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Competitiveness, Efficiency and Environmental Impact of Protected Agriculture in Zacatecas, Mexico

Luz E. Padilla Bernal[Φa], Alfredo Lara-Herrera[b], Elivier Reyes-Rivas[c], and Oscar Perez-Veyna[d]

[a] *Researcher Professor, Unidad Académica de Contaduría y Administración, Universidad Autónoma de Zacatecas, Comercio y Administración s/n, Col. Progreso, Zacatecas, Zac. C.P. 98066, Mexico*

[b] *Researcher Professor, Unidad Académica de Agronomía, Universidad Autónoma de Zacatecas, Carr. Zacatecas - Guadalajara Km 15.5 Cieneguitas, Zac., México*

[c] *Researcher Professor, Unidad Académica de Contaduría y Administración, Universidad Autónoma de Zacatecas, Comercio y Administración s/n, Col. Progreso, Zacatecas, Zac. C.P. 98066, Mexico*

[d] *Researcher Professor, Unidad Académica en Estudios del Desarrollo, Universidad Autónoma de Zacatecas, Av. Preparatoria s/n, Col. Hidráulica, Zacatecas, Zac. C.P. 98064, Mexico*

Abstract

In Zacatecas, agriculture consumes 77% of the underground water; 44% of the aquifers are over extracted. All protected agriculture production systems pump water from the aquifers for irrigation, and 96% of the production units were constructed with government support. They also receive support for inputs and domestic production factors. This paper analyzes the impact of agricultural policy on protected tomato production in the state of Zacatecas, Mexico, by examining competitive and efficient technologies and considering alternative sustainable production practices. The Extended Policy Analysis Matrix was applied. The analysis included four technologies under current conditions and two scenarios: a) adoption of sustainable production practices and b) unsustainable practices, at economic and private prices. The sustainable project paid for itself under both private and economic prices.

Keywords: greenhouses, agricultural production systems, comparative advantage

[Φ]Corresponding author: Tel: + 492.9223309
Email: luze@uaz.edu.mx A. Lara-Herrera: alara204@hotmail.com
E. Reyes-Rivas: ereyes21@yahoo.com.mx O. Perez-Veyna: pveyna@uaz.edu.mx

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Introduction

In the state of Zacatecas, located in the north-central region of Mexico, the number of protected agriculture production units (PU) has had accelerated growth in recent years. The mean rate of annual growth of the cultivated area during the period 2000 to 2010 was 25% (Padilla-Bernal, Lara-Herrera, Reyes-Rivas, and Pérez-Veyna 2011). In 2010, this area was estimated to be 277 ha, of which 90% was cultivated under tomato (SEDAGRO 2010). The area under protected agriculture in Zacatecas accounts for nearly 10% of the total in Mexico (Cook 2007). Given the growth rate of these PU, the area is now estimated to be larger.

The protected agriculture production systems, in the modality of intensive agriculture, aim to obtain the highest yield possible, isolating the crop from natural conditions and applying artificial climate and cultural techniques to obtain maximum profitability (Castellanos and Borbón 2009, 1), implicating better use of the natural resources water and soil (Antón 2004). Technologically advanced production units require higher investment, but yields are higher and risk is lower (Padilla-Bernal, Rumayor, Pérez-Veyna and Reyes-Rivas 2007).

One of the main factors to which rapid expansion of protected agriculture is attributed is government aid for construction. The authorities have considered this modality as an alternative to contribute to regional development (GODEZAC 1999; 2005; 2011). Recently, around 96% of the PU were granted support by the program Alianza para el Campo (SAGARPA 2006; Padilla-Bernal et al. 2010). Furthermore, protected agriculture producers, like other farmers, have access to other types of government aid: subsidy to diesel for agricultural use (SAGARPA 2009), subsidy to electricity for pumping irrigation water, zero aggregated value tax (IVA) on fertilizers, pesticides and other agrochemicals, among others. Some of this support forms part of the government Alianza para el Campo (Contigo) and Apoyos a la Comercialization (SAGARPA 2009). These programs appeared in the 1990s to help incorporate producers into the process of trade aperture and to increase their competiveness in the face of the State's withdrawal from agricultural production and commercialization. The support that reduces relative prices of agrochemicals and diesel induces higher consumption than would be determined by an undistorted market, resulting in false profitability. A lower relative price of agrochemicals, diesel or irrigation water also discourages the adoption of new technologies (Ávila et al. 2005).

For irrigation, 100% of the protected agriculture production systems in Zacatecas extract underground water; that is, they pump water from the aquifers. The main source of water for the diverse activities of the region is 34 aquifers, of which 44% are over-extracted (CNA 2011). Agriculture consumes 77% of the available underground water (CNA 2008; 2011), irrigating more than 130 thousand hectares (INEGI 2010) with high water consumption caused by over-irrigating and obsolete irrigation systems (OECD 2008, 7; Mojarro et al. 2010, 2-3). In Mexico, whoever receives an underground water concession can use a given amount of water from the aquifer free of charge, an implicit subsidy.

Over-extraction of the aquifers causes damage to the environment. Over-extraction means less water in the future leading to greater salinization of the soil and reduction of crop yields, and thus less sustainable production systems (OECD 2008, 7). A production system is not sustainable if agricultural practices impose negative externalities or degrade the environment, creating a market failure. Agricultural production costs in unsustainable systems ignore negative immediate impacts on other people or long-term degradation of this natural resource base. On the other hand, eliminating environmental market failures contributes to the creation of sustainable agricultural production systems. It would also contribute to sustainability if government policy corrects negative externalities and degradation of resources (Pearson, Gotsch, and Bahri 2003, 67). Agricultural production costs in the sustainable production systems are fully accounted because they include immediate negative external impacts on other people and expenses to offset long-term degradation of the natural resource base.

In protected agriculture, besides the environmental problems that all agricultural practices generate such as affecting soil quality, soil degradation and salinization, especially where water is limited, there is the additional problem of generating residues (Stanghellini 2003; Ren 2003). For this reason and given the accelerated increase in these production units, the government authorities in Zacatecas are interested in having information that would lead to the creation of a development strategy and the definition of policies oriented toward planning growth of protected agriculture production units and creating norms that help to protect the environment.

The objective of this study was to examine the impact of agricultural policy on protected agriculture tomato production systems in the state of Zacatecas, Mexico, by identifying competitive and efficient technologies, considering alternative sustainable production practices (alternative projects). The analysis is performed under two accounting perspectives. The first perspective uses existing distorted private prices and the second perspective uses efficient economic prices that recognize the true social benefit opportunity cost of using resources in protected agriculture. Elements are provided to contribute to the formulation of policies for sustainable rural development and strategies for increasing the value chain’s competitiveness. The following research question is answered: What is the behavior of competitiveness and efficiency in the production systems when they adopt sustainable production practices?

Agricultural Policy and Environmental Market Failures

Agricultural policies are government decisions that have the intention of influencing the level of input and product price stability, public investment that affects agricultural production, costs and incomes, and revenue allotment. Policies that impact the agricultural sector can fall into one of the following three categories: agricultural price policies, macro-economic policies, or public investment policies. One distorting policy is government intervention that forces market prices to diverge from their efficient valuation. Taxes and subsidies, international trade restrictions, or price regulations can lead to divergence from efficient valuation. Distorting policies are usually established to promote non-efficiency objectives, such as equity or safety (Pearson, Gotsch, and Bahri 2003).Another way to make efficient price valuations diverge is market failures. A market failure is created when price mechanisms do not achieve competitive results or efficient prices. The common types of market failures are monopolies, externalities, environmental degradation and imperfections in the market of factors. Environment degradation refers to changes in physical resources such as soil, water or air. In the case of environmental market failures in the agricultural sector, most occur when farmers misuse use a physical resource since they do not have to pay full costs, as is the case of irrigation water in Mexico. There are two types of environmental market failures: environmental externalities and environmental degradation

(Monke and Pearson 1989, 5; Kydd, Pearce, and Stockbridge 1997; Pearson, Gotsch, and Bahri 2003, 67). The existence of an environmental market failure provides a rationale for government intervention to attempt to correct the divergence.

Negative environmental externalities in the agricultural sector are distinguished by involving the use of soil and water; this is the case of water pollution from use of chemical pesticides. They appear when the producer or consumer imposes immediate costs on other people for which they cannot be charged. In contrast, positive externalities occur when producers or consumers generate immediate benefits for others for which they cannot receive compensation. When negative externalities occur, the market fails since they cannot include negative external costs for producers that damage the environment (Baumol and Oates 1995).

Environmental degradation refers to overuse of physical resources (soil, water, air and forests) by producers or consumers. This imposes future costs on all of the users of natural resources including those individuals responsible for degradation of the resource base (Pearson, Gotsch and Bahri 2003, 68). If the negative effects do not occur for many years, producers will have few incentives to invest in resource conservation actions for the future. When users understand the probable impact on the future use of current resources, they may be motivated through policies aimed to conserve resources.

Kydd, Pearce, and Stockbridge (1997, 337-338) assert that, to a certain degree, environmental degradation associated with agricultural production can be reduced through application of conservation measures (Anaya 2010, 65) and improved agricultural practices. Costs associated with these measures are borne directly by expenses incurred in the development of these practices or indirectly through loss of productivity associated with different farming practices. In either case, environmental costs are borne by the producer in absence of government subsidies. Kydd, Pearce, and Stockbridge (1997) add that in most countries the cost of these market failures are not internalized in the indicated way, but are borne by the society as a whole.

Materials and Methods

Extended Policy Analysis Matrix

The Extended Policy Analysis Matrix (EPAM) was used to examine the impact of agricultural policy on protected agriculture production systems in Zacatecas under alternative sustainable production practices (alternative projects). This is used to determine the impact of the policies on competitiveness and efficiency, or comparative advantage, of the production systems in the present and two hypothetical scenarios: a) with the adoption of resource conservation practices, denominated sustainable, and b) with agricultural practices that generate negative externalities, denominated unsustainable. It is also used to guide agricultural research policies and technological change (Monke and Pearson1989; Pagiola 1991; Kydd, Pearce, and Stockbridge 1997; Pearson, Gotsch, and Bahri 2003).

It should be pointed out that internalizing costs of environmental degradation and taking into account some benefit of alternative sustainable production practices is not an easy task. Although the area to be studied has quite uniform climatic, topographical and physical production conditions, the quantity of required data is enormous. Where these conditions are diverse, as in most cases, obtaining sufficient information with some degree of detail is practically and financially impossible. Despite all this, a rough estimation that can serve to formulate policy for some commodity can be arrived at (Kydd, Pearce, and Stockbridge 1997, 337; Pearson, Gotsch, and Bahri 2003, 69).Thus, in the case of protected tomato production in the state of Zacatecas, environmental impact of the production systems is incorporated through lower productivity caused by environmental degradation attributed to overuse of underground water.

The main empirical task in the application of EPAM is determining the budgets of agricultural production systems at private or market prices as well as economic efficiency prices. Economic efficiency prices are those that reflect values of scarcity or that recognize the true social opportunity cost. Moreover, prices denominated “sustainable” that are aimed to correct environmentally related market failures were used.

The first row of EPAM is a budget that shows current revenues, costs, and profits at market prices. The second row shows the budget of a scenario denominated “unsustainable”, also at market prices. This registers the drop in productivity associated with environmental degradation. The third row presents a scenario denominated “sustainable” at private prices, which considers the costs and investment required for adoption of alternative sustainable production practices (alternative project).

The fourth row of the matrix (Table 1) is a budget of the current situation valued at economic efficiency prices. The fifth and sixth rows show the “unsustainable” and “sustainable” scenarios also valuated at economic efficiency prices, considering environmental costs and their internalization, respectively. The last three rows of the matrix, called divergences, are determined by the difference between the first and fourth rows, between the second and fifth, and between the third and sixth rows. These show the net impact of distorting policies and market failures. The signs of divergences in revenues, costs and profits indicate whether the net effect of the policy and market failures point to a subsidy or a tax, or alternatively, market failures. The costs in EPAM are divided into two columns, one for tradable inputs and another for domestic factors. Tradable inputs are traded or could be traded internationally. Domestic factors are the primary factors of production: labor, capital, land, natural resources.

Applying EPAM, there is competitiveness when, under present market conditions, an individual producer obtains profits in a production system. There is comparative advantage, or it is efficient if, prevalent market distortions are eliminated, a production system is able to generate the highest levels of output and income (Monke and Pearson 1989, 20).

Therefore, if π_p is positive, the system generates profit under current market policies and conditions, and it is said to be competitive. Likewise, if π_e is positive, the system is capable of generating profit valued in prices that reflect scarcity values or social opportunity costs, that is, without subsidies or restrictions imposed by taxes, and therefore, the system is efficient. For example, if a system receives a subsidy to inputs or pays labor at prices lower than those determined by an efficient labor market, the system can be competitive but is not efficient, or does not have a comparative advantage. Also, $\lambda\pi_{pn}$ and $\lambda\pi_{en}$ registers profits or losses of the systems denominated unsustainable, while $\lambda\pi_{ps}$ and $\lambda\pi_{es}$ does so for those with alternative projects, valued at both market and economic efficiency prices.

Table 1. Extended Policy Analysis Matrix

	Revenues *(R)*	**Costs** *Tradable inputs (TI)*	*Domestic factors* (*DF*)	**Net profit** (*π*)
Private prices (current)	R_p	TI_p	DF_p	π_p
Private prices (unsustainable)	λR_{pu}	λTI_{pu}	λDF_{pu}	$\lambda\pi_{pu}$
Private prices (sustainable)	λR_{ps}	λTI_{ps}	λDF_{ps}	$\lambda\pi_{ps}$
Economic prices (current)	R_e	TI_e	DF_e	π_e
Economic prices (unsustainable)	λR_{eu}	λTI_{eu}	λDF_{eu}	$\lambda\pi_{eu}$
Economic prices (sustainable)	λR_{es}	λTI_{es}	λDF_{es}	$\lambda\pi_{es}$
Divergences (current)	Rd_t	TId_t	DFd_t	πd_t
Divergences (unsustainable)	λRd_{tu}	λTId_{tu}	λDFd_{tu}	$\lambda\pi d_{tu}$
Divergences (sustainable)	λRd_{ts}	λTId_{ts}	λDFd_{ts}	$\lambda\pi d_{ts}$

Source. Monke and Pearson 1989; Kydd, Pearce, and Stockbridge 1997; Pearson, Gotsch, and Bahri 2003.

To compare the production systems, which can be different in terms of the relative proportions of inputs they use, with the data registered in EPAM, indicators of competitiveness or profitability and efficiency or comparative advantage are obtained. The indicator of private profitability is the private cost ratio (PCR), also called the competitiveness ratio. PCR measures the proportion of the domestic factor cost relative to value added. Value added is the difference between the value of output and the cost of tradable inputs.

$$1)\ PCR = \frac{DF_p}{R_p - TI_p}$$

Where DF_p are domestic factors; R_p and TI_p are output value and tradable inputs at private prices. If the ratio is greater than one (PCR>1), the domestic factor cost is greater than the value added or created wealth, and therefore, the system is not profitable: the crop is not profitable for the producer in terms of the prices paid and prices received. If PCR<1, the system is profitable, and earns extraordinary profits. Thus, the most profitable production systems are those with a PCR closest to zero.

The domestic resource cost (DRC) ratio provides a measure of efficiency or level of comparative advantage. This is a ratio similar to that of competitiveness but calculated at economic efficiency prices, obtained with the following equation:

$$2)\ DRC = \frac{DF_e}{R_e - TI_e}$$

Where R_e, TI_e and DF_e are output value, tradable inputs and domestic factor costs at economic efficiency prices. If DRC>1, the system does not have comparative advantage; if DRC<1, the system has comparative advantage and is said to be economically efficient. Under the assumption that subsidies or taxes and market distortions are eliminated, the empirical analysis of comparative advantage determines whether, in a medium term, certain commodities produced in different regions of the country will be competitive with equivalent products on the international markets. The main limitation of EPAM is its inability to calculate how the production systems expand or contract when prices change, although its structure allows simulation of changes and evaluation of other scenarios.

Unsustainable and Sustainable (Alternative Project) Scenarios

The scenario denominated "unsustainable" considered environmental degradation from the overuse of irrigation water, thereby impacting the productivity of production systems. This is evaluated at both market prices and economic efficiency prices (Pearson, Gotsch, and Bahri 2003, 67-5). Multi-annual budgets were constructed assuming a 2% decrease in yields (Castellanos and Ojodeagua 2009, 187-04; Macías-Duarte et al. 2010, 11-9) with a 15-year time horizon. Adjustments were made for use of day labor during harvest and packing, and an additional investment of digging a well 14 meters deeper was considered (CNA- GODEZAC-UAZ, 2008).In contrast, the scenario denominated "sustainable" adopts sustainable production practices (alternative project). In this scenario, constant production yields over time (15 years) are assumed as well as less use of water by the plant, rainwater harvesting and storage in cisterns, and use of moisture sensors are considered.

Within the EPAM structure, values in the unsustainable and sustainable scenarios are determined by deducting revenues, costs (tradable costs and domestic factor costs) and profits represented by λR, λTI, λDF and $\lambda\pi$ at present value (PV), with both private and economic prices, where the sub-indexes *pn, ps, en* and *es*, refer to valuation at private and economic prices in unsustainable and sustainable production systems, respectively. The prefix λ means that the variable represents discounted revenues, costs or profits at a given time period—for this case, 15 years. For example, λR_{pu} represents the present value (PV) of returns from tomato production in the unsustainable system over 15 years. Therefore,

$$3)\ \sum_1^n R_{pu} \frac{1}{(1+r)^n}$$

Where *r* is the interest rate and *n* the number of years.

The divergences attributed to the adoption of alternative sustainable production practices are calculated by the difference in profits: unsustainable system (with no project) minus sustainable system (alternative project) (Pearson, Gotsch, and Bahri 2003, 58-4).

$$4)\ \lambda\pi_p = \lambda\pi_{ps} - \lambda\pi_{pn}\ ;$$

$$5)\ \lambda\pi_e = \lambda\pi_{es} - \lambda\pi_{en}\ ;$$

where $\lambda\pi_p$ and $\lambda\pi_e$ are the PV at market (p) and economic efficiency (e) prices of the divergences from adoption of sustainable agricultural practices; $\lambda\pi_{ps}$, λ_{pn} and $\lambda\pi_{es}$, $\lambda\pi_{en}$ are the PV of the net benefits from applying sustainable (s) agricultural practices or unsustainable (ns) practices, also valued at market (p) and economic efficiency (e) prices.

Selection of Production Systems and Sources of Information

To determine which production systems to study, tomato production units were grouped by technological level using cluster analysis. The variables used in the analysis were structure, culture method, climate control and size (Padilla-Bernal et al. 2010). Four groups were obtained: high, intermediate (transition), intermediate, and low. One production unit was selected to represent each technological level. The main characteristics of the production systems analyzed are presented in Table 2.

Table 2. Principal characteristics of the protected agriculture production systems.

	Technological Level			
	Low	*Intermediate*	*Intermediate (transition)*	*High*
Tomato type	Saladette	Saladette	Saladette	Raceme globe
Structure	*Raspa y amagado*	Multitunnel	Multitunnel	Multitunnel
Culture method	Soil	Soil	Hydroponics+soil	Hydroponics
Climate control	Passive	Passive	Active	Active
Size	Large	Medium	Medium	Large
Production period	June-September	May-October	July-November	August-April
Destination market	Domestic and USA	Domestic	Domestic	Domestic and USA
Domestic market	Central wholesale market, Iztapalapa, D.F.	Central wholesale market, Guadalajara	City of Zacatecas and Jerez, Zac.	Central wholesale market, Aguascalientes
Growing cycle (days)	180	240	210	334

Source. Constructed by authors with data obtained in fieldwork.

The information on the technical coefficients of the production systems studied was obtained through a survey carried out in May to June, 2010, of technicians from the selected production units. The unit of analysis was one hectare cultivated in the 2009 cropping season. The technical coefficients per production system were validated by specialists in the area. Private prices of tradable inputs were obtained from suppliers. Information on investment in the structure, wells and irrigation equipment was determined with estimates from construction companies and equipment suppliers. Investment in cisterns for harvesting rainwater was that indicated by Anaya (2010) and Brown, Gerston, and Colley (2005), considering the mean annual rainfall recorded during the period 2002-2010 in the areas where the production systems are located. Additional information was collected during visits to the production units, for which an observation data card was designed.

The private tomato price considered the market destination, domestic and/or international, and was determined at the farm level taking into account the months the produce was traded. Reference prices were obtained from the Sistema Nacional de Information e Integración de Mercados (SNIIM - National System of Market Information and Integration) and the US International Trade Commission (USITC), for domestic and international markets, respectively.

The economic efficiency price of tomato was determined as an export parity price and tradable inputs as import parity price at the farm level. To calculate parity prices, an adjustment was made for the overvaluation in the exchange rate of the Mexican peso relative to the US dollar. The average annual rate of overvaluation in 2009 was 11.4% (CEFP 2010). The international reference for these inputs was the average price paid by US farmers in April of 2006, 2007 and 2008 (NASS-USDA 2009). In the case of labor, mechanized work, administrative salaries, farm insurance, social security and land, it was assumed that the economic efficiency prices are the same as market prices.

For short and long term credit, the economic opportunity cost of capital was considered with a real interest rate of 10% and 12 %, respectively (Monke and Pearson, 1989), and a rate of accumulated inflation of 3.5% (BANXICO 2010) for the year 2009. In this way, the interest rate on nominal short term credit used in the analysis at market prices (13.91%) was adjusted to an annual 13.92% in the economic analysis, while long term credit ascends from an annual 14.61% to 15.99%. The nominal interest rates are those reported by the Fideicomisos Instituidos en Relación con la Agricultura (FIRA 2009) in 2009, for short term (one year) and long term (10 years) credits to producers with yearly incomes above 1,000 times the minimum wage. The subsidized 9 CU rate of Mex $0.42 kwh in 2009 (CFE 2007) was adjusted to its real cost, Mex $1.50 kwh (Fernández 2009).

Results

Tables 3a, 3b and 3c summarize the revenues, costs and profits at both private and economic efficiency prices, as well as the total divergences obtained in the current situation and the two scenarios of the production systems studied. In all cases, profits are reported, although these are higher at economic efficiency prices. This is attributed to the fact that the divergence obtained between the economic price of tomato and the price on the domestic market is higher than the divergence generated by the effect of the policy of overvaluation of the exchange rate in tradable inputs plus the subsidies to the cost of electricity for pumping irrigation water and to the interest rate. As expected, the highest profits occurred in the production system with advanced technology, while the lowest occurred in those with low technology. It should be pointed out that the latter has lower investment than the other systems and produces only during the spring-summer growing season, and consequently, has lower annual yield.

Table 3a. Extended Policy Analysis Matrix for protected tomato production systems. Current situation (thousands of Mexican pesos/ ha).

	Revenues	Costs		Net profits
		Tradable inputs	*Domestic factors*	
Low technology				
Private prices	1,604	483	688	433
Economic prices	2,157	550	695	912
Divergences	-554	-67	-7	-480
Intermediate technology				
Private prices	2,235	648	893	694
Economic prices	3,038	737	902	1,399
Divergences	-803	-89	-9	-705
Intermediate technology (in transition)				
Private prices	2,437	934	960	542
Economic prices	3,999	1,113	981	1,905
Divergences	-1,563	-178	-21	-1,363
Advanced technology				
Private prices	7,774	2,948	2,065	2,762
Economic prices	9,203	3,507	2,104	3,592
Divergences	-1,429	-560	-39	-830

Notes. Calculated at present value in a period of 15 years, with an interest rate of 14.61% at private prices and 15.99% at economic efficiency prices.

Table 3b. Extended Policy Analysis Matrix for protected tomato production systems. Scenario with unsustainable practices (thousands of Mexican pesos/ha).

	Revenues	Costs		Net profits
		Tradable inputs	*Domestic factors*	
Low technology				
Private prices	8,646	2,878	4,087	1,682
Economic prices	10,966	3,069	3,864	4,033
Divergences	-2,319	-191	222	-2,351
Intermediate technology				
Private prices	12,058	3,866	5,305	2,887
Economic prices	15,442	4,114	5,018	6,310
Divergences	-3,384	-248	287	-3,423
Intermediate technology (in transition)				
Private prices	13,154	5,571	5,702	1,881
Economic prices	20,328	6,209	5,457	8,662
Divergences	-7,174	-639	245	-6,781
Advanced technology				
Private prices	42,063	17,573	12,280	12,210
Economic prices	46,919	19,570	11,717	15,632
Divergences	-4,856	-1,997	563	-3,422

Notes. Calculated at present value in a period of 15 years, with an interest rate of 14.61% at private prices and 15.99% at economic efficiency prices.

Table 3c. Extended Policy Analysis Matrix for protected tomato production systems. Scenario with sustainable production practices (thousands of Mexican pesos/ha).

	Revenues	Costs		Net profits
		Tradable inputs	*Domestic factors*	
Low technology				
Private prices	9,557	2,832	4,100	2,624
Economic prices	12,033	3,021	3,864	5,148
Divergences	-2,477	-188	236	-2,525
Intermediate technology				
Private prices	13,320	3,806	5,320	4,195
Economic prices	16,946	4,050	5,015	7,880
Divergences	-3,626	-245	305	-3,686
Intermediate technology (in transition)				
Private prices	14,521	5,514	5,720	3,287
Economic prices	22,308	6,148	5,458	10,702
Divergences	-7,786	-634	262	-7,415
Advanced technology				
Private prices	46,331	17,480	12,299	16,552
Economic prices	51,337	19,470	11,707	20,160
Divergences	-5,006	-1,990	592	-3,608

Notes. Calculated at present value in a period of 15 years, with an interest rate of 14.61% at private prices and 15.99% at economic efficiency prices.

In the current situation, all the indicators of competitiveness (PCR) and efficiency or comparative advantage (DRC) are below one (Table 4). These results show that with no government aid, the production systems obtain extraordinary profits and could survive under a policy of eliminating subsidies to internal factors and distortions to the exchange rate. The lowest private cost ratio (PCR) was found in the production system with advanced technology, which generates the highest return on domestic factors at private prices. In contrast, the lowest domestic resource cost (DRC) ratio in the current situation is found in the system with intermediate technology in transition, followed by that with advanced technology.

Table 4. Indicators of competitiveness and efficiency of the protected tomato production systems (current situation).

Technological level	**Competitiveness** (PCR)	**Economic efficiency** (DRC)
Low	0.61	0.43
Intermediate	0.56	0.39
Intermediate (transition)	0.64	0.34
High	0.43	0.37

Source. Constructed by author with information collected during fieldwork.

The net benefit for investing in adoption of sustainable production practices determined as the difference between the profits gained in the sustainable system (with project) and those gained in the unsustainable system (without project)at both private and economic prices is shown in Table 5. Despite the high investment required, in all cases NPV is positive and tends to increase with advances in technology level.

Table 5. Net present value for investing in sustainable production systems.

	Technological level			
	Low[1/]	Intermediate[1/]	Intermediate[1/] (transition)	Advanced[2/]
Private prices				
Investment in cistern (000/ Mex$)	170.10	210.64	210.64	3,113.19
Benefit NPV[3/] (000/Mex$)	942.03	1,307.56	1,406.00	4,342.44
Economic efficiency prices				
Investment in cistern (000/Mex$)	189.0	234.1	234.1	3,459.7
Benefit NPV[3/] (000/Mex$)	1,115.6	1,570.1	2,039.9	4,528.8

Notes. 1. Geomembrane cistern. 2. Welded steel cistern. 3. Discounted rates used were 14.61% at private prices and 15.99% at economic efficiency prices.
Source. Constructed by author with information collected in fieldwork and from Anaya (2010); Brown, Gerston, and Colley (2005).

Table 6 presents the indicators of competitiveness (PCR) and economic efficiency (DRC) of the unsustainable and sustainable scenarios. Both the private cost ratio (PCR) and the domestic resource cost (DRC) ratio are lower in the scenario where conservation practices are used. In the sustainable scenario, the indicators obtained are similar to those of the current situation, suggesting that adopting conservation practices, besides reducing environmental degradation, helps to maintain current competitiveness and efficiency. Given the results obtained in this study, it is proposed that government support granted for construction of protected agriculture production units be conditioned to adoption of sustainable production practices. Also, we suggest evaluating other alternatives that help producers become aware of the probable impact of excessive use of irrigation water on the future, and encouraging research in the development of agricultural practices that conserve resources.

Table 6. Indicators of competitiveness and efficiency of the tomato production systems under protected agriculture. Scenarios with unsustainable and sustainable production practices.

Technological level	Unsustainable		Sustainable	
	Competitiveness (PCR)	Efficiency (DRC)	Competitiveness (PCR)	Efficiency (DRC)
Low	0.71	0.49	0.61	0.43
Intermediate	0.65	0.44	0.56	0.39
Intermediate (transition)	0.75	0.39	0.64	0.34
Advanced	0.50	0.43	0.43	0.37

Note. Calculated with the present value of revenue, cost and profit flows.

Conclusions and Recommendations

This study was an analysis of competitiveness and economic efficiency of protected tomato production systems in the state of Zacatecas, Mexico, considering the possibility of adopting sustainable production practices (alternative projects). In the current situation, all the production systems studied generated extraordinary profits for the producers. The systems are able to compete at market prices, which include the effects of policies and market failures. Likewise, all the technology used is economically efficient, that is, under a scheme of elimination of subsidies and taxes and market distortions; with all the tomato growing technology studied, the production systems are able to compete at international prices.

Adopting production practices that make more efficient use of irrigation water in protected agriculture will help prevent environmental degradation, favor competitiveness of the producers and, in the case of elimination of subsidies to tradable inputs and domestic factors, the production systems will be able to remain in the market.

It is proposed that government aid for constructing protected agriculture production units be conditioned to the use of conservation practices, under constant supervision, to prevent resources from being diverted. Moreover, it is suggested that training be given to producers and technicians of these systems; training should include topics that support sustainable agriculture and contribute to create awareness of the impact over-extraction of aquifers has on the environment. Moreover, it is recommended that research and technological processes be oriented toward developing inputs and other products that minimize environmental deterioration.

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