using the binomial decision tree procedure described by Copeland and Antikarov (2003) and used by Iwai and Emerson (2008). The details of the calculations and the assumptions are summarized in the result section.

Results

The non-stochastic NPVs can be computed when all assumptions are substituted into the financial model at the mean values. Table 8 presents cash balances and net incomes for field-grown and greenhouse tomato production for ten-year periods. We use equation (1) to separately calculate NPVs for each technology.

Table 8. Cash balances (CB) and net incomes for field-grown and greenhouse tomato productions ($/acre)*

	Field-grown		Greenhouse - FL		Greenhouse - HT	
Years	**CB**	**Net Incomes**	**CB**	**Net Incomes**	**CB**	**Net Incomes**
2014	$14,404.89	$992.06	$226,838.19	$2,478.53	$394,471.53	($ 6,193.80)
2015	$15,654.05	$981.08	$257,196.79	$5,290.71	$400,997.94	$1,002.08
2016	$16,892.13	$964.64	$287,299.40	$8,245.50	$406,864.84	$6,923.71
2017	$18,113.69	$942.65	$261,829.38	$10,299.70	$402,877.48	$12,977.68
2018	$19,313.16	$914.97	$277,034.58	$13,328.65	$406,776.82	$19,539.92
2019	$20,484.85	$881.52	$252,064.54	$15,890.36	$409,288.96	$26,473.89
2020	$21,622.99	$842.15	$151,496.24	$18,725.42	$255,378.75	$33,679.74
2021	$22,721.66	$796.77	$199,911.79	$21,934.31	$303,641.17	$40,144.11
2022	$23,774.85	$745.24	$277,684.01	$21,639.57	$436,434.02	$39,720.92
2023	$24,776.40	$687.45	$308,825.43	$20,603.35	$558,720.30	$38,998.94

Note. *1 acre is equal to 4,046.86 square meters.

Table 9 suggests that high-tech greenhouse production is the most feasible investment opportunity at the mean. Florida greenhouse technology is the second best investment (given the assumptions made). The [deterministic] NPV results presented in Table 9 are insufficient to explain the greenhouse investment decision made by Florida tomato producers. Therefore, to explain the producers' choices, deterministic NPV values are simulated using Monte Carlo method applied to the financial model in Simetar© add-in to Excel.

Table 9. Deterministic net present values per an acre field grown and greenhouse tomato productions*

	Present Value	Initial Equity	Net Present Value
Field-grown	$3,705.19	$—	$3,705.19
Greenhouse - FL	$74,130.33	$35,000.00	$39,130.33
Greenhouse - HT	$105,289.52	$35,000.00	$70,289.52

Note. * 1 acre is equal to 4,046.86 square meters.

NPV simulations are completed for the stochastic components which represents the risk associated with the tomato production technologies considered (i.e., yield, sale prices, gas price, and electricity price). The simulation results are summarized in Table 10. "Greenhouse-HT" has the largest mean; however, "Field-grown" has the lowest standard deviation. Therefore, we cannot rank the investment decision by using the mean variance method only.

Table 10. Summary statistics of Monte Carlo simulation for NPVs of alternative technologies

	Units*	Greenhouse-HT	Greenhouse-FL	Field-grown
Mean	$/acre	57,494.36	30,204.39	320.34
Standard Deviation		60,035.25	37,676.04	4,130.99
Coefficient of Variation	%	104.42	124.74	1,289.58
Minimum	$/acre	(122,421.19)	(85,587.57)	(14,079.44)
Maximum	$/acre	222,902.09	126,208.66	10,434.16

Notes. * 1 acre is equal to 4,046.86 square meters.

The cumulative distribution function (CDF) of NPV values for alternative production technologies are illustrated in Figure 5. CDFs cross each other and, hence, the technologies cannot be ranked using the first order stochastic dominance criterion (Table 11 and Figure 5).

In turn, the second-order stochastic dominance criterion suggests that "Greenhouse-HT" dominates both "Greenhouse-FL" and "Field-grown". Furthermore, "Greenhouse-FL" dominates "Field-grown". This result indicates that "Greenhouse-HT" is the most preferred investment option, and "Greenhouse-FL" is the second-best choice, among the three technologies considered.

Table 11. First and second order stochastic dominance rankings for alternative technologies

	Greenhouse-HT	Greenhouse-FL	Field-grown	Approx. Area
First Degree Dominance				
Greenhouse-HT FDD:	-	-	-	
Greenhouse-FL FDD:	-	-	-	
Field-grown FDD:	-	-	-	
Second Degree Dominance				
Greenhouse-HT SDD:	-	Dominates	Dominates	167,059.7
Greenhouse-FL SDD:	-	-	Dominates	194,511.2
Field-grown SDD:	-	-	-	224,362.5

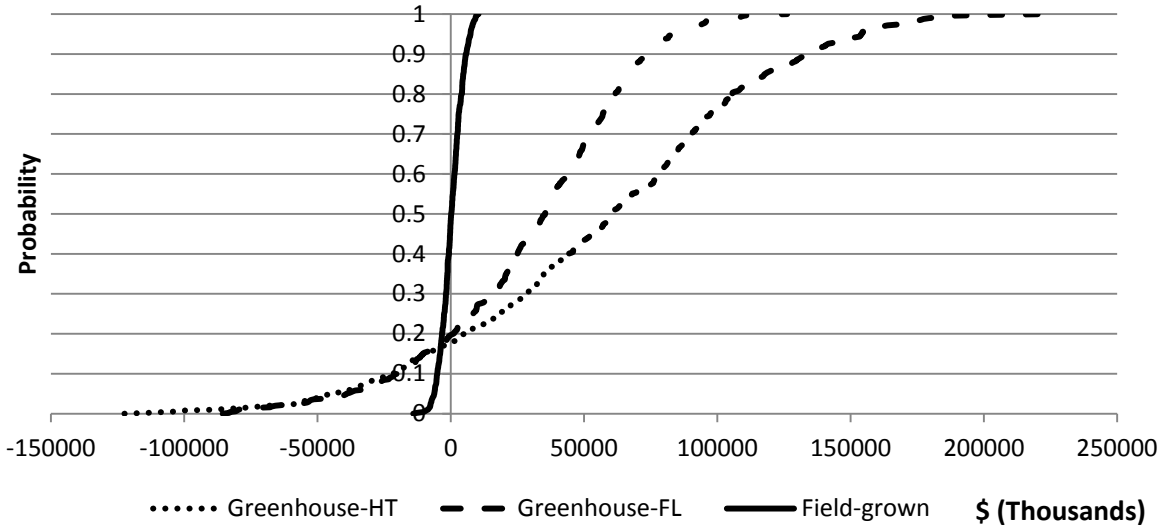

Figure 5. CDFs of simulated NPVs for alternative technologies

Risk aversion of the decision maker is taken into consideration when we rank the investment alternatives with stochastic dominance with respect to a function (SDRF) analysis (Richardson and Outlaw 2008). The first preferred set based on SDRF at the lower risk aversion coefficient (ARAC=0) shows the ranking for a risk neutral producer (Table 12). The ranking for risk neutral producer suggests that "Greenhouse-HT" is the first preferred alternative, followed by "Greenhouse-FL" and "Field-grown" technologies, which is consistent with the second-degree stochastic dominance result. However, the investment preference among the alternative options changes for the extremely risk-averse producer (ARAC=0.00004). Thus, extremely risk-averse decision makers prefer field-grown tomato production over both greenhouse technologies.

Table 12. Stochastic dominance with respect to a function results

Ranking	Name	Level of Preference
Risk-neutral producer		
	1 Greenhouse-HT	Most Preferred
	2 Greenhouse-FL	2nd Most Preferred
	3 Field-grown	3rd Most Preferred
Extremely risk-averse producer		
	1 Field-grown	Most Preferred
	2 Greenhouse-FL	2nd Most Preferred
	3 Greenhouse-HT	3rd Most Preferred

The SDRF results also show that "Greenhouse-FL" dominates "Greenhouse-HT" when the decision maker is extremely risk-averse (Table 12). To explain this result, one can search for the cases where "Greenhouse-FL" might dominate all other alternatives with stochastic efficiency with respect to a function (SERF). SERF provides us a broad overview of the risky alternatives over a range of absolute risk aversion coefficients (ARAC). Figure 6 illustrates the certainty equivalent of the alternative technologies for a range of producers' risk-aversion levels (i.e., from risk neutral to extremely risk-averse). The figure indicates that "Greenhouse-HT" dominates for the ARAC values from 0 to 0.000026, and "Greenhouse-FL" dominates from 0.000026 to 0.000035 and "Field-grown" dominates for ARACs greater than 0.000035. This result implies that "Greenhouse-HT" is the preferred technology for the risk neutral and normally risk-averse producer. In turn, "Greenhouse-FL" is the preferred risky alternative for moderately risk-averse producer, and finally, "Field-grown" is only preferred by an extremely risk-averse producer.

Real option approach is implemented by constructing the binomial decision tree. Field-grown tomato production is taken as a base production technique for Florida, and the investment option for greenhouse tomato is investigated. The procedure described by Copeland and Antikarov (2003) is followed for the multiplicative stochastic process to calculate ROA. The uncertainty in field-grown production is estimated by generating 500 sets of net income based on the simulating cost and revenue terms. We obtain the volatility from the standard deviation of the simulated annual rate of return defined as $z = (PV_{2014}^{fg} + NI_{2014}^{fg}) / \ln(PV_{2013}^{fg}) - 1$ where PV_1 and NI_1 represent the present value of field grown production and net income, respectively, for the 2014 season, and PV_0 is the fixed present value at \$16,855.19 for the 2013 season. The mean (μ_z) and the standard deviation (σ_z) of the annual rate of return are found as 0.16 and 0.92, respectively. The standard deviation indicates the high volatility for the field-grown production; therefore, we

expect high option value to incentivize growers to postpone the new investment (Dixit and Pindyck 1994).

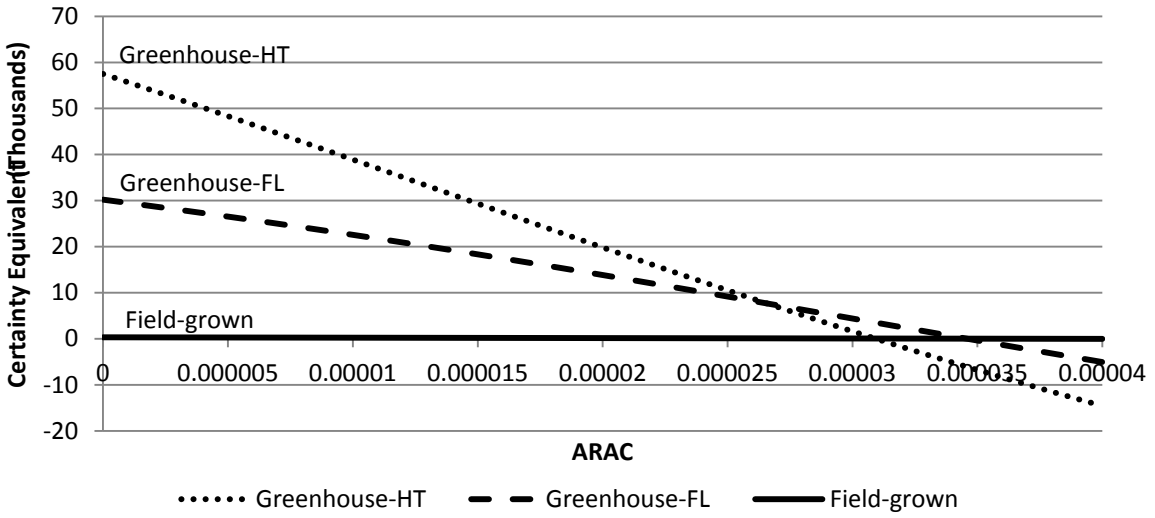

Figure 6. Stochastic efficiency with respect to a function under a negative exponential utility function

The present value for the 2014 season ($14,405) is the cash balance for the field-grown technology (Table 8), and NPV for 2014 is calculated by adding net income ($992) to the present value of the same year, yielding $15,397. The upper and lower values for 2015 are calculated by using the annual volatility of the field-grown production, 0.92; therefore, NPV for 2015 would either be $35,954 ($PV_{2014}^{fg} \cdot e^{(\sigma_z \sqrt{dt})}$) or $5,771 ($PV_{2014}^{fg} \cdot e^{(-\sigma_z \sqrt{dt})}$) where *dt*=1 (Figure 7). Then, we could find PVs for the 2015 season by discounting the calculated NPVs with the ratio calculated as $NI_{2015}^{fg} / (PV_{2015}^{fg} + NI_{2015}^{fg})$. This procedure is followed for the all the years until we calculate all branches in the decision tree (Figure 8).

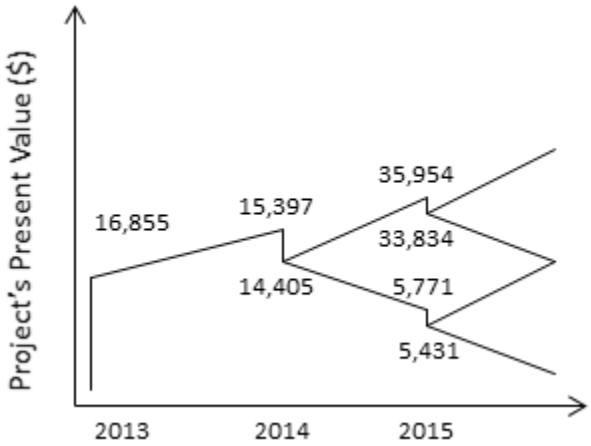

Figure 7. Present value binomial tree for the first three years

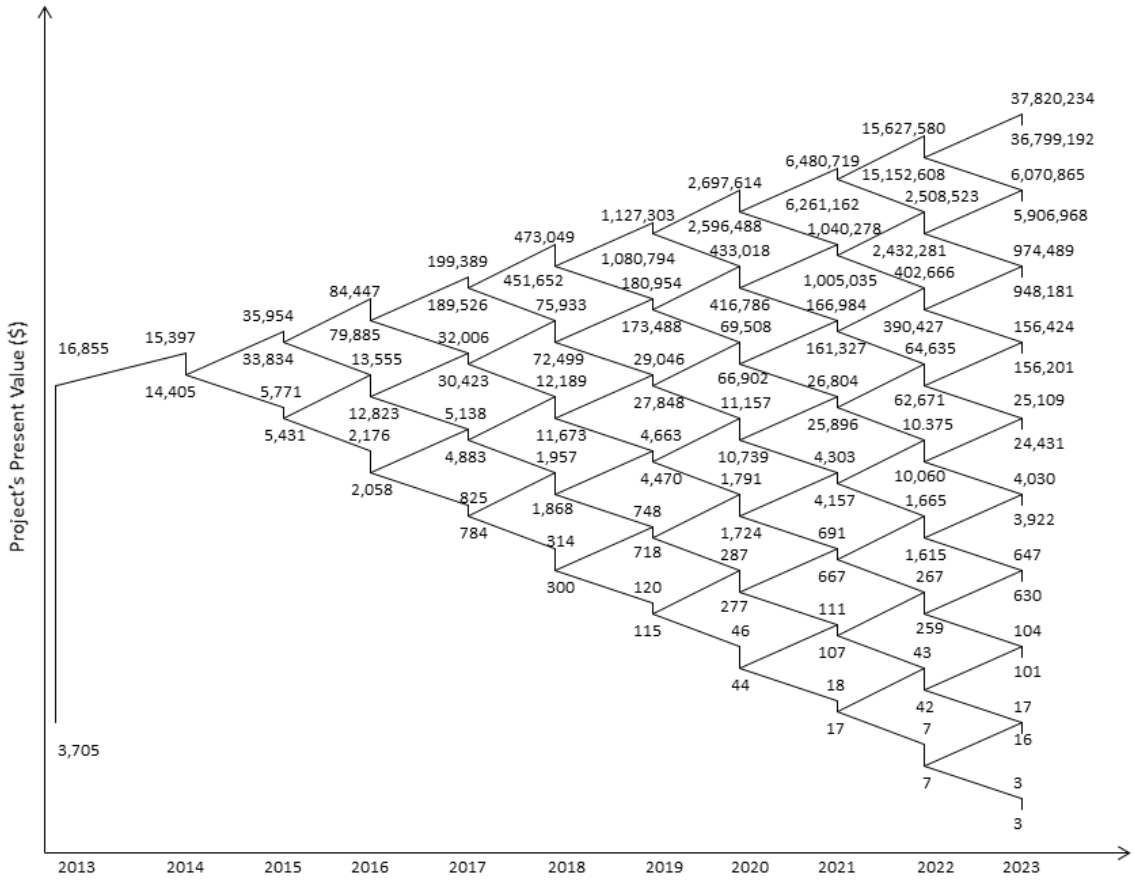

Figure 8. Present value binomial tree for field-grown tomato production

As described in Copeland and Antikarov (2003), we analyze the optimal execution of real options starting at the end of the tree when the option expires. We analyze two different investment options for the field-grown producer: (1) investment in Florida greenhouses and (2) investment in high-tech greenhouses. The final nodes of the option calculation are chosen as the maximum of the three values demonstrated as $MAX(PV_{2023}^{fg}, PV_{2023}^{fl} - IE_{2023}^{fl}, PV_{2023}^{ht} - IE_{2023}^{ht})$. The values are the present value of the final year (PV_{2023}^{fg}) in Figure 8, present value of high-tech greenhouse in 2023 minus discounted initial equity for 2023 ($PV_{2023}^{fl} - IE_{2023}^{fl}$) in Table 8, and the present value of the Florida greenhouse in 2023 minus the discounted initial equity for 2023 ($PV_{2023}^{ht} - IE_{2023}^{ht}$) in Table 8. For instance, the top node of the end of three is the maximum value comparing the present value \$36,799,192 from the binomial tree, the value given from the Florida greenhouse as \$308,825–\$35,000/(1+0.3)^{10}, and the value given from the Florida greenhouse as \$558,720–\$35,000/(1+0.3)^{10}, shown in Figure 9.

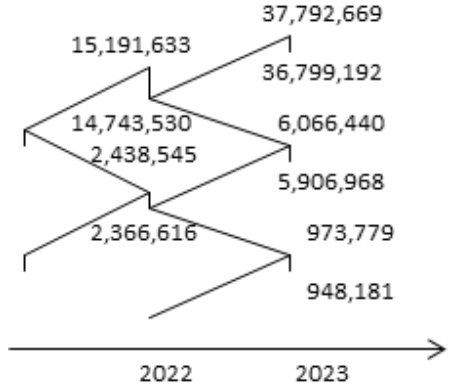

Figure 9. Real option calculation for top nodes of last two years

The remaining nodes are calculated by replicating portfolio approach. Following Iwai and Emerson (2008), one can derive the equation for holding option value (C_t) at time t as $C_t = \left[qC_{t+1}^u + (1-q)C_{t+1}^d\right]/(1+r_f)$ where q is the risk neutral probability $q = ((1+r_f) - e^{-\sigma_z})/(e^{\sigma_z} - e^{-\sigma_z})$, risk-free rate of return is taken as 3% calculated from ten-year Treasury bills and, C^u and C^d denote the up and down state of the option values, respectively. Next, we compare the holding option value with the investment options as $MAX(C_t, PV_t^{fl} - IE_t^{fl}, PV_t^{ht} - IE_t^{ht})$ and repeat the procedure for the all the remaining nodes. Finally, we compute NPV with option value as \$421,240 (Figure 10). Option value is simply calculated by subtracting NPV value from the NPV with option value which is \$421,240 – \$15,397 = \$405,843. This option value indicates how much a grower loses when the investment option is exercised.

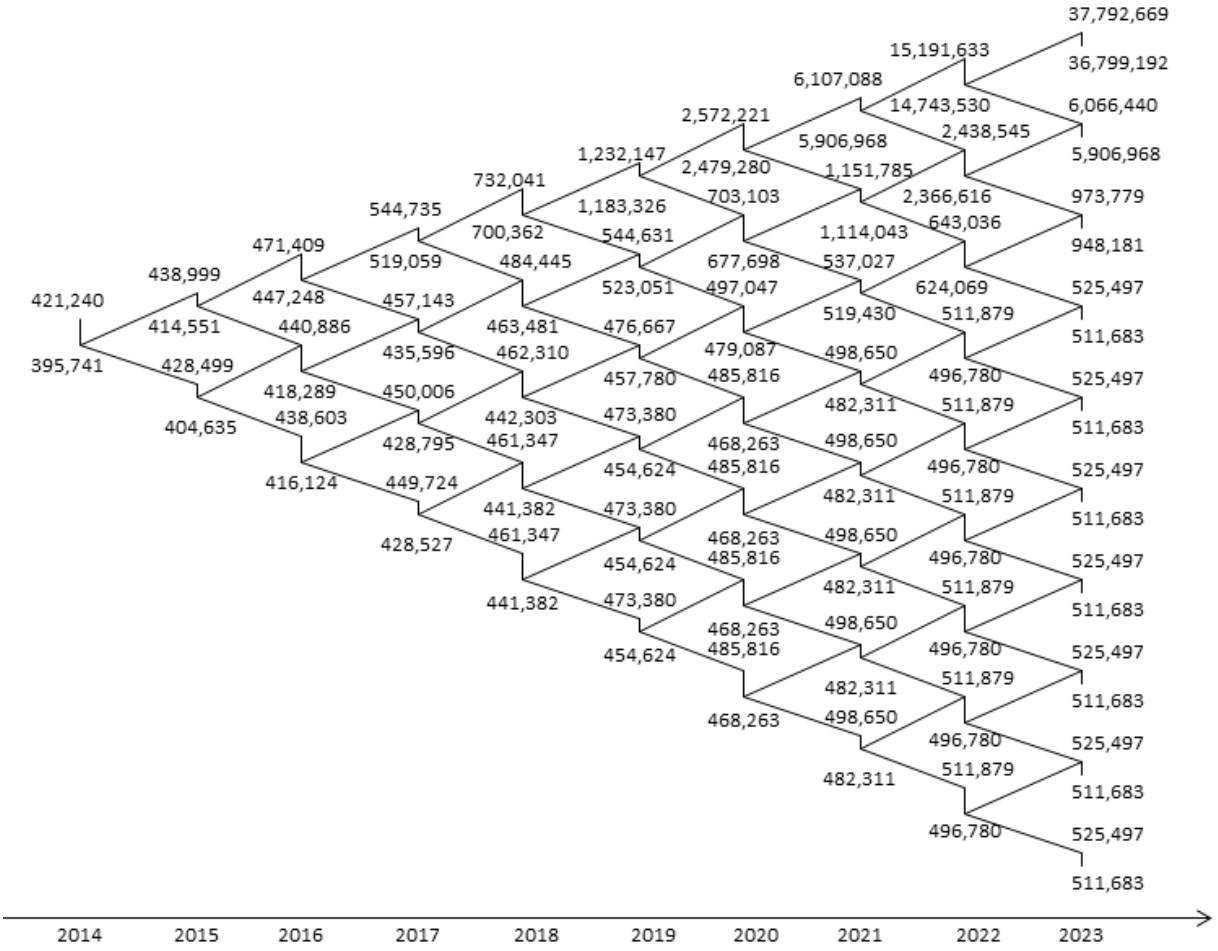

Figure 10. Real option calculation for greenhouse tomato investment

Table 13 summarizes the NPV results for each tomato production technology with the option value. The results suggest that a grower in field-grown production still has a high option value to invest in greenhouse technology given the assumed production information. The results explain why we may not have seen greenhouse investment in Florida.

Table 13. Net present values with option value for field grown and greenhouse tomato production ($/acre)*

	Present Value	Initial Equity	Net Present Value	Option Value
Field-grown	$3,705.19	-	$3,705.19	
Greenhouse – FL	$74,130.33	$35,000.00	$39,130.33	$405,842.66
Greenhouse – HT	$105,289.52	$35,000.00	$70,289.52	$405,842.66

Note. * 1 acre is equal to 4,046.86 square meters.

Conclusions

Florida tomato growers have lost market share in the last decade to increasing Mexican greenhouse tomato imports. Although Florida producers achieved an agreement with Mexican producers for a fixed floor price for Mexican tomatoes in 1996, domestic tomato sales continued to decline in the winter season. The renegotiated antidumping investigation suspension agreement came into force in the summer of 2013. This agreement could help Florida growers in competing with imported greenhouse tomatoes, but the lower-cost imported field-grown tomatoes will still be a threat for the market share of the domestic growers. In addition, a greenhouse tomato receives premium prices compared to a field-grown mature green tomato at retail since consumers in the United States perceive a greenhouse tomato as high quality and flavorful.

This study examines the investment potential of Florida producers in greenhouse tomato production. Greenhouse production technology is considered as a strategy to mitigate the impact of the increasing Mexican greenhouse tomato imports on the profitability of Florida's tomato producers. The NPV analysis suggests that investment in the high technology greenhouse is preferred over regular greenhouse and field-grown production (if the crop yield for each technology is fixed at the break-even point). However, the investment decision preferences change with an increase in a producer's risk-aversion coefficient. Stochastic efficiency ranking of the investment decision shows that the high technology greenhouse is preferred by risk-neutral and normally risk-averse decision makers. However, moderately risk-averse decision makers would prefer to invest in a regular Florida greenhouse technology while extremely risk-averse growers would continue to produce field-grown tomatoes. These results are consistent with what has been witnessed in tomato production in Florida. The increase in greenhouse investment shows that some growers are beginning to take more risk because they find greenhouse investment as a way to compete better in the market. However, at this point in time, the producers continue to choose to have the option open instead of committing to investment in greenhouse technology because of high option values in Florida. This explains why there are few greenhouse operations in Florida.

The risk of the new tomato production technology is related to the price, production and financial risks. Policies or market conditions that decrease these risks (by affecting credit availability, interest rates, insurance, energy prices, tomato prices, effective risk management strategies, technological advancement in greenhouse production, etc.) would decrease the option value. Thus, with these policies or market conditions, greenhouse tomato production becomes preferable for Florida producers. Otherwise, greenhouse production in Florida will most likely come from outside of Florida exactly as it has done in Arizona (EuroFresh Farms), Texas (Village farms), California (numerous producers), Maine (Backyard farms), and Canada (mainly

immigration from Holland) because Florida tomato producers are least likely to convert to greenhouse production due to their extremely high costs of investments in their field operations and packing houses.

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Appendix

Table A-1. High technology greenhouse production expenses ($/acre)*

Items	Unit	Quantity	Total Cost
Materials			
Plant Material (January / August)	acre	1.00	38,400.00
Substrate	acre	1.00	15,680.00
Fertilization	acre	1.00	99,000.00
Plantprotection chemical	acre	1.00	2,946.53
Plantprotection biological	acre	1.00	1,180.67
Small/other materials	acre	1.00	4,800.00
Work by third parties	acre	1.00	800.00
Transport/waste plants	acre	1.00	700.00
Plant insurance	acre	1.00	6,000.00
Other cultivation costs	acre	1.00	640.00
Total Materials			$170,147.20
Energy			
Gas Boiler	acre	1.00	36,666.67
Electricity	acre	1.00	49,666.67
CO2	acre	1.00	6,963.84
Total Energy			$93,297.17
Labor			
Corporate Labor	acre	1.00	30,113.89
Maintenance and Other	acre	1.00	2,021.07
Harvesting Team	acre	1.00	33,347.60
Cultivating Team	acre	1.00	57,600.40
Packing Team	acre	1.00	8,084.27
Total Labor			$131,167.23
Sales, General & Administrative			
General & Administrative			
Maintenance company	acre	1.00	16,576.00
Other costs	acre	1.00	10,000.00
Growing advice	acre	1.00	919.80
Insurance	acre	1.00	2,242.98
General costs	acre	1.00	3,204.32
Real Property Tax (Est.)	acre	1.00	384.53
Unforeseen Expenses (Contingency)	acre	1.00	824.00
Total G&A			$34,151.64
Sales & Marketing			
Packing/cask	acre	1.00	19,685.72
Transport (Est.)	acre	1.00	—
Sales costs	acre	1.00	60,000.00
Sales Commissions	acre	1.00	834.58
			$80,520.31
Total Annual Production Costs			$509,283.54

Note. *1 acre is equal to 4,046.86 square meters.

Table A-2. Regular Florida greenhouse production expenses ($/acre)*

Items	Unit	Quantity	Price ($ per Unit)	Total Cost
Materials				
A mix 8-12-32	kg	1,918.62	3.62	6,945.40
CaNO3	kg	1,645.60	1.50	2,468.40
Sulfuric acid	liter	230.50	6.30	1,452.00
Soap	liter	23.00	9.70	223.12
Neem	liter	11.50	100.50	1,155.55
DiPel	kg	5.50	13.09	72.00
Liquid sulfur	liter	11.52	8.35	96.20
Layflat bags	each	3,549.29	2.29	8,127.88
Trust (seeds)	each	10,648.00	0.44	4,685.12
Speedling flats 128	each	84.70	1.55	131.29
Fafard Germ Mix	bag	12.10	15.60	188.76
Greenshield	liter	91.92	13.15	1,208.79
Mousetraps	pair	36.30	7.95	288.59
Total Materials				$27,043.08
Energy				
Electricity	kwh	158,510.00	0.11	17,436.10
LP Gas	liter	99,035.50	0.41	40,604.58
Total Energy				$58,040.68
Labor				
Pre-harvest	hrs	5,662.80	7.79	44,113.21
Harvest	hrs	3,484.80	7.79	27,146.59
Cleanout	hrs	435.60	7.79	3,393.32
Total Labor				$74,653.13
Sales, General & Administrative				
General & Administrative				
Analytical services& repairs	units	12.10	150.00	1,815.00
Travel	km	4,704.00	0.35	1,646.40
Overhead	%	131,011.97	10.00%	13,101.20
Taxes & Insurance **	%	459,596.72	1.37%	6,289.63
Total G&A				$22,852.22
Sales & Marketing				
Delivery costs	km	9,600.00	0.35	3,360.00
Packing labor	hrs	1,913.63	7.79	14,907.20
Boxes, foams & labels	box	21,300.00	0.76	16,188.00
Marketing & miscellaneous	box	21,300.00	0.80	17,040.00
				$51,495.20
Total Annual Production Costs				$234,084.31

Notes.*1 acre is equal to 4,046.86 square meters.

** The taxes and insurance are taken as the 1.37% of the total structure cost.

Table A-3. Field-grown tomato production expenses ($/acre)*

Items	Unit	Quantity	Price	Total Cost
Materials				
Seeds/Transplants	acre	1.00	624.00	624.00
Fertilizer, mixed and Lime	acre	1.00	1,449.25	1,449.25
Fumigant	acre	1.00	736.00	736.00
Tractors and Equipment	acre	1.00	1,882.29	1,882.29
Tractors and Machinery	acre	1.00	241.65	241.65
Herbicide	acre	1.00	21.40	21.40
Insecticide and Nematicide	acre	1.00	448.85	448.85
Fungicide	acre	1.00	392.21	392.21
Stakes + others	acre	1.00	771.17	771.17
Plastic String	acre	1.00	28.75	28.75
String and Stake Disposal	acre	1.00	123.42	123.42
Pull and Bundle Mulch	acre	1.00	181.50	181.50
Cross Ditch	acre	1.00	27.20	27.20
Tie Plants	acre	1.00	145.20	145.20
Trickle Tube	acre	1.00	145.20	145.20
Total Materials				$7,218.09
Energy				
Total Energy				$—
Labor				
General Farm Labor	acre	1.00	140.63	140.63
Tractor Driver Labor	acre	1.00	214.29	214.29
Total Labor				$354.92
Sales, General & Administrative				
General & Administrative				
Land Rent	acre	1.00	500.00	500.00
Overhead and Management	acre	1.00	3,632.85	3,632.85
Taxes & Insurance	%	—	1.37%	—
Total G&A				$4,132.85
Sales & Marketing				
Pick, Pack and Haul	box	1,620.00	2.60	4,212.00
Sell	box	1,620.00	0.15	243.00
Containers	box	1,620.00	0.75	1,215.00
Organization Fees	box	1,620.00	0.09	145.80
				$5,815.80
Total Annual Production Costs				$17,521.66

Note.* 1 acre is equal to 4,046.86 square meters.

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Offering Low-Cost Healthy Food: an Exploration of Food Manufacturers' and Retailers' Perspectives

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Abstract

This study investigates food manufacturers and retailers attitudes concerning offering healthy and low-cost food to consumers. Results show that the main barriers are: price perception, costs of production, easy accessibility of unhealthy food, and lack of supporting public policy. Solutions include consumers' heightened awareness and knowledge, affordability, better food chain coordination, positioning strategy, and healthy food campaigns. Bigger food manufacturers and retailers, although cautious, are more capable than smaller size enterprises in implementing relevant investment strategies. All food system actors, from agribusinesses to consumers and policymakers, need to play a role in furthering the initiative.

Keywords: manufacturer, retailer, healthy food, low-cost, food chain, barrier, solution, multidimensional scaling unfolding

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Introduction

Non-communicable diseases (NCDs) are becoming the leading causes of deaths worldwide (WHO 2010b), with 36 million (63%) deaths in 2008 and an expected increasing trend up to 55 million deaths by 2030. NCD deaths are mainly caused by cardiovascular diseases (48%), cancers (21%), and chronic respiratory diseases (12%) (WHO 2010b). About 80% of coronary heart diseases and cerebrovascular diseases are due to an unhealthy diet and other behavioural risk factors (including tobacco use, physical inactivity, and alcohol abuse) (WHO 2012). The concept of malnutrition is not synonymous with under-nutrition, as the concept currently includes unhealthy eating habits. Although low fruit and vegetable intake is considered the most common and well known interpretation of an unhealthy diet, especially from the consumers' point of view, other bad food habits such as consumption of an excessive level of salt and high consumption of saturated fats and trans-fatty acids also play an important role. These bad food habits are spreading globally and affecting consumers across different socio-economic levels. Past research efforts have focused on understanding facilitators to consumers' healthy eating habits. More recent studies have focused on the private sector's role in determining the production and commercialization of healthy food and on retailers' and food manufacturers' impact on eating behaviour. Research shows that consumers' healthy food habits cannot be attributed to individual actors in the food chain, but rather to the combination of the strategies and actions of the actors in the chain. The responsibilities have been expanded and shifted. The focus is on not only the approach of single actors to healthy food, but rather how the food is 'substituted, transformed, distributed and marketed through the supply chain' (Hawkes et al. 2012), thereby involving many actors in the food chain. In other words, the food system and global supply chains are seen as not just contributors to the expansion of unhealthy food, but rather as increasingly responsible for producing and distributing a limited range of 'processed, energy- and fat-dense commodities however fortified' (Garnett 2013). The increased attention on the responsibilities of the producers and retailers in the food chain for the inadequate availability of healthy food, especially if low-cost, calls for a better understanding of food manufacturers' and retailers' experience in this respect. The objective of this paper is to explore the reasons, expectations, and critical factors along and outside the food chain that food manufacturers and retailers perceive as barriers or solutions to offering low-cost healthy food (Appendix A).

Literature Review

The literature review focuses on the past analyses of the role that food system actors —including consumers, food manufacturers, food retailers, and policy makers have in offering low-cost healthy food.

Consumers and Healthy Food

Past research strongly focused on facilitators to consumers' healthy eating habits. A positive attitude seems to be influenced by many elements, including interest in diet; perception and motivation towards healthy diets; understanding and use of nutrition labelling (Grunert and Wills 2007, Hess et al. 2012); belief in healthy food as a source for not just preventing cardiovascular diseases, but also for complete physical, mental and social well-being (Geeroms et al. 2008); high socio-economic status; accessibility to affordable healthy food (Dibsdall et al. 2003); food related

lifestyle and adequate time to cook and plan food shopping and preparation (Brunsø et al. 2004); low constraints because of household size (Burch and Lawrence 2005, Shiu et al. 2004, Holgado et al. 2000, Lawrence and Barker 2009); and good knowledge and awareness of healthy food (Dickinson-Spillman and Siegrist 2011). There are also a number of elements that prevent consumers' interest in healthy food. Price is a crucial issue, as consumers expect healthy food to be expensive or perceive the actual high price of healthy food as not attractive relative to other food (Vander Wekken et al. 2012). In addition, consumers expect healthy food not to be as enticing as 'familiar' food, which is consumed on a regular basis (Vander Wekken et al. 2012, Nestle et al. 1998, Lähteenmäki et al. 2010). In addition, consumers often do not trust the positive benefit of healthy food or have low awareness and knowledge about the nutritional value of healthy food (Ajzen 1991, Bogue et al. 2005).

Food Agribusiness Sector and Healthy Food

Increased worldwide consumption of unhealthy food is influenced by the private sector's marketing strategies focused on low-cost and high availability or accessibility of unhealthy food (Pomeranz 2012, Park 2014). Throughout the world, an extensive variety of food and drink products with high fat, sugar or salt content are now widely available and strongly promoted and advertised by food manufacturers and food retailers. The following section focuses on these two food system actors and their relationship.

Food Industry

A number of studies analysed which factors might influence the food industry to produce healthy food. 'Food industry needs time, resources and expertise to adapt their business model and to find new palatable products that meet healthy guidelines' (Vander Wekken 2012). Food product innovation and development and product differentiations are the result of marketing strategies (Hooker and Downs 2014), with impact on technical aspects and requirements. According to Burch and Lawrence (2005) and Harvey (2002), traditional manufacturers may take several years to market a new product line with a very slow return on investment. Furthermore, the price of food inputs can affect food manufacturers' inclination to innovate or reformulate. Less expensive inputs, even small differences, can have 'relatively large effects on aggregate production costs' (Golan et al. 2008). Innovation is also influenced by profit margin expectations along the food chain. In particular, according to Boesso et al. (2009), companies that offer health value-added products target consumers who are willing to pay more for specific health food attributes. The production and commercialization of health value-added food, especially when innovative and at a 'buyable' price, entails a financial risk as the significant 'investment required to research, develop, equip for and promote new healthy food' (Vander Wekken 2012) can negatively affect profit margin potential.

Food Retailers

The retailing system also plays a progressively pivotal role in shaping the food offer available to consumers. Some consider retailers as the 'gatekeeper in the provision of nutrition to the public by virtue of their ability to control access to supermarket shelves' (Wardle and Baranovic 2009). Some interpret the gatekeeper's role for the physical accessibility of food that retailers provide. This is connected to the so-called 'food desert' concept, that is supermarkets located in poorer

neighbourhoods provide fewer healthy product choices and at higher prices (Cummins et al. 2005). Yet, limited access to healthy food has been found to be partly responsible for poor diets (Walker et al. 2010, Larson et al. 2009, Beaulac et al. 2009, Kyureghian et al. 2013). The retailing issue, especially in highly urbanised areas as in most European countries, is more than accessibility to food. The retailing system plays a leading role in terms of variety of food choices, promotion and marketing strategies, prices, market positioning, and the increasing competitiveness of their private label products. A future scenario could be that food retailers invest in convenience and sustainability and 'deliver new healthier food' (Bunte et al. 2011), possibly sold as private label products, and that food manufacturers remain an important 'driver for more radical innovations in terms of food quality' (Bunte et al. 2011). In addition to their capability of offering a range of new food products (Burch and Lawrence 2005, Kadiyali 2005), retailers have long experience in providing low-cost alternatives to consumers (Burch and Lawrence 2005).

Food System Relations

Retailers have a significant influence on food manufacturers' corporate strategies and practices, thereby creating an imbalanced relationship along the food chain. Retailers buying large quantities of product can dictate manufacturers' decision-making processes, thus limiting their contractual power (Burch and Lawrence 2005). The issue of balance of power among actors in the chain is one of the most debated issues at the academic level (Kadiyali et al. 2000), as well as in grey literature (European Commission 2009a, 2009b). Kadiyali et al. (2000) identify the following key aspects as drivers of power shifting towards the retail sector: strong competition among manufacturers; increased concentration in the retail sector; scarcity of shelf space compared to an increased number of new products; and advanced use of information technology. Within the dynamics of the food chain, bargaining power determines the terms of economic transactions between actors and can strongly affect competition and the actors' independency (European Commission 2009a, 2009b).

Public Policy and Healthy Food

Policymakers

Public policies can and should play a role in facilitating the offer and the consumption of healthy food and minimizing unhealthy food habits. Sound public policies are necessary to improve healthy dietary habits at all food system levels. It is unclear, though, which public policies are effective 'to leverage the supply chain towards healthier eating' (Hawkes et al. 2012). 'Interventions targeting the market environment, such as fiscal measures and nutrient, food, and diet standards, are rarer and generally more effective, though more intrusive' (Brambila-Macias 2011). A public policy that promotes competition among food chain actors, for instance, is seen as a fruitful instrument. Food manufacturers may be more inclined to food reformulation in favour of healthier food proposals (Mancino et al. 2008). Lowering retailing concentration could favour affordability, accessibility, quality and choice of healthy food options to consumers (Wardle and Baranovic 2009). In addition, nutritional regulations may lead to better product quality choices by the private sector, which in turn creates a fertile competitive environment (Duvaleix-Treguer et al. 2012). Still, there is awareness that even if food industry competition can

introduce healthier products, it may not result in healthier diets (Golan and Unnevehr 2008, McCarthy et al. 2013).

International Organizations

International organizations have recently taken a rather strong position in making food manufacturers and food retailers responsible for producing and selling unhealthy food. The World Health Organization (WHO) (2010a) called for 'a need to ensure that the private sector markets its products responsibly' through restrictions on unhealthy food marketing practices and by taxing unhealthy diets. The United Nations promotes 'cost-effective interventions to reduce salt, sugar and saturated fats, and eliminate industrially produced trans-fats in foods, including through discouraging the production and marketing of foods that contribute to unhealthy diet' (UN 2011). According to the WHO, the Nutrition Action plan proposal was to promote the reformulation of mainstream food products in order to reduce the amount of salt, added sugar, saturated fat, and trans fatty acids in food and to promote the availability of healthier products. This can be achieved by establishing a dialogue with food manufacturers; providing technical support, particularly to small businesses; and setting specific reformulated targets after an assessment of all potential effects (WHO 2013). The strong position of international organizations is also justified by the lack of engagement of the world's food companies on the seriousness and urgency of the transformation called for by the WHO's Global Strategy on Diet, Physical Activity and Health of 2004 (Lang et al. 2006).

Materials and Methods

Design and Sample Selection

For the research, a structured interview method was adopted to gather data and information from representatives of food manufacturers and retailers. This interview technique provided an effective and efficient method to gather qualitative information and the opinions of persons who were informed and had experience with the issues investigated. Interviews were carried out between March and July 2012. The research included 42 interviews: 24 with food manufacturers and 18 with retailers[1] (Table 1). In terms of food categories, the group of manufacturers covered a good variety of food sectorial specialization to avoid biases due to uncontrolled sectorial concentration. The food manufacturers interviewed already produced processed healthy food or quality food, sold under the manufacturers' commercial brands or private labels and were active at a national level. For the retail actors, the researchers chose large retailers, discount retailers, and traditional retailers. Large retailers were selected from those with the highest annual turnover

[1] In terms of size-category, for the food manufacturers the research applied the definition of Commission Recommendation 2003/361/EC as published in the Official Journal of the European Union L 124, p. 36 of 20 May 2003, Article 2 "Staff headcount and financial ceilings determining enterprise categories: 1. The category of micro, small and medium-sized enterprises (SMEs) is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million, and/or an annual balance sheet total not exceeding EUR 43 million. 2. Within the SME category, a small enterprise is defined as an enterprise which employs fewer than 50 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 10 million. 3. Within the SME category, a microenterprise is defined as an enterprise which employs fewer than 10 persons and whose annual turnover and/or annual balance sheet total does not exceed EUR 2 million"

(counting only national sales) in 2009 or 2010[2]. The European distribution of interviewees complies with the explorative aim of the research, provides an overview of the food chain actors' views of the heterogeneous European context[3], and limits bias due to single countries' overrepresentation. It does not aim to be representative.

Table 1. Interviews per country and per typology of company

	Finland	Italy	Lithuania	Serbia	Total
Food Manufacturers	**5**	**8**	**2**	**9**	**24**
Dairy					
Small	1	1		1	3
Medium					
Big	1	1		1	3
Meat/Fish					
Small		1		3	4
Medium		1			1
Big	1				1
Vegetable/Fruit					
Small		1	1	1	3
Medium	2			1	3
Big		1			1
Cereals/Bakery					
Small		1	1	1	3
Medium					
Big		1		1	2
Food Retailers	**5**	**5**	**4**	**4**	**18**
Large	2	4	1	1	8
Discount	2			1	3
Traditional	1	1	3	2	7
Total food manufacturers and food retailers	**10**	**13**	**6**	**13**	**42**

Data Gathering

Through a structured questionnaire, interviews aimed to gather the interviewees' opinions about offering low-cost healthy food. To ensure that the concept of healthy food was homogeneous throughout all interviews, at the beginning of the meeting the interviewers defined the concept of semi-processed or processed healthy food to be used as reference by interviewees. The

[2] The selection of the companies to interview and the choice of the individuals to interview within the companies were crucial steps in the research process. Companies were identified after the consultation of different sources of information: official databases (e.g. from Bureau Van Dijk), annual reports, companies' websites, personal contacts. For both food manufacturers and retailers, most interviewees belong to top management or are assistants to the board[2]. Interviews lasted around one hour and were carried out on the premises of the companies. Interviews were carried out using the native language common to interviewees and interviewers, with the interview questionnaire translated in advance. This approach avoided misunderstanding or lack of understanding due to limited language skills of the interviewees.

[3] The interviewing process was carried out as part of the 'Chance' project, a European research project funded under the 7th Framework Programme (Grant agreement no: 266331).

questionnaire included a number of close-ended statements. The statements refer to elements coming from the literature review carried out and presented in the above section. Single statements represent synthetic conceptual aggregations fed by one or more sources of literature (Appendix B). The literature review covered the food chain, food manufacturing, food retailing, food innovation, accessibility, and the consumer found relevant to offering low-cost healthy food. The main elements emerging from the literature review were then transposed into concise, clear cutting, and at the times provocative, statements representing barriers and solutions, so to stimulate a clear view of the interviewees' reasons, expectations, and critical factors to low-cost healthy food. Then, the statements were clustered into the following seven main research topics, according to their conceptual consistency in relation to the barriers and solutions to offering low-cost healthy food:

i. *food manufacturers and retailers' relations*, in particular the interactions, dynamics, and power misbalances of food chain actors;
ii. *price*, in particular price perception, quality perception, and affordability;
iii. *innovation and differentiation strategies*, in particular product innovation, differentiation, roles of food chain actors, private standards, financial performance, and comparison with unhealthy food;
iv. *food manufacturers and retailers' competitiveness strategies*, in particular positioning strategies, brand competition, and market trends;
v. *private labels*, in particular the brand strategy of retailers;
vi. *public policy and regulations*, in particular the awareness and knowledge of food chain actors about the issue of nutrition, the definition of healthy food, publicly funded promotions and campaigns, incentives, and labelling;
vii. *food accessibility*, in particular access to healthy and unhealthy food.

Interviewees graded the level of importance of each statement with a Likert scale from 1 (it does not absolutely represent a barrier/solution to low-cost healthy food production/ commercialization) to 7 (it is a crucial barrier/solution to low-cost healthy food production/commercialization). Interviewees graded first the entire set of barriers and then the entire set of solutions. This approach was designed to generate independent and unrelated thinking on the barriers and solutions to avoid biased feedback due to forced or involuntary consistency of the answers. For the sake of clarity and as an example of target segment, some statements stressed the attribute of low-cost of healthy food by adding at-risk-of-poverty or low-income population.

Data Analysis

The objective of the data analysis was to identify the significance of the single statements for food manufacturers and retailers and to highlight whether the two typologies of food chain actors react similarly or differently to the ideal combination of a given set of barriers and solutions concerning the same topic. This methodological approach served to analyse the perception of individual respondents and to understand the systemic framework determined by the interaction of food manufacturing and retailing actors. The availability of low-cost healthy food on the market comes from decisions taken by single actors that act within a multi-actor economic frame. These data analysis objectives were achieved, first, through frequencies, and then, by applying

the multidimensional scaling unfolding (MDU) technique of analysis[4] (Borg and Groenen 2005). MDU, as a model for preferential choice, shows that even if different individuals might rank various objects of choice similarly, they might differ with respect to what they consider an 'ideal combination of the object's attributes' (Borg and Groenen 2005). In order to facilitate the exploration of the latent patterns underlying each topic, the results obtained were illustrated through a joint display of the respondents, barriers and solutions in the same map for each of the seven topics mentioned above. The visual analysis of the maps facilitates the comprehension/interpretation of the relations between respondents and stimuli (both barriers and solutions), according to the resulting distances and aggregations within the map (Borg and Groenen 2005). To interpret each map, it is useful to take into account that the more the stimuli (or cluster of them) are surrounded by the respondents the more highly these stimuli (or cluster of them) are being rated by the respondents. That is to say that the preference scores of different respondents become proximities between the elements of two sets of choice objects, which are barriers and solutions. Food manufacturers and retailers are represented as 'ideal points in the space of perceptual map so that the distances from each ideal point to the object points correspond to the preference scores' (Borg and Groenen 2005). In the same way, the close distance between barriers and solutions represents the perception of the effectiveness of those solutions, and combination(s) of them, to solve the barriers as perceived by the respondents in relation to an ideal situation. In carrying out the MDU analysis, the focus was also to assess whether the differences in the combination of barriers and solutions contain patterns of aggregation due to the country, size-category of the food manufacturers, or the typology of the retailers. The data analysis adopted the non-metric MDU, using the algorithm PREFSCAL available in the statistical package for the social sciences, SPSS v. 20.0 (Busing et al. 2005) (See Appendix C for further details).

Results

The results show the outcomes from the seven topics of analysis. The focus on single issues allows an in-depth examination of each of these topics, which is then cross-analysed in the discussion section to provide the overall views of the food chain actors on low-cost healthy food production and commercialization.

Food Manufacturers' and Retailers' Relations

Food manufacturers' and retailers' relations (Table 2) are not considered very important solutions for low-cost healthy food production and commercialization (mean between 3.5 and 4.5). Lack of coordination and agreement among retailers and manufacturers (BLC, mean 4.5) and the increasing power of retailers (BRP, mean 4.2) are generally perceived as barriers that moderately limit the production and commercialization of low-cost healthy food.

[4] MDU is a method generally used in marketing research to allow researchers to build an image about the relationship between respondents and objects evaluated (Borg and Groenen 2005). MDU analysis can be explorative as well as confirmatory, or present a basis to identify questions to explore in subsequent analysis.

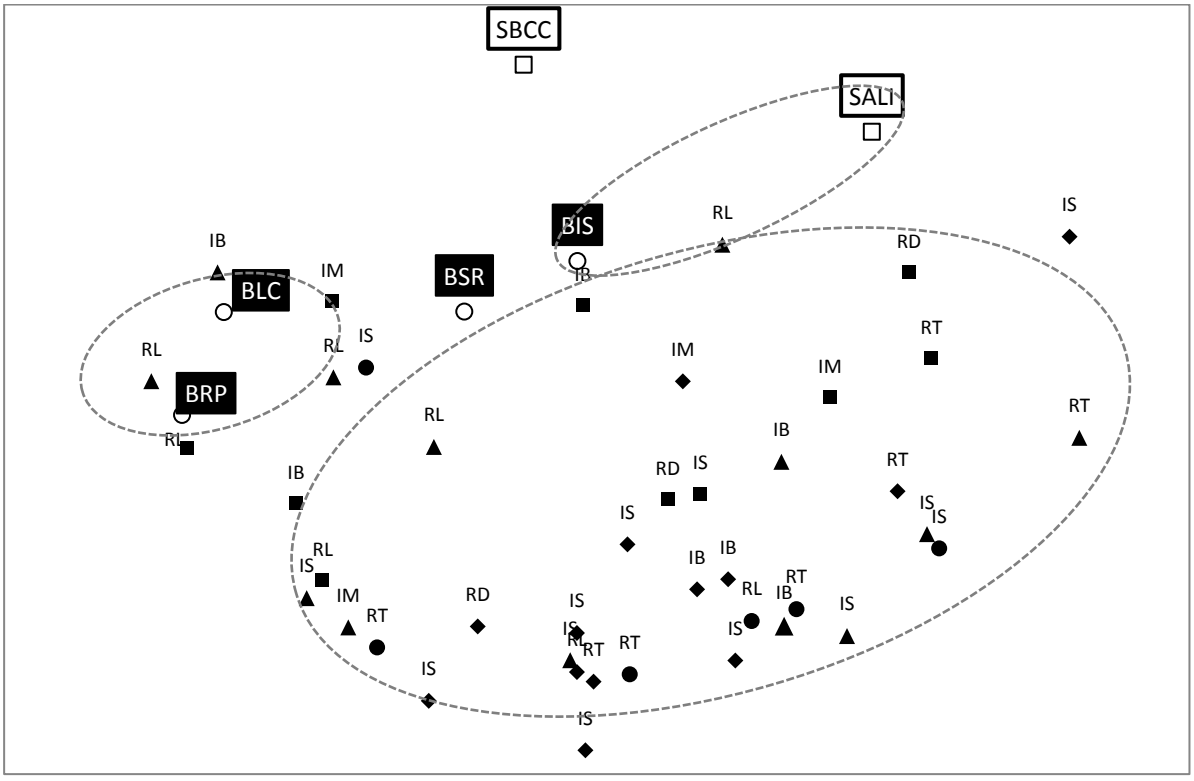
Table 2. Relations between food manufacturers and retailers — basic data.

	Food Manufacturers		Food Retailers		All	
Barriers	Mean	Mode	Mean	Mode	Mean	Mode
BIS. High bargaining power of suppliers of ingredients for low-cost healthy food (due to, i.e., limited number/monopoly of suppliers, scarce/no possibility to switch to other suppliers, high price of alternative suppliers)	4.0	6.0	3.5	5.0	3.8	2.0
BSR. Manufacturers favour relationships with retailers supplying the same 'old' products rather than proposing new products such as low-cost healthy food	3.3	1.0	3.8	6.0	3.5	1.0
BRP. Increasing power of retailers over what will be commercialised impedes food manufacturers interest in low-cost healthy food	4.5	7.0	3.9	2.0a	4.2	7.0
BLC. Lack of coordination and commercial agreement between manufacturers and retailers (in terms of production and commercialization) limits interest of manufacturers and retailers in low-cost healthy food	4.5	7.0	4.5	7.0	4.5	7.0
Solutions						
SBCC. Better coordination and commercial agreement between manufacturers and retailers (in terms of production and commercialization) increases interest of manufacturers and retailers in low-cost healthy food	5.5	6.0	5.7	7.0	5.6	6.0a
SALI. Increased availability of ingredients for low-cost healthy food	5.2	5.0a	5.2	6.0a	5.2	7.0

Note. Multiple modes exist. The smallest value is shown

Food manufacturers and retailers share the same perspectives on the solutions to low-cost healthy food, which focused on improving their relations (SBCC, mean 5.6) and the higher availability of low-cost ingredients (SALI, mean 5.2). Still, food manufacturers give more importance to retailers' power as a barrier to low-cost healthy food (BRP) and do not think there are limitations in proposing new products (BSR, mean 3.3, mode 1) due to stagnant chain relationships. As far as the relations between food manufacturers and retailers are concerned, the perceptions that food chain actors have about the combination of the barriers and solutions to low-cost healthy food production and commercialization are rather similar (Figure 1), regardless of the categories of respondents, nationality, or size-category of the food company. Yet interviewees' proximity to barriers suggests that respondents perceive the set of barriers as appropriate and pertinent. In addition, if barriers are also closer to each other, it suggests that interviewees think that barriers are related to each other and consistent with one another. The remoteness of food chain actors from the solutions suggests that the combination of barriers and solutions is not ideal or sufficient, that the solutions provided cannot be the *only* ones to improve low-cost healthy food production and commercialization, and that they believe that these solutions might also be accompanied by other solutions. Moreover, given that the closer solution to the barrier BIS is SALI, both manufacturers and retailers agreed that adequate availability of ingredients is a problematic issue that can be alleviated through an increase in low-cost healthy food ingredients.

The proximity of the barriers BRP and BLC shows that the increased availability of low-cost healthy food, as for many other food products, has to deal with the issue of unbalanced food chain power relationships between food manufacturers and retailers. This unbalanced relationship could however be lessened if these two food actors enter into commercial agreements to share their respective business risks.



Legend:

IS — Small Food Manufacturer
IM — Medium-sized Food Manufacturer
IB — Big Food Manufacturer
RL — Large Food Retailer
RD — Discount Food Retailer
RT — Traditional Food Retailer
Lithuania
Finland
Italy
Serbia

Badness-of-fit: σ_n=0.071; σ_1=0.267; σ_2=0.756
Goodness-of-fit: VAF=0.653; ρ_τ=0.788; τ_b=0.632
Nondegeneracy and intermixedness: Shepard's rough index= 0.707; DeSarbo intermixedness index=0.158

Figure 1. Map of relations between food manufacturers and retailers

Price

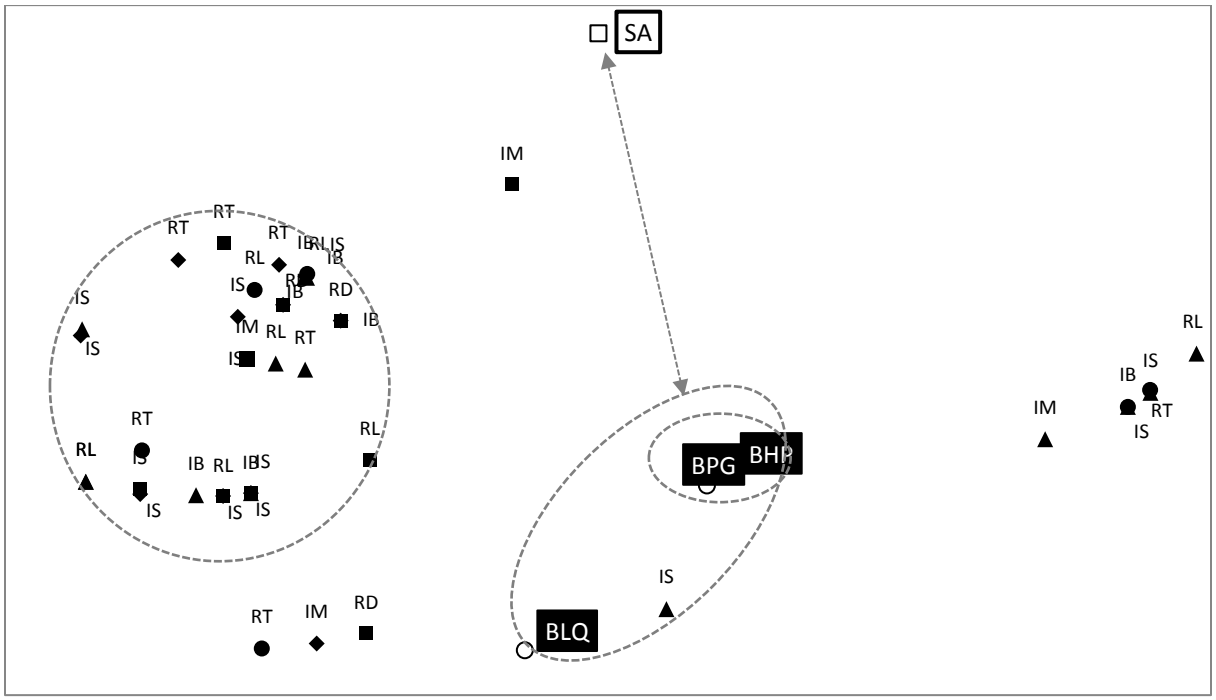
Interviewees think that the perception of at-risk-of-poverty consumers of the high price of healthy food, even if low-cost (BHP), and of the gap in price between healthy food, even if low-cost, and other familiar food (BPG) are important barriers (respectively with a mean of 5.5 and 5.3) (Table 3). Conversely, the issue of the perception of the low quality of low-cost healthy food does not represent such an important barrier (mean 4.6, mode 3). Moreover, food manufacturers and retailers are strongly concerned about the affordability of healthy food (SA, mean 6.1). The price issue generated different reactions from food manufacturers and retailers. Unlike retailers,

manufacturers seem more concerned about the perception of quality (BLQ) and less worried about high price (BHP) and gap price (BPG). This shows how food manufacturers are more concerned about production feasibility and capacity of innovation. On the other hand, retailers are more concerned about consumers' acceptability of price. Food chain actors have a similar perception regarding price issues (Figure 2). The map suggests that food manufacturers and retailers are not optimistic that low price will change the price perception of healthy food, even if the food is offered in the market at an affordable price. Low price is important and it provides an incentive for low-income consumers to buy healthy food, but it is not considered the only solution and cannot be expected to solve the problem. In addition, the actors in the food chain do not think that the quality barrier (BLQ), high price barrier (BHP), and high gap price barrier (BPG) can be solved simply by providing healthy food at an affordable price (SA). Overall respondents seem to believe that low-cost, as the only or the main product attribute at the basis of a competitive advantage strategy, is not the solution. Food affordability alone cannot overcome other misconceptions or false stereotypes that consumers might have about healthy food. Low-income and risk-of-poverty consumers are not expected to increase their consumption of healthy food, even if the healthy food is offered at a low price, thereby financially discouraging food chain actors from investing in this group of consumers and helping them to alter their food consumption habits.

Table 3. Price — basic data

	Food Manufacturers		**Food Retailers**		**All**	
Barriers	Mean	Mode	Mean	Mode	Mean	Mode
BHP. At-risk-of-poverty consumers' perception of high price of healthy food, even if low-cost	5.2	6.0	5.9	7.0	5.5	6.0
BPG. At-risk-of-poverty consumers' perception of high gap in price between healthy food, even though low-cost, versus their familiar food	5.0	6.0	5.6	5.0a	5.3	6.0
BLQ. At-risk-of-poverty consumers' perception of low quality of low-cost healthy food	5.0	5.0a	4.2	3.0	4.6	3.0a
Solutions						
SA. Affordability of healthy food would stimulate at-risk-of-poverty and low-income consumers' interest in this kind of food	6.2	7.0	5.9	7.0	6.1	7.0

Note. Multiple modes exist. The smallest value is shown



Legend:

IS — Small Food Manufacturer
IM — Medium-sized Food Manufacturer
IB — Big Food Manufacturer
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RT — Traditional Food Retailer
Lithuania
Finland
Italy
Serbia

Badness-of-fit: σ_n=0.015; σ_1=0.121; σ_2=0.508
Goodness-of-fit: VAF=0.8; ρ_n=0.851; τ_b=0.724
Nondegeneracy and intermixedness: Shepard's rough index=0.536; DeSarbo intermixedness index=0.136

Figure 2. Map of price

Innovation and Differentiation

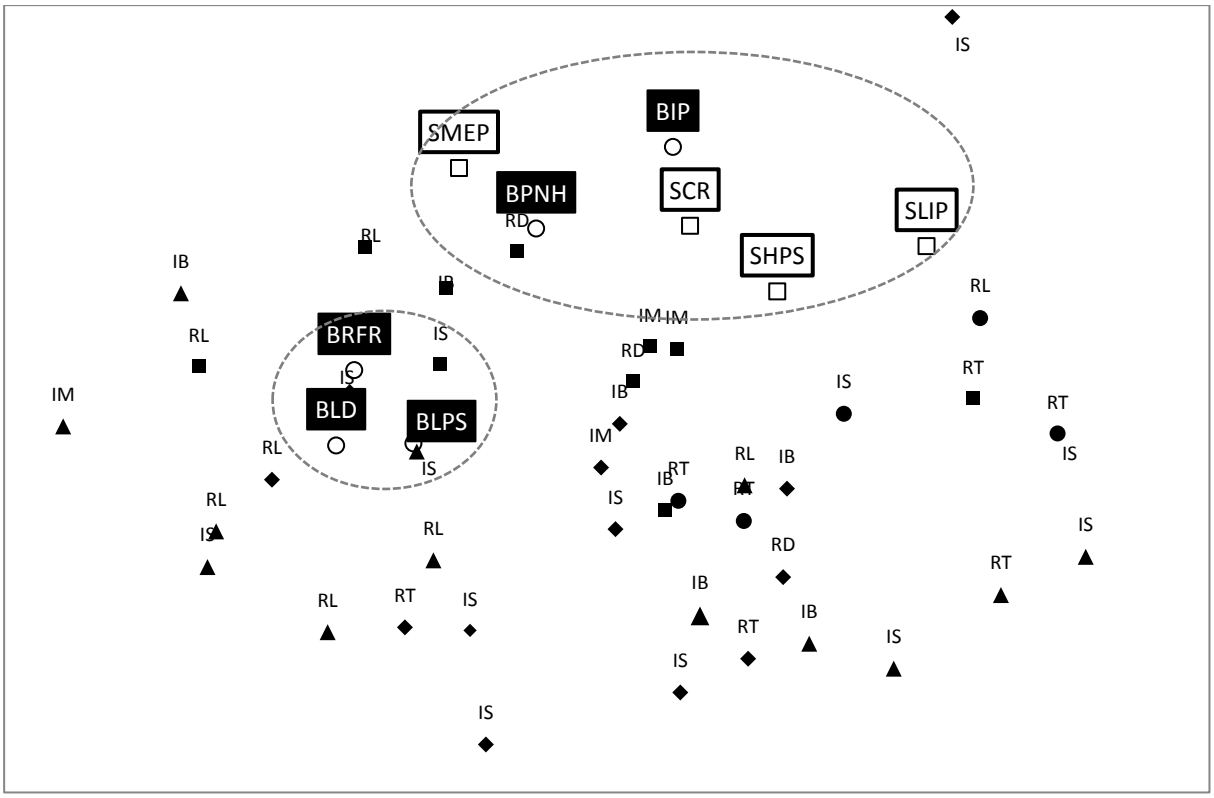
Food manufacturers and retailers perceive that barriers to innovation and differentiation have a more limited importance (mean from 4.1 to 5.5) compared to solutions (mean from 5.0 to 5.4) (Table 4). Prices of ingredients play an important role in healthy food product innovation and differentiation. Manufacturers and retailers have a similar vision of this issue, even though retailers more strongly perceive the financial risk connected with low-cost healthy food (BRFR), and food manufacturers are more concerned about the capability of differentiating (BLD) healthy food products. Food chain actors have a different perception about innovation and differentiation issues according to the size of the company or to the category of retailer (Figure 3). Unlike bigger companies, small food manufacturers and traditional retailers are less concerned by innovation and differentiation issues. This is significant and rather plausible since smaller food manufacturers or retailers have less impact on product innovation or differentiation, especially for the products under investigation. Small companies or retailers are followers rather than leaders that can influence the healthy-food industry. The map shows that bigger companies and larger retailers consider the barriers related to the level of standards (BLPS), capacity of differentiation of healthy food (BLD), and financial risk (BRFR) as more connected to their overall business strategies and operating management. In addition, the clustering of these barriers highlights the respondents' fear that low-cost healthy food cannot be adequately differentiated (BLD) due to the

attributes of price or healthiness and to the lack of private standards (BLPS), which leads to the perceived barrier connected to high financial risk (BRFR) of low-cost healthy food. The manufacturers and retailers located close to this grouping perceive that low-cost healthy food still lacks an effective food marketing positioning strategy and margin potential. The second combination of barriers and solutions shows that the barrier of high price of ingredients (BIP) can be addressed by lowering the price of ingredients (SLIP), inserting private standards of production for healthy food (SHPS), and better defining complementary roles between food manufacturers and retailers in promoting innovative products (SCR). One solution is through food chain agreements that sustain strategies of market entry protection (SMEP). This food system strategic approach could exclude competitors and allow competition with other high margin performance products (BNPH).

Table 4. Innovation and differentiation — basic data

	Food Manufacturers		**Food Retailers**		**All**	
Barriers	Mean	Mode	Mean	Mode	Mean	Mode
BLD. Manufacturers and retailers think that low-cost healthy food cannot be sufficiently well differentiated/does not have a valuable competitive advantage over other food	4.3	5.0	3.9	6.0	4.1	5.0
BLPS. The lack of private standards focused on healthy food production, commercialization and distribution limits consumers' interest in healthy food	4.2	1.0a	3.9	6.0	4.1	6.0
BIP. High price of ingredients to be used for low-cost healthy food	5.5	7.0	5.5	7.0	5.5	7.0
BRFR. Manufacturers and retailers believe low-cost healthy food has a high financial risk	4.1	2.0	4.4	7.0	4.2	2.0
BPNH. High margin of performance of other food in comparison to low-cost healthy food for manufacturers and retailers	4.9	6.0	4.6	6.0	4.7	6.0
Solutions						
SCR. Defining complementary roles in innovation processes between manufacturers and retailers for low-cost healthy food production/commercialization; for example, food manufacturers focused on quality innovation and retailers focused on understanding and flexibly adjusting to food market response to low-cost healthy food	5.2	6.0	5.3	7.0	5.2	5.0
SHPS. Commercializing food produced with private standards for healthy food can increase the intention of consumers at-risk-of-poverty to buy healthy food	4.9	4.0	5.2	4.0	5.0	4.0
SMEP. Raising manufacturers and/or retailers' standards in favour of healthy food can create barriers to marketplace entry of other manufacturers and/or retailers	5.3	7.0	5.4	7.0	5.4	7.0
SLIP. Decreased prices of ingredients for low-cost healthy food	5.2	7.0	4.8	7.0	5.0	7.0

Note. Multiple modes exist. The smallest value is shown



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Badness-of-fit: σ_n=0.124; σ_1=0.352; σ_2=0.916
Goodness-of-fit: VAF=0.546; ρ_n=0.742; τ_b=0.575
Nondegeneracy and intermixedness: Shepard's rough index=0.752; DeSarbo intermixedness index=0.175

Figure 3. Map of innovation and differentiation

Competitiveness Strategies

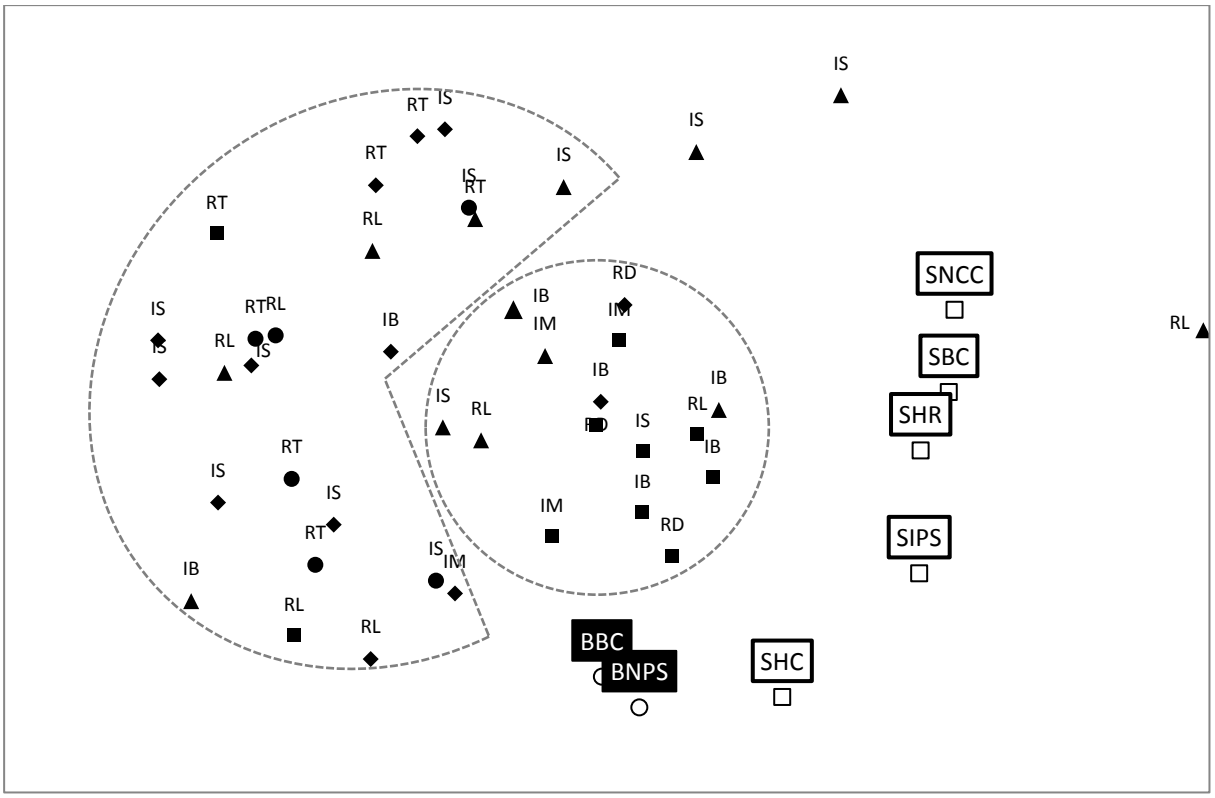
Food chain actors give importance to solutions focused on competitiveness strategies in order to increase low-cost healthy food production and commercialization (Table 5, mean between 5 and 5.5), whereas barriers receive less attention (mean between 4.6 and 4.9). The perceptions of food manufacturers and retailers differ significantly when it concerns brand competition (BBC and SBC). Retailers give more importance than food manufacturers to the strategies of healthy brand competition. In terms of a one barrier (BBC), retailers believe more strongly than food manufacturers that the competition is not sufficiently focusing on healthy food. As solutions (SBC), in the retailers' view, investment in increasing brand reputation as a healthy-food provider could lead to the production and commercialization of healthier food. This is also in line with stronger attention and investments that retailers are putting into developing their own brands, in competition with other commercial brands. Food manufacturers have competitiveness strategies for managing healthy food (Figure 4) that differ according to the size of the company. Big and medium-sized food manufacturing companies consider producing and marketing low-cost healthy

food a part of their overall competitiveness strategies and are therefore more strongly influenced by the combination of barriers and solutions presented. On the other hand, small companies perceive low-cost healthy food as worthy of attention, but these smaller companies do not design business strategies to focus on providing low-cost healthy food. According to the map, big companies believe that a better positioning strategy (SIPS) and more brand competition (SBC) of food system actors could address the low level of interest of food manufacturers and retailers in healthy food (BNPS, BBC), which could lead to an increase in low-cost healthy food production. Making healthy food recipes (SHR) and cooking classes easily accessible (SNCC) can contribute to an increased positioning strategy focused on low-cost healthy food and as instruments for stimulating the competition between food manufacturers and retailers, thereby increasing the competitiveness of food chain actors. Large food manufacturers and retailers have a vested interest in supporting public campaigns (SHC) that educate the population about consuming healthier food as part of their competitiveness strategy oriented more on healthy food.

Table 5. Competitiveness strategies — basic data

	Food Manufacturers		**Food Retailers**		**All**	
Barriers	Mean	Mode	Mean	Mode	Mean	Mode
BNPS. Positioning strategy of manufacturers and retailers not sufficiently focused on low-cost healthy food	4.8	6.0	5.0	7.0	4.9	7.0
BBC. Insufficient competition between manufacturers and retailers over healthy brand reputation/positioning	4.2	5.0	5.1	7.0	4.6	5.0
Solutions						
SIPS. Food manufacturers' or retailers' increased positioning strategy focused on low-cost healthy food	5.5	7.0	5.4	7.0	5.5	7.0
SBC. Food manufacturers and retailers competition over healthy brand reputation/positioning favours propensity to healthier food (re)formulation	4.7	5.0a	5.6	7.0	5.1	7.0
SHC. Introducing or strengthening the supporting role of retailers and/or food manufacturers in favour of public health campaign and healthy food consumption	5.4	7.0	5.7	7.0	5.5	7.0
SHR. Food manufacturers' or retailers' provide consumers recipes for low-cost healthy food/meals	4.8	7.0	5.3	5.0a	5.0	7.0
SNCC. Conduct nutrition education classes and cooking classes, including shopping and food budgeting guidance, at the retailers' store targeted at risk-of-poverty/low-income population	5.0	7.0	5.4	7.0	5.2	7.0

Note. Multiple modes exist. The smallest value is shown



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Badness-of-fit: σ_n=0.061; σ_1=0.248; σ_2=0.788
Goodness-of-fit: VAF=0.606; ρ_n=0.767; τ_b=0.612
Nondegeneracy and intermixedness: Shepard's rough index=0.686; DeSarbo intermixedness index=0.377

Figure 4. Map of competitiveness strategies

Private Label

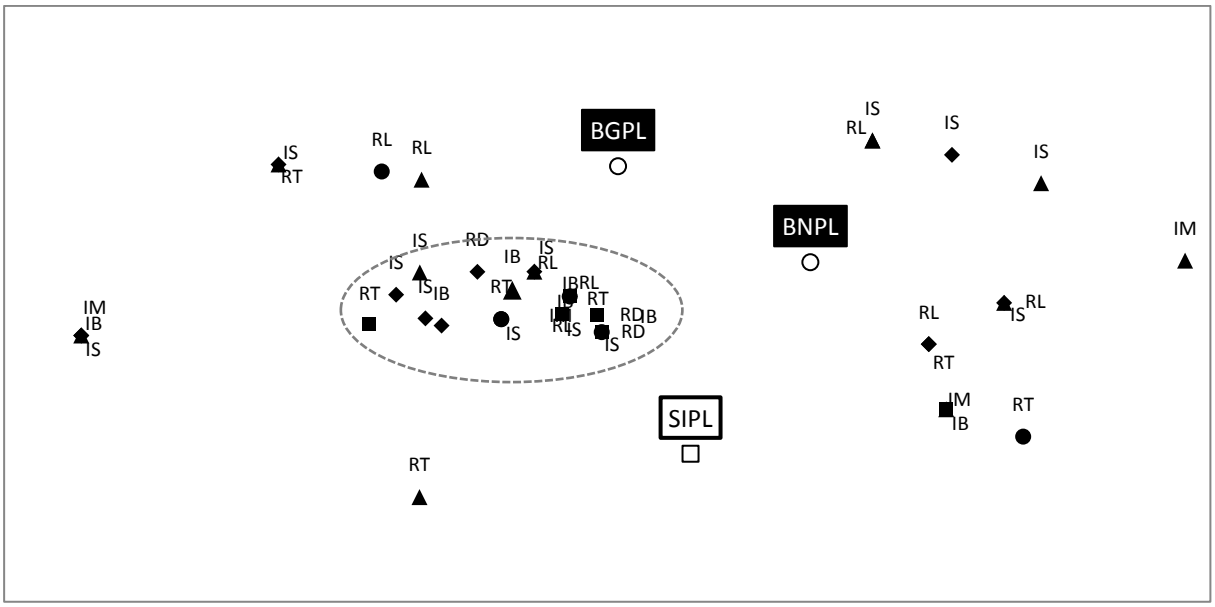
Food chain interviewees agree that the current growth of private label sales (BGPL) and retailers' limited interest in private label lines as brands for low-cost healthy food (BNPL) are relevant, but not very important barriers to low-cost healthy food (Table 6, respective means are 4.5 and 4). There is stronger agreement over the suggestion of using a private label as a carrier brand for low-cost healthy food (SIPL, mean 5.4). Still, the differences among food manufacturers' and retailers' opinions are noteworthy. Food manufacturers seem to give a prominent role to private labels. Food manufacturers (mean 4.9) believe more strongly than retailers (mean 4.1) that the ever-growing phenomenon of private label versus commercial brands is limiting food manufacturers' capacity for investment in low-cost healthy food (BGPL). Again, food manufacturers' (mean 5.5) trust in private labels as a way to enter the low-cost healthy food market (SIPL) is higher than retailers (mean 5.2). The respondents' position on the map (Figure 5) suggests that many respondents perceive that retailers' current private label management strategy (BGPL and BNPL) is limiting the possibility of offering low-cost healthy food. Reacting by increasing retailers' interest in marketing low-cost healthy food with a private label is considered a constructive strategy (SIPL). The central cluster of respondents includes a mix of

food manufacturers and retailers with most of the big companies. These big companies' consistent position demonstrates the rather cohesive thinking of the group. On the contrary, smaller companies are both inserted in the central group and spread around the map, thereby showing quite variegated opinions on the issue. Moreover, retailers' position around the map shows that the issue of private labels in relation to low-cost healthy food induces dissimilar opinions among retailers. This is the likely consequence of the manifold strategic approaches that private label brands have in food commercialization management and product innovation.

Table 6. Private label — basic data

	Food Manufacturers		Food Retailers		All	
Barriers	Mean	Mode	Mean	Mode	Mean	Mode
BGPL. Consumers' increasing interest in private label vs. commercial brands limits food manufacturers' intentions to invest in low-cost healthy food	4.9	5.0	4.1	1.0a	4.5	5.0
BNPL. Retailers' very limited interest in private label lines for low-cost healthy food	4.0	3.0	3.8	1.0	4.0	3.0
Solutions						
SIPL. Inserting low-cost healthy food in the market within a private label	5.5	7.0	5.2	5.0	5.4	5.0

Note. Multiple modes exist. The smallest value is shown



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Serbia

Badness-of-fit: σ_n=0.009; σ_1=0.093; σ_2=0.26
Goodness-of-fit: VAF=0.938; ρ_n=0.933; τ_b=0.826
Nondegeneracy and intermixedness: Shepard's rough index=0.681; DeSarbo intermixedness index=0.022

Figure 5. Map on private label

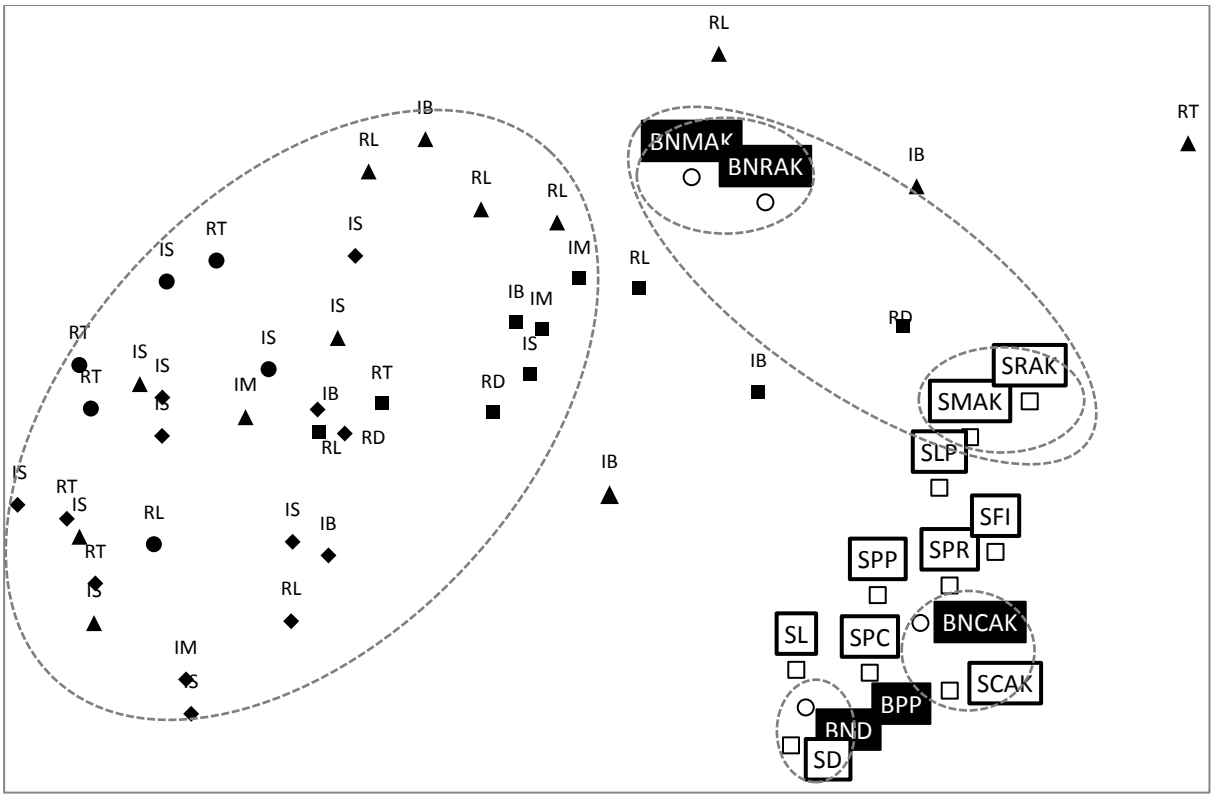
Public Policy and Regulations

Food chain actors perceive the lack of adequate public policy in support of healthy food (BPP, mean 6.1) and the inadequate comprehension of consumers about healthy food (BNCAK, mean 5.6) (Table 7) as significant barriers. This issue should be addressed by improving consumer awareness and knowledge about nutritional issues (SCAK, mean 6.3). The lack of an official definition of what healthy food is (BND, mean 5.6) is also a barrier. This should be addressed with an official agreement on the definition of *healthy food* (SD, mean 5.8).

Table 7. Public policy and regulations — basic data

	Food Manufacturers		**Food Retailers**		**All**	
Barriers	Mean	Mode	Mean	Mode	Mean	Mode
BND. Lack of an official definition of healthy food	5.5	7.0	5.7	7.0	5.6	7.0
BNMAK. Inadequate awareness and knowledge of manufacturers about nutritional issues	4.3	7.0	3.6	1.0	4.0	1.0a
BNRAK. Inadequate awareness and knowledge of retailers about nutritional issues	4.5	3.0	3.7	3.0	4.2	3.0
BNCAK. Inadequate awareness and knowledge of at-risk-of-poverty consumers about nutritional issues	5.5	7.0	5.8	7.0	5.6	7.0
BPP. Lack of adequate public policy intervention concerning the promotion of healthy food for at-risk-of-poverty and low-income people	6.0	7.0	6.2	7.0	6.1	7.0
Solutions						
SMAK. Improving awareness and knowledge of manufacturers about nutritional issues	5.2	7.0	5.8	7.0	5.5	7.0
SRAK. Improving awareness and knowledge of retailers about nutritional issues	5.7	7.0	5.4	7.0	5.6	7.0
SCAK. Improving awareness and knowledge of consumers about nutritional issues, with specific focus on those at risk of poverty	6.1	7.0	6.5	7.0	6.3	7.0
SD. Agreement about an official definition of healthy food	5.8	7.0	5.8	7.0	5.8	7.0
SPP. Promotion of low-cost healthy food recipes (for example, low budget, limited available time) by web, funded/promoted through national schemes	5.2	5.0a	5.7	7.0	5.4	7.0
SPC. Providing publicly funded communication campaign about low-cost healthy food	5.6	5.0	6.0	7.0	5.8	7.0
SPR. Public policy and public regulations can contribute to guaranteeing low-cost healthy food production, commercialization and distribution	5.6	7.0	5.9	7.0	5.7	7.0
SFI. Identifying financial incentives and disincentives to levering the supply chain in the direction of low-cost healthy food	6.1	6.0a	5.3	7.0	5.8	7.0
SLP. Introduction of policies affecting commodity (ingredient) prices could result in product reformulation to less expensive healthier inputs	5.4	7.0	4.9	7.0	5.2	7.0
SL. Introduction of a regulation in favour of labelling healthy food	5.0	6.0	5.7	7.0	5.3	7.0

According to respondents, other important solutions may include publicly funded educational campaigns about healthy food consumption (SPC, mean 5.8) and financial incentives and disincentives in developing and sustaining a more healthy food–oriented supply chain (SFI, mean 5.8). Food manufacturers and retailers showed different levels of interest in a small number of propositions. As far as barriers are concerned, food manufacturers think that both their own (BNMAK, mean 4.3) and retailers' (BNRAK, mean 4.5) awareness and knowledge represent a relevant barrier to producing and selling healthy food. Food manufacturers believe more strongly than retailers in the support that financial incentives (SFI, mean 6.1) could encourage all food chain actors to increase their investment in producing low-cost healthy food. Finally, retailers seem more strongly interested than food manufacturers in appropriate healthy food labelling (SL, mean 5.7). Respondents share similar opinions regarding the combination of barriers and solutions concerning public policy and regulations (Figure 6).



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Badness-of-fit: σ_n=0.042; σ_1=0.206; σ_2=0.795
Goodness-of-fit: VAF=0.62; ρ_n=0.768; τ_b=0.625
Nondegeneracy and intermixedness: Shepard's rough index=0.578; DeSarbo intermixedness index=0.925

Figure 6. Map on public policy and regulations

The barriers that respondents admit as relevant and related are the lack of adequate manufacturers' (BNMAK) and retailers' (BNRAK) awareness and knowledge about nutrition,

which should be faced by directly targeting them (SMAK and SRAK). Similarly, food chain actors believe that the inadequate awareness and knowledge about nutritional issues of low-income consumers (BNCAK) can be addressed with the corresponding solution (SCAK), but in coordination with other publicly promoted actions. Respondents have a similar judgment about another pair of statements: lack of definition (BND) and the need for a uniformed definition of healthy food (SD). This means that interviewees believe that the barrier can be addressed by acting directly in favour of targeting that specific problem. Finally, respondents believe that these barriers can be addressed through public support for healthy food (SPP), campaigns (SPC), financing (SFI), and regulation (SPR, SD, SL). The map also shows that interviewees believe that only coordinated actions can increase healthy food production and commercialization.

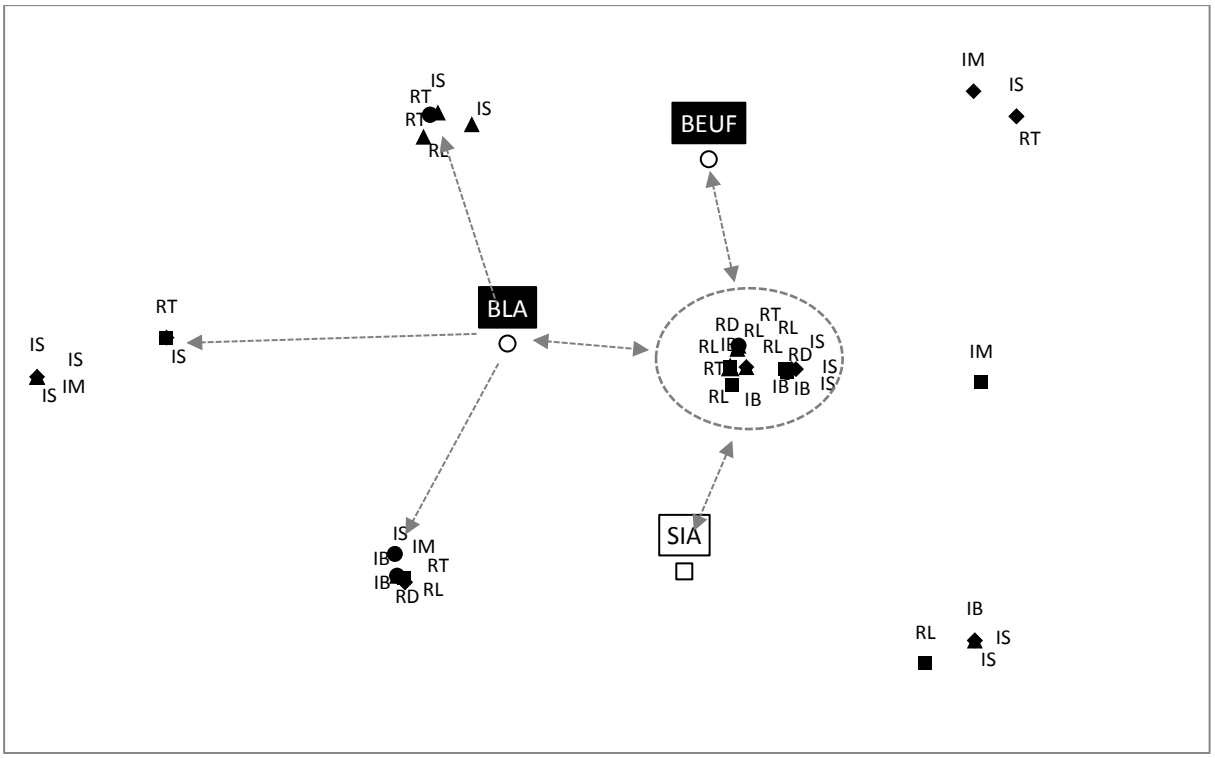
Food Accessibility

Lack of access, even though appropriate, is not an important barrier to healthy food consumption and commercialization (BLA, mean 4.2), as far as food chain actors are concerned (Table 8). In fact, consumers' easy access to unhealthy food is believed to be a more important barrier (BEUF, mean 5.2). Interviewees believe that if consumers, even those at a low-income level, have easier access to low-cost healthy food, they will increase their consumption of more nutritious food, albeit only moderately (SIA, mean 5.4). Food manufacturers and retailers have different views on these issues. Food manufacturers generally give more importance to both barriers and solutions, especially if the barrier represents the lack of access to healthy food (BLA, mean 5 of food manufacturers versus 3.2 of retailers). The issue of food accessibility is rather controversial, as shown by the many micro-clusters of respondents (Figure 7). Still there is relatively strong agreement among the majority of respondents over the positive contribution that the improvement of at-risk-of-poverty consumers' access to low-cost healthy food (SIA) can have in lowering the barrier of the lack of access to low-cost healthy food (BLA).

Table 8. Food accessibility — basic data

	Food Manufacturers		**Food Retailers**		**All**	
Barriers	Mean	Mode	Mean	Mode	Mean	Mode
BLA. At-risk-of-poverty consumers' lack of access to low-cost healthy food	5.0	7.0	3.2	1.0	4.2	7.0
BEUF. Consumers' easy access to food that is not healthy	5.5	7.0	4.8	6.0	5.2	7.0
Solutions						
SIA. Improving access of consumers at risk of poverty to low-cost healthy food (for example, increasing commercialization and distribution in areas with risk of poverty and making low-cost healthy food easily reachable by those at risk of poverty)	5.7	7.0	4.9	6.0a	5.4	7.0

Note. Multiple modes exist. The smallest value is shown



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Badness-of-fit: σ_n=0.012; σ_1=0.107; σ_2=0.274
Goodness-of-fit: VAF=0.931; ρ_n=0.895; τ_b=0.757
Nondegeneracy and intermixedness: Shepard's rough index=0.567; DeSarbo intermixedness index=0.037

Figure 7. Map on food accessibility

Summary of Results

Food manufacturers and retailers can prioritise the most prominent barriers to providing consumers with healthy food, but they have limited capability to prioritise one solution. The main perceived barriers concern the price, easy accessibility to unhealthy food, and lack of adequate public policy to support the provision of low-cost healthy food. The most relevant solution to increasing healthy food availability is to heighten consumers' awareness and knowledge about healthy food. Of course, other equally important solutions such as the affordability of healthy food, better coordination and commercial agreement between the manufacturers and retailers, support for a healthy food campaign, and a shift in retailers' and manufacturers' business strategy to focus on healthy food will also play a defining role in increasing healthy food consumption. These responses show that food chain actors acknowledge that there exists a market for healthy food, but that food chain actors are not ready to fully engage in this market, because of a number of perceived critical factors that concern both the private and the public dimensions. Not only food manufacturers and retailers could have a role in increasing low-cost healthy food offer, but also all other food system actors, including consumers and policy makers. All food chain actors

regardless of size or category demonstrated the lack of a concrete investment strategy for these products. Small and medium-sized enterprises provided more diverse and uncertain feedback, and big food manufacturers and large retailers have more experience and provided more informed feedback as far as innovation, differentiation and competitiveness strategies are concerned. Yet they have not yet taken a prominent or initiating role in manufacturing and commercializing low-cost healthy food.

Discussion

The reasons, expectations, and critical factors expressed by food chain actors about low-cost healthy food production and commercialization demonstrate that the issue is multifaceted and should be addressed on many different fronts. First, low-cost healthy food is a consumer good that, if placed within the product life cycle, seems to be in its *introduction* stage. The exploratory survey shows that both food manufacturers and retailers are interested in investing in producing healthy food, but they are cautious. This is even more evident if healthy food is to be sold at a low price. The newness of the low-cost healthy food market prevents food chain actors from investing resources to develop a business strategy to bring healthy food to the masses. The innovativeness of the market is spread throughout various countries and, though to a lesser extent, is also related to the size-category of the companies.

The food chain actors' cautious approach to the newness of low-cost healthy food market suggests that public sector initiatives are necessary to reach the *growth* stage. Second, low-cost healthy food is a challenge in terms of price to market, price adequate to cover the costs, and a source of financial risk. Food chain actors are sceptical that healthy food affordability is a real barrier to its consumption. Food manufacturers and retailers believe that price is a key attribute to healthy food, but they are aware that ensuring a low price is not a sufficient solution, even for low-income people. In their view, the importance of the price of healthy food is often overestimated, and the solution should be found in a well-balanced basket of product attributes. Third, food chain actors are sceptical about consumers' appreciation of healthy food. In their view, the image of healthy food should improve and become more attractive and, especially, competitive if compared with the image of other familiar or unhealthy food. The concept of *healthy* should get closer to *tasty*. Food manufacturers and retailers fear that the capacity to differentiate healthy food, compared with other food, is too low and not sufficiently competitive. Therefore, food chain actors should strive at improving consumers' understanding and appreciation of healthy food, which will lead to heightened acceptability of healthy food. Finally, food chain actors call for concrete public policies that support low-cost healthy food production and commercialization. Although self-serving, their views are worth consideration because of their experience and expertise. In line with food chain actors' expectations, public actors could set financial incentives and targeted policies to sustain, initiate and boost the evolving healthy food market and to define public policies better responsive to the alarming health phenomenon. This can eventually lead to fewer illnesses or deaths attributable to NCDs, thus reducing the strain on the economy and healthcare system.

Conclusion

The plausible disenchantment of food chain actors in the development and increase in the consumption of low-cost healthy food discloses the distance between current food manufacturers' and retailers' corporate strategy and alarming social and health trends. Yet, in order to match the legitimate economic interests of the private sector with the need to increase the supply of low-cost healthy food, the reasons, expectations and critical factors expressed by the food chain actors must be addressed through targeted and strengthened private and public cooperation.

Acknowledgements

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Appendix A

Definition of semi-processed or processed healthy food provided to interviewees

A food with a *good nutrient profile*, that is a food not containing a high amount of nutrients (sodium, total fat, saturated fat, and sucrose), the high intake of which could be responsible for an increase in the risk of disease; or a food with *good nutritional density*, that is a food with a high content of fiber, micronutrients (vitamins and minerals) and bioactive compounds (polyphenols, phytosterols, carotenoids [such as lycopene], tocopherols, probiotics, etc.). Interviewees can also refer to a food *with a nutritional claim*, that is any claim that states, suggests or implies that a food has particular beneficial nutritional properties due to the nutrients or other substances it (i) contains, (ii) contains in reduced or increased proportions, or (iii) does not contain. Interviews did not refer to food with a health claim or functional food. Examples of good nutrient profile food or food with a nutritional claim given to interviewees: food that does not contain, or contains in reduced proportions, any of the following: sodium, total fat, saturated fat, sucrose; and food that contains, or contains increased proportions of, any of the following: fiber, micronutrients (vitamins and minerals), and bioactive compounds such as polyphenols, phytosterols, carotenoids (such as lycopene), tocopherols, probiotics, etc. This concept refers to Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on foods (OJ L 404, 30.12.2006, p. 9).

Definition of low-cost provided to interviewees

Food with *good nutrient profile* and with *good nutritional density*, particularly if sold with a nutritional claim, is usually sold at a higher market price (because of higher costs of production and of higher margin expectations) compared with food without specific nutritional characteristics. Interviewees were asked to provide opinions about healthy food, as defined above, sold at a market price lower than the common market prices. The healthy food being referred to could have been produced or sold (or not produced or sold) by the company the interviewee worked for.

Appendix B

Relations between Food Manufacturers and Retailers	Sources of Literature
Barriers	
BIS. High bargaining power of suppliers of ingredients for low-cost healthy food (due to, i.e., limited number/monopoly of suppliers, scarce/no possibility to switch to other suppliers, high price of alternative suppliers)	Golan et al. 2008, Kadiyali et al. 2000
BSR. Manufacturers favour relationships with retailers supplying the same 'old' products rather than proposing new products such as low-cost healthy food	Kadiyali et al. 2000, Vander Wekken 2012
BRP. Increasing power of retailers over what will be commercialized impedes food manufacturers interest in low-cost healthy food	Burch and Lawrence 2005, European Commission 2009a, Kadiyali et al. 2000, 2009b, Wardle and Baranovic 2009
BLC. Lack of coordination and commercial agreement between manufacturers and retailers (in terms of production and commercialization) limits interest of manufacturers and retailers in low-cost healthy food	European Commission 2009a, 2009b, Kadiyali et al. 2000, Vlachos and Bourlakis 2006, Wardle and Baranovic 2009
Solutions	
SBCC. Better coordination and commercial agreement between manufacturers and retailers (in terms of production and commercialization) increases interest of manufacturers and retailers in low-cost healthy food	European Commission 2009a, 2009b, Kadiyali et al. 2000, Wardle and Baranovic 2009
SALI. Increased availability of ingredients for low-cost healthy food	Golan et al. 2008, Kadiyali et al. 2000
Price	**Sources of Literature**
Barriers	
BHP. At-risk-of-poverty consumers' perception of high price of healthy food, even if low-cost	Vander Wekken et al. 2012
BPG. At-risk-of-poverty consumers' perception of high gap in price between healthy food, even though low-cost, versus their familiar food	Vander Wekken et al. 2012
BLQ. At-risk-of-poverty consumers' perception of low quality of low-cost healthy food	Ajzen 1991, Bogue et al. 2005, Lähteenmäki et al. 2010, Nestle et al. 1998, Vander Wekken et al. 2012
Solutions	
SA. Affordability of healthy food would stimulate at-risk-of-poverty and low-income consumers' interest in this kind of food	Vander Wekken et al. 2012
Innovation and Differentiation	**Sources of Literature**
Barriers	
BLD. Manufacturers and retailers think that low-cost healthy food cannot be sufficiently well differentiated/does not have a valuable competitive advantage over other food	Lähteenmäki et al. 2010, Nestle et al. 1998, Vander Wekken et al. 2012
BLPS. The lack of private standards focused on healthy food production, commercialization and distribution limits consumers' interest in healthy food	Brambila-Macias 2011

Appendix B *-Continued*

Innovation and Differentiation	**Sources of Literature**
Barriers	
BIP. High price of ingredients to be used for low-cost healthy food	Kadiyali et al. 2000, UN 2011
BRFR. Manufacturers and retailers believe low-cost healthy food has a high financial risk	Burch and Lawrence 2005, Harvey et al. 2002, Vander Wekken 2012
BPNH. High margin of performance of other food in comparison to low-cost healthy food for manufacturers and retailers	Boesso et al. 2009, Burch and Lawrence 2005, Harvey et al. 2002, Vander Wekken 2012
Solutions	
SCR. Defining complementary roles in innovation processes between manufacturers and retailers for low-cost healthy food production/commercialization; for example, food manufacturers focused on quality innovation and retailers focused on understanding and flexibly adjusting to food market response to low-cost healthy food	Hooker and Downs 2014, WHO 2013
SHPS. Commercializing food produced with private standards for healthy food can increase the intention of consumers at-risk-of-poverty to buy healthy food	Brambila-Macias 2011, Hooker and Downs 2014, WHO 2013
SMEP. Raising manufacturers and/or retailers' standards in favour of healthy food can create barriers to marketplace entry of other manufacturers and/or retailers	Brambila-Macias 2011, Hooker and Downs 2014, WHO 2013
SLIP. Decreased prices of ingredients for low-cost healthy food	Golan et al. 2008, Kadiyali et al. 2000, UN 2011
Competitiveness Strategies	**Sources of Literature**
Barriers	
BNPS. Positioning strategy of manufacturers and retailers not sufficiently focused on low-cost healthy food	Lang et al. 2006, Wardle and Baranovic 2009
BBC. Insufficient competition between manufacturers and retailers over healthy brand reputation/positioning	Lang et al. 2006, Wardle and Baranovic 2009
Solutions	
SIPS. Food manufacturers' or retailers' increased positioning strategy focused on low-cost healthy food	Hooker and Downs 2014, Lang et al. 2006, Wardle and Baranovic 2009, UN 2011
SBC. Food manufacturers and retailers competition over healthy brand reputation/positioning favours propensity to healthier food (re)formulation	Hooker and Downs 2014, Lang et al. 2006, Mancino et al. 2008, UN 2011, Wardle and Baranovic 2009, WHO 2013
SHC. Introducing or strengthening the supporting role of retailers and/or food manufacturers in favour of public health campaign and healthy food consumption	Caraher and Coveney 2004, European Commission 2009b, UN 2011
SHR. Food manufacturers' or retailers' provide consumers recipes for low-cost healthy food/meals	Food Marketing Institute 2012, Gloria and Steinhardt 2010, WHO 2013
SNCC. Conduct nutrition education classes and cooking classes, including shopping and food budgeting guidance, at the retailers' store targeted at risk-of-poverty/low-income population	Food Marketing Institute 2012, Gloria and Steinhardt 2010, Hartmann 2013, Worsley et al. 2014

Appendix B *-Continued*

Private Label	**Sources of Literature**
Barriers	
BGPL. Consumers' increasing interest in private label vs. commercial brands limits food manufacturers' intentions to invest in low-cost healthy food	Bunte et al. 2011, Burch and Lawrence 2005, Kadiyali et al. 2000
BNPL. Retailers' very limited interest in private label lines for low-cost healthy food	Bunte et al. 2011, Burch and Lawrence 2005, Kadiyali et al. 2000
Solutions	
SIPL. Inserting low-cost healthy food in the market within a private label	Bunte et al. 2011, Burch and Lawrence 2005, Kadiyali et al. 2000
Public Policy and Regulations	**Sources of Literature**
Barriers	
BND. Lack of an official definition of healthy food	Duvaleix-Treguer et al. 2012, UN 2011, WHO 2013
BNMAK. Inadequate awareness and knowledge of manufacturers about nutritional issues	Lang et al. 2006, WHO 2010a
BNRAK. Inadequate awareness and knowledge of retailers about nutritional issues	Lang et al. 2006, WHO 2010a
BNCAK. Inadequate awareness and knowledge of at-risk-of-poverty consumers about nutritional issues	Ajzen 1991, Bogue et al. 2005, Costa and Jongen 2010, De Irala et al. 2000, Dickinson-Spillman and Siegrist 2011
BPP. Lack of adequate public policy intervention concerning the promotion of healthy food for at-risk-of-poverty and low-income people	Brambila-Macias 2011, Golan and Unnevehr 2008, Grunert and Wills 2007, Hess et al. 2012, McCarthy et al. 2013, Wardle and Baranovic 2009, WHO 2013
Solutions	
SMAK. Improving awareness and knowledge of manufacturers about nutritional issues	Lang et al. 2006, WHO 2010a
SRAK. Improving awareness and knowledge of retailers about nutritional issues	Lang et al. 2006, WHO 2010a
SCAK. Improving awareness and knowledge of consumers about nutritional issues, with specific focus on those at risk of poverty	Ajzen 1991, Bogue et al. 2005, Dickinson-Spillman and Siegrist 2011
SD. Agreement about an official definition of healthy food	Duvaleix-Treguer et al. 2012, UN 2011, WHO 2013
SPP. Promotion of low-cost healthy food recipes (for example, low budget, limited available time) by web, funded/promoted through national schemes	Brunsø et al. 2004, UN 2011, Wardle and Baranovic 2009
SPC. Providing publicly funded communication campaign about low-cost healthy food	Brunsø et al. 2004, Hawkes et al. 2012, UN 2011,WHO 2013
SPR. Public policy and public regulations can contribute to guaranteeing low-cost healthy food production, commercialization and distribution	Brambila-Macias 2011, Duvaleix-Treguer et al. 2012, UN 2011, Wardle and Baranovic 2009, WHO 2013
SFI. Identifying financial incentives and disincentives to levering the supply chain in the direction of low-cost healthy food	Brambila-Macias 2011, Duvaleix-Treguer et al. 2012, Golan et al. 2008, Hawkes et al. 2012, UN 2011, Wardle and Baranovic 2009, WHO 2013

Appendix B -*Continued*

Public Policy and Regulations	**Sources of Literature**
Solutions	
SLP. Introduction of policies affecting commodity (ingredient) prices could result in product reformulation to less expensive, healthier inputs	Brambila-Macias 2011, Duvaleix-Treguer et al. 2012, Golan et al. 2008, Hawkes et al. 2012, Mancino et al. 2008, UN 2011, WHO 2013
SL. Introduction of a regulation in favour of labelling healthy food	Duvaleix-Treguer et al. 2012, Grunert and Wills 2007, Hess et al. 2012, UN 2011, WHO 2013
Food Accessibility	**Sources of Literature**
Barriers	
BLA. At-risk-of-poverty consumers' lack of access to low-cost healthy food	Beaulac et al. 2009, Cummins et al. 2005, Kyureghian et al. 2013, Larson et al. 2009, Pomeranz 2012, Walker et al. 2010
BEUF. Consumers' easy access to food that is not healthy	Dibsdall et al. 2003, Pomeranz 2012
Solutions	
SIA. Improving access of consumers at risk of poverty to low-cost healthy food (for example, increasing commercialization and distribution in areas with risk of poverty and making low-cost healthy food easily reachable by those at risk of poverty)	Beaulac et al. 2009, Cummins et al. 2005, Kyureghian et al. 2013, Larson et al. 2009, Walker et al. 2010

Appendix C

The MDU technique of elaboration has been applied by including the 42 questionnaires, and the missing data (3%) have been treated by substituting the missing value with the median value achieved by the proposition. Evaluation of each map concerning the capability of adapting or producing degenerating results is conducted through the analysis of three groups of parameters (Busing et al. 2005). The first group, named *badness-of-fit*, includes *Normalised Stress* (σ_n), *Kruskal's Stress- I* (σ_1), and *Kruskal's Stress- II* (σ_2) (Kruskal 1964, Borg et al. 2005). Resulting σ_n values close to 0 express the effectiveness of the cognitive map to collocate stimuli, that is statements, and respondents so that the visualised map best represents the interviewees' opinions. Nonetheless, another point of consideration is that, even though low values of σ_n indicate that the solution achieved is well adapted to data, data cannot assure that the solution is not degenerating. Thus σ_1 and σ_2 are adopted as indices that can better express the possibility of achieving degenerating solutions. According to the creation of these indexes (Borg and Groenen 2005, Busing et al. 2005), high values for σ_1 and σ_2 show the intensity of a possible degeneration of the represented phenomenon. In addition, σ_1 is always inferior to σ_2. The second group of parameters refers to the means of the squares of Pearson's coefficients of correlation between preferences and distances (*variance accounted for* VAF), *Spearman's Rho* (RHO), and *Kendall's Tau-b* (TAU), all included in the category named *goodness-of-fit*. The VAF index in particular represents a measure that is ranged between 0 and 1, where values close to 1 express the capability of the model to approximate the opinions of the interviewees. The third group of parameters aims at measuring the degree of degeneration of the solution by considering Shepard's rough nondegeneracy index (Busing et al. 1997) and DeSarbo's intermixedness indices (DeSarbo et al. 1997). Shephard's index shows that the solution is not degenerative when its value is close to 1 (interval range 0–1). DeSarbo's indices represent the goodness in terms of the degree of degeneration of a solution; within a scale of values that goes from 0 to 3, the best is close to 0. The analysis of these three groups of parameters were effectively applied for each map and no concerns resulted.

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Value Chain Analysis of Traditional Vegetables from Malawi and Mozambique

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Abstract

Several studies have shown that traditional vegetables have high market potential and contribute substantially to household incomes and nutrition. Until recently however, the scientific and donor community often give less attention to research on traditional vegetable crop value chains. The resurgence of traditional vegetables' importance in human nutrition is accompanied by a need to understand the interactions among various actors in their value chain to determine ways to add value to produce and improve marketing efficiency. Based on a multistage cross-sectional survey of 240 respondents in Malawi and Mozambique, this study employed participatory evaluation and market research to identify potential outlets and target crops, and define value chain processes, including choice of market outlets and mode of farmer-buyer linkages. Traditional vegetable sales contributed about 35% and 30% of smallholders' income in Malawi and Mozambique respectively. Linkages between value chain actors were found to be weak; mostly based on spot market transactions, except for those between retailers and supermarkets, which were based on relationship marketing.

Keywords: African traditional vegetables, commodity value chains, human nutrition, marketing efficiency, SWOT analysis, value chain mapping.

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Introduction

Despite constituting only a small share of the arable land area, vegetable production in Eastern and Southern Africa has the potential to be highly profitable, provide employment opportunities, generate income and bring about increasing commercialization of the rural sector (Weinberger and Lumpkin 2007). To realize this potential, farmers and other value chain actors must improve the competitiveness of their vegetable production and marketing commodities to increase market share and profits. In addition, diseases related to imbalanced diets from insufficient vegetable and fruit consumption cause 2.7 million deaths annually worldwide, and are among the top 10 mortality risk factors (Ezzati et al. 2002). Malnutrition is rampant in the tropics, where per capita vegetable consumption averages only 43% of the minimum recommended 73 kg/person/year (Ali and Tsou 1997). Re-igniting an interest in — and a taste particularly, for traditional foods can help improve nutrition and also increase incomes, restore biodiversity, and preserve local cultures (Stone et al. 2011).

According to Ambrose-Oji (2009) there are a host of terms describing traditional African vegetables (TAV), including indigenous African vegetables (IAV); African indigenous vegetables (AIV) traditional leafy vegetables (TLV); African leafy vegetables (ALV); traditional African leafy vegetables (TALV or TLV)—and all are subject to contested meanings. In the context of this paper traditional vegetables follows the FAO (1998) definition, and refers to all categories of plants whose leaves, fruits or roots are acceptable and used as vegetables by urban and rural communities through custom, habit and tradition. Traditional vegetables domesticated in Africa, including amaranth (*Amaranthus* spp.) and African eggplant (*Solanum aethiopicum*) have been known to be rich in micronutrients such as iron and vitamin A (Weinberger and Msuya 2004), possess antibiotic, probiotic and prebiotic properties (Park et al. 2002; Erasto, Bojase-Moleta, and Majinda 2004; Veluri et al. 2004), and contain antioxidants and phytochemicals that help protect people against non-communicable diseases (Yang and Keding 2009; Uusiku et al. 2010). African eggplant, a readily cultivated vegetable crop, recently has been found to possess protective properties against ulcers induced experimentally, making it a cheap, natural anti-ulcer remedy (Chioma et al. 2011).

A number of critical bottlenecks hamper the growth of the traditional vegetable sector in Eastern and Southern Africa: lack of access to high quality seeds, including hybrids produced by local seed companies; high on-farm production losses; high perishability and post-harvest losses, particularly, for leafy traditional vegetables such as amaranth; lack of appropriate market infrastructure for handling perishable produce; weak linkages between supply chain actors (i.e., input suppliers, producers and markets); lack of well-structured and organized markets leading to high transaction costs along the supply chain due lack of reliable market information and support systems; lack of mechanisms to set prices (i.e., traditional vegetables are usually sold by farmers mostly on the basis of "cost of living" rather than production costs or supply and demand conditions), resulting in low bargaining power of farmers; and ineffective institutional policies to enhance trade within and between regions and countries (Lenné and Ward 2010; Lyatuu et al. 2009).

Value chain analysis of the traditional vegetable supply chain offers the opportunity to assess the efficiency of value-added operations/services as well as systemic competitiveness along the

supply chain to increase production, trade and the income-generating potential of farmers and other actors. A value chain describes the full range of activities required to bring a product or service from conception through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final customers, and final disposal after use (Kaplinsky and Morris 2001). The connection between producers and buyers may be reinforced at the level of customer loyalty, and perhaps to the point of establishing a partnership. Food value chain research has developed significantly in recent years as a response to major shifts in the agribusiness sector, including significant change in international trade patterns; advances in retailing, notably with the emergence of supermarket chains in developing countries; growing urbanization and related change in consumer behavior (Dolan and Humphrey 2000; Ahumada and Villalobos 2009; Gereffi and Christian 2010; Lee, Gereffi, and Beauvais 2010). Many development interventions now use a value chain approach as an entry point to engage smallholders, individually or collectively, in local and high value export markets (GTZ 2007). To this end, the value chain approach involves addressing the major constraints and opportunities faced by businesses at multiple levels of the value chain through a wide range of activities such as ensuring access to the full range of necessary inputs, facilitating access to cheaper or better inputs, strengthening the delivery of business and financial services or increasing access to higher-value markets or value-added products.

Several studies have outlined the strengths and weaknesses of the qualitative nature of generic value chain analysis and the need to improve analytical rigor by complementing it with quantitative analytical approaches (Rich et al. 2011; Trienekens 2011; Bair and Werner 2011). While this study combines both qualitative and quantitative approaches, it does not address the strengths and weaknesses of the underlying methodological approach. For an exposition of the strengths, weaknesses and extensions and options to improve the analytical rigor of the value chain methodology see for example, Rich et al. 2011; Trienekens 2011.

Relatively few studies have been conducted on traditional vegetable value chains and related subjects in Southern Africa (Hichaambwa and Tschirley 2006; Odhav et al. 2007; Lyatuu et al. 2009; Lenné and Ward 2010; Shackleton et al. 2010; Weinberger et al. 2011). These studies have mostly targeted specific segments of the supply chain, such as characteristics of production systems, nutritional attributes, nature of marketing outlets, and participation of women, but have hardly looked at the entire supply chain, particularly from seed production and distribution through to produce marketing. To the best of our knowledge, very little research has been done to assess the interaction of the structure, conduct and relationships among value chain actors along the traditional vegetable value chains, and evaluate the impact of farmers' social capital and networks on household production and consumption decisions for traditional African vegetables in Southern Africa.

The objective of the study was to carry out participatory evaluations and market research on a range of traditional vegetable value chains to select actual and potential target crops, establish modes and types of farmer-buyer linkages and their corresponding marketing outlets, identify value chain constraints and opportunities and draw agribusiness policy-related recommendations for Malawi and Mozambique. The rest of the paper is organized as follows. First, given the peculiarity of the spatial and time gaps in seed distribution systems, we give a brief overview of traditional vegetable seed systems in the study area. Section 3 outlines the choice of value chain

approach used, describes the study area, field survey methods and techniques of data analysis. This is followed by a presentation of the study findings with a highlight of the value chain mapping, opportunities and constraints following a SWOT analysis. Finally, a summary of the major findings and conclusions out of the empirical analysis is drawn along with outlined associated agribusiness investment and policy implications, and recommendations.

Overview of Traditional Vegetable Seed Systems in Malawi and Mozambique

Traditional vegetables are produced and consumed by many households in most countries in Southern Africa including Malawi and Mozambique (Ambrose-Oji 2010). Despite the popularity of these crops, public sector breeding activities to produce good quality seeds are almost non-existent and are limited by a lack of funding and private sector involvement (Afari-Sefa et al. 2012). Malawi has made significant strides in developing and embracing vegetable research and breeding in its national policies in comparison to Mozambique, which does not have a well-structured vegetable research program (Chadha et al. 2007). Nevertheless, the Instituto de Investigação Agrária de Moçambique (IIAM) is in the process of building the necessary infrastructure and institutional mechanisms to improve vegetable research and development. The IIAM is a public entity that has the mandate for carrying out action research, development and dissemination of agricultural technology in Mozambique. Current research thrusts in Mozambique include varietal trials; cropping season trials to determine vegetable crops adapted to particular agro-climatic zones; and studies on the improvement of agronomic practices such as plant spacing, plant density and optimum time for harvesting (Chadha et al. 2007).

Vegetable cultivar and breeding research has a significant national priority in Malawi. The country's major research objectives in the horticulture sector are to address increased availability of high yielding cultivars, adaptability of improved cultivars to both biotic (pest and disease resistance) and abiotic stresses (heat tolerance), improvement of soil fertility, good on-farm agricultural practices, and minimization of postharvest losses (Chadha et al. 2008). To date, neither Mozambique nor Malawi has officially released any traditional vegetable varieties. Research on traditional vegetables was initiated in 1983 at Bunda College of Agriculture in Malawi, emphasizing germplasm collection, documentation, seed multiplication and agronomic studies. The Bvumbwe Research Station in Malawi and IIAM in Mozambique (public research institutions) in collaboration with AVRDC – The World Vegetable Center and Bioversity International under the Sub-Saharan Africa Challenge Program (a CGIAR program led by the Forum for Agricultural Research in Africa (FARA) in 2008 identified, characterized and popularized a few traditional vegetables such as amaranth and African eggplant.

In most African countries seed laws have been updated, with recent efforts to undertake regional harmonization of laws and policies to enhance the growth of the seed industry in terms of certification and commercialization (Rohrbach et al. 2003; Setimela et al. 2009). Nevertheless, most laws give little legal room for use of farmer-saved seeds, although in some cases there is a small legal opening through the use of Quality Declared Seed, seed for disaster response projects, or seed of species not covered by laws. Mozambique's Seed Law of 2001 for example openly welcomes the registration of 'traditional' and 'local' varieties for commercialization, but only if they satisfy the industrial Distinctiveness, Uniformity and Stability (DUS) criteria (Setimela et al. 2009; GRAIN. 2005). Up until the 1990s, seed regulations in most African

countries were mostly organized around public seed programs, with seed laws limited to import and export restrictions. There was little coordination between countries, with regulations often heavily influenced by the respective donors and very little enforcement on the ground (GRAIN. 2005; Waithaka et al. 2011).

Consequently, most exotic vegetable seed is imported from Europe (mainly, the Netherlands) to South Africa, Zimbabwe, Malawi and Mozambique. Local seed companies produce small quantities of seed of tomato *(Solanum lycopersicum)*, kale *(Brassica oleracea)*, watermelon *(Citurs lanatus)* and other vegetables. Some seed companies are involved in importing, repacking and marketing vegetable seeds in Mozambique and Malawi. Seed of most traditional vegetables like African eggplant and nightshade *(Solanum villosum)* are imported from Tanzania; while little seed is produced locally, such as amaranth, is mainly done by community based seed producer groups. Imported seed is usually packed in perforated plastic bags or plastic coated paper to enhance the viability and storage life of the seeds under ambient temperature conditions. Some of the input suppliers in the study villages re-pack seeds in smaller plastic bags for sale to meet the demand of small producers. Thus in both Mozambique and Malawi most traditional vegetable farmers use farmer-saved seeds.

Study Methods and Analytical Framework

Justification for choice of value chain approach used for study

As a descriptive tool, value chain analysis forces the analyst to consider both the micro and macro aspects involved in production and exchange between different actors. A number of methodologies and their contributions to commodity value chain analyses have been proposed for economic processes at global and national level studies (see for example, Kaplinsky and Morris 2001; Kaplinsky 2000; Keyser and Tchale 2010; Bellù and Guilbert 2008). In the context of sub-Saharan Africa, a number of studies have been undertaken to examine vegetable commodity value chains from different perspectives. Such studies include: the role of research institutions in vegetable value chains (Ojiewo et al. 2010; Afari-Sefa et al. 2012), theoretical concepts for socioeconomic research on vegetables (Waibel 2011), approaches to strengthen vegetable value chains for increasing food and nutritional security and income under both sole crop and integrated farming systems (Ngugi et al. 2007, Lenné and Ward 2011; Sounkoura et al. 2011, Afari-Sefa and Beed 2012), institutionalization and agribusiness innovations in value chains (Eaton et al. 2008; Kibwika et al. 2009). Results from southern Africa specific value chain related studies (see for example, Lyatuu et al. 2009; Hichaambwa and Tschirley 2006) also show that with growing demand, consumers are becoming more sensitive on sanitary and phytosanitary aspects, whereby existing and emerging high value markets for traditional vegetables impose stringent conditions on quality of the produce they purchase. Retail outlets consequently demand consistency in supply and prefer to deal with groups rather than individual farmers so as to cut on transaction cost.

For the microeconomic analysis employed in this study, the commodity-based approach provides a better insight into the organizational structures and strategies of different actors engaged in

traditional vegetable chains, do not typically have well-structured markets to exhibit global commodity value chains characteristics.

A similar methodology with modifications to what was earlier applied by Kaplinsky and Morris (2001) and Van den Berge et al. (2005) to quantitative value chains is described by Henning and Donahue (2008). This methodology deals with upgrading value chain competitiveness with informed choice as a tool for end-market research. This approach was found to be a consistent fit for the objectives of this study and was adapted to reflect the situation of the study area. A value chain map that provided alternative actor linkages from the producer to the final consumer via mapping out flow relationships between actors was developed. Figure 1 illustrates the analytical approach applied to measure the objectives of the study. A four-step approach to determine criteria for selecting sub-sectors, products or commodities for analysis was devised, including weighting the relative importance of those criteria to value chain actors, determining the potential sub-sectors, products or commodities that could be considered, and then constructing a matrix to enable ranking of the products according to the criteria. Finally, priorities were selected on the basis of the ranking obtained.

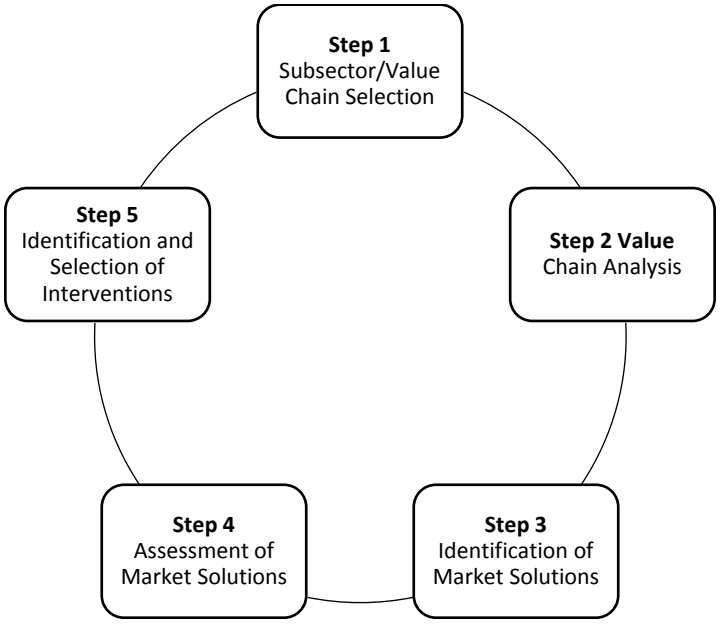

Figure 1. Source: Adapted from Action for Enterprise (2006)

Characteristics of Study Sites

The study was carried out in four districts: Barue (Manica province) and Milange (Zambezia province) in Mozambique, and Thyolo and Zomba in the Southern region of Malawi. The Mozambique study sites are characterized by a poor resource base, low levels of literacy and high levels of malnutrition. Few households have regular cash income and most practice subsistence agriculture. In some cases supplemented by fishing and other activities. Much of the area is drought and/or flood-prone, although some areas have a relatively higher elevation. Maize *(Zea mays)* and, to a lesser extent, cassava *(Manihot esculenta)* are the primary staples; both are

cooked as a paste and served with simple sauces, usually of beans *(Phaseolus vulgaris)*, dark green leaves, and/or dried or fresh fish. Tempe (2007) reiterates that traditional crops have always been part of the Mozambican diet even in urban areas such as Maputo, a fact which may be attributed to the movement of people from rural areas into cities during the civil war from May 1977 to October 1992.

In the Malawi study sites, field crops, especially maize and tobacco *(Nicotiana tabacum)*, have traditionally dominated agricultural production. However, in recent years, high input costs and unfavourable weather conditions have restricted maize and tobacco cultivation. The decline in the tendency of farmers to grow field crops coupled with enhanced horticultural sector development policies has led to increased diversification into hardy crops such as traditional vegetables (Chadha et al. 2008). The authors further note that, although vegetables are grown almost everywhere in the country, the study sites in the two selected districts are major vegetable producing locales for sale to the urban populace.

Study Design and Data Collection

The analyses presented in this paper are based on primary data collected from value chain actors in the study area from June to August, 2010. Multistage stratified random sampling was carried out to select five villages from each district based on availability of information on chain actors. In each village, we conducted one producer focus group and interviews with four middlemen (person who buys goods from producers and sell them to retailers or consumers, also referred to as *collectors*), four retailers, and four seed suppliers. In all, a total of 20 focus groups involving various value chain actors and 240 individual respondent interviews were conducted for the purpose of this study. Both focus group discussion participants and individual interview respondents were randomly selected based on available information.

Specific surveys were designed for four types of identified actors in the study sites: middlemen, producers, input suppliers, and retailers. The focus group interviews were targeted toward the main stakeholders involved in production and marketing of traditional vegetables. Trained enumerators elicited information on the nature and types of traditional vegetables collected, cultivated and marketed, as well as on institutional characteristics of key chain actors. The producer, input, middleman and retailer surveys elicited information on production, consumption and marketing of traditional vegetables, as well as the institutional characteristics of each group (Figure 1 and Table 1).

A priority-setting exercise for 24 commodities was carried out based on data obtained from the respondents (Appendix B). Fourteen of the criteria captured information on production activities, food security coping strategies, marketing structure and potential of the various commodity value chains (Appendix B). Once the criteria were defined, the commodities were ranked against each criterion; a score of 100% meant that the particular commodity best met that criterion based on the proportion of respondents favouring the specific crop, and a score of 0% meant that the commodity did not meet that criterion (ranked against all the other commodities). The evaluation of each criterion was done by estimating the proportion of respondents. Once each criterion was evaluated, a simple average score was calculated; commodities with a higher score were ranked higher.

Value chain analysis involved a sequence of steps, from identification of actors through chain actor mapping, linkages, and quantification of earnings into rewards by various actors using information gathered from observation, rapid appraisals, and the quantitative and qualitative surveys augmented by secondary data (Figure 1 and 2). Constraints and opportunities within the value chains were categorized into appropriate classifications and analysed. The types of market services available along the value chain were described to serve as conduits for outlining constraints and opportunities of identified value chains. Finally, the Strengths, Weaknesses, Opportunities and Threats (SWOT) assessment tool was applied to identify and evaluate the controllable and non-controllable factors that future interventions ought to address to improve the entire traditional vegetable value chain.

Results and Discussion

Value Chain Description

The results of the priority-setting exercise indicated that in the Thyolo and Zomba districts of Malawi, amaranth, Ethiopian mustard *(Brassica carinata)* and blackjack *(Bidens pilosa)* were most important traditional vegetables, whereas pumpkin *(Cucurbita maxima)*, okra *(Abelmoschus esculentus)*, tomato and cabbage *(Brassica oleracea)* were most important among the exotic vegetables. In Barue and Milange districts of Mozambique, African eggplant, amaranth, jute mallow *(Corchorus olitorius)*, Ethiopian mustard, and wild cucumber *(Marah macrocarpus)* were ranked high for the traditional vegetables while pumpkin, kale, onions, tomato, cabbage, and okra were ranked high for exotic vegetables.

Table 1 presents the distribution of identified actors and their respective roles along the traditional vegetable value chain. The table present actors (middleman, retailers and input suppliers) in both Malawi and Mozambique involved in various roles or occupation (grocery shop trader, street vendor, traditional vegetable collector, farmer, grocery store owner, wholesaler, seed dealer, agrochemical dealer and trader in farm tools).

Input suppliers: Given the lack of inputs, particularly seeds for traditional vegetables, some vendors take the onus upon themselves to provide farmers with agro-inputs such as seeds, fertilizers, and farm implements with the option of having the first purchase of produce upon harvest. There are no organized input suppliers with adequate stocks of inputs in visited villages of Zomba and Thyolo. This situation forced farmers to walk on foot to local providers operating in nearby villages within a radius of 5-9 km to buy relevant inputs. Input suppliers in Malawi sell seeds, farm tools and agro-chemical, while in Mozambique, they only sell seeds and farm tools. Production inputs such as agrochemicals, farm implements and seeds for production were mainly supplied by stockist distributors usually located in nearby cities. Most inputs supplied by these providers are imported and delivered through local distributor networks. Some individual farmers also act as input dealers. Government outlets supported by the Ministry of Agriculture provided inputs such as fertilizers in some villages. In addition to offering production assistance, the Bvumbwe Research Station also provided vegetable seed to farmers in some of the surveyed villages. In general, the input providers did not have contractual arrangements with their trading partners. Traditional vegetable seed sales accounted for about 7% of total agricultural seeds sales and 37% of vegetable seed sales of input providers. Among the traditional vegetables produced in Malawi, Ethiopian mustard, and African eggplant seed were the most traded. Ethiopian

mustard seeds contributed the highest turnover, with 'Mostert' noted as the most common variety. Percentage of germination, physical characteristics such as shape and size, quality of packaging material and price, purity and uniformity, yield, size of produce from seed and price were the main determinants of type of seed purchased by farmers.

Table 1. Indigenous vegetable value chain actors and their main activities in Malawi and Mozambique, June-August, 2010.

	Malawi			Mozambique			Test (a)	
Main Occupation	Middlemen[+]	Retailer	Input supplier	Middleman	Retailer	Input supplier		
	A	**B**	**C**	**D**	**E**	**F**		
Grocery shop trader	28.6	18.3		25.9	18.5		**A>D	
Street vendor	21.4	26.7		25.9	22.2		*A<D	**B>E
Traditional vegetable collector	35.7	1.7		3.7			***A>D	*B<D
Farmer	14.3	43.3		29.6	48.2		***A<D	
Grocery store owner		6.7		3.7				
Wholesaler		1.7		7.4	11.1			***B<E
Seed dealer			50.0			66.7		**C<F
Agrochemical dealer			25.0			33.3		***C<F
Trader in farm tools			25.0					
Others		1.7		3.7				
Total (%)	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**	**100.0**		
N	**14**	**91**	**34**	**27**	**27**	**3**		

Notes. Significance of sample T-test comparing actors (A) and (D), (B) and (E); and (C) and (F): * indicates significant difference at 10% level, ** at 5%, and *** at 1%.

[+] A person who buys goods from producers and sells them to retailers or consumers, also referred to as collectors. The table shows different activities or roles (grocery shop trader, street vendor, traditional vegetable collector, farmer, grocery store owner, wholesaler, seed dealer, agrochemical dealer and trader in farm tools) engaged by various value chain actors (middleman, retailers and input suppliers).

Farmers: These are persons involved in crop production, including traditional vegetables. In the four districts surveyed, traditional vegetables were produced mainly by small-scale farmers, on less than one hectare of land. The main traditional vegetables grown and or sometimes collected from the wild include Ethiopian mustard, African eggplant, amaranth, cowpea, spider plant, jute mallow, leafy sweet potatoes and wild cucumber. Traditional vegetable production is based on conventional, traditional production practices; producers did not apply recommended good agricultural practices such as use of high quality improved cultivars, integrated pest management practices and drip irrigation. Only Ethiopian mustard, okra, pumpkin and African eggplant seeds were sold commercially. Other traditional vegetable crops like leafy sweet potatoes and vegetable cowpea, among others, were mainly produced using local landraces. Farmers in both countries are not involved in supplying inputs but in retail and middlemen activities, with 14.3% and 29.6% of famers involved in middlemen activities in Malawi and Mozambique respectively (Table 1).

Middlemen: These are persons who buy goods from producers and sell them to retailers or consumers, also referred to as collectors and transport contractors. The main activities of these actors in Malawi included collection of traditional vegetables (36%), ownership and management of grocery shops (29%), street vending (21%), and farming (14%) (Table 1). In Mozambique, some middlemen had other responsibilities in addition to those observed in Malawi. Some collectors also managed grocery shops as a secondary occupation, where they sold fast moving consumer goods in the communities where they live. Most transporters vertically integrated their activities by also engaging in the production and selling of vegetables.

Guaranteeing home consumption and generating extra income were the main reasons for cultivating and marketing traditional vegetables among value chains actors. In Malawi, about 21% of traditional vegetables produced were consumed at home, while in Mozambique farm households consumed about 30% of the produced traditional vegetables. Besides household consumption, fresh traditional vegetables were sold in traditional green markets without any value addition. On the whole, the study found that traditional vegetable sales contributed about 35% of smallholders' income in Malawi, and about 30% of household income in Mozambique. In most of the study villages in Malawi, producers were involved with farmers' associations. Although some of the farmers' groups received technical production assistance and seeds from the Bvumbwe Research Station, on-farm yield levels were quite low, reflecting the general lack of improved traditional vegetable cultivars and technologies.

Processing of traditional vegetables in the four survey districts was rudimentary and not commonly practiced. Only 12% of retailers in Malawi and 6% of retailers in Mozambique said they processed their produce in some way prior to selling. In Malawi, amaranth and cowpea were sundried and/or blanched. Most of the preserved traditional vegetables were meant for home consumption, not for sale in the market. In Mozambique, pumpkin, eggplant, cowpea, sweet potatoes, and Ethiopian mustard were cut in smaller pieces before selling. Cowpea was also sundried.

Given the fact that processing is lacking in traditional vegetable marketing chains, the high perishability of traditional vegetables poses major challenges for marketing and distribution. About 20% of traditional vegetables were discarded during the produce marketing process. Simple postharvest handling practices such as a bicarbonate wash could help minimize losses, and enable availability during the periods when vegetables are in short supply (Van den Berge et al. 2005). Improvement of packaging and processing standards is an important step for increased competitiveness of traditional vegetables products along the entire value chain.

Non-structured informal markets are major outlets for traditional vegetables. Most rural vendors and traders purchased their produce from farmers. Farmers also sold their produce along roadsides or at village markets directly to consumers or to middlemen who later sold them in major markets. The traders' market and retailers' market are the same. Some middlemen transported their produce to major village markets. In general, produce was mainly marketed through three channels: (i) farmers produced and sold their own traditional vegetables directly to consumers as market retailers or street vendors; (ii) farmers sold to retailers and; (iii) farmers sold to middlemen (collectors). The type of packaging used varies. In most cases, traditional vegetables were packed in bamboo baskets to the next selling point, where they were repacked

and sold in bundles with no labels. However, in a few cases, traditional vegetables were packed in plastic bags or sacks and unpacked at the next selling point. Most traditional vegetable value chain actors transported their products to rural markets on foot by carrying them on heads/shoulders or by using their own or hired bicycles. Value addition through packaging and branding to maintain high quality standards is required if produce is to reach high value formal markets such as supermarkets in urban areas and export markets, and ultimately increase farmers' profit margins. Traditional vegetable marketing channels in the two visited districts were constrained by diverse factors such as small production quantities and heterogeneous quality due to limited access to input supplies, lack of capital and market information, poor infrastructure, and lack of sound farm management skills. As a consequence, several value chain actors including input supplies, farmers, and middlemen were confronted with limited economies of scale.

Relationships among Value Chain Actors in Malawi and Mozambique

Relationships existing among the various value chain actors were established based on three marketing transaction typologies: spot markets (actors make a transaction including negotiations on price, volume and other requirements directly at the market without prior discussion); persistent network relations (buyer and seller meet to discuss transaction, come to an agreement and continue relationship when there is a preference for repeated transactions with each other based on trust or other factors), and horizontal integration along value chain (typically goes beyond the definition of a relationship, because both actors share the same legal ownership). A summary of the value chain actor linkages in the study locales is shown in Figure 2. Most linkages were based on spot market relationships, except for the linkages between supermarket retailer, which was better coordinated and based on persistent relationships.

Tables 2 and 3 depict type of relationships existing between various value chain actors in Malawi and Mozambique. Input suppliers in Malawi took the lead in terms of collaboration with other partners in the traditional vegetable chain, with 71% participation, followed by retailers with 54% and middlemen with 40% (Table 2). In Mozambique, input suppliers led with 100%, followed by middlemen at 50% and retailers constituting 38%. Although input suppliers had a higher level of collaboration with other business partners, in Malawi this collaboration was not made on the basis of written contracts, as was the case with most other actors along the value chain.

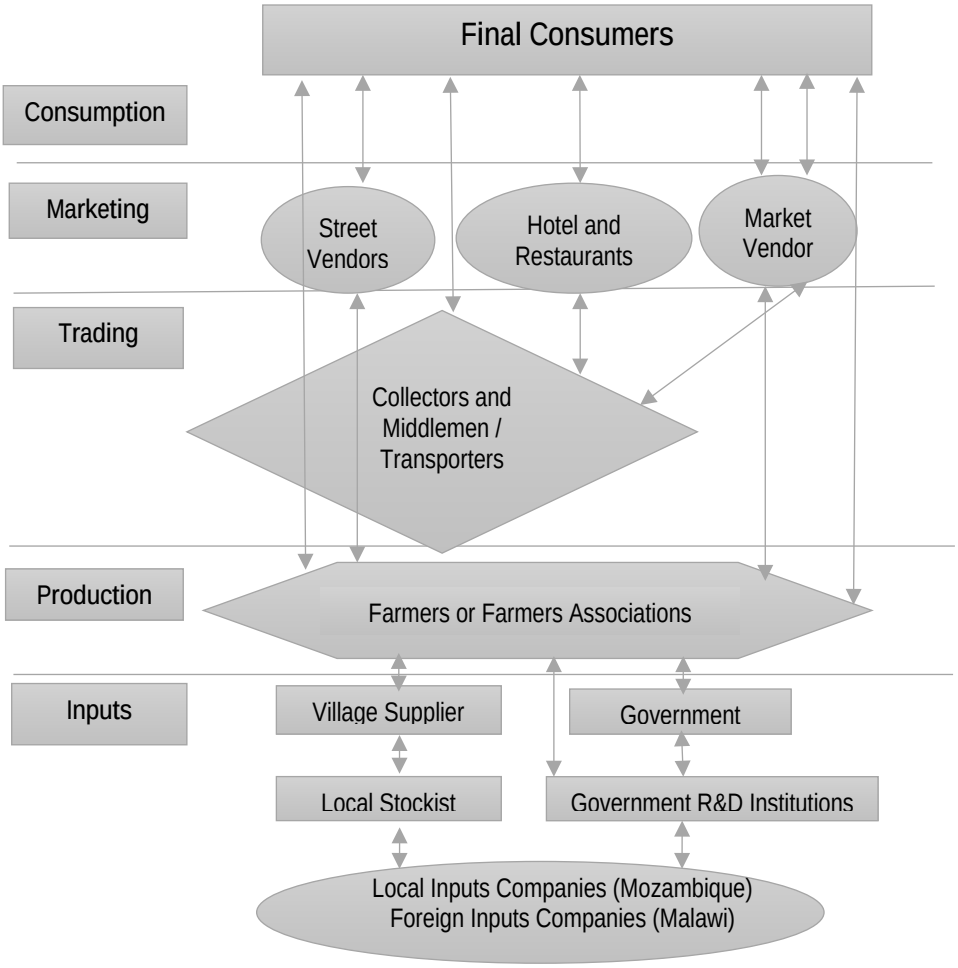

Figure 2. Summary of linkages of value chain actors in Malawi and Mozambique

Table 2. Relationships existing between various value chain actors

	Malawi			Mozambique			Test (a)		
Item	Input supplier	Middleman	Retailer	Input supplier	Middleman	Retailer			
	A	**B**	**C**	**D**	**E**	**F**			
Collaborate with others (%)	71	40	54	100	50	38	**A<D	*B<E	**C>F
Sample size (n)	**14**	**91**	**34**	**27**	**27**	**3**			
Type of collaboration %									
Share price/market information	40	50	43	29	44	38			*C>F
Share storage facilities	20	50	14		6	8		***B>E	**C>F
Supply vegetable inputs to others when supply is lacking	20	0	36	14	6	8		***B<E	***C>F
Purchase vegetable inputs together	20	0	0	29	28	15		***B<E	***C<F
Lend/borrow money	0	0	7		11	23		***B<E	***C<F
Have contract arrangement (%)	0	80	20	29	6	8	***A<D	***B>E	***C>F
Contract based in written agreement (%)	N/A	0	0	100	7	13		***B<E	***C<F
Number of trading partners you collaborate with	1.3	3.5	4.7	50	N/A	50	***A<D		
Have more than one supplier (%)	43	80	46	5	4	5	***A>D	***B>E	***C>F

Note. Significance of Sample T-test comparing (A) and (D), (B) and (E); and (C) and (F): * indicates statistically significant difference at 10% level, ** at 5%, and *** at 1%.

Table 3. Relationships existing between various value chain actors

	Malawi			Mozambique			Test (a)	
Item	Input supplier	Middleman	Retailer	Input supplier	Middleman	Retailer		
	A	**B**	**C**	**D**	**E**	**F**		
Sample size (n)	**14**	**91**	**34**	**27**	**27**	**3**		
Number of supplier by type		N/A		100	0	31		
Foreign seed company	2.3							
Local stockiest	1.0			2	N/A	N/A		
Farmers			6	N/A	N/A	N/A		
Collectors			6	N/A	N/A	1		
Wholesalers			2	N/A	N/A	5		
Main supplier (%)	N/A			N/A	N/A	4		
Farmer		92	96	N/A				
Wholesaler		8			27	46	***B<E	
Other			4		63	44		***C<F
Sold to more than one partner (%)	N/A	100			10	11	****B>E	
Main customer (%)	N/A			N/A	N/A	N/A		
Household		100	79	N/A				
Transporter			18		17	13		
Supermarket			1		21	12		***C<F
Wet market			3		26	37		***C<F
Collector					29	26		
Retailer					1	3		

Note. Significance of Sample T-test comparing (A) and (D), (B) and (E); and (C) and (F): * indicates significant difference at 10% level, ** at 5%, and *** at 1%.

All of the actors in the chain had more than one business partner. Input suppliers usually purchase their seeds and, where applicable, other inputs from foreign private companies, while local stockists, farmers and middlemen based in the cities (collectors and transporters) usually obtain their traditional vegetable produce from local farmers and local wholesalers. The retailers, also include wholesalers who sometimes directly retail part of their produce that they source from farmers, other wholesalers and collectors. In the course of our interaction with respondents, we noted that there was no clear identification of the main clients of input suppliers; we assumed them to be farmers. These clients did not consider extension services, advice provided by the input suppliers, or the proximity of the supplier as important factors to improve efficiency. This may be because some input suppliers are also known to occasionally sell their inputs to farmers directly at the farm gate by providing a kind of "door to door" service. On the other hand, farmers with no access to technical advisory services on how to handle seeds or those already experienced in seed handling may have ignored the messages provided by extension agents and decided to explore alternative applications. To investigate the real reasons behind this occurrence, it is important to analyse the structure and performance of both input and supply markets.

The major determining attributes of consumers in purchasing traditional vegetable produce include: price, freshness, shape, size, the origin of culture, food safety (i.e., residual effect of pesticides) and product grading in Thyolo and Zomba (Table 4). In Barue and Milange, the middlemen's customers considered physical attributes of the produce, produce size, and freshness (including colour) as the most important features of traditional vegetables. Retailers' customers shared the same preference for the first five features as the middlemen's clients in Thoylo and Zomba, but were unconcerned about other important factors (Table 4). In Barue and Milange, retailers' customers were generally not concerned with residual effects of agro-inputs like insecticide/fertilizers that could endanger their health (Table 4). Against our expectations, the survey results showed that product classification is not an important attribute for modern

retailers such as supermarkets. Quality attributes, such as absence of pests and pathogens, and packaging would be expected to be top priorities. This may reveal a low level of knowledge about food quality standards and human health effects caused by ingestion of contaminated food. Thus, awareness creation on quality and food safety standards for fresh produce would be an important area of future intervention to reduce public health hazards and promote efficiencies along the value chain. The fact that supermarkets do not care much about produce quality results in two contradicting issues: it allows the supermarket to obtain large volumes of produce from different suppliers, and leads to decreased motivation to establish contracts specifying quality standards with specific producers.

Table 4. Consumer preference information on most important traits of traditional vegetables and their seeds

Traits	Input supplier buyers	Input supplier buyers	Traits	Middlemen buyers Malawi	Middlemen buyers Mozambique	Retailer buyers	Retailer buyers Mozambique
Germination	Yes	Yes	Colour	Yes	Yes	Yes	Yes
Physical qualities: shape, size	Yes	n/a	Price	Yes	Yes	Yes	Yes
Price	Yes	n/a	Shape	Yes	No	Yes	No
Packaging	Yes	No	Size	Yes	No	Yes	No
Analytical qualities: purity, uniformity	Yes	n/a	Freshness	Yes	Yes	Yes	Yes
Wide variety	No	n/a	Origin of crop	Yes	No	No	No
Proximity of the seller to the farm	No	n/a	*Food safety*	No	No	No	No
Advices given by seller	No	n/a	Fertilizer residues	Yes	No	No	No
Seed company extension services	No	n/a	Pesticide residues	No	No	No	No
Produce yield	Yes	n/a	Presence of food-	No	No	No	No
Produce price	Yes	n/a	Certification schemes	No	No	No	No
Produce size	Yes	n/a	Sorting	No	Yes	No	Yes
Produce colour	No	n/a	Grading	Yes	Yes	No	Yes
Produce taste	No	n/a	Packaging	No	No	No	No

Analysis and Quantification of Value Chains

The marketing of traditional vegetables generated significant income (Figure 3). In Malawi, average monthly sales of traditional vegetables by middlemen were approximately US $50, while the mean monthly sale for retailers was US $37. Traditional vegetable sales accounted for 51-75% of the total income of 60% of middlemen in Thyolo and Zomba, while it accounted for 50% of the income of 70% of retailers (Table 5). The peak sale of traditional vegetables by middlemen was observed in November, with a minimum of US $20 observed in February and March. A similar pattern was observed for traditional vegetable retailers.

In Mozambique, both middlemen and retailers generated lower monthly incomes compared with their Malawian counterparts. On average, monthly sales of middlemen from Barue and Milange amounted to US $28, while mean monthly sales for retailers was about US $26. Peak sales of traditional vegetables by middlemen was observed in April (US $49.86) with minimum values of US $15.14 and US $12.74 in September and August, respectively. A different pattern was noted for retailers, with peak sales observed in August (US $92.74) and the minimum sale in October (US $13). The flow of capital was approximately US $337 per year for middlemen while that for the retailers amounted to US $315 per year. The contribution from the sale of traditional vegetables to the total income was more important for middlemen than for retailers.

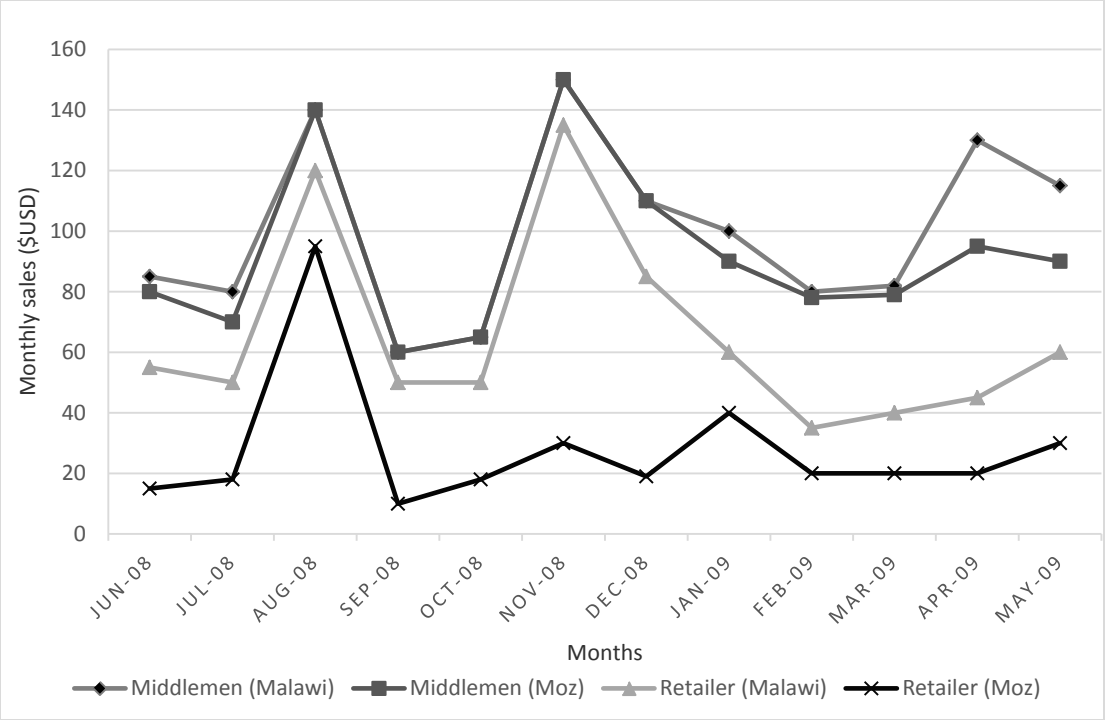

Figure 3. Monthly traditional vegetable sales for amaranth, Ethiopian mustard and African eggplant in Malawi and Mozambique

In Barue and Milange, traditional vegetables accounted for at least 50% of the income, with middlemen recording the highest (86%) followed by retailers (84%). Given the high proportion of total income from these actors, future intervention to boost the commercialization of traditional vegetables in Malawi should focus on producers as well as on market support and information services for both middlemen and retailers. In Mozambique, both actors deserve attention. Services targeted toward value chain actors in the study area are not well developed. The production, collection, and marketing of produce provide economic benefits to practitioners, and also make a major contribution to household nutrition. Results from the field survey showed that in Thyolo and Zomba, 20% of the traditional vegetables produced or marketed by both middlemen and retailers were used for home consumption, while in Barue and Milange, about 30% of produce traded by both agents were used for home consumption, contributing to food biodiversity and balanced diets (FAO 2010; Grivetti and Ogle 2000). Similarly, farmers were found to consume about 30% of their produce, for example out of an average of 30 bundles (60kg) of amaranths 9 bundles (18kg) were consumed in Barue and Milange which further underscores the importance of traditional vegetables in meeting household nutritional needs in the study area (Grivetti and Ogle 2000).

Table 5. Proportion of income derived from the sale of traditional vegetable to total income

Actors	10% or less	10-25%	26-50%	51-75%	76-100%	Did not respond	Total	N
				Malawi				
Retailer (%)	4	35	35	12	8	8	100	91
Middlemen (%)		20	20	60			100	14
				Mozambique				
Retailer (%)	**6**	**44**	**31**	**19**			100	27
Middlemen (%)		**36**	**50**	**7**		**7**	100	27

Value Chain Constraints

Constraints expressed by key informants and the respondents in the course of the field survey for Malawi and Mozambique are summarized in Table 6, see Appendix A. Interestingly, the two countries experienced similar constraints, although the degree slightly differs in some cases. On the production side, the main constraints expressed are: high susceptibility to diseases for exotic vegetables, limited knowledge of seed quality features, and limited technical knowledge. Similar production constrains were reported in previous studies in Malawi (Chadha et al. 2008). These constraints suggest two types of interventions: technical education/training of end users of seeds and other inputs, and provision of plant protection inputs for farmers.

The main constraints regarding input supply were low input demand, lack of access to farm inputs, and lack of good quality seed. These constraints offer opportunity for various interventions such as: alternatives for development of input markets (input fairs, input vouchers, etc.), provision of good quality seed, and input price regulation and control to guarantee fair prices for quality seed. Lack of marketing services such as processing and packaging were also seen as major constraints in the chain. The provision of training and adequate equipment seems to be a desirable alternative, which was also noted in Zambia (Nenguwo 2004). Although there is a significant movement toward growing and trading commercial produce in the study area, farmers complained of some losses on the quantity harvested. According to the focus group interviews in Malawi, more than three-quarters of the participants usually throw away their produce at the end of the market day because they were unable to sell about one-third of their stock (approximately the same amount that was diverted for home consumption). In Mozambique, the majority of the interviewed farmers indicated that less than 20% of the vegetables were thrown away at the close of the day's market sale. The observed results are consistent with those of other authors found elsewhere in sub-Saharan Africa (see for example, (Ngugi et. al, 2007) where it has been noted that, the supply of traditional vegetables has not matched the growing demand in terms of quantity and most importantly, quality of produce. Most farmers are semi commercially oriented poor farmers, are not organized, and lack inputs and skills to enable them to satisfy the dynamic market requirements. They are not able to access high value markets such as supermarkets and are often exploited by middlemen. These present promising opportunities for agribusiness practitioners to upgrade existing value chains.

SWOT Analysis of Traditional Vegetable Value Chains

The SWOT analysis presented in Table 7 provides a framework for understanding the controllable and non-controllable factors that future interventions should address for the entire value chain and was extracted from survey results and analysis of value chain constraints. In designing possible interventions, it is suggested that development practitioners and policy makers place emphasis on exploiting the outlined strengths rather than simply addressing weaknesses. Similarly, the opportunities and threats—the external trends that influence the subsector—are also analysed. External opportunities and threats have typically been categorized into political, economic, social, technological, demographic and legal forces. These external forces, such as providing the sector with improved cultivars, can change business trends, increase competition, and change regulations, among others. However, opportunities that are ignored can become threats; threats that are dealt with appropriately can be turned into opportunities. The non-controllable factors can best be dealt with through advocacy and networking to bring about changes in the policy framework.

Table 7. Summary of SWOT Analysis of traditional vegetable value chains

Strengths	**Weaknesses**
▪ Willingness to sell more traditional vegetables in future ▪ Indigenous vegetables as an important source of income ▪ Input supplier selling seeds and other inputs at farmstead ▪ Strong collaboration among actors	▪ Lack of contract arrangements ▪ Low demand for inputs ▪ Lack of capital ▪ Poor infrastructure ▪ Low producer and market prices ▪ Lack of processing services ▪ Poor packaging materials and services ▪ Poor seed quality
Opportunities	**Threats**
▪ Creation of strong farmer associations ▪ Training in production and marketing of produce ▪ Introduction of elite varieties	▪ Introduction of other high value crops ▪ Changing weather patterns (climate change) ▪ Changes in government policy favouring cultivation of major field crops

Agribusiness Investment and Policy Implications

The underlying value chain mapping SWOT analysis entails the following agribusiness implications for practitioners and policy makers in terms of investment and marketing decision making;

i. Lack of good quality seed – agribusiness may decide to start up small to medium traditional seeds business to supply quality customized seeds to farmers and home gardeners. These businesses may take the model of contract farming as discussed in Afari-Sefa et al. (2013).

ii. Low input demand and lack of access to adequate farm inputs – agribusiness such as seed companies, may need to partner with research institutions to engage in cost effective demand creation activities, like farmer field days where demonstrations will be mounted, seed fairs and agricultural shows to induce behavioural change of farmers to see the

benefits of using improved and good quality inputs such as quality seeds and recommended agrochemicals. In-depth market research is required to ensure profitable supply of customized inputs at minimal investment cost.

iii. Given the growing demand for traditional vegetables in general due to the increasing awareness on the nutritional importance of traditional vegetables in general vis-à-vis the weak linkages among their value chain actors affords the opportunity for agribusiness practitioners in the wholesale, retail sector (e.g., modern super market chains) and processing sector to mobilize farmers into groups for direct marketing relationships while reducing transaction costs through brokers to increase their profit margins. Agribusiness practitioners can also take advantage of the underlying consumer preference attributes for specific quality traits such as freshness, shape, size, the origin of culture, food safety (i.e., residual effect of pesticides) to upgrade existing value chains by targeting specific market segments such as convenience packaging for urban working class populations. This may require vertical integration of smallholders into their existing retail or processing business at the farm level to ensure standards are complied with right from the field.

Conclusions and Recommendations

Amaranth, Ethiopian mustard, and blackjack were the most important traditional vegetables while pumpkin, okra, tomato and cabbage were the most important exotic vegetables in Malawi. In Mozambique, African eggplant, amaranth, jute mallow, Ethiopian mustard, and wild cucumber were ranked high for traditional vegetables while pumpkin, cowpea, kale, onions, tomato, cabbage, and okra were ranked high for the exotic vegetables. The observed dynamics over time and the current performance of vegetables along the value chain in Malawi indicate that although amaranth, pumpkin, and okra are seen as the most preferred crops for commercial trade, cabbage and rape, grown by 18% and 12% of farmers respectively, are actually the most popular crops compared with the situation 10-15 years ago. In Mozambique, kale (17%), pumpkin (13%) and cabbage (13%) are the current popular crops grown by the sampled respondents. Although amaranth is not widely grown compared to 10-15 years ago, it was found to be the most collected from the wild.

A significant level of collaboration occurred among partners along the value chain. The input suppliers took the lead, followed by retailers, and finally the middlemen in collaborating with other middlemen partners. Although the input suppliers had higher levels of collaboration with other business partners, this collaboration was not made on the basis of written contracts, as it was for other types of agents along the value chain. Results of this study indicated that most linkages were spot market relationships, except for the linkage between retailers and supermarkets, which is an ongoing relationship.

To address the classic value chain problems for traditional vegetables discussed in this paper, the following recommendations are offered:

First, the successful introduction and producer accessibility of quality improved vegetable cultivars may require new management practices, which in turn require smallholders to make an investment in seed acquisition and supplies. This activity can be partially centralized by targeting

common initiative farmer groups or community seed production groups whose capacity will be built to produce and market quality seeds in their respective localities.

Second, smallholders should also be encouraged to engage in value-added institutional arrangements required for providing them with market opportunities for increased household income while also ensuing reduction in postharvest losses. An example could involve minimal processing of vegetables in large volumes from contracted traditional vegetable farmers for high value supermarkets retail outlets chains and possibilities for producing solar dried vegetables for both domestic market and export markets. One way to achieve this can be through a "One Village One Product" approach, a business development strategy from Oita Prefecture in Japan (One village one product 2003). The approach involves zoning production, processing and marketing of goods and services so that communities direct their efforts in areas in which they have comparative advantages over other communities. Such a program has been launched by the Malawian government, in which small-to-medium-size processing factories are set up in villages (Chidumu 2007) and groups like Zakudimba Producers Cooperation (ZAPCO) in Blantyre have started at a small scale to dry and market locally traditional vegetable like amaranths.

In addition, further market research is required in crop and market information systems in the study area. In the absence of the current realistic projections of crop size, competitive market conditions, harvest schedules and packing shed activity, farmers base their harvesting decisions on speculation as to potential moves in distant markets. In Kenya and Uganda for example, the use of mobile phones to convey market information has been a huge success. In Uganda, Muto and Yamano (2009) reported that, the mobile phone coverage expansion seems to induce the market participation of farmers in remote areas who produce perishable crops. Several opportunities exist for agribusiness practitioners to invest in the upgrading of traditional vegetable value chains, particularly in the formal seed sector and other agricultural input supply sector as well as integrating smallholders into emerging and restructured markets such as supermarkets through contracting arrangements for produce synchronization and assurance of quality standards through appropriate technology transfer. Finally, options for increasing value addition and improving produce quality (e.g., produce grading and convenience packaging by supermarket retailers and convenience retail shops) for targeted niche high-value market segments can also be explored by agribusiness practitioners.

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Appendix A

Table 6. Summary of constraints of traditional vegetable value chains in Malawi and Mozambique

Table 6. Summary of constraints of traditional vegetable value chains in Malawi and Mozambique

Constraints	Who is/are affected	Existing service provider	Potential /Opportunities for interventions
Limited knowledge of seed quality features	Farmers	Existent but weak	Awareness campaigns on issues of product quality
Limited technical advice for production	Farmers	Existent but weak	Promote and disseminate messages on production techniques
High susceptibility to diseases in standard vegetables	Collectors, retailers, middlemen	Existent but weak	Help farmers with materials for protection of plants.
Low demand for inputs	Input suppliers	Existent but weak	Align seed prices and respective quality. Opt for packages accessible to producers
Lack of access to inputs	Farmers/households	Existent but weak	Align seed prices and respective quality. Opt for packages accessible to producers
No available good quality seeds	Collector, retailers, middlemen	Existent but weak	Restricting the sale of seed to only the best quality seed
Absence of contractual arrangements for marketing	All	Existent but weak	Training on business management and negotiation of contracts
Lack of packaging services	All	Existent but weak	Encourage the processing and packaging of traditional vegetables
No processing of traditional vegetables before trading	Middlemen	Existent but weak	Encourage the processing and packaging of traditional vegetables
Lack of capital	Wholesaler, transporters, collectors, input suppliers, retailers, middlemen	None	Promote alternative access to capital, such as formal or informal credit
Poor infrastructure	Collector, input supplier, Retailers, middlemen	Existent but weak	Invest in the improvement of access routes for disposal of products
Market price is relatively low	Collector wholesaler, Retailers, middlemen	None	Promote methods of increasing value to traditional vegetables such as processing, branding. Market research and market information is important. Promotion of producer and trader associations can help get better prices on the market.
Too many sellers and very few buyers	Retailers, middlemen,	Existent but weak	Promote methods of processing to increase shelf life of traditional vegetables and sell when supply is low. Market research and market information is important. Promotion of producer and trader associations can help manage low cost of market transactions and product transfer.
Climate	Retailers, middlemen	Existent but weak	Training on natural resources management

Appendix B.

List of 24 commodities and 14 criteria used in the study

24 Vegetable Commodities	14 Criteria Used
1. Amaranths	1. Grown/traded commercially
2. Black Jack	2. Grown/traded commercially
3. Cabbage	3. Good prices
4. Carrots	4. Production experience
5. Hot pepper	5. Available market
6. Kale	6. Home consumption
7. Chinese	7. Opportunity to earn extra income
8. Corchorus (Jute Mellow)	8. Cultural reasons
9. Cowpea	9. Grown now that was not collected before
10. Bean leaves	10. Collected now that was not collected before
11. Okra	11. Traded commercially by middleman
12. Pumpkin	12. Traded commercially by input supplier
13. Rape	13. Traded commercially by retailer
14. Nightshades	14. Other reasons
15. Spider plant	
16. Pumpkin leaves	
17. Wild cucumber	
18. Sweet potato (including leaves)	
19. African eggplant	
20. Onions	
21. Lettuce	
22. Tomato	
23. Ethiopian mustard	
24. Wild Sesame	

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Manure as a Resource: Livestock Waste Management from Anaerobic Digestion, Opportunities and Challenges for Brazil

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Abstract

The idea of looking at manure as a resource, not a waste, has been central to much of the more recent thinking on the whole subject of good farm management. That is also the central idea of the present study, which maintains that the lessons of international experience suggest that the development of biogas systems is important for farm waste management. Brazil is abundant in livestock waste resources, but its livestock production management is very inefficient, particularly in the small rural properties. The objective of this article is to study the environmental impact of intensive livestock production systems and how the use of biodigesters should be an option in waste treatment and management.

Keywords: livestock, waste management, anaerobic digestion, biogas, Brazil.

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Introduction

It is widely known that livestock production has great potential for environmental degradation. As a result of this activity, a large volume of gases, organic material, bacteria, and other substances are produced, posing a risk factor for air, soil, and water contamination.

High levels of effluents flow directly or indirectly into surface waters. When the organic matter decomposes, it produces methane gas. Anaerobic fermentation in open lagoons also results in high methane emissions, and a danger that toxic gases can be released during the biological decomposition of the manure, with negative consequences for farmers and livestock (DENA 2010).

The increasing demand for food leads to a process of intensification in livestock production, which can lead to serious environmental problems if animal waste is not managed properly. In this sense, alternative technologies for good waste management can and must be used, as is the case of biodigesters, which produce biogas and biofertilizers and are an adequate form of animal waste treatment.

Some experiences in countries such as China, India, and the European Union (particularly Germany) demonstrate the use of biogas technology offers a way of avoiding the negative environmental consequences such as methane emissions and toxic gases (Poeschl et al. 2012; DENA 2010; FAO 2010). It can also lead to improvements in manure management on farms and prevent the dangerous flux of effluents into the waters. The installation of a biogas plant can also be expected to have a beneficial effect on nutrient emissions, as sensitivity regarding the efficient use of nutrients is bound to increase.

The idea of looking at manure as a resource, not a waste, has been central to much of the more recent thinking on the whole subject of good farm management (Burton and Turner 2003). That is also the central idea of the present study, which maintains that the lessons of international experience suggest that the development of biogas systems is important for farm waste management.

Brazil is abundant in livestock waste resources[1]. The country is one of the largest producers and exporters of beef and pork and has a large number of heads of cattle and swine that, in intensive systems, produce a large amount of pollution, particularly water pollution and gas emissions[2]. Brazil's intensive livestock production, particularly in the southern region, has high environmental impact. Pig farms predominate in the region and are the source of emissions into

[1] Not only Livestock. According to Ministry of Agriculture, Livestock and food Supply (Brasil 2010) Brazil plays a leading role as a global supplier of agribusiness products. In 2010 Brazil was ranked as the major exporter of Sugar (US$ 12,76 billion), Coffee (US$ 5,76 billion), Orange Juice (US$ 1,77 billion), Beef (US$ 4,79 billion), Tobacco (US$ 2,70 billion), Sugarcane Ethanol (US$ 2,02 billion). Also was ranked in second place in soybean exports (US$ 17,70 billion), third in Corn (US$ 2,13 billion) and fourth in pork (2,67 billion).

[2] Brazil has also a very important poultry production. However, as described in the literature, the potential for the conversion of poultry waste into biogas is very low compared to that of cattle and swine. Therefore, the present study is limited to the last two activities. The literature review shows that poultry manure seems to be most suitable in conjunction with pig manure in respect to their biogas yields compared to other types of manures.

the air, ground, and water. Confined swine production is also significant in the region, which together with the country's data, define the spatial limitation of this study.

The problem is that in Brazil, agricultural and livestock production management is very inefficient, particularly in the small rural properties that are so important. There is no adequate animal waste treatment, which leads to a growing environmental problem associated with the productive process. In that sense, this work defends the hypothesis that social and environmental sustainability in Brazil's current model of rural production becomes viable with the inclusion of agroenergy in the rural properties, based on environmental sanitation technology using residual biomass treatment in biodigesters.

Thus, the primary objective is to study the environmental impact of intensive livestock production systems and how the use of biodigesters (and consequently biogas generation) could be an option in waste/slurry treatment and management. The specific objective is to study the potential of biogas generation in Brazil's swine and cattle livestock production.

To achieve the proposed objectives, the study will be based on an extensive literature review, and the empirical analysis will be focused on descriptive statistics. Based on the analysis of data from the IBGE (Brazilian Institute of Geography and Statistics) Agricultural and Livestock Census and conversion indicators obtained from Brazilian literature, we estimate the potential for biogas production using swine and cattle waste.

The remainder of the paper is organized as follows. The next section presents the relationship between livestock systems and environmental problems, with emphasis on biogas as sustainable waste management. In the following section we present a few lessons from international experience in relation to the development of biogas systems, notably the cases of China and India. After that, we estimate the potential for biogas production derived from confined swine and cattle production in Brazil. Finally, we present the conclusions of the work.

Livestock Systems and Environmental Problems

Livestock, as part of global ecological and food production systems, are a key commodity for human well-being. Their importance in the provisioning of food, incomes, employment, nutrients and risk insurance to mankind is widely recognized (Herrero et al. 2010). In contrast, the interactions of livestock with its environment are complex and depend on location and management practices. Most traditional livestock production systems are resource driven, making use of locally available resources with limited alternative uses.

The relationship between livestock production and greenhouse gas (GHG) emissions it is widely recognized. As pointed out by Steeg and Tibbo (2012) agriculture contributes between 59% and 63% of the world's non-carbon dioxide (non-CO_2) GHG emissions, including 84% of the global nitrous oxide (N_2O) emissions and 54% of the global methane (CH_4) emissions[3].

[3] To Gerber *et al.* (2007) animal agriculture emits greenhouse gases at various levels of the food chain: feedcrops and pasture (mainly N_2O and NH_3); animal (mainly CH_4 from enteric fermentation); manure (CH_4, NH_3, and N_2O, to a lesser extent); and transport and other fossil fuel consumption (mainly CO_2 and N_2). In ruminant based systems, enteric fermentation and emissions from manure represent the bulk of emissions, whereas manure management and feed production represent the bulk of emissions associated with monogastrics.

According to Food and Agriculture Organization (FAO 2010), in general, environmental impacts of bioenergy (energy that is derived from biomass) are considered smaller than those of conventional (fossil and nuclear) energy systems. Once renewable biomass is CO_2-neutral when burnt, the resource base can be maintained if harvested biomass is re-grown, and residues easily decompose or can be recycled. Bioenergy can have positive employment and income effects, and could increase security of supply. Still, bioenergy crops can cause land-use change with severe environmental impacts, e.g. biodiversity loss and increased greenhouse gas emissions, and might negatively impact water resources and soil.

According to Michael et al. (2007) much of the estimated 35% of global greenhouse-gas emissions deriving from agriculture and land use comes from livestock production. Livestock production – including deforestation for grazing land and soy-feed production, soil carbon loss in grazing lands, the energy used in growing feed-grains and in processing and transporting grains and meat, nitrous oxide releases from the use of nitrogenous fertilizers, and gases from animal manure (especially methane) and enteric fermentation – accounts for about 18% of global greenhouse-gas emissions[4]. To Gerber et al. (2007), methane emissions from animal manure, although much lower in absolute terms, are considerable and growing rapidly.

Therefore, the expansion of livestock production creates the need to deal with subsequent environmental problems. There are some opportunities for mitigating environmental problems in livestock related to improved management (Steinfeld et al. 2006):

- Improved feeding management. It is consequence of feed composition that has an effect on enteric fermentation and the emission of methane. In this case, a higher proportion of concentrate in the diet results in a reduction in methane emissions;
- Improved feed conversion. Feed efficiency can be increased by developing breeds that are faster growing, that have improved hardiness, weight gain or milk or egg production and by enhancing herd health through improved veterinary services, preventive health programs and improved water quality;
- Grazing management. Increased use of pasture and good pasture management through rotational grazing are potentially the most cost effective ways to reduce and offset GHG emissions. This strategy increases vegetation cover and soil organic-matter content sequesters carbon, while inclusion of high-quality forage in the animals' diets contributes to reducing CH_4 emissions per unit of product.

Another one, which is the main interest of this work, is improved waste management through enhanced manure management and biogas production for energy. Improperly managed animal waste can have severe consequences for the environment such as odor problems, attraction of rodents, insects and other pests, release of animal pathogens, groundwater contamination, surface water runoff, deterioration of biological structure of the earth and catastrophic spills (Sakar et al. 2009).

[4] Specifically, livestock production generates 18% of the world's GHG emissions and there is potential for great increase since, according to the FAO 2006, global production of meat is projected to more than double from 229 million tons in 1999/2001 to 465 million tons in 2050, and that of milk to increase from 580 to 1043 million tons.

High livestock density is always accompanied by production of a surplus of animal manure, representing a considerable pollution threat for the environment in these areas. Cattle are the largest contributors to global manure production (60%), while pigs and poultry account for 9% and 10%, respectively (Herrero et al. 2009).

Recovery of nutrients from manure is highly variable and depends significantly on infrastructure and handling. Intensive animal production areas need suitable manure management, aiming to export and to redistribute the excess of nutrients from manure and to optimize their recycling. When untreated or poorly managed, animal manure can become a major source of air and water pollution. Nutrient leaching, mainly nitrogen and phosphorous, ammonia evaporation and pathogen contamination are some of the major threats (Holm-Nielsen et al. 2009).

Through international experience we can learn that anaerobic digestion and biogas production are promising means of producing an energy carrier from renewable resources while achieving multiple environmental benefits. This will be discussed in the next section.

Sustainable Waste Management and Bioenergy Production from Livestock: the Importance of Biogas

One of the beneficial and advantageous processes in manure treatment is anaerobic digestion (AD). The AD of various organic feedstocks, predominantly animal manures and municipal wastewater sludges, produce a methane rich gaseous mixture called biogas.

The conversion of animal waste to biogas through AD processes can provide added value to farm livestock manure as an energy resource. The wastes that can be treated by AD cover a wide spectrum. The older uses of the technology were for the treatment of sewage sludge and agricultural manures. The focus of this work is on animal manures[5].

The generation of biogas from the AD of biomass is a technology which can produce sustainable energy and also reduce the environmental risks associated with manure and waste management. Biogas is produced by bacterial conversion[6] of organic matter under anaerobic conditions and is a mixture of carbon dioxide (CO_2) and the flammable gas methane (CH_4) (Jiang et al. 2011). The biogas produced, consists of methane (50–80%), carbon dioxide (20–50%) and traces of, for example, hydrogen sulphide (0–0.4%) (Lantz et al. 2007).

Bond and Templeton (2011) clearly express the benefits of the use of biogas: “Biogas technology offers a unique set of benefits. It can improve the health of users, is a sustainable source of energy, benefits the environment and provides a way to treat and reuse various wastes – human, animal, agricultural, industrial and municipal” (Bond and Templeton 2011, 353).

[5] Anaerobic digestion of animal manure has the general goal of convert organic residues into two categories of valuable products: on one hand biogas, a renewable fuel further used to produce green electricity, heat or as vehicle fuel and on the other hand the digested substrate, commonly named digestate, and used as fertilizer in agriculture (Holm-Nielsen et al. 2009).

[6] Bacteria that function without oxygen degrade organic matter inherent in poultry and livestock waste (Sakar et al. 2009).

Biogas can be used for different energy services, such as heat, combined heat and power (CHP) and vehicle fuel, although the latter requires upgrading, by which most of the carbon dioxide and the hydrogen sulphide are removed. Additional treatment will also make injection into the natural gas grid possible (Lantz et al. 2007).

According to IEA 2001 there are a number of benefits resulting from the use of AD (biogas) technology.

Table 1. Benefits resulting from the use of biogas systems

Waste Treatment Benefits	▪ Natural waste treatment process ▪ Requires less land than aerobic composting or landfilling ▪ Reduces disposed waste volume and weight to be landfilled
Energy Benefits	▪ Net energy producing process ▪ Generate high quality renewable fuel ▪ Biogas proven in numerous end-use applications
Environmental Benefits	▪ Significantly reduces carbon dioxide and methane emissions ▪ Eliminates odors ▪ Produces a sanitized compost and nutrient-rich liquid fertilizer ▪ Maximizes recycling benefits
Economic Benefits	▪ Is more cost-effective than other treatment options from a life-cycle perspective

Source. Adapted from IEA 2001.

Animal waste treatment based on biogas systems provides the solution to environmental problems and generates biofertilizer, contributing to the reduction in methane gas emissions. This type of treatment is highly valued in the international market, particularly in the European Union as well as China and India[7]. The implementation of biogas systems often leads to significant improvements concerning resource efficiency and environmental impacts compared to current waste handling and agricultural production practices (Lantz et al. 2007).

An overview of the waste management and biogas systems in livestock systems is shown in Figure 1.

[7] To Srinivasan (2008) biogas digesters have come to symbolize access to modern energy services in rural areas and are slated to considerably improve health and sanitation, and to yield significant socioeconomic and environmental benefits.

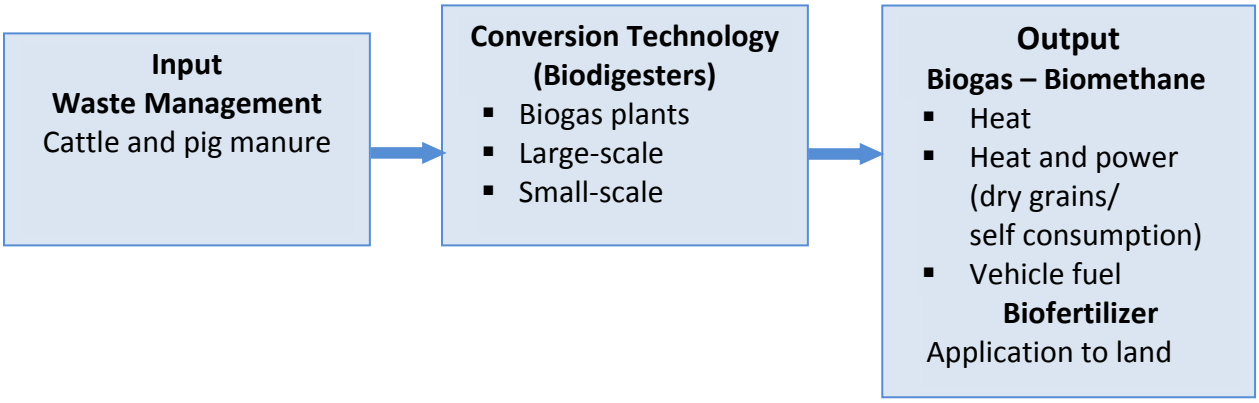

Figure 1. Overview of the waste management and biogas systems in livestock systems

In this schematic view, cattle and pig manure are the input to convert into biogas and biofertilizer, using biodigesters technology.

As Lantz et al. (2007), for Deutsche Energie-Agentur (DENA 2010) the use of biogas technology offers a way of avoiding the negative environmental consequences such as methane emissions and toxic gases. It can also lead to improvements in manure management on farms and prevent the dangerous flux of effluents into the waters.

Biogas production derived from animal waste is particularly important in swine and cattle producing countries with geographic dispersion between potential sites of animal waste recycling. Salomon (2007) clearly summarizes the importance of animal waste treatment:

> *The employment of anaerobic digestion technology for waste treatment is possible and desirable given that it contributes to environmental conservation, makes modern production systems viable, and optimizes the enterprise's cost/benefit ratio (...) In the same way, rational use of raw material and correct waste management optimize productive systems to achieve a harmonious coexistence between man and the environment* (Salomon 2007, 81).

In fact, generation of biogas from the anaerobic digestion of biomass is a technology that can produce sustainable energy and also reduce the environmental risks associated with manure and waste management (Jiang et al. 2011).

Compared to other bioenergy systems, biogas systems are more complex, involving many actors such as municipalities, farmers and energy companies, with several factors influencing the system, acting as either incentives or barriers (Lantz et al. 2007). In effect, there are not only advantages, but disadvantages as well as we can see in Table 2:

As shown in Table 2, costs of biogas projects construction, operation and maintenance are high. Karellas et al. (2010) present techno-economic viability to evaluate of the feasibility of biogas-to-electricity investments. In terms of costs are taken into consideration total plant costs (TPC)

and the CAPEX (the total project cost including development and contingency)[8]. Furthermore are considered total operating costs (TOCs)[9].

Table 2. Advantages and disadvantages of biogas technology

Advantages	Disadvantages
Improved sanitation	Laborious operation and maintenance
– Reduced pathogens	Limited lifespan (~20 years for many plants)
– Reduced disease transmission	Construction costly
Low cost energy source: cooking, lighting etc.	Less suitable in cold regions
Low cost fertilizer: improved crop yields	Less suitable in arid regions
Improved living conditions	Negative perception where low functionality of existing plants
Improved air quality	
Reduced greenhouse emissions	Requires reliable feed source
Reduced nitrous oxide emissions	Requires reliable outlet for treated sludge
Less demand for alternative fuels	Poor hygiene of sludge from mesophilic digestion
– Conservation of woodland	High construction costs relative to income of many potential users
– Less soil erosion	
– Time saved collecting firewood	

Source. Bond and Templeton (2011).

Although the process of producing methane from waste biomass materials has been known for over a century, the cost of techniques for using this process have been considered to be too expensive and not economically competitive with the price of natural gas. Due to the costs involved, production of methane from biomass has continued to be an underutilized process for generating renewable energy (Albertson et al. 2006).

There are several methods to assess the economic viability of biogas systems. According to Djatkov et al. (2012) assessment of overall performance of biogas plants has been seldom reported. Two popular methods are Multi Criteria Decision Making (MCDM) method and Data Envelopment Analysis (DEA) for assessing biogas plants with respect to economic, environmental and social criteria.

Another method, which considers a broader analysis, is life cycle assessment (LCA). LCA is a method that takes into consideration all inputs and outputs. It is a methodological framework for estimating and assessing the environmental impacts attributable to a product's life-cycle, i.e., from raw material acquisition, through the production and use phases, to waste management at end of life (Poeschl et al. 2012). There is an extensive literature review based on LSA, including applied to some countries (Patterson et al. (2011); Poeschl et al. (2012); Ishikawa et al. (2006); White et al. (2011)).

[8] Include the costs of the basic equipment plus costs for erection, piping, instrumentation, electrical works, civil works, buildings, engineering, management, commissioning, contingency and interest during construction.
[9] Include: 1) personnel (labor) costs and overheads; 2) Operation and maintenance (O&M); 3) Consumables; 4) Utilities (electricity and heat); 5) Liquid fertilizer disposal; 6) Feedstock cost; 7) Contingency; and 8) Amortisation.

The economic factor of biogas system development is important, but it is not the only factor and, according to international experience, it is hardly the most decisive. According to Djatkov et al. (2012, 105):

> *Economic parameters, particularly profit, are the most important performance indicators for biogas plant owners. However, it is necessary to consider other aspects of biogas plant performance that directly or indirectly influence the economic performance. Although economic performance may be satisfactory, there is a chance to improve other aspects and achieve even greater profit. Apart from the micro-economy, benefits of biogas installations for the society are energy production from renewable sources and mitigation of environmental impacts.*

It is exactly because of these indirect objectives, which are not necessarily economical, that the presence of the State is fundamental to the development of biogas systems. That will be shown from the lessons on international experiences.

Biogas Production: Some Lessons from International Experience

Biogas production from animal waste is particularly useful in countries with swine and cattle herds and where the possible sites for residue use are geographically dispersed (Mathias and Mathias, 2013). That is the case of Brazil, China and India, where locally produced biogas can be used in the farms themselves, whether for electricity generation for local supply (avoiding investments in the expansion of energy distribution networks to remote areas), for generation of thermal energy (useful in countries with harsh winters) or for drying grain (in farms with simultaneous cattle raising and production of foods that require thermal processes). If such farms are already connected to distribution networks of electricity or natural gas, the excess energy (electricity or methane, as long as specified) could be injected into the networks to increase the country's energy supply and reduce its dependence of possible energy importation and delaying the need for investment in energy generation and network expansion.

There are different biogas technologies on the market, mainly in China and India, countries from which Brazil could take some lessons in biogas development.

Biogas Technologies on the Market

Biogas plants of all sizes and different levels of sophistication exist. Of course, the main interest is the biogas plants for livestock manure. Karellas et al. (2010) emphasize that anaerobic digesters are separated according to their operation type (batch, semi-continuous or continuous operations). It is particularly noted that anaerobic digestion technology has recently been developed to suit the conversion of energy crops. According to the aforementioned authors, when it comes to plant size, anaerobic digestion of organic wastes and energy crops can be divided in:

- Horizontal digesters (volume 50–150 m^3) suitable for the smallest size plants and well-suited for treatment of cow and poultry manure as well as feedstocks with increased TS (energy crops) due to the very good mixing conditions.

- Upright standard agricultural digesters (volume 500–1500 m^3, with height 5–6 m and diameter 10–20 m). The tanks are equipped with an internal heating system and external motor(s) for mixing, while in the top of the tank a double-membrane, gasholder roof is fitted. This device has a treatment capacity of up to 10,000 m^3/ year and the hydraulic retention time is between 3 and 80 days depending on the input substrate.
- Upright large digester (volume 1000–5000 m^3, with height 15–20 m and diameter 10–18 m). In these devices the input material is pre-heated and mixing is performed by centrally located, continuously operating, roof-mounted mixer. The advantages of preheating and continuous mixing achieve much lower hydraulic retention times (20–30 days). This type of digester is used for the treatment of up to 90.000 m^3/ year per single unit. Larger centralized plants (i.e. in Denmark or Germany) have often two or more such digesters.

Sakar et al. (2009) present a literature review of anaerobic digestion technology in poultry and livestock waste treatment. They present four major reactor types of anaerobic digesters used to treat livestock waste and produce biogas[10]:

- CSTR (continuously flow stirred tank reactors),
- UASB (up-flow anaerobic sludge blanket) ,
- UAF: (up-flow anaerobic filter)
- Baffled

Choice of reactor type is determined by waste characteristics, especially particulate solid contents or total solids (TS). High TS feedstocks and slurry waste are mainly treated in CSTRs, while soluble organic wastes are treated using high-rate biofilm systems such as anaerobic filters, fluidized bed reactors and upflow anaerobic sludge blanket (UASB) reactors (Karellas et al. 2010).

There are many types of biogas plants in Europe, categorized according to the type of digested substrates, according to the technology applied or according to their size. The biogas plants digesting manure are categorized as agricultural biogas plants, and they usually co-digest manure and other suitable organic residues, many of them of agricultural origin as well. A common classification of the agricultural biogas plants is: (1) the large scale, joint co-digestion plants[11] and (2) the farm scale plants (Holm-Nielsen et al. 2009).

Modern developments in agricultural waste digestion have developed the concept of centralized anaerobic digestion (CAD) where many farms co-operate to feed a single larger digestion plant[12]. The wastes provided to this will be principally agricultural manures and production

[10] A low-technology option is covered lagoons, which are dug in the ground, waterproofed, and covered with plastic tarpaulin to isolate and contain the biogas.

[11] The joint biogas plants co-digest animal manure collected from several farms, mixed with suitable organic residues from the food and feed industries and from the overall society. The joint biogas plants are usually of large scale, with digester capacities ranging from, e.g., few hundreds m^3 up to several thousands m^3 (Holm-Nielsen et al. 2009)

[12] Centralized energy schemes of AD are under detailed investigation by industries and governments in many high-income industrial countries. In fact, there are now over 800 farm-based digesters operating in Europe and North America (Batzias et al. 2005).

residues but in some cases small amounts of industrial and municipal wastes will also be treated (IEA 2001).

Medium and large-scale biogas plants can treat the large amounts of manure produced by large-scale livestock and poultry farms and also municipal and industrial organic waste streams (Jiang et al. 2011). The large digesters provide large amounts of renewable energy to society and due to the larger size of the plant there may be technology and management skills available to ensure an efficient distribution of the digestate to neighboring farmers, who can use this high-value organic fertilizer to meet crop needs. The cost per unit of gas produced is also reduced due to the economies of scale that can be made.

The farm scale biogas plants co-digest animal manure and slurry from one single farm or, rarely two or three smaller neighboring farms. The applied technology is similar to the joint biogas plants and the farm scale plants are usually established at large pig farms, confronting themselves with environmental problems due to excess of slurry production. The farm scale biogas plants apply also pre- and post-treatment and separation technologies (Holm-Nielsen et al. 2009).

Farm scale plants are more common in developing countries. Currently, decentralized farm based manure facilities represent probably the most common AD-technology in low income agricultural countries; e.g. six to eight million family sized low-technology digesters are used in China and India to provide biogas for cooking and lighting (Batzias et al. 2005). It will be discussed ahead in details.

China and India dominate the best technologies in the use of biodigesters[13]. The primary objective of the Chinese is to obtain biofertilizers for food production. In contrast, India's aim is to reduce the great energy deficit. The biodigester models are distinct: the Chinese model is simpler and less expensive, and the Indian model is more sophisticated and technical in order to take the most advantage of biogas production (Bond and Templeton 2011).

According to Chen et al. (2012), a household-scaled biogas is a system with one digester occupying 8–20m.^{3} China has achieved breakthroughs in the construction and process technologies of household-scaled digester. Standardized series of digester types have been manufactured according to different climates, materials, and uses. The basic types are hydraulic pressure digester, floating cover digester, semi-plastic-type digester, and tank digester.

China's biogas production technologies are fully developed to take on environmental protection, energy production, and integrative utilization. Almost all kinds of anaerobic digesters have been applied, including continuous stirred tank reactor (CSTR), plug flow anaerobic reactor, up-flow anaerobic sludge blanket, up-flow solids reactor (USR), anaerobic contact digester, anaerobic sequential batch reactor, anaerobic Baffled Reactor, up-flow blanket filter, inner circulation

[13] There is a very significant biogas industry in Europe, especially in Germany (Ferreira et al. (2012); Holm-Nielsen et al. (2009); Karellas et al. 2010). But because of spatial and economic similarities, this work will focus on China's and India's case.

reactor, expanded granular sludge blanket, among others. However, the biogas plants with CSTR and USR technologies are prominent, comprising 65% of all plants (Chen et al. 2012).

The technologies for the development of biogas systems are widely developed and accessible, however high investments are often required, and international experience has shown that this is a discouraging factor. Thus, a strong presence of government policies has been instrumental to the development of biogas systems, both in developed and developing countries. Given the socioeconomic and territorial similarities, India and China can provide some lessons to Brazil.

Chinese and Indian Experiences: Lessons for Brazil

The development of biogas technology in China and India is based on animal management, especially swine and cattle livestock production. Bond and Templeton (2011) present a history of biogas and assess its future in developing countries, particularly China and India. According to the authors, starting in the 1970s, China promoted the use of biogas in all rural residences in the country.

Jiang et al. (2011) also present an overview of China's biogas industry. The authors describe the enormous Chinese livestock production, which favors biogas production, once generation of biogas from the anaerobic digestion of biomass is a technology that can produce sustainable energy and also reduce the environmental risks associated with manure and waste management. A set of actions of the government promoted a great biogas development in China.

According to Chen et al. (2012) by the end of 2010, 38.51 million household-scaled biogas digesters in rural China were built, with an annual biogas output of 13.08 billion m^3. Today, China is the largest biogas producer and consumer worldwide. More than 72,600 biogas plants deal with agricultural wastes; the industry has a total digester capacity of 8.57 million m^3 and annual output biogas of 1.05 billion m^3. Of these there are 4,641 large-scaled biogas plants, 22,795 medium-scaled biogas plants, and 45,259 small-scaled biogas plants, with a total digester capacity of 3.60 million m^3, 3.07 million m^3, 1.90 million m^3, respectively, and annual biogas output of 613 million m^3, 277 million m^3, 164 million m^3, respectively.

Jiang et al. (2011) present three policy measures to biogas systems development in China: i) Energy policies; ii) Environmental policies; and iii) Economic policies.

The framework for energy policies in China is the "Renewable Energy Law" which provided incentives for biogas production in 2006. This shows that a country with ample reserves of hydrocarbons, particularly coal and more recently non-conventional natural gas, also has an interest in the use of biogas and other alternative energies.

In order to control the pollution from livestock and poultry production facilities, the following measures of environmental policies have been established and implemented: ''Discharge Standard of Pollutants for Livestock and Poultry Breeding'', ''Management Approach for Pollution Prevention of Livestock and Poultry Farms'' (2001), ''Criteria for evaluating the environmental quality of the livestock and poultry farm'' (2004) and ''Technical Specifications for Pollution Treatment Projects of Livestock and Poultry Farms'' (2009). The construction of

medium and large-scale livestock and poultry farms also comes under the ‘‘Environmental Impact Assessment System’’ and the ‘‘Three Simultaneous Systems’’.

Finally, in terms of economic policies, the central government has given high priority to the rural biogas sector. The support is given through rural small-scale, public, infrastructure projects and rural basic construction projects, particularly since the implementation of the ‘‘National Debt Project for Rural Biogas Construction’’ in 2003. From 2003 to the end of 2009, the total investment from the central government to the rural biogas industry reached over 19.0 billion CNY[14], of which about 82% went to the construction of household biogas digesters, about 10% went to the construction of medium and large-scale biogas plants, and about 8% financed service systems.

Despite the outstanding achievements, particularly in rural biogas production, Chen et al. (2012) points out many problems and challenges to biogas industry:

1. Some biogas plants are in fact underutilized. This development can be attributed to the poor economic benefits resulting from the low integrative utilization rate of biogas production and the unstable supply of raw materials caused by fluctuations in livestock breeding;
2. Inferior equipment technology and low level of industrialization. Low manufacturing, lack of species, poor durability, and inadequate product support are just some of the problems confronting the biogas production industry;
3. Policies and incentives need to be improved, and subsequent service abilities must be strengthened. Policies, regulations, and standards for the construction and integrative utilization of large and medium-scaled biogas plants are currently far from industry standards;
4. Faulty market impacts on integrated benefits of biogas which have yet to be felt. In turn, problems such as weak demand and an immature biogas market, deficiency in matched measures and market orientation, and long-term payback period have been highlighted.

India, with its vast territory and widely dispersed rural properties, granted government subsidies for the construction of 4 million family biogas plants between 1999 and 2007[15]. Since the early 1980s, the country has conducted a project known as the National Project on Biogas Development (NPBD), which provides funding and training to the various development programs proposed by the government[16]. These government subsidies for the development of family biodigesters covered 30% to 100% of the total price of equipment between 1980 and 1990 (Bond and Templeton 2011).

[14] CNY is the abbreviation of Chinese Yuan, and a dollar equivalent to 8.07 CNY at Jan 1, 2006 and 6.62 CNY at Jan 1, 2011 (Jiang et al. 2011).

[15] Vijay et al. (1996) present an alternative concept of community biogas plants, a rural industrial complex, once use of biogas for applications in small industries were found to be more successful. There are some advantages in terms of local resource utilization, decentralized energy generation, diversified rural activities, environmental friendliness, etc. The activities of the complex are centered on the biogas plant and dairy unit.

[16] In the beginning of the1990’s an estimation of biogas generated by cattle dung in India would be equivalent to nearly 195 billion KWh of energy annually (Vijay et al. 1996).

According to Gopinathan and Sudhakaran (2009) energy security is a growing concern for India's energy policy. During 2000–2006 period a Planning Commission constituted a series of committees such as Hydrocarbon vision-2025, India vision-2020, and Integrated Energy Policy-2006 and prepared an integrated energy policy linked with sustainable development addressing all aspects of energy use and supply. The broad vision behind the energy policy was to reliably meet the demand for energy services of all sectors at competitive prices. In addition, essential energy needs of all households must be met even if that entails subsidies to vulnerable households. The demand must be met through safe, clean, and convenient forms of energy at the least cost in a technically efficient, economically viable, and environmentally sustainable manner. Considering the set of energy services options, biogas is one of the renewable energy resources with the highest potential for growth in India according the mentioned authors.

Given the similarities in the size of their territories and the large number quantity of cattle and swine, two of the most important developing countries that successfully use biogas systems can share their experiences and provide examples for Brazil to follow. As in China and India, Brazil's vast swine and cattle herds represent a significant potential for biogas (biomethane) production. Concurrently, waste treatment reduces environmental problems and allows the production of organic fertilizer. Waste treatment also contributes to reduction in GHG emissions, which is highly valued particularly in the European Union. International experience shows that China and India are the main examples of positive external factors derived from the development of biogas systems. In Brazil's case, it is possible to identify opportunities, especially in the Southern region where cattle and swine production is concentrated.

Undoubtedly, Chinese and Indian experience suggests that the development of biogas systems requires a set of focused political measures with strong government participation, particularly with regard to the legal framework and the financial incentives provided. Another topic highlighted in international experience is the incentive for the development of small biogas plants in rural areas (Mathias and Mathias 2013).

Although not described here, the experience of developed countries also indicates great governmental support. According to Gerber et al. 2007, experience in both developed and developing countries confirms that a laissez-faire approach, simply standing back and allowing market forces to play out, is not a viable option. In the absence of effective policies, many of the hidden costs of increased livestock production – cleaning up the environment, expanding safety nets and economic opportunities for poor traditional livestock owners, and fending off threats to veterinary and human public health, are eventually charged to governments and the public.

The Potential of Biogas Production in Brazil's Swine and Cattle Livestock Production

Status of Livestock Sector in Brazil, According Census Data

The literature indicates that the biogas production initiatives in Brazil are incipient and isolated. In reality, renewable energies in general are still classified as "alternative", which renders them inferior to hydropower, still considered the noblest renewable source (Bley Jr. et al. 2009). Sector statistics ignore the energy potential of organic residues, if not for the purposes recorded in the distribution of spaces of the so-called alternative energies, then at least for the correct identification of the economic potential that these residues and effluents represent to their generators.

Even though initiatives for biogas generation from animal waste are isolated, there is significant potential for it in Brazil's rural areas, particularly in cattle and swine farms. The Southern region has characteristics that are very favorable to the development of biogas systems, given that it holds a large part of the cattle and swine production.

In 2006, the Agricultural and Livestock Census counted 5,175,489 agricultural and livestock establishments and data show that there is room for the development of biogas systems in Brazil and particularly the Southern Region[17], where intensive production is very significant and where most of the heads of swine and cattle are concentrated. Table 3 shows that only a few properties have adequate treatment for manure:

Table 3. Treatment of manure per establishment. Brazil and Southern Region, 2006.

Brazil and Southern Region	Total properties	Treatment in anaerobic lagoon	Treatment in open tanks	Treatment in bio-digester	Treatment with composting	Treatment elsewhere
Brazil	*5,175,489*	*3,269*	*131,232*	*2,387*	*31,849*	*27,197*
Southern Region	*1,006,181*	*1,618*	*82,609*	*1,223*	*21,379*	*7,877*
Paraná	371,051	490	13,036	393	6,271	3,043
Santa Catarina	193,663	529	28,016	490	7,823	1,478
Rio Grande do Sul	441,467	599	41,557	340	7,285	3,356

Source. IBGE, Agricultural and Livestock Census 2006.

Not only is there a small number of properties with waste treatment, but most of them use treatment in open tanks. Treatment in biodigesters was insignificant in 2006. A simple data analysis shows that there is room to adopt policies that allow the treatment of animal waste with simultaneous generation of biogas and biofertilizer.

The first conclusion drawn from the analysis of the Table 3 is that, if the deficiencies of Brazil's rural areas were addressed with biogas systems, there could be immediate benefits from an economic perspective (at the very least energy generation for private consumption and biofertilizers) and from an environmental perspective (animal waste treatment).

According to Deutsche Energie-Agentur (DENA 2010), a variety of systems for the storage and treatment of pig manure exist in Brazil, particularly in southern region, all of which collect the manure with the aim of degrading the organic matter with anaerobic fermentation and reducing the number of pathogenic germs. The most common manure management system in use in Brazil is the open tank or lagoon known as an *Esterqueira*. The manure is stored and stabilized here and then removed and spread as fertilizer. The system is characterized by low implementation costs and easy operation, but the significant physical area required to distribute the sludge and the low nitrogen removal efficiency are a disadvantage.

The Canadian biodigester is the most common model used in the south of Brazil. This has a digester volume of 150m^3, a 0.8mm PVC cover, a hydraulic retention time of about 30 days, an internal combustion motor and a 1mm PVC gas holder with a capacity of 136m^3. It is designed to treat the manure from a 50 sow pig farm during a complete production cycle. The gas is pumped to a heat control device where water vapor and then volatile sulfides are removed. The resulting biogas is used to heat poultry farms, and in domestic applications or grain driers (DENA 2010).

[17] There are three states in the southern region: Paraná, Santa Catarina, and Rio Grande do Sul.

In the next section, we present an estimation of the potential for biogas production, based on Agricultural Census data.

Brazil's Potential for Biogas Production within Swine and Cattle Livestock Production

In this section, we estimate the potential for the generation of biogas derived from cattle and swine waste. The methodology used to obtain this estimate is based on descriptive statistics data[18]. In Brazil's case the most recent Agricultural and Livestock Census was published in 2006 by IBGE, which shows the structural data of Brazilian agriculture and livestock production. The information needed to obtain the estimates for animal waste and, consequently, biogas production refers to the total heads of swine and cattle. In the case of swine, the information of interest is the total number of heads and, in the case of cattle, the number of confined animals, as the objective is to obtain biogas from dry animal waste, which is not possible in extensive cattle farming. In sum, we use the following formula:

$$BP_t = NHxDMxE_t$$

Where:

- BP_t = is the theoretical biogas potential (biomethane – CH_4) over the time in (m^3/CH_4)
- t = time (here is daily production)
- NH = the number of livestock heads
- DM = dry manure
- E_t = coefficient to convert a given slurry (dry manure from cattle or pig) into biogas (m^3/CH_4).

The data from the Agricultural and Livestock Census (IBGE 2007) included in Table 4 shows the number of swine in the country in 2006, which exceeded 31.1 million heads, more than half of them (16.7 million) concentrated in the Southern region. Although the number of heads of cattle is far greater (nearly 200 million), only confined animals can be considered for the potential of waste generation, which in 2006 exceeded 4 million heads including a little over 600 thousand heads in the Southern Region.

Table 4. Number of heads of swine and confined cattle. Brazil and Southern Region: 2006

Region and States	Swine		Confined Cattle	
	Number of establishments	Number of heads	Number of establishments	Confined animals
Brazil	1,496,107	31,189,339	20,864	4,049,210
Southern Region	451,870	16,750,420	5,750	603,153
Paraná	135,477	4,569,275	2,633	366,577
Santa Catarina	82,324	6,569,714	1,299	77,104
Rio Grande do Sul	234,069	5,611,431	1,818	159,472

Source. IBGE (2007)

With the number shown in Table 4 and the estimates of daily production of dry material from swine and cattle waste, it is possible to calculate the potential for waste production in tons/day.

[18] A very common approach to estimate the potential of biogas production is based on descriptive statistics and applied to different countries or regions. See Chen et al. (2012) to China's case, White et al. (2011) to Ontario's case and Bond and Templeton (2011) to developing world.

Considering that swine produce 2.3 to 2.5 kg of dry waste per day and that cattle produce 10 to 15 kg per day (Solomon and Lora 2005), it is possible to estimate two scenarios with scenario 1 being the lowest and scenario 2 being the highest. The indicator for conversion of animal waste into biogas, more precisely methane gas[19], is provided by Castanón (2002): for beef cattle, 40m^3 of methane gas per ton of dry material and, for swine, 350m^3 of methane gas per ton of dry material[20] (Table 5).

Table 5. Brazilian coefficients of biogas conversion

Coefficients	Swine	Confined Cattle
Dry manure (kg/day)	2.3-2.5	10-15
Coefficient of conversion (m^3 CH_4) kg/ DM	0.35	0.04

Source. Adapted from Solomon and Lora (2005).

Table 6 shows the potential for methane gas production in Brazil and its Southern Region. The data are very representative, given that in 2006 the country imported 26.8 million m^3/day of natural gas (95% from Bolivia and 5% from Argentina). In other words, if all of the swine and cattle waste in Brazil was treated in biodigesters, the potential for gas generation would meet the country's importation needs.

Table 6. Potential for methane gas production. Brazil and Southern Region: 2006 (in m^3/ day)

Region and States	Swine		Confined Cattle	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Brazil	25,107,418	27,290,672	1,619,684	2,429,526
Southern Region	13,484,088	14,656,618	241,261	361,892
State of Paraná	3,678,266	3,998,116	146,631	219,946
State of Santa Catarina	5,288,620	5,748,500	30,842	46,262
State of Rio Grande do Sul	4,517,202	4,910,002	63,789	95,683

Source. Prepared by author based on data from IBGE (2007).

An additional issue, related biogas systems development, is the size of rural properties. In Brazil, particularly the Southern Region, there is a strong presence of small family farms (almost 85% of all rural properties), as seen in the data analysis of the Agricultural and Livestock Census of 2006. Based on this census, IBGE conducted a study on Family Agriculture in the country. The Institute used the concept of Family Agriculture defined by Law 11 326 of July 24, 2006. According to this law, rural family units must meet the following criteria simultaneously: the area of the rural establishment must not exceed four modules for tax purposes; the labor employed in the economic activities must be predominantly from the family; the family income

[19] The typical composition of biogas is predominantly methane gas (CH_4), which represents between 55% and 75% of biogas. Another important gas that is generated is CO_2, with a participation of 25% to 45% in biogas (Karellas et al. 2010).

[20] The data from Castanón (2002) are close to those seen in international experience. Karellas et al. 2010 provide an indicator of 362.5 m^3 of methane gas (CH_4) per ton of dry material for swine. When measured in m^3/animal/day, Bond and Templeton (2011) provide an indicator of 1.43 m^3/animal/day for swine and 0.32 m^3/animal/day for cattle. However, this refers to the indicator for biogas production and not specifically methane gas. In that case, the data from Bond and Templeton 2011) are similar to the data from Cervi et al. (2010), who show indicators for biogas production from dry material from cattle and swine (1.40m^3/animal/day) in Brazil.

must come predominantly from these activities; and the establishment must be managed by the family (IBGE 2009).

In Brazil, literature shows livestock waste main use as an energy source. Some experiences shows biogas potential use to produce electricity in Southern Region. According to DENA 2010, because of a constant demand for natural gas by industry and growing consumption in the transport sector, the substitution of natural gas with biogas in Rio Grande do Sul is an alternative to a fossil energy source worth exploiting. If the region's biogas potential were to be used to its full extent for energy, it would account for around 1% of the electricity consumed or 10% of the natural gas used in Rio Grande do Sul (DENA 2010).

In case of Paraná State, the use of biogas energy source is being encouraged with the Project Distributed Generation Energy with Environmental Sanitation, as an important tool to meet the requirements of sustainable development in the region. The premise of this project is to use the biomass generated in four demonstration units, which through the process of anaerobic digestion generates biogas that moves a plant for generating electricity. Part of this energy is used to feed their own production with the possibility of selling surplus energy to Electricity Company (Hachisuca et al. 2010).

Therefore, it can be concluded that the development of biogas systems, particularly Southern region, can be a favorable strategy for local sustainable development, once there is potential production (supply) and an energy use (demand). However, there are various challenges to be overcome before biogas can be produced on a large scale and not only in isolated local properties.

Limitations and Challenges to Develop Biogas Systems in Brazil

Although Brazil has an important potential to develop the biogas industry, there are also equally huge challenges. Biogas is not yet treated as a primary energy source. There are also political challenges, once there is no specific program to promote biogas industry development.

Undoubtedly, international experience suggests that the development of biogas systems requires a set of focused political measures with strong government participation, particularly with regard to the legal framework and the financial incentives provided. Another topic highlighted in international experience is the incentive for the development of small biogas plants in rural areas. However, there are many political and legal obstacles to biogas development in Brazil that warrant a governmental agenda on the issue.

Mathias and Mathias (2013) based on the legal framework, present a governmental agenda for biogas development in Brazil. According to the authors, the analysis of the legal framework and the duties assigned to the different public agencies leads to the conclusion that this framework was developed in a hermetic fashion and did not consider the specificities of the biofuel industry. The different legal documents overlap duties, while also leaving gaps that which require attention. One of the main juxtapositions is the role of regulating the direct use and trade of biogas. It is unclear whether it is a responsibility of the federal regulatory agency (ANP) or the

state regulators. There is legal basis for both interpretations. One of the main gaps is the definition of biogas itself, which is not found in any of the normative frameworks provided.

The first topic on the governmental agenda for biogas is the clear definition of the duties of the State agencies regarding the production, movement, and use of biogas derived from animal waste, so that its development will not run into legal or bureaucratic matters that hinder the construction of an enterprise that could bring environmental and energy benefits to its area. Even without changes to the legal framework, it is fundamental to coordinate the public agencies in order to allow the development of biogas enterprises.

To achieve that, each public agency of the energy sector must perform its role as prescribed in the legal framework. Thus, the National Council for Energy Policy (CNPE) should establish guidelines for specific programs, such as those for biofuel use, and propose policies for the use of local resources, which can stimulate local biogas production and use. However, this agency has not had a proactive role in proposing policies.

Another important element is the interaction between the different Ministries of State involved in biogas production and use. In order to achieve that, the Ministry of Agricultural Development (focused on small rural properties), the Ministry for the Environment (focused on waste treatment and environmental protection), and the Ministry of Mines and Energy should make a joint effort to allow the CNPE to propose policies that facilitate the inclusion of biogas as an energy source, both for thermal energy and electricity.

After the technological and bureaucratic issues are overcome, there is still the need to obtain financing for biogas enterprises. There are government institutions that can be used in this financing, i.e. Bank of Brazil, which has low interest rate loans for small rural enterprises, and the National Bank for Economic and Social Development (Banco Nacional de Desenvolvimento Econômico e Social - BNDES), which can finance investments in medium-size and large rural properties. It must be pointed out, however, that this is only one of the requirements for achieving the investments. The fundamental issue is to find a solution to the legal barriers, primarily through the coordination of the abovementioned agents (Mathias and Mathias 2013).

Conclusions

Intensive livestock production systems produce a large quantity of animal manure. The treatment of manure as a resource can offer benefits to livestock producers. One possibility, highlighted in the present study, is the use of biogas systems.

This study shows a large and unexplored potential for the use of agricultural waste, specifically cattle and swine waste, for biogas production in Brazil. It is very important to identify the potential, but it is still the first step. How to transform the potential biogas generation into real biogas production is the next research step.

The potential expansion of biogas systems in Brazil is affected by a number of factors regarding, among other things, energy supply, environmental goals and sustainability issues expressed in

various policies (governmental agenda and appropriate policy instruments). Literature revision shows few and weak instruments favoring a biogas production today in Brazil.

The development of biogas systems in Brazil, though potentially difficult to implement, require substantial research to verify their feasibility, including cost-benefits models. International experience shows that improvement of that natural resources management, particularly livestock waste, is more an issue of policy and regulation than of technical capacity building and research. Therefore, the enormous potential can only become a reality if it receives incentives from various agents, particularly from all levels of government.

Indeed, the review of international experience recommends considerable government involvement in terms of incentives for the use of biogas, and this is a continuous effort over time. Therefore, as previously emphasized, Brazil has an extensive governmental agenda to meet the challenge of developing biogas systems.

Clearly, the country needs to promote the implementation of biogas valorization plants in order to take advantage of its huge potential. And, as shown in this study, resource availability is abundant. The implementation of smaller-scale projects, mainly treating available organic effluents, could be a first step for this country with enormous potential for biogas production and use, but it lacks political tools such as a more focused legislation that would facilitate the development of biogas systems.

The overall conclusion is that the prospects of developing biogas systems in Brazil will depend on a large variety of incentives and barriers within several different sectors. The promotion of biogas systems is thus not only relevant to energy policies, but also in several other policy domains, such as agricultural-, environmental and waste-handling policies.

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Potential Economic Impact of Biofortified Maize in the Indian Poultry Sector

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Abstract

The study examines the current feed use in the rapidly-growing Indian poultry sector and evaluates the potential economic impact of using biofortified maize with higher levels of amino acids as feed. Data collected from 185 poultry firms of South India form the empirical base. A significant share of broiler firms were found using amino acids in quantities above the recommended levels with negligible production and negative profitability effects, demonstrating a clear dearth of managerial skill to obtain and utilize information on poultry nutrition. A linear programming model for estimating the least-cost feed formulation showed that the potential economic impact of biofortified maize is limited by the availability of low-cost protein from the alternative sources, and that the potential cost savings from the technology would be marginal. Similar findings were obtained from additional estimation done by relaxing the assumption that the firms have perfect information on feed formulation. Also, lack of awareness of the small-scale firm management regarding poultry nutrition could pose additional challenges in the development of innovative maize-poultry value chains for diffusion of this innovation.

Keywords: biofortification; credence good; feed cost; optimization; quality protein

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Introduction

Growing at a compound growth rate of 15% per annum over the past two decades, India's poultry sector was recently contributing Rs. 350 (US$ 6.3) billion annually to the country's gross national product (PDP 2011). The industry's substantial growth has largely been driven by the demand from the rapidly expanding population of middle-income households and their changing consumption preferences (Gulati et al. 2007). This, in turn, has spurred the domestic production of poultry feed crops, viz., maize and soybean. Maize is the main source of energy in the feed rations of both broilers and layers, while soybean meal provides the required protein (Hellin and Erenstein 2009). More than 50% of the maize produced in India is currently used by the poultry feed sector (Sethi et al. 2009). Since maize grain is a poor source of essential amino acids for poultry (Atlin et al. 2011), many poultry firms are found depending on synthetic amino acid supplements to meet the required dosage of these nutrients. Hence, the development and distribution of biofortified maize – Quality Protein Maize (QPM) and High Methionine Maize (HMM), containing enhanced levels of limiting amino acids – might hold significant economic potential in India.

Previous research and development (R&D) efforts have focused on QPM, a product of biofortification for higher levels of two essential amino acids for human and poultry nutrition – Lysine and Tryptophan. A dozen QPM varieties have been released in India (Agrawal and Gupta 2010), but only five of them are commercially available, and their adoption rates are marginal (Atlin et al. 2011). More recently, plant breeders started developing maize rich in Methionine – the third essential amino acids for poultry and more limiting in terms of nutrition than Lysine or Tryptophan in India. Products of such biofortification are postulated to have significant positive economic impact in the Indian poultry sector by substantially reducing the requirement for synthetic amino acid supplements (Panda et al. 2013, Panda et al. 2010, Prasanna et al. 2001). An earlier qualitative value chain study by Hellin and Erenstein (2009; p 259) flagged some of the associated challenges of biofortified maize as poultry feed and the innate weaknesses in the maize-poultry value chains in India, which include weak linkages between maize farmers and local poultry firms, limited access to improved technology and to channels of information and other business services for small-scale maize and poultry producers, and low prevalence of value chains with both growth and poverty reduction potential.

There are a number of studies documenting the nutritional benefits of QPM over conventional maize (Lauderdale 2000, Sullivan et al. 1989, Asche et al. 1985). In Brazil and El Salvador, the use of QPM as animal feed could reduce the use of soybean meal by about 50%, besides substantially lowering the usage of synthetic Lysine (Lopez-Pereira 1992). Based on the international prices of feed components, and assuming equal prices of QPM and normal maize, Lopez-Pereira (1993) estimated cost-savings from QPM to be about 3-4% for poultry production. A similar study from Kenya reports a 5% cost reduction (De Groote et al. 2010). In China, the effect of replacing normal maize with QPM was found more prominent for pigs than poultry at various growth stages (Sofi et al. 2009). However, these results depend largely on the relative prices of feed components and the efficiency of maize-poultry value chains. Amino acid content of maize grain is inherently a credence attribute along the value chain, including the poultry firm managers – that is, the naked eye cannot easily distinguish the high protein quality, although this could potentially be done through additional lab analysis.

The present study primarily aims to estimate the economic benefits of biofortified maize *ex ante* in the Indian poultry production sector. To our knowledge, no such quantitative study has so far been undertaken in the Indian context. The paper is structured as follows. The next section describes the relevance of biofortified maize (QPM and HMM) development in India. The methodology includes the details on data sources and the analytical framework. A linear programming optimization model, which is applied to derive the least-cost combination of feed ingredients with and without biofortified maize available in the market, is explained. The subsequent section analyses and discusses the feed use structure prevailing in the sample poultry firms, and the cost and return impacts of various sources of essential amino acids. The last section concludes.

Background

The share of poultry in India's total meat production has grown rapidly in the recent past – from 23% in 2004-05 to 51% in 2009-10 (GOI 2011). Poultry is low-cost relative to other meat products, and has comparatively wider acceptability as a food component across regions and religions (Landes et al. 2004). Demand for poultry products is often cross-correlated with demand for maize, an important feed crop (Marsh 2007). Hence, alongside the expansion of the poultry industry, the cultivation of maize has also spread at a rapid pace in India (Sethi et al. 2009, Singh 2001). The relative importance of maize over other cereals was primarily due to its cost-effectiveness. About 7 million tons of maize is produced annually to feed poultry, supporting 20 million maize farmers (Saxena 2009). With the projected figures on poultry sector indicating continuous growth at a similar rate in the coming decade, an estimated 12 million tons of maize would be required for feed by 2020 (PDP 2011), causing significant spill-over effects and welfare impacts on the maize farming community in India.

Six Indian states account for two-thirds of the country's maize production and area under maize cultivation. Four of these are traditional maize growing states located in a horizontal belt across northern/central India: Rajasthan, Madhya Pradesh, Uttar Pradesh, and Bihar; and two are non-traditional maize-growing states in southern India: Andhra Pradesh and Karnataka. Most of the rapid growth in maize production has occurred in the non-traditional states where the crop is a relatively recent arrival and is primarily produced for the (poultry feed) market, with widespread use of hybrid seeds and external inputs. Although poultry producers range from the small-scale "backyard" farmers to "industrial" undertakings, it is the commercial end of the spectrum, particularly in southern India, that has seen the fastest growth in the recent past. The states of Andhra Pradesh and Karnataka have experienced a drastic expansion in poultry production. Together these two southern states account for 19% of the domestic poultry meat and 37% of eggs produced in India (GOI 2011).

Feed is the single largest cost item in commercial poultry production, comprising 55–64% of the variable costs in India (Landes et al. 2004). Maize is typically the main source of energy in commercial poultry. However, the protein profile in normal maize does not adequately cover the essential amino acids which humans and monogastric animals cannot synthesize and have to acquire through diet (Ferreira et al. 2005). The most common source of protein in poultry meal is soybean (Masuda and Goldsmith 2009). In India, this has contributed to a drastic expansion of the soybean production sector – from 2.6 million tons in 1990 to 11.9 million tonnes in 2013 (FAOSTAT 2014) – making the country the fifth largest soy producer in the world (Masuda and Goldsmith 2009).

As emerging market economies expand and food consumption patterns change, there will be an increasing pressure on the global markets for the livestock feeds and the prices are expected to soar (Hansen 2012). The international maize and soybean prices have been volatile over the last decade: for example, during the 2004-08 global food inflation, these crops exhibited rapid price increases in the order of 50–90% (Headey and Fan 2008). It is somewhat unique for India and the other countries of South Asia that fish meal and peanut meal are also common protein sources for poultry (Hellin and Erenstein 2009, Landes et al. 2004).[1] However, the availability and market price of these meals varies widely both spatially and temporally, and with the largely absent futures market, it is difficult to predict and control feed prices.

In recent years, supplementation of feeds with commercially produced and relatively cheap synthetic amino acids has become a common practice in the developing countries, including India (Lauderdale 2000). These feed supplements can be either synthetic amino acids or mineral mixtures. The latter is a combination of essential amino acids, trace minerals, vitamins, medicaments etc. Biofortification of maize with essential amino acids has significant economic potential as it could reduce the poultry firms' dependence on other protein sources, without compromising on poultry production and quality. Whether or not the enhanced amino-acid composition achieved through biofortification of maize would translate into increased profits for (and therefore potential interest and demand from) the livestock producers, depends primarily on the relative price of other feed components and the stage of feed market development.

The existing QPM hybrids provide grains with 125% more Tryptophan and 62% more Lysine than the regular maize (Table 1). The nutritional superiority is linked to *opaque*-2 gene and associated modifiers (Gupta et al. 2009), but in terms of cultivation and phenotype QPM is comparable to normal maize. A detailed history of development of QPM is given by Atlin et al. (2011) and its development in India is summarized elsewhere (Agrawal and Gupta 2010, Hellin and Erenstein 2009). Past research on biofortified maize rich in essential amino acids has primarily focused on QPM – both globally and in the Indian context. Only recently has plant breeding research been initiated in India to include another essential amino acid, Methionine, in maize kernels. It is expected to address concerns within the poultry industry regarding the increasing cost of Methionine in the feed rations (Devegowda and A.K. Panda, *personal communication*). Research has shown that increasing dietary Methionine content in feed substantially increases the weight of broiler chicks (Mack et al. 2010, Panda et al. 2010). Methionine intake also enhances egg output and feather growth (FAO 2011), which can be nutritionally limiting in conventional poultry feeds (Atlin et al. 2011, Panda et al. 2010), and Methionine shortage can be offset through external supplementation. However, synthetic Methionine is often costlier than other synthetic amino acids (B.S. Raghav, *personal communication*). High Methionine Maize (HMM) can potentially be of value to the poultry industry by its implied potential cost savings and increased profitability. HMM is still in the early phases of the R&D pipeline, and is yet to be commercialized. The present study therefore assesses the potential of a prototype HMM (alongside existing QPM), whose likely range of

[1] Fish meal was a conventional, much demanded, protein source for poultry in South Asia, due to its high protein content. But dry fish is also used for human consumption. Due to the high demand, the price of dry fish started increasing drastically, which alongside an unsteady supply, led to its replacement by other protein sources, like soybean meal (Hossain et al. 2003).

amino acid levels are based on literature search and expert opinion (for sources cf. Table 1). Therefore, in addition to enhanced levels of Methionine, the HMM prototype has enhanced levels of Tryptophan and Lysine in comparison to normal maize. Methodological details are provided in the next section. Throughout this narrative, the term "biofortified maize" generically refers to QPM and HMM.

Table 1. Amino acid profile of normal and biofortified maize and the recommendation for poultry feed in India

	Normal Maize	**Quality Protein Maize (QPM)**	**Prototype* High Methionine Maize (HMM)**	**Recommended nutrient level in the poultry feed for**	
				Broilers	Layers
Protein (%)	8 - 11	8 – 11 [0]	8 – 11 [0]	19.50 – 22.50	15.00 – 18.00
Lysine (%)	0.26	0.42 [62]	0.34 [31]	1.14 – 1.40	0.45 – 0.70
Tryptophan (%)	0.04	0.09 [125]	0.07 [63]	0.18 – 0.22	0.12 – 0.17
Methionine (%)	0.18	0.19 [6]	0.40 [122]	0.50 – 0.58	0.20 – 0.30

Notes. Figures [in square brackets] show percentage change over the protein content of normal maize.
* Under development and hence assumed indicative levels.
Source. Gupta et al. 2009, Hellin and Erenstein 2009, Panda et al. 2009, Vivek et al. 2008, Prasanna et al. 2001, FAO 1992.

Methodology

Primary Data

The empirical focus of the present study is on the current feeding pattern in the commercial poultry sector in South India, including both broiler and layer production. The Indian states of Andhra Pradesh (AP) and Karnataka were purposively selected as the study area, due to their rapidly growing poultry and maize production sectors. Landes et al. (2004) indicated that the per-capita annual poultry meat consumption (4 kg) in South India is significantly higher than the national average, and the increasing demand for poultry products has triggered an economic opportunity for all the feed components, including maize. Two districts per state (one peri-urban and one rural), representative of the rapid maize and poultry sector expansion, were purposively selected for a survey of poultry firms – Bangalore Rural and Davanagere in Karnataka; and Ranga Reddy and East Godavari in AP (Figure 1).[2] Bangalore Rural and Ranga Reddy districts are peri-urban, covering parts of the metropolitan cities of Bangalore and Hyderabad respectively. Poultry production is increasing rapidly in these districts, owing largely to the increasing urban demand. Although some maize production takes place in these districts,

[2] In a recent (June, 2014) development, Ranga Reddy became part of newly formed Telangana state of India.

majority of the maize feed grain comes from other districts and/or states. Maize and poultry production largely co-exist in the two other rural districts (Davanagere and Eastern Godavari). Poultry firms in each of the districts were randomly selected from a stratified list of member firms of the poultry growers' co-operative societies. The stratification was done by the main product (meat/broiler or eggs/layers) and then by the firm types (independent or integrated along the value chain). The composition and structure of Indian poultry industry and contract farming are detailed by Ramaswami et al. (2005) and Landes et al. (2004). The firm type influences the feeding practice. Integrated units are supplied with a required feed mix from the contracting firm, and the managers are largely unaware of its composition. Therefore, despite their popularity as suppliers of broilers, we purposively under-sampled firms from this category for this study. The resulting sample totalled 185 units, consisting primarily of independent broilers firms (75 firms) and independent layer or egg producing units (72 firms), with 38 contract-based integrated broiler firms (Table 2). No integrated egg production firm was found in the study area.

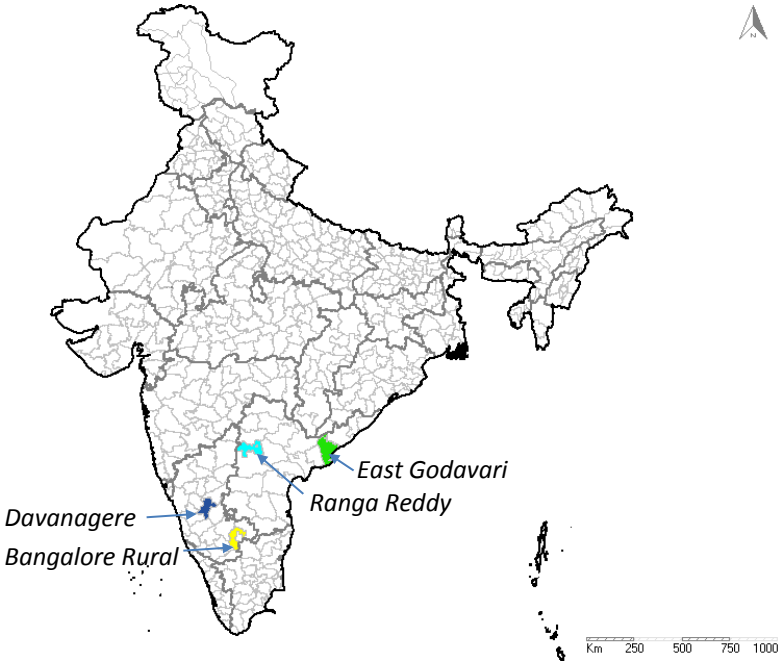


Figure 1. Map of India showing the sample districts

Source. N. Chowdhury, CIMMYT, New Delhi.

The firm survey was conducted between November 2010 and January 2011 in the selected districts and included face-to-face interviews with poultry firm owners/managers. The interviews were conducted in the local languages with the help of trained enumerators and employing a structured questionnaire, which was developed using insights from a preliminary interview of managers of 15 firms in Karnataka, and after consultation with poultry nutrition experts at the Project Directorate on Poultry (PDP) in Hyderabad. This instrument included questions on (i) general aspects of management structure; (ii) poultry feed composition; (iii) purchasing price of feed ingredients; (iv) feed sources; and (v) output marketing. As there is a significant dearth of economic literature on poultry feed and nutrition in India, we also conducted an expert survey

among scientists in the field of poultry nutrition and production to understand the roles of different feed ingredients (in particular maize and its supplements). This has also helped us gain insights on the poultry industry orientation (for example the classification of firms into independent and integrated ones).

Secondary Data

To estimate the most economic feed composition, with and without biofortified maize, the market price of ingredients (including that of the synthetic amino acids) from the firm survey, and the recommended minimum and maximum levels of feed components in the Indian poultry production sector were used. The recommended levels were fixed based on the secondary information obtained mainly from PDP, Hyderabad. Literature was reviewed on the role of essential amino acids in poultry production, and the level of amino acids in the major feed ingredients used by poultry firms, to complement the firm-level data. Further, an expert survey was conducted among subject matter specialists at the University of Agricultural Sciences (Bangalore), Karnataka Veterinary, Animal and Fisheries Sciences University (Bidar), private firms dealing with the import of amino acids, and poultry feed manufacturing units. Secondary data were also obtained from government statistics viz., Basic Animal Husbandry Statistics of Government of India (2006, 2010 & 2011), the Livestock Census of India (2003 & 2007) and the Report of Project Directorate on Poultry (PDP 2011).

Table 2. Categorization of sample firms with respect to feed sources

Firm Type	**Feed Use**	**% Sample Firms**			**Average Size of Firms in '000 Birds**	
		Broiler (n=113)	Layers (n=72)	Total (n=185)	Broiler	Layer
Independent	Completely rely on feed mixing	7	92	40	23.3 (3.6)	52.3 (3.4)
	Uses both ready-made feed and feed-mixing	59	4	38	15.0 (2.2)	80.3 (6.2)
	Completely rely on ready-made feed	0	4	2	--	70.0 (7.8)
Integrated	Contractual arrangement	34	0	20	9.9 (0.6)	--
Overall					13.9 (2.0)	73.9 (6.9)

Note. Figures in simple brackets show standard errors. Due to oversampling of independent firms for the study, the percentage of different firm-types may not be considered as representative of the poultry sector of South India.
n: Number of observations (firms).
Source. Firm survey (2010).

Analytical Frame

The analytical frame comprises two scenarios – differing with respect to underlying assumptions on a firm's behaviour – to study the potential economic impact of biofortification. The prevalence and impacts of imperfect information on managerial level for the small-scale industries in the developing countries has seldom been studied in the literature. In the farming sector, on the other hand, it is shown that limited information leads farmers to copy adoption decisions of neighbouring producers (Pomp and Burger 1995). The information asymmetry between producers and marketers is also found leading to over-priced inputs and under-priced outputs, and forms an impediment in productivity enhancement (Rota and Sperandini 2010). Such imperfect information also reduces awareness among the potential entrepreneurs of possible market transactions, thereby generating inefficiencies in both allocative and production functions of the markets (Arndt 1988; North 1993). For example, Kristiansen (2003) reported that rural small-scale poultry growers of Indonesia, due to having limited access to information on price fluctuations in the egg markets, were feeling bereaved while competing with the well-connected large scale operators. The study concluded information asymmetry and related information market failures having a huge impact on business opportunities and that a different set of production possibilities would have been present if more information were available. Currently, interaction between various actors in the Indian value chains has been constrained by limited access to information on markets and production technology (Hellin and Erenstein 2009).

We will be using two different analytical scenarios to address the different sectors of poultry production, with varying level of understanding about optimal feed mixtures.

1. The first scenario estimates the least-cost poultry feed rations, with and without biofortified maize, assuming no information constraints for feed costs minimization. In the present context, the integrated large-firms of South India are more likely to enjoy the benefits of feed cost minimization compared to the small-scale poultry producers, given their asset base (e.g. greater access to computer programs and skilled human resources) and integration with contracting firms that supply the feed mix. The first scenario would thus provide plausible results in case of high information availability, especially for the integrated firms.

2. The second scenario acknowledges likely information constraints for optimization – and takes a narrower and simpler approach to estimate the potential cost saving with biofortified maize as a replacement only for synthetic amino acids in the feed. We will subsequently examine the knowledge level of managing staff of small-scale firms on nutrient composition of components of feed mixtures, and show that they are only inadequately informed about the feed composition, so the second scenario would provide, more plausible results for the information constrained small-scale firms.

Calculation of least-cost poultry feed rations, with and without biofortified maize (Scenario 1):

A linear programming (LP) model was used to calculate the least-cost feed formulation to meet the minimal feed recommendations for the birds at different growth stages based on market prices and feed composition. The LP model assumes that the poultry firms have perfect

information on feed composition and recommended feed needs, and they try to minimize feed cost and maximize their profits, which may be relevant mainly for the large and integrated firms. The rations are so devised that the aggregate nutritional values of different alternative formulations are equal, irrespective of the presence or absence of a biofortified product in them, and the overall nutrient requirements of the industry are met. This method was also employed by De Groote et al. (2010) and Lopez-Pereira (1993). The nutrient composition of different feed ingredients and the recommended dosage of the nutrients are provided in Appendix B. The model estimation is done by:

$$Minimize\ Z = \sum_{i=1}^{n} P_i X_i$$

$$Subject\ to \quad A_j \le \sum_i N_{ij} X_i \le B_j$$

$$C_i \le X_i \le D_i; \quad Z \ge 0$$

where,

Z is the total cost per kilogram of poultry feed for a given bird growth stage, in Indian Rupees (Rs).
P_i is the price of ingredient i (Rs/kg).
X_i is the level of ingredient i in the ration (kg).
N_{ij} is the content of nutrient j (from 1 to m), in ingredient i, measured in kcal/kg for energy and % for other nutrients
A_j is the minimum requirement of nutrient j in the feed formulation, in kcal/kg for energy and % for other nutrients.
B_j is the maximum allowed level of nutrient j in the feed formulation, in kcal/kg for energy and % for other nutrients.
C_i is the minimum level of ingredient i required (kg), and
D_i is the maximum level of ingredient i required (kg).

Solving the LP model for the lowest positive value of Z, we estimate the cheapest poultry feed, with and without biofortified maize, separately for starter, grower and finisher and for broiler and layer firms. The list of ingredients and prices are obtained from the firm surveys. An additional variation of the scenario 1 model was estimated, imposing constraints on two feed ingredients (fish meal and groundnut meal), which, irrespective of their nutritional superiority, are used scantly by firms as their availability is limited in the market. The total nutrient levels are calculated by multiplying content matrix with quantity vector; that is, $N_{ij}X_i$. The price of biofortified maize is assumed to be equal to that of normal maize – reflecting the inherent invisibility of the trait and earlier experiences with QPM. Under these specifications, the quantities of different ingredients (maize, soy, synthetic amino acids etc.) required to produce 1 kg of feed at minimal cost for each growth stage, separately for broilers and layers, were estimated.

Calculation of cost saving with biofortified maize as a simple replacement for synthetic amino acids and normal maize in the feed (Scenario 2):

The above mentioned LP model rests upon the assumption that the poultry firms have perfect information on feed composition and feed requirements to minimize the cost, which may be true in case of large and integrated poultry firms. However, generation of cost-minimizing feed mixtures demand significant managerial skill, as relative prices of the ingredients fluctuates over time. Scenario 2 thus estimates potential cost-savings of biofortified maize as a replacement only for synthetic amino acids and normal maize in the feed. It is more realistic, as most of the firm managers interviewed were of the opinion that the variable of interest would be the quantity of synthetic amino acids saved after the introduction of biofortified maize. No incremental price is assumed for the biofortified maize over the existing normal maize, and cost savings are divided by quantity of maize intake and compared with the market price of normal maize to examine the possibility of evolution of specialized value chains for the quality protein trait.

The surveyed poultry firms used synthetic amino acids in two different forms: (i) commercial mixtures having low amino acid content, which are relatively cheaper; and (ii) unmixed high concentration synthetic amino acids (e.g. synthetic Lysine), which are costlier. In case of (i), biofortified maize may not lead to reduced use of the mixture, unless maize contains the limiting essential amino acid. For example, conventional QPM does not provide additional Methionine, and if Methionine is actually the limiting amino acid in the existing feed composition, firms may not save any commercial mixture at all upon adoption of QPM feed ration. However, the replacement is easier in case of unmixed synthetics. In order to capture both inputs, the potential cost saving from biofortified maize is calculated as the cost of the minimum amount of synthetic input that can be saved due to the use of biofortified maize. Here, we base our calculations on the feed regime of independent poultry firms, except for the synthetic amino acid supplements. The potential cost saving, for (i) commercial mixtures:

$$(1)\ \Delta C^s = \Delta Q^s.P^s = \left[Min\left[Q_0^s - \left[\frac{N_j^s - N_j^b}{S_{N_j^s}} \right] \right] \right] P^s \quad \text{if } N_j^s > N_j^b;\ \left[\frac{N_j^s - N_j^b}{S_{N_j^s}} \right] = 0 \text{ if } N_j^s \le N_j^b$$

for (ii) unmixed synthetic products providing single amino acid:

$$(2)\ \Delta C^s = \Delta Q^s.P^s = \left[Q_0^s - \left[\frac{N^s - N^b}{S_{N^s}} \right] \right] P^s \quad \text{if } N^s > N^b;\ \left[\frac{N^s - N^b}{S_{N^s}} \right] = 0 \text{ if } N^s \le N^b$$

where,

ΔC^s is the cost saving from replacing only synthetic feed compounds with biofortified maize (Rs/bird)

ΔQ^s is the quantity of synthetic feed compound saved (kg/bird)

P^s is the price of synthetic feed compound (Rs/kg)

Q_0^s is the quantity of synthetic feed compound provided to poultry before introduction of biofortified maize.

N_j^s is the quantity of essential amino acid *j* (kg) additionally obtained from synthetic sources.

N_j^b is the quantity of essential amino acid *j* (kg) additionally obtained from biofortified maize (QPM or HMM), when conventional maize is replaced with biofortified one.
$S_{N_j^s}$ is the share (0-1) of essential amino acid *j* obtained in synthetic feed compound.

Not many feed trials have been conducted to estimate the comparative impacts of biofortified maize and synthetic substitutes with the total intake of amino acids constant. In previous studies carried out in other countries, the production impact of QPM were calculated relative to normal maize (De Groote et al. 2010), but not against synthetic substitutes. Based on expert opinion, we assume that the yield impact of substituting synthetic sources with biological protein from biofortified maize is negligible, although feed trials are to be conducted in order to substantiate this assumption.

Results and Discussion

Current Feed Practices by Poultry Firms

Before estimating the cost impact of including biofortified maize as a feed component, we examine the existing feeding practices of the sample poultry firms. The structure and cost of poultry production shows significant regional variation; while independent and small-scale producers still account for most of the poultry production in India, large-scale integrated firms contribute to a growing share of output in some regions (Landes et al. 2004). In our feed composition analysis, we exclude the integrated firms, as an already mixed feed is directly supplied to them from the contracting firm, and the managers have limited knowledge of the ingredients of the feed supplied. To facilitate understanding, the feed components used by the independent small-scale firms are divided into two groups: the components of Group A provide the major nutrients, while those of Group B are elements required for better intake of these nutrients by the birds. The feed structure of broiler and layer firms differed substantially (Table 3). Maize is the major source of energy, used by all surveyed firms in the feed mixtures. The main source of protein is soy, used by 71% of broiler and 98% of layer firms. Maize and soybean thereby make up the highest feed cost shares – together accounting for 70% of broiler and 56% of layer average feed cost. Broiler rations, on average, contain 64% maize and 20% soybean cake and 14% mineral mixture. About 95% of the procurement cost of broiler feed is accounted for by these three ingredients.

Maize and soybean cake still form the major feed ingredients in the layer firms, contributing equally (28% each) to the feed cost. They also use maize/soybean-substitutes for energy and protein. For example, broken rice is used for energy and fish meal for protein. Mineral mixture is rarely used (by just 9% of layer firms) as an amino acid supplement. Unmixed amino acids, like synthetic Lysine and synthetic Methionine, are popular and used by 52% and 85% layer firms, respectively. However, these supplements are used in traces and they contribute only marginally to the total feed cost (Table 3). Use of synthetic Tryptophan was not reported.

Table 3. Composition of poultry feed used by the sample firms

	Broiler Firms (n =65)			Layer Firms (n = 65)		
	% of Firms Using	Quantity (kg/bird)*	Feed Cost Share (%)	% of Firms Using	Quantity (kg/bird)*	Feed Cost Share (%)
Component group A (major nutrients)						
Maize	100	3.45 (0.19)	37.79	100	21.96 (0.97)	28.18
Soy	71	1.51 (0.20)	32.21	98	8.62 (1.69)	28.17
Oil	29	0.24 (0.05)	1.01	8	0.05 (0.01)	0.00
Broken rice	1	0.11 (--)	0.01	49	8.08 (0.63)	4.33
De-oiled rice bran	1	0.18 (--)	0.02	100	4.98 (0.36)	6.07
Sunflower	1	0.18 (--)	0.03	68	4.62 (0.27)	7.23
Fish	6	0.34 (0.04)	0.46	51	2.82 (0.26)	3.27
Di-calcium phosphate	5	0.12 (0.01)	0.06	94	0.42 (0.07)	1.55
Mineral mixture	91	0.80 (0.08)	25.41	9	4.53 (0.73)	1.45
Groundnut	1	1.02 (--)	0.26	20	19.03 (0.38)	7.97
Sorghum	0	0.00 (--)	0.00	38	11.35 (0.88)	2.72
Synthetic Lysine	1	0.01 (--)	0.02	52	0.03 (0.00)	0.28
Synthetic Methionine	1	0.01 (--)	0.06	85	0.04 (0.00)	1.02
Component group B (nutrient intake enhancing elements)						
Toxin binder	9	0.01 (0.00)	0.12	82	0.04 (0.00)	0.32
Phytase enzyme	1	0.00 (--)	0.01	74	0.01 (0.00)	0.22
Liver powder	3	0.01 (0.00)	0.02	60	0.03 (0.00)	0.16
Trace minerals	1	0.01 (--)	0.01	89	0.06 (0.00)	0.36
Antibiotic growth promoter	3	0.00 (--)	0.04	21	0.01 (0.00)	0.07
Vitamin premix	2	0.01 (0.00)	0.03	82	0.02 (0.00)	0.62
Salt	3	0.03 (0.00)	0.01	91	0.18 (0.01)	0.09
Other ingredients	6	0.19 (0.02)	2.54	42	5.24 (0.61)	5.93

Note. *Shows conditional (on use) mean values, and the figures in brackets show standard error for sample excluding the integrated firms and extreme values.
Source. Firm survey (2010).

On average, broiler firms spend Rs. 87 and layer firms Rs. 654 to provide nutrients (only Component A) for a bird during its entire life. However, these total costs show a wide variation across individual firms, (from Rs. 25 to 177 in broiler firms; and from Rs. 225 to Rs.1151 in layer firms; Figure 2). The cost differences are primarily associated with significant difference in feed composition, especially in the case of layer firms – and can only be marginally attributed to the differential price of inputs and diverse input-value chains. For example, the layer firms that include fishmeal in the feed could reduce total feed cost by 20%, compared to others. Even more pronounced is the impact of groundnut meal in the layer feed (27% cost reduction). The cumulative distribution of feed cost for layer firms is relative flat for the range of Rs. 500-700, comprising 46% of the firms. These firms are found partly substituting fish meal for soymeal in the feed mixture, especially when the soymeal price is high. Similarly, there may be a cost saving for the few firms that use sorghum as a source of energy in the feed mixture.

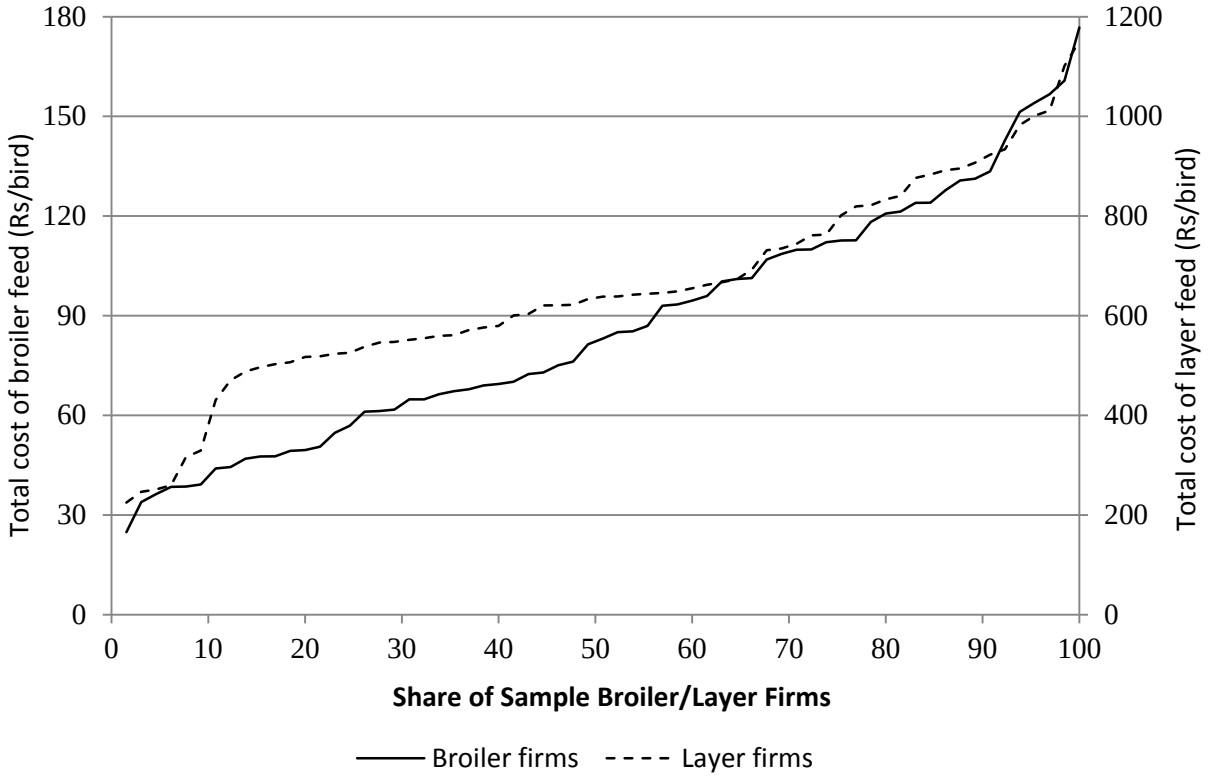


Figure 2. Cumulative distribution of sample firms with respect to nutrient feed cost

Note. Cost includes that of feed components from Group A only.
1 US$ = Rs. 45.7 (average of 2010).
Source. Firm survey (2010).

The survey results allow us to estimate the amount of each of the essential amino acids fed to birds in broiler and layer firms (Appendix C). In the case of layer firms, most firms use about the recommended dosage, each amino acid use showing a relatively flat cumulative distribution, typically around the recommended dosage – although with a relative underutilization of Methionine in the majority of firms. In the case of broiler firms, each amino acid use shows an inclined cumulative distribution, with only a few firms using about the recommended dosage, and with a relative underutilization of Lysine and again Methionine in majority of the firms.

A significant share (45%) of broiler firms was found to be using the essential amino acids higher than the dosage recommended by the PDP for profit maximization. One of the reasons could be the excessive use of mineral mixture, which also contains a number of trace minerals and vitamins, necessary for gaining body weight at a faster rate, alongside amino acids. This is less pronounced for layer firms, and the quantity of amino acid used by the layer firms above the recommended dose is not very high. One of the reasons is that over-use of amino acids is associated with the availability of cheaper fish meal in the local market. A comparison of feed composition, feed cost, productivity and gross revenue of these "over-users" (of all the three essential amino acids) with that of the others is made in Table 4.

Table 4. Impact of amino acid use on poultry production

	Broiler Firms			Layer Firms		
	"Over-users" (n =29)	Others (n =36)	Difference [#]	"Over-users" (n =39)	Others (n =26)	Difference [#]
Cost share (%) in the feed						
(i) Maize	38	43	-5	32	36	-4
	(0.4)	(0.5)	(0.6)	(0.2)	(0.6)	(0.5)
(ii) Soybean cake	38	19	19***	29	18	11***
	(0.4)	(0.7)	(0.8)	(0.3)	(0.4)	(0.5)
(iii) Fishmeal	--	--	--	6	2	4**
				(1.1)	(0.8)	(1.5)
(iii) Protein supplements[##]	21	34	-13**	3	3	0
	(0.4)	(0.7)	(0.8)	(0.1)	(0.4)	(0.4)
Feed cost (Rs/bird)	125.5	61.0	64.5***	763.8	646.5	117.3***
	(1.1)	(0.5)	(1.1)	(5.1)	(11.8)	(12.6)
Other costs (Rs/bird)	4.1	3.6	0.5	31.1	31.8	-0.7
	(0.3)	(0.3)	(0.4)	(1.6)	(1.4)	(2.2)
Total cost (Rs/bird)	129.6	64.6	65.0***	794.9	678.3	116.6***
	(6.4)	(3.0)	(6.7)	(32.7)	(70.9)	(70.3)
Productivity (kg meat or eggs /bird)	2.3	2.2	0.1*	302	303	-1
	(0.0)	(0.0)	(0.0)	(0.5)	(0.6)	(0.8)
Revenue – main product (Rs/bird)	95	95	0.0	731	717	14
	(0.6)	(0.3)	(0.6)	(1.4)	(2.0)	(2.4)
Revenue – by-product (Rs/bird)	5.9	4.7	1.2***	50.3	51.8	-1.4
	(0.4)	(0.2)	(0.4)	(2.6)	(3.6)	(4.3)
Profit (Rs/bird)	-29.0	35.1	-64.1***	-13.3	90.6	-103.9**
	(7.4)	(3.7)	(7.9)	(31.0)	(68.5)	(67.5)

Note. "Over-users" category is defined as the group of poultry firms that uses feed with a higher dose for each of the three essential amino acids (Lysine, Tryptophan and Methionine). Figures in simple brackets show standard errors. ***, **, * show statistical significance at 0.10, 0.05 and 0.01 levels, estimated with Kruskal-Wallis rank test (Due to the small sample size, we cannot assume with surety that the data is normally distributed, and hence cannot employ the parametric test. The nonparametric Kruskal-Wallis rank test does not assume normality of distribution).
[#] Difference of over-users over others. [##] This group includes unmixed synthetic Lysine/Methionine and mineral mixture.
1 US$ = Rs. 45.7 (average of 2010).
Source. Firm survey (2010).

For both broiler and layer firms, the difference arises mainly because of the higher proportion of soybean cake in the feed mixture. No difference was observed with respect to the quantity of

maize used, while the "over-users" among broiler firms were actually spending less on synthetic amino acids. There exists a significant difference in the feed cost across the two groups of firms, which is more pronounced for broiler firms (105%) than layer firms (18%). Nevertheless, the "over-use" of amino acids has only marginal impact on the average meat production (by 4%) in case of broilers, and none on the egg production. Impact on gross revenue is insignificant for both types of firms. Feed is a major poultry production cost and improving feed efficiency is important for maximizing profitability (Singh et al. 2002). Our findings suggest that the firms that over-use the amino acids incur an average financial loss on their produce (losses of Rs. 29 per bird for broiler and Rs. 13 for layers), and even larger relative losses relative to those firms that do not over-use (and attain average profits of Rs. 35 per bird for broiler and Rs. 91 for layers). Hence there is substantial scope for increasing efficiency and profitability for these over-users, for which firms need to be provided information on optimal feed composition and nutrition. Lack of adequate information on amino acid use is also likely to affect the potential demand for and adoption of biofortified maize as feed component by poultry firms.

Impact of Biofortified Maize on the Provision of Least-Cost Feed

Assuming that the producers are fully aware of the birds' nutrient requirement and the nutrient composition of different feed components, we have calibrated the LP model. Although this assumption may not hold true for many small-scale independent poultry firms, it is reasonable to assume that integrated and large firms use feed mixtures with the least-cost combination of different ingredients. Using these in the LP model, Table 5 (see Appendix A) presents the most economic formulation for different feeds aggregated over the different stages of bird growth in order to find the optimal quantity per bird. The minimum cost of providing the recommended dose of nutrients for a bird is calculated as Rs. 47 (46% lower than the average cost of feed as reported by sample firms) for broilers and Rs. 577 (12% lower than the average feed cost) for layers. There are also significant differences in the structure of the feed ration, mainly due to the availability of fish meal, a cheap protein substitute in the locality. Fish meal is considered to be one of the "best" ingredients for broilers and layers rations, as it enhances the feed consumption and feed efficiency (Solangi et al. 2002). It was found to be priced on a par with soybean cake, but had a higher percentage of all the three essential amino acids than mineral mixture and soybean cake. Hence, in the cost minimizing formulation, it replaces soybean cake and synthetic amino acid supplements completely in both broiler and layer rations. For broiler firms, maize remains the major source of energy. However, for the layer firms, broken rice substantially replaces maize.

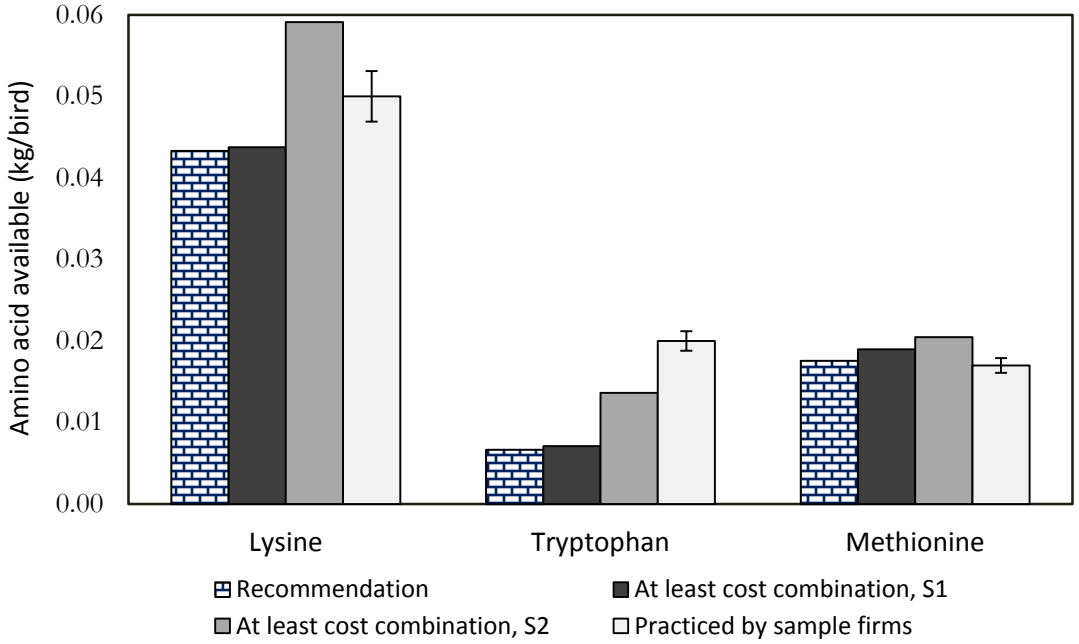
This optimal formulation, especially in the absence of soybean cake in the feed mixture, is not the one commonly followed by the firms. This could be due to a number of constraints – both with respect to the physical availability and quality of fish and groundnut meal, as well as the lack of awareness of the poultry managers. In order to estimate a more realistic cost minimizing feed composition, and to understand and incorporate these constraints (see Appendix B), we recalibrated an additional model with more stringent bounds for fish and groundnut meal (Specification 2, Table 6 (see Appendix A)). Upon these additional constraints, the feed cost has increased by 12% for broilers and 8% for layers. These figures are not only closer to the observed practice by sample firms, but the use of soybean meal also increased drastically as a major protein source.

Both specifications agree on certain aspects. Metabolizable energy and total protein are the most limiting components in poultry ration. Feed mixtures that meet the required calories and protein have been found to provide the recommended dose of amino acids, without synthetic supplements. In both specifications, when total protein requirement is met, either from low-cost protein sources or from soybean meal, the recommended dose of Lysine, Tryptophan and Methionine are already met, without depending on any synthetic sources. Replacing normal maize with biofortified maize would just add to the levels of Lysine, Tryptophan and Methionine (supplied by low cost protein sources) which are already in excess of the recommended dosage in feed mixtures of firms in the area of this study, especially under Specification 2 (Figure 3). It also implies that for a firm that already follows the optimal feed composition, there would be only marginal cost-saving due to adoption of QPM or HMM grains, and there will be zero demand for the biofortified maize even at the slightest price increment. In other words, the current availability of cheap protein necessitates no additional amino acid through biofortification or synthetic substitutes, at the present price levels. According to experts, fish meal has long been one of the cheapest sources of protein in South India (Solangi et al. 2002, Devegowda and A.K. Panda, *personal communication*). In countries like Kenya where fish meal is relatively expensive, the substitution of normal maize by QPM is found resulting in positive cost savings (De Groote et al. 2010). However, the relative prices depend on seasonal availability and nature of supply chains. These factors, alongside the price variability of major feed components, should be studied further to understand the consistency of these findings.

Impact of Biofortified Maize as Substitute for Synthetic Amino Acid Supplements

Generalization of LP results pre-requisites that all firms face the feed supply constraints uniformly, and uniform input price structure prevails. Furthermore, the assumption of perfect information is likely to be violated; as we have already seen that firms often “overuse” amino acids, possibly because of lack of awareness regarding poultry nutrition. The survey also assessed their awareness of various amino acids, with a marked divergence between managers of broiler and layer firms. Most of the broiler firm managers had not heard about the essential amino acids (Figure 4) and the majority (72%) believed that the intake of essential amino acids will have no impact on meat production. The level of awareness was considerably higher among managers of layer firms (particularly for Lysine and Methionine), and 60% associated yield-enhancements with the intake of amino acids. This could be one of the reasons why the amino acids in the feed mix of most layer firms approximate the recommended dosage. However, many of the lower-cost ingredients (e.g. fish meal) may not be available in the market throughout the year, causing difficulties for the poultry firms to follow the least-cost feeding strategy.

a. Broiler



b. Layer

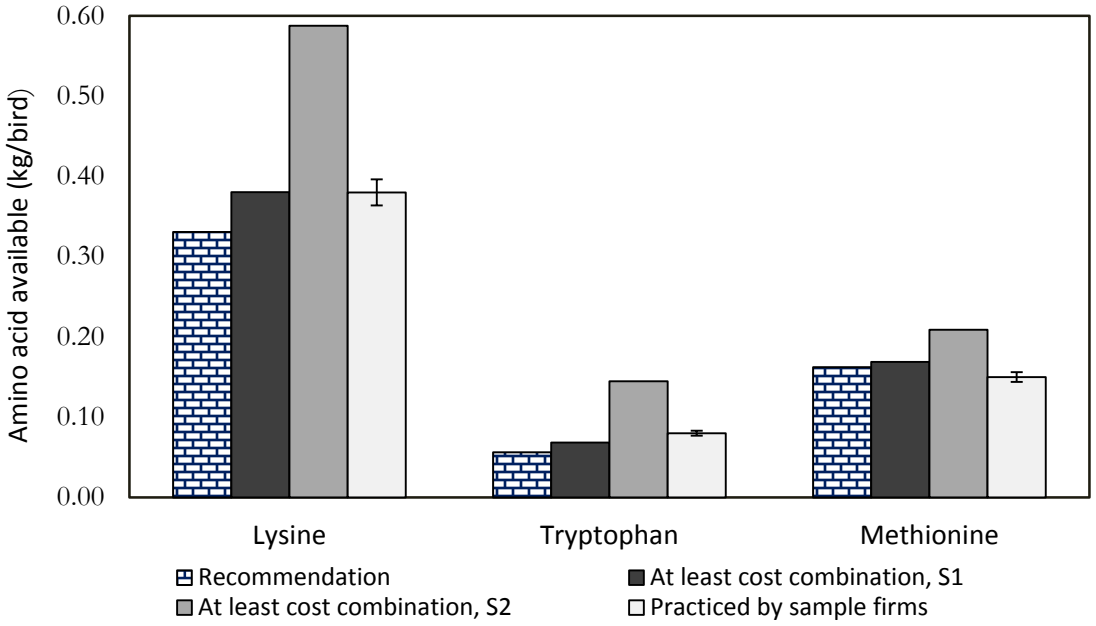
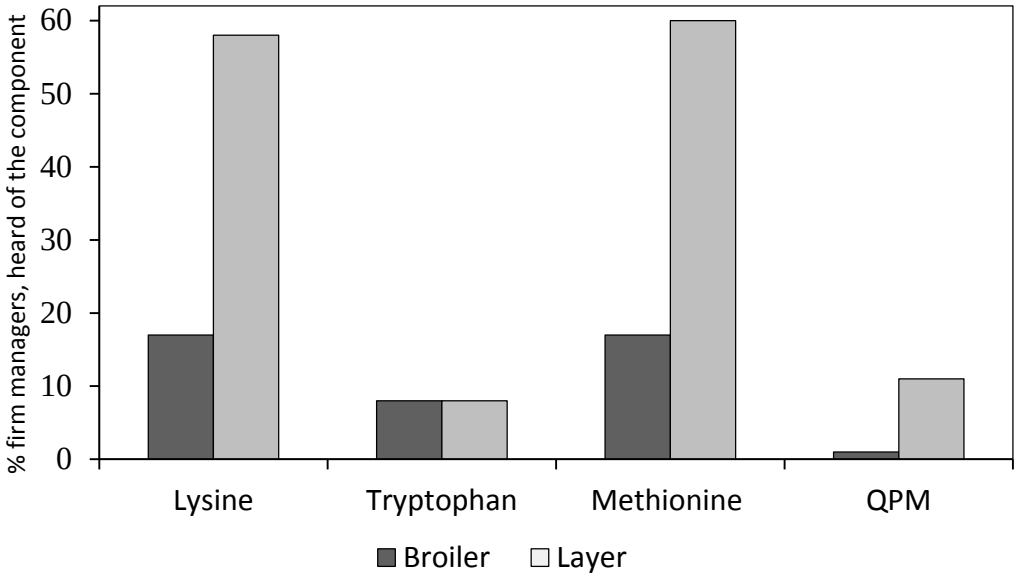


Figure 3. Essential amino acids: recommendation availability at minimized cost, and use by sample firms

Note. Error bars show standard errors. S1: Model specification 1; S2: Model specification 2.
Source. Mandal et al. (2004 & 2005), Panda et al. (2009), PDP (2011), Ranjhan (1998), estimation from Firm survey (2010).

a. Knowledge of importance of amino-acid use in poultry feed



b. Firm managers' perception on impact of amino acids intake by birds

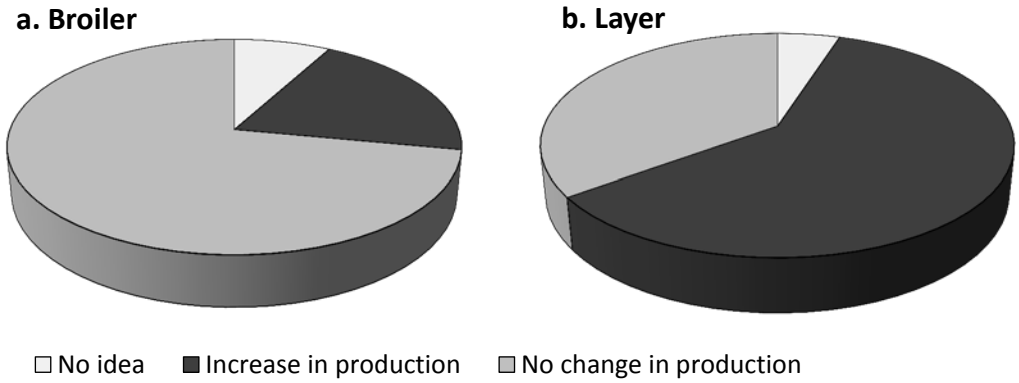


Figure 4. Firm managers' awareness and perception on amino acids

Source. Firm survey (2010).

Also, only a small proportion of all managers had heard of QPM. This limited awareness poses practical hurdles for the wider adoption of biofortified maize, further exacerbated by the fact that the product is inherently credence good.[3] A distinct supply chain for QPM grain would seem to be the only way of ensuring that the high protein quality of QPM is transmitted down the value

[3] Credence goods are goods for which consumers cannot easily verify the process-attribute claims even after consumption (Roe and Sheldon 2007). Examples include organically produced food, free-range poultry, non-genetically modified foods etc. Although laboratory tests could distinguish biofortified maize from the normal maize, most of the firms do not have the capital, human resource or willingness to incur additional transaction costs to carry out such tests, and hence QPM and HMM falls under the category of credence goods.

chain. Concomitant development of value chains and institutions (e.g. contract farming, labelling and certification etc.) is also necessary for the wider adoption of biofortified maize by the poultry and feed industry.

Since a large share of firm managers in the study area, especially those of broiler firms, have only limited information on role of amino acids and its sources, availability of biofortified maize may not result in a drastic change in the feed composition, and it is more realistic to assume that firms might only reduce the use of synthetic sources of protein in response to the increased availability of essential amino acids from biofortified maize (Scenario 2). Based on this assumption, the potential firm-level impact of QPM and HMM were re-estimated. These are considered to be more realistic because the assumption that the firms have perfect information on profit maximizing feed composition is not imposed. Also, maize biofortified with only two essential amino acids (as QPM) may not lead to any savings over composite amino acid supplements, especially when the third amino acid is limiting. The results of impact estimation, based on these more realistic assumptions, are provided in Table 7.

Table 7. Impact of biofortified maize under imperfect information on feed composition (Scenario 2)

	Broiler Firms		**Layer Firms**	
Quantity of amino acids (g/bird) currently available from synthetic sources				
(i) Lysine	8.8		20.3	
(ii) Tryptophan	0.4		0.2	
(iii) Methionine	4.3		36.0	
Cost of amino acids from synthetic sources (Rs/bird)	19.5		22.0	
Quantity of amino acids (g/bird) additionally provided if normal maize is replaced by biofortified maize	**QPM**	**Prototype HMM**	**QPM**	**Prototype HMM**
(i) Lysine	5.5	2.8	35.1	17.6
(ii) Tryptophan	1.7	1.0	11.0	6.6
(iii) Methionine	0.4	7.6	2.2	48.3
Potential cost saving synthetic amino acids (Rs/bird)	1.6	6.1	1.2	17.0
Potential saving as % of total feed cost	1.0	4.0	0.2	2.4

1 US$ = Rs. 45.7 (average of 2010)
Source. Calculated from firm survey (2010); PDP (2011) for the number of broiler/layer birds in year 2009.

On average, broiler firms spend Rs. 19.5 (12% of the total feed cost) and layer firms Rs. 22.0 (3% of the total feed cost) per bird on amino acid supplements. In the case of broilers, synthetic substitutes come mainly as composite supplements and in the case of layers, as unmixed concentrates. Replacing regular maize with QPM for broilers would provide 63% of Lysine that

is currently provided through synthetic sources, but Methionine will still be critically limiting. About 92% of the Methionine required would still have to be provided through synthetic sources, which means replacing regular maize entirely with QPM would translate into savings of 1% on the total feed cost. If the normal maize is replaced with the Methionine-enriched HMM prototype, synthetic Tryptophan and Methionine would not be required, but, 69% of the Lysine would still have to come from synthetic sources to meet firms' practice. The cost savings would be slightly greater in this case – at 4% of the feed cost (Rs. 6.1 per bird). However, only 3.45 kg of maize is used for broiler feed on average (Table 3 shows an average spending of Rs. 35 per bird the total cost of maize in the feed mixture). It means that the HMM could imply a potential synthetic amino acid saving of Rs. 1.8/kg maize (Rs. 6.1 per bird per 3.45 kg maize per bird), which corresponds to 17% of the current maize price. This potential saving would be eliminated only if the maize farmers are paid a premium of 17% for HMM over normal maize. In other words, there might be a potential market for HMM as broiler feed component if the price premium is less than 17%. Whether this implies sufficient financial incentive to generate a segregated value chain for biofortified quality protein trait with labelling and certification and/or contract farming requires additional market research.

In the case of layers, most of the firms use unmixed synthetic substitutes at high concentrations. QPM can substitute for all the synthetic Lysine and Tryptophan, and 6% of the synthetic Methionine, but the cost saving is only marginal (0.2%; Rs. 1.2 per bird). With prototype HMM (incorporated into QPM), 87% of Lysine and 100% of Tryptophan and Methionine requirement from synthetic sources can be met through biofortification. Even though most of the synthetic amino acids can be replaced, the magnitude of feed cost change would be just 2.4% (Rs. 16.9 per bird). The maximum price increment economically feasible for maize grains after biofortification (7% or Rs. 0.80 per kilogram) would be lower than in the case of broilers. Although synthetic Methionine is more expensive than synthetic Lysine (around 54% higher), only small quantities are needed to meet the dietary requirement, which is why the estimated feed-cost savings are relatively low. Due to the small potential price increment, it would be more difficult to realize segregated value chains linking biofortified maize production and layer firms.

As HMM is still under development, the amino acid composition of these biofortified varieties at the commercial scale can still only be speculated. A Methionine-enriched QPM variety, with higher Lysine and Tryptophan in addition to Methionine, could produce relatively higher economic benefits than the existing QPM hybrids, but the magnitude of the impact would still be less than 5% of current variable costs for poultry meat and egg production. On the other hand, there is only limited information on the impact of biofortification on the production and quality of poultry meat in comparison with amino acids from synthetic sources. Only a few studies (e.g., Amonelo and Roxas 2009) indicate the possibility of differential productivity impacts of protein from biofortified maize and from the synthetic sources. Feed trials will have to be conducted to ascertain this. One of the recent studies indicated that, although the quantity of meat production was unaffected by QPM uptake by broilers, it helps reduce fat content and increase breast meat (Panda et al. 2013). Even if such differential impacts are proven pervasive and niche market for the chicken so produced can be realized in India, distinct maize-poultry value chains would be necessary for the successful diffusion of the biofortified maize varieties, given its inherent credence good attribute for the poultry firm managers.

For now it remains a challenge to construct a marketing scenario in India with positive price premium for biofortified maize, which would imply sufficient incentives for farmers to adopt the speciality maize varieties and poultry firms assure that the maize supplied is biofortified. An important dimension of product differentiation and segregation for speciality traits throughout the value chain is the added handling and transaction costs incurred, and some organizational arrangements may be necessary to reduce these (Miranowsky et al. 2004). One of the possible solutions is poultry firms getting into contracts with the maize farmers. Such institutional arrangements are not widely observed in India, but could be a potential market development for mitigating the information asymmetry in the value chain due to the credence good attribute of biofortified maize.[4] Valuable insights can be derived from a number of studies examining the wide array of cash contracts with varying terms that pose strategic alternatives for buyers, particularly as they seek to use contracting as an element of risk mitigation, for different crops across countries (e.g., Wilson and Dahl 2011, Goldsmith et al. 2008, Darroch et al. 2002). Broadly, the major challenges in successful marketing of speciality crop/variety include the capacity to realize premiums sufficient to cover increased costs, contract price flexible with general market trends, fair and effective distribution of benefits throughout the supply chain, traceability, managing risks of climatic induced quality losses etc. Under these conditions, contractual arrangements are shown co-existing and relatively stable with other conventional market forms (Van Wechel et al. 2007, Janzen and Wilson 2002, Carriquiry and Babcock 2002).

Conclusion

The development of biofortified maize with enhanced levels of (essential) amino acids has gathered significant research attention, first in relation to human consumption in the developing countries and, more recently, from a business perspective due to the rapid growth of the poultry sector in, for instance, India. However, mainly due to the cheap protein substitutes available in the market, the financial potential of biofortification of maize as poultry feed component appears limited. Beyond this *ex ante* impact assessment, the study also indicates the importance of information at the firm managerial level. In the Indian poultry sector, small-scale firm managers typically lack awareness on the role of amino acids or on new biofortified products, leading to overuse of amino acids, and limiting the economic potential of biofortified maize. Further, the sector appears to incur significant financial losses due to the lack of information diffusion related to the role of nutrients in poultry production and the nutritive value of different feed components. Therefore, in the case of India, it is imperative for the regional governments to develop and strengthen organizational solutions that disseminate appropriate information for the small-scale poultry sector to raise technology adoption and profitability.

The paper also indicates the necessity for carrying out a feasibility study on novel value chains for quality attributes. The inherent credence good status of biofortified maize is a major challenge to realize its market potential. Thus, the potential biofortified maize induced savings, which are already marginal, are based on the assumption that there is perfect substitutability

[4] An example for poultry firms getting into contractual arrangement for ensured supply of maize is shown by Mehta and Nambiar (2008): Suguna Poultry Farm Ltd, a leading poultry firm in South India has tied up with the farmers of Karnataka state for the cultivation of more than 6400 hectares of maize in 2007.

between biofortified and synthetic amino acids: that is, there are no other effects, viz. relative poultry yield, meat quality or efficiency. If indeed (and subject to validation with empirical feed data) biofortified maize (compared to synthetic amino acids) improves poultry yield, meat quality or efficiency (as claimed by the preliminary information), the scenario of financial impact estimates would change considerably and could trigger demand for such a product. Furthermore this would provide sufficient impetus to increase research investment in developing new biofortified HMM and QPM varieties or their combinations for the Indian poultry sector. Despite significant information gaps on the potential of biofortified maize, the development of HMM-QPM could be a first step towards further enrichment with high oil content. This is beyond the scope of this study, but given the importance of oil in poultry feed, could be more of a potential game changer. Such a trait pyramiding approach could further increase the potential economic benefits. Further, there is some evidence emerging in the literature (Panda et al. 2013) that feeding poultry with biofortified maize could increase the quality of meat production, which is credence attribute for the poultry consumers. Our paper thereby complements the more qualitative study by Hellin and Erenstein (2009) – but also shows that the economic benefits of current QPM varieties would be marginal if the quality impacts on the end product (poultry meat) are not accounted for, and hence the technology diffusion critically depends on the development of distinct value chains both for maize grains and for poultry products.

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Appendix A

Table 5. Cost minimizing poultry feed composition (Scenario 1, Specification 1)

Table 5. Cost minimizing poultry feed composition (Scenario 1, Specification 1)

	Market price (Rs/kg)	Cost-minimizing feed composition (kg/bird for the entire lifespan)					
		Broiler [lifespan: 42 days] feed with			Layer [lifespan: 504 days]		
		Normal Maize	QPM	HMM	Normal Maize	QPM	HMM
Maize	10.2	2.74	--	--	11.54	--	--
Biofortified maize (QPM/HMM)	10.2	--	2.74	2.74	--	11.54	11.54
Soybean cake	19.3	0.00	0.00	0.00	0.00	0.00	0.00
Fish cake	19.2	0.77	0.80	0.80	7.27	7.27	7.27
Broken rice	7.5	0.40	0.40	0.40	4.68	4.68	4.68
De-oiled rice bran	7.0	0.03	0.03	0.03	2.29	2.29	2.29
Sunflower	13.5	0.00	0.00	0.00	0.00	0.00	0.00
Groundnut cake	15.8	0.02	0.03	0.03	16.16	16.16	16.16
Sorghum	9.1	0.05	0.00	0.01	0.00	0.00	0.00
Mineral mixture	26.8	0.00	0.00	0.00	0.00	0.00	0.00
Oil	44.2	0.01	0.01	0.01	0.00	0.00	0.00
Di calcium phosphate + other sources of calcium	24.8	0.00	0.00	0.00	4.89	4.89	4.89
Synthetic lysine	162.8	0.00	0.00	0.00	0.00	0.00	0.00
Synthetic methionine	250.8	0.00	0.00	0.00	0.00	0.00	0.00
Total feed quantity		4.02	4.02	4.02	46.83	46.83	46.83
Feed cost in Rs/bird for the entire lifespan [% change over normal maize]		47.2	47.2 [-0.1]	47.2 [-0.1]	576.8	576.8 [0.0]	576.8 [0.0]

Note. Estimates are obtained from LP model using the feed ingredient price and nutrient composition.
1 US$ = Rs. 45.7 (average of 2010).
Source. Optimization results from Appendix B and ingredient prices from firm survey, 2010.

Table 6. Cost minimizing poultry feed composition, with limited fish and groundnut meal availability (Scenario 1, Specification 2)

Table 6. Cost minimizing poultry feed composition, with limited fish and groundnut meal availability (Scenario 1, Specification 2)

	Market price (Rs/kg)	Cost-minimizing feed composition (kg/bird for the entire lifespan)					
		Broiler [average lifespan: 42 days] feed with			Layer [average lifespan: 504 days]		
		normal maize	QPM	HMM	normal maize	QPM	HMM
Maize	10.2	2.51	--	--	17.63	--	--
Biofortified maize (QPM/HMM)	10.2	--	2.51	2.51	--	21.54	21.54
Soybean cake	19.3	0.58	0.58	0.58	2.98	2.63	2.63
Fish cake	19.2	0.20	0.20	0.20	2.34	2.34	2.34
Broken rice	7.5	0.00	0.00	0.00	4.68	4.68	4.68
De-oiled rice bran	7.0	0.17	0.17	0.17	2.36	3.33	3.33
Sunflower	13.5	0.00	0.00	0.00	0.11	0.11	0.11
Groundnut cake	15.8	0.40	0.40	0.40	4.68	4.68	4.68
Sorghum	9.1	0.00	0.00	0.00	6.14	1.62	1.62
Mineral mixture	26.8	0.00	0.00	0.00	0.00	0.00	0.00
Oil	44.2	0.04	0.04	0.04	0.00	0.00	0.00
Di calcium phosphate + other sources of calcium	24.8	0.10	0.10	0.10	5.89	5.90	5.90
Synthetic lysine	162.8	0.00	0.00	0.00	0.00	0.00	0.00
Synthetic methionine	250.8	0.00	0.00	0.00	0.00	0.00	0.00
Total feed quantity		4.02	4.02	4.02	46.83	46.83	46.83
Feed cost in Rs/bird for the entire lifespan [% change over normal maize]		52.8	52.8 [0.0]	52.8 [0.0]	625.0	610.15 [-2.4]	610.2 [-2.4]

Note. Estimates are obtained from LP model using the feed ingredient price and nutrient composition.
1 US$ = Rs. 45.7 (average of 2010)
Source. Optimization results from Appendix B and ingredient prices from firm survey, 2010.

Appendix B

Nutrient composition of different ingredients and their recommended dose for broilers and layers

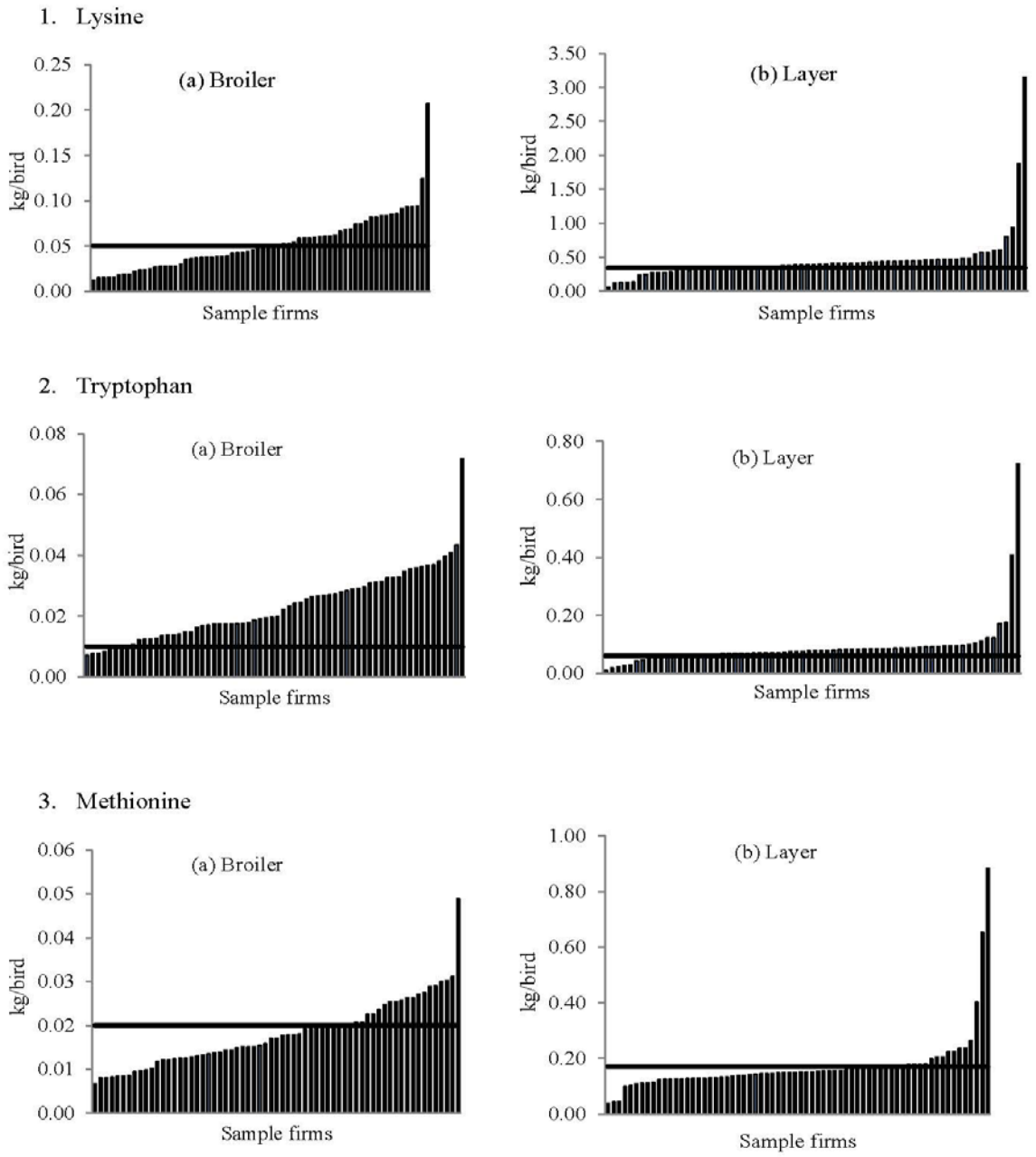
Nutrient composition of different ingredients and their recommended dose for broilers and layers

	Energy (Kcal/kg)	Crude protein (%)	Lysine (%)	Tryptophan (%)	Methionine (%)	Crude fat (%)	Crude fibre (%)	Calcium (%)	Available Phosphorous (%)	Constraint imposed in optimization	Recommended feed requirement (gram/day/ bird)
Feed ingredients											
Maize	3350	10.00	0.26	0.04	0.18	3.80	3.00	0.02	0.13	= 70%	
QPM	3350	10.00	0.42	0.09	0.19	3.80	3.00	0.02	0.13	= 70%	
HMM	3350	10.00	0.34	0.07	0.40	3.80	3.00	0.02	0.13	= 70%	
Soybean cake	3300	36.49	2.18	0.47	0.54	18.00	5.50	0.25	0.24	= 35%	
Broken rice	2800	7.00	0.14	0.09	0.11	3.00	5.00	0.02	0.04	= 10%	
De-oiled rice bran	1700	14.00	0.83	0.21	0.31	1.00	14.00	0.10	0.19	= 20%	
Sunflower	1800	19.20	0.68	0.23	0.44	1.00	26.00	0.37	0.30	= 10%	
Fish cake	2500	60.00	4.20	0.60	1.62	9.00	3.00	5.00	2.00	= 5%**	
Groundnut cake	2400	45.00	7.47	2.07	2.25	1.00	10.00	0.20	0.19	= 10%**	
Sorghum	3000	8.80	0.18	0.09	0.14	3.00	4.00	0.03	0.13	= 35%	
Mineral mixture	0	0.00	1.20	0.05	0.58	0.00	0.00	0.00	0.00	= 5%	
Oil	10000	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	= 5%	
Di calcium phosphate + other sources of calcium	0	0.00	0.00	0.00	0.00	0.00	0.00	23.00	18.00	= 20%	
Synthetic lysine	0	0.00	98.50	0.00	0.00	0.00	0.00	0.00	0.00	= 5%	
Synthetic methionine	0	0.00	0.00	0.00	99.00	0.00	0.00	0.00	0.00	= 5%	
Recommended dose in poultry feed											
Broiler											
Pre-starter (1st week)	2950	23.50	1.25	0.20	0.55	6.00*	7.00*	0.95	0.47		20
Starter (2nd & 3rd weeks)	3050	21.50	1.15	0.18	0.48	6.00*	7.00*	0.95	0.45		61
Finisher (4th to 6th week)	3150	19.00	1.05	0.16	0.42	6.00*	7.00*	0.90	0.40		144
Layer											
Chick (1st to 6th week)	2750	20.50	1.05	0.17	0.45	6.00*	7.00*	1.00	0.45		24
Grower (7th to 18th week)	2500	17.00	0.80	0.13	0.35	6.00*	7.00*	1.00	0.40		55
Layer (19th to 72nd weeks)	2600	16.00	0.70	0.12	0.35	6.00*	7.00*	3.50	0.30		109

Note. *: Indicates the upper limit values (in case of other nutrients, lower limit values are given); **: Constraints used in *Specification 2* (fish meal was taken as unbounded and groundnut meal = 35% in Specification 1).

Source. PDP 2011, Panda et al. 2009, Mandal et al. 2005, Mandal et al. 2004, Ranjhan 1998

Appendix C Amino acid consumption by sample firms



Note. In these graphs, bar represent the actual use of amino acid by the sample firms and line the recommended dosage.
Source. Firm survey 2010.

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Struggling with Uncertainty: The State of Global Agri-Food Sector in 2030

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Abstract

Multiple tools, including surveys, exploratory and confirmatory factor analysis, and cross-impact analysis were employed to identify likely scenarios for the agri-food system in 2030. A principal finding of the research is that global warming is perceived as almost inevitable and will lead to major changes in global food production, processing, and trade. However, the dynamic nature of the food chain offers many possibilities to mitigate the negative supply system impacts of global warming through efficiencies gained by increasing firm concentration in the agri-food sector through the application of biotechnology, or adaptations in local food production.

Keywords: Scenario analysis, expert opinion, global food system, exploratory factor analysis, confirmatory factor analysis, Smic-Prob-Expert

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Introduction

According to the definition of Jarke, Bui, and Carroll (1999) a scenario is a "description of a possible set of events that might reasonably take place." During the last several decades, a large number of scenarios have been developed to predict the future state of the world or specific regions (Glenn, Gordon, and Florescu 2009; Kuhlmann and Edler 2003). Some of these scenarios are industry-specific, focusing, for example, on the future of transportation systems (Shiftan, Kaplan, and Hakkert 2003), while others couched their predictions in vague, ethereal terms (Raskin et al. 2002).

In recent years, we have seen increasing public and scientific attention toward the future of the agri-food sector. Numerous scenarios have been prepared focusing mainly on the effects of climate change on agricultural production. The changing ecological situation (Lorenzoni et al. 2000; Ericksen, Ingram, and Liverman 2009) and socio-economic environment (Schafer and Victor 2000) of agri-food systems make a compelling case for the application of scenario development and analysis to this sector. Our aim is to investigate the perspectives of food system experts on the future of the agri-food sector and to develop several scenarios that illustrate the future of the world's food system.

Understanding the possible paths for the development of the agri-food sector is important for several reasons. First, the sector is characterized by high human and physical capital requirements and a long time horizon for return on investment (Christóbal 2008). Second, the agri-food complex exhibits strong linkages to other sectors of the economy for inputs and outputs and, therefore, the sector's accelerative and multiplicative effects have a considerable influence on the dynamics of national and regional economies. Moreover, governmental and managerial decisions affecting the agri-food sphere exert a considerable influence on the socio-economic structure and equilibrium of entire geographic regions (van Ittersum et al. 2007). Third, the development of the agri-food system has wide-ranging implications for the natural environment (Steenge 2004). Therefore, the identification of potential future scenarios may aid in better harmonizing the economic, social, and natural consequences of food and fiber production.

The remainder of the paper is organized as follows. We first discuss scenario planning, its development, and its application to business and the agri-food sector. We then discuss the methods used in this research, followed by a presentation of the results of a survey of an international group of agri-food specialists. Next, we report the results of exploratory factor analysis and identify and discuss the underlying constructs, which we evaluate using confirmatory factor analysis. We then assess the probability of various outcomes and develop several scenarios using a panel of industry experts. Finally, we conclude by discussing the implications of our findings. Because of the numerous results that accompany the application of the several analytical methods we employ, we have chosen to focus on what we consider to be the major results and our interpretation of the findings. This comes at the expense of completeness and we leave it to the reader to consider the results that we do not discuss and to develop alternative interpretations.

Scenario Planning

Modern scenario planning may be traced to the first years of the Cold War era (Nye 1994). Herman Kahn (1960) is generally credited with developing the methods for scenario development while working at Rand Corporation for the U.S. military (Fahey and Randall 1998). Kahn employed the term "scenario" to describe future states in relation to the possibility of thermonuclear war.

The 1970s saw the application of scenario planning to the world of business. Pierre Wack, an executive with Royal Dutch/Shell developed "scenario planning" to create scenarios that did not rely on forecasts that assumed "tomorrow's world will look much like today's" but rather considered the possibility of a major change in the business environment (Wack 1985). His work at Royal Dutch/Shell is credited with helping the company prepare for the energy crisis of 1973.

Huss and Honton (1987) argue that the value of scenario planning is in providing a tool for the forecasting of long range, complex, and highly uncertain business environments. Wilkinson and Eidinow (2008) add that scenario planning aids decision-makers in identifying uncertainties and their potential effects so that they can formulate appropriate responses. In recent years, scenario planning has been studied and used by academia, business, consultants, policymakers, governments, and NGOs in a variety of contexts and many authors have published on the subject, including Godet and Roubelat (1994), Schoemaker (1995), Phelps et al. (2001), and Mietzner and Reger (2005), to name a few.

Global Food System Projections

McCalla and Revoredo (2010) note that there have been at least 30 quantitative studies projecting the global supply and demand for food. This number has grown over the last several years and the number of studies that forecast various elements of the food system is extremely large when we consider research that is more narrowly focused on individual elements of the global food system. For the purpose of this literature review, we have chosen to focus on those studies that make future projections of key elements of the global food system, such as energy, water, and the global supply and demand for food, regardless of whether the scenario analysis method was used. We do so in order to provide a robust view of the projections using various forecasting techniques. Some of the more comprehensive studies in the categories of natural resources, climate change, and global food supply and demand are discussed below. Given the thousands of forecasting studies that have been published on the future of the global food system, this literature review is necessarily a small sample of the published works.

Natural Resources

Land. Many of the published studies focusing on natural resources address a single resource, such as land, energy, or water. Land use studies typically address the multiple demands for land, including urban, crop and pasture, forestry, and conservation uses. Lambin and Meyfroidt (2011) note that land is becoming increasingly scarce due to urbanization, greater demand for cropland, and deforestation. They estimate that the current land reserve could be exhausted by 2050. Seto et al. (2011) estimated that urban land cover will increase from 430,000 km^2 to 12,568,000 km^2

with the most likely estimate of 1,527,000 km^2. They note that increased urban development will put millions of people at risk to the effects of climate change and challenge conservation efforts. Increased urbanization and the increasing scarcity of land available for agricultural uses were common themes in many of these studies.

Water. As with land, there is general agreement in the literature that water will be an increasingly scarce resource. Alcamo, Flörke, and Märker (2007) estimate that water stress will increase in approximately two-thirds of the world's total river basin area, with increasing stress being largely attributable to greater water withdrawals. Hejazi et al. (2014) develop socio-economic scenarios to evaluate future water demand. They develop six scenarios, with names such as, "Collapse," Muddling Through," and "Social Conservatism," They conclude that water is likely to be a limiting factor in the future with an increased reliance on groundwater, water reuse, and desalinization. Veolia Water (2013) estimates that 36% of the global population currently lives in water-scarce regions and that 39% of global grain production is not sustainable with regards to water use. They estimate that a "business as usual" approach could put 52% of the world population and 49% of grain production at risk of having insufficient water.

Energy. Studies that examined energy tended to focus on either energy as an input to agriculture (e.g. fuel or fertilizer) or as an output (e.g. ethanol or biodiesel). For example, Frei et al. (2013) developed two scenarios focusing on energy production and use through 2050. The "Jazz" scenario foresees a world driven by consumer demand, affordability, and quality with multi-national companies and price conscious consumers being the major players. Investments in nuclear energy and large hydro energy projects would be limited but there would be better access to unconventional resources. The "Symphony" scenario foresees an emphasis on sustainability and energy security with governments taking the lead role. Neither of the scenarios developed by the World Energy Council foresee a world where biomass utilization shows significant growth. Several studies examined the production of biofuels as a driver of agricultural prices. One study (USDA, ERS 2008) found that biofuel production led to short-term increases in food commodity prices, but that global demand would be the primary contributor to long-term increases in commodity prices. Both Ajanovic and Haas (2010) and Zhang and Wei (2010) found no substantial relationship between the production of biofuels and long-term price increases in commodity prices.

Climate Change

Publications addressing climate change as well as those addressing climate change and agriculture number in the thousands. Probably the most widely cited research on climate change and its impact is the Intergovernmental Panel on Climate Change (IPCC). In a 2007 report, the IPCC predicted that global average temperatures will increase by 2^0C to 4^0C, that close to a third of global coastal wetlands will be in danger of being submerged, and that millions of people are likely to face food and water shortages. Parry et al. (2004) estimates climate change will be responsible for placing 30 million to 220 million people at risk of hunger without taking into account the effect of CO_2 fertilization. When the CO_2 fertilization effect is considered, the risk falls to between 12 million and 20 million people. Rosenzweig and Parry (1994) argue that a more nuanced approach is needed to consider the effects of climate change on specific regions and countries. They predict that disparities between the productive capacity of the developed and

developing world will increase with climate change. Fischer et al. (2005) find that total cereal production will not be greatly impacted by climate change at the global level, but that there will be differential impacts on cereal production and hunger in various regions of the world with the tropical semi-arid regions and developing countries suffering the greatest decreases.

Global Food Supply and Demand

Research on the global supply and demand for food typically addresses factors such as population, agricultural production, food prices, calorie consumption, and malnutrition. Several comprehensive studies, including some that employ scenario analysis, are described here to provide some perspective on the breadth of the various global food system analyses. Chen and Kates (1994) examine factors including the number of undernourished people, population, dietary changes, income distribution, relative poverty, and economic integration. They develop scenarios for 2060 including "Food Secure" and "Basic Linked System," as well as 12 climate change scenarios. The European Commission (2012) developed scenarios for Europe that addressed population demographics, renewable energy use, world population, food prices and malnutrition. The scenarios were entitled, "Nobody cares: Standstill in EU Integration," “Fragmented Europe - EU under Threat," and "EU Renaissance." Nelson et al. (2010) developed three scenarios for 2050, "Optimistic," "Baseline," and "Pessimistic," that included population, GDP growth, price changes for maize, wheat, and rice, and child malnutrition. Pinstrup-Andersen et al. (1999) forecast demand for food, cereals, and meat, cereal imports, food prices, and malnutrition of children under five years of age for both developing and developed countries in 2030. The Institute for the Future (2011) developed four scenarios, for 2030 labeled, "Growth," "Constraint," "Collapse," " and "Transformation." They focus on issues such as calorie consumption, the food supply chain, food scarcity, and technology. Hoogwijk (2003) developed three scenarios based on the type of diet with scenarios called "Vegetarian Diet," "Moderate Diet," and "Affluent Diet."

We cannot readily summarize the findings of the various studies, particularly those involving scenario analysis, as they do not lend themselves to calculating averages or even ranges. Rather, it is insightful to view the way that the authors characterize the future states and the factors that they include in the analyses. Many of the scenarios focus on whether the system will be in balance or out of control. Others describe the positive or negative nature of the outcomes. Still others characterize the systems by describing key characteristics that describe key features, such as the type of diet that might predominate. It is also insightful to look at the variables included in the studies. Many of the variables, such as those mentioned above, including populations agricultural production, food prices, calorie consumption, and malnutrition appear in numerous studies. However, other factors, such as water availability, dietary components, system of economic organization, and energy and other agricultural inputs, appear in relatively few studies. Of course, the real value of scenario development lies not in looking at the outcomes, but in understanding the complete story that the scenario describes, how the various factors influence the outcomes, and particularly how the factors work together, often leading to an outcome that may be far different than could be envisioned by examining the impact of any individual factor. McCalla and Revoredo (2001) argue that, notwithstanding the inaccuracies of forecasts, the models have been able to focus the attention of policy makers on major issues that need attention.

Methods

In this study, we drew on several different research methods that have been widely applied in management research and forecasting to develop the scenarios and associated probabilities. The methods employed reflect the specific research objectives as well as practical limitations such as securing access to and commitment from agribusiness experts. Ideas regarding possible future states were generated using the brainstorming technique (Osborn 1963). These ideas were then screened by a small group of experts based on the significance and relevance of the items so as to achieve a manageable number of potential future states. To evaluate the probability of the prospective future states, we employed expert probability estimation, as discussed by Hogarth (1975), with two large groups of experts. The future state probabilities were then analyzed to identify the underlying constructs using exploratory factor analysis and confirmatory factor analysis, methods commonly employed in management research (Scandura and Williams 2000). Scenarios were generated utilizing the consensus probability assessments of experts and employing the Smic-Prob-Expert cross-impact analysis tool, so as to combine the favorable aspects of qualitative and quantitative research methods as recommended by Godet (2000). The research process is summarized in Figure 1 and detailed in the following paragraphs.

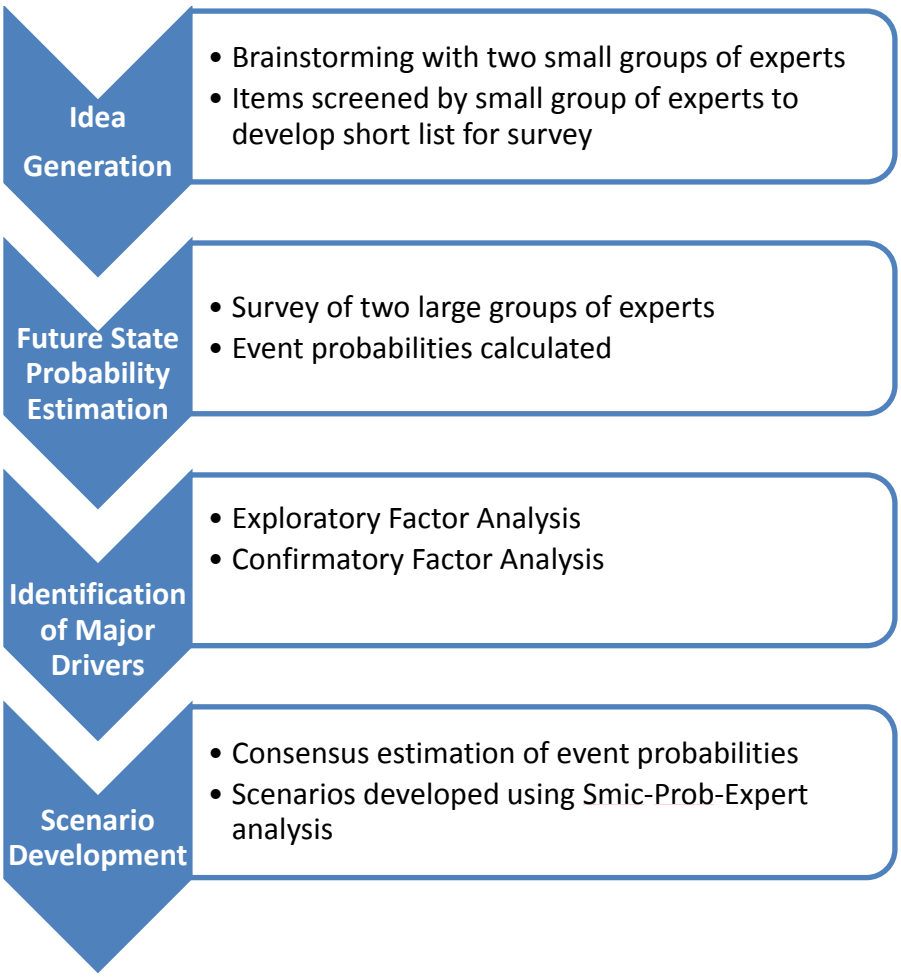

Figure 1. Research process flow

In order to generate reasonable and realistic scenarios, we began with a combination of a direct-question survey and an expert-based, scenario-analysis process whereby we utilized the expertise of large and small groups of industry specialists. We employed a typology of scenarios as described by van Notten et al. (2003), who identified 14 scenario types and characteristic choices associated with each type of scenario (Table 1). The characteristic choice employed in this study is highlighted in bold.

Table 1. Scenario-analysis characteristic descriptions

Overarching Themes	Scenario Type	Characteristic Choice*
A. Project Goal:	I	Inclusion of norms: **descriptive** vs. normative
Exploration vs.	II	Vantage point: **forecasting** vs. backcasting
Decision Support	III	Subject: **issue-based**, area-based, or institution-based
	IV	Time scale: **long-term** vs. short-term
	V	Spatial scale: **global/supranational** vs. national/local
B. Process Design:	VI	Data**: qualitative** vs. quantitative
Intuitive vs. Formal	VII	Method of data collection: **participatory** vs. desk research
	VIII	Resources: extensive vs. **limited**
	IX	Institutional conditions: **open** vs. constrained
C. Scenario Content	X	Temporal nature: **clean** vs. snapshot
Complex vs. Simple	XI	Variables: **heterogeneous** vs. homogenous
	XII	Dynamics: peripheral vs. **trend**
	XIII	Level of deviation: alternative vs. **conventional**
	XIV	Level of integration: high vs. **low**

Source: van Notten et al. (2003).
Note. Boldface type indicates the type of scenario used in this study.

We began the process of identifying possible future states for the agri-food system by holding two brain-storming sessions with industry experts. Participants were encouraged to suggest trends without discussion or criticism. Nine experts participated in the first session and 10 in the second. The first session was held in an agricultural region, Dusnok, Hungary, with support from the Regional Agricultural Chamber. The nine participants included six farmers, two owners of medium-sized food processing companies, and one representative from a nation-wide input-trading organization. Seven of the participants had degrees in higher education and four had substantial international experience. The second session was held at Corvinus University of Budapest in Budapest, Hungary. The participants included three representatives from medium-sized food processing companies (two were owners), three representatives from the Hungarian Ministry of Rural Development, and four agricultural researchers. Four of these participants were members of the Hungarian Association of Food Science and Technology, a scientific NGO.

The brainstorming sessions led to a total of 63 different ideas concerning the future development of the agri-food chain. This large number of items required consolidation so that a manageable number of potential events could be presented to the expert panels for evaluation. As a guideline we used the findings of Parenté and Andersen-Parenté (1987) who suggest that when using the Delphi-method, the upper limit of items that can be reasonably processed is 25.

Three experts evaluated each of the 63 statements based on three criteria: global character, importance and relevance from the point of view of food industry, and specificity from the point of view of the actual research. One expert was a professor emeritus from Serbia with considerable international experience gained as a consultant for FAO and UNIDO. Another expert was been an international lawyer from Nigeria, with considerable experience in the field of rural development in northern (Sub-Saharan) Nigeria. The third expert was a professor at Corvinus University of Budapest and an expert in food security and the impact of climate change on agriculture.

The process of reducing the number of statements resulted in the initial elimination of 27 statements. Seven statements were eliminated because they reflected processes of local importance, three were eliminated because they were unimportant from a practical perspective, another three were omitted because they were irrelevant from the point of view of the development of the agri-food sector, and fourteen were eliminated because they did not reflect directly on the development of agri-food sector. The remaining 36 statements were reformulated and consolidated into 20 future state statements.

The final version of the questionnaire was prepared with the assistance of nine members of the Program Planning Committee of 19th Annual World Forum and Symposium of the International Conference of the International Food and Agribusiness Management Association (IFAMA). This committee had a broad representation of international experts from many different fields, was geographically diverse, and included members from both industry and academia.

Respondents were asked to estimate the probability of occurrence of the 20 different states using a seven-point probability scale. The scale described the probability of an event occurring as 0% to 5%, 6 to 20%, 21 to 40%, 41% to 60%, 61 to 80%, 81 to 95%, and 96 to 100%. The seven-point scale was utilized in order to simplify the task for respondents and maximize the response rate. To avoid the possibility of bias based on the order in which the possible events were presented, the order was determined by a random-number generator.

The sample was drawn from two sources. All registered participants of the annual IFAMA conference (Budapest, June 2009) received the questionnaire by e-mail via the IFAMA office. Experts from Central Europe were selected from participants in several scientific conferences held during the period of February to May 2009 in Hungary, Romania, and Serbia. The meetings included the 4th International Conference for Rural and Agricultural Development, at Debrecen University, Debrecen, Hungary and preparatory meetings of the Techfood project “Solutions and Interventions for the Technological Transfer and the Innovation of the Agro-food Sector in South East Regions” held at the Bucharest Academy of Economic Studies, Bucharest, Romania as well as the Faculty of Agriculture at Belgrade University and Serbian Scientific Research Institute of Economic Sciences, both in Belgrade, Serbia.

IFAMA members and Central European experts were sent 350 and 280 questionnaires, respectively. The IFAMA group completed 109 questionnaires and the Central European group returned 97 questionnaires for response rates of 31% and 35%, respectively. The geographic distribution of all 206 respondents is summarized in Table 2.

The data from the 206 observations were recorded and summary statistics were calculated. This provided a perspective on the raw probabilities of future states as viewed by the expert panels and served as input into the next stages of the scenario development process.

Table 2. Geographic distribution of respondents

International Specialists	
North-America	51
South and Central America	22
European Union	22
South Africa, Australia, India	14
Total	109
Central-European Specialists (non-IFAMA members)	
Hungary	67
Serbia	8
Ukraine	9
Romania	13
Total	97
Grand total	206

The next step was to use exploratory factor analysis to identify the underlying constructs associated with the relatively large number of future states. Exploratory factor analysis is typically used to identify latent constructs in data matrices with correlated variables (Floyd and Keith 1995). This eigenvector–based, multivariate analysis is a theoretically optimal, linear scheme (in terms of least, mean-square error) for compressing a set of high dimensional vectors into a set of lower dimensional vectors. Factor analysis is based on a correlation and covariance matrix and assumes that the observed variables are measured continuously, are distributed normally, and that the associations among indicators are linear. Because our expert responses were measured on an interval scale, we used the Categorical Principal Component Analysis (CATPCA) method to analyze the data (Linting et al. 2007). Based on CATPCA output there appeared to be some underlying factors, also known as background or latent variables, that were not measured directly and which may have served as the basis for respondents' expectations.

We used the CATPCA results to establish the relationship between the directly observed and latent variables by constructing a model of key agri-food chain events and future states that we tested using confirmatory factor analysis. This combination of exploratory and confirmatory factor analysis is consistent with the general logic behind the application of different types of factor analysis, reflecting the inherent, successive approximation commonly used with these methods (Schriesheim and Eienach 1995; Anderson and Gerbing 1988). In contrast to exploratory factor analysis or principal component analysis, where all loadings are free to vary, confirmatory analysis tests hypotheses relative to theoretical underpinnings. This analysis can include both directly measurable and latent variables using the CATPCA as input.

In the next phase of the analysis, we used the results of both the exploratory and confirmatory factor analyses to identify the most important future agri-food sector events, which we have labeled as outcomes. Scenarios were developed based on the estimation by a group of experts of the probability that the various outcomes would occur. While a simple questioning of the experts on the probability of the occurrence of future events would be the simplest method, such a process would imply that each event is independent of other events. To properly account for the interrelationships between events, it was necessary to use a method that accounts for the cross-impacts of different processes.

Several algorithms have been developed to account for the effect of one event on another. The goal of these cross–impact algorithms is the manipulation and harmonization of probability estimates (Cho and Kwon 2004). We chose the Smic-Prob-Expert cross-impact analysis tool, developed by team a team led by Michael Godet (Godet and Roubelat 1996; Bradfield et al. 2002). Duperrin and Godet (1975) state, "in practice, the opinions given in response to certain specific questions about non-independent events disclose some degree of inconsistency with the overall opinion (which is implicit although not expressed), revealed by the answers given to all the other questions." These primary opinions must be corrected, is such a way as to conform to various constraints. The mathematical foundations of the Smic-Prob-Expert method used in estimating the probability of the various scenarios are presented in Appendix A.

The Smic-Prob-Expert software is capable of generating a hierarchical rank of scenarios, based on their probabilities. The input for the analysis includes three components, a vector of *a priori* estimations of the probability of the different outcomes and two square matrices. The first matrix contains the experts' estimation of the pairwise probability of the co-occurrence of events. The second matrix contains the estimated probabilities of the occurrence of processes in pairwise form, should the other process in the pair not occur.

Developing the input matrices for Smic-Prob-Expert analysis turned out to be extremely complicated. Originally, a Delphi–type questioning of experts had been planned. However, even after two rounds of the questioning there were still considerable differences. Subsequently, a two-hour workshop was organized in July, 2009. Six experts, a moderator, and one of the authors of this article participated in the workshop. All of the experts had at least ten years of international experience in agri-food research in a variety of geographical locations, under different socio-cultural conditions (Africa, China, Serbia, Northern Cyprus, and Hungary). The outcome probabilities were estimated by consensus and the probabilities were then used to develop the scenarios and their probability of occurrence.

Several limitations should be considered in interpreting the results discussed in the following section. First, the input for the scenarios, starting with the identification of the future state variables and ending with the estimates of the conditional probabilities of the outcomes, was subject to the judgments of the chosen experts. The various panels of experts were selected to ensure that the chosen experts had ample expertise across a broad range of issues affecting the global food system. Nevertheless, a disproportionate number of experts were from Central Europe. It is also important to acknowledge that, as with any research, the interpretation of the results will be subject to the perspective of the writer. We, therefore, encourage the reader to view the results in that light and form his or her own opinion on what the findings mean.

Results

Descriptive Analysis

In the first phase of the research, we attempted to characterize respondents' evaluation of the probability of the various events regarding the future state of the agri-food sector. In some cases response patterns could be described by Erlang or lognormal functions, but in most cases the distributions did not fit any common probability density functions.

In analyzing the responses, it became obvious that many of respondents believed that the agri-food complex will face significant new challenges over the coming decades (Table 3). For example, both groups believed that as a consequence of global warming, water will become one of the most important limiting production factors. The Central-European experts assigned a somewhat higher probability to this event than did the IFAMA group perhaps because they have observed decreasing precipitation and many different adverse climate predictions possibly foreshadowing the increased frequency of severe droughts (Arnella 1999; Bartholy, Pongracz, and Gelybo 2007).

There was good agreement that we should expect increasing energy prices and the internalization of environmental externalities. This prediction is in line with the majority of forecasts from other sources (Yergin 2006). More than half of respondents also predicted a further increase in food imports by China and India. This reflects the generally accepted view that incomes will continue to rise in these countries and result in shifting patterns of trade in food and agricultural products (Kaplinsky 2006; USDA, ERS 2008). At the same time, the majority of respondents attached a low probability to finding a solution to the global malnutrition problem and for a decrease in the prices of agricultural commodities. These rather pessimistic expectations support the opinions of other experts who argue that if no corrective action is taken, the target set by the World Food Summit in 1996 (halving the number of undernourished people by 2015) will not be met (Rosegrandt and Cline 2003). Based on these predictions, we may anticipate an agri-food sector that will play an even more important role in the world economy in the decades to come. The threat of global warming, increasing food demand in emerging economies, and the continuing need for food aid for the world's poorest countries highlight the significance of preserving the productive capacity of world food system.

Another important future tendency, as viewed by our expert respondents, will be the challenge of meeting the demands of diverse consumer segments. This phenomenon will manifest itself in increasing interest in organic products and tailor-made nutritional products. Moreover, a growing demand for locally produced foods may be expected.

Table 3. Experts' assessments of the probability of future state events through 2030

Future State Variables	International Experts (percent)	Central-European Experts (percent)
1. Water becomes a limiting factor of production-output (WATER)*	82.8	94.5
2. Increasing interest in bio-products (BIOPROD)*	72.8	60.3
3. Increasing energy prices and environmental taxes considerably increase prices of food produced in distant regions (FOODPRICE)	72.4	69.8
4. Increasing interest in specific, tailor-made nutrition, supported by the latest methods of medical science (NUTRIFOODS)	68.7	66.2
5. Increasing trust in locally produced food products (TRUSTLOCAL)	68.6	69.7
6. Increased agricultural and food import in China and India (EMKTS)	68.4	64.2
7. General proliferation of genetically modified agricultural products globally (GM)	67.8	72.1
8. Increasing role of bio-mass in energy production (BIOMASS)	67.4	69.8
9. Further concentration of agricultural production (AGRCONC)	64.7	68.9
10. Increasing urbanization, some regions lose their population even in developed states (URBAN)	63.6	61.6
11. Further and increasing migration from third world to the developed states (MIGRATE)*	59.7	72.8
12. Increasing threat of agri and food terrorist attacks (BIOTERROR)	58.8	64.5
13. Increasing trust in biotechnology (ACCEPTGM)*	58.7	65.6
14. Drastic decreases in the number of small-scale, family-owned retail shops (TRADECONC)	54.4	58.8
15. Global warming considerably decreases production potential (LOWOUTPUT)*	53.4	68.4
16. Many high-tech agri production parks near big metropolitan areas (Metropolitan Agriculture) (METROPAGR)	38.7	36.8
17. Increased influence of religion and traditions on eating habits (TRAD)	23.2	25.4
18. Concentration of food production will narrow to 30-40 firms producing the overwhelming majority of the world's food (FOODCONC)*	18.6	29.4
19. The number of malnourished people decreases to at least one-quarter of the current number (MALNUTR)	17.6	16.8
20. Real price of agricultural commodities will decrease considerably (PRICEDECR)	15.1	16.7

Note. The probabilities were calculated by replacing the interval ranges with mid-point values and multiplying each value by the number of experts who selected each probability range. An asterisk (*) indicates a statistically significant difference between the two groups based on the results of the Mann-Whitney test.

In most cases, the probability assessments of the two expert groups were similar. For four of the future states, the Central European experts' assessments were higher by 10% or more than their international counterparts. These events included decreased production potential as a result of global warming, water becoming a more limiting factor of production, increasing migration from the third world to developed states, and increasing concentration of food production. One explanation is that the assessments may reflect the experience of the group members. For example the expectation of increased concentration in food production may reflect the current low concentration of the food trade in Central and Eastern Europe relative to that of Western Europe, where significant concentration in the food trade occurred in the 1980s and 1990s (Juhász, Seres, and Stauder 2008). In only one case, increasing interest in bio-products, did the international experts assign a substantially higher probability to the future state than did the Central European experts. In no case did the probability estimates between the two groups differ by more than 15%.

For some variables, the expert responses showed sharp differences of opinions within the combined groups as to what the future holds. For example, approximately one-fourth of the respondents estimated that increasing acceptance of biotechnology is rather improbable (probability of 20% or lower), while roughly one-fourth of the respondents seemed confident in the increasing acceptance of biotechnology (probability of 81% or higher). This may be explained by the great differences in the assessment of the potential of genetically modified agricultural products among different groups (Lusk and Rozan 2006).

The experts do not predict that changes in firm concentration within the agri-food system will be uniform throughout the various subsectors, i.e. production, processing, and distribution. For example, approximately two-thirds of the experts foresaw further concentration in the agricultural production sector. However, a relatively small percentage of respondents accepted the opinion of some experts (Steiner 2000) that mergers and acquisitions in the food industry will lead to a small number of firms (30 to 40) that will produce most of the world's food. The probability of a further, drastic decrease in the number of small-scale, family-owned food shops was estimated at slightly more than 50%.

Exploratory Factor Analysis

The input data obtained from the questionnaire is categorical (experts' estimations of ranges of probability of the occurrence of events, processes, or states) and we have therefore used categorical principal component analysis (CATPCA), as explained above. This method has proven to be an efficient method for analyzing the underlying constructs in which a large number of variables are involved, some of which may not be measurable. The principal component analysis yielded seven components with an eigenvalue of one or greater. However, the contribution of the seventh factor was marginal and the variable was omitted. The internal consistency of scales was evaluated by using Cronbach's alpha. This statistic was greater than 0.65 for each of the remaining principal components. Because only two factors loaded on factor 4, Cronbach's alpha was not calculated for this factor.

Because the factor analysis yielded results that were difficult to interpret, we employed factor rotation. We chose the most commonly-used method, Varimax rotation, developed by Kaiser

(1970). A principal advantage of this method is that the variables tend to have either high or low loadings on the factors. Put another way, each state variable tends to be associated with a relatively small number of factors making the results more easily interpreted. Abdi (2003) states that "because the rotated axes are not defined according to a statistical criterion, their raison d'être is to facilitate the interpretation." Although the application of other rotation methods may have led to slightly different results (Schmitt 2011), we did find that the Varimax method lead to meaningful results. The component-structure before and after rotation is summarized in Table 4.

Table 4. Summary results of the categorical principal component analysis

Principal Component	**Extraction Sums of Squared Loadings**			**Rotation Sums of Squared Loadings**			**Chronbach's Alfa**
Number	Total	Percent of variance	Cumulative percentage	Total	Percent of variance	Cumulative percentage	
1	5.744	28.718	28.718	2.625	13.123	13.123	0.826
2	2.209	11.046	39.764	2.542	12.710	25.833	0.799
3	1.802	9.009	48.773	2.418	12.092	37.925	0.789
4	1.523	7.617	56.390	2.333	11.663	49.588	-
5	1.282	6.408	62.799	1.899	9.496	59.084	0.685
6	1.132	5.660	68.459	1.504	7.521	66.605	0.657
7	1.010	5.050	73.509	1.21	6.050	72.655	0.515

Note. Cronbach's alpha is not reported for principal component 4 since only two variables load on this factor.

The results of the principal component analysis indicate the possibility that underlying the observed variables are some well-defined latent variables. These six, unobservable and unmeasurable latent variables, may be interpreted based on the variables that load on (or have the strongest relationships with) these factors (Table 5). We identify the six principal components by giving them each a name that reflects the underlying processes.

The majority of variables that have a significant loading on the first principal component, LOCAL, are related to factors that support the development of local food production systems. These include variables related to metropolitan agriculture, urbanization, trust in locally produced food products, and increases in prices of food from distant regions. Likewise, the variables related to the second principal component, WARMING, are generally related to the phenomenon of global warming. For the third factor, CONCENTRATE, the highest loading factors pertain to the concentration of firms within the global food system. Two of the three areas of possible concentration, including concentration in the agricultural production and retail sectors, load on this component. The variable concerning trust in locally produced food products has a significant negative loading on CONCENTRATE, indicating that further concentration within the agri-food sector is deemed less likely given growing trust in locally produced foods. For the fourth component, BIOTECH, the highest loading factors are related to statements regarding the acceptance and use of biotechnology and the use of biological products in energy production (biomass). Paradoxically, the loading of another item, GM, the global proliferation of genetically modified agricultural products, received a loading value less than 0.3 and was not

included in the table for the BIOTECH factor. This result may be due to the divergence of opinion among the experts regarding the prospects for GM products. The highest loading factors for the fifth factor, INDIV, pertain to the increasing importance of individualization in food consumption patterns, including the increased importance of traditional eating habits and tailor-made, nutritional foods. The sixth principal component, SUPPLY, has positive loadings for potential changes associated with the global food supply, including lower output, greater imports in emerging economies, and higher food prices, as well as a negative loading for malnutrition, which presumably means increased consumption.

Table 5. Principal component factor loadings of state variables on outcome variables

	Principal Component					
State Variables	LOCAL	WARMING	CONCENTRATE	BIOTECH	INDIV	SUPPLY
WATER		0.790				
BIOPROD	0.570				0.416	
FOODPRICE	0.473					0.477
NUTRIFOODS					0.784	
TRUSTLOCAL	0.648		-0.346			
EMKTS						0.784
GM			0.456			
BIOMASS				0.351		0.739
AGRCONC			0.683			
URBAN	0.443				0.355	0.462
MIGRATE		0.708				
BIOTERROR	0.593					0.456
ACCEPTGM				0.706	0.304	
TRADECONC			0.707			
LOWOUTPUT		0.641				0.424
METROPAGR	0.701					
TRAD					0.811	
FOODCONC		0.656				-0.405
MALNUTR	0.532					-0.627
PRICEDECR						-0.766

Note. The numbering of the principal components is the same as in Table 4, where the first principal component is named LOCAL, the second, WARMING, and so forth. Only values above 0.300 are presented.

Confirmatory Factor Analysis

To better understand the structure of respondent's future expectations, we formulated a conceptual model to describe the relationship between the observed, directly-measured variables and their underlying latent (unobserved) constructs as expressed in the exploratory factor analysis. Confirmatory factor analysis was conducted by employing structural equation modeling, based on the Analysis of Moment Structure method (Arbuckle and Wothke 2004). The

approach of this method is similar to regression analysis. We specified a multivariate system of equations representing the relationships between the latent and observed variables with the latent variables allowed to freely intercorrelate. As is general practice, directly observed variables are portrayed as rectangles, circles represent the unobservable, latent variables, statistically significant standardized regression coefficients between observed and latent variables are shown as single-headed arrows, and double-headed arrows represent correlations relationships between pairs of latent variables.

The results of the structural equation model are presented in Appendix B. The Chi-square of the model was 0.12, possibly a consequence of non-normality of the data. The Sattorra-Bentner scaled chi-square was 0.071 is considered acceptable. The adjusted goodness-of-fit index was 0.89 and the Browne-Cudeck criterion was 0.86. In summary, the model appears to have an acceptable fit.

The results of the confirmatory factor analysis generally support our conceptual model. However, we were unable to determine a statistically significant model that included the latent variable, CONCENTRATE, and this variable was omitted from the model presented here. Some of the key findings and our interpretations are discussed in the following paragraphs.

There is a strong, significant relationship between the global warming latent variable (WARMING) and two observed variables, the expectation of decreasing agricultural production due to global warming (LOWOUTPUT) and the expectation of the increasing importance of water in agricultural production (WATER). We also see that the latent variable SUPPLY, which we use to describe concerns and tensions associated with the global food supply, is projected to impact several aspects of the food system. Supply issues are expected to lead to increased malnutrition (MALNUTR), increased food imports in emerging markets (EMKTS), and a decreased chance of a decline in food prices (PRICEDECR). The strongest linkage among the latent variables is between global warming and supply issues suggesting that these two issues are likely to be coincident.

The increased importance of local food systems (latent variable LOCAL) is expected to give rise to growth in metropolitan agricultural production systems (METROPAGR) as well as increased interest in bio-products (BIOPROD). In another expression of consumer preferences, individualization in food consumption patterns (latent variable INDIV) is a strong driver of the increased importance of tailor-made nutritional food products (NUTRIFOODS).

Finally, the latent variable BIOTECH has a relatively weak association with the observed variable, ACCEPTGM, which measures society's acceptance of genetically modified food and BIOMASS, representing an increased role for biomass in energy production.

Event Probabilities

The input-data for the scenario analyses were based on the results of the expert workshop as described above. We drew on six basic outcomes, which correspond to the six principal components of the categorical principal component analysis. Although the variable CONCENTRATE was discarded from the confirmatory factor analysis, we decided to include

the variable in the development of the future scenarios. Despite being the weakest of the latent constructs, it represents an important aspect of industry structure. These six outcomes are as follows:

- Increasing global warming (WARMING);
- Further concentration of the agri-food industry, including agriculture, food processing, and trade (CONCENTRATE);
- Increasing importance of local food supply systems (LOCAL);
- Increasing use of biotechnology in agricultural production (BIOTECH);
- Increasing importance of satisfying individual food demands (INDIV); and
- Increasing global food supply issues (SUPPLY).

The group of six experts was asked to develop the input matrices based on the summary survey results. Their charge was to estimate the probabilities and conditional probabilities of the six outcomes described above, including: 1) the probability of occurrence of a given outcome without taking into consideration the other outcomes (*a priori* probability); 2) pairwise estimation of the probability of each event occurring given that the other event in the pair occurs (Appendix A, equation 8); and 3) pairwise estimation of the probability of each event occurring given that the other event in the pair does not occur (Appendix A, Equation 9). In this way, we obtained a vector of *a priori* probabilities consisting of six elements and two matrices of conditional probabilities. We then calculated simple averages of all of the individual estimations. The final estimates were determined by group discussion until a consensus was reached. The vector of *a priori* probabilities and the two matrices of conditional probabilities served as the input to the Smic-Prob-Expert software for the generation of the scenarios. The *a priori* and conditional probability estimates are presented in Tables 6, 7, and 8.

Table 6. *A priori* Probabilities of Events

Event	Probability of Occurrence
LOCAL	0.81
WARMING	0.87
CONCENTRATE	0.65
BIOTECH	0.82
INDIV	0.85
SUPPLY	0.78

Table 7. Conditional probabilities of different events based on the occurrence of conditional events

	Probability Event					
Conditional Event (Event Occurs)	**LOCAL**	**WARMING**	**CONCENTRATE**	**BIOTECH**	**INDIV**	**SUPPLY**
LOCAL	-	0.87	0.55	0.72	0.85	0.69
WARMING	0.92	-	0.74	0.90	0.82	0.95
CONCENTRATE	0.60	0.87	-	0.92	0.81	0.77
BIOTECH	0.71	0.87	0.70	-	0.87	0.72
INDIV	0.90	0.87	0.65	0.88	-	0.78
SUPPLY	0.92	0.87	0.77	0.90	0.75	-

Table 8. Conditional probabilities of different events based on the non-occurrence of conditional events

	Probability Event					
Conditional Event (Event Doesn't Occur)	**LOCAL**	**WARMING**	**CONCENTRATE**	**BIOTECH**	**INDIV**	**SUPPLY**
LOCAL	-	0.84	0.78	0.91	0.58	0.72
WARMING	0.68	-	0.57	0.64	0.70	0.57
CONCENTRATE	0.84	0.54	-	0.65	0.85	0.59
BIOTECH	0.75	0.92	0.60	-	0.61	0.84
INDIV	0.62	0.84	0.87	0.73	-	0.82
SUPPLY	0.54	0.67	0.51	0.54	0.82	-

In the following discussion, we examine how the expert panel viewed the likelihood of each of the six events both independently and in relation to the other events. In addressing the global warming and supply issue variables we discuss how these expert assessments compare with those from other forecasting and scenario analysis studies as well as the assessments of other experts. Because the number of studies relating to these events is extremely large, we have chosen to limit our discussion to only a few, representative studies that we deem most relevant based on the extent to which the studies address factors relevant to global agriculture and food systems.

The subject of global warming and climate change has received a great amount of attention by politicians, scientists, activist groups, and the public in general. Moreover, a great deal of research has been devoted to the topic. Among our experts, there is a strong consensus that global warming is almost certain. This is our strongest and most consistent finding with an estimated likelihood of 0.87. Interestingly, the pairwise probability estimates indicate that the prospect of global warming is perceived to be generally independent of the occurrence or non-occurrence of other events (Tables 6 and 7). Only when the CONCENTRTATE or SUPPLY events are not expected to occur is the probability of WARMING deemed to be substantially less. One interpretation is that supply issues and further concentration may be seen as indicators of more rapid development and that the absence of these events may be interpreted as an indicator of slower development which in turn may make severe climate change less likely.

Our results are highly consistent with the results of many recent studies and reflect growing consensus in the scientific community that global warming is inevitable. The IPCC estimates various scenarios for climate change with projected increases varying between 1.8^0C to 4^0C for the period of 2000 to 2100 (IPCC 2007). In another study, Rogelj, Meinshausen, and Knutti (2012) estimate global temperature increases of 2.3^0C to 4.6^0C above the pre-industrial level by 2090 to 2099.

The impact of global warming on agriculture is less certain and will likely depend on other factors. Gornall et al. (2010) argue that climate change will have both positive and negative impacts on agriculture and that the outcome is location dependent. Some regions are likely to benefit from increased rainfall while others will experience a decrease in precipitation. Likewise, some crops are expected to benefit from increased temperatures while others will suffer. Despite the predictions of variable responses to climate change, Jaggard et al. (2010) note that the increased prevalence of extreme events, including heavy rainfall, flooding, extreme heat, and droughts will negatively affect food production overall. The IPCC (2007) also predicts an overall reduction in crop yield and lower livestock productivity as a result of climate change.

We view the possibility of supply issues (SUPPLY) as closely related to that of climate change. This is supported by our expert panel's evaluations. While the independent probability expectation of supply issues is 0.78, this increases to 0.95 should WARMING occur. Indeed many of the potential supply issues could be triggered global warming, including water availability, crop and livestock productivity, restrictions on the use of fossil fuels, and the susceptibility of agricultural production to extreme events such as droughts and floods.

Supply issues, particularly those focusing on specific resources, such as land, water, or energy, have been the focus of many studies. Lambin and Meyfroidt (2011) note that the supply of land not currently in production is expected to be exhausted by 2050. Alcamo et al. (2007) predict that water stress will increase in the majority of river basins (62% to 76%) and that the principal cause will be increasing water withdrawals. Hejazi et al. (2014) foresee that a growing demand for water will result in low to severe water scarcity in most regions of the world by 2050, with the severest scarcities occurring in the Middle East, India, and China. Aleklett et al. (2010) conclude that peak oil production has already occurred and that there will be a "gentle" decline between 2008 and 2030 in production in their "Uppsala" scenario. The expectation of our panel of experts that supply issues will likely be an important characteristic of the agri-food sector are consistent with the many studies that foretell increasing scarcity of some of the primary inputs to the agri-food sector, specifically, land, water, and energy.

The increasing use of biotechnology in agricultural production (BIOTECH) was estimated to have a probability of 0.78. In contrast with some of the other factors, particularly global warming, the BIOTECH factor is not expected to have a large impact on the occurrence of other events. That is the occurrence or nonoccurrence of this event does not generally influence the experts' assessment of the likelihood of other events. We feel that it is significant that the BIOTECH factor was assigned such a high probability of occurring by the panel, especially given the controversy surrounding the technology in much of the world. While an overwhelming majority of the global scientific community supports the application of modern biotechnology (Varshney et al. 2010; Ahmad et al. 2012), the political debate is far from over. Even the United

States, which has traditionally been at the forefront of the application of biotechnology, there is a move in many states to mandate labelling of genetically modified foods.

The expert group assigned a high probability estimate (0.81) to the increased importance of local food production systems (LOCAL). Moreover, the probability that local food systems will grow in importance is estimated to be higher than its *a priori* estimate should the world experience increased individualization in food demand (INDIV), increased food supply issues (SUPPLY) and increased global warming (WARMING). Our interpretation is that global warming, supply issues, and individualization of consumer demand will lead to an increased emphasis on local food production.

The importance of satisfying individual food demands (INDIV) had an *a priori* estimate of 0.85. The results of the pairwise, conditional probabilities indicated that the INDIV variable did not vary much with the occurrence of other events. However, the demand for individualized foods was perceived as much less likely should the increased importance of local food systems or the increased acceptance and use of biotechnology not occur. We believe that it is likely that the demand for local and individualized food may be driven by the similarities in consumer preferences associated with the outcomes. While the link between the use of biotechnology and individualization of food demand is less clear, we see the application of biotechnology as key to the development of specific products, such as nutraceuticals, that will enable the production of individualized food products.

The further concentration of businesses in the agri-food chain (CONCENTRATE) was deemed to be the least likely of the six outcomes, although it was estimated to have a roughly two-thirds chance of occurring (0.65). In contrast to some of the variables WARMING and BIOTECH, the concentration of firms in the agri-food sector is viewed as being dependent on other outcomes. The expert panel expected increased concentration in the agri-food sector to be more likely in the event that global warming (WARMING) or global supply issues (SUPPLY) occur. This can be seen by comparing the relatively high probability assigned to firm concentration should global warming or supply issues develop as compared to the *a priori* estimation of the probability of agri-food firm concentration. On the other hand, the expert assessment of the probability of further industry concentration drops when it is assumed that global warming or supply issues do not develop. We believe that this assessment is due to the presence of scale effects associated with issues that might accompany global warming or supply problems. In other words, larger firms may be better equipped than smaller firms to deal with the significant challenges associated with global warming and supply issues.

Scenario Analysis

Based on the expert estimations of *a priori* and conditional probabilities of the six different outcomes, we generated a set of scenarios using the Smic-Prob-Expert algorithm. The output of the algorithm is a set of scenarios with different combinations of the six outcomes. Although 38 scenarios were generated, only the three scenarios with a probability of at least 10% are presented and discussed below. The three scenarios along with a descriptive name and the probability of the scenario's occurrence are presented in Table 9. The subsequent discussion will

focus on how the various events within the three listed scenarios relate to each other and add "color" to the main features of each of the scenarios.

Table 9. Three most likely scenarios for the Agri-Food Industry

Scenario Name	Scenario Characteristics	Probability (%)
PANTA RHEI (Everything Moves)	Includes… - increasing effects of global warming - increasing concentration of agricultural, food processing and trade - increasing importance of local food production systems - increasing use of biotechnology - increasing individualization in food consumption - increasing food supply problems	26
DISTRIBUTED FOOD SYSTEMS	Includes… - increasing effects of global warming - increasing importance of local food production systems - increasing use of biotechnology - increasing individualization in food consumption Without - increasing concentration of agricultural, food processing and trade - increasing food supply problems	19
CONCENTRATED SUPPLY SYSTEMS	Includes - increasing effects of global warming - increasing concentration of agricultural, food processing and trade - increasing use of biotechnology - increasing individualization in food consumption Without... - increasing importance of local food production systems - increasing food supply problems	12
All other scenarios		43

The highest probability scenario (26%) is characterized by presence of all of the principal outcome variables. We call this scenario PANTA RHEI[1] or Everything Moves. PANTA RHEI forecasts a future of concentrated agri-food systems, characterized by considerable changes in

[1] Πάντα ῥεῖ (*panta rhei*) "everything flows," or "all things are in flux"–a Greek philosophical statement, falsely attributed to Heracleitos. This phrase is attributed to Theodorus, an associate of Protagoras (Chappel 2004).

the conditions of agricultural production (supply issues and global warming), increased application of biotechnology, and local and individualized food production.

One way to view this scenario is that it represents a collection of all of the outcomes viewed as likely by the expert panel. It includes three outcomes that represent the continuation of strong trends affecting the agri-food system and which have been well-documented: global warming (IPCC 2007), increased firm concentration within the agri-food sector (Watts and Goodman 1997), and increased emphasis on local food systems (Feagan 2007). A fourth outcome, global food supply issues, may be viewed as related and at least somewhat dependent on the global warming outcome. We view the final two predicted outcomes, the growing demand for individualized food products and the increasing use of biotechnology, as less certain. Both of these outcomes represent relatively recent trends and in the case of genetic engineering the path to public acceptance has been problematic in much of the world.

The presence of all six outcomes in the PANTHA RHEI scenario may seem somewhat contradictory. In our analysis of the conditional probabilities, we saw that some variables are perceived as more or less likely depending on the occurrence or nonoccurrence of other variables. However, under PANTHA RHEI all of the events are expected to occur. This begs the question of how all outcomes might occur simultaneously despite apparent contradictions between some outcomes. For example, increased concentration in the agri-food chain is in apparent conflict with the growing importance of local food systems. Of course, there are multiple pathways whereby the events might occur and in fact relate to each other. We can envision a world wherein increased concentration in the production of food may be a viable way to confront the challenges of global warming and the associated supply issues because of the increased efficiencies that might be achieved. However, increasing firm concentration does not necessarily imply increasing geographical concentration. It is entirely possible, if not likely, that demand for locally produced food may be met by large firms with sophisticated production and operation systems that focus on regionally- or locally-appropriate production systems. Hawkes and Murphy (2010) argue for this nuanced view, whereby we experience increasing globalization even as firms engage in local production through what they call “multi-domestic strategies.”

The second scenario, DISTRIBUTED SYSTEMS, has a probability of 19%. It foretells a world that emphasizes local production without further concentration of agricultural production and distribution capacities and without major food supply issues. Global warming is expected to occur as is the increased use of biotechnology and greater individualization of the food supply. This scenario provides insight into how an unexpected configuration of events might occur based on adaptation within the global food system in response to external events.

One factor that could give rise to this scenario is rising energy prices, possibly in response to global warming, which would lead to considerable increases in transportation costs (Egger et al. 2013). Higher energy prices would make food produced in distant locations relatively more expensive than that produced locally, other things equal. This scenario highlights the increasing tendency to internalize the full cost of energy, which could lead to a shift to more local food production systems (Fouquet 2011). Moreover, this scenario is consistent with the local food movements’ emphasis on reducing “food miles.” This scenario, with the absence of increased supply pressures, is supported by results of Parry et al. (2004). According to their simulation

results, a less concentrated (more regional) food production system would result in lower yield reductions than would a system with more concentrated production. A system as described by our DISTRIBUTED SYSTEMS scenario would meet Dahlberg's (1992) vision of a food system that achieves a global balance between food, population, resources, and the conservation of genetic and biological diversity by emphazing the importance of local and regional markets, maintaining farm and regional diversity, rural revival, decentralization, and utilizing local species.

The CONCENTRATED SUPPLY SYSTEMS scenario (probability of 12%) foresees a world without increasing supply pressures and is in some ways the opposite of the DISTRIBUTED SYSTEMS scenario. It portrays a world with more concentrated production, processing, and distribution systems without an increased emphasis on local production. Global warming is expected to occur along with the increased use of biotechnology and growing individualization in the food supply.

As we discussed previously, expert opinion was split on the likelihood of increased concentration in the subsectors of the agri-food system, which may in part explain the contradictory visions of how the global food system will evolve. The impacts of increased firm concentration in economic systems in general (Daughety 1990; Brock and Obst 2009), and on the agri-food chain in particular (Sexton 2000), have been heavily debated with strong arguments on both sides of the issue. Apart from the academic debate, it is clear that numerous forces support continued concentration of firms in food production processes. One such force is a persistent tendency towards concentration in the agricultural inputs industry (USDA, ERS 2001). Another force is regional economic integration that promotes geographical concentration, a phenomenon that has been demonstrated in the case of the European Union (Krieger-Boden et al. 2008), and ASEAN countries (Kuroiwa 2012). Yet, a third force is the increasing activity of multinational companies in the agri-food sphere (Rama, 2005).

On the other hand, proponents of emphasizing local food production argue that reducing the number of miles that food travels benefits the environment (Pretty et al. 2008). However, there is increasing evidence that focusing primarily on food-miles may lead to serious unintended consequences or be less effective than other strategies in increasing sustainability. Ballingall and Winchester (2010) have shown that decreasing the number of miles that food travels could actually have a negative effect on world's poorest economies without yielding a significant reduction in environmental damage. Weber and Matthews (2008) show that the greenhouse gas emissions associated with food are dominated by the production phase (83%) and that long-distance transportation and the final delivery from producer to retail contributes to only 15% of life-cycle emissions. They argue that a much more effective strategy to lowering a household's climate footprint is to shift consumption away from red meat to chicken or fish. While a move away from local production appears to run counter to current consumer preferences, it may be the preferred option once consumers better understand the full implications of their choices.

Shaping the Global Food System of 2030

We have chosen the title of the concluding section deliberately so as to highlight the possibilities that our described in our analysis. It would be misleading to view scenario modeling from a probabilistic perspective whereby we simply look at the most likely scenarios and plan accordingly. While there is value in examining the probabilities associated with the scenarios, viewing them from this perspective misses the point. We see the true value of the analysis in what it contributes to our understanding of the situation, the relationships it reveals, and the conversations, research, and policy analysis it will inspire.

Maack (2001) suggests that there are four primary uses for scenario analysis, managing risk, building consensus for change, augmenting understanding about the future, and monitoring and scanning changes in the environment. Each of these uses will prove beneficial and insightful for the scenarios we have developed for the agri-food sector in 2030. Food production is inherently risky and it is likely to become more so as we deal with the unfolding implications of climate change. It is imperative that we identify the key variables in this complex system and understand the relationships among them in order to identify the critical levers for change that will lead to a stable and robust global food system in 2030 and beyond.

It is with this perspective that we view the scenarios we have developed and ask several questions, including: What are the key variables and the relationships between them? How can we manage and influence change as well as minimize risk? What do the most likely scenarios tell us about the future and the opportunities to shape the global food system in 2030?

As we examine the scenarios, the major outcomes, and future state variables, it is tempting to view the factors in light of the probabilities assigned to them. For example, our panel of experts believes that the global warming outcome has approximately a 90% chance of occurring. While global warming is viewed as almost inevitable, it is not a simple binary outcome, that is, it is not as if global warming will either occur or not occur. It would be more accurate to think about the extent to which global warming will happen. In fact, Keith (2014) argues that we could reduce global warming in short order by spraying tiny droplets of sulfuric acid into the upper atmosphere (this does not come without its own environmental costs). None of the events or outcomes is known with certainty and all of them may be and likely will be influenced by actions taken by people, organizations, and governments.

Two variables that play a central role in the scenarios we have developed are global warming and food supply issues. They are key outcomes because they are considered to be very likely to occur, they are expected to have a large impact on the system, and they are interrelated (supply disruptions are expected to increase due to global warming). Moreover, the supply issues that result from changing worldwide moisture and temperature patterns, specifically the possibility of reduced and more variable yields (including total crop failure), will likely represent the most serious impacts of global warming on the global food production system. Indeed, the strongest relationship between outcomes in our model was between global warming and supply disruptions.

Two key industry variables that have the potential to shape the global agri-food landscape emerged in our analysis: the use of biotechnology and the concentration of firms in the industry. We view these as important because of the possibilities for these outcomes to influence the ability of industry to respond to changing circumstances and their impact on consumers. The use of biotechnology in agriculture, particularly genetic engineering, has been a lightning rod for the expression of consumer concern. Regardless of the outcome of regulatory and labeling disputes, biotechnology must be viewed by policymakers as a critical tool to modify plants and animals so that yields may be maintained in the face of climate change. Specifically, biotechnology could prove useful in developing heat- or drought-tolerant crops. Again our model showed strong relationships between the use of biotechnology and the global warming and supply disruption variables.

The level of industry concentration will also be of great interest to policymakers as issues of monopoly power and control over the food supply make this an issue of high interest to both governments and consumers. Moreover, the concentration of firms in the agri-food sector and the extent to which we rely on local food systems will be important determinants of the structure of the global food system. Will food production, processing, and distribution be controlled by a few, large, centrally-organized firms, or will we have a more distributed system where decisions are made at the regional level? Regardless of the organizational form, will the world rely on highly-concentrated, mass production systems or numerous, local, diversified, specialized growers, or will we see some intermediate outcome? What combination of these factors will most effectively meet the challenges posed over the next decades and satisfy consumers as well? Additionally, what role will rising consumer demand for individualized food products play in this evolving system?

The three scenarios that we describe exhibit stark differences that should give us pause. They should cause us as citizens, societies, policymakers, interest groups, and governments to consider the nature of the food system we want envision for the coming decades and what must be done to shape that system. Many of the factors and outcomes involve long-term, complex issues that will require early action to achieve the desired outcomes. Global warming is well underway and the decisions we make today will have a limited impact on temperatures in 2030. Nevertheless, the scenarios we describe paint alternative visions of the future that can serve as a catalyst for discussion surrounding what outcomes are most desirable, what actions must be taken, and how we will measure progress toward meeting the goals that are established.

With regards to global warming and the supply disruptions that it may cause, the scenarios we describe contain two contrasting visions of the world in 2030. In both cases global warming occurs. However, in one scenario (PANTHA RHEI) it occurs with major supply issues while in the others (DISTRIBUTED SYSTEMS and CONCENTRATED SUPPLY SYSTEMS) global warming occurs without major supply disruptions. The discussion surrounding these very different scenarios will certainly center around which scenarios are more desirable, which outcomes are most favorable, and what steps must be taken to achieve the desired outcomes. With regards to global warming and the potentially severe impact it may have on global food supplies, we can envision many possible responses that would address the most severe effects of global warming. These include investing in research to adapt crops and focusing on water conservation and/or building additional water storage capacity in order to mitigate some of the

worst disruptions to the food system caused by climate change. Likewise, each of the other outcomes (use of biotechnology, firm concentration, local food production, and individualization) should be explored as they were revealed to be key variables that will influence the important future state variables that will define the global food system in 2030.

The scenarios that we describe should encourage a discussion of how we approach the major issues facing the global food system. Historically, we have often addressed problems with targeted solutions that address the symptoms but not the underlying issues. Will this be our answer to emerging problems or might we take a more holistic perspective that delivers solutions that assure the health of the entire system? Scenario analysis can help elucidate the choices and encourage discussion of a broad set of alternatives so that outcomes are not foregone conclusions. If we look far enough into the future and address emerging issues before we are in crisis, we have a greater opportunity to consider a variety of approaches, experiment with solutions, monitor key indicator variables, and ultimately develop responses that are better-suited to the problem and more consistent with societal values.

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Appendix A

Mathematical foundations of the Smic-Prob-Expert approach (Source: Duperrin and Godet, 1975)

For the estimation of the probability of an event:

(1) $\mathbf{H} = (e_1, e_{2,}. \ldots e_n)$,

where **H** represents the list of events denoted as e_i.

The probability that an event will occur is denoted by P(i). The conditional probability of event e_i when e_j event occurs is denoted by P(i/j) and the conditional probability of the occurrence of e_i if the e_j does not occurs is denoted by $P(i/\bar{j})$, subject to the following constraints.

(2) $0 \leq P(i) \leq 1$;

(3) $P(i/j)P(j) = P(j/i)P(i) = P(ij)$,

referring to the estimation of the probability of event e_i when the event e_j occurs: and

(4) $P(i/j)P(j) + P(i/\bar{j})P(\bar{j}) = P(i)$,

referring to the estimation of the probability of event e_i when the event e_j does not occur.

In a system **S,** consisting of n separate events, there will be r possible states, where $r=2^n$.
The separate events are considered to be non–recurring during the time period T being studied.

Each state E_k has an unknown probability, Π_k, where $\sum \Pi_k=1$.

For each separate event e_i we can determine individual and conditional probabilities, espressed as a function of Π_k.

(5) $P^*(i)= \sum_k \Theta_{ik}\Pi_k$,

where $\Theta_{i,k} = 1$ if e_i forms part of E_k and $\Theta_{i,k} = 0$ if e_i is not part of E_k.

The conditional probability P*(i/j) can be expressed as a function of Π_k and P*(j) as follows:

(6) $P^*_{(i/j)} = \dfrac{\sum_{k=1}^{r} t(ijk)\Pi_k}{P^*(j)}$,

for all *i,j*, where $t_{(ijk)} = 1$ if e_i and e_j are part of $\boldsymbol{E}_{k,}$ and $t_{(ijk)}=0$ if e_i and e_j are not part of $\boldsymbol{E}_k$.

In an analogous way, the conditional probability of the occurrence of P(i) in the case of the non-occurrence of P(j) can be expressed as:

$$(7)\ P^*_{(i/\bar{j})} = \frac{\sum_{k=1}^{r} s(ijk)\Pi_k}{1 - P^*(j)},$$

for all *i,j*, where $s_{(ijk)} =1$ if e_i and $\underline{e}_j$ are part of $\boldsymbol{E}_k$ and $s_{(ijk)} = 0$ if e_i and $\underline{e}_j$ are not part of $\boldsymbol{E}$.

In this way the algorithm is capable of incorporating the expert-estimations in such a way that the results conform to the following constraints:

$$(8)\ 0 \leq P^*(i) \leq 1,$$

for the probability of occurrence of P*(i) event;

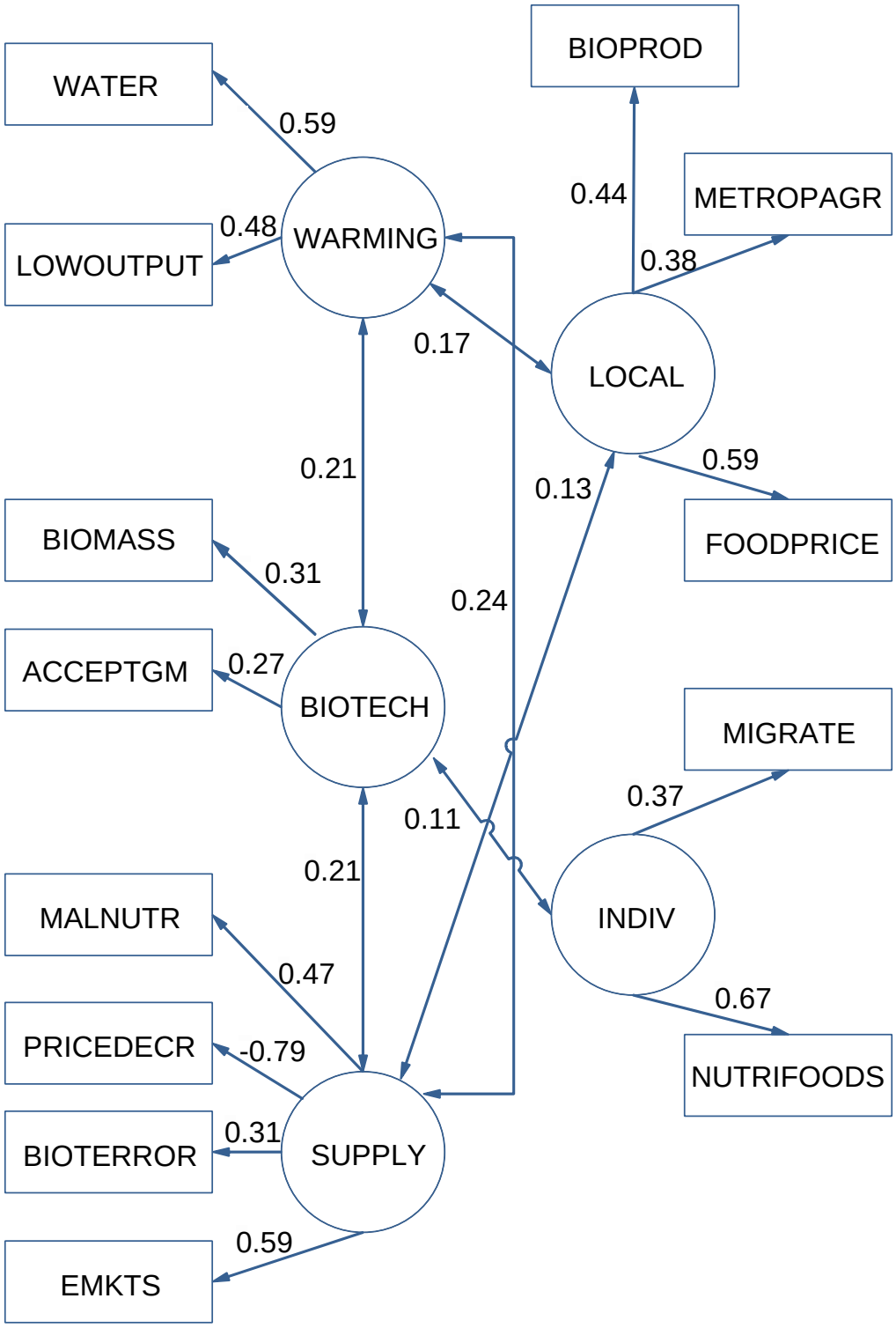
$$(9)\ P^*(i/j)P^*(j) = P^*(j/i)P^*(i) = P^*(ij),$$

for the conditional probability of P*(i) event, if P*(j) event occurs; and

$$(10)\ P^*(i/j)P^*(j)+P^*(i/\bar{j})P^*(\bar{j})=P^*(i),$$

for the conditional probability of P*(j) event, if P*(j) event does not occur.

Appendix B



Structural equation model of the future of the agri-food sector

Note. The values shown between latent and future state variables figure are standardized regression coefficients; the values between the latent variables are correlation coefficients.

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Key Success Factors of Innovation Projects of Vegetable Breeding Companies in China

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Abstract

The vegetable breeding industry is generally recognized as an innovation-driven industry. However, innovation is costly, time-consuming and uncertain. This study aims to identify the key success factors of innovation project performance of vegetable breeding companies (VBCs) in China. Based on empirical data that was collected from 53 innovation projects in 38 VBCs, it was found that integrative capabilities play an important role in the novelty and newness of the innovation to enhance product potential (superiority) and also in improving functional capabilities and in gaining market potential. Furthermore, market competition is a positive factor for inspiring innovation in the breeding industry.

Keywords: Key success factors, integrative capabilities, innovation project performance, vegetable breeding companies, China

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Introduction

As agricultural inputs, such as arable land, labor, fertilizer, crop protection, and irrigation grow increasingly scarce or more expensive, continuous improvements in crop production are expected in the quality of varieties used. This requires continuous innovation in the plant breeding industry in order to meet the challenges of food production and consumption through the development of new varieties with higher yields, resistance to biotic stresses, tolerance to abiotic stresses and better quality. This is especially true for the vegetable breeding industry in a country like China, which accounts for nearly half of the world's vegetable production and consumption, yet its average yield is 1/3 lower than in western European countries (FAO 2012). Vegetable breeding companies (VBCs) in China are embedded in a competitive environment and this industry has been experiencing restructuring since 2001. Old companies have merged and new players have entered the market. Companies from various backgrounds such as traditional seed companies, vegetable research institutes, foreign seed companies, new biotechnology and agrochemical companies, food processors and wholesalers/retailers now compete and/or collaborate in supplying seed to the market. Their performance is increasingly dependent on continuous improvement of breeding processes and the fast introduction of innovative products (new varieties). The vegetable breeding industry is recognized as an innovation-driven industry, which invests intensively in research and development (R&D). It requires large financial resources to apply innovative technologies for the development of new varieties (Dons and Bino 2008).

In a survey conducted by the American Management Association (AMA) (Jamrog 2006), innovation was identified by more than 90% of 1,400 top executives from large-multinational companies as important to a company's long-term survival. However, innovation is also costly, risky, time-consuming and uncertain. For example, Cooper and Edgett (2009) found that 44% of all innovation projects fail to achieve their profit target, only one out of seven concepts for new products becomes a new product winner and half of all new product launches are late to market. In our research on the vegetable breeding industry, senior managers of all prospector companies indicated that innovation is essential to their business. They set up strategies to fight for product leadership, position the R&D department as the core functional unit, and organize the R&D activities on innovation project base. The duration of innovation projects in the breeding sector is long, it takes about 6-8 years to develop a new variety and this might even be longer for specific crops. The new variety needs to combine good traits to ensure optimal performance under a variety of conditions including: resistance against pests and diseases, tolerance to extreme climate conditions such as drought, flood, salty conditions, etc. and; catering to consumers' demand for better taste, improved nutrition and longer shelf time. In China, for instance, the plant breeding industry has to innovate quickly in response to the changing Chinese customer demands, which are highly affected by changing lifestyles. In addition, crop production can be highly influenced by the unpredictability of nature, such as the frequency and intensity of extreme weather events (de'Donato and Michelozzi 2014).

Previous studies of innovation in the seed industry were either about seed policies or the seed business in general. These were studies about intellectual property rights (Srinivasan 2004; Lence et al. 2005; Louwaars et al. 2005; Dons and Louwaars 2009; Hu et al. 2009; Moschini

2010), the impact of seed industry concentration (Schimmelpfennig et al. 2004; Howard 2009; Schenkelaars et al. 2011), production, trade and related institutions (Kamphuis 2005), entrepreneurial processes (Kumar and Ali 2010), industry structure (Huang et al. 2001; Gadwal 2003), marketing (Larson and Mbowa 2004), and the supply chain (Burer et al. 2008). However, few studies focused on the innovation project level. In this research, we aim to find the key success factors and mechanisms that affect innovation project performance in the vegetable breeding industry, using empirical data from on-going R&D projects of VBCs in China.

The next section provides an overview of the theoretical background and conceptual framework. It addresses definitions and previous research conducted on innovation and innovation management. Key success factors in previous innovation projects are reviewed. A conceptual framework and hypotheses concerning the relationship between innovation-related factors, integrative capabilities, organizational capabilities, innovation potential and project performance are introduced. The methodology section describes the method of data collection, the measurements, as well as the method of analysis. In the results section, the results based on PLS modelling are presented, and discussed again in the last section with general conclusions and managerial recommendations for the vegetable breeding industry in China.

Theoretical Background

Innovation

Innovation is highly recognized as one of the major drivers of business success and economic development in the knowledge-driven economy nowadays. Researchers have found that innovation makes a significant contribution to economic growth, as it is the basis for increasing productivity, both through incremental improvements and breakthrough change (Pavitt 1969). Innovation is also widely recognized as playing a central role in creating value and sustaining competitive advantage (Jamrog 2006).The concept of innovation was initially defined by the economist Schumpeter as a process of creative destruction, where the quest for profits pushes innovation by constantly breaking old rules to establish new ones (1934). It implies introduction of new products, new processes, the opening of new markets or the introduction of new organizational forms. Since then, innovation is of interest to researchers and practitioners across a range of business and management disciplines. Based on the review of 60 definitions of innovation collected from the various disciplinary literatures, a generic definition of innovation, given by (Baregheh et al. 2009), is "*the multi-stage process whereby organizations transform ideas into new or improved products, services or processes, in order to advance, compete and differentiate themselves successfully in their marketplace"*.

Innovation Project Management

Management of innovations projects is challenging, as innovation is a broad-ranging, complex and difficult issue. Starting with the SAPHHO study (Rothwell 1972) and Cooper's pivotal work developing the NewProd assessment tool (Cooper 1979; Cooper and Kleinschmidt 1987; Cooper 1999), numerous empirical studies have been conducted in order to disclose the key success factors of innovation projects. Various groups can be recognized within these studies. One group focused on factors related to planning and execution of the innovation process, such as select the

right project, clearly define the role of the project, organize true cross-functional projects teams, build tough go/kill decision points into process, etc. (Cooper 1978; Cooper and Kleinschmidt 1987; Johne and Snelson 1988). Another group of studies focused on in-depth aspects of information-processing, such as communication, knowledge sharing, selection of new ideas, etc. (Cooper 1999; Lievens and Moenaert 2000; Fortuin et al. 2007; Aramburu and Saenz 2010; Oke and Idiagbon-Oke 2010; Tranekjer and Søndergaard 2013). The third group focused on tangible resources, such as physical and finance assets, and intangible resources, such as human capital and reputation, as strengths from which the company distinguishes itself from competitors and ensures its competitive advantage (Grant 1991; Balachandra and Friar 1997; Barney et al. 2001; Belout and Gauvreau 2004; Blindenbach-Driessen and van den Ende 2006; Lu and Yuan 2010). From resource-based view, both resources and capabilities to develop resources are important, because innovation requires creative and innovative re-combination of resources and skills (Grant 1991; Teece et al. 1997) to develop superior new products and introduce them quicker in the market. The different groups of studies aligned to the research results from Harmancioglu et al. (2009) suggest that successful management of innovation projects is often related either to the proficiency of the project execution or to the fit between the resources and capabilities with the requirements of the project.

Based on these studies, Tepic et al. (2013) summarized the factors that influence innovation performance into three categories:1) innovation-related factors, i.e. product novelty and newness of innovation project to the company; 2) organizational capabilities, including functional capabilities that are related to specific knowledge of the different functional units of the company, e.g. R&D, manufacturing, marketing, distribution, sales and financing, etc., and integrative capabilities that refer to communication, team interaction, knowledge sharing; and 3) innovation potential (i.e. product and market potential).

Innovativeness and Newness

Innovation can vary from incremental innovations, which reproduce existing products with marginal improvements to current practice (Amasona et al. 2006), to radical innovations, which are completely novel and totally different from existing practices. Innovativeness and newness are two dimensions that both affect management and outcome of innovation projects, because these two aspects are considered as uncertainty enhancing factors in innovation processes (Tepic et al. 2013). Innovativeness is positively linked to product advantage, which refers to customer-perceived superiority (quality, benefit, functionality) and has been noted as a strategic factor that drives new product performance (Montoya-Weiss and Calantone 1994, Subramanian and Nilakanta 1996, Zhou 2006).

Innovation newness to the company is determined by the extent to which the customers, competitors, customer needs, market, product are new to the company (Danneels and Kleinschmidtb 2001). Although newness of an innovation might enhance product potential (superiority), it could also have a negative effect on the innovation process itself. Speed of market introduction could be decreased because of the task-related uncertainty and high complexity. Or there could be inadequate functional capabilities at hand to execute innovative projects that are new to a company (Cooper and Kleinschmidt 1987).

Functional Capabilities and Integrative Capabilities

From the resource-based view of innovation management, adequate resources and the capabilities to develop those resources are important. Innovation requires a creative and innovative re-combination of resources and skills to develop superior new products and introduce them quickly into the market (Grant 1991; Teece et al. 1997). Two capabilities are considered especially important within the context of innovation (Tepic 2012). One is functional capabilities, which are related to deep and specific functional knowledge, e.g. R&D, manufacturing, marketing, distribution, sales and financing. These different kinds of knowledge enable the company to execute innovation projects adequately, to develop novel products in a timely fashion, to screen, use and disseminate market information properly, and to capture customer needs and preferences precisely, as well as to ensure sales, distributions and services. The second factor is the integrative capabilities, e.g. communication, team interaction and knowledge sharing. These capabilities are important for the combination and assimilation of the different competencies present in various company departments (Grant 1991,1996, 2009).

Product and Market Potential

Based on integrative and functional capabilities, the innovation team works with the novelty, complexity and newness of innovation, and then the transformation into product potential (superiority). Product potential refers to the superiority of a new product in terms of better quality, unique features or attributes, reduced costs, high technology, etc., compared to current or competing products. The market potential refers to the market demand for new product in terms of large volume, quickly grow, great need, etc. These will be further described in the following section.

Conceptual Model and Research Hypotheses

Conceptual Model

To understand the dynamics of innovation processes, we propose a conceptual model (Figure 1), based on the three essential key factors in innovation project performance and further investigate the interactions of these factors. Firstly, integrative capabilities play an important role as they are the basis to acquire external information and identify new opportunities, which could be assimilated into developing novel products. Functional capabilities present in the company could facilitate the transformation of innovative ideas into novelty products. However, if the innovation project is too new to the company, it could be a challenge to have adequate functional capabilities to deal with. Novel products could have big potential and eventually a good market potential. Finally, the functional capabilities together with market and product potential will affect the innovation project performance, which could be also influenced by external environment such as market competition.

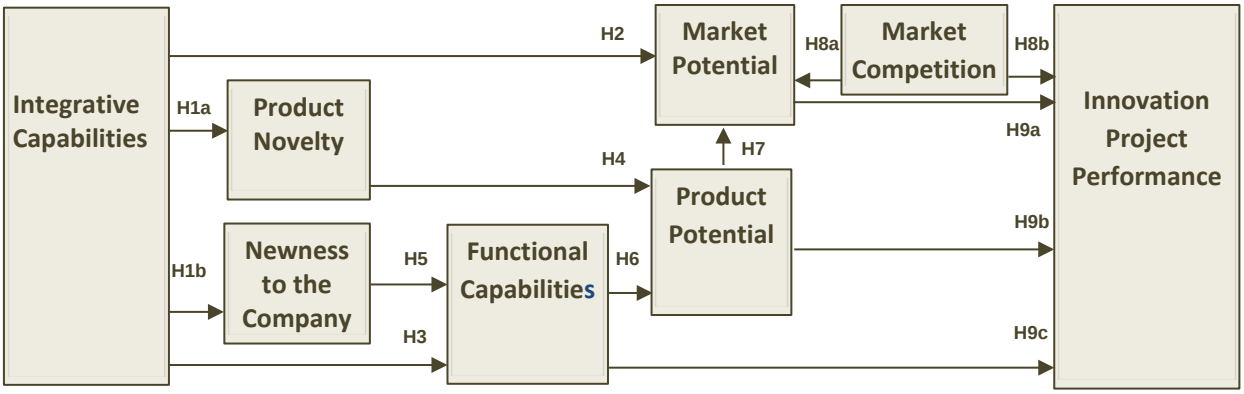

Figure 1. Conceptual model, the interaction of key factors in innovation project performance.

Research Hypotheses

Novelty is highly emphasized as important by many researchers in studies on innovation (Amara et al. 2008; Therrien et al. 2011). However, determination of the value of new products is mainly based on existing knowledge and that might create barriers to innovation (Carlile and Lakhani 2011). Integrative capabilities, e.g. communication, team interaction and knowledge sharing are important to overcome such barriers, because it creates clarity and understanding of the value of new knowledge, and to acquire a shared understanding of complex, inter-related activities. Previous research about new product development found that the qualities of communication, team interaction, and knowledge sharing have a positive effect on the innovation process(Kivimaki et al. 2000; Moenaert et al. 2000; Aramburu and Saenz 2010; Kyriazis et al. 2012; Liu et al. 2012a). There are two kinds of communication: one is team communication, which refers to the communication among innovation project team members. Another is cross-functional communication, which refers to the communication between the innovation project team and the other functional units in the company and the collection of information from outside the company. The openness of communication, which is defined as the degree to which team members are willing to exchange their ideas and knowledge within the project team, as well as with the functional units within the company, plays an important role in knowledge implementation (Lin 2011). The openness to acquire internal and external information and exchange information with team members and other functional units will help identify the most advanced technology and latest market trends, and then implement and develop this knowledge in innovation projects. Cross-functional communication can help the company to develop its functional capabilities to support product development (Lievens and Moenaert 2000; Lawson et al. 2009; Kyriazis et al. 2012). Cross-functional communication has been identified as a key driver of new product success, by helping to build and maintain a productive interface between the functional units. It assures that integration takes place among the separate capabilities delivered by engineering, production, and marketing departments (Pinto and Pinto 1990; Griffin and Hauser 1992; Thamhain 2003; Sarin and O'Connor 2009). This leads to the following hypotheses concerning integrative capabilities:

Hypothesis H1: Integrative capabilities will be positively related to product novelty (H1a) and to newness to the company (H1b).

Hypothesis H2: Integrative capabilities will be positively related to identifying the market potential of an innovation.

Hypothesis H3: Integrative capabilities will be positively related to the development of the functional capabilities.

Innovative projects usually need the application of advanced technology to solve complex problems and offer solutions to customers that existing products are not able to offer. From the customer's perspective, product novelty is regarded as levels of change in product attributes and consumer's behavior patterns (Danneels and Kleinschmidt 2001). The degree of novelty is likely to affect the dynamics of disclosure and the speed of new product development (Rindova and Petkova 2007), and would entail a less open discussion with competitors (Cooper 1978; Oakey and Cooper 1991). Furthermore, advanced innovative technologies are not easy for competitors to imitate, because they need to invest heavily to accumulate relevant knowledge and technologies. The more novel the innovation project is, the greater the opportunities for the company to develop outstanding products to meet potential market demand (Im and Workman Jr 2004). Support from a company's different functional capabilities is indispensable in developing successful commercial products. It is also key in acquiring insight into the specific needs of the customer during the design phase, and subsequently developing the adequate production, marketing and sales skills necessary to successfully launch the new product into the market (Cooper and Kleinschmidt 1987). However, Cooper (1979) also found that the newness of an innovation project to the company was negatively related to the success of the project, because it leads to a high level of uncertainty as it might require new engineering skills, new distribution channels or stresses coming from new customers and/or competitors. Therefore, new areas of activities may lead to difficulties and uncertainties when adapting current functional capabilities to these new requirements. This leads to the following hypotheses:

Hypothesis H4: Product novelty will be positively related to product potential.

Hypothesis H5: Newness to the company will be negatively related to the company's existing functional capabilities.

Hypothesis H6: Functional capabilities of the company will be positively related to product potential.

Market potential is defined as the potential demand for a new product in the target market. When a new product shows unique benefits to customers, such as high quality, attractive cost or innovative features, there could be a strong market demand (Mahajan et al. 1979; Im and Workman Jr 2004; Tepic 2012, Flipse et al. 2013). So a positive relationship is expected between product potential and market potential, but highly competitive environments may bring greater uncertainty to an innovation project, as competitors may launch similar products on the market earlier or with a lower price. This could affect innovation performance negatively (Mikkola 2001). It is expected that in case of high market competition, it is more difficult to introduce a new product for which the market is growing very quickly. Therefore, market competition could limit market potential of a new product and negatively influence the innovation project performance (Prajogo and Ahmed 2007). With the support of functional capabilities, companies

can introduce new products, which bring unique benefits to customers and potentially big market opportunities. This leads to the following hypotheses:

Hypothesis H7: Product potential will be positively related to market potential.

Hypothesis H8: Market competition will be negatively related to market potential (H8a) and to innovation project performance (H8b).

Hypothesis H9: Market potential (H9a), product potential (H9b) and functional capabilities (H9c) will all be positively related to innovation project performance.

Research Context and Methodology

The Chinese Vegetable Breeding Industry

The Chinese seed market, second after that of the USA (ISF 2011), has been experiencing a transformation from a centrally controlled industry into an open and active market since the enforcement of the new Seed Law in 2000 (Huang et al. 2001). Recently, the threshold for participation in the seed industry has been increased based on the *Guiding Opinions on Accelerating the Development of the Modern Crop Seed Industry*, released by the State Council in April 2011, and its enforcement regulation – the *Crop Seeds Production & Operation Licensing Rules* (MoA 2010b). This has led to an increase in mergers and acquisitions in this industry, aimed at improving the innovative power and the production of novel products by breeding (crop varieties).

At the end of 2010, there were over 8,700 licensed seed companies in China, but most of them were seed producers, processers, or trading companies. When the threshold for taking part in the seed industry was raised by these new regulations, the number of seed companies decreased to less than 6,500 in March 2013 (MoA 2013). However, the seed industry is still fragmented and integrated breeding companies, who are really active in breeding (and seed production and sales), are still a small group within in the seed industry. There are about 200 integrated breeding companies that operate nation-wide (MoA 2010a). For the vegetable subsector, we estimated that in China only 112 VBCs could meet the following three criteria: 1) the company should be active in breeding; 2) seed production and sales, should focus on vegetables; and 3) have more than 10 employees (Liu et al. 2012b).

The VBCs in China can be divided into three groups: 1) public companies, which are the so-called state-owned companies, often originating from vegetable research institutes; 2) domestic private companies; and 3) foreign private companies, including wholly owned subsidiaries and joint ventures. The public VBCs have had a monopoly in the seed industry in China for a long time. Most state-owned companies went bankrupt or were privatized after 2000 (Tong 2010), whereas vegetable research institutes were encouraged by the government to separate their research and commercial activities, though some are still active in commercializing their cultivars. The number of private VBCs has increased rapidly since 2000, often founded by former plant breeders from research institutes or employees of state-owned companies. The large market opportunities and economic reform in China also attracted foreign VBCs (Liu et al.

2012c). Competition is growing more intense, requiring the VBCs to innovate in order to introduce better performing new products to the market.

Sample

This study focused only on VBCs that are active in innovation and are continuously working on the development of new cultivars for vegetable crops. The target group is the 112 VBCs mentioned above. The list of these 112 VBCs was verified and by several interviewed vegetable seed business experts, in order to ensure they still met the three criteria mentioned above.

In 2009, we conducted an in-depth case study of three Chinese VBCs (one per group) for pre-testing purposes. We interviewed senior managers about their innovation strategy and the organization of innovation in their company, and then asked project managers to complete a questionnaire prior to an in-depth semi-structured interview. Based on their comments, we improved the questionnaire. In 2010 and 2011, we randomly visited 70 of the 112 VBCs to interview the senior managers to gain more insight about innovation management in their companies. These VBCs are located in ten provinces and three municipalities (Beijing, Shanghai and Tianjin), representing the major locations for VBCs and the primary regions of vegetable production in China (Figure 2).

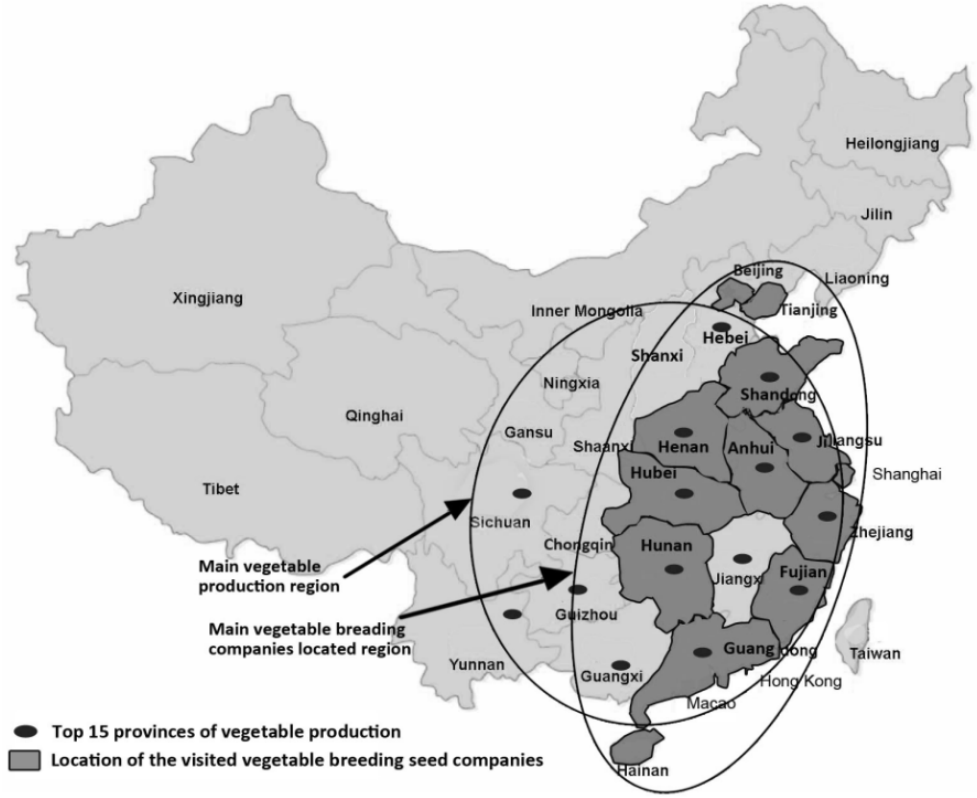

Figure 2. Location of vegetable breeding companies in China, visited for the research and the 15 main provinces known for the production of vegetables.

In 36 of the VBCs, innovation managers filled out a questionnaire about one or two of the most important innovation projects (a respond rate of 51.4%). In total, 53 valid questionnaires were filled out. The questionnaire contained 58 ten-point Likert scale questions about the perception of the respondents on a number of constructs. These were: integrative capabilities, product novelty, project newness to the company, functional capabilities, product and market potential, market competition and innovation project performance. The respondents were asked to indicate to what extent they agreed with the statement using a ten Likert scale going from completely disagree (1) or completely agree (10). The questionnaire was built on the NewProd innovation assessment tool (Cooper 1979), and was combined with questions about the communication capabilities of the innovation team, as developed by Hollander (2002) and was used in Wageningen Innovation Assessment Toolkit (WIAT) (Im and Workman Jr 2004; Fortuin et al. 2007; Batterink 2009).

Construct Measurement and Data Analysis

SPSS was used to select the most relevant items for all constructs by applying exploratory factor analysis with oblique rotation. Thirty-nine items were identified and valid to measures those described constructs (Table 2, see Appendix). A structural equation modeling (SEM) was used to analyze the cause-effect relations between latent constructs, which has become a quasi-standard method in marketing and management research. For many researchers, SEM is equivalent to carrying out covariance-based SEM (CB‑SEM) analyses using software such as Amos, EQS, LISREL, Mplus, and others (Hair et al. 2011a). CB-SEM's statistical objective is to estimate a covariance matrix that matches that of the observed sample data as closely as possible. So the focus is largely on achieving model "fit" assuming valid and reliable constructs.

In this research, Wold's (1980) PLS model was used to test the conceptual model and the nine hypotheses. Besides emphasizing prediction, PLS-SEM offers other advantages. The target of present study was to find key success factors of innovation projects of VBCs, so the use of partial least squares (PLS)-SEM path modeling was chosen, as its overriding objectives predict the dependent (endogenous) variables (constructs) (Hair et al. 2011b). Our sample size was relatively small (53). PLS path modeling has an advantage that it can avoid small sample size problems, and can, therefore, be applied in situations where other methods (e.g. LISREL) cannot be used (Götz et al. 2010). Furthermore, PLS path modeling has several advantages over covariance structure analysis and is generally preferred when: 1) requirements of multivariate normality and interval scaled data cannot definitely be met; 2) the primary concern of the analysis lies in the prediction accuracy when estimating a complex model with many variables and parameters; 3) the observations are not truly independent from each other; or 4) the model contains formative indicators (Sarstedt 2008, Henseler et al. 2009).

For this analysis, the SmartPLS 2.0 software developed by Ringle et al. (2005) was used. Then factor loadings (item reliability), composite reliability, and average variance extracted (AVE) were obtained for each measurement separately, and for the structural model as a whole. Following Chin (1998), we ran a 500 resampling bootstrap with replacement. PLS, bootstrapping is a resampling procedure used to examine the stability of estimates for each parameter in the PLS model. The bootstrap procedure utilizes a confidence estimation procedure other than the

normal approximation (Efron and Tibshirani 1993), which helped us to judge whether the proposed relationships were significant or not.

Results

In this section, the comparative assessment of the three types of VBCs and the innovation activities in the Chinese vegetable breeding industry are presented. Then the relationships among the factors that might affect the performance and success of an innovation project are analyzed.

Comparative Assessment of the Three Types of VBCs

Table 1 shows the baseline description of the VBCs in China we visited. The VBCs are characterized as small-sized in terms of the number of employees and the turnover, 75% of the VBCs has less than 60 employees and a turnover of less than 30 million RMB (approximately 3 million Euros). The VBCs invest intensively in R&D (14.2% of turnover) and in R&D human resources (R&D personnel accounts for 1/3 of the total personnel of the VBCs). However, please note that the public VBCs, especially the research institutes that are active in the breeding business, received a large amount of R&D subsidies from the Chinese government. The cultivars sold by public VBCs all stem from the research institutes they are affiliated with; which explains why the percentage of R&D compared to turnover could rise to 60% of the turnover.

The size of public and domestic private VBCs is similar both in number of employees and turnover, but much smaller than foreign ones, especially taking into account that they only represent 1-10% of their mother company. The R&D budget of public and foreign VBCs is at the same level (18% of turnover), and nearly double that of private ones. But it should be noted that the public VBCs gain substantial governmental funding, while the foreign VBCs are strongly supported by their mother companies.

Table 1. Basic information of three types of vegetable breeding companies in China

					Mean		
	Min.	**Max.**	**Mean**	**S.D**	**Public(26)**	**Private(32)**	**Foreign(12)**
Number of employees	12	167	44	33	40	41	74
Turnover 2010 (million RMB)	1	90	23	22	20	20	69
Number of R&D employees	2	80	15	16	19	9	28
R&D budget (% of turnover)	2	60	13	11	18	10	18
Age of company (years)	3	52	15	9	15	14	16

[a] This high percentage is due to the public VBCs that are affiliated with the research institutes, that receive large amounts of R&D subsidies and are functioning as R&D departments of the public VBCs.
[b] The age of the R&D department is higher than the age of the oldest company. This is due to the fact that the vegetable research institutes were founded much earlier than their affiliated seed companies (public VBCs), which use the former as R&D functional unit.

Innovation Activities in the Chinese Vegetable Breeding Industry

In the interviews with the 70 VBCs senior managers in China, we also asked for a priority list of the most important innovation activities within their company. As expected all put plant breeding on top of their list. Figure 2 presents the other main research activities. The most important activities are germplasm collection and seed technology. This aligns to the fact that the core innovation activity in a breeding company is the development of competitive new varieties and provides high quality seeds to their clients. In general, the public VBCs are more active in almost all activities than the private and foreign VBCs— especially in basic research. This might be due to the fact that research activities are heavily subsidized for public VBCs, up to 60% of their turnover. Since public VBCs have easy access to listed germplasms kept in the National Crop Gene Bank and the National Medium-term Storage, the necessity to collect germplasm is not so crucial for public VBC's as for private VBCs (Liu et al. 2012b). The germplasm collection is even much lower for foreign companies. There might be two explanations for this. Firstly, mother companies of foreign VBCs in China may already have a large germplasm collection based on their global operations and long-term development. Secondly, the restrictions for foreign VBCs to access to National Crop Gene Bank and National Medium-term Storage are much tighter. Furthermore, Figure 2 also shows that the vegetable breeding industry very rarely applies modern technologies. Less than one third of public VBCs are using modern technologies, such as plant tissue culture, molecular markers assistant breeding, genetic modification, genomics and bioinformatics. So, traditional breeding is the main innovation activity.

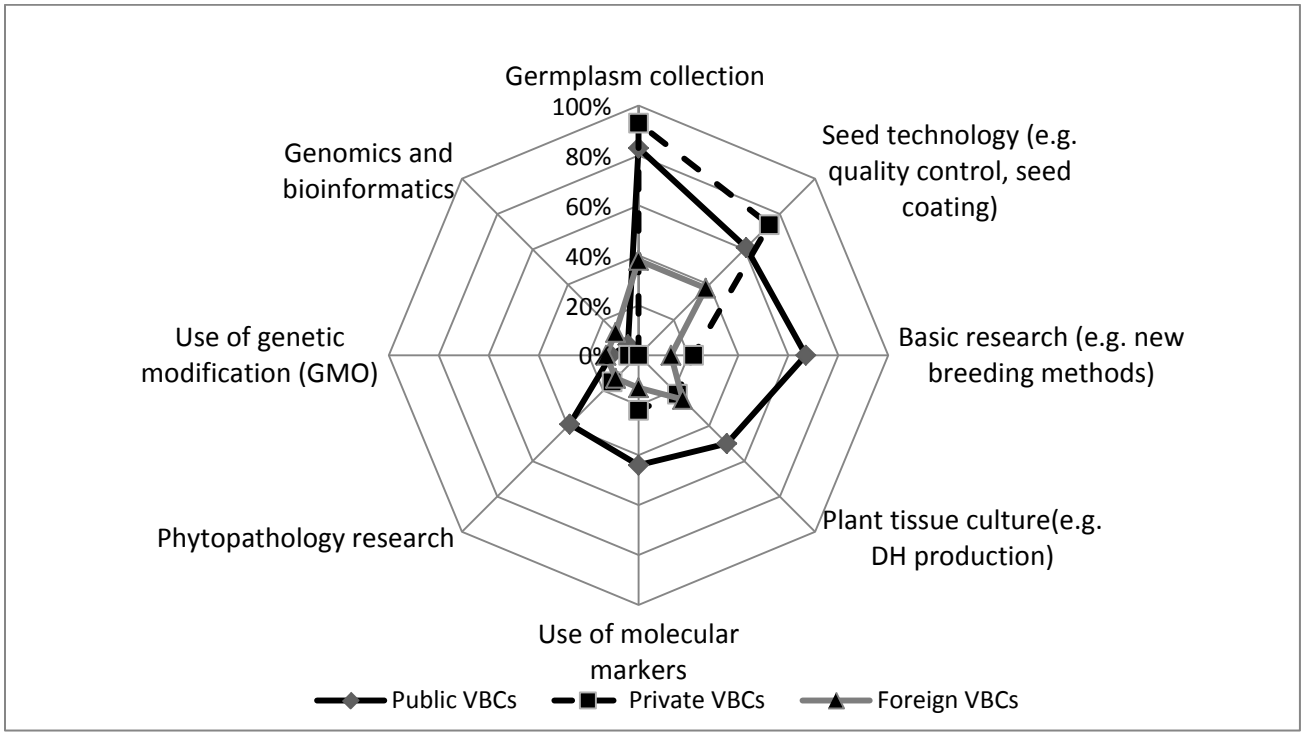

Figure 2. Percentage of innovation activities conducted by companies in each type of vegetable breeding companies in China

Reliability, Model Validity, Explanatory Power and Effect Size of Constructs

Table 2 (see Appendix) presents the mean, standard deviation (S.D.) and factor loading of all the indicators of different constructs. The individual item reliability (factor loading), internal consistency (composite reliability) and discriminant validity for each construct by the criteria given by Fornell and Larcker (1981) was examined. Factor loadings for most individual items were higher than 0.7 (Table 2), and shows good reliability for the individual items. A few items showed a factor loading a bit less than the cut-off point of 0.7 still indicating an acceptable individual reliability (Götz et al. 2010). The composite reliability (CR) and Cronsbach alpha for all constructs exceeded 0.75 (see Table 2), indicating a robust internal consistency of the constructs (Hair et al. 2011a).

The discriminant validity was accessed in two ways. First, the square root of the average variance extracted (AVE) should be greater than all construct correlations. Second, all items should load higher to their associated construct than to the other constructs. Both criteria for discriminant validity were met (see Table 3, in Appendix).The average variance explained (R^2) was used to evaluate the explanatory power of the structural model, the path Coefficients, t-value and the effect size were used to evaluate the correlation of constructs, their significant level and effect size. Table 4 gives a visual overview of the relations among the constructs. For product novelty (0.13), newness to the company (0.12), and functional capabilities (0.33) show an acceptable explanatory power significant at t 0.05 level (Eisenhauer 2009). Furthermore, R^2 of product potential (0.49), market potential (0.61), and innovation project performance (0.58) indicate robust explanatory power.

Structural Model

The results of the structural model are provided in Table 4 (see Appendix). Below we describe the result of confirmed, not confirmed and rejected hypotheses in more detail in Table 5.

As expected, integrative capabilities are significant and positively related to product novelty (β=0.34), newness to the company (β=0.34) and market potential (β=0.23). This shows the importance of integrative capabilities to identify new opportunities and to implement new knowledge into an innovation project. With more open communication, intensive team interaction and more knowledge sharing, VBCs can better recognize and make better use of the valuable external resources such as: the introduction of advanced technologies, seize new market demand, develop novel distribution channels, and maybe also target different market segments. Meanwhile, strong integrative capabilities might also stimulate the project team and the company to develop new functional capabilities such as R&D ability, production processes, and distribution systems.

Innovation projects aim to develop novel products that could bring extra benefit to clients, reduce the cost, and improve the efficiency, etc. It was found that product novelty is significantly and positively related to product potential (β=0.48), with a medium effect size (f^2=0.28). Furthermore, in order to be able to develop novel products with high potential, a company needs specific capabilities, such as R&D, engineering and processing, marketing and sales, etc. Indeed,

a significant positive relationship was found between functional capabilities and product potential (β=0.37), with a medium effect size (f^2=0.19).

Table 5. Overview of the confirmed, not confirmed and rejected hypotheses

Hypotheses	Result
Hypothesis 1	
a. Integrative capabilities will be positively related to product novelty.	Confirmed
b. Integrative capabilities will be positively related to newness to the company.	Confirmed
Hypothesis 2	
Integrative capabilities will be positively related to identifying the market potential of an innovation.	Confirmed
Hypothesis 3	
Integrative capabilities will be positively related to the development of the functional capabilities.	Not confirmed
Hypothesis 4	
Product novelty will be positively related to product potential.	Confirmed
Hypothesis 5	
Newness to the company will be negatively related to the company's existing functional capabilities.	Rejected
Hypothesis 6	
Functional capabilities of the company will be positively related to product potential.	Confirmed
Hypothesis7	
Product potential will be positively related to market potential.	Confirmed
Hypothesis 8	
a. Market competition will be negatively related to market potential.	Rejected
b. Market competition will be negatively related to innovation project performance.	Not confirmed
Hypothesis 9	
a. Market potential will be positively related to the innovation project performance.	Confirmed
b. Product potential will be positively related to the innovation project performance.	Not confirmed
c. Functional capabilities will be positively related to the innovation project performance.	Not confirmed

The structural model also shows that newness of the company is not negatively related to the company's existing functional capabilities, but shows a medium positive effect (β=0.49, f^2=0.23). Interestingly, this is different from our expectation that newness could bring uncertainty and the company's functional capabilities would be inadequate to execute successfully an innovation project. However, we also found that newness to company had a mediated effect on integrative capabilities and functional capabilities. This means that integrative capabilities can only partially contribute to the improvement of functional capabilities. In order to enhance functional capabilities, newness to the company is needed.

An innovation project that leads to a high product potential also proved to gain higher market potential (β=0.66), because new products with unique benefits to customers can lead to a strong

market position. The effect of product potential on market potential is large (f^2=0.45). Meanwhile, market potential also shows a significant positive effect on innovation project performance (β=0.60), with a medium effect size (f^2=0.29). Product potential was not found to have significant effect on innovation project performance directly, but more than half of the effect of product potential onto innovation project performance is mediated by market potential. This means that product potential can only partially be considered a substitute for the success of an innovation project. In order to achieve better innovation project performance, the innovation project should lead to both high product potential and high market potential. Furthermore, market competition, which was supposed to hamper successful introduction of new products, is positively related to market potential (β=0.25). This indicates that intensive competition can help innovation projects achieve a better performance, because it stimulates both the team members and the company as a whole to really come up with an innovative product in time.

Discussion and Conclusions

The Importance of Integrative Capabilities: Direct and Indirect Effects

From the resource-based view it is well known that knowledge and learning are key determinants of innovation, and the interaction between proprietary and external knowledge is important (Malerba 2002). This study further extends the essential role of integrative capabilities and shows that communication, team interaction, and knowledge sharing indeed increases the innovativeness of innovation projects. The exchange of information and interactions between individuals of the project team can create novel ideas through brainstorming and identifying new opportunities. Good cross-functional communication and knowledge sharing make the innovation project team aware of existing capabilities of various functional units available, whereas the functional units will most likely be informed of missing skills, routines and processes that are needed to support the development of a new products and launching them into the market. A good understanding of these missing requirements might be the starting point for adjustment and improvement. So, with a higher level of product novelty and newness to the company, integrative capabilities will contribute to improve functional capabilities and market potential indirectly.

In this research we introduced three types of VBCs in China: public, private and foreign VBCs. Although the sample size is limited to really test the differences on the basis of the conceptual model, we have seen differences based on interviews conducted with the project managers. It was found that in foreign VBCs a form of matrix organization is widely applied and innovation project teams are organized with members from different functional units, but share the same crop/topic focus. Furthermore, these foreign VBCs heavily encourage their project team members to communicate intensively and effectively. In contrast to this, and for historical reasons, in public VBCs, which are affiliated to vegetable research institutes, participation of members from different functional units is rather limited, especially the interaction between R&D and M&S. This can be explained by the fact that the original goal of such companies was to bring varieties developed by the affiliated research institute to the market. The new Chinese policy (MoA 2010b) requires further separation of the two functional units (R&D and M&S). We expect that this will lead to further reduction in innovative varieties from public VBCs. Take

as example Shouguang, the most famous vegetable production area, has become .more and more specialized vegetable farmers are demanding more innovative and high-quality seeds. With their innovative and high quality products, foreign VBCs are now already dominating the market.

Constrained integrative capabilities in public VBCs limit product innovativeness and also reduce market potential since the functional capabilities are not only less developed, they are not able to respond to new market demand quickly. Private sector VBCs are doing somewhat better, but there is still much need for improvement. For example, a senior manager from a large private VBC, who was building a new biotechnology center, complained that it was difficult for breeders and biotechnologists to share information. Breeders hesitate to share information because it has been their competitive strength for many years'— accumulated know-how and experience. They did not want to give up their own benefits. Moreover they had the impression that the contributions of biotechnologists were limited.

Newness to the Company: A Challenge but also an Opportunity

Innovation projects that are closer to existing products, markets and technologies of the firm are more successful (Zirger and Maidique 1990) because the greater the extent of newness to the company, the higher the chance that the company's functional capabilities are insufficient to execute the innovation project. This was further proved by Tepic (2012), who studied innovation projects from nine large multinational companies representing different industries. In contrast to these studies, we found a positive effect of newness to the company on functional capabilities and also a positive effect from integrative capabilities on functional capabilities, mediated by newness to the company. So newness to the company in innovation projects could be a challenge because a company needs a higher level of flexibility and adaption when it engages in a completely new innovation. However, newness to the company might also stimulate the need for adaption and improvement of functional capabilities in order to execute a new innovation project. This could be related to a specific type of innovation in plant breeding. In most cases the VBCs projects include the development of novel varieties, a time consuming process, which normally takes up to 10 years or even longer. In general VBCs are small and communication lines are short, while cross-functional teams are widely used for innovation projects. So during the long period phase of new product development, the company is able to gradually develop the functional capabilities needed to support innovation. Furthermore, we found that "newness to the company" category of innovation projects scored lower than five on a ten-point Likert scale. This could mean that the production process, distribution, advertising and promotion for the innovation projects of VBCs are in general not totally new, so the flexibility and adaption of functional capabilities needed for innovation projects are not too radical.

Market Competition: A Positive Factor for Innovation in the Breeding Industry

Market competition stimulates innovation project performance because such competition urges companies to develop unique new products faster, as shown by Tepic (2012) in her research on large European agri-food companies. We made the same observation in our research of Chinese VBCs indicating that market economy is important for innovation. This form of "healthy tension" or "good competition" is a stimulus for innovation and was mentioned by several CEOs of outstanding breeding companies. Foreign VBCs have brought intensive competition into the

Chinese vegetable breeding industry but foreign VBCs also bring new technologies and forms of management, that are widely shared with domestic VBCs so can learn from them and can improve their innovation. Increased competition is good for innovation. However, within the vegetable breeding industry there is no free competition. There are political reasons for the Chinese government to stimulate domestic VBCs in order to avoid allowing this industry to be controlled by foreign VBCs. However, limited competition, could constrain innovation. Furthermore, improving intellectual property rights such as with plant breeders' is essential to fair competition. Although legislation and regulation of property rights have improved considerably as government as well as the private sector recognizes its importance, poor intellectual property protection is still a very large constrain for VBCs to invest in innovation.

Product and Market Potential: Two Pillars for Innovation Project Success

Product potential has a positive effect on innovation project performance, but it is mediated by market potential. This means that even if the new product is novel, (such as novel traits in crop plants or novel breeding technologies), if there is no need for it, the innovation project would not be successful. Innovation projects of public VBCs are subsidized by government, with a requirement of scientific contribution, so product potential such as new traits or new technologies are highly emphasized and widely applied. However, without the target to fill a market request, it would be difficult to gain market success. Public VBCs had been the dominant players in the vegetable seed sector for historical reasons. However, this gradually changed about ten year ago. Private and foreign VBCs are taking the lead because their innovation is more focused on market demand rather than technology advancement.

Recommendations and Further Research

This study identifies the importance and interaction of integrative capabilities and functional capabilities, product novelty and newness to the company, as well as product potential and market potential for innovation project performance. In order to improve innovation performance, vegetable breeding companies need to improve their integrative capabilities, which can be stimulated by open communication, knowledge orientation and sharing, teamwork, training, and their functional capabilities, which are the skillsets needed in order to introduce novel products into the market successfully. Furthermore, market competition also plays a positive role to stimulate innovation in the vegetable breeding industry. It needs to be further improved by reducing governmental interaction with the market activities in the breeding industries. Instead of playing multiple functions in this industry e.g. legislation and regulation, supporting breeding activities in governmental research institutes and even supporting stat-owned breeding companies, it would be more effective for government to take measures to ensure a free and fair market, with good intellectual property protection.

The present study identifies direct and indirect effects coming from integrative capabilities, which also link access to external information and knowledge. The diversity and scope of team members' personal networks could facilitate access to non-redundant sources of knowledge that could expand the innovation possibilities of the project (Uzzi and Lancaster 2003; Kao et al. 2009). Therefore, it could be valuable to include the social networks of team members in further studies on the innovation process. Furthermore, this research is based on empirical data collected

in the Chinese vegetable breeding industry, which might be quite different from other agri-food sectors, so further study is needed to verify generalization of this conceptual model.

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Appendix

Table 2. Measurement and factor loadings for each construct of the model

Construct	Items	Mean	S.D.	Factor Loading
Integrative capabilities	1. I have enough communication with my team members to do my work efficiently and in an effective way.	7.85	1.61	0.81
	2. In this project, I am the one who most frequently provides information and support to other team members.	7.77	1.79	0.74
	3. We always give other departments (e.g. M&S, manufacturing, etc.) the information they ask for.	8.62	1.50	0.69
	4. We always get the information from other departments (e.g. M&S, manufacturing, etc.) we ask for.	8.32	1.53	0.78
	5. All our team members are focused on "collecting" knowledge for our project.	7.94	1.67	0.67
	6. The cooperation with marketing and sales is essential for the success of this project.	8.79	1.20	0.67
Product novelty	7. The product type is totally new for our company (e.g. new crops, etc.).			0.67
	8. We have never made or sold products to satisfy this type of customers need or use before (e.g. new disease-resistant, new shape, etc.).	6.70	2.02	0.79
	9. The potential customers for this product are totally new for the company (e.g. new area, new type of customers, etc.).	5.40	2.51	0.87
	10. The technology required to develop this product is totally new to our company.	5.53	2.79	0.73
	11. The competitors we face in the market for this product are totally new to our company.			0.66
Newness to the company	12. The nature of the production process is totally new for our company.	4.75	2.52	0.69
	13. The distribution system and/or type of sales-force for this product is totally new to our company.	4.91	2.58	0.91
	14. The type of advertising and promotion required is totally new to our company.	4.92	2.51	0.87
Functional capabilities	15. Our engineering skills and people are more than adequate for this project.	6.19	2.47	0.85
	16. Our marketing research skills and people are more than adequate for this project.	6.21	2.19	0.88
	17. Our advertising and promotion resources and skills are more than adequate for this project.	6.13	2.20	0.81
	18. Our sales and/or distribution resources and skills are more than adequate for this project.	6.28	2.26	0.92

Table 2. *Continued*

Construct	Items	Mean	S.D.	Factor Loading
Product potential	19. Our product will be of higher quality than competing products.	7.17	1.97	0.87
	20. Compared to competitive products, our product will offer a number of unique features or attributes to the customer.	7.64	1.77	0.86
	21. Our product will permit the customer to do a job or do something he/she cannot presently do with what is available.	7.08	2.00	0.89
	22. Our product will permit the customers to reduce their overall costs, when compared to what they use now.	7.00	2.06	0.78
	23. Our product is highly innovative totally new to the market.	6.34	2.12	0.86
	24. Our product is a very high technology one.	6.49	2.01	0.73
	25. Our product is mechanically and/or technically very complex.	6.36	2.03	0.84
Market potential	26. The market for this product is growing very quickly.	7.19	1.82	0.80
	27. Potential customers have a great need for this type of product.	7.57	1.58	0.77
	28. The customer will definitely use the product.	6.68	1.86	0.65
	29. This product has a high potential (i.e. can additional products, multiple styles, price ranges).	7.55	1.44	0.86
	30. This project will contribute to the competitive advantage of the company.	8.17	1.17	0.82
	31. This new product will surely meet the applicable laws (e.g. product liability, regulations, and product standards).	8.79	1.26	0.62
Market competition	32. The market is a highly competitive one.	8.51	1.49	0.94
	33. There are many competitors in this market.	8.55	1.61	0.95
Innovation project performance	34. What is the probability that this project will be completed within the original planning?	8.00	1.27	0.83
	35. What is the probability that this project will be completed within the original budget?	7.72	1.38	0.87
	36. What is the probability that this project fulfils all its objectives?	8.06	1.22	0.85
	37. What is the probability that this project will directly benefit the end-users (either through increasing efficiency or effectiveness)?	8.17	1.28	0.76
	38. What is the probability that this project will earn more money for the company than it costs?	8.21	1.56	0.76
	39. What is the probability that this project will improve customers' loyalty to the company?	8.11	1.44	0.76

Note. All items expect the items of "innovation project performance" were measured by ten-point Likert scale that respondents completely disagree (1) or completely agree (10) with the statements. The items of innovation project performance were measured by the expected probability by scale of 0-10.

Table 3. Discriminant validity of constructs

	Mean	S.D.	AVE	CR	a	1	2	3	4	5	6	7	8
1. Integrative capabilities	8.25	1.13	0.53	0.87	0.83	**0.73**							
2. Product novelty	6.21	1.97	0.75	0.92	0.89	0.34*	**0.87**						
3. Newness to the company	8.03	1.09	0.65	0.92	0.89	0.34*	0.49*	**0.81**					
4. Functional capabilities	8.53	1.47	0.90	0.95	0.89	0.34*	0.35*	0.55**	**0.95**				
5. Market potential	7.74	1.13	0.58	0.89	0.85	0.22	0.61**	0.35*	0.54**	**0.76**			
6. Product potential	4.87	2.12	0.69	0.87	0.77	0.53**	0.43**	0.08	0.34*	0.65**	**0.83**		
7. Market competition	5.89	1.77	0.55	0.86	0.79	0.65**	0.38**	0.13	0.16	0.02	0.41*	**0.74**	
8. Innovation performance	6.90	1.66	0.70	0.94	0.93	0.48**	0.30	0.09	0.23	0.54**	0.75**	0.31	**0.84**

Note. *Correlation is significant at the 0.05 level (2-tailed)
**Correlation is significant at the 0.01 level (2-tailed).
[a] The bold numbers on the diagonal are the square roots of the variance shared between the constructs and their measures (square root of average variance extracted, AVE). CR refers to composite reliability and Off-diagonal are the correlations among the constructs. α refers to Cronsbach alpha.
[b]all the constructs measured by ten-point Likert scale indicators

Table 4. Path coefficients, t-values and significant level of structural model

	Path Coefficients (β)[1]	**T-value**	**f^2-value**
Product novelty (R^2=0.12)			
Integrative capabilities	0.34	2.20**	0.12
Newness to the company (R^2=0.11)			
Integrative capabilities	0.34	2.62***	0.11
Functional capabilities (R^2=0.33)			
Integrative capabilities	0.17	1.22	0.04
Newness to the company	0.49	3.18***	0.23
Product potential (R^2=0.49)			
Product novelty	0.48	3.75***	0.28
Functional capabilities	0.37	3.28***	0.19
Market potential (R^2=0.61)			
Integrative capabilities	0.23	1.74*	0.06
Product potential	0.60	4.75***	0.45
Market competition	0.25	2.67***	0.07
Innovation project performance (R^2=0.58)			
Market potential	0.66	5.08***	0.29
Product potential	0.16	1.11	0.02
Functional capabilities	-0.09	0.85	0.01
Market competition	0.06	0.52	0.00

Note. [1]* Path coefficient is significant at 0.1 level (2-tailed); ** Path coefficient is significant at 0.05 level ng (2-tailed); *** Path coefficient is significant at 0.01 level (2-tailed).
[2]f [2]-values of 0.02, 0.15 and 0.35 can be viewed as a gauge for whether a predictor latent variable has a week, medium or large effect at the structural level.

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Consumer Attitudes in Germany towards Different Dairy Housing Systems and Their Implications for the Marketing of Pasture Raised Milk

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Abstract

There is currently much debate surrounding the housing systems for dairy cattle. Large farms, which represent a growing share of the dairy farms, prefer indoor housing systems whereas smaller farms concentrate on low-input systems by giving extended pasture access to milk cows. A consumer survey from 2013 with 1,009 German consumers dealt with consumers' attitudes towards outdoor and indoor systems as well as quality aspects of food. A factor and a cluster analysis are used to reduce the complexity and identify different consumer clusters. The results give recommendations for farmers, constructors of animal sheds, agricultural technology and the processing dairy industry concerning strategic decisions.

Keywords: Housing systems, dairy cattle, pasturing, consumer research, cluster analysis

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Introduction

There is currently much debate surrounding housing systems for dairy cattle. At one end of the spectrum there are the purely indoor housing systems where cows are fed mainly with concentrated feed and that aim to maximize milk production per cow (high-output). At the other end of the spectrum there are cost-minimizing systems that focus on pasture-grazing (low-input) (Steinwidder et al. 2009; Baur et al. 2010). In addition, there are systems that combine free-range and fully housed systems: e.g., housed systems with principally concentrated feed but with access to an outdoor area or systems where cows are at pasture for at least some hours in the summer and have the opportunity of grazing as well as being provided with concentrated feed (Brade 2012). Each system has its advantages and can be cost efficient. This depends on various conditions, such as consolidated pasture, land costs or legal requirements. As a consequence, the focus of the different housing systems differs between countries: e.g., Sweden has regulations for dairy farms that require cows to have access to pasture for at least six hours per day in summer (Spörndly 2012). In countries like Ireland, much grassland is available so outdoor systems with grazing is the obvious choice (Laepple et al. 2012).

Besides some other North-western European countries like the Netherlands, Belgium, or Denmark, Germany is an example for a country with no legal regulations for dairy cow pasturing and an environment which allows different dairy systems. In Germany, the structure of the dairy farms has changed over the last decades. The number of dairy farms has decreased, whereas herd sizes have grown (Federal Statistical Office 2011). Due to the increasing number of cows per farm, the challenges of grazing in Germany are rising. If the farmer wishes to offer free-range for cows, the size of the pastureland has to be proportional to the increased number of cows. But not every farm has the possibility of obtaining more pastureland as the herd size grows (Ostermann-Pfalz and Stöcker 2013). In this case, farmers may opt for a fully housed system where it is possible to enlarge herd size and improve economies of scale. Genetic predisposition also needs to be taken into account as most breeds are bred for high milk performance and so require concentrated feed to achieve the required performance. When they are fully housed it is easier to provide the required feed. Another limiting factor is the workload involved in having to drive the cows to pasture that is far-removed from the farm, as a result of the insufficient number of contiguous parcels (Schleyer et al. 2013). Against these factors, Reijs et al. (2013) predict a decline in German dairy farms with pasturing for cows (regardless of the length of time of pasturing) from almost 50 % in 2012 to less than 5 % in 2025 leading to a new debate in the general public about animal welfare and product quality.

The Dairy Industry from the Consumer Viewpoint

The fact that dairy cattle are visible is also important for the public's collective understanding of dairy farming and seems to have a positive influence on its image. At the very least, the image of the dairy industry is not as negative as the image of the meat industry (Schleyer et al. 2013). Several studies show that consumers generally prefer pasturing or at least an access to pasture for animals. Access to open-air is an important criterion for most consumers (Fearne and Lavelle 1996; Deimel et al. 2012). This factor could have an influence on the image of farming systems as well as on the food processing sector. How crucial public perception of a sector is can be seen in the case of battery cages for laying hens. The media debate and corresponding pictures

regarding the keeping of laying hens in cages supports the consumer preference for free-range. Pressure from consumers is the reason why eggs from battery hens are now outlawed in Germany (Hörning 2009).

Nevertheless, as shown in the introduction, there is an opposing trend in the German dairy system towards housed dairy cow systems while from a social perspective pasturing should be maintained. On account of these antagonistic requirements, this paper focuses on the German market and consumer perception in Germany. No specific research has been carried out regarding approval of free-range systems (particularly not for the dairy sector). It thus seems very important to obtain deeper insights into consumer attitudes towards the different housing systems so as to avoid situations akin to that of the egg market.

Initial indications that consumers prefer pasture-based systems for dairy cattle is shown by the market share of over 20 % in Denmark for milk which is advertised as pasture-raised milk (Heerwagen et al. 2013). Preliminary efforts are being made to launch pasture-raised milk in Germany. In other countries like the Netherlands (FrieslandCampina), Switzerland (Mirgros), USA (Sweet Meadows Farms) and, as mentioned above, Denmark (Arla Foods), premium products have already been established with the term “pasture” or “meadow” so that higher prices for pasture-raised milk can create an incentive for farmers to continue using pasture-based systems. Moreover, some studies have shown that there is a consumer segment that is willing to pay more for milk from cows that have access to pasture (e.g. Pirog 2004 [USA], Ellis et al. 2009 [UK], Hellberg-Bahr et al. 2012 [GER]). Concern for animal welfare (Ellis et al. 2009) and environmental aspects are identified as major reasons for buying pasture-raised milk, as well as the expectation of a healthier product (Hellberg-Bahr et al. 2012).

In general, quality considerations are important purchasing motivations for some consumers (Caswell and Joseph 2008). The food choice decisions that consumers currently face are already very complex and include a wide variety of situational (e.g. time, price), egoistic (e.g. taste, health) and altruistic (e.g. environmental protection, animal welfare) motivations (e.g. Caswell and Joseph 2008; Tsakiridou et al. 2007). In their review Aertsens et al. (2009) describe the personal determinants of organic food consumption. These are actually more abstract values such as “safety”, “hedonism”, “universalism”, “benevolence”, “stimulation”, “self-direction” and “conformity”. As well as attitude, subjective and personal as well as (perceived) behavioural norms influence the consumption of organic food. Today, milk and milk products are increasingly advertised with additional features for product differentiation. In Germany, the main focus is on GMO freeness, fair payment for dairy farmers, regional origin and the quality attributes of organic milk (Bickel et al. 2009; Zander and Hamm 2010). Environmental and animal welfare characteristics are also important to consumers (Zander and Hamm 2010). McGarry Wolf et al. (2009) showed that the purchasing interest for milk in American organic buyers centered around the qualities of fresh and aromatic taste, safety, high quality, healthy and high nutritional quality, a proper price-quality ratio and a subjectively appropriate price. Many of these aspects can be found in pasture-raised milk. However, pasture-raised milk is based on credence attributes (Akerlof 1970), as consumers must rely on the message that dairy cows have had access to pasture. The marketer therefore needs to provide a sign of reliability.

Although some consumers may show positive attitudes towards pasturing or the furthering of animal welfare issues, a higher price might still be a barrier to purchasing these products (McEachern and Schröder 2002; Padel and Foster 2005; Plaßmann and Hamm 2009). This phenomenon could be explained by the theory of the consumer-citizen-gap. This describes the gap between the attitudes of citizens and their actual behaviour as customers in their shopping situations (especially in respect to animal welfare aspects in food) (Coff et al. 2008; Harvey and Hubbard 2013). While citizens may state that they support pasturing, they may fail to follow through with it in their purchasing as consumers. This has already been shown with the organic food market: Pearson et al. (2011) come to the conclusion that a gap exists between positive attitude and actual behaviour when it comes to making decisions between organic and conventional foods.

This leads to the conclusion that, as well as analysing attitudes toward fully housed and pasturing systems, the survey presented in this paper should integrate the quality orientation of consumers, often related to a high involvement in the product. These consumers are thus more willing to purchase premium products (Aertsens et al. 2009). The assumption of this paper is therefore that there are consumers who prefer pasturing and who are also willing to purchase pasture-raised milk, since they are interested in quality. However, at the same time, there are people that, although they may prefer free-range systems as citizens, as consumers they block it out and so do not consider whether the milk originates from pasturing or from fully-housed systems; it is here that the consumer-citizen-gap is present.

In order to integrate the theory of the consumer-citizen-gap found in this literature, this analysis includes the quality aspect. The evidence encourages further research to be undertaken involving the separation of consumers according to their purchasing behaviour for foods, especially milk. This is of particular interest to the German market given the current small market share for pasture-raised products.

Goals

All the studies presented in the last section focus on whether consumers would purchase pasture-raised milk, on willingness to pay (WTP) analyses or the general preferences of consumers for free-range in livestock farming. The difference in housing systems is not the focal point in this research, or is not even included. What is important is learning more about attitudes towards housing systems and food quality for the purposes of strategic decision-making in the industry concerned.

This paper contributes important background information regarding the perception of housing systems. Due to the issues presented above, regarding decline in pasturing, consumer preference for free-range systems and quality as buying motives, the following three research questions shall be answered:

- How important is pasturing for consumers?
- What is the image of fully housed systems?
- Can the existence of the consumer-citizen-gap regarding quality be verified by different clusters?

It is important for farmers, agricultural technicians and animal shed builders to have this information, so they can be prepared for a possible development regarding consumer expectations. The following factor and cluster analysis have the advantage of combining consumer attitudes towards housed and outdoor systems, while simultaneously separating consumers into different groups depending on their quality orientation. The market potential for pasture-raised milk and further manufactured products can thus be established. The results also lead to recommendations for strategic decision-making in the long run. The results are especially important for dairies and the dairy processing industry regarding their long-term business development.

Methodology

The data collection took place in July 2013 via an online access panel. The sample size was 1,009. To obtain representative results for the German population, quotas were set for age, gender, education and regional distribution. The survey consisted of questions on milk purchasing frequency as well as the relevance of milk production and milk quality. The focus was on animal welfare aspects of pasture and indoor systems. Respondents scored their answers on a five-point Likert scale. The data was analysed using the statistical software IBM® SPSS, version 21.

First, descriptive analyses showed the impression of consumers when prompted with images of indoor and outdoor systems. The association was measured by a semantic differential. One set of questions showed three images of modern indoor housing systems and another set displayed cows at pasture. Both sets were randomly presented in order to prevent sequence effects. Next, an explorative factor analysis was used to reduce complexity. Finally, a cluster analysis was conducted for the purpose of identifying different consumer clusters. The cluster analysis was performed in several steps to optimize results. Ward's method was used as a cluster method, and the squared Euclidean distance as an interval measure. K-means clustering was conducted to refine the solution. A discriminant analysis verified the goodness of separation of the K-means algorithm. An analysis of variance (ANOVA) was used to describe the clusters. Post-hoc tests were used to determine significant differences between the means of the ANOVA. Finally, cross tables identified the socio-demographical differences between the resulting clusters.

Results

Due to the quotas set, the survey approximately represents the German population. Average age is 41 years, 49.4 % are male and 50.6 % are female. Regional distribution and education levels correspond with the German population. 29.9 % of the respondents have a net household income of less than € 1,500 per month, 28.4 % have between € 1,500 and € 2,500 per month and 24 % have € 2,500 or more per month. 17.9 % did not specify. Table 1 shows the percentage share in relation to the sample and its given distribution in the German population.

Table 1. Sample characterization

Variable	Description	Frequency (%) Sample	Frequency (%) Germany[1]
Age	16 to 30	26.1	24.8
	31 to 50	42.8	41.2
	Older than 50	31.4	34
Gender	Male	49.4	49.6
	Female	50.6	50.4
Region	North	15.8	15.9
	South	27.5	28
	East	20.7	20.5
	West	36.1	35.6
Education level	No qualification	5.2	7.8
	Primary school	40.2	36.6
	Secondary school	28.2	28.8
	A-level	13.0	13.6
	University or vocational qualification	13.4	13.2
Net household income	Less than 1,500	29.9	-
	1,500-2,500	28.4	-
	More than 2,500	24.0	-
	n. s.	15.7	0.4

Source. Authors' calculation; Federal Statistical Office (2012)

First of all, the respondents were asked to provide their semantic association to images of cows by means of a semantic differential (Figure 1 and Figure 2). The pictures were taken from typical farms and discussed with experts from the industry. Especially the indoor system is presented with images coming from newly built and modern farms using cubicle housing systems.

Figure 1. Presented pictures of housed system

[1] Quota of the German population solely for the purposes of showing the quota (age, gender and region) used to build the sample

Figure 2. Images presented of outdoor systems

Tables 2 and 3 show higher mean values for positively connoted words, connected with images of outdoor systems. As Tables 2 and 3 illustrate, the housed system evoked more negative connotations than did the images of the dairy cows outdoors.

Table 2. Semantic differential for fully housed systems (answers in %)

	Very (2)	**Slightly (1)**	**Partly / partly (0)**	**Slightly (-1)**	**Very (-2)**		**Mean value**
Animal friendly	9.2	10.9	28.2	25.9	25.9	Cruel towards -animals	-0.48
Healthy	10.4	15.9	35.6	20.1	18.1	Unhealthy	-0.20
Traditional	11.0	14.4	22.8	20.1	31.8	Industrial	-0.47
Modern	26.2	30.4	28.0	7.1	8.3	Old-fashioned	0.59
Environmentally -friendly	9.1	14.3	41.2	20.6	14.8	Environmentally -harmful	-0.18
Caring	7.4	10.3	25.0	27.1	30.1	Loveless	-0.62
Close to nature	6.9	7.6	20.6	24.9	40.0	Unnatural	-0.84
n = 995-1,003							

Table 3. Semantic differential for outdoor systems (answers in %)

	Very (2)	**Slightly (1)**	**Partly / partly (0)**	**Slightly (-1)**	**Very (-2)**		**Mean value**
Animal friendly	70.4	17.2	10.0	1.8	0.6	Cruel towards animals	1.55
Healthy	65.6	21.6	11.3	1.0	0.6	Unhealthy	1.5
Traditional	65.2	21.6	10.3	2.1	0.9	Industrial	1.48
Modern	27.5	21.4	34.6	12.5	4.0	Old-fashioned	0.56
Environmentally -friendly	56.0	25.7	14.9	2.7	0.7	Environmentally -harmful	1.34
Caring	54.7	26.9	15.4	2.2	0.8	Loveless	1.32
Close to nature	74.2	15.2	8.9	0.9	0.8	Unnatural	1.61
n = 999-1,004							

In a second step, attitudes towards the different systems were evaluated using likert scale questions, resulting in a factor analysis. According to the Kaiser-Meyer-Olkin criterion, the result of the factor analysis is excellent (KMO = 0.929; Kaiser 1974). Bartlett's test of sphericity is highly significant, which demonstrates that the variables are highly correlated (Backhaus et al. 2006). The survey had several goals. As the aim was to identify consumers' attitudes concerning fully housed systems and outdoor systems, the first two factors from Table 4 were chosen. As the third factor pertains to the consumer-citizen-gap, it was chosen as well. Thus, only the first three out of the resulting six factors in Table 4 entered the cluster analysis as the focal point. Adding the other factors to the cluster analysis might also have resulted in clusters being too complex. It

is these three factors that are presented hereafter. The first factor includes eight items regarding pasture-raised milk. It is thus named pro pasturing. The second factor combines seven items that support fully housed systems and is thus named pro fully-housed systems. The third factor includes seven items regarding attitudes towards quality. Items loading on this factor refer to regional milk purchase, WTP for known brands, purchase of organic milk as well as environmentally-friendly and animal-friendly production standards, in addition to the items "Healthy nutrition is important to me" and "I like to try new things". All items and factor loadings are outlined in detail in Table 4.

Table 4. Results of the factor analysis

Factors and Items	**Factor Loadings**
Pro pasturing (Cronbach's Alpha = 0.918; % of variance = 17.950)	
Pasture grass is important for the good nutrition of animals.	0.847
Outdoor exercise in the fresh air is important to make the animals feel comfortable.	0.826
Pasture is important for our natural environment.	0.802
Dairy cows at pasture are important in our agricultural landscape.	0.799
Dairy cows need outdoor exercise in the fresh air.	0.745
Fresh grass as feed makes animals healthier.	0.744
For me, pasturing is the most natural form of dairy farming.	0.681
I cannot imagine an agricultural landscape without grazing cows.	0.666
Pro fully housed systems (Cronbach's Alpha = 0.833; % of variance = 11.994)	
Dairy cows in indoor systems are better looked after.	0.799
Animal illness will be noticed faster in indoor systems.	0.746
Dairy cows in indoor systems can be fed according to requirements.	0.741
Dairy cows in indoor systems are better protected against heat and cold.	0.735
Dairy cows in indoor systems produce more milk and are therefore more climate-friendly.	0.655
Milk can be produced more cost-effectively in indoor systems.	0.631
I can understand that farmers these days do not want to push dairy cows onto pasturage every day.	0.445
Quality orientation (Cronbach's Alpha = 0.809; % of variance = 9.959)	
While shopping I try to look out for products that were produced in an environmentally-friendly way.	0.703
While shopping I try to look out for products that were produced in an animal-friendly way.	0.689
I mostly buy organic milk.	0.680
For known brands, I would definitely pay a surcharge.	0.609
I prefer buying milk from my region.	0.565
Healthy nutrition is important to me.	0.556
I like to try new things.	0.519
Dairy company policy (Cronbach's Alpha = 0.898; % of explained variance = 9.288)	
The dairy farm behaves in an environmentally-conscious way.	0.814
The milk is from species-appropriate livestock farming.	0.809
Fair milk prices for farmers in Germany.	0.796
Milk in its natural state.	0.710
Pragmatism (Cronbach's Alpha = 0.746; % of explained variance = 6.971)	
If indoor housing means cheaper milk, it suits me.	0.670
I have to do my shopping fast; I don't look out for differences in milk.	0.655
I especially look out for low-priced milk prices.	0.645
If the cows are well, indoor housing is fine.	0.538
If modern cowsheds provide animals with plenty of exercise and fresh air, that is completely fine.	0.508
Animal Welfare (Cronbach's Alpha = 0.644 % of explained variance = 4.624)	
I cannot imagine that cows that are living only in a barn can feel well.	0.669
For me, keeping cows indoors year-round is cruelty to animals.	0.653
KMO (Kaiser-Meyer-Olkin) = 0.929; explained total variance = 60.79 % Bartlett-Test for sphericity = 16,946.484; significance = 0.000 n = 1,009	

Based on Ward's method, scree tests, a dendrogram and other practical considerations, a four-cluster solution was decided upon. K-means gave F values for all the cluster-forming variables that were significant at the 1 % level, suggesting that the clusters were homogeneous. The average value for Eta is 0.726, showing that there are significant differences between the cluster-forming factors and that the variance within the clusters, is negligible. Eta-squared is 0.529; therefore, 52.9 % of the variance within the cluster-forming factors can be attributed to differences between the clusters. 96.8 % of the cases were attributed to the same clusters by both K-means and discriminant analysis. Table 5 (see Appendix) contains the detailed results of the cluster analysis.

The four clusters can be characterized as follows: The first cluster is the second largest, with a total of 281 consumers. It has high mean values for the pro pasturing and quality orientation factors, whereas the pro fully housed systems factor has a negative mean value. This is therefore the "quality-conscious" cluster. The second cluster is the smallest one. It has no high values for any factor mean value. Therefore, it could be characterized as the "undecided" cluster. The third cluster has a size of 257 respondents. These consumers are less quality-orientated, but show positive values for the pro pasturing and pro fully housed systems factors. This cluster is named the "generalists". The fourth cluster is the largest one. It has a high value for the pro pasturing factor, but lower values for the pro fully housed systems and quality orientation factors. This is therefore the "pasture-supporters" cluster.

The results illustrate that clusters 1, 3, and 4 have the highest mean values for the pro pasturing factor. Since the third cluster also has a high score for the pro fully housed systems factor, this cluster is a less optimal target group for pasture-raised milk. The quality orientation factor is an important aspect for consumers in the first cluster, whereas consumers in the fourth cluster have less interest in the quality characteristics of the products. This difference could be explained by socio-demographic relationships. Whereas the first cluster contains significantly more women and more consumers with a higher education level, cluster number four is overrepresented by consumers from the lower income classes. This group also has significantly more consumers with only a secondary school education and significantly less with a university degree.

To discover whether the theory of the consumer-citizen-gap can be verified, the WTP for pasture-raised milk was requested in the survey. The respondents were asked to imagine that they were in front of a supermarket shelf. They saw four realistic offers of milk with the corresponding realistic prices, as follows: private label (€ 0.65), milk brand one (€ 0.95), organic milk (€ 1.05), milk brand two (€ 1.25). The respondents were also shown a product dummy of pasture-raised milk. Then, they were requested to state their WTP for 1 litre pasture-raised milk. Outliers stating a WTP more than 30 % of the average WTP or less than 30 % of the average WTP were removed from the WTP calculation.

On average a WTP of € 1.04 was stated. The WTP for 1 litre of pasture-raised milk was also calculated for each different cluster and compared to reference prices. The result for the first cluster is a WTP of € 1.13, for the second € 0.98 and respondents of the third and fourth cluster each stated a WTP of € 1.01 for 1 litre of pasture-raised milk. The WTP of the first cluster is significantly higher than the WTP of the other clusters. Table 6 below gives an overview of the WTP for the four clusters.

Table 6. Results of the calculated WTP

WTP for Cluster 1	WTP for Cluster 2	WTP for Cluster 3	WTP for Cluster 4
€ 1.13	€ 0.98	€ 1.01	€ 1.01

Discussion

The literature shows that there is a gap between the rising number of large farms that prefer housed systems for dairy cattle (Schleyer et al. 2013) and customers who demand milk from cows with access to pasture (Ellis et al. 2009; WSPA 2010). The survey presented reveals that consumers differ in their attitudes towards the different housing systems and in their quality orientation. As this was an approximately representative sample, the results can be transferred to the German population.

The semantic differential clearly gives an initial indication that free range systems have positive connotations whereas images of indoor systems evoke more negative emotions. A reason for that might be that grazing cows are firmly anchored images. As known in the literature, pictures can be recollected better than words (e.g. Paivio and Csapo 1973; Graber 1996). The factor analysis confirms a separated perception of housed and outdoor systems, by items loading on two different factors (pro fully housed system / pro pasturing). The positive associations of pasturing are therefore separate from the negative associations of a fully housed system. The items loading on the factor pro fully housed system are perceived primarily as technical advantages by farmers, as opposed to the emotional items loading on the factor pro pasturing.

A particularly suitable target group for pasture-raised milk is the first cluster of quality-conscious participants with a high education level, but the value attached to pasturing by the fourth cluster also makes it a suitable candidate. Both clusters demonstrate high levels of agreement with statements concerning cows having access to pasture and fresh air. They also both agree that they wish to retain dairy cattle in the landscape.

There are, however, clear differences between the clusters regarding quality aspects. For the first cluster respondents it is important to know where the milk they purchase comes from. They have the highest agreement levels to the statements “While shopping I try to look out for products that were produced in an environmentally-friendly way.” ($\mu = 1.34$) and “While shopping I try to look out for products that were produced in an animal-friendly way.” ($\mu = 1.38$). These two statements are less distinctive for the fourth cluster ($\mu = 0.06$ and $\mu = 0.21$). Quality orientation is generally not an important aspect for pasture-supporters ($\mu = -0.15$). This might be due to the fact that the fourth cluster has significantly more respondents with a lower education level and also a significantly higher proportion of respondents distributed across the two lowest income classes. Pasturing might be a very important aspect to these consumers, but when out shopping they pay less attention to food quality aspects. Price might be more important for this group as they show a lower WTP than the quality-conscious cluster. The first cluster of quality-conscious, which makes up 28.1 % of the participants, can therefore be seen as the core target group. The results are congruent with the present market share of 20 % of pasture-raised Danish milk (Heerwagen et al. 2013) and the calculated WTP: While the first and fourth clusters have similar attitudes towards the housing systems, the WTP of the quality-conscious cluster at € 1.13 is 12 cents higher than the WTP of the pasture-supporters. The fourth cluster of pasture-supporters (28.3 %)

can be seen as an extended target group given that they also prefer pasturing, but are not willing to pay such a high price for pasture-raised milk as the quality-conscious cluster. The differences between cluster 1 and cluster 4 are a strong indication of a possible consumer-citizen-gap. Both clusters show similar attitudes concerning the factor pro pasturing and pro fully housed system. But when comparing the WTP for pasture-raised milk between the clusters, it can be seen that the first cluster has a significantly higher WTP (€ 1.13) than the fourth cluster (€ 1.01). Thus, it can be assumed that for the fourth cluster pasturing is not an important buying motive and so does not influence the purchase decision what is also supported by their lower agreement to quality attributes.

The third cluster, the generalists (25.7 %), may also be an extended target group for pasture-raised products. Statements about pasture-access are important for them, but they do not disapprove of indoor-housing as much as the other groups. In this respect they agree particularly with the statements in favour of the indoor-housing system that refer to advantages for animals (e.g., "In indoor systems, animal illness will be noticed faster."). In addition, they tend to look for animal-friendly produced products ($\mu = 0.47$). If they are informed about the gains of outdoor systems it might influence their purchasing decision. The positive attitude towards both housing systems ($\mu = 1.18$; $\mu = 1.04$) confirms that indoor and outdoor systems are separately perceived. Consumers in the third cluster see positive aspects for indoor and outdoor systems. They seem to be open to arguments for both housing systems.

A clear market potential for pasture-raised milk is thus shown. Moreover, all groups would pay a surcharge for pasture-raised milk, which is consistent with results from previous surveys (Pirog 2004; Ellis et al. 2009, Hellberg-Bahr et al. 2012). The results mean that a financial incentive for producing pasture-raised milk and dairy products would be reasonable for producers, processors and marketers, as long as this aspect is highlighted and promoted on the product. Offering an incentive is important in developing a solid market. However, the calculated WTP has to be carefully considered due to the theory of the consumer-citizen-gap. A known gap exists between the attitudes of citizens and their actual behaviour as customers during their purchasing situations (especially with respect to animal welfare aspects in food) (Coff et al. 2008; Harvey and Hubbard 2013). Animal welfare aspects as well as environmental and quality aspects can be overlooked during the decision-making process in the supermarket as while completing the survey customers are answering as citizens who are presenting their general opinion. The two most promising target groups differ in their attitudes towards quality orientation ($\mu = 0.97$ for the first cluster and $\mu = -0.15$ for the fourth cluster) and their WTP (€ 1.13 and € 1.01), which might confirm that for some customers there is a gap in their behaviour as citizen and consumer. While the quality-conscious will also pay a premium, pasturing-supporters decide according to the price they see on the product shelf in the supermarket. This is confirmed by the significantly higher WTP of the first cluster.

Conclusions

As the results show, housed systems evoke negative connotations. In the semantic differential and the cluster analysis more than 50 % of respondents consider fully housed systems problematic. Obviously, many consumers have clear preferences for pasturing. This attitude has already created a severe image problem for those keeping laying hens in cages. In Germany,

today, legal guidelines forbid this type of livestock farming. In order to prevent a similar crisis, the dairy sector has to face up to this consumer perception.

At first thought it could be seen as a paradox to compensate by a higher price and used as a marketing tool the fact that dairy cattle have access to pasture, given that this was a norm only a few decades ago. The changes of structure in dairy farming (less use of grassland in dairy farming; see above) have caused the dairy sector to face up to these new issues. The conducted consumer survey shows that pasturing is an important issue for customers and can be used as a sales argument for a relatively large group of customers.

Today, only a few countries, such as the Netherlands, have consistent standards for dairy products labelled as pasture-raised. But it is only fixed standards for the term pasture-raised milk that can guarantee consumers will not feel deluded. Honest and transparent standards and an appropriate labelling system for pasture-raised milk must therefore be built up in the near future to target cluster one: a consumer group of 28.1 % of the German population which is characterized by a significantly higher WTP for pasture-raised milk. Otherwise, farmers may tend to give up on pasture-grazing for their dairy cattle due to higher economies of scale of indoor housing systems. Additionally, a study by Kehlbacher et al. (2012) examined the fact that information about certification has a positive influence on WTP. It is therefore important to live up to the demands of consumers and also to the practicalities of farmers. Taking all market participants into account, a solid system can be generated that retains and builds upon the grazing system. Given these conditions, the market potential demonstrated encourages farmers and the dairy-products sector to highlight and promote the positive aspects of pasture-raised milk.

Limitations

Due to the discrepancy between consumer and citizen, future WTP research has to be verified by demonstrated preferences, e.g., in a supermarket test. Furthermore, the results are only valid for the German population and no comparable research yet exists for housing systems. Further research in Germany and in additional countries therefore needs to be carried out to discover consistent or contrary results. The survey also provides hints on the importance of food source for dairy cows in terms of grass and the fatty acid composition of milk in terms of omega-3 fatty acids. More detailed research is necessary to evaluate their importance on a purchasing decision. For example, in Austria instead of pasture-raised milk, a prominent marketing trend in the milk sector is hay milk (“Heumilch”), a label that guarantees the abandonment of silage fodder.

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Appendix

Table 5. Results of the cluster analysis

	Cluster 1 Quality-Conscious	**Cluster 2 Undecided**	**Cluster 3 Generalists**	**Cluster 4 Pasture-Supporters**	**Sample** [6]
Cluster size absolute and in %	281 (28.1 %)	179 (17.9 %)	257 (25.7 %)	283 (28.3 %)	
	Mean value (SD) [factor value]	Mean value (SD) [factor value]	Mean value (SD) [factor value]	Mean value (SD) [factor value]	Mean value (SD)
Factor 1: Pro Pasturing[1]	**1.57 (0.561) [0.36]**	**0.2 (0.855) [-1.54]**	**1.18 (0.711) [0.05]**	**1.55 (0.563) [0.57]**	
For me, pasturing is the most natural form of dairy farming.[4]	1.54[ad] (0.708)	0.28 (0.895)	1.16 (0.784)	1.56[ad] (0.633)	1.22 (0.880)
I cannot imagine an agricultural landscape without grazing cows.[4]	1.4[ad] (0.765)	0.02 (0.840)	0.92 (0.879)	1.36[ad] (0.766)	1.02 (0.955)
Fresh grass as feed makes animals healthier.[4]	1.51[ad] (0.683)	0.15 (0.771)	1.2 (0.693)	1.42[ad] (0.663)	1.16 (0.851)
Dairy cows need outdoor exercise in the fresh air.[4]	1.66[ad] (0.632)	0.26 (0.833)	1.18 (0.690)	1.6[ad] (0.582)	1.27 (0.844)
Outdoor exercise in the fresh air is important to make the animals feel comfortable.[4]	1.7[ad] (0.506)	0.36 (0.796)	1.34 (0.614)	1.72[ad] (0.489)	1.37 (0.771)
Pasture grass is important for the proper nutrition of animals.[4]	1.69[ad] (0.494)	0.28 (0.762)	1.28 (0.677)	1.63[ad] (0.539)	1.32 (0.794)
Dairy cows at pasture are important in our agricultural landscape.[4]	1.5[ad] (0.628)	0.07 (0.768)	1.15 (0.760)	1.51[ad] (0.662)	1.16 (0.877)
Pasture is important for our natural environment.[4]	1.59[ad] (0.633)	0.2 (0.794)	1.22 (0.744)	1.59[ad] (0.618)	1.25 (0.859)
Factor 2: Pro Fully Housed Systems[2]	**-0.58 (0.706) [-0.62]**	**-0.06 (0.692) [-0.24[bd]]**	**1.04 (0.506) [1.27]**	**-0.31 (0.718) [-0.36[bd]]**	
Milk can be produced more cost-effectively in indoor systems.[4]	-0.36 (1.247)	0.22[bd] (1.083)	1.25 (0.979)	0.17[bd] (1.289)	0.30 (1.314)
I can understand that farmers these days do not want to push dairy cows onto pasturage every day.[4]	-0.27[ab; ad] (1.050)	-0.08[ab; bc] (0.878)	0.51[bc] (0.977)	-0.27[ad] (1.059)	-0.04 (1.053)
Dairy cows in indoor systems produce more milk and are therefore more climate-friendly.[5]	-1.03[ad] (0.862)	-0.24 (0.852)	0.45 (1.204)	-0.96[ad] (0.751)	-0.50 (1.115)
Dairy cows in indoor systems are better looked after.[5]	-0.71 (0.889)	-0.03 (0.885)	1.33 (0.966)	-0.36 (1.071)	0.02 (1.243)
Dairy cows in indoor systems can be fed according to requirements.[5]	-0.86[ad] (0.891)	-0.22 (0.872)	0.91 (1.128)	-0.72[ad] (0.951)	-0.26 (1.200)
Dairy cows in indoor systems are better protected against heat and cold.[5]	-0.51 (1.014)	-0.12[bd] (0.890)	1.33 (0.951)	-0.02[bd] (1.159)	0.16 (1.239)
Animal illness will be noticed faster in indoor systems.[5]	-0.35 (1.118)	0.04[bd] (0.982)	1.46 (0.877)	-0.02[bd] (1.251)	0.27 (1.291)

Table 5. *Continued*

Factor 3: Quality Orientation[3]	**0.97 (0.621) [0.93]**	**-0.09 (0.808) [-0.1^{bc}]**	**0.27 (0.834) [0.06^{bc}]**	**-0.15 (0.675) [-0.88]**	
I prefer buying milk from my region.[4]	0.78 (1.030)	-0.1^{bd} (1.083)	0.34 (1.139)	-0.29^{bd} (1.133)	0.20 (1.178)
For known brands, I would definitely pay a surcharge.[4]	0.39 (1.182)	-0.52 (1.088)	-0.23 (1.180)	-0.84 (1.015)	-0.28 (1.219)
I mostly buy organic milk.[4]	-0.1 (1.252)	-0.74^{bc} (1.098)	-0.94^{bc} (1.079)	-1.49 (0.698)	-0.84 (1.165)
Healthy nutrition is important to me.[4]	1.6 (0.533)	0.31 (0.749)	0.96 (0.706)	0.73 (0.836)	0.95 (0.844)
I like to try new things.[4]	1.39 (0.700)	0.24 (0.785)	0.84 (0.827)	0.56 (0.836)	0.81 (0.889)
While shopping I try to look out for products that were produced in an environmentally-friendly way.[4]	1.34 (0.700)	0.12^{bd} (0.769)	0.45 (0.849)	0.06^{bd} (0.823)	0.53 (0.947)
While shopping I try to look out for products that were produced in an animal-friendly way.[4]	1.38 (0.668)	0.08^{bd} (0.788)	0.47 (0.821)	0.21^{bd} (0.894)	0.58 (0.950)

All results are significant at the 0.1 % level; n = 1,000; SD = standard deviation
[1] Min. = -5.32; Max. = 2.07
[2] Min. = -2.76; Max. = 2.35
[3] Min. = -3.95; Max. = 3.13
[4] Scale from +2 = "I totally agree" to -2 = "I totally disagree"
[5] Scale from +2 = "I find it very convincing" to -2 = "I do not find it convincing at all"
[6] n = 1,000-1,009
a, b, c, d: If the values in one row are marked with the same letters, the difference between the clusters is not significant (Tamhane's/Scheffé's post hoc test)

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Innovativeness of Ceretto Aziende Vitivinicole: A First Investigation into a Wine Company

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Abstract

As the second greatest producer and largest exporter of wine, Italy has been impacted by the global economic crisis. This study investigates a long established and highly successful family owned and operated business in the wine sector and their ability to continuously innovate products, processes and target markets. This research is aimed at ascertaining whether effective firm management in the wine sector depends on the combination of internal and external innovation.

Keywords: innovation, wine sector, family businesses, internal and external innovation, product development

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Introduction

The wine sector is highly deeply rooted in the Italian economic pattern, both in terms of the turnover produced by wine businesses and the plethora of high-quality wines that domestic and international markets appreciate. Italy is the second greatest producer of wine in the world and the first global exporter when it comes to volume (Giacosa et al. 2014).

The wine sector has a considerable number of family owned and operated businesses, a phenomenon that has gained growing importance both in Italy and abroad as a source of growth, development and socio-economic stability (Cappuyns et al. 2003; Pistrui 2002; Prencipe et al. 2008).

This research positions itself within this context, and investigates a family business in the wine sector and its capacity to innovate. In the present-economic crisis, which has affected wine consumption, conventional strategies of international outsourcing might not suffice for maintaining a competitive advantage and supporting wine consumption. In fact, wine businesses need to be able to innovate in terms of product, process and target markets.

This research is aimed at ascertaining whether the effective management of innovation by a representative family firm operating in the wine sector depends on the combination of internal and external innovation.

This research is based on qualitative methodology and focuses on one case study, i.e. Ceretto Aziende Vitivinicole, an Italian internationally successful business that produces a wide range of high-end wines. For decades, “Italian wine” was identified with the “Barolo brothers”, i.e. Bruno and Marcello Ceretto (Mariani 2007).

They are characterized by an innovative business approach that has been handed from generation to generation as a method to manage innovation both internally and externally.

The paper is structured as follows: 1) the introductory section describes the wine business and identifying characteristics. 2) The methods chosen for this research are discussed; and 3) followed with a review and analysis of the existing literature on innovation and family businesses. 4) Next, a case study analysis of the Ceretto family's winery is chosen as the focus of this research. 5) Finally, the conclusions, practical implications and limitations are presented.

Methodology

In order to reach the goal of this research, the following hypothesis has been developed:

HP: Family firms operating in the wine sector need to be able to find an effective combination of innovation and tradition, which are closely related elements although apparently clashing. When internal innovation takes place, it is indicative of adherence to traditional values. On the other hand, external innovation is mostly influenced by the innovation drive and is more significantly technical and scientific.

The case study methodology was applied within the qualitative approach. Ceretto Aziende Vitivinicole, was deemed to be particularly representative for this study, because they are well established in international markets as a quality-oriented company and, they have managed innovation both internally and externally.

A methodology based on a single case study is reliable (Yin 1984 and 2003) if the case study chosen is "extreme, unique, revealing, and pioneering". Ceretto Aziende Vitivinicole can be considered as such, since the company is an internationally successful firm that produces a wide range of high-end wines, with a 2012 turnover of €13.7m.

Although the data and information used in case studies may come from a variety of sources (Eisenhardt 1989), the tool of conducting an interview (Astrachan et al. 2002) was chosen to write this paper. The first interview was conducted with Bruno Ceretto, the President of Ceretto Aziende Vitivinicole in charge of innovation strategies, focused on family and company history, the role played by each family member in managing the company and the internal management of innovation. The second interview was conducted with Donato Lanati, an internationally well-known oenologist in charge of the external management of innovation for Ceretto Aziende Vitivinicole. The interview explored the activities undertaken by Enosis Meraviglia to manage innovation for Ceretto Aziende Vitivinicole.

Both interviews are qualitative, semi-structured (Potter & Wetherell 1987; Alvesson & Deetz 2000; Corbetta 2003) and were prepared with the participation of all authors. They were conducted by two of the authors, who used a set of questions previously developed by all authors. Each interview lasted about two hours. Each author analysed the results independently in order to avoid being influenced by any other author. All the authors then compared their own observations and outlined the main factors that contributed to reaching the conclusions stated in this paper. Finally, a model of innovation management in family businesses operating in the wine sector was provided.

Literature

Existing literature has strongly focussed on the tendency for innovation in family businesses. The prevailing belief is that family firms are less attracted by innovation, i.e. they tend to be less creative, or more conservative, when developing products and processes (Donckels & Frohlich 1991; Morck & Yeung 2003). Traditionally family companies are less risk-adverse and tend to be less inclined to build external relationships that might foster innovation (Dunn 1996). It follows that they tend to invest in seeking a higher share of existing markets rather than in innovation (Bresciani et al. 2013). Some scholars have shown that family businesses limit their investment in diversifying to new areas, which influences innovation choices (Morris 1998): usually, family firms tend to invest in sectors that are an extension of the field of the founder family (e.g. the textile sector) and a development of family tradition (e.g. the food sector) (Donckels & Frohlich 1991). Some studies have criticised the innovation policy within family businesses, due to its being driven by tradition (Carney 2005).

Scholars have focussed on innovation as a way to compare the strategic marketing choices of family and non-family firms (Tanewski et al. 2003). This has shown that family businesses are

characterized by "familiness" (Habbershon & Williams 1999; Culasso et al. 2013), i.e. a set of unique, tacit and distinctive competencies (Teece 1982) that have a considerable impact on their competitive advantage. Human capital influences such "familiness" (Dunn 1995; Sirmon & Hitt 2003) when "warm, friendly and intimate" relationships exist among family members (Horton 1986) and when financial capital is invested in the medium- and long-run (Dreux 1990). Such "patient capital" is invested without predictable return and designed to lead to future creativity and innovation (Teece 1992). As family businesses have a long-term investment time horizon, innovative investments are suitable due to their capacity to generate return on investments (Culasso et al. 2013).

More recent studies have suggested that a combination of tradition and innovation might be necessary to achieve and maintain competitive advantage (Dublini et al. 2013; Re 2013). It has been shown that innovation works for family firms only when family members interact across generations. (Litz & Kleysen 2001). Without such interaction between generations, an innovative policy reduces the business' competitiveness because it does not take advantage of the wide range of skills and insights of the mix of older and younger family members (Kellermanns et al. 2008).

Other studies have analysed the ways in which innovation might be managed (Chesbrough 2003; Schilling 2009):

a) Internally, i.e. within the company by some members of the family or trusted managers and staff. Managing innovation depends on the role it plays: in particular, innovation might apply only to Research & Development or other functions, such as Manufacturing or Marketing;

b) Externally, i.e. using external resources, typically experts in the firm's sector, such as oenologists, universities or chemical analysis laboratories. External resources should always consider the peculiarities of a firm's surroundings. When innovation is managed externally, it is crucial that the knowledge and results gained are fully assimilated into the firm in order for it to be successful (Cohen & Levinthal 1990);

c) Innovation might be managed both internally and externally. When this combination is successful, the benefits of innovation peak, provided that the firm is able to put the external experts' suggestions into practice (Pistrui 2002). An effective relationship between the internal and the external units engaged on innovation projects is then created. This holds true both in large companies and in small and medium businesses (Chesbrough & Crowther 2006; Enkel et al. 2009).

Experts in the technical and oenological fields and management scholars have only recently started to study innovation in the wine sector in general, and more specifically in competitive strategies adopted by wine sector companies (Rossi 2008; Vrontis & Viassone 2013). Product innovation has been driven by the need to cope with the decrease in worldwide wine consumption, especially considering the crucial role that wine has always played in the economy (Chaikind 2012). Furthermore, studies have emphasized the benefits of creating networks with other firms operating in the wine sector to encourage innovation (Bell & Giuliani 2007).

The study of the relationship between the family, the firm and its surroundings, which has been mentioned above, might be effectively applied to the wine sector. The geographical proximity of potential networking companies as well as their being rooted in their surroundings might have a positive impact on innovation processes (Giuliani 2007).

This research aims to fill gaps in the literature on managing innovation within family firms that operate in the wine sector, using a case study approach. This research will attempt to ascertain whether, in the wine sector, effective innovation management depends on combining internal and external innovation.

Case Study: Ceretto Aziende Vitivinicole

History of the Company and the Ceretto Family

Riccardo Ceretto founded his first winery in Santo Stefano Belbo in the late 19th Century. In the early 1930s, the Casa Vinicola Ceretto was established in Alba, where Bruno and Marcello, Riccardo's sons, started to help their father in the 1960s.

Today the company owns over 160 hectares (i.e. about 400 acres) of vineyards located in the best areas of both Langhe and Roero. Ceretto Aziende Vitivinicole is one of the best-known wineries in the world, with a 2012 turnover of €13.7m.

The company's performance improved in 2013. Revenues grew from €13.7m to €14.3m while the EBITDA was €408,253 (€818,549 Euro in 2012). Net earnings also improved - losses were €-196,784 (€-385,943 in 2012). The total assets were €34.5m (€32.9m in 2012) and the net equity was €17.6m (€15.8m Euro in 2012). The organisational structure was increased to 30 employees from 19 (2012).

Riccardo's sons still work in the company. Bruno represents the dynamic side of the family, he created the company's hugely successful sales and marketing structure. Marcello is the wine making expert who has made Ceretto wines famous all over the world.

Bruno's and Marcello's children started to work in the family business in 1999. Lisa, Marcello's daughter, has a Bachelor's degree in Economics and Business and supervises the management of finance and administration. Alessandro, Marcello's son, who studied at Istituto Tecnico Agrario Viticolo Enologico in Alba, has worked in some of the best winemaking regions in the world (i.e. Bordeaux, Australia, California, South Africa), and now supervises production. Federico, Bruno's son, supervises export sales. Roberta, Bruno's daughter, has a Bachelor's degree in Foreign Languages and Literature and supervises communication, PR and the organisation of cultural events. Both the second and the third generation are involved in managing the company.

Bruno and Marcello, who represent the traditional side of the company, both supervise the work of their children. In their case, tradition is closely related to the land where the family live and work, hence their culture is deeply rooted in such tradition.

The company has chosen to manage innovation both internally and externally.

The Internal Management of Innovation at Ceretto Aziende Vitivinicole

During the interview, Bruno Ceretto said that internal Research & Development is not formalized a business function. This is typical in small family firms, where R&D is normally part of production. Moreover, R&D has not been bureaucratised: it is very lean and informal, and fosters wide-ranging creativity (Volontè 2003). However the absence of a specific and formalized R&D business function can become problematic in future. Two of the main problems of family businesses are maintaining expertise through generations and making it possible for external managers to become part of the innovation process. Without a dedicated business function it is more difficult to manage any process.

Creativity and innovation are encouraged throughout the whole production and supply chain. Ideas and suggestions put forward by the whole workforce, as well as by people who work closer to customers (such as salesmen, wine shop managers, restaurant owners) are taken seriously. As a result, new ideas are incorporated into products and/or the production processes.

Although at Ceretto the organisational chart is quite simple, innovation means creating a certain mind-set at all levels of the organisation, as well as involving both the creative and managerial sides of the company. The two sides are integrated - the managerial side is mainly represented by the family (i.e. Bruno and Marcello Ceretto and their children); the creative side involves a number of experts, whose work is supervised by the family, and it also includes the lower levels of the organisation (Bertini 1991a; Coda 1991).

Internal innovation is jointly managed by the two generations. Bruno and Marcello, who have been working in the company since the 1960s, represent the tradition and the past; their children represent the future. Tradition is reflected in individual expertise: Bruno Ceretto, experienced in sales and marketing, supervises the members of the third generation who work in such functions, and takes care of administrative budgets and budget control. Marcello Ceretto, together with Alessandro, supervises the technical and scientific aspects of production.

Innovation policies at Ceretto Aziende Vitivinicole are structured as a) products and b) processes (Bertini 1991b).

Product Innovation

During the interview, Bruno Ceretto said that product innovation is related to both tangible and intangible attributes (Giunta 1993; Pellicelli 2005; Bruce & Hines 2007; Giacosa 2011):

Tangible elements: innovation means not only extending the product range, i.e. offering customers a wider choice (Farneti 2007), but also developing new features for an existing product, i.e. improving the product. Although their brand is well established worldwide, the

Cerettos think that there is always room for improvement and that innovating is a never-ending process. Even the best wine might be improved in its organoleptic features. Moreover, they aim to balance extensive research into product quality with a consideration for "wine" in the broadest sense of the word for its tangible and intangible attributes.

Intangible elements: the Cerettos have been emphasizing the intangible attributes of wine for years. Such elements might be combined with tangible attributes in order to increase their benefits, for example to make the product more appealing or increase customer loyalty. At Ceretto Aziende Vitivinicole, sales policies have been influenced by choices designed to promote the corporate image worldwide. In turn, the corporate image has had a positive effect on the intangible elements. Choices that have contributed to promoting the brand include:

a) Packaging—designing tailor-made labels. The Cerettos were the first family firm in Piedmont (one of the most famous Italian wine making regions) to invest in the image of their products, having their labels and bottles designed by famous designers. According to Bruno Ceretto, in this way "people who drink a wine can also look at a photograph of the vineyards where the grapes come from. Vineyards are part of history, and the names of these hills do not change over time. This makes us even more reliable. People can then look for that vineyard, visit it, touch its leaves. Any day, any time";

b) Organizing a number of national and international events to promote "wine-culture". For example, the *Premio Langhe Ceretto,* an international committee that selects works of fiction related to culture from a sociologic and enogastronomic point of view;

c) Designing iconic buildings that have become landmarks in the area, such as the Chapel decorated by Sol LeWitt and David Tremlett, the Glass Cube, the Berry. These are built in colours and materials that can be seen from all over the surrounding area.

In conclusion, product innovation is successfully managed within the company, because it is implemented in ways that combine extensive research into product quality with a focus on the consumer's perception of the product and the business.

Process Innovation

At Ceretto Aziende Vitivinicole process innovation is defined as follows:

1. **Production:** this function aims to improve the tangible attributes of wine and to create a product whose organoleptic characteristics stay perfect over time, especially when considering that some of the wines undergo an ageing process. Extensive research into new production techniques also means a constant improvement in the quality of products. The quality of the raw material (grapes) used is crucial, as a good wine inevitably comes from "good berries". All production facilities are fully equipped with state-of-the-art automated technology (Staudt 1989). Such facilities are instrumental not only in putting research, experimentation, creativity, challenge and vision of future targets into effect (Bastia 2001), but also in leading to better performance in terms of efficiency, effectiveness and quality;

2. **Sales:** the company has focussed on sales in Italy and abroad for years. The Cerettos were able to enter the international markets well before their competitors thanks to an effective corporate image policy, which has been very appealing to foreign consumers. The family has also used several distribution channels, both traditional and modern. For example Doyouwine.com, a website developed by Federico and Alessandro Ceretto dedicated to selling wine online. The site generates business while meeting the needs of two categories of consumers, i.e. connoisseurs (who look for specific wines and vintages) and amateurs (who are not experts);

3. **Administration:** product competitiveness is achieved not only in relation to competitors, but also within the company itself. Each wine is allocated its own cellar space and staff. Each product has its own profit and loss statement and should always be profitable. When a new products does not meet profit expectations, production is discontinued. For example, if Blangé had not been successful, the Cerettos would not have financed that project with the profits from Barolo.

In conclusion, process innovation is successfully managed within the company, because it is implemented through effective choices made in production, sales and administration. All actions are supported by a production structure equipped with cutting-edge technology and modern sales policies.

The External Management of Innovation

Ceretto Aziende Vitivinicole also manage innovation externally. Like other firms operating in the wine sector, they have used expertise offered by Enosis Meraviglia in new products, quality control, health and safety.

Enosis Meraviglia is located in the Monferrato region and offers not only scientific expertise, but also assistance in the actual winemaking process. Laboratories, tasting rooms, winemaking facilities, virtual facilities and university lecture rooms cover an area of 2,500 square metres (about 27,000 square feet). It is an “amazing forge”, where experts in food sciences, biologists and technicians select and analyse vines and wines.

“Blangè”, one of the most successful wines produced by Ceretto Aziende Vitivinicole (800,000 bottles a year), was created thanks to the collaboration of Ceretto Aziende Vitivinicole and Enosis Meraviglia.

The Cerettos decided to work with Donato Lanati because the latter shares the family’s philosophy, which is based on combining natural processes and scientific research. Together, they have been concentrating on tradition and innovation, past and present. Environmental-friendliness and scientific expertise are crucial for Donato Lanati. In Donato Lanati’s own words, “a successful market has to be consumer-oriented. People who buy wine today want to be reassured about health and safety, about the origin of the product. Those who seek quality wines also wonder about how environment- and tradition-friendly the producer is”.

Donato Lanati said that the crucial element of the collaboration with Ceretto Aziende Vitivinicole is understanding the client’s objective, assessing its feasibility and providing the

expertise needed to achieve it. The organoleptic characteristics of each wine are analysed by the oenologists at Ceretto Aziende Vitivinicole and the team of Enosis Meraviglia simultaneously, then results are compared. Enosis Meraviglia then provides Ceretto Aziende Vitivinicole with all the information they need to transfer the flavour in their grapes into each bottle.

The choice to manage innovation both internally and externally turned out to be crucial for the success of Ceretto Aziende Vitivinicole. Donato Lanati's expertise has made a major contribution not only to the high quality of Ceretto wines, but also to implementing the family's distinctive production and marketing philosophy.

Conclusions, Implications and Limitations

Both Bruno Ceretto and Donato Lanati confirmed that their internal and external innovation policies are designed to produce high quality products, as Ceretto Aziende Vitivinicole is positioned at the top end of the market. Top-quality products enable the company to increase its visibility, attract consumers' attention, and fight off competitors. Having considered the segment's spending power, the company has chosen to target customers who will be influenced by the technical and aesthetical features of the product. Such segments are usually less significantly affected by declining consumption, thus offering the company some growth opportunities.

Innovation policies make it possible for the company to operate competitively in a given context, thanks to new, better or adapted products and processes. However, highly innovative ideas should always be supported by passion and tradition. Tradition retains value and meaning in modern society as long as it is successfully paired with innovation.

The roles of the Cerettos, who manage innovation within the company, and of Enosis Meraviglia, which contributes to innovation as an external expert, do not conflict. Since internal innovation is product-oriented, the family concentrates on quality (from grapes to wine) and image, ranging from advertising campaigns to sales strategies and packaging. At the same time, Enosis Meraviglia focusses on product innovation in a more technical sense, i.e. on the outstanding organoleptic quality of the wine.

Although the company is highly innovative, innovation and tradition do not conflict at Ceretto Aziende Vitivinicole. The two principles, only apparently opposing, are deeply rooted in the wine sector. In a successful competitive family business, innovation and tradition should coexist.

Finally, the combination of tradition and innovation has been crucial for the success of their company. If the Cerettos ignored tradition in favor of innovation, they would lose the values with which consumers identify them. If they ignored innovation in favor of tradition, they would hold onto traditional values without benefiting from innovation. In a difficult economic, political and social context, successful companies are able to cope with change quickly and decisively, combining tradition and innovation is crucial to maintain a competitive advantage. One of the limitations of the company is the informal way in which the innovation process is managed. Although it works for now, in the future it may limit the company growth as it will make it difficult to involve external managers in that business function.

The implications of this research are related to the findings, showing that innovation is crucial along the production and supply chain. This work aims to provide information about the managing innovation that might be useful to owners and managers of family firms operating in the wine sector who want to improve their business performance. A single case study may be considered a limitation; a comparison with other family firms in wine sector would improve our findings.

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Yealands Wine Group: Balancing Business and Sustainability

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Abstract

Yealands Wine Group is a young NZ wine company established in 2008, incorporating environmental sustainability as a core business principle from inception. In 2012, Yealands was the sixth largest wine company in NZ with sales of 750,000 cases. They achieved a significant growth in sales for a short period of time. However, the sales forecasted in the next few years are less optimistic. Can Yealands use sustainability to drive sales and growth?

Keywords: New Zealand (NZ) wine industry, environmental sustainability, wine sustainability, Yealands

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*Think boldly, tread lightly and never say it can't be done***.**
— Peter Yealands, Executive Director and Founder, Yealands Wine Group Estate

Introduction

It was a beautiful summer day in Marlborough, New Zealand (NZ). Peter Yealands, chairman and founder of Yealands Wine Group Limited (Yealands), was sitting in his office overlooking the vineyards sprawled across the rolling hills of Awatere Valley. He was thinking about the amazing growth of Yealands since 2008 and how to use sustainability to drive future growth. The company had achieved significant growth in a very short period of time due to increased grape and wine production as well as a successful acquisition. However, a decreased growth rate was forecasted for this year and the next couple of years. In 2011/12, the company experienced about 90% growth in wine sales over the previous year. However, the estimate for 2012/13 was roughly 25% growth due to consolidation within the company. Established in 2008, Yealands owned two wineries and 12 vineyards spread across New Zealand; it produced 15,000 tonnes of grapes from its own vineyards and 12 million litres (L) of wine in 2011/12. Yealands had become the sixth largest wine exporter in New Zealand with sales of 750,000 cases[1] in 2011/12 (see Exhibit 1 for Yealands company data).

The history of Yealands dated back to 2001 when entrepreneur Peter Yealands bought his first Seaview vineyard of 120 ha. Developing a passion for grape growing, he continued buying neighboring vineyards. By 2013, the Seaview vineyard had grown to 1,150ha and was the largest privately-owned single vineyard in New Zealand[2] (see Exhibit 2 for the map of wine regions in NZ) (see Exhibit 3 on Peter Yealands).

Environmental sustainability involving innovation was Yealands' competitive advantage. Yealands' goal was to become the most sustainable vineyard and winery in the world, and the company had invested in environmental initiatives since its inception. A pioneering GPS technology had been used to accurately run the vineyards rows and orient them for the best aspect of the slopes. The design of the new winery incorporated various energy and water saving ideas. And a range of innovative environmental activities and certifications had been introduced. As a result, Yealands had achieved various environmental awards for their wines, which attracted new buyers including Tesco in the UK.

Global Wine Industry

The global wine industry had become very competitive and had changed dramatically over the last decade. Wine production and consumption in the Old World countries such as France, Italy, and Spain had declined while the New World countries such as Australia, New Zealand, and Chile had increased in both production and exports. China was one of the fastest-growing wine markets, accounting for about 7% of the global wine consumption in the last few years (see Exhibit 4 for a summary of the global wine industry).

[1] A case comprises 9 litres of wine (12 bottles of wine in a case; 0.75 litre in a bottle
[2] The second largest privately-owned single vineyard in New Zealand is about 600 ha

International Wine Certification and Initiatives

A number of environmental certification schemes were available to wineries around the world. These included region- or country- specific wine programs (such as Certified California Sustainable Winegrowing[3], Entwine Australia[4]; Certified Sustainable Wine of Chile[5]; and Integrated Production of Wine in South Africa). Other certification schemes were not linked to specific geographical areas; examples included The Carbon Trust's Reducing CO_2 and CO_2 Measured Labels[6], and certification to ISO14001[7] (see Exhibit 5 for details of a selection of key international and NZ certification schemes).

The wine industries in different countries had co-operated on a number of wine environmental initiatives including:

1. A set of Global Wine Sector Environmental Sustainability Principles (GWSESP) was produced in 2006 by FIVS (Federation Internationale des Vins et Spiritueux, the trade association for all sectors of the alcohol beverage industry). The purpose of these principles was to "…ensure that there is a coordinated, efficient and results-driven approach to the international wine industry's commitment to environmental sustainability"[8];

2. The International Wine Industry Greenhouse Gas Accounting Protocol was released in 2008, the result of a partnership between the Wine Institute of California, NZ Winegrowers, South Africa's Integrated Production of Wine program, and the Winemakers' Federation of Australia. It provided a free greenhouse gas (GHG) protocol and calculator for measuring the carbon footprints of vineyard operations and wineries.[9]

Internationally, an increasing number of wineries were investing in environmental initiatives and certification to demonstrate their environmental credentials. Examples of recent environmental award-winning wineries[10] included Viñedos Emiliana[11] in Chile, Avondale[12] in South Africa, Torres[13] in Spain, and Jackson Family Wines[14] in California.

New Zealand Wine Industry

The New Zealand wine industry had experienced significant growth in production and exports in the last decade (see Exhibit 6 for a summary of the NZ wine industry). In 2012, there were 703 wineries in New Zealand divided into three categories based on production per year: more than 2 million L; between 200,000 L - 2 million L; and less than 200,000 L.

[3] http://www.sustainablewinegrowing.org/certified-sustainable-winegrowing.php
[4] http://www.wfa.org.au/entwineaustralia
[5] http://www.sustentavid.org/en/
[6] http://www.carbontrust.com/client-services/footprinting/footprint-certification/carbon-footprint-label
[7] http://www.iso.org/iso/iso14000
[8] http://www.ipw.co.za/content/pdfs/sustainability/eng/GWSESP_Brochure.pdf
[9] http://www.wineinstitute.org/ghgprotocol
[10] Winners of awards at the DB Green Awards 2012 and 2013 (see Green Awards at http://www.thedrinksbusiness.com/)
[11] http://www.emiliana.cl/
[12] http://www.avondalewine.co.za/
[13] http://www.torres.es/
[14] http://www.kj.com/ (Kendall-Jackson wines are the best known wines from Jackson Family Wines)

Competitors

Pernod Ricard (NZ$236 Million in revenue in 2012), a French spirits group that owned several iconic New Zealand wine brands such as Brancott/Montana, Church Road and others, was the largest wine company (wine production and distribution) in New Zealand, selling about 3 million cases[15] a year of NZ-produced wines. The second largest wine company in NZ was *Delegat* (NZ$222 Million in revenue in 2012), a publicly owned company enjoying global success with its Delegat and Oyster Bay brands. Delegat sold around 2-2.5 million cases of NZ wine per year. In third position was *Constellation Brands NZ* (NZ$192 Million in revenue in 2012), an international company that was the world's biggest wine producer and owned several NZ brands like Nobilo, Selaks and Kim Crawford. Constellation sold around 2.0 million cases of NZ wine per year. The next largest company was *Villa Maria* (NZ$120 Million in revenue in 2012), the top NZ-owned company with its own Villa Maria brand and the fourth largest company in terms of sales of NZ wine; it sold around 1.5 million cases per year. *Treasury Wine Estates* (NZ$112.7 Million in revenue in 2012), an Australian-based wine making and distribution company that owned NZ brands including Matua, sold around 1.3 million cases of NZ wine per year. Yealands was in sixth place overall. The next position was shared by several companies, such as Mud House Winery, Guisen Wines, Babich Wines. The sales for each of these companies were about 500,000 cases per year.

New Zealand Wine Sustainable Certificates and Initiatives

Many New Zealand wine companies chose to associate themselves with the "clean and green" image of New Zealand in their marketing messages and branding. The benefits of this branding had been recognised for some time, and were promoted in a coordinated way through NZ Winegrowers, the national organization for New Zealand's grape and wine sector. NZ Winegrowers was mainly funded through a compulsory levy on the sale of grapes and wine. Perhaps the most tangible expression of the New Zealand wine sector's coordinated approach could be found in the development of the Sustainable Winegrowing New Zealand (SWNZ) program which was launched in 1998/99. In 2007, NZ Winegrowers launched its Sustainability Policy, which stipulated that wines from vintage 2010 on must have been produced under one of the recognized, independently audited, sustainability programs in order to be included in NZ Winegrowers' national and international marketing, promotional and awards events.[16] Effectively this meant that almost all New Zealand wine producers moved to achieve either SWNZ certification or organic/biodynamic certification by 2012. Accredited members of SWNZ who were also members of the Wine Institute of New Zealand were entitled to use the SWNZ logo on their wine bottle labels; however, some wine companies had expressed concerns that SWNZ did not provide them with a marketing edge.[17]

In New Zealand, greenhouse gas ("carbon footprint") certification was available for organizations, products and services through the CEMARS and carboNZero programs provided

[15] The data about the sales of cases of different NZ wine companies is based on case writers estimates.

[16] The approved certification schemes are: Sustainable Winegrowing NZ (SWNZ), BioGro-NZ, AsureQuality, Demeter, and ISO 14001. (http://wineinf.nzwine.com/sustainability.asp#sustain_policy)

[17] Strategic Report by Pricewaterhouse Coopers. 2011. November, p.23 (http://www.nzwine.com/assets/sm/upload/42/9r/g9/vf/NZW%20Strategic%20Review%20Dec%202012.pdf)

by carboNZero holdings. These two programmes provided support tools, technical advice, and guides for measuring greenhouse gas (GHG) emissions. Programme requirements included developing a GHG management plan, independent verification of GHG claims, and support for marketing of CEMARS or carboNZero certification status. Only companies achieving the carboNZero certification were able to offset their GHG emissions by purchasing verified carbon credits (at an additional cost). Certification was awarded only after verification of the measurement and management of GHG emissions by independent approved verifiers. Organisations and products attaining certification were entitled to use the CEMARS and carboNZero logos respectively on their publicity materials, including use of the carboNZero logo on the wine bottle label for certified wine products.

Several wine companies in NZ had some form of environmental sustainability certification. Brancott Estate (owned by Pernod Ricard) had ISO 14001 certification and managed a number of environmental projects but did not have carboNZero certification. Treasury Wine Estates had carboNZero certification for two of its New Zealand wine brands (Squealing Pig and 900 Grapes). Villa Maria had CEMARS certification. Yealands had carboNZero certification on their core brands as well as ISO 14001 certification. A number of other smaller wineries, such as Kono Beverages and Kaimira Ventures Ltd, also had carboNZero certification for selected brands. In addition, a small number of Chilean wineries had attained CEMARS certification.

Yealands: Sustainable Wine Producer

Company Background

Yealands had been growing grapes since 2001 but in 2007 the company decided to build their own winery as a response to the rapid increase in grape production in the region. A fundamental principle for the design of the winery was the efficient use of energy and water. Energy was generated from vineyard prunings and the roof of the building was designed with an expansive curve in order to match the rolling hills and to collect rainwater. The winery was opened officially on August 8, 2008 and had maximum capacity of around 10-11million L per year.

After experiencing some distribution challenges and slow growth of sales in New Zealand, Yealands decided to establish its own distribution within New Zealand in 2010. The company wanted to establish closer relationships with their customers and have a greater control of its products. “No one can sell your wine better then yourself” Peter stated.

In early 2012, Yealands acquired Ager Sectus, another New Zealand wine producer that operated in two locations: Hawkes Bay in the North Island, and Marlborough in the South Island. Ager Sectus had small vineyards (around 100 ha) and a winery (maximum capacity of around 1 million L per year) in each location. The main objective of the acquisition was to establish a presence in the red wine market through buying strong brands in red wines. “Before the acquisition we produced mainly Sauvignon Blanc. We needed to diversify our wine portfolio, we needed to offer red wine to our customers too” explained Peter.

Peter and his wife Vai owned 75% of the shares of Yealands Wine Group Limited. The remaining shares were held by Ager Sectus Wine Estates Limited which consisted of 14 individuals (New Zealand and overseas based) who were former Ager Sectus shareholders. Peter was Executive Director and Board Chair of Yealands Wine Group Limited.

Sustainability was managed in a flexible way at Yealands. A Committee for Sustainability existed to coordinate and instigate activities; it comprised five people including Peter. However, decisions about sustainability matters were often made as part of the normal decision-making processes in the company and new ideas might originate from staff in the company or from external people who came to Peter with suggestions. As an example, the winery engineer had an idea to produce biochar[18] from the vine prunings; in 2013, he was engaged in building a pilot plant in one of the vineyard barns to burn the prunings under controlled conditions in order to produce biochar. A "Green Ideas Competition" was popular among the employees: each month all staff members were invited to submit their suggestions for environmental improvements, and a prize[19] was awarded for the best idea.

Products and Brands

Over 85% of the wine produced at Yealands was white wine (mainly Sauvignon Blanc). Red wines such as Pinot Noir (over 10%) and Tempranillo (1%) were also produced. In the last two years, Yealands had worked on an innovative wine named 'Sauvignoir', which was a blend of 80% Sauvignon Blanc and 20% Teinturier (a grape variety with red flesh that was traditionally used for deepening the color of Pinot Noir). The new wine was created to serve customers who were not familiar with white wine varieties, and in particular for the Asian and Chinese market.

Between 40-45% of the wine produced at Yealands was sold under company-owned brands, which included three core brands (Yealands Estate, Crossroads and The Crossings) and several strategic brands (Three Stones, Flexborne, Babydoll, etc.). The company had four tiers for their core brands, which included Yealands Estate Reserve at the top; Yealands Estate Single Block Series and the Crossroads brand in the second tier; Yealands Estate and The Crossings in the third tier; and various other Yealands brands (Yealands Way, Peter Yealands, etc.) in the fourth tier (see Exhibit 7 for Yealands core brands). Yealands' top tier branded wines had been certified with carboNZero since 2011, and their product labels declared this certification. The issue of declaring sustainability credentials on Crossroads and the Crossings branded wine was under debate following the merger with Ager Sectus. "We still haven't decided if we want to put carboNZero stickers on Crossroads and the Crossings products. We are very protective of the sustainability value proposition of the Yealands Estate brand," commented Michael Wentworth, Yealands General Marketing Manager.

Eighty-five per cent of the company budget for advertising and promotions was spent on the three core brands. The fourth tier products made up approximately 70% of all the branded products, and

[18] Biochar is charcoal produced by heating biomass in the total or partial absence of oxygen.
[19] Mystery air flight

were sold in over 65 markets (key markets - Australia, New Zealand and UK). Only third and fourth tier products were subject to sales promotions. Yealands strategic brands (comprising almost 50% of their branded products) were designed to serve specific markets.

The rest of the wine produced in Yealands was non-branded and sold as private labels. Michael explained: "The average selling price per bottle of New Zealand wine was around NZ$9, Yealands wine was selling from around NZ$13 through to late NZ$30s. The market for our branded product was small and if we wanted to gain some presence in the market, we needed to offer less expensive wines that the majority of people were purchasing. For Yealands, private labels were tools that secured a position on the shelf, without lowering the price of our branded wine. This way we were not pressured to sell large volumes of our branded wines." Yealands supplied about 50 private labels: customer-owned private labels (marketed under retailers' brands, such as Tesco) and other private labels owned by Yealands.

Markets and Distribution

In 2012, about 90% of Yealands production was exported and sold in more than 70 countries. Of the 675,000 cases that were exported in 2011/12, about 38% went to Europe, 36% to Australasia, 22% to Americas, 3% to Asia and the rest Middle East and Africa. The four key export markets in which Yealands aimed to strengthen its brand support and consumer awareness were: the United Kingdom, Australia, USA and China. In other markets, the company planned to increase retail presence and develop more efficient distribution. "We have stepped into many markets in the last few years, therefore now our strategy is to increase our presence in these markets, rather than increasing the number of countries we are in," commented Michael. Globally, around 85% of Yealands' wine was sold through supermarkets and retailers and the rest was sold directly to restaurants, bars, hotels, caterers or online.

Yealands held 5% share or less of the New Zealand-produced wine category in all of its overseas markets except in the Netherlands, where it had a 40% share of the New Zealand category due to Peter's personal connection with one of the major suppliers in that market. "They were our first distributor in 2008 and were our key client for the first three years. At one point in time, this distributor bought 30% of our wine. The risk of having a single market was too high so we tried to diversify our markets" recalled Peter. By 2012, the share of the Netherlands in Yealands' business was comparable to that of the Australian market. Peter also noted that the European market in general had become very difficult for New Zealand wine exports due to strong appreciation of the NZ dollar against the Euro. Moreover, the recession in Europe had caused the sales to slow down dramatically.

Yealands' growth rate in Asia and China in particular was over 600% in 2012 and it was becoming a very important market for the company. "We were probably one of the top five New Zealand wine exporters to China. We expect that China would be our biggest market in the next five years. Customers in China preferred red wines so we developed our new wine 'Sauvignoir' primarily for this market" explained Peter.

Yealands worked mainly with distributors in export markets due to the distributors' market/consumer knowledge and local networks. Furthermore, the company had strengthened its wine distribution in key export markets by establishing subsidiaries and placing its own staff in the market. Building subsidiaries was part of Yealands' growth strategy. The company had two subsidiaries: one in Australia (since 2008) and one in the US (since 2009). Additionally, in 2010, one full-time employee was located in Brazil to support distribution of Yealands wines in the country. However, Peter explained that exporting wine to Brazil was very challenging: "We were the first major New Zealand wine supplier in the country, and we have a distribution agreement with the biggest retailer in Brazil. However, the Brazilian government is trying to restrict imports of wine through duties and taxation. If a bottle sells for NZ$100 at retail, the duties and taxes are 83% and only 17% is the wine value."

In China, Yealands had distributors in different regions and was in the process of establishing a subsidiary there with the goal of strengthening sales throughout Asia. Peter explained, "The competition in China is high, but the potential opportunities are enormous. We hope that having a subsidiary in China will push our growth in this market".

Since 2010, Yealands had been selling its wine in New Zealand through its own distribution system. The majority of the wine (around 75%) was sold through supermarkets in New Zealand.

Yealands Sustainable Certificates and Initiatives

Yealands first achieved carboNZero organisation certification in the 2008/2009 year, and had maintained its certification since that time. The certification addressed greenhouse gas (GHG) emissions associated with growing the grapes, producing the wine, production of bottles and the bottling processes, and distributing the product for Yealands Estate wines produced from the winery. Once they had been measured, the GHG emissions were offset as part of the certification scheme through purchase of carbon credits[20]. Yealands also achieved separate carboNZero product certification for its Yealands Estate wine products in the 2011/2012 year; this meant that these products could display the carboNZero logo on the bottle labels (see Exhibit 8 for Yealands bottle label).

As well as the carboNZero certification, Yealands Wine Group Limited invested in ISO 14001 certification (achieving certification in 2012), and was also a member of Sustainable Wine Growing NZ (SWNZ).

The environmental sustainability initiatives at Yealands could be divided into four broad groups:

1. **Design and operation of the winery**
   Rainfall was collected from the roof and either used in the winery for cooling or piped out to the wetlands in the vineyards. A wind turbine was used to generate electricity, and prunings from the vineyards were burned to produce heat; the electricity and heat were

[20] See http://www.carbonzero.co.nz/documents/Disclosure_Yealands_org_1112.pdf for organization certification, and http://www.carbonzero.co.nz/documents/Disclosure_Yealands_prod_1112.pdf for product certification.

used in the winery. Various energy saving features in the winery included: advanced refrigeration systems, extensive insulation of fermentation and storage tanks, temperature and energy monitors, motion sensors for lighting, and external air cooling.

2. **Everyday operations in the vineyards**
   Sheep (a special breed named "Babydoll"[21]) were grazed in the vineyard in order to reduce use of diesel for mowing grass, and hydrogen generators were being installed on tractors in order to increase their efficiency. Use of synthetic pesticides was minimised through alternative means of controlling pests such as use of plastic strips around vines to stop wetas[22] climbing up them, and lights on the lakes running alongside the vineyards to attract grass grubs in the mating phase of their life cycle which then dropped into the water. There was a focus on encouraging biodiversity through maintaining 25 wetlands in the vineyard with associated plantings of native trees and flaxes, and on soil quality through use of compost produced from by-products in the winery and sourced from other local businesses.

3. **Improving the environmental profile of the wine product**
   Yealands introduced plastic bottles in 2012 which used less energy in production and in transportation compared with glass bottles.

4. **Ongoing innovative environmental projects**
   There was a continuing investment in innovative new projects that might improve the environmental performance of the Yealands vineyards, winery and its products. Examples of recent projects included: production of biochar from prunings (to sequester carbon and improve soil quality), and keeping chickens in the vineyards (to eat harmful insects) (see Exhibit 9 for details about Yealands' environmental initiatives).

Many of these environmental initiatives were relatively cost-effective because they offset existing costs such as fuel purchase; for example, it took just 18 months to pay back the cost of installing the two boilers for burning the prunings.

Yealands had also extended its sustainability focus beyond environmental considerations to include some activities that supported the local community. For example, staff managed a community garden close to the winery that provided vegetables to a community centre in town, along with eggs from the chickens in the vineyards. However, the social and economic dimensions of sustainability were yet to be explored in detail.

Looking Forward

Yealands had achieved significant growth as a young company. Yealands' short term goals in 2013/14 were to reach one million cases in sales and turnover of NZ$ 100 million. Peter explained, "We expect to reach NZ$ 100 Million turnover in a year and to sell one million cases

[21] "Babydoll" is a special breed with short legs. The sheep can graze but are not tall enough to damage the plant buds or the grapes.
[22] Wetas are similar to grasshoppers and are endemic to New Zealand.

in two years. We have been growing NZ$ 25 Million a year in the last three years." Yealands also wanted to become NZ's fifth biggest wine company in sales, a goal that could take a few years to achieve.

In terms of the environment, Yealands' goal was to be the most sustainable producer of wine in the world. Peter was determined to take world leadership in sustainable winegrowing. In order to realise this goal, Yealands had started entering a range of different competitions. In 2012, it was the Gold Winner in the category "Most Sustainable Medium Business" at the International Green Awards[23]. In 2013, it was shortlisted in the "Sustainability Company of the Year" and "Green Company of the Year" categories for the Drinks Business Green Awards[24]. However, Peter's ambition was not limited to environmental sustainability. Yealands became one of the finalists in the Best Employer Award in New Zealand in 2012 and in 2013 South Island Farmer of the Year award. "If we do it, we want to do it well. We want to be the first in everything: in sustainability, quality, and as an employer," commented Peter.

Yealands were constantly on the lookout for new opportunities. They intended to build another winery with greater capacity, invest in R&D projects for alternative packaging, and were considering developing non-alcoholic wine and using manuka honey for sweetening wine.

As the Babydoll sheep bleated in the vineyard, Peter sat in his office and reflected on the future development of the company. He was thinking about how to maintain their growth. His thoughts moved further to the sustainability agenda that underpinned their whole business. How could the company use their sustainability credentials to drive growth?

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[23] The International Green Awards is the leading platform for sustainability intelligence, leadership and innovation. Launched in 2006, the objective is to recognize the best-in-class examples of sustainability communications (http://www.greenawards.com/winners/winners- 2012).

[24] The Drinks Business Green Awards is the world's largest program to raise awareness of green issues in the drinks trade (wine, spirits, beer, cider or soft drinks) and recognize and reward those who are leading the way in sustainability and environmental performance. (http://www.thedrinksbusiness.com/2013/04/db-reveals-shortlist-for-green-awards-2013)

Appendix

Exhibit 1. Yealands company data

	2008	2009	2010	2011	2012	2013E
Vineyard (hectares)	1,150	1,150	1,150	1,500	1,500	1,500
Wine sales (thousand cases)	101	226	319	603	750	900
Growth (%)		123	41	89	24	
No. of full-time employees	15	21	35	60	105	131

Source. Company data

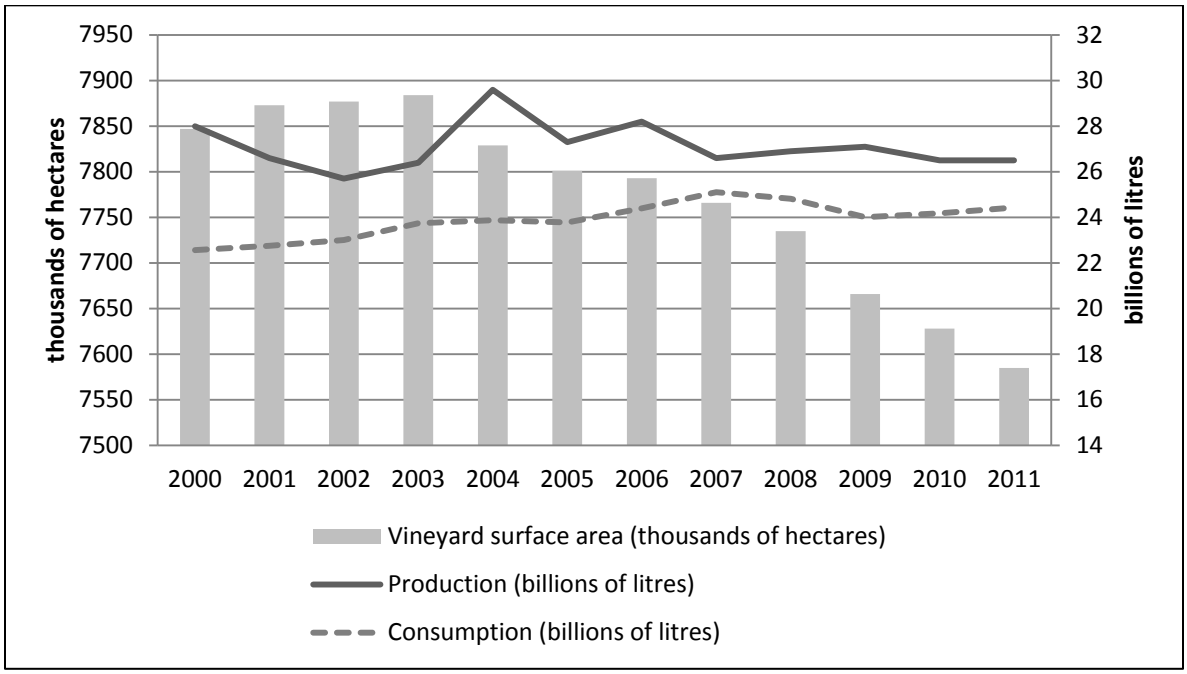
Exhibit 2. Main wine production regions in NZ

Source. New Zealand Winegrowers website http://www.nzwine.com/

Exhibit 3. Who is Peter Yealands?

Peter is a third-generation Marlborough resident who has been involved in many different businesses. At the beginning of his working life, he had a contract for building work with the local government. In 1968, he became involved in aquaculture and remained in that industry for 15-20 years, receiving the first licence for mussel farming in NZ in 1975. He was also involved in a forestry business and animal farming. He developed the first embryo transplant programme with red deer in NZ. Peter was also a supplier of aggregates to the major concrete companies in the 1990s. The pre-history of Yealands began in 1998, when Peter Yealands bought 20 hectares (ha) of land in Wairau Valley, Marlborough. The price he paid was low because the land was perceived to be unfavourable for cropping and grape growing due a shortage of water. He transformed this 'unwanted' land using machinery and equipment he already owned, and planted grapes. He fell in love with the process of land transformation, and with grape growing, and bought another 300 ha of 'unwanted' land at Wairau Valley (then a river bed) in 2000 and transformed it into vineyards over an 18 month period; this land was later sold to an Australian owned wine company. 'With a pocket full of money' he bought his first Seaview vineyard of 120 ha in 2001 and over the next few years he bought more land and vineyards. *"I knew nothing about horticulture when I started and my learning curve was very steep,"* recalled Peter. He became passionate about grape growing and, supported by the increased demand for wine grapes from the region, he continued to buy more land and vineyards. The land transformation process was facilitated by Peter's pioneering use of GPS technology that enabled him to accurately run the vineyard rows, and orientate them for best aspect on the slopes.

Exhibit 4a. Global wine production and consumption



Source. FAOSTAT

Exhibit 4b. World's top wine producers/exporters/importers

Rank in 2010	Country	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Production (tonnes)											
1	France	5,338,800	5,000,000	4,749,060	5,910,690	5,344,170	5,349,330	4,711,600	4,268,900	6,113,630	5,846,290
2	Italy	5,229,300	4,460,410	4,408,610	5,313,520	5,056,650	4,963,300	4,251,380	4,609,550	4,624,500	4,580,000
3	Spain	3,095,100	3,454,000	4,246,240	4,280,430	3,643,700	3,890,730	3,520,870	3,736,690	3,250,610	3,610,000
4	US	2,395,000	2,286,000	2,415,000	2,466,000	2,888,000	2,360,000	2,488,000	2,530,000	2,730,000	2,211,300
5	China	1,080,000	1,120,000	1,200,000	1,300,000	1,350,000	1,400,000	1,450,000	1,500,000	1,550,000	1,657,500
11	**NZ**	**53,300**	**89,000**	**55,000**	**119,200**	**102,000**	**133,200**	**147,600**	**205,200**	**178,000**	**189,800**
Exports by quantity (tonnes)											
1	Italy	1,537,064	1,518,682	1,280,200	1,435,898	1,552,077	1,793,152	1,826,635	1,733,889	1,918,407	2,192,254
2	Spain	904,986	901,638	1,175,810	1,352,196	1,364,746	1,336,762	1,433,966	1,698,171	1,457,607	1,771,386
3	France	1,551,660	1,536,883	1,496,243	1,435,043	1,367,842	1,461,663	1,492,933	1,345,513	1,215,987	1,411,363
4	Australia	376,154	471,505	536,467	646,121	695,475	762,278	781,419	701,050	771,949	799,465
5	Chile	486,717	344,227	391,000	468,207	411,233	471,557	601,734	581,685	691,823	729,938
11	***NZ***	***21.920***	***25.615***	***27.205***	***40.669***	***57.400***	***64.765***	***84.171***	***92.050***	***128.555***	***244.098***
Exports by value (thousands of US$)											
1	France	4,787,033	5,397,735	6,562,663	6,919,726	7,014,774	7,820,853	9,254,180	10,000,580	7,694,175	8,392,084
2	Italy	2,289,075	2,589,934	2,986,474	3,550,372	3,717,972	4,038,408	4,741,609	5,277,540	4,843,769	5,170,569
3	Spain	1,138,328	1,215,237	1,598,461	1,835,577	1,892,950	1,958,962	2,395,881	2,856,434	2,293,668	2,453,272
4	Australia	997,803	1,272,366	1,539,094	2,001,889	2,111,735	2,082,612	2,488,462	2,146,061	1,817,686	1,955,028
5	Chile	645,010	603,772	662,990	835,486	874,775	960,338	1,251,000	1,352,833	1,374,242	1,541,139
9	**NZ**	**97,196**	**127,275**	**157,691**	**245,451**	**331,970**	**396,741**	**559,343**	**599,167**	**643,242**	**789,130**
Imports by quantity (tonnes)											
1	Germany	1,126,787	1,170,961	1,190,564	1,304,256	1,258,954	1,330,423	1,418,522	1,366,335	1,411,069	1,421,739
2	UK	994,339	1,027,038	1,133,991	1,297,578	1,315,753	1,184,626	1,178,888	1,080,247	1,102,908	1,253,093
3	US	468,794	552,140	608,245	641,477	712,919	782,423	845,234	831,788	926,883	938,418
4	Russia	256,615	298,380	416,361	505,125	622,702	369,977	399,595	417,515	471,736	692,745
5	France	511,113	452,827	469,583	472,765	544,451	528,685	526,227	570,018	576,715	583,690
N/A	**NZ**	**40,192**	**40,227**	**47,159**	**37,965**	**35,097**	**39,094**	**42,478**	**38,410**	**31,791**	**51,697**
Imports by value (thousands of US$)											
1	US	2,324,904	2,654,634	3,408,778	3,577,778	3,944,567	4,369,830	4,856,118	4,841,338	4,189,623	4,461,891
2	UK	2,773,622	3,026,437	3,535,175	4,248,918	4,137,027	4,139,239	5,010,178	5,149,419	4,315,072	4,318,981
3	Germany	1,653,418	1,674,950	2,040,199	2,286,155	2,202,429	2,383,743	2,697,134	3,013,386	2,759,222	2,696,515
4	Canada	581,568	611,091	820,562	908,175	1,042,021	1,263,982	1,470,082	1,566,037	1,463,845	1,698,913
5	Japan	779,419	800,392	904,446	1,050,216	1,006,922	1,158,878	1,244,057	1,318,270	1,058,606	1,150,477
N/A	**NZ**	**62,060**	**73,845**	**95,509**	**103,024**	**108,201**	**107,820**	**130,928**	**136,149**	**91,809**	**106,590**

Source. FAOSTAT

Exhibit 5. Some key international and New Zealand environmental standards and certification schemes

ISO 14001

*No specific logo for accreditation to ISO.

ISO 14001 sets out the criteria for an environmental management system and can be certified to. It does not state requirements for environmental performance, but maps out a framework that a company or organization can follow to set up an effective environmental management system.

http://www.iso.org/iso/home/standards/management-standards/iso14000.htm

PAS2050

The PAS2050 is a publicly available specification for the assessment of the life cycle greenhouse gas emissions of goods and services (published by British Standards Institution). It can be used by organizations of all sizes and types in any location. It offers practical advice to organizations wanting to assess the carbon footprint of their products, identify hotspots and reduce emissions in their supply chain.

http://shop.bsigroup.com/en/Browse-By-Subject/Environmental-Management-and-Sustainability/PAS-2050/

The Carbon Trust

The Carbon Trust Standard verifies the carbon footprint and emission reduction of organizations. It was developed in consultation with the private and public sector in the UK to implement carbon management strategies and international standards, such as the Greenhouse Gas Protocol.

http://www.carbontrust.com/client-services/footprinting/footprint-certification

GLOBALG.A.P.

*No specific logos for GLOBALG.A.P. certifications.

GLOBALG.A.P. (Global Partnership for Good Agricultural Practices) provides benchmarks for food safety, sustainability, social welfare, animal welfare, etc. Producers may obtain an accredited certificate to gain globally accepted credibility to food retailers and food manufacturers. Its 142 independent and accredited certification bodies worldwide conduct both announced and unannounced onsite farm inspections and audits throughout the year.

http://www.globalgap.org/uk_en/what-we-do/the-gg-system/benchmarking/

carboNZero

Established in 2001 by Landcare Research NZ Limited, carboNZero is an internationally accredited greenhouse gas certification scheme based on over a decade of research on climate change, greenhouse gas measurement and carbon monitoring. There are five key steps to attaining certification through the carboNZero program: measure, manage, mitigate, verify, and market. CarboNZero program may certify organizations, products, services, events, or individuals.

http://www.carbonzero.co.nz/about/

CEMARS

CEMARS (Certified Emissions Measurement And Reduction Scheme) certification is an alternative certification option for carboNZero, offered also by the carboNZero program. CEMARS is essentially the first two steps of carboNZero certification. This scheme is developed for large organization or large emitting industries where offsetting is not a viable option or they wish to take a measured approach and further gauge the cost benefit of positioning their organization and products/services in the carbon neutral market space.

http://www.carbonzero.co.nz/cemars/

SWNZ

SWNZ (Sustainable Winegrowing New Zealand) was established in 1995 as an industry initiative, and was adopted by growers from all the grape growing regions in 1997. The SWNZ program provides a framework for viticultural and winemaking practices. The seven focus areas in the SWNZ program are: biodiversity; soil, water and air; energy; chemicals; byproducts; people; and business practices. The program uses a scorecard approach for practices and management in both the vineyards and wineries; certified organizations are independently audited at least once every three years. Audited and certified companies may put the logo on their products which delivers a quality assurance from the vineyard through to the bottle.

http://wineinf.nzwine.com/swnzabout.asp

Exhibit 6a New Zealand wine industry overview

New Zealand is a small international player in terms of volume; however, it recorded the strongest growth in the New World countries in both exports and wine production in the last decade, predominantly in Sauvignon Blanc. Some key data are presented in the Figure 3a. New Zealand was also the fastest-growing wine exporter globally in the last decade and total New Zealand wine exports increased significantly over this period. Sauvignon Blanc dominated NZ's wine exports, accounting for 80% of bottled wines sold overseas. In 2011-12, the average export price for New Zealand wine was NZ$6.60 per litre and the national average grape price was $1,315 per ton. Grape prices moved up more than wine prices in 2012-13 due to a supply deficit. The top three markets for New Zealand wine were Australia, UK and USA, which account for about 90%. The wine industry was the eight most valuable export earner in New Zealand with $1.2 Billion in 2012.

Exhibit 6b. New Zealand wine industry overview

	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Wine companies*	421	463	516	530	543	585	643	672	698	703
Growers	625	589	818	866	1,003	1,060	1,117	851	791	824
Producing areas (hectares)	15,800	18,112	21,002	22,616	25,355	29,310	31,964	33,428	33,400	33,400
Average yield (tonnes per hectare)	4.8	9.1	6.9	8.2	8.1	9.7	8.9	8.0	9.8	8.1
Average grape price (NZ$ per tonne)	1,929	1,876	1,792	2,022	1,981	2,161	1,629	1,293	1,239	1,315
Tonnes crashed	76,400	165,500	142,000	185,000	205,000	285,000	285,000	266,000	328,000	269,000
Total production (millions of litres)	55.0	119.2	102.0	133.2	147.6	205.2	205.2	190.0	235.0	194.0
Domestic sales of NZ wine (millions of litres NZ wine)	35.3	35.5	45.0	50.0	51.0	46.5	59.3	56.7	66.3	63.5
Consumption per Capita NZ wine (litres NZ wine)	8.8	8.8	11.2	12.1	12.2	11.1	13.9	13.0	15.2	14.3
Total sales of all wine (millions of litres)	74.5	79.7	81.7	86.0	91.8	87.4	92.7	92.1	93.9	91.3
Consumption per Capita all wines (litres)	18.6	19.6	19.8	20.6	21.7	20.8	21.5	21.1	21.3	20.6
Export volume (millions of litres)	27.1	31.1	51.4	57.8	76.0	88.6	112.6	142.0	154.7	178.9
Export value (millions of NZ$ FOB)	281.9	302.6	434.9	512.4	698.3	797.8	991.7	1,041	1,094	1,177

*Includes companies without actual sites

Source. New Zealand Winegrowers, 2013

Exhibit 7. Yealands core wine brands

Brand	Name	Tier - Retail Price	Certificate Markets	
Yealands Estate	**Yealands Estate Reserve Range**	Top Tier ~NZ $35	carboNZero, sold in key markets (UK, NZ, Australia)	
	Yealands Estate Single Block Range	2nd Tier NZ $27.95	carboNZero, sold in key markets (UK, NZ, Australia)	
	Yealands Estate Range	3rd Tier NZ $24.95 (or less on promotion)	carboNZero sold in over 55 countries	
	Yealands Range (Peter Yealands, Yealands Way, etc)	4th Tier NZ$ 17.95 (or less on promotion)	carboNZero, sold in all 72 markets	
	Violet Sparkling Range	4th Tier NZ $17.95 (or Less on Promotion)	carboNZero	
Crossroads	**Crossroads**	2nd Tier NZ $27.95	Sold mainly in NZ, Asia and UK	
The Crossings	**The Crossings**	3rd Tier NZ $19.95 (or less on promotion)	Sold in the key markets (UK, NZ, Australia, US)	

Source. Company data

Exhibit 8. Yealands Estate carboNZero labelling

Source. Company data

Exhibit 9. Environmental Initiatives at Yealands

Project and year	Stage	Benefits	Description
Wetlands (2007-)	Vineyard	Water conservation. Biodiversity.	25 wetlands are strategically positioned on the vineyard to capture water run-off from the vineyard and slowly release it back into the soil. Over 75,000 native trees and flaxes are planted and are home to a range of wildlife. In addition, the endangered New Zealand Falcon, the Karearea, released on Yealands vineyard as part of the breeding programme, helps in protecting grapes from other birds.
Compost (2012-)	Vineyard	Reduced synthetic fertilizer ($) Water retention	Over 10,000 tonnes of compost is produced and applied annually, using by-products from wine production, untreated bark from saw mills, mussel shells, and seaweed from aquaculture. It is planned to increase compost production in future using increased quantities of marc (waste left after pressing grapes for their juice) obtained from other wineries.
Biochar from pruning (2010-)	Vineyard	Improve soil quality, carbon storage. Displace synthetic fertilizers ($).	Experimental work underway for biochar generation from prunings for application onto soil in the vineyards.
Animal grazing (2011-)	Vineyard	Reduced diesel emissions ($). Reduced soil compaction from machinery. Reduced herbicides ($). Reduced synthetic fertilizers ($). Reduced diesel use ($) Animal products ($).	Babydoll miniature sheep grazed in vineyards (currently around 500 sheep). The sheep are being bred to build up an anticipated flock of 10,000 sheep. It is anticipated that another business will be created to sell their wool and meat; the meat has already been sold as a premium product to a UK supermarket, Marks & Spencer. Kunekune pigs grazed in vineyards and eat foodscraps from the staff kitchen (experimental trial).
Pest control (2008-)	Vineyard	Reduced pesticides ($). Protection of soil organisms. Chicken products ($).	Use of plastic sleeves on vines and posts to stop weta (similar to a grasshopper and endemic to New Zealand) climbing up them. Solar powered lights on some of the lakes attract grass grubs in their mating phase which then fall into the water and are eaten by fish. Chickens range around vineyards and eat pests.

Exhibit 9. Environmental Initiatives at Yealands-*Continued*

Exhibit 9. Environmental Initiatives at Yealands-*Continued*

Project and year	Stage	Benefits	Description
Beehives and native plants (2012-)	Vineyard Winery	Encourage beneficial insects. Produce honey to sell and/or use in wine production ($).	Trial of beehives in the vineyards, and planting native plants in between the vine rows to encourage bees (and other beneficial insects); honey can be collected and sold – or may be used in wine production.
Music in vineyards (2012-)	Vineyard	Better growth of vines.	Solar-powered loudspeakers play music over vineyards in an experiment to see if it benefits the vines.
Organics conversion (2009-)	Vineyard	Trial organic methods on vineyard.	A small vineyard has been converted to organic production in order to investigate methods for reducing agrichemical and fertiliser applications across Yealands owned vineyards.
Hydrogen generators (2012-)	Vineyard	Reduced carbon emissions Reduced diesel use ($).	Hydrogen generators installed onto the tractors.
Rainfall collection (2008-)	Vineyard Winery	Recycling of water.	Rainfall from the roof is collected in swale drains on either side of the building, and piped out to the wetlands in the estate.
Prunings for energy generation (2008-)	Vineyard Winery	Energy generation LPG cost savings ($).	Approximately 10% of the grapevine prunings are baled and burned; the energy is used to heat water and glycol (the liquid used on the exterior of wine tanks to heat and cool the wines) in the winery. Each 200 kg bale provides heat equivalent to burning 60kg liquid petroleum gas (LPG). The remainder of the prunings are mulched back into the soil.
Wind turbines and solar panels (2008-)	Vineyard Winery	Energy generation ($).	Two small wind turbines, and a small number of solar panels, are used to generate electricity. Investigations are underway for installation of a much larger wind turbine so that the winery can be self-sufficient for electricity.
PET bottles (2012-)	Packaging	Reduced weight (and therefore less transport fuel). Reduced carbon emissions.	PET bottles that incorporate a vapour barrier have replaced glass bottles for some brands. PET bottles are 89% lighter, have 54% less greenhouse emissions, and consume 19% less energy compared with traditional glass bottles.
Hybrid cars	Sales	Reduced carbon emissions.	Yealands sales team use hybrid cars.

Note.'$' cost saving and/or revenue generation

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