THREE STUDIES ON MEXICAN AGRICULTURE

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CHAPTER I

Study I: CHINESE COMPETITION AND ITS EFFECTS ON MEXICAN AGRICULTURE

Abstract

This paper intends to determine if changes in Mexican, U.S. and Chinese economies have had a significant effect on the agricultural labor market in Mexico. The objective is to analyze if changes in Mexico's gross domestic product (GDP), U.S. GDP, Mexican agricultural wage rate, rural population in Mexico, and the real relative manufacturing wage between Mexico and China have had an effect on the demand for agricultural workers in Mexico. To accomplish the objective of this study Ordinary Least Squares (OLS) regression and Step up procedure were used on time series data covering the period of 1995 through 2008. Misspecification tests show no evidence of model misspecification. Empirical results indicate that the demand for agricultural workers in Mexico is affected by the real relative manufacturing wage between Mexico and China and also by Mexico's GDP. Estimations show large positive effects from changes in the relative real manufacturing wage rates between Mexico and China. A small negative effect from changes in Mexico's GDP on agricultural labor demand in Mexico was also observed.

Introduction

The agricultural sector is considered to be very important in most countries due to its role in food supplies, employment, and as a source of foreign currency. With over one billion people employed in this sector, agriculture is the second largest source of employment worldwide after services. Wages in agriculture tend to be low, particularly in developing countries where many workers are paid below the national minimum wage, making agricultural wages one of the most debated rural labor issues (ILO, 2011).

Worldwide, agricultural employment and the contribution of this sector to GDP have shown a declining trend over the past two decades (ILO, 2011). Mexico is no exception to this trend. Figure I-1 shows the contribution of the agricultural sector, the industrial sector, and the services sector to the Mexican GDP for the 1991 – 2010 period. The contribution from the agricultural sector has decreased, going from 7.52 percent in 1991 to 3.91 percent in 2010. The services sector in Mexico has followed the same trend. This means that the industrial sector (including manufacturing) has gained relative importance in the Mexican economy during the last two decades (1991-2010).

Employment in the agricultural sector has also shown a declining trend. Figure I-2 depicts employment in the agricultural sector for the same period. The agricultural sector went from employing 8.5 million workers in 1991, to 7.95 million by 2010, with the year 1997 having the highest of agricultural employment with 8.8 million workers. Both figures show that the importance of the agricultural sector in the Mexican economy has been continuously declining during the last two decades.

The agricultural sector in Mexico is characterized by a wide range of farm types from highly technified farms to subsistence farms. There are several critical issues faced by farmers and ranchers in Mexico, some of the most important ones are related to the land tenure, size of the farms, lack of financing, low production efficiency, rural poverty, production deficit in key agricultural commodities like corn, climate conditions, among others (OECD, 2006). Regardless of these problems there are several comparative advantages that Mexico has like its climate, product diversity, geographic location, the abundance of labor, and the opening of the economy during the 1990s. All of these have played a determinant role on attracting foreign investment, particularly from the United States. Regardless of the many advantages that Mexico offers to foreign investors, FDI inflows to all sectors in Mexico have shown a declining trend starting in 2001, the year when China joined the World Trade Organization (WTO).

Chinese trade flows have increased uninterruptedly in the last two decades as a consequence of China's economic liberalization policies undertaken since the late 1970s. The huge increase of Chinese exports has raised concerns among many developing countries competing with China in the same sectors and products. Mexico is one of these countries. The main concern for Mexico is that the increase of U.S. FDI flows to China will hurt Mexico's FDI share from the U.S. and as a consequence negatively effects will be faced by the manufacturing and the agricultural sectors.

Changes in the U.S. investment to Mexico are important because more than 50 percent of the FDI for manufacturing in Mexico comes from this source. Effects on the agricultural and manufacturing sectors in Mexico are expected due to the close relation between the labor markets of both sectors. Labor markets are highly seasonal in Mexican agriculture, therefore most of the rural population is employed part time in agriculture and work the rest of the time in nonfarm jobs like manufacturing. This constant movement of labor from the agricultural sector to the manufacturing sector makes the changes in foreign direct investment flows a serious concern for both sectors in Mexico.

The main focus of this paper is to determine the potential effects of changes in the Mexican, U.S. and Chinese economies on the agricultural employment in Mexico. This study is mainly motivated by the recent increase in U.S. FDI to China and the correspondent decline in U.S. FDI to Mexico. The explanatory variables are: Mexico's GDP, U.S. GDP, Mexican agricultural wage rate, rural population in Mexico and the relative real manufacturing wage between Mexico and China. To accomplish the objective of this research, ordinary least squares regression and Step–up procedure were used to determine which of the explanatory variables included in this analysis have a significant effect on agricultural employment in Mexico.

The effect of economic changes in the Mexican economy was studied by adding Mexico's GDP as an independent variable. The demand factors and the foreign direct investment for which Mexico competes was analyzed by including the U.S. GDP as an explanatory variable. Agricultural wages in Mexico was included as an explanatory variable because changes in agricultural wages determine if workers will remain doing farm jobs or will look for alternative jobs like manufacturing. In Mexico the greater part of the rural population works in the agricultural sector, therefore rural population in Mexico was also included. The real relative manufacturing wages between Mexico and China was included because although the changes in Mexican agricultural and manufacturing production and employment corresponds to the U.S. recession and changes in the Mexican economy, there are likely to be other factors such as the increased competition from other countries like China affecting these sectors.

Literature Review

An Overview of Agricultural Policies and Trade in Mexico

After the Revolution Mexico did not have significant agricultural policy reforms until the late 1970s. The agricultural sector began to privatize in the late 1980s and by the early 1990s, most domestic agricultural and trade policy reforms were devoted to encourage privatization and increase competition. These reforms were a combination of price support and general consumption subsidies (OECD, 2006). Reforms in the agricultural sector were aimed at all aspects of food production, from eliminating State enterprises related to agriculture, staple price supports, and subsidies like CONASUPO (National Company for Popular Subsistence) to trade liberalization. The implementation of these policies coincided with the first negotiations for the North American Free Trade Agreement (NAFTA) in 1991 and continued well beyond NAFTA's adoption (Yunez-Naude, 2006).

The North American Free Trade Agreement is the most significant market liberalization step in Mexico and the determinant factor which tied the Mexican economy to the U.S. (Yunez-Naude, 2006). NAFTA was adopted in 1994, opening the North American market, lowering the prices of imports and creating greater competition between Mexico and its northern neighbors (U.S. and Canada). Full trade liberation under NAFTA was achieved in 2010.

The Mexican government's official position has been to view NAFTA as a pillar of modern Mexico's future economic success, assuming that it would create positive structural changes in the agricultural sector. On the other hand, critics view NAFTA as the road to deeper dependence of Mexico on the United States and a source of rural poverty. The main concerns have been Mexico's historically low and inefficient production of basic crops (grains and oilseeds) and the United State's high subsidies to producers of the same crops (Yunez-Naude, 2006).

The economic assumption that the Mexican government used to justify NAFTA and Mexico's trade liberalization policies were that free trade will affect relative prices in Mexico. The changes in relative prices will change resource allocation and they will increase efficiency as farmers adjusted the use of their resources in order to survive and succeed under free trade. These changes were expected to be achieved by creating a structural transformation affecting trade and the composition of production, making noncompetitive crops competitive.

Supporters also argued that eventually, NAFTA along with internal agricultural reforms in Mexico were expected to lead to the "law of one price" for the agricultural commodities produced for internal use, the commodities produced to be exported, and for goods imported into Mexico. The “law of prices” meant that prices paid to Mexican producers for basic crops were expected to decline following international prices and, with free trade, commodity prices were expected to be equal in Mexico, Canada, and the U.S. This prediction was based on the traditional economic expectation that without intervention, prices for the same goods will be equal within and between countries (Yunez-Naude, 2006).

Regarding labor, an increase in employment related to exports in general was expected to occur in Mexico as a result of NAFTA, but not one large enough to absorb all the workers who would be displaced by reduced staples production. The expected result was a large increase in rural out-migration inside and outside the country (Calva, 1995; Levy and van Wijnbergen, 1992; Robinson, 1991). Inside the country migration was expected to be towards the manufacturing sector, the services sector and to informal employment. This inside migration was expected because a lot of U.S. companies were opening new manufacture plants in Mexico after NAFTA creating new jobs. Employment predictions assumed macroeconomic stability, which Mexico did not have starting with the peso devaluation in 1994 through 1996 (Audley, 2003).

Changes in Mexican wages and employment cannot be solely attributable to the trade agreements itself. Wages are reflective of a number of economic variables, including GDP, productivity, exchange rates, international trade and other economic variables (Villareal, 2010). Moreover, the effects of trade on the economic sectors in Mexico depends on many factors, including economic variables, political stability, the efficiency of other economic sectors in the country, the economic performance of competing countries and which tariffs are reduced or eliminated by each country, at what speed, and in what order.

Labor Market in Mexico

Mexico has an abundance of labor due to the very high population growth rates during the 1970s which translated into an increase in the workforce through the late 1990s. High population growth rates during the 1970s were mainly a consequence of improvements in health programs and services during that decade. In addition, during the 1980s and 1990s more women joined the labor force (STPS, 2008).

The agricultural sector employs a large proportion of the workers in some parts of Mexico, particularly people from rural areas (STPS, 2008). By 2009, about 28 million people lived in rural areas in Mexico and the vast majority of them depend largely on agriculture for their incomes (INEGI, 2009). This is particularly true in the southern States, which have relatively high levels of poverty and a larger indigenous population. The potential amount of agricultural workers in Mexico consists of almost 6 million people. (STPS, 2008). In the central states of Mexico agricultural employment is decreasing at an average rate of 7.6 percent per year primarily due to urbanization absorbing land and labor (SIAP, 2011).

Labor markets are highly seasonal in Mexican agriculture. Most rural workers are employed part time in agriculture and work the rest of the time in nonagricultural sectors such as construction, manufacturing, and services particularly in the southern States where there is only one crop growing season due to very limited infrastructure for irrigation. Rural workers generally shift from one economic activity to another, and usually none of these activities becomes a permanent job.

Factors that influence the market for hired farm labor also affect the future of the agricultural sector in Mexico. Some of these factors are specific to agriculture like the land tenure. Other factors are related to the country's economy, other economic sectors like manufacturing and government policies. The most important factor affecting agriculture are commodity prices because the demand for hired farm labor and other inputs is influenced mainly by the value of farm output. So, when commodity prices are low, wage rates for farm workers are most likely to be low.

Other factors affecting the agricultural sector are the technologies that substitute for labor and the wage rate difference with other sectors. The degree to which the agricultural sector is able to hire labor depends in part on the attractiveness of nonfarm jobs. The difference in wages rates between farm and nonfarm jobs narrows considerably when earnings of farm workers are compared with workers in nonfarm occupations that require little or no advanced education. While construction workers or butchers earn substantially more than farm workers, the earnings of janitors or textile sewing machine operators are comparable to those of farm workers.

Foreign Direct Investment and Maquiladora in Mexico

Historically, despite the importance of FDI, only a few countries have been recipients of considerable absolute flows, particularly China, Brazil and Mexico. The United States is the world's largest recipient of FDI and it is also the largest foreign direct investor in Mexico. Several U.S. companies use parts assembled in Mexico in the final goods produced in the U.S. (Waldkirch, 2010). The abundance of labor and the opening of the Mexican economy during the 1990s were determinant factors in attracting foreign companies who looked for cheaper production costs compared to those at home. The vast majority of the U.S. investments received by Mexico are allocated in the manufacturing sector, also known as maquiladora.

Maquiladoras can be defined as assembly plants, largely located across Mexico. An assembly plant is a factory where manufactured parts are assembled into a finished product (Waldkirch, 2010). The maquiladora industry has been an important economic activity for the Mexican economy, particularly during the 1990s when it had double digit growth rates (Mundra, 2010). With the adoption of NAFTA, trade and investment in the manufacturing sector increased at a rapid rate, becoming one of the forces of economic integration between the United States and Mexico, particularly at the Border States (Mendoza, 2010). For Mexico, the maquiladora industry is a source of economic stability, housing, and a large and important source of foreign exchange. For the Mexican worker, it provides a relatively high paying and skill developing job in a emergent economy.

In Mexico the manufacturing sector is the second largest revenue generator, it is also the main contributing sector for Mexican exports. Manufacturing exports account for an average of $50 billion dollars per year in Mexico (SE, 2011). The manufacturing sector was responsible for more than 80 percent of Mexican exports in 2011, making a considerable increase from the 15 percent the sector contributed in 1980 (Mollick, 2006).

The maquiladora industry is important to Mexico for a variety of reasons: first because maquiladoras are engaged in “outsourcing”, implying that the rise in maquiladora establishments will generate an increase in the number of workers employed by them. This means that the opening of new maquiladora plants increase available jobs. Second, the location of maquiladoras is concentrated in few States, resulting in a large region variation in maquiladora employment and a concentrated inside country migration to some States (Airola, 2008). Figure I-3 shows a comparison between the years 1990 and 2000 for the Mexican States with the highest concentration of maquiladora workers relative to the total number of workers in all industries for each State. It can be observed that the percentage of workers employed in maquiladoras has decreased for all States during that decade. It is also important to note that there is no southern State with a significant amount of maquiladora workers. This confirms that maquiladora employment is mainly concentrated in the center and northern regions of the country.

After NAFTA took effect there was a discharge of labor from the agricultural sector which largely offset the employment gains in the manufacturing sector. While the growth of trade-related employment since NAFTA is disappointing, the substitution of agricultural jobs for manufacturing jobs is generally considered positive for development (Audley, 2004). A large portion of new foreign manufacturing activities in Mexico are the result of outsourcing by U.S. multinationals. This has important consequences for the relative wages and employment of skilled and unskilled workers in Mexico. Foreign direct investment has showed a positive correlation with the relative demand for skilled labor in Mexico mainly because it has been of a sufficient magnitude to have large effects on the country's labor market (Feenstra, 1997).

U.S. Foreign Direct Investment from Mexico to China

Mexico and China are two nations with cultural, economic and political differences that, initially, will appear to make any comparison between them pointless, but this is not the case. Both nations had until the late 1970s closed economies, which began to open after both countries faced agrarian reforms and food self-sufficiency problems that were attempted to be solved by strategies based principally on protectionism and agricultural subsidies. It was not up to the 1970s when China initiated dialogs with Western countries and international organizations. Of particular interest are Chinas entrance to United Nations (UN) in October, 1971, its integration to the Asia- Pacific Economic Cooperation (APEC) forum in November, 1991, and its incorporation to the World Trade Organization on November 10, 2001 (Celaya, 2004).

In 1979, China began an economic reform and started to open its economy. Today, China´s trade has doubled. In addition the FDI China receives from other countries has increased dramatically, most of it going to the manufacturing sector. In the process of trade liberalization, the Chinese economy adopted a very important commercial position in the world, due to the exponential growth of its exports, which allowed that nation to access an important share of the markets of the most industrialized countries particularly the United States (Mendoza, 2010).

The wage advantage of China has been decisive to attract enormous capital flows and to turn to this country into the powerful economy it is today. Studies on the locational determinants of foreign direct investment flows in the manufacturing industries generally arrive at similar conclusions. These conclusions are that the most influential locational advantages for FDI outflows from the United States are per capita GDP, the growth rate of GDP, and market size of the recipient country. This fits with the general observation that most FDI flows to developed countries, which already have high per capita GDP and high GDP growth rates. FDI not bound for developed countries goes to the few developing countries with large markets and high growth population rates such as China and Mexico (Worth, 2002).

In Mexico it is a popular perception that the rapid economic growth of China and its increasing participation in the world economy threatens Mexico´s economy, particularly the maquiladora and agricultural sectors. This perception is based on the decreasing participation of Mexico on the American markets starting 2001, year when China entered the WTO. By 2008 more than 30 percent of the jobs that were created in the manufacturing industry in the 1990s had disappeared. Many of these companies were relocated to lower- wage countries, particularly China (STPS, 2008). In addition to the reduction in manufacturing employment, the recession of the U.S. economy also affected negatively the flow of exports from Mexico. On the other hand, exports from China to the U.S. increased during the same time, achieving a bigger participation than Mexican exports. While Mexico has either lost or reduced its comparative advantages in goods like televisions and computers, China has increased its advantage and participation in the U.S. market on the same commodities (Guzman, 2005).

International Trade, Foreign Direct Investment and Labor

The late twentieth century has witnessed a rapid growth of off-shoring of productive activities and labor intensive goods to low-wage countries like China and Mexico, and, simultaneously, the relative decline of domestic manufacturing in developed countries.

Increasing production and productivity of a country is in part dependent upon the concept of domestic product cycle (Vernon, 1966), where entrepreneurs develop new techniques and products in urban centers. As these techniques become mature, more standardized, easier to transfer away from the center of operations of the firm, and more productive, the production process eventually relocates to low-wage regions.

International trade is typically believed to aggregate welfare gains for trading countries. However, it is also often viewed as a source of growing social disparity by causing unemployment and greater inequality within countries (Helpman, 2010a). In an open economy, only the most productive firms export; firms of intermediate productivity produce only for the domestic market; and the least productive firms exit without producing because they cannot cover fixed production costs. Exporting firms have higher revenue than non-exporting firms, and pay higher wages. Opening closed economies to trade increases wages and employment of high-productivity exporters. As a result, opening of trade also raises wage inequality. Workers employed by high-productivity exporting firms receive higher real wages in the open economy than in the closed economy. In contrast, workers employed by low-productivity domestic firms may receive lower real wages in the open economy than in the closed economy (Helpman, 2010b). The Mexican manufacturing sector experienced wage increase, creation of new jobs, and high productivity levels during the first years after the economy was opened to trade. On the other hand the agricultural sector faced lower wages after the economy was opened.

There are several theories on how firms decide where best to locate their production. Ultimately, the firms final goal is to maximize their profits, whether by investing abroad or by expanding domestic production and exports. Earliest theories explain FDI as capital seeking its highest return. Therefore, capital should flow from developed, capital-abundant countries to less-developed countries where capital is limited, factors of production are cheaper, and where they can earn higher profits (Worth, 1998).

The Model

Previous econometric studies on Mexican labor demand have focused on maquiladora labor and they all assumed that maquiladora labor demand in Mexico is a function of Mexican wages, domestic competitive factors, and external factors derived from globalization (Hanson 1994; Mendoza 2001; Mendoza 2010). Recent studies like Mollick (2003) and Mollick (2005) analyzed Mexican maquiladora employment using the general framework proposed by Milner (1998). This estimation method attempts to investigate labor market responses to trade liberalization in an industrializing country. The analysis is conducted in the context of a relatively simple, low dimension model. It does however capture a number of the broad features that are typical of many developing country economies like Mexico. The econometric analysis in this paper was conducted within the framework of a static profit-maximizing model of firm behavior. It begins by assuming a Cobb-Douglas production function of the following type:

$$Y_t = A^{\gamma} K_t^{\alpha} L_t^{\beta} \tag{1.1}$$

where *Y* represents real output, *K* is the stock of capital, *L* is the units of labor utilized, and *A* is a productivity factor, its parameter γ allows for efficiency changes in the production process, α is the capital share of the real output, β is the labor share of the real output and *t* represents the year analyzed. Real output means that the effects of general changes in the economy over time have been removed.

Economic theory states that a profit maximizing firm will employ capital and labor at such levels that the marginal revenue product of labor equals the wage (w) and the marginal revenue product of capital equals the user cost (r):

$$MRP_L = w = \frac{\partial Y}{\partial L} = A^{\gamma} K^{\alpha} \beta L^{\beta - 1} \quad \text{and} \tag{1.2.1}$$

$$MRP_K = r = \frac{\partial Y}{\partial K} = A^{\gamma} \alpha K^{\alpha - 1} L^{\beta} \tag{1.2.2}$$

From 1.2.2, we have that $L^{\beta} = \frac{Kr}{(A^{\gamma} \alpha K^{\alpha})}$. Further from equations 1.2.1 and 1.2.2 we obtain:

$$K = \frac{w \alpha L}{\beta r} = \left(\frac{w}{r}\right)(\alpha L)/\beta \tag{1.3}$$

$$Y_{t=} A^{\gamma} \left[\left(\frac{\alpha L_t}{\beta}\right)\left(\frac{w}{r}\right)\right]^{\alpha} L_t^{\beta} \tag{1.4}$$

Taking logarithms and rearranging:

$$Log\ Y_t = \gamma log A + \alpha Log \alpha + \alpha log L_t - \alpha Log \beta + \alpha Log\left(\frac{w}{r}\right) + \beta Log L_t \tag{1.5}$$

$$Log\ Y_t = (\gamma log A + \alpha Log \alpha - \alpha Log \beta) + (\alpha + \beta) Log L_t + \alpha Log\left(\frac{w}{r}\right) \tag{1.6}$$

$$Log\ L_t = \left[-\frac{1}{\alpha+\beta}\right](\gamma log A + \alpha Log \alpha - \alpha Log \beta) - \left[\frac{\alpha}{\alpha+\beta}\right] Log\left(\frac{w}{r}\right) + \left[\frac{1}{\alpha+\beta}\right] Log Y_t \tag{1.7.1}$$

Finally following Milner (1998) the equation that describes the demand for labor in the Mexican agricultural sector is 1.7.2:

$$Log\ L_t = \beta_0 + \beta_1 Log\left(\frac{w}{r}\right) + \beta_2 Log Y_t \tag{1.7.2}$$

where $\beta_0 = \left[-\frac{1}{\alpha+\beta}\right](\gamma log A + \alpha Log \alpha - \alpha Log \beta)$, $\beta_1 = -\left[\frac{\alpha}{\alpha+\beta}\right]$, and $\beta_2 = \left[\frac{1}{\alpha+\beta}\right]$.

Assuming perfect capital markets as indicated by Mollick (2005), the real cost of capital fluctuates over time. Following Fullerton (2001), Mollick (2003), and Mollick (2006) real U.S. GDP is assumed to capture demand factors and also accounts for the U.S. foreign direct investment for which both Mexico and China compete. At this stage Mollick (2006) proposes to incorporate additional variables. Because of the relation between the manufacturing and the agricultural sectors and the changes in maquiladora labor demand as a consequence of Chinese participation in the U.S. FDI, the real relative manufacturing wage between Mexico and China was added to the model as an explanatory variable. The variable rural population (RP) was incorporated because agricultural labor is mainly composed of workers from rural areas of Mexico. Even though rural population tends to have highly diversified income activities the most important one is still agriculture, therefore the real agricultural wage in Mexico was also added as another explanatory variable. Finally Mexico's GDP was included in the model to determine how agricultural labor demand is affected by the economic performance of the country. Therefore, the final model shown in equation 1.8 is specified as:

$$Log\ L_t = \beta_0 + \beta_1 LogW_t + \beta_2 logA_t + \beta_3 logY_t + \beta_4 logX_t + \beta_5 logRP_t + e_t \qquad (1.8)$$

where L_t is the number of agricultural employees working in year *t* in Mexico, β_0, β_1, β_2, β_3, β_4 and β_5 are the coefficients to be estimated, W_t denotes the real relative manufacturing wage between Mexico and China for year *t*, A_t represents the real agricultural wage in Mexico in year *t*, Y_t denotes U.S. GDP for year *t*, X_t denotes Mexico GDP for year *t* and RP_t represents the rural population in Mexico in year *t*, and $e_t \sim N(0, \sigma^2)$.

Estimation Procedures and Statistical Tests

Estimators of model 1.8 were obtained using ordinary least squares. The econometric analysis was based on time-series data from 1995 through 2010. To determine which of the proposed explanatory variables have significant effects on the dependent variable and should be included in the final model, the Step up procedure explained by Efroymson (1960), was used to linearly model the agricultural labor demand for Mexico.

Ordinary Least Squares is widely used to analyze data and is the base of many other techniques like ANOVA. The main advantages of this technique are that it is gives powerful predictions and it is easy to check the model assumptions of linearity, constant variance, amongst others. The basic assumption underlying OLS is that the dependent variable (at least to some approximation) is a linear function of the independent variable. The ultimate goal is to find the "best" choices of values for the constants to make the model as accurate as possible. The coefficients have to be chosen so that in every sample point of the data the sum of squared differences between the actual dependent variable and the predicted value for the dependent variable are minimized.

The main problems regarding OLS are: outliers in the data, nonlinearity, too many independent variables, dependence among variables, and heteroskedasticity. In order to check and correct for this problems, log transformation of the data, misspecification tests along with the Step up procedure, were used. Even though OLS has a lot of problems, it is still a successful and important technique if the best solutions for the given prediction problems are applied.

The Step up Regression

Step up regression is a procedure that enters explanatory variables in the model one at a time rather than entering all the variables as a block, the order of entry is determined by the variable that causes the greatest R^2 increase, given that the variables were already entered into the model. The Step up regression is computed by first calculating the correlation coefficients between the number of agricultural employees in year *t* in Mexico (dependent variable) and all the predictor or independent variables. To compute the correlation coefficients between the dependent and the independent variables, the PROC CORR procedure in SAS® was used.

The next step consists of choosing the independent variables with the highest significant correlation with the dependent variable and regressing them in order to obtain the residuals. The correlations of the independent variables are then computed with the residuals from the previous model and the independent variable with the highest significant correlation is added to the model. This step is repeated until no significant correlations with the residuals are found.

Misspecification Tests

One set of concerns in statistical modeling has to do with gaps between variables in a statistical model, but an even more important concern is whether the assumptions needed to reliably model the statistical variables are met (Mayo, 2004). Misspecification tests were conducted to the model in order to check the assumptions on which the estimation method of the model is based. These tests tell how to specify and validate statistical model, and how to proceed when statistical assumptions are violated. The misspecification tests performed on the model used in this paper are: serial autocorrelation, parameter instability, dynamic and static heteroskedasticity, stability of the variance and normality.

In order to check for serial autocorrelation in the error terms Durbin-Watson (DW) statistics and Godfrey test including two lags were performed. Serial correlation occurs in time-series studies when the errors associated with observations in a given time period carry over into future time periods. Serial correlation, also known as autocorrelation in the residuals means that they contain information, which should itself be modeled. The DW statistic is a test for the detection of first order serial correlation in the residuals.

Parameter instability is a common form of misspecification. Parameter stability tells us if the same relationship hold over the whole sample period. The Chow test was used because it shows whether there are breakpoints in the data and if the variables are statistically significant in the model.

It is important to test for heteroskedasticity when OLS is used because when the residuals are heteroskedastic the OLS estimator remains unbiased and consistent but ceases to have minimum variance. In particular, if the residuals are heteroskedastic, OLS produces biased estimates of the standard errors of the coefficients making hypothesis testing unreliable. To test for heteroskedasticity the Breusch-Pagan test was used. The presence of dynamic and static heteroskedasticity and the stability of the variance were tested using conditional mean test.

The K2 and Bera- Jarque tests were performed to test for normality. If the assumption of normality does not hold, then the OLS estimators remain the Best Linear Unbiased Estimator (BLUE), i.e. they have the minimum variance among all linear unbiased estimators. Estimators will remain consistent, but they will not be the maximum likelihood estimators.

Data

Data for the number of agricultural employees in Mexico, Mexican manufacturing, Mexican agricultural wages, Chinese manufacturing wages, U.S. GDP, Mexico's GDP, and rural population in Mexico were all taken from the World Bank databases. All data goes from 1995 through 2010. Real relative manufacturing wages between Mexico and China were calculated so that the wages were comparable in terms of buying power. They were obtained by dividing the real manufacturing Mexican wage by the real manufacturing Chinese wage. The nominal wages for China and Mexico were adjusted for inflation separately using Consumer Price Index (CPI) for each respective country with 2010 as the base year. CPI data were obtained from the International Labor Organization.

Data on Mexican and Chinese wages use the same definitions of wages and include the average monthly wage per year for workers in the agricultural sector. It is presented in U.S. dollars so that the average monthly total earnings per year between the two countries could be compared. The spot exchange rate used to convert the wage data into U.S. dollars was obtained from the International Monetary Fund.

Figure I-4 plots real agricultural wages of Mexico from 1995 through 2010. On December 20, 1994, less than twelve months after NAFTA took effect, Mexico faced economic disaster causing the Mexican government to devaluate the peso value in half. The graph shows how agricultural wages declined dramatically starting 1995. It also shows that this declining trend continued during the analyzed period.

The real relative manufacturing wage between Mexico and China is shown in Figure I-5. After the depreciation of the peso at the end of 1994, the wage ratio between Mexico and China showed a downward trend. This negative trend was mainly due to the rigidity of the yuan and smaller adjustments in the floating Mexican peso. The relative wage ratio decreased to 4.18 so that Mexican maquiladora wages were about four times the Chinese manufacturing wages in 2001. By 2010 the rate reduced, reaching 1.45, meaning that Mexican manufacturing wages are just about 1.5 times the Chinese ones indicating that the difference between both countries wages has narrowed during recent years reducing the low wage comparative advantage for China.

Stationarity

Much of modern theories of time series are concerned with stationarity of the time series. For this reason time series analysis often requires to transform a nonstationary series into a stationary one so these theories can be used (Chatfield, 2004). A time series is said to be stationary if there is no systematic change in mean (no trend), if there is no systematic change in variance and if strictly periodic variations have been removed. Economic data are generally not stationary; this can be concluded when structural breaks in time series are visible on the graphed data (See Figures I-4 through I-8). Non-stationarity can be due to evolution of the economy, legislative changes, technological changes, and political disorder (Hendry, 1999). The logarithmic transformation of the production function provides a log-linear form which is convenient and commonly used in econometric analysis using linear regression techniques. Because high variance is observed throughout all the series of data (See Figures I-4 to I-8), a log transformation was made to all variables data in order to achieve variance stationarity across time.

Results and Discussion

Correlation Coefficients and Model Estimates

Correlation coefficients and parameter estimates obtained from the Step up procedure are presented in Tables I-1 and I-2. Table I-1 shows all the correlation coefficients between the dependent variable (*L*) and all the independent variables (*W*, *A*, *Y*, *X* and *RP*). Notice that the largest significant correlation between the five explanatory variables and the dependent variable is the one from the real relative manufacturing wage between Mexico and China (*W)* with a 0.88101 value. Following the procedure, variable *W* was added to the model as an independent variable. The new model shown in equation 1.9.

$$Log\ L_t = \beta_0 + \beta_1 LogW_t + e_t \tag{1.9}$$

where L_t is the number of agricultural employees working in year *t* in Mexico, β_0 and β_1 are the coefficients to be estimated, W_t denotes the real relative manufacturing wage between Mexico and China for year *t*, and $e_t \sim N(0, \sigma^2)$.

Model 1.9 was estimated and residuals where obtained. Results of the estimations of model 1.9 are shown in Table I- 2. Next, the correlation coefficients were computed from the residuals of model 1.9. These coefficients are presented on the second column in Table I-1. Notice that the highest significantly correlated variable is Mexico's GDP (*X*) with a value of -0.48331, consequently this variable is added to model 1.9. This new model is depicted in equation 1.10.

$$Log\ L_t = \beta_0 + \beta_1 LogW_t + \beta_2 logX_t + +e_t \tag{1.10}$$

where L_t is the number of agricultural employees working in year *t* in Mexico, β_0, β_1 and β_2 and are the coefficients to be estimated, W_t denotes the real relative manufacturing wage between Mexico and China for year *t*, X_t denotes Mexico's GDP for year *t* and $e_t \sim N(0, \sigma^2)$.

Following the procedure, model 1.10 was estimated and residuals where obtained. Estimations of model 1.10 are presented in Table I-2. The third column in Table I-1 shows the correlation coefficients obtained from the residuals of model 1.10. Notice that there are no more significant correlations. Therefore it is concluded that following the Step up procedure, the model that best describes agricultural labor demand in Mexico is equation 1.10.

Following Table I-2, the R^2 value for equation 1.10 tells us how good of predictors are the independent variables included in the model. In this case it is 0.8455 which shows a very good fit. The p-values of both independent variables (Real relative manufacturing wage between Mexico and China and Mexico's GDP) are very close to zero proving that the coefficients are statistically significant. These p-values also show that there exists a very strong relationship between the variables.

All the estimates of model 1.10 shown in Table I-2 are significant. The coefficient of the real relative manufacturing wage between Mexico and China presents a positive sign. This indicates that as the real relative manufacturing wage of Mexico increases with respect to China the number of agricultural employees in Mexico increases, the estimated magnitude is large (3.32748). A 10 percent increase in the relative wages of Mexican workers compared with their Chinese counterparts yields a 33.2 percent increase in agricultural labor demand in Mexico.

A possible explanation to the above results is that as manufacturing wages in Mexico increase it becomes less attractive for foreign manufacturing companies to locate their operations in Mexico mainly because their revenues are lower than before. This results in less demand for manufacturing workers and more of them not leaving or returning to agricultural jobs. Higher wages in manufacturing will increase the competition for these jobs, making it harder for agricultural workers to obtain a manufacturing job. This will also translate in fewer agricultural workers leaving farm jobs.

A negative sign was found on the estimated coefficient for Mexico GDP meaning that as Mexico's GDP increases the demand for agricultural workers in Mexico decreases. This result indicates adverse employment effects in the Mexican agricultural sector caused by a GDP increase in the country. However, the magnitude is not large (-0.011615), a 10 percent increase in Mexico's GDP yields to 0.11 percent decrease in agricultural labor demand in Mexico.

Misspecification Tests Results

Misspecification tests results are presented in Table I-3. Inspection of Durbin-Watson statistics and formal tests for serial autocorrelation i.e. Godfrey test including two lags indicate that there is no evidence of positive autocorrelation and also there is no presence of serial autocorrelation in the error terms. The result of the Chow test shows that there are no breakpoints in the data and therefore all the variables in model 1.10 are statistically significant. To test for heteroskedasticity the Breusch-Pagan test was used, results show no evidence of static heteroskedasticity.

The outcome of the K2 and Bera- Jarque tests both fail to reject the null hypothesis of normal distribution. Conditional mean test tested the null hypothesis that all the parameters equal to zero against the alternative hypothesis that at least one parameter is not equal to zero. The test indicates that there is not enough evidence of dynamic and static heteroskedasticity and that the variance is stable. All the tests performed show that there is no evidence of misspecification in this model. Based on these results it is proven that the assumptions and estimations of the chosen statistical model hold for the data used.

Conclusions

Previous empirical research on the impact of Chinese competition on Mexico has mainly focused on the employment in the manufacturing and the maquiladora sectors. This study provides evidence that the agricultural sector in Mexico is affected by Chinese economy, the effect comes from the real relative manufacturing wage between Mexico and China. Results also confirm the link between employment in the Mexican agricultural sector and employment in Mexican maquiladora industry.

For Mexico, China's growth is more threatening than it is for other countries in Latin America because other large Latin nations tend to export commodities that China imports like minerals and agricultural commodities. The challenge for Mexico is that both countries (China and Mexico) specialize in similar goods. Mexico needs to encourage the production of goods demanded by China in order to take advantage of its market size and increasing economic power. The non agricultural sectors where there are export opportunities to China are the mining sector, tourism, and renewable energies. Mexico has silver, iron, and copper which are minerals that China needs. The service sector in Mexico can benefit from Chinese tourism, by taking advantage of the growing middle class in China.

For better or worse, Mexico's fortune in the global economy is tied to manufacturing, and it is necessary for manufacturing firms to make the transition from maquiladoras that import inputs, assemble or process them, and then export the finished goods, into original-equipment manufacturing and own-brand production. It is vital to recognize that the loss of competitiveness of Mexican maquiladoras is not only a consequence of Chinese economic growth, but it is also linked to internal reasons, inherent in the models of economic and institutional development followed by the country during the last three decades.

Regarding the agricultural sector, Mexico can take advantage of the strategic partnership Mexico-China which started negotiations in 2003. With the recent establishment of the "China-Mexico Permanent Bi-national Commission" early 2012, the Mexican government is seeking to export several agricultural products to the Chinese market, such as pork, lime, beef, poultry, mango, and avocado. Other agricultural commodities that have a potential to be exported to China are: soybeans, vegetable oils, poultry, cotton, hides, and skins (USITC, 2011). The challenge for Mexican producers is to quickly adopt the phytosanitary requirements imposed by China. The challenge for the Mexican government is to incentive the production of agricultural commodities with potential to be exported to China and to help producers meet the requirements imposed by this market by always taking into account the characteristics, strengths and weaknesses of the producers.

To improve the agricultural sector in Mexico it is necessary to understand the nature of its farming structure. Given the priorities of poverty alleviation, the globalization trends of agricultural markets, and that most of the poor population are concentrated in rural areas, it is essential for policymakers to have a micro-level understanding of the economy wide impacts of existing and proposed development policies in the whole economy and the sectors integrating it (Yunez-Naude, 2006). Rural poverty continues to be an ongoing challenge for Mexico as almost 60 percent of the poor live in rural areas (OECD, 2006).

The main challenges for the Mexican government regarding the agricultural sector are the high levels of rural poverty, low productivity in the agricultural sector, under-developed infrastructure, and unclear property rights for land. Agricultural policies have shown to be insufficient to address these challenges without coordinated initiatives across all government agencies and State authorities throughout the country. This coordination is essential to ensure a coherent set of policies (OECD, 2006).

Employment programs in rural areas can alleviate the effects of the open economy and increase rural income by offering temporal employment on the construction of infrastructure like roads, irrigation, schools and housing. These programs will not only improve rural income and living conditions of the rural population, but will also benefit agricultural producers. Better infrastructure, higher rural income and higher agricultural production efficiency are key factors to attract FDI inflows to the agricultural sector. Efficient policies must consider the dual character of Mexico's agricultural production characterized by the coexistence of commercial farmers along with subsistence farmers. From this perspective, it can also take into account discrepancies in the market context where commercial and subsistence farmers make their economic decisions. The agricultural sector's growth in Mexico and its ability to compete in foreign markets and meet the challenges of foreign competitors like China depends on the government's ability to first address problems inside the country.

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APPENDICES

Table I-1. Summary of correlation coefficients for agricultural labor demand in Mexico using Step up procedure, 1995-2008.

	Correlation coefficients[1]	**Correlation coefficients[2]**	**Correlation coefficients[3]**
W_t	0.88101***		
	(<0.0001)		
A_t	0.51412**	-0.30034	-0.08650
	(0.0416)	(0.2584)	(0.7501)
Y_t	-0.91730***	-0.17128	-0.04909
	(<0.0001)	(0.5259)	(0.8567)
X_t	0.20763	-0.48331**	
	(0.4403)	(0.0579)	
RP_t	-0.65916***	0.17445	-0.09561
	(0.0055)	(0.5182)	(0.7247)

Source: Authors' estimations.

Parenthesis ( ) denote the Pr >|t|

** Denotes significance at the 5 percent level.

*** Idem, 1 percent.

[1] Refers to the correlation coefficients obtained when all 5 explanatory variables were included in the model

[2] Refers to the correlation coefficients obtained from the residuals of model 1.9

[3] Refers to the correlation coefficients obtained from model 1.10

Table I-2. Summary of model estimations for agricultural labor demand model in Mexico using Step up procedure, 1995-2008.

Parameter	Model 1.9	Model 1.10
β_0	58.17467***	74.45699***
	(<0.0001)	(<0.0001)
β_1	2.84333***	3.32748 ***
	(<0.0001)	(<0.0001)
β_2		-0.011615 **
		(0.0313)
R^2	0.7762	0.8455
Adj. R^2	0.7602	0.8217

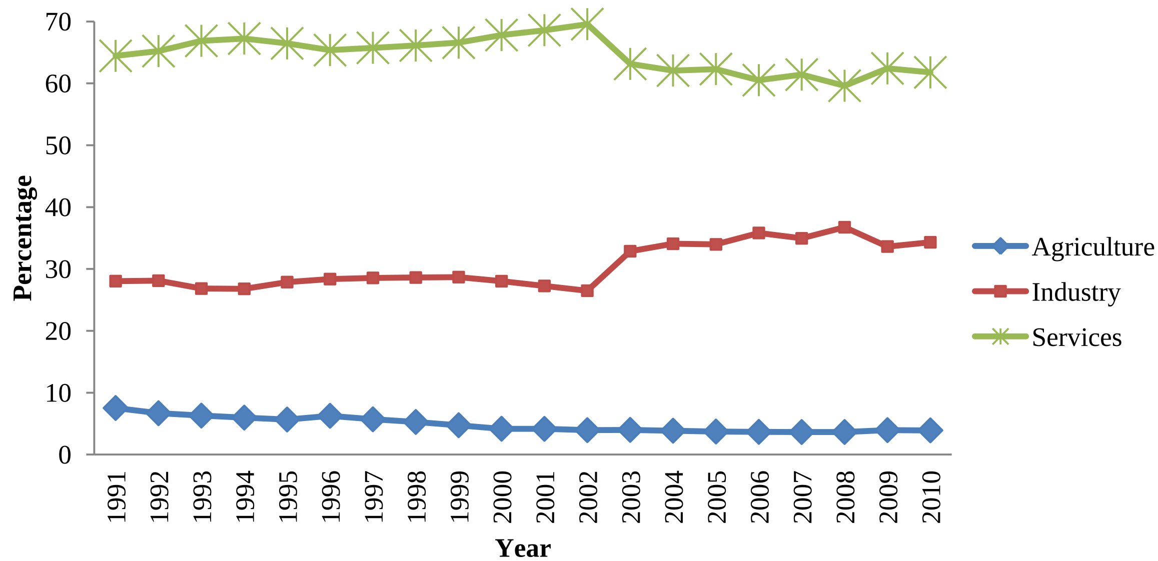
Source: Authors' estimations.
Parenthesis ( ) denote the Pr >|t|
** Denotes significance at the 5 percent level.
*** Idem, 1 percent.

Table I-3. Summary of misspecification tests results for the agricultural labor demand model in Mexico, 1995-2008.

	Model 1.10	
Test	**Estimate**	**P-value**
Durbin-Watson (Pr<DW)	1.9734	0.2594
K2	7.0412	0.2960
Bera-Jarque	2.7701	0.2503
RESET test P2	0.5747	0.4630
RESET test P3	0.7822	0.4813
Godfrey test lag 1	0.0234	0.8785
Godfrey test lag 2	0.0259	0.9871
Chow test (F-value)	5.1500	0.2080
Breusch Pagan test	2.8700	0.1568
White test	7.9900	0.2385
Conditional mean	1.3800	0.3164
Conditional variance	2.1300	0.1540

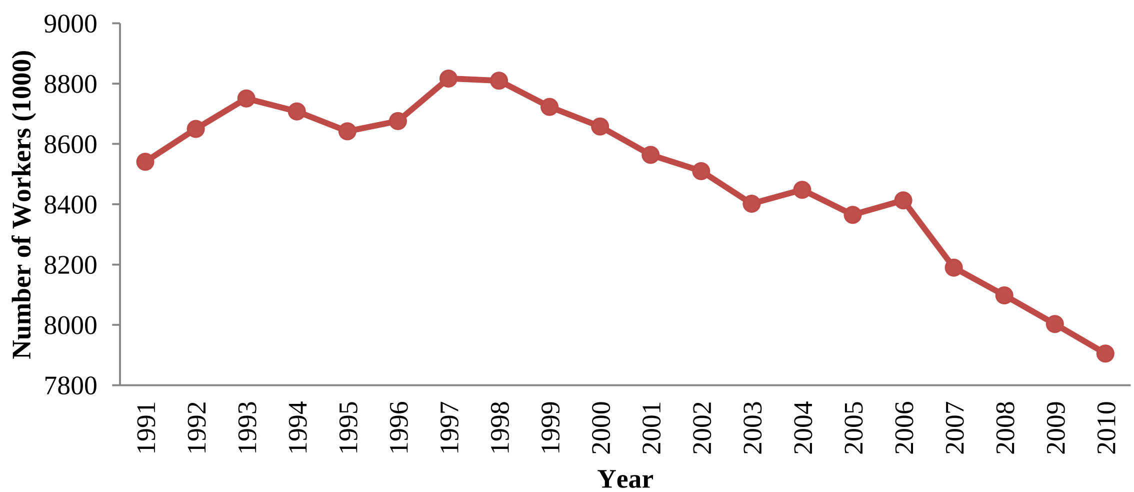
Source: Authors' estimations.

Figure I-1. Contribution to gross domestic product in Mexico by sector in percentage, 1991-2010



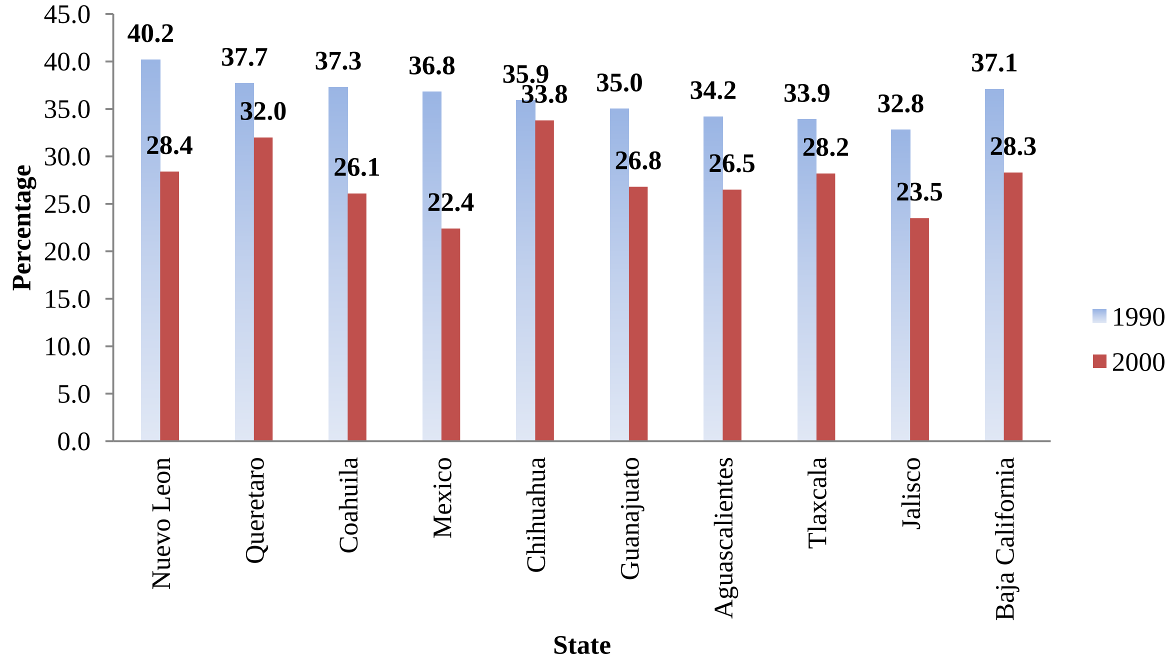
Source: World Bank, World Development Indicators (WDI) and Global Development Finance (GDF), 2012.

Figure I-2. Total economically active population in Mexico engaged in agriculture in thousands, 1991-2010



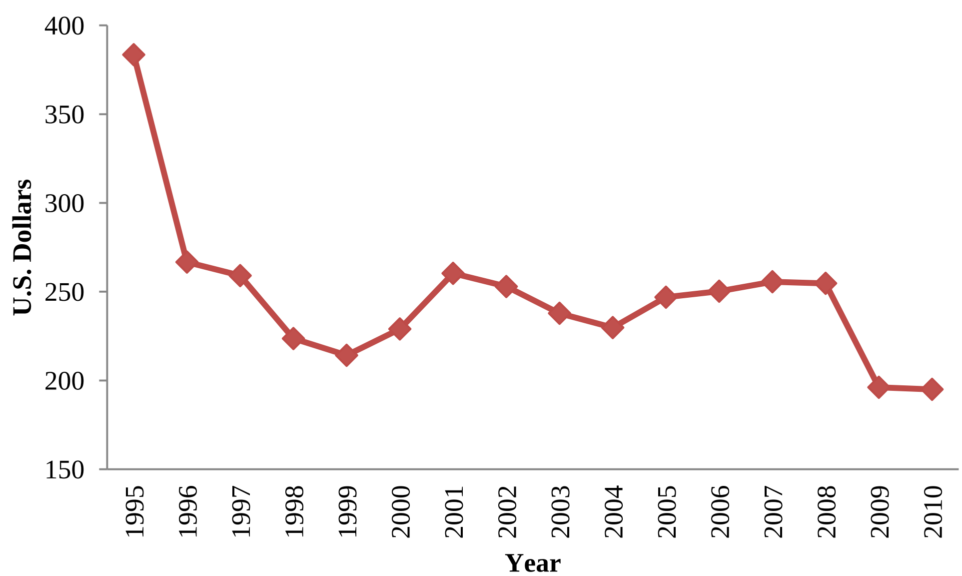
Source: FAOSTAT, Population data, 2012.

Figure I-3. States in Mexico with the highest maquiladora employment in percentage, 1990 and 2000



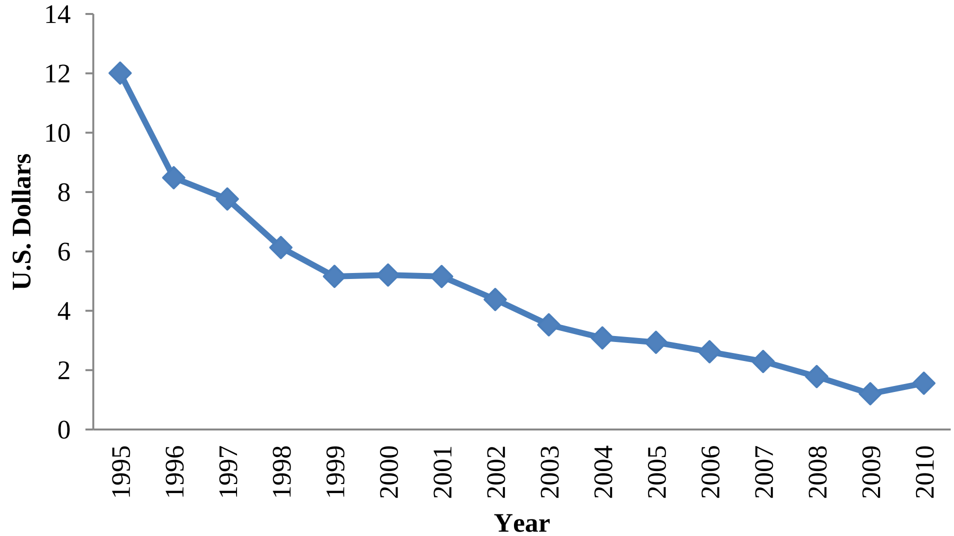
Source: Authors' estimations with data from INEGI, 2012.

Figure I-4. Real agricultural wages in Mexico in U.S. dollars, 1995-2010



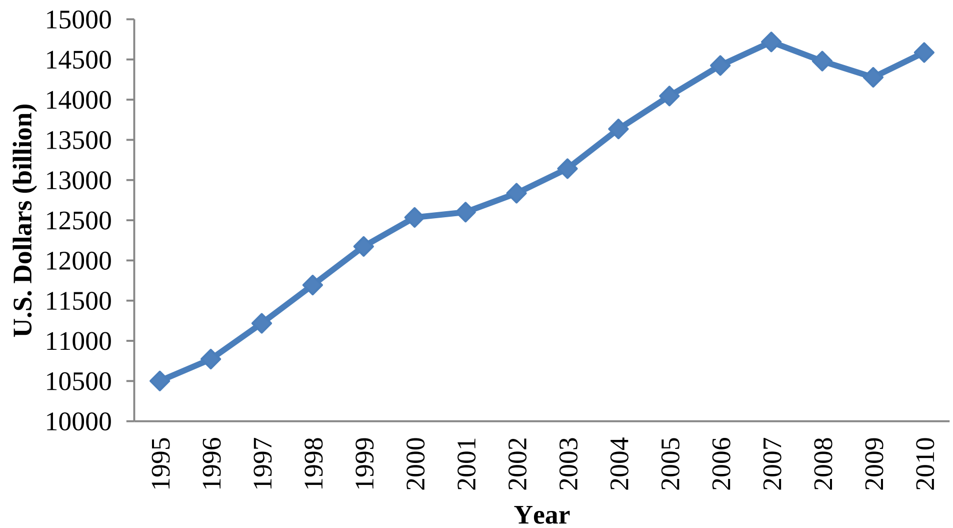
Source: World databank data for U.S. from World Bank, 2011.

Figure I-5. Real relative manufacturing wages between Mexico and China in U.S. dollars, 1995-2010



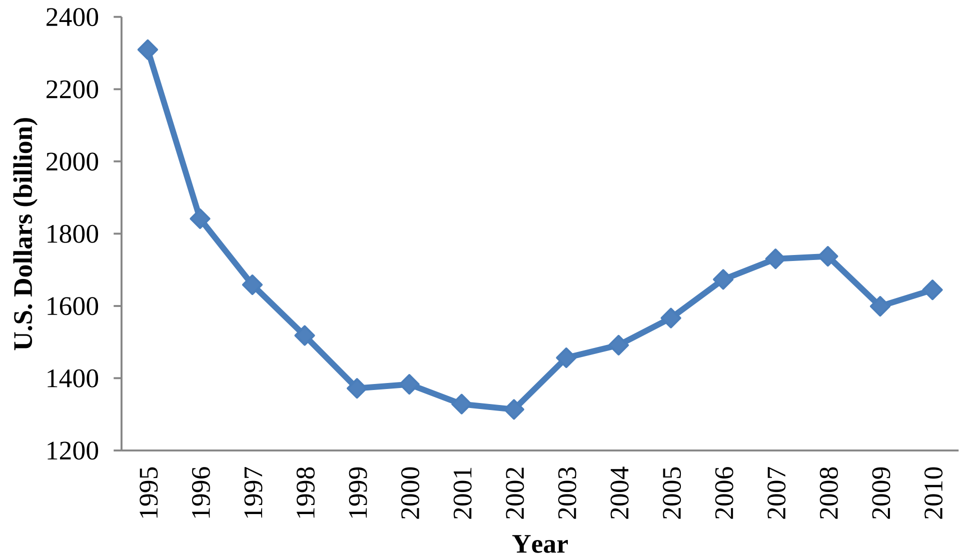
Source: Authors' estimations using World databank data for Mexico and China from World Bank, 2011 .

Figure I-6. Real gross domestic product in U.S. in billion U.S. dollars, 1995 – 2010



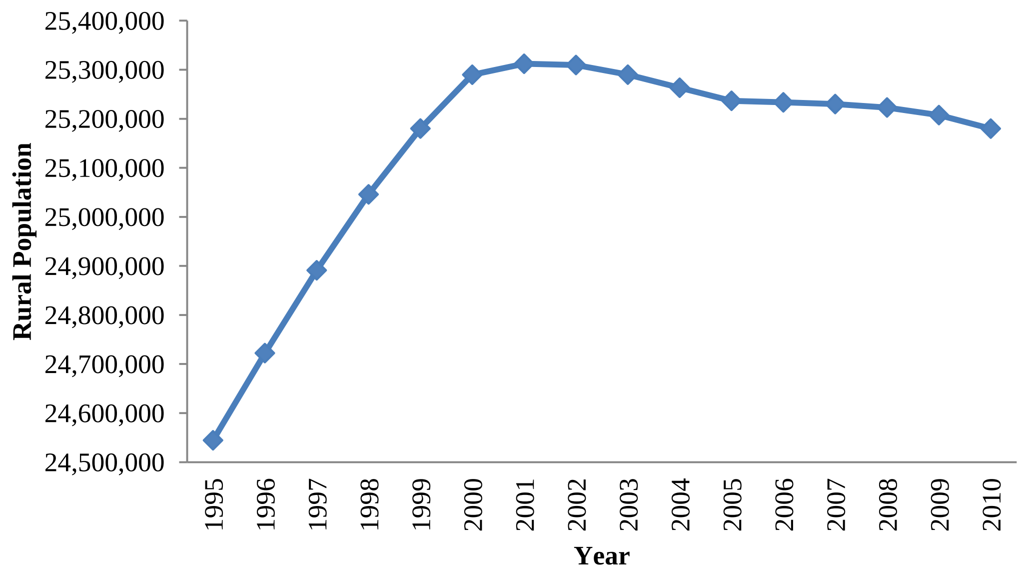
Source: Authors' estimations using World databank data for Mexico from World Bank, 2011.

Figure I-7. Real gross domestic product in Mexico in billion U.S. dollars, 1995 – 2010



Source: Authors' estimations using World databank data for Mexico from World Bank, 2011.

.**Figure I-8**. Rural Population in Mexico, 1995-2010



Source: World databank data for Mexico from World Bank, 2011.

CHAPTER II

Study II: AGRICULTURAL PRODUCTION EFFICIENCY ANALYSIS IN MEXICO USING DATA ENVELOPMENT ANALYSIS

Abstract

Mexico has experienced several changes in the agricultural sector over the past 30 years, from changes in production practices to changes in agricultural policies. All of these structural changes have affected the efficiency of the agricultural sector in Mexico. This paper presents a production efficiency analysis of the agricultural sector for the 32 States in Mexico. Data Envelopment Analysis (DEA) was applied to data for 2007 to measure the impact of agricultural labor, mechanical power, the amount of fertilizer applied and the harvested area of agricultural crops on meat and grain production in Mexico. Using both input and output-oriented analysis results show that there are only five States in Mexico that have an efficient agricultural production, these States are: Guerrero, Sinaloa, Sonora, Tabasco and Yucatán. The rest twenty seven States of Mexico present several degrees of agricultural production inefficiency. Based on the results of this study, the States of Distrito Federal, Nayarit and Zacatecas were determined to be the States with higher inefficiency levels. Having 27 out of 32 States with inefficient agricultural production, it was concluded that the agricultural production in Mexico is inefficient.

Introduction

Mexican agriculture performance can be illustrated starting from the legacy of Spanish colonialism which left the country with high levels of wealth inequality which facilitated that huge amounts on land were owned by only one individual. At the time of the Mexican Revolution in 1910 an estimated 830 landowners held 97 percent of the land, around 738,758 square miles. The principles of land reform were incorporated into Article 27 of the Mexican Constitution of 1917, which provided for division of large landholdings into small properties, communally owned by villages, known as ejidos. Ejido land tenure was created in order to guarantee that the rural population in Mexico had access to land where they could live and farm.

Agricultural practices in Mexico range from traditional techniques, such as the slash-and-burn cultivation of indigenous plants, to the use of advanced technology and marketing expertise in large scale, and capital intensive export agriculture (OECD, 2006).

Agricultural producers in Mexico generally have limited land (plots under five hectares), often rent their land, and do not have access to irrigation (INEGI, 2009). In addition, such small farms face obstacles to access markets because of inadequate infrastructure, limited communication, and inefficient transportation resulting in high transaction costs. Generally these households survive by, in addition to farming, having nonfarm jobs in nearby rural and urban sectors and also by receiving remittances from family members employed in the bigger cities of Mexico or in the U.S. In contrast, commercial farmers in Mexico do business in the same way as farmers in developed countries. Because they are resource wealthy, they produce for a profit. Commercial farmers in Mexico react to price changes in their supply of agricultural goods and are in a better position to benefit from government supports (Yunez-Naude, 2006a).

The survival of agricultural businesses depends on the optimal use of resources which guarantees a profit. Monetary gain is the primary incentive to keep farmers in operation. In order to secure monetary gains farmers must aim to minimize costs and maximize profit. It is common that in order to achieve these monetary objectives farmers use their resources inefficiently. If production inputs are used inefficiently, production costs increase resulting in a profit reduction. By using efficient amounts of inputs farmers will reduce production costs, increase the quantity of outputs produced and therefore increase their profits. Here relies the importance of measuring the efficiency of agricultural production and to calculate the efficient amounts of resources to be used in the production process.

Commonly used efficiency measures are calculated relative to an efficient technology, which is generally represented by some form of frontier function. The frontier based approach traditionally involves the evaluation of an individual decision making unit (DMU) economic performance relative to the production technology that is used by all DMUs (Hoang, 2011). Data envelopment analysis is one of the main frontier based methods. This method is very useful in complex situations like measuring agricultural production efficiency, where there are multiple outputs and multiple inputs which cannot be easily analyzed with other techniques, and where the number of DMUs being evaluated is so large that the management does not have the time or the resources needed to evaluate each unit in depth (Sherman, 2006).

The main purpose of this paper is to analyze the agricultural production efficiency of the 32 States in Mexico using data envelopment analysis to estimate input and output-oriented measures of technical efficiency. Results of this study will contribute to the understanding of the Mexican agriculture performance as a country by computing and analyzing the efficiency scores of each State relative to the others. This analysis will also provide a deeper understanding of the challenges that each State present in the agricultural sector and a guideline for policies designed to increase agricultural production efficiency in Mexico.

An Overview of the Agricultural Sector in Mexico

Mexico's agricultural sector is characterized by a wide range of farm types from highly technified farms to subsistence farms. There are several critical issues faced by farmers and ranchers in Mexico, some of them related to the land tenure, size of the farms, lack of financing, low production efficiency, rural poverty, production deficit in key agricultural commodities like corn, climate conditions, among others (OECD, 2006).

After the Mexican Revolution in 1910, the majority of the arable land was expropriated for the establishment of ejidos. Ejidal land is land mainly destined to agricultural production that is given to farmers in the form of lifetime land grants, which cannot be sold or transferred. The proportion of ejidal owned land relative to all total area of land destined to agricultural production in Mexico went from 7.5 percent in 1930 to 26.3 percent in 1960 and to 47 percent in 1970. Beginning in the late 1970s, the government attempted to group together ejidal landholdings into larger collectives in order to increase production. By 1986, 61.1 percent of farming land in Mexico was ejidal and it only yielded about 33 percent of total agricultural output. Agricultural production in ejido land is mainly focused on corn and beans, with 88 percent of ejido landowners producing one or both of these crops (PA, 1999).

Mexico has gone through significant agricultural policy reforms starting in the late 1970s, majority of these reforms have been focused on all aspects of food production, from eliminating State enterprises related to agriculture, staple price supports, and subsidies to trade liberalization and changes in land tenure laws. Since the mid-1990s, the Mexican government stopped single commodity support, while continuing to encourage market liberalization (Yunez-Naude, 2006). Government extension programs have encouraged the wider use of machinery, fertilizers, and soil conservation techniques.

Corn is the major staple in Mexico and its production comes from deeply rooted cultural and economic origins. The cultivation of corn is heterogeneous: traditional or subsistence production (located in the southern, southeastern, and central parts of Mexico), and commercial production (mainly in the western and northern parts of the country). Although corn is grown on almost half of Mexico's cropland, the country became a net importer of grain during the 1970s. Since the early 1980s corn production has been inefficient in Mexico for both commercial and subsistence farmers. Farmers that face natural disasters, that produce corn for subsistence using diverse seed varieties of the grain in small plots, are more inefficient than other farmers. On the other hand farmers located in communities with marketing facilities benefit from infrastructural investments and produce corn in a less inefficient manner. (Yunez-Naude, 2006b).

Agricultural production in Mexico is a high risk activity due to its low expected probability of return. As a result, private financial capital does not usually flow to agriculture, except for large and modern farms. In fact, large commercial farmers of basic crops have received more benefits from the new agricultural policies (Yunez-Naude, 2006a).

This has proven especially true for corn production in the State of Sinaloa, sorghum production in the State of Tamaulipas, and wheat production in the State of Sonora (De Ita, 2003).

In Mexico, about 28 million people live in rural areas and depend largely on agriculture for their incomes. The potential amount of agricultural workers in Mexico consists of almost 6 million people, the majority of them from the southern States which have relatively high levels of poverty and a larger indigenous population (STPS, 2008)

Efficiency

Efficiency Measurements

Over the past 40 years frontier functions have been estimated using many different methods. The two principal methods are: data envelopment analysis and stochastic frontiers, which use mathematical programming and econometric methods respectively. Modern efficiency measurements begin with Farrell (1957) who defined a simple measure of firm efficiency which could account for multiple inputs. This measure assumes that the efficiency of a firm has two main components: technical efficiency (TE), which reflects the ability of a firm to obtain maximal output from a given set of inputs, and allocative efficiency (AE), which shows the ability of a firm to use the inputs in optimal proportions, given their respective prices. By combining these two measures a total economic efficiency measure is obtained (Coelli, 1996). Later studies assume that for a representative firm operating at an inefficient point in the production set a measure of inefficiency is obtained by measuring the Euclidian distance from that point to the frontier. (Tulkens and Eeckaut 1995; Monchuk 2010) Euclidian distance can be defined as the straight line distance between two points (Black, 2004).

Following Farrell´s original efficiency measurement, two possible orientations for the measure are identified: input-oriented measures and output-oriented measures. The input-oriented technical efficiency measure determines how much input quantities can be proportionally reduced without changing the output quantities produced. On the other hand, the output-oriented technical efficiency measure determines how much output quantities can be proportionally expanded without altering the input quantities used.

Input-Oriented Efficiency Measures

Assume that a firm uses two inputs (x_1 and x_2) to produce a single output (y). The assumption of constant returns to scale allows representing the technology using a unit isoquant. The use of a unit isoquant assumes a fully efficient firm which is not known in practice and therefore must be estimated from observations on a sample of firms in the industry concerned. Graphically, the fully efficient firm is represented by SS´ in Figure II-1 which allows the measurement of technical efficiency. If a given firm uses quantities of inputs, defined by the point P, to produce a unit of output, the technical inefficiency of that firm could be represented by the distance QP, which is the amount by which all inputs could be proportionally reduced without a reduction in the quantity of output produced. This can be expressed in percentage terms by computing the ratio (QP/0P), which represents the percentage by which all inputs could be reduced. The technical efficiency is measured by the following ratio:

$$TE = 0Q/0P \tag{2.1}$$

From Figure III-1 it can be see that equation 2.1 is equal to:

$$TE = 1 - \left(\frac{QP}{0P}\right) \tag{2.2}$$

The numerical value resulting from both equations will be between zero and one, providing an indicator of the degree of technical inefficiency of the firm. A value of one indicates a fully technically efficient firm. The point Q on Figure II-1 is technically efficient because it lies on the efficient isoquant (Coelli, 1996).

Allocative efficiency also known as price ratio is represented by the line AA´ on Figure II-1. The allocative efficiency of the firm at P is defined by the ratio:

$$AE_1 = 0R/0Q \tag{2.3}$$

Since the distance RQ represents the reduction in production costs that could take place if production occurred at the allocatively and technically efficient point Q´, instead of occurring at the technically efficient but allocatively inefficient point Q. The total economic efficiency is defined by the ratio:

$$EE_1 = 0R/0P \tag{2.4}$$

where the distance RP can be interpreted in terms of a cost reduction. Note that equation 2.4 is equal to the product of technical and allocative efficiency.

Output-Oriented Efficiency Measures

Consider the case where production involves two outputs (y_1 and y_2) and a single input (x_1). Assuming constant returns to scale as in the input-oriented measure, the technology can be represented by a unit production possibility curve in two dimensions. Line ZZ´ in Figure II-2 is the unit production possibility curve representing the upper bound of production possibilities. Point A corresponds to an inefficient firm, because it lies below the curve. The distance AB represents technical inefficiency, that is, the amount by which outputs could be increased without requiring extra inputs. The measure of output-oriented technical efficiency is the ratio:

$$TE_o = 0A/0B \tag{2.5}$$

If there is price information available the isocurve line DD´ can be drawn, and from this the allocative efficiency will be:

$$AE_o = 0B/0C \tag{2.6}$$

The overall economic efficiency is obtained by the product of technical and allocative efficiency:

$$EE_0 = \frac{0A}{0C} = TE_0 \times AE_0 \tag{2.7}$$

Similarly to the input-oriented measure, all efficiency calculated values of the output-oriented measure will lie between zero and one (Coelli, 1996).

It is important to point out that all the efficiency measures described above are measured along a ray from the origin to the observed production point. Therefore, these measures hold the relative proportions of inputs (or outputs) constant. One advantage of these radial efficiency measures is that they are unit invariant. This means that changing the units of measurement (e.g. measuring quantity of labor in person hours instead of person years) will not change the value of the efficiency measure. A non-radial measure, such as the shortest distance from the production point to the production surface, may be argued for, but this measure will not be invariant to the units of measurement chosen (Coelli, 1996).

Data Envelopment Analysis

Data Envelopment Analysis is an axiomatic, nonparametric mathematical programming approach used to analyze the productivity and efficiency of different decision making units part of a firm. As previously discussed, efficiency can be defined as the ratio of output to input. More output per unit of input reflects higher relative efficiency.

Economic or technical efficiency refers to the producer's ability to reach her/his production possibility frontier, characterized by the minimum inputs necessary to obtain a given product.

Those who do not reach the frontier are said to be "technologically inefficient", and vice-versa (Yunez-Naude, 2006b). Charnes (1978) developed an input oriented model which assumed constant returns to scale (CRS). This quantitative technique is used to establish a best practice group of units also known as efficiency reference set and to determine which units are inefficient compared to the best practice units and the magnitude of inefficiencies present. Later Banker (1984) proposed the variable returns to scale (VRS) model.

Data envelopment analysis can be either input-oriented or output-oriented. In the input oriented case, the DEA method defines the frontier by seeking the maximum possible proportional reduction in input usage (optimize input use), with output level held constant for each DMU. Input oriented DEA is more appropriate in situations where resources (inputs) used can be controlled without difficulty, but where the output level or output demand is not easily manageable. While the output-oriented case, DEA method seeks the maximum proportional increase in output production, with input held fixed. The results obtained from the output-oriented DEA focus on increasing outputs instead of reducing inputs. The two measures provide the same efficiency index when constant returns to scale is assumed, but are unequal when variable returns to scale is assumed (Fandel, 1998).

The main advantage of DEA compared to econometric regression-based tools is its nonparametric treatment of the frontier function; this means that it incorporates outputs that have no clear price or market value, like training. Data envelopment analysis relies on general axioms of production theory like monotonicity, convexity and homogeneity (Kousmanen, 2010). It also allows multiple inputs and outputs to be considered at the same time without any assumption on data distribution. Data envelopment analysis also identifies what specific changes (type and amount) in inputs and outputs are needed to make inefficient units efficient. Data envelopment analysis is highly objective and focuses primarily on technical and scale efficiency. Results are obtained through the use of linear programming and indicate which units should be able to improve productivity and the amount of resource savings and/or output increases that these inefficient units must achieve to meet the level of efficiency of the best practice units.

The Models

Data Envelopment Analysis Model

The general data envelopment analysis mathematical model of a random decision making unit is shown in equation 2.8. This equation represents the objective function and the set of equations 2.8.1 are the restrictions imposed on the objective function. These equations can be read as “Maximizing the efficiency score θ for the decision making unit 0 subject to the constraint that when the same set of u and v coefficients is applied to all other decision making units being compared with, no DMU will be more than 100 percent efficient” (Sherman, 2006).

$$Maximize\ \theta = \frac{u_1 y_{10} + \ldots + u_r y_{r0}}{v_1 x_{10} + \cdots + v_m x_{m0}} = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_m x_{m0}} \tag{2.8}$$

subject to

DMU$_1$ $$\frac{u_1 y_{11}+\ldots+u_r y_{r1}}{v_1 x_{11}+\cdots+v_m x_{m1}} = \frac{\sum_{r=1}^{s} u_r y_{r1}}{\sum_{i=1}^{m} v_m x_{m1}} \leq 1 \qquad (2.8.1)$$

…

DMUj $$\frac{u_1 y_{1j}+\ldots+u_r y_{rj}}{v_1 x_{1j}+\cdots+v_m x_{mj}} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_m x_{mj}} \leq 1$$

$$u_1, \ldots, u_s \geq 0 \quad \text{and} \quad v_1, \ldots, v_m \geq 0$$

where u_r are the coefficients assigned by DEA to output r, v_i are the coefficients assigned by DEA to input i, r are the number of outputs generated by the DMUs, i are the number of inputs used by the DMUs, DMUj is the decision making unit defined as j, x_{ij} represents the amount of input i used by DMU j, y_{rj} is the amount of output r used by DMU j, j is the total number of DMUs ($j = 1, \ldots n$). The detailed mathematical forms of the estimated input and output oriented models used by the DEAFrontier™ software and described by Sherman (2006) are illustrated next.

Input –Oriented DEA Model

To compute the efficiency scores for each DMU using input –oriented data envelopment analysis assuming constant returns to scale, the objective function 2.9 is solved for each unit.

$$Max \sum_{r=1}^{s} u_r y_{rj} \qquad (2.9)$$

subject to

$$\sum_{r=1}^{s} u_r y_{ro} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \;\; j = 1, \ldots, n$$

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

$$u_r, v_i \geq 0$$

where u_r are the coefficients assigned by the DEA to output r, v_i are the coefficients assigned by the DEA to input i, r are the number of outputs generated by the DMUs, i are the number of inputs used by the DMUs (four inputs where used in this study), x_{ij} represents the amount of input i used by DMU j, y_{rj} is the amount of output r used by DMU j, j is the total number of DMUs ($j = 1, \ldots n$) where $n = 32$.

To compute the efficiency scores (θ) the dual linear program for model 2.9 is needed. This dual linear program is shown in equation 2.10.

$$\min \theta \qquad (2.10)$$

subject to:

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{i0} \qquad i = 1, \ldots, m; \qquad (2.10.1)$$

$$\sum_{j=1}^{n} \lambda_j y_{ri} \geq y_{r0} \qquad r = 1, \ldots, s; \qquad (2.10.2)$$

$$\lambda_j \geq 0 \qquad j = 1, \ldots, n. \qquad (2.10.3)$$

where θ is the efficiency score of the DMU being evaluated, λ_j is the weight applied to the sum of inputs for DMU j in equation 2.10.1 and the weight applied to the sum of outputs for DMU j in equation 2.10.2, x_{ij} represents the amount of input i used by DMU j, y_{rj} is the amount of output r used by DMU j, j is the total number of DMUs ($j = 1, \ldots n$) where $n = 32$.

In order to make individual DMU recommendations it is important to know the amount of individual reductions in inputs and outputs that each decision making unit should make in order to become efficient. Following the methodology developed by Sherman (2006), these reductions are called “DEA slacks”. The computation of “DEA slacks” is done by solving models 2.9 and 2.10 using linear programming followed by solving equation 2.11 for each DMU.

$$\max \sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+ \tag{2.11}$$

subject to

$$\sum_{j=1}^{n} x_{ij}\,\lambda_j + S_i^- = \theta^* x_{i0} \qquad i = 1, \dots, m;$$

$$\sum_{j=1}^{n} y_{rj}\,\lambda_j - S_r^+ = y_{r0} \qquad r = 1, \dots, s;$$

$$\lambda_j \geq 0 \qquad j = 1, \dots, n.$$

where θ^* is the efficiency score obtained by solving equation 2.10, S_i^- is the input slack, S_r^+ is the output slack, λ_j is the weight applied to the sum of inputs for DMU j in equation 2.10.1 and the weight applied to the sum of outputs for DMU j in equation 2.10.2, x_{ij} represents the amount of input i used by DMU j, y_{rj} is the amount of output r used by DMU j, j is the total number of DMUs ($j = 1, \dots n$) where $n = 32$.

A complete DEA calculation for model 2.9 involves two stages: first, calculate the efficiency score for each DMU (θ^*), followed by the computation of the slacks while keeping θ^* fixed. The DEAFrontier™ software solves both stages separately.

Output-Oriented DEA Model

To compute the efficiency scores for each DMU using output –oriented data envelopment analysis assuming constant returns to scale, model 2.12 is solved for each unit.

$$\max \phi + \varepsilon \left(\sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+ \right) \tag{2.12}$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} + S_i^- = x_{i0} \qquad i = 1, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - S_r^+ = \phi y_{r0} \qquad r = 1, \dots, s;$$

$$\lambda_j \geq 0 \qquad j = 1, \dots, n.$$

where ε is a non-Archimedean defined to be less than any real positive number, ϕ represents the output oriented efficiency score, S_i^- is the input slack, S_r^+ is the output slack, λ_j is the weight applied to the sum of inputs for DMU j in equation 2.10.1 and the weight applied to the sum of outputs for DMU j in equation 2.10.2, x_{ij} represents the amount of input i used by DMU j, y_{rj} is the amount of output r used by DMU j, j is the total number of DMUs ($j = 1, \dots n$) where $n = 32$.

The dual linear program shown in equation 2.13 is the multiplier version of the output-oriented DEA model shown in equation 2.12.

$$\min \sum_{i=1}^{m} v_i x_{i0} \tag{2.13}$$

subject to

$$\sum_{i=1}^{m} v_i x_{ij} - \sum_{r=1}^{s} u_r y_{rj} \geq 0 \qquad j = 1, \dots, n$$

$$\sum_{r=1}^{s} u_r y_{r0} = 1$$

$$u_r, v_i \geq \varepsilon \geq 0$$

where u_r are the coefficients assigned by the DEA to output r, v_i are the coefficients assigned by the DEA to input i, r are the number of outputs generated by the DMUs, i are the number of inputs used by the DMUs, x_{ij} represents the amount of input i used by DMU j, y_{rj} is the amount of output r used by DMU j, j is the total number of DMUs ($j = 1, \dots n$) where $n = 32$ and ε is a non-Archimedean defined to be less than any real positive number.

A complete DEA calculation for the output oriented model 2.12 involved two stages: first, calculate the efficiency score for each DMU (ϕ^*), followed by the optimization of the slacks while keeping ϕ^* fixed in model 2.14.

$$\max \sum_{i=1}^{m} S_i^- + \sum_{r=1}^{s} S_r^+ \tag{2.14}$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} + S_i^- = x_{i0} \qquad i = 1, \dots, m;$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - S_r^+ = \phi^* y_{r0} \qquad r = 1, \dots, s;$$

$$\lambda_j \geq 0 \qquad j = 1, \dots, n.$$

Estimation Methods

Data envelopment analysis can be performed using a wide range of commercial and non-commercial software tools. This is evidenced by availability of interoperable tools with a variety of user interfaces, advanced modeling options, and the power to evaluate large-scale data sets on inexpensive computing platforms (Barr, 2004). The use of Excel for this analysis is useful because it does not involve elaborate codes or programs and emphasizes that DEA is not a high complex process which can be understood using basic algebra (Sherman, 2006).

To compute the agricultural production efficiency scores and the input and output-oriented measures for the 32 States in Mexico, the DEAFrontier™ software (Joe Zhu, 2006) is used. DEAFrontier™ is an add-in for Microsoft® Excel Solver which uses a linear programming technique to find the set of coefficients that will give the highest possible efficiency ratio of outputs and inputs for the decision making units evaluated, in this case each State in Mexico.

All DMUs were analyzed using both input-oriented and output-oriented models and assuming constant returns to scale. As previously discussed equal results are expected from both input and output-oriented models because constant returns to scale are assumed. The output-oriented model will identify the exact same units as inefficient as the input-oriented model, by doing the results of each analysis will be confirmed by the other. Differences between each model results will be explained in later sections.

The DEAFrontier™ software will: 1) identify high cost DMUs, 2) identify specific changes that each DMU must do in order to elevate their performance to the best practice level providing high quality output at low cost, and 3) guide the improvement process (Sherman, 2006). The software performs a two-stage DEA calculation for both input and output-oriented models where first the efficiency scores are computed followed by the optimization of the DEA slacks described previously.

Data

Charnes (1984), Boussofiane (1991), Raab (2002) and Ablanedo-Rosas (2010) all agree that the data has to meet the convention that the number of DMUs has to be greater than the product of the number of inputs and outputs and that the number of DMU observations should be greater than three times the number of inputs plus outputs. Note that for this study the number of DMUs and the number of DMU observations are the same. For this analysis, the above conventions are met with 32 DMUs analyzed, 4 inputs and 2 outputs.

The output variables used are grain production and meat production measured in tons. The input variables are agricultural labor in thousands; mechanical power measured by the number of tractors used, fertilizer in tons and harvested area of agricultural crops in hectares. All data was obtained for each State in Mexico for the year 2007.

Data for grain production, meat production and harvested area of agricultural crops was retrieved from the database SIACON developed by the Mexican Agroalimentary and Fishery Information Service, known by its Spanish acronym SIAP. Data for mechanical power and fertilizer consumption were obtained from the Agricultural Census 2007 available at the Mexican Government Statistical Agency known by the spanish acronym INEGI. Information regarding agricultural labor was taken from the 2007 Employment Survey made by the Mexican Secretariat of Labor and Social Welfare.

Results and Discussion

It is very important to recognize that the results of this study only show absolute advantage. This is due to the heterogeneity of the variables that affect the chosen inputs and outputs across the Mexican States, for example, amount of precipitation accumulated, soil types, average temperature, amongst others. Weather conditions have enormous variations across Mexico. Southern States like Chiapas have a precipitation accumulation of 1060 mm (41.7 in) per year whereas States like Zacatecas accumulate an average of 290 mm (11.4 in) per year. In order to get results that show comparative advantage across States adjustments must be made in order to account for resource quality. Taking into consideration the above, results will be discussed next.

By definition, the performance of a decision making unit using input oriented DEA is considered to be fully DEA efficient if and only if both (i) $\theta^* = 1$ and (ii) $S_i^- = S_r^+ = 0$. This is when the efficiency score (θ^*) is equal to one and both input and output slacks are equal to zero. On the other hand, the performance of a decision making unit is considered to be weakly DEA efficient if and only if both (i) $\theta^* = 1$ and (ii) $S_i^- \neq 0$ and/or $S_r^+ \neq 0$ for some i (inputs) and r (outputs). This is when the efficiency score (θ^*) is equal to one and at least one input or one output slack are different to zero. Similarly when the output oriented DEA is used, the performance of a decision making unit is considered to be fully efficient if and only if $\phi^* = 1$ and $S_i^- = S_r^+ = 0$. The performance of a decision making unit is weakly efficient if and only if the efficiency score ($\phi^* = 1$) and $S_i^- \neq 0$ and/or $S_r^+ \neq 0$ for some i (inputs) and r (outputs). If $\phi^* > 1$ then the DMU is considered inefficient (Sherman, 2006).

Next, efficiency scores, input slacks, output slacks, and target values are presented and discussed for both input and output oriented measures. These parameters give a unique insight on the current performance of each state in Mexico and on the changes the inefficient states have to make in order to be efficient compared to their Efficiency Reference Set (ERS).

Input-Oriented Model Results

Based on the efficiency scores from Table II-1 it can be concluded that the States that are considered efficient under the input-oriented DEA are: Guerrero, Sinaloa, Sonora, Tabasco and Yucatán. This is because they all obtained an efficiency score of 1.00. Using the definitions of fully and weakly DEA efficient explained above and the results from Tables II-1 and II-2 it can be concluded that only the States of Guerrero, Sonora and Yucatán are fully DEA efficient, because they are the only States who have both an efficiency score of 1.00 and all their input and output slack values equal to zero. The States of Sinaloa and Tabasco are considered weakly efficient because even though they have an efficiency score of 1.00, not all their input and output slack values are equal to zero. All the remaining 27 States are considered inefficient based on the input-oriented DEA and will be the States for which the Mexican government will have to focus on in order to improve the productivity of the agricultural sector of the country.

The efficiency scores from Table II-1 do not really provide a basis for pure rank ordering of the most to the least inefficient unit. Technically it can be concluded that the States with the same efficiency reference set can be ranked by the efficiency rating. The ERS includes the group of States against which each inefficient State was found to be most directly inefficient (Sherman, 2006). Each of the five States determined to be efficient based on the efficiency scores are considered the efficiency reference sets. The remaining twenty seven States were compared and classified in one of the five ERS. Table II-3 portrays the efficiency rankings for the 27 inefficient States based on the ERS they were ranked in. The efficiency reference set that has more States is Sonora with twelve, followed by Guerrero with eleven and Sinaloa with four. The ERS of Tabasco and Yucatán do not have any additional States on their set, meaning that none of the inefficient States were found directly inefficient compared to them.

The efficiency rankings go from more efficient to less efficient compared to the reference State which will always have the first ranking. For example, Nuevo León's efficiency rating of 0.63 means that it is less efficient that Baja California with an efficiency rating of 0.98. Similar analyses can be conducted for each of the inefficient States belonging to the same ERS. This comparison is possible because both States have the same ERS (Sonora). It is not possible to compare efficiency ratings of units from different ERS, like Zacatecas and Oaxaca.

Based on the ERS classifications, the more inefficient States are: Distrito Federal (the country's capital) with 80 percent inefficiency relative to Sonora; Nayarit with 76 percent inefficiency compared to Guerrero and Zacatecas with 82 percent inefficiency relative to Sinaloa. For the Mexican government the more inefficient States represent a more immediate concern than for example Baja California with only 2 percent inefficiency relative to Sonora.

The input and output slack values presented in Table II-2 are used along with the efficiency scores (See Table II-3) to compute the target values shown in Table II-4. For example, for the State of Baja California the target value for the harvested area of agricultural crops (Input 1) is 182,045 hectares. This value was obtained by solving equation 2.15:

$$Target\ Value = (actual\ input * efficiency\ score) - slack \qquad (2.15)$$

$$Target\ Value = (185{,}477.9 * 0.98149) - 0.00$$

$$Target\ Value = 182{,}045$$

The above calculation logic applies to all input and output target values for both input and output-oriented models. The difference between the target and the actual value are the potential resource savings if the State operates as efficiently as the best practice ERS State, this are the slack values.

The target input levels for each State in Mexico using input-oriented DEA are presented in Table II-4. As previously discussed, the difference between the target values and the actual values of the inputs is the potential resource reductions and cost savings for each input if the DMU operates as the best practice efficiency reference set units. All of the input reductions together would increase that unit's productivity to the best practice level (Sherman, 2006). For the efficient States the target values are the same as the actual values of inputs and outputs because no change is needed to make these units efficient. Results for input-oriented target values will be further explained on the next section.

Output-Oriented Model Results

The output-oriented model identified the exact same efficient and inefficient States as the input-oriented analysis. From Table II-5 it can be observed that the States that have an efficiency score of 1.00 and therefore considered efficient under the output-oriented DEA are: Guerrero, Sinaloa, Sonora, Tabasco and Yucatán. From Tables II-5 and II-6 it can be concluded that only the States of Guerrero, Sonora and Yucatán are fully DEA efficient, because they have both an efficiency score of 1.00 and all the input and output slack values are equal to zero. The States of Sinaloa and Tabasco are considered weakly efficient because even though they have an efficiency score of 1.00, not all their input and output slack values are equal to zero. All the remaining 27 States are considered inefficient based on the output-oriented DEA.

Even though the output-oriented model identified the same efficient and inefficient States as in the input-oriented model, output-oriented analysis focuses on increasing the output and therefore generates a different set of slack (λ) values. These values are presented in Table II-5. The difference between the λ sets from the input and output-oriented models can be illustrated with the State of Zacatecas, which had the lowest efficiency score using the input-oriented model with a score of 0.18 or 18 percent (See Table II-1), The efficiency score for Zacatecas using the output-oriented model (See Table II-5) is 5.53 which is more than 1.00 suggesting that it is an inefficient State. The input-oriented efficiency score of 0.18085 is equal to dividing 1 over the output-oriented score of 5.52932. All the inefficient States are classified in the exact same efficiency reference sets and have the same efficiency rankings as in the input-oriented analysis (See Table II-7). For Zacatecas the ERS is again Sinaloa.

The key difference between input and output-oriented results are the target values and the excess resources or additional output quantities that each model suggests would make each inefficient State as efficient as its ERS. For the five efficient States the amounts of all inputs used and the quantities of outputs produced are efficient relative to the other States, meaning they will not change. The target values for the input and output-oriented models are reported in Tables II-4 and II-8 respectively. These values represent what the output and input levels could be if the unit was performing as well as its ERS. Using the results for the State of Zacatecas (See Table II-9) the difference between target values from both models will be illustrated next.

The input-oriented model results suggest that the State of Zacatecas has the potential to reduce all four inputs in order to become as efficient as the best practice ERS State (Sinaloa). The suggested reductions by input are 947,501 hectares for Input 1, 468,488 workers for Input 2, 22,232 units for Input 3 and, 45,190 tons for Input 4. The input-oriented model suggests that no change in the outputs would be possible. This means that the same quantities of grains and meat could have been produced if the proposed input quantities were used efficiently. The reduction in the inputs used will translate in a reduction of the production costs and therefore an increase in revenues. The output change will not always be zero for every State, and will often suggest that the unit can achieve the suggested savings by reducing production costs and also increase the output quantities produced (Sherman, 2006).

In contrast, the output-oriented model suggests that the State of Zacatecas has the potential to increase its grain production (Output 1) by 2,250,493 tons and its meat production (Output 2) by 744,120 tons. Results for the inputs show no reduction in the number of people employed in the agricultural sector (Input 2) but suggest a reduction of the three remaining inputs by 310,393.47 hectares, 12,197 units and, 14,804.16 tons for Inputs 1, 3 and 4 respectively. An increase in quantities of outputs produced and a decrease in the use of inputs can be achieved if the suggested quantities of all inputs are used efficiently. In general if all inputs are used efficiently, the quantities used will be less and the outputs produced will increase or at least remain the same. Similar analysis can be made for the remaining 26 inefficient States.

The output-oriented model will always focus on increasing outputs, but results of this model can also suggest input reductions as well. For the State of Zacatecas an increase in both meat and grain production and a decrease in 3 of the inputs were recommended at the same time. These results imply that the agricultural production in the State operated inefficiently in 2007. This inefficiency comes from Zacatecas farmers using larger quantities of the chosen inputs than needed in order to produce grain and meat. Therefore, based on the output-oriented model results by using efficiently all four inputs the more meat and grain would have been produced and less land, less fertilizer and less mechanical power would have been used by the State of Zacatecas in 2007.

Note that for each inefficient State input and output-oriented models will suggest different input and output changes. In many cases quantities were suggested to be maintained equal for particular inputs or outputs. Also note that the inefficient States that are ranked on the top positions (closer to the ERS) were suggested to have smaller changes in order to become efficient relative to their ERS.

Conclusions

While the use of data envelopment analysis is unlikely to allocate all the inefficiencies in the agricultural sector in Mexico at the same time, it is true that the inefficiencies identified using DEA are real. It is essential to keep in mind that results using DEA are sensitive to the chosen mix of inputs and outputs, but results of this study give a clear idea of the agricultural production efficiency for each of the 32 States in Mexico. It is also vital to consider the lack of homogeneity in the resources across the country. This input and output heterogeneity causes the results to show only absolute advantage across States. Taking this into consideration, results of this study are representative of Mexican agriculture because of the chosen inputs and outputs, which include all areas of the production process: quantities of grain and meat produced, labor, land, fertilizer, and mechanical power.

When using input and output-oriented DEA only five out of the thirty two States in Mexico were determined to be efficient. These results lead to the main conclusion of this paper being that the agricultural production in Mexico is inefficient.

This study is useful for agricultural government agencies and for the Mexican government because it gives a guideline to which States in Mexico have higher levels of agricultural production inefficiency. Results show that the more inefficient States are Distrito Federal, Nayarit and Zacatecas. On the other hand, States like Baja California and Jalisco show less inefficiency and therefore might not require a lot of government intervention or drastic policies to achieve full efficiency relative to their ERS.

Findings of this study are also useful because they verify if the location and magnitude of the inefficiencies are consistent with prior view of agricultural production in Mexico. For example, results for the State of Zacatecas are consistent with previous conception of the agricultural production for this State which, for several years has been considered inefficient. On the other hand States like Sinaloa or Baja California have been characterized for having high efficient, high profit, and large scale production of commodities like vegetables.

Outcomes of this study are useful for policy makers because it used both input and output-oriented DEA. For policies that seek increasing profits and reducing costs, the input-oriented model results are more valuable. On the other hand, if the policies aim to control the output levels more than the resources needed, results from the output-oriented model results are more useful. If the Mexican government wants to know how much each inefficient State can increase its outputs before requiring additional resources, the output-oriented model will also be preferred. The actual changes in inputs and outputs will be determined by the Federal and State governments based on the assessment of the practicality and viability of these changes.

Future analysis might include the use of the same DEA methodology, same inputs and same outputs but for different years. This analysis will determine how agricultural production efficiency for all States relative to the others and to themselves has changed through time by obtaining the efficiency scores for each State for different years. The scores can be later compared and agricultural production efficiency for each State in Mexico could be tracked.

In order to get results that reflect comparative advantage across States, it is necessary to adjust for resource quality between States. This adjustment can be done by applying restrictions to the model. Some useful restrictions for agricultural production efficiency analysis are the ones offered by Golany (1997). The first one is called "categorization constraints", is consists on using an external constraint to categorize the DMUs into subsets. These subsets are defined by whether the units meet the desirable characteristics to be part of the best practice units for the rest of the DMUs. The second restriction called "dynamic clustering" allows a different categorization of the set of DMUs into the subset of DMUs that have the desired characteristics and another subset of DMUs that do not have the desirable characteristics for each analyzed DMU. Thus, each DMU is creating its own "frontier" of units whose distinction is that of being close to itself. In the case of agricultural production efficiency these characteristics can be different soil types, amount of precipitation received, amongst others.

Results of this analysis for successive time periods will also indicate whether previously inefficient States have become relatively efficient or relatively inefficient through remedial policies. The DEA methodology can also be applied at the county (municipio) level for each State in Mexico. By doing so, it could be determined which individual counties are the major sources of inefficiencies of each State. This analysis will also give a guideline for each State's government on where to target agricultural programs across each State.

It is important to consider that even though it is well known that climate play a huge role in agricultural production efficiency no input accounting for it was included in this analysis. This is because of the lack of homogeneous data involving all 32 States in Mexico for the chosen year. Also, it is imperative to understand that unfavorable climatic conditions are exogenous to policy makers. Usually crop insurance is used to reduce the impact on farmer's income of unfavorable climatic conditions (Yunes-Naunde, 2006).

The following suggested policies all include government intervention which can help the Mexican agricultural sector to become more efficiently. The first policy is the increase of public investments in rural infrastructure like roads, access to transportation, irrigation, and replacement of old machinery. Investments should be directed not only to the States with potential to produce agricultural commodities efficiently but also to the States that show high degrees of inefficiency. Investments targeting agricultural infrastructure will also increase rural development.

Policies aimed to create non-farm jobs are also suggested. This is imperative for the States with higher levels of inefficiency because these States are the ones with higher rural poverty and more rural population. Non-farm, jobs can be dedicated to built or improve rural infrastructure. The creation of rural jobs will not only increase rural development but will also prevent or at the least reduce migration of rural unemployed workers.

It is important for all State governments to create programs that will increase the agricultural education of farmers. This education can range from access to information regarding optimal quantities of fertilizer to apply to diffusion of best practice technologies, all in the aim of promoting an efficient production of agricultural commodities.

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APPENDICES

Table II-1. Efficiency score results for the 32 States in Mexico using the Input-oriented DEA model assuming constant returns to scale, 2007

State	Efficiency Score	Lambda (Σλ)
Aguascalientes	0.53520	0.097
Baja California	0.98149	0.333
Baja California Sur	0.53600	0.032
Campeche	0.50031	0.126
Coahuila de Zaragoza	0.59985	0.316
Colima	0.27388	0.087
Chiapas	0.76506	1.778
Chihuahua	0.37373	0.390
Distrito Federal	0.20353	0.013
Durango	0.28657	0.296
Guanajuato	0.53420	0.637
Guerrero	1.00000	1.000
Hidalgo	0.41851	0.335
Jalisco	0.75494	1.670
México	0.74707	0.687
Michoacán de Ocampo	0.49360	0.619
Morelos	0.23798	0.044
Nayarit	0.23734	0.141
Nuevo León	0.62564	0.227
Oaxaca	0.44553	0.884
Puebla	0.56675	1.118
Querétaro	0.68043	0.174
Quintana Roo	0.38010	0.113
San Luis Potosí	0.25206	0.440
Sinaloa	1.00000	1.000
Sonora	1.00000	1.000
Tabasco	1.00000	1.000
Tamaulipas	0.39371	0.365
Tlaxcala	0.51501	0.155
Veracruz Llave	0.62112	3.308
Yucatán	1.00000	1.000
Zacatecas	0.18085	0.245

Source: Authors' estimations.

Table II-2. Input and output slacks for the 32 States in Mexico using the input-oriented DEA model assuming constant returns to scale, 2007

State	Inputs				Outputs	
	Harvested Area Ag Crops[1]	Ag Labor[2]	Mechanical Power[3]	Fertilizer[4]	Grain Production[5]	Meat Production[6]
Aguascalientes	0.000	17834.701	1255.476	0.000	130301.176	0.000
Baja California	0.000	105007.269	1765.692	0.000	129991.716	0.000
Baja California Sur	0.000	35639.135	442.088	0.000	12436.316	0.000
Campeche	0.000	54418.748	0.000	0.000	0.000	0.000
Coahuila	0.000	0.000	0.000	0.000	433924.397	0.000
Colima	0.000	0.000	0.000	0.000	30890.310	0.000
Chiapas	0.000	40842.802	0.000	0.000	0.000	0.000
Chihuahua	84449.498	0.00000	5820.944	4027.804	0.000	0.000
Distrito Federal	0.000	10410.849	0.000	0.000	2455.941	0.000
Durango	26697.423	0.000	1273.962	1273.328	204651.972	0.000
Guanajuato	0.000	87416.578	4079.280	0.000	0.000	0.000
Guerrero	0.000	0.000	0.000	0.000	0.000	0.000
Hidalgo	0.000	118761.468	0.000	0.000	0.000	0.000
Jalisco	0.000	0.000	0.000	0.000	0.000	0.000
México	0.000	180296.223	0.000	0.000	0.000	0.000
Michoacán	0.000	197836.915	0.000	0.000	0.000	0.000
Morelos	0.000	54722.660	0.000	0.000	0.000	0.000
Nayarit	0.000	1150.153	0.000	0.000	0.000	0.000
Nuevo León	104789.615	0.000	825.963	4997.922	290363.895	0.000
Oaxaca	0.000	0.000	0.000	0.000	0.000	0.000
Puebla	0.000	448491.814	0.000	0.000	0.000	0.000
Querétaro	0.000	66071.452	22.338	0.000	0.000	0.000
Quintana Roo	0.000	0.000	0.000	0.000	12625.277	0.000
San Luis Potosí	0.00000	0.000	0.000	0.000	195343.507	0.000
Sinaloa	**0.00001**	0.000	0.000	0.000	0.000	0.000
Sonora	0.000	0.000	0.000	0.000	0.000	0.000
Tabasco	0.000	**0.00001**	0.000	0.000	0.000	0.000

Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Table II-2. (continued) Input and output slacks for the 32 States in Mexico using the input-oriented DEA model assuming constant returns to scale, 2007

State	Inputs				Outputs	
	Harvested Area Ag Crops[1]	Ag Labor[2]	Mechanical Power[3]	Fertilizer[4]	Grain Production[5]	Meat Production[6]
Tamaulipas	326266.51755	0.000	1735.238	15561.225	24902.697	0.000
Tlaxcala	0.000	24671.244	0.000	0.000	0.000	0.000
Veracruz	0.000	19514.821	0.000	0.000	847.722	0.000
Yucatán	0.000	0.000	0.000	0.000	0.000	0.000
Zacatecas	56135.955	0.000	2205.884	2677.394	0.000	0.000

Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Table II-3. Efficiency rankings based on the ERS for the 27 inefficient States in Mexico using the input-oriented DEA model assuming constant returns to scale, 2007

Efficiency Reference Set	State	Efficiency Score	Efficiency Rating	Percentage of Inefficiency
Sonora	Sonora	1	1	0
	Baja California	0.98149	2	1.851
	Nuevo León	0.62564	3	37.436
	Veracruz	0.62112	4	37.888
	Coahuila	0.59985	5	40.015
	Baja California Sur	0.53600	6	46.4
	Aguascalientes	0.53520	7	46.48
	Tamaulipas	0.39371	8	60.629
	Quintana Roo	0.38010	9	61.99
	Durango	0.28657	10	71.343
	Colima	0.27388	11	72.612
	San Luis Potosí	0.25206	12	74.794
	Distrito Federal	0.20353	13	79.647
Guerrero	Guerrero	1	1	0
	Chiapas	0.76506	2	23.494
	Jalisco	0.75494	3	24.506
	México	0.74707	4	25.293
	Puebla	0.56675	5	43.325
	Tlaxcala	0.51501	6	48.499
	Campeche	0.50031	7	49.969
	Michoacán	0.49360	8	50.64
	Oaxaca	0.44553	9	55.447
	Hidalgo	0.41851	10	58.149
	Morelos	0.23798	11	76.202
	Nayarit	0.23734	12	76.266
Sinaloa	Sinaloa	1	1	0
	Querétaro	0.68043	2	31.957
	Guanajuato	0.53420	3	46.58
	Chihuahua	0.37373	4	62.627
	Zacatecas	0.18085	5	81.915
Tabasco	Tabasco	1	1	0
Yucatán	Yucatán	1	1	0

Source: Authors' estimations.

Table II-4. Input and output target values for the 32 States in Mexico using the input-oriented DEA model assuming constant returns to scale, 2007

State	Inputs				Outputs	
	Harvested Area Ag Crops[1]	Ag Labor[2]	Mechanical Power[3]	Fertilizer[4]	Grain Production[5]	Meat Production[6]
Aguascalientes	52968.141	38903.421	843.596	2526.306	177606.326	66702.68
Baja California	182045.132	133706.38	2899.340	8682.611	610411.586	229249.09
Baja California Sur	17473.456	12833.699	278.290	833.393	58589.866	22004.29
Campeche	75842.606	66645.932	1026.641	3617.3	236559.37	77728.49
Coahuila	163429.846	131831.231	2225.460	7794.758	468032.787	188134.85
Colima	45757.569	37249.068	427.520	2182.399	90902.560	42472.97
Chiapas	1037404.791	1819335.309	2432.884	49478.842	1527952.26	349130.56
Chihuahua	276163.868	201941.976	4175.957	13171.587	1010154.16	231793.61
Distrito Federal	4782.715	6155.657	59.837	228.110	12097.151	5643.45
Durango	161964.494	118957.789	2579.526	7724.868	543079.632	203961.58
Guanajuato	501471.725	366141.065	7444.507	23917.607	1886664.94	348716.75
Guerrero	833929.26	1373959	1400	39774.111	1305581.01	175761.23
Hidalgo	223056.405	245525.088	2244.476	10638.636	599595.14	170609.61
Jalisco	1032958.228	783664.809	15028.664	49266.764	3416890.39	1051497.27
México	661948.028	707211.257	6334.440	31571.496	2051664.06	203828.8
Michoacán	503734.055	424047.607	6636.986	24025.508	1772261.99	303849.95
Morelos	31836.365	24343.0644	463.348	1518.429	114883.55	24771.83
Nayarit	85993.786	78883.1294	1113.847	4101.458	261187.43	85091.3

Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Table II-4. (continued) Input and output target values for the 32 States in Mexico using the input-oriented DEA model assuming constant returns to scale, 2007

State	Inputs				Outputs	
	Harvested Area Ag Crops[1]	**Ag Labor**[2]	**Mechanical Power**[3]	**Fertilizer**[4]	**Grain Production**[5]	**Meat Production**[6]
Nuevo León	124087.148	91138.0788	1976.272	5918.315	416073.925	156262.71
Oaxaca	563441.034	861353.856	1388.720	26873.222	782242.63	201585.23
Puebla	494877.721	775349.788	3418.661	23603.107	950381.96	359625.8
Querétaro	108086.712	79204.0613	1676.002	5155.177	379620.17	112413.26
Quintana Roo	26333.703	57539.1412	173.326	1255.981	29312.717	27154.12
San Luis Potosí	158723.257	205867.505	1851.862	7570.278	373673.897	180545.44
Sinaloa	1258530.28	914238	17522	60025.384	5174407.91	269471.52
Sonora	546573.61	401441	8705	26068.733	1832704.12	688299.11
Tabasco	206001.04	518718	1010	9825.183	143044.87	206670.55
Tamaulipas	199361.850	146424.963	3175.134	9508.528	668475.897	251056
Tlaxcala	122857.155	117732.813	1423.999	5859.650	394258.42	71827.54
Veracruz	791874.209	1677883.133	5836.077	37768.303	1021042.692	839824.76
Yucatán	757413.94	409366	184	36124.726	139257.68	303886.37
Zacatecas	140663.122	103213.840	2215.638	6708.903	480976.27	164289.88

Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Table II-5. Efficiency score results for the 32 States in Mexico using the Output-oriented DEA model assuming constant returns to scale, 2007

State	Efficiency Score	Lambda (Σλ)
Aguascalientes	1.86844	0.181
Baja California	1.01886	0.339
Baja California Sur	1.86568	0.060
Campeche	1.99875	0.252
Coahuila de Zaragoza	1.66707	0.526
Colima	3.65129	0.317
Chiapas	1.30709	2.324
Chihuahua	2.67573	1.045
Distrito Federal	4.91335	0.065
Durango	3.48957	1.034
Guanajuato	1.87195	1.193
Guerrero	1.00000	1.000
Hidalgo	2.38942	0.802
Jalisco	1.32460	2.212
México	1.33856	0.920
Michoacán de Ocampo	2.02592	1.255
Morelos	4.20202	0.183
Nayarit	4.21332	0.596
Nuevo León	1.59837	0.363
Oaxaca	2.24451	1.983
Puebla	1.76443	1.973
Querétaro	1.46967	0.256
Quintana Roo	2.63087	0.297
San Luis Potosí	3.96736	1.748
Sinaloa	1.00000	1.000
Sonora	1.00000	1.000
Tabasco	1.00000	1.000
Tamaulipas	2.53993	0.926
Tlaxcala	1.94171	0.301
Veracruz Llave	1.60999	5.326
Yucatán	1.00000	1.000
Zacatecas	5.52932	1.353

Source: Authors' estimations.

Table II-6. Input and output slacks for the 32 States in Mexico using the output-oriented DEA model assuming constant returns to scale, 2007

State	Inputs				Outputs	
	Harvested Area Ag Crops[1]	Ag Labor[2]	Mechanical Power[3]	Fertilizer[4]	Grain Production[5]	Meat Production[6]
Aguascalientes	0.000	33323.139	2345.786	0.000	243460.436	0.000
Baja California	0.000	106987.358	1798.987	0.000	132442.929	0.000
Baja California Sur	0.000	66491.369	824.797	0.000	23202.238	0.000
Campeche	0.000	108769.460	0.000	0.000	0.000	0.000
Coahuila	0.000	0.00001	0.000	0.000	723382.705	0.000
Colima	0.000	0.000	0.000	0.000	112789.357	0.000
Chiapas	0.000	53385.236	0.000	0.000	0.000	0.000
Chihuahua	225963.971	0.000	15575.268	10777.312	0.000	0.00002
Distrito Federal	0.000	51152.118	0.000	0.000	12066.893	0.000
Durango	93162.406	0.000	4445.574	4443.364	714146.467	0.000
Guanajuato	0.000	163639.805	7636.225	0.000	0.000	0.000
Guerrero	0.000	0.000	0.000	0.000	0.000	0.000
Hidalgo	0.000	283771.164	0.000	0.000	0.000	0.000
Jalisco	0.00064	0.000	0.000	0.00003	0.000	0.000
México	0.000	241336.497	0.000	0.000	0.000	0.000
Michoacán	0.000	400801.671	0.000	0.000	0.000	0.000
Morelos	0.000	229945.881	0.000	0.000	0.000	0.000
Nayarit	0.000	4845.968	0.000	0.000	0.000	0.000
Nuevo León	167492.150	0.000	1320.192	7988.509	464107.756	0.000
Oaxaca	0.000	0.000	0.000	0.000	0.000	0.000

Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Table II-6. (continued) Input and output slacks for the 32 States in Mexico using the output-oriented DEA model assuming constant returns to scale, 2007

State	Inputs				Outputs	
	Harvested Area Ag Crops[1]	Ag Labor[2]	Mechanical Power[3]	Fertilizer[4]	Grain Production[5]	Meat Production[6]
Puebla	0.000	791333.936	0.000	0.000	0.000	0.000
Querétaro	0.000	97103.202	32.830	0.000	0.000	0.000
Quintana Roo	0.000	0.000	0.000	0.000	33215.463	0.000
San Luis Potosí	0.000	0.000	0.000	0.000	774997.535	0.000
Sinaloa	**0.00001**	0.000	0.000	0.000	0.000	0.000
Sonora	0.000	0.000	0.000	0.000	0.000	0.000
Tabasco	0.000	**0.00001**	0.000	0.000	0.000	0.000
Tamaulipas	828693.767	0.000	4407.383	39524.406	63251.082	0.000
Tlaxcala	0.000	47904.509	0.000	0.000	0.000	0.000
Veracruz	0.00003	31418.578	0.000	0.000	1364.820	0.000
Yucatán	0.000	0.000	0.000	0.000	0.000	0.000
Zacatecas	310393.468	0.000	12197.030	14804.162	0.000	0.00003

Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Table II-7. Efficiency rankings based on the ERS for the 27 inefficient States in Mexico using the output-oriented DEA model assuming constant returns to scale, 2007

Efficiency Reference Set	State	Efficiency Score	Efficiency Rating
Sonora	Sonora	**1**	1
	Baja California	1.01886	2
	Nuevo León	1.59837	3
	Veracruz L	1.60999	4
	Coahuila	1.66707	5
	Baja California Sur	1.86568	6
	Aguascalientes	1.86844	7
	Tamaulipas	2.53993	8
	Quintana Roo	2.63087	9
	Durango	3.48957	10
	Colima	3.65129	11
	San Luis Potosí	3.96736	12
	Distrito Federal	4.91335	13
Guerrero	Guerrero	**1**	1
	Chiapas	1.30709	2
	Jalisco	1.32460	3
	México	1.33856	4
	Puebla	1.76443	5
	Tlaxcala	1.94171	6
	Campeche	1.99875	7
	Michoacán	2.02592	8
	Oaxaca	2.24451	9
	Hidalgo	2.38942	10
	Morelos	4.20202	11
	Nayarit	4.21332	12
Sinaloa	Sinaloa	**1**	1
	Querétaro	1.46967	2
	Guanajuato	1.87195	3
	Chihuahua	2.67573	4
	Zacatecas	5.52932	5
Tabasco	Tabasco	1	1
Yucatán	Yucatán	1	1

Source: Authors' estimations.

Table II-8. Input and output target values for the 32 States in Mexico using the output-oriented DEA model assuming constant returns to scale, 2007

State	Inputs				Outputs	
	Harvested Area Ag Crops[1]	Ag Labor[2]	Mechanical Power[3]	Fertilizer[4]	Grain Production[5]	Meat Production[6]
Aguascalientes	98968	72688.860	1576.213	4720.261	331847.454	124630.214
Baja California	185477.9	136227.641	2954.012	8846.336	621921.924	233571.96
Baja California Sur	32599.95	23943.630	519.202	1554.848	109310.185	41053.055
Campeche	151590.39	133208.539	2052	7230.077	472822.979	155359.799
Coahuila	272449.13	219772	3710	12994.414	780243.807	313634.120
Colima	167073.97	136007	1561	7968.564	331911.242	155080.958
Chiapas	1355981.87	2378035.764	3180	64673.320	1997171.77	456345.212
Chihuahua	738939.668	540342	11173.731	35243.599	2702898.773	620216.882
Distrito Federal	23499.14	30244.881	294	1120.787	59437.50586	27728.229
Durango	565185.713	415111	9001.425	26956.434	1895111.959	711737.296
Guanajuato	938731.95	685399.194	13935.774	44772.658	3531749.787	652781.679
Guerrero	833929.26	1373959	1400	39774.111	1305581.01	175761.23
Hidalgo	532975.69	586662.835	5363	25420.183	1432685.303	407658.209
Jalisco	1368258.569	1038044	19907	65258.855	4526019.961	1392815.423
México	886054.16	946641.503	8479	42260.199	2746266.166	272836.156
Michoacán	1020524.66	859086.328	13446	48673.747	3590460.171	615575.546
Morelos	133777.14	102290.118	1947	6380.477	482743.326	104091.801
Nayarit	362319.52	332360.031	4693	17280.766	1100466.767	358517.053
Nuevo León	198336.669	145672	3158.807	9459.633	665038.385	249764.991
Oaxaca	1264650.12	1933319	3117	60317.268	1755752.909	452460.452
Puebla	873178.78	1368053.064	6032	41646.110	1676885.672	634535.772

Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Table II-8. (continued) Input and output target values for the 32 States in Mexico using the output-oriented DEA model assuming constant returns to scale, 2007

State	Inputs				Outputs	
	Harvested Area Ag Crops[1]	Ag Labor[2]	Mechanical Power[3]	Fertilizer[4]	Grain Production[5]	Meat Production[6]
Querétaro	158851.75	116403.797	2463.169	7576.406	557916.205	165210.345
Quintana Roo	69280.55	151378	456	3304.323	77117.948	71438.959
San Luis Potosí	629711.91	816750	7347	30034.000	1482497.952	716288.311
Sinaloa	1258530.28	914238	17522	60025.384	5174407.91	269471.52
Sonora	546573.61	401441	8705	26068.733	1832704.12	688299.11
Tabasco	206001.04	518718	1010	9825.183	143044.87	206670.55
Tamaulipas	506364.932	371909	8064.616	24150.987	1697881.274	637664.398
Tlaxcala	238553.5	228603.490	2765	11377.767	765537.224	139468.563
Veracruz	1274905.95	2701367.421	9396	60806.418	1643863.872	1352105.639
Yucatán	757413.94	409366	184	36124.726	139257.68	303886.37
Zacatecas	777770.931	570702	12250.969	37095.650	2659470.057	908410.755

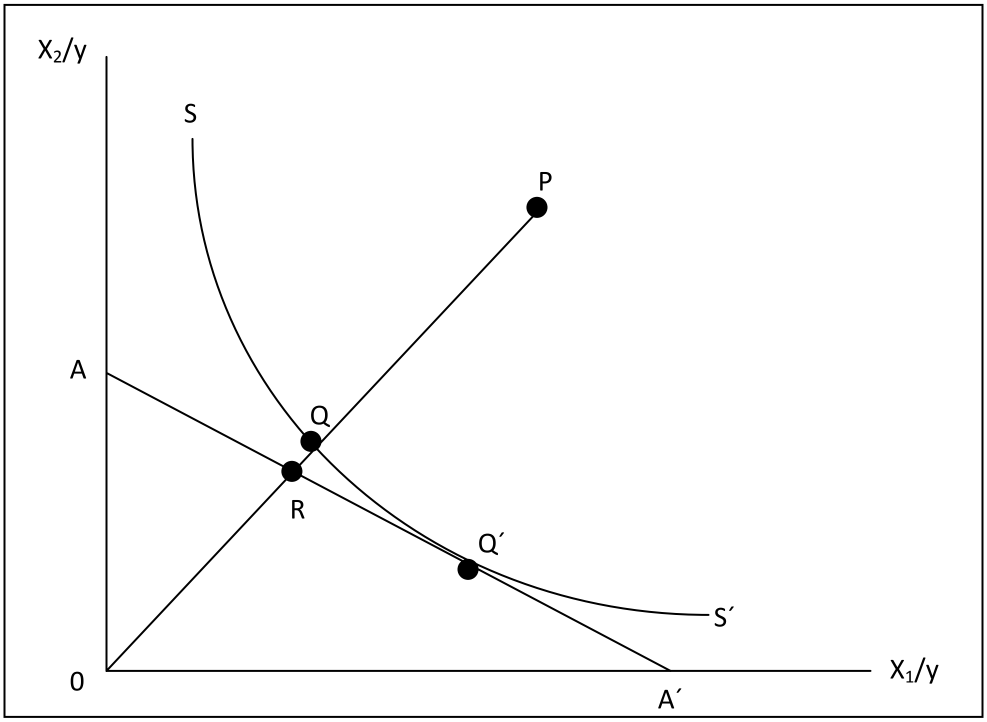
Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Table II-9. Summary of input and output target values for the States of Zacatecas in Mexico using the input and output-oriented DEA models assuming constant returns to scale, 2007

	Inputs				Outputs	
	Harvested Area Ag Crops[1]	**Ag Labor[2]**	**Mechanical Power[3]**	**Fertilizer[4]**	**Grain Production[5]**	**Meat Production[6]**
Zacatecas actual inputs and outputs	1,088,164.40	570,702	24,448	51,899.81	408,976.27	164,289.88
Input-oriented target	140,663.12	103,214	2,216	6,708.90	480,976.27	164,289.88
Actual input-oriented target resource reductions	947,501.28	467,488	22,232	45,190.91	0.00	0.00
Output-oriented target	777,770.93	570,702	12,251	37,095.65	2,659,470.06	908,410.75
Actual output-oriented target output increases	310,393.47	0.00	12,197	14,804.16	-2,250,493.79	-744,120.87

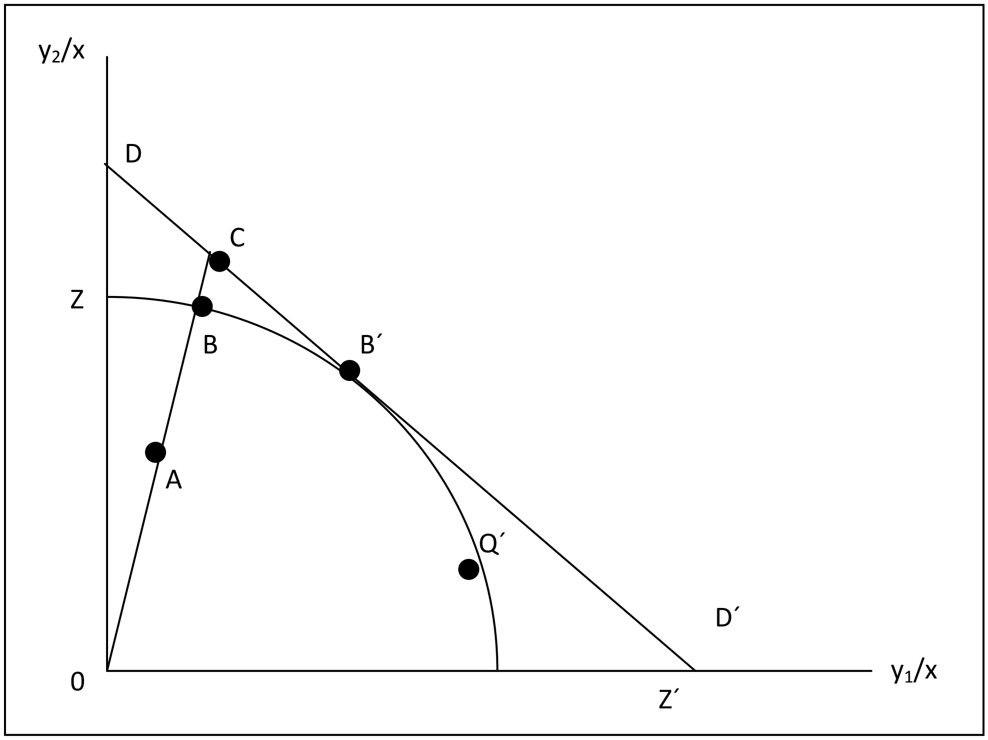
Source: Authors' estimations.
[1] Measured in hectares.
[2] Number of people employed in the agricultural sector.
[3] Number of tractors used in agricultural production.
[4] Measured in tons.
[5] Measured in tons.
[6] Measured in tons.

Figure III-1. Technical and Allocative Efficiency Measures from an Input-Orientation.



Source: Coelli, 1996.

Figure III-2. Technical and Allocative Efficiency Measures from an Output-Orientation



Source: Coelli, 1996.

CHAPTER III

Study III: FOREIGN DIRECT INVESTMENT IN THE MEXICAN AGRICULTURAL SECTOR

Abstract

Foreign direct investment (FDI) is a critical factor for developing countries who want to achieve the growth level necessary to have a strong economy. Exports are an important pre-requisite for FDI, particularly in the agricultural sector. This paper is intended to investigate the potential causal link between agricultural foreign direct investment, agricultural exports, and agricultural gross domestic product (GDP) in Mexico. Time-series Vector Error Correction Model (VECM) approach of stationarity test, cointegration test, and Granger causality test were applied to time series data covering the period of 1993 through 2010. From the results in this study a bi-directional causality between agricultural FDI and agricultural exports in Mexico was found. On the other hand, results show only a one way causality from agricultural GDP to agricultural foreign direct investment.

Introduction

An important consequence of globalization is that it encourages trade as well as capital liberalization across countries. One aspect of such capital liberalization is foreign direct investment which is an important source of external finance, since it contributes to capital formation and facilitates the transfer of technology across countries (William, 1998). The importance of FDI relies on the fact that it is a major element, essential if developing countries want to have the growth level necessary for a healthy economy (Mwilima, 2003). Foreign direct investment is the most important capital flow from the point of view of poverty reduction (Goldin, 2006).

A country opens its economy to foreign capital flows generally through trade agreements in which tariffs, taxes and duties are established on imports and exports of the participant countries (Blomström, 1997). Mexico has attempted to increase its foreign investment inflows by having one of the most open trade systems in the world with 44 free trade agreements. Trade liberalization in Mexico officially started in 1983, but agricultural and service sectors remained closed until 1994 when the agricultural sector started to be liberalized gradually, being fully opened in 2010 (Waldkirch, 2010).

In general exports are a pre-requisite for FDI, particularly in the agricultural sector where attracting FDI offers a window of opportunity in relation to the access of new markets and new technology (UNCTAD, 2009). Foreign direct investment in agricultural production in Mexico is very small relative to food processing and food distribution FDI. The United States direct investment in Mexico for the food and beverage industries relative to agricultural production follows the same trend. The U.S.

direct investment in Mexico for 2009 was about $3.2 billion in the food industry and only $356 million in crop and animal production combined (BEA, 2010).

This paper aims to investigate the existence of a potential cause and effect relationship between agricultural FDI, agricultural exports and GDP of the agricultural sector in Mexico. Once causality direction is known it will give a guideline for investment attraction programs targeting the agricultural sector in Mexico. Results of this study are expected to be useful for Mexican policy makers because once the factors affecting FDI are identified more responsive policies can be made and Mexican agricultural exports can be promoted. The ultimate goal is that this study will help understand the factors affecting foreign direct investment in the Mexican agricultural sector and contribute to the formulation of better policies that will generate better conditions in Mexico for future foreign direct investors.

Background

An Overview of Trade and the Agricultural Sector in Mexico

The agricultural sector in Mexico is characterized by great disparities in farm types as well as several critical issues some of them related to the land tenure, size of the farms, lack of financing, low production efficiency, rural poverty, production deficit in key agricultural commodities like corn, climate conditions, among others (OECD, 2006). These characteristics have contributed to the small amounts of FDI received by the agricultural sector in Mexico.

Starting in the late 1970s, Mexico has assumed significant agricultural policy reforms. The agricultural sector in Mexico began to privatize in the late 1980s. By 1991 most domestic agricultural and trade policy reforms were dedicated to further privatization and increased competition. Since the late 1980s, the Mexican government started to partially reform land tenure and continued encouraging market liberalization being the NAFTA the most significant market liberalization step (OECD, 2006). In the early 1990s, the main agricultural policies were a combination of price support and general consumption subsidies. Trade barriers and direct market intervention prevailed. During the 1990's, the Mexican government intensified its efforts to orient the country's agricultural sector towards the export market in order to increase rural income, employment, reduce migration from rural areas, and alleviate poverty (Yunez-Naude, 2006).

The effect of NAFTA on foreign direct investment appears minor for the United States, Canada, and Mexico. Canada and the United States had liberal trade and investment agendas before NAFTA. Mexico had restrictive trade and investment policies, but many of those restrictions were relaxed before NAFTA. Since the enactment of NAFTA in 1994, U.S. FDI into Mexico has grown very little. This is partly due to Mexico's currency devaluation in December of 1994 and low growth rates. Many U.S. firms had already made their investments in Mexico before NAFTA when Mexico unilaterally relaxed its investment and trade provisions.

The reasons for Mexico's liberalization process can be summarized as three internal and two external reasons. The first internal reason was the increasing incapacity of the import-substitution trade policies used from 1952-1970. These policies were imposed in order to create a sustainable economy with the creation of new jobs. This import-substitution model consisted on raising import controls on consumer goods but relaxing them on capital goods. The second reason was the positive effect that free trade had on the export sector, as well as its positive effect in the creation of new jobs. The creation of new jobs was above all in the manufacturing sector, also known as maquiladora industry in Mexico. The third internal reason was the positive effects felt in the economy since the opening process started in 1983 (Roberts, 2001).

The two external reasons were the opportunity to expand to other markets by forming economic blocks in the world economy and the intense competition for capital, which obligated countries to make the necessary reforms in order to have stable economic environments that encourage local and foreign investment (Roberts, 2001).

Foreign Direct Investment in Mexico

Historically, despite the importance of FDI, only a few countries have been recipients of substantial FDI inflows, particularly China, Brazil and Mexico. The United States is the largest foreign direct investor in Mexico. Several U.S. companies use parts assembled in Mexico in the final goods produced in the U.S. Between 1994 and 2004 Mexico received around $170 billion, with U.S. providing around 60 percent of this. From 1983 until the early 1990s, two thirds of FDI received by Mexico were concentrated in the maquiladora industry. Maquiladoras are assembly plants, largely located across Mexico. An assembly plant is a factory where manufactured parts are assembled into a finished product (Waldkirch, 2010).

Mexico's competitive advantages as an FDI recipient from the U.S. include proximity, short merchandise transit time, lower transportation costs, developed transportation and communications infrastructure, experienced workforce, intellectual property protection, less unwanted technology transfer, more transparent government regulations, easy access to the U.S. markets and ease of customer factory visits (SE, 2010). Foreign direct investment is considered beneficial for Mexico not only because it brings in much needed capital, but generates employment and presumably contributes to enhanced economic growth as it provides access to advanced technologies.

The geographical location of FDI in Mexico is not homogeneous, being the central and northern regions of the country the ones that have received larger capital flows. Figure III-1 shows a comparison between the major FDI recipient States in Mexico for the period of 1994 through 2006. These States combined accounted for 94.3 percent of the total FDI received by Mexico during that period. The States located in the central region of the country received 65.9 percent of the total FDI. Note that no State from the southern part of the country was recipient of a significant amount of FDI.

Foreign direct investment targeting the agricultural sector has always been noticeable in food processing and food distribution in Mexico. Among the foreign companies operating in Mexico are some of the biggest food companies in the world, such as Nestle, Coca Cola, General Foods, and PepsiCo. Today the food industry in Mexico represents one of the fastest growing segments for FDI. Figure III-2 depicts the difference between FDI for manufacturing industries (including maquiladora) and the FDI for the agricultural sector in Mexico. Foreign direct investment in the agricultural industries (processed foods and related products) claimed only 6 percent of total U.S. FDI in the manufacturing industries in 1996.

The agricultural industries are capital-intensive and undertake FDI to maintain quality, protect a trademark, and take advantage of economies of scale. The vast majority of U.S. foreign direct investment targeting the food and agricultural industries is destined for Europe. The major determinants for U.S. FDI in the agricultural industries are per capita GDP, growth rate of GDP, and market size of the recipient country. The costs of labor and capital inputs are less important. This suggests that agricultural FDI is aimed to provide the recipients country market rather than to create a platform for exports (Worth, 1998).

One of the main reasons why investment in agricultural production is so small is the difficult legal structure governing the land tenure system in Mexico known as ejido. Ejido is an area of communal land used for agricultural production, on which community members individually possess and farm a specific parcel. The limitations imposed in ejido lands are: 1) land holdings size is legally limited; 2) non-resident foreigners are prohibited from owning farm land (only through specialized structures and only in a minority position); 3) ejido land cannot be rented or sold; 4) corporate farming is not allowed; and 5) resident foreigners are restricted from owning land by the coast and borders due to the Restricted Zone and limits on foreign investment in ranching and farming. Many of these restrictions also hold back Mexican investment in the agricultural sector. Some options exist for partnerships but these are, however, limited.

Foreign Direct Investment and Free Trade Agreements

Foreign direct investment is defined as foreign investment that establishes a lasting interest in or effective management control over an enterprise. It can include buying shares of an enterprise in another country, reinvesting earnings of a foreign- owned enterprise in the country where it is located, and parent firms extending loans to their foreign affiliates (Soubbotina, 2004). Foreign direct investment has become a more visible topic because of its rapid growth worldwide in the last two decades.

Effects of regional trade agreements will vary by industry and by country. Those industries with direct investments based on ownership or internalization advantages have less incentive to change their level of investment in response to a change in external tariffs than industries engaged in tariff jumping investments do. Countries with the strongest locational advantages will receive most of the FDI oriented towards serving the regional market. Countries with weak locational advantages will see little change in their level of incoming FDI as a result of the trade agreements. In fact, countries with weak locational advantages may experience FDI outflows as firms relocate production to the most competitive country in the regional agreement (Blomström, 1997).

All firms must decide where it is best for them to locate their production. There are several theories on how firms make this decision. Ultimately, firms are seeking to maximize their profits, whether by investing abroad or expanding domestic production and increasing their exports (Worth, 1998). Early theoretical analysis in international trade has concluded that product trade and foreign direct investment are substitutes (Mundell, 1957). However, later a theoretical basis for a complementary relationship between product trade and FDI was provided (Dunning, 1979).

Regarding the analysis of the causal relation between FDI, exports and GDP, most of the existing empirical literature like Dlamani (2010) test bivariate causality relations between each pair of GDP, exports and FDI. Recently, a series of works have examined the relations among the three variables simultaneously. Makki (2004) provided evidence for a positive impact of exports and FDI on economic growth. Wang (2004) argues that FDI is relatively more important for high income countries, while international trade is more beneficial to lower income developing countries. Hsiao (2006) found evidence that

FDI has unidirectional effects on GDP, both directly and indirectly through exports, and that there exists bidirectional causality between exports and GDP.

The Model

To test for causality between agricultural foreign direct investment, agricultural exports, and agricultural gross domestic product in Mexico, the Vector Error Correction model was used. Following Dlamani (2010) the economic model is based on the assumption that the FDI is a function of agricultural exports in Mexico and GDP in the Mexican agricultural sector. A dummy variable was incorporated to the model in order to capture the effect of economic fluctuation over the period of study. Economic fluctuations typically involve shifts over time between periods of relatively rapid economic growth (an expansion or boom), and periods of relative stagnation or decline (a contraction or recession). The functional relationship and the causality relationships to be tested can be written as follows:

$$FDI = f(EXP, GDP, Dum), \tag{3.1}$$

$$FDI \leftrightarrow EXP$$

$$FDI \leftrightarrow GDP$$

$$FDI \leftrightarrow Dum$$

where

FDI is the stock of foreign direct investment in the agricultural sector of Mexico.

EXP is agricultural exports in Mexico.

GDP is the gross domestic product of the agricultural sector in Mexico; and

Dum is the dummy variable (Dum=1 and captures the effects of the other factors).

All the variables were transformed using logarithms, therefore they are referred as $logFDI$, $logEXP$ and $logGDP$. The logarithm form is presented in equations 3.2 and 3.3. In both equations the error term (e_t) is normally distributed.

$$logEXP = \alpha_0 + \alpha_1 logFDI + Dum + e_t \quad (3.2)$$

$$logGDP = \alpha_0 + \alpha_1 \log FDI + Dum + e_t \quad (3.3)$$

Estimation Methods

Using a general specification of the Granger causality two tests are obtained, the first examines the null hypothesis that a variable X does not Granger-cause variable Y and the second test examines the null hypothesis that the variable Y does not Granger-cause X. If we fail to reject the first null hypothesis and reject the second one, then it can be concluded that X changes are Granger-caused by a change in Y. Unidirectional causality will occur between two variables if either null hypothesis is rejected. Bidirectional causality exists if both null hypotheses are rejected and no causality exists if neither null hypothesis is rejected (Asari, 2011).

The Granger causality test requires that both the stationarity or unit root test and the cointegration test are performed as prerequisites. There are two forms of Granger causality, depending on the test results. If the tests results determine that the two variables are integrated of order one (non-Stationary at their levels) and not cointegrated, then the Granger causality test is implemented using the first differences of the variables (ECM without the error-correction term). On the other hand, if the variables are stationary I(1) and cointegrated, then an error-correction model should be used to estimate the causal relationship between the variables. The VECM methodology used in this study has three steps: stationarity test (unit root test), cointegration test, and the Granger causality test (ECM) (Bashier, 2007).

Stationarity

Before testing for Granger causality, it is important to establish the properties of the time series involved. Studies by Park (1989) and Stock (1989) show that the use of non stationary data in causality testing can yield to false causality conclusions, so in order to generate reliable results it is vital to test for stationarity of the data. As mentioned before, Granger causality requires the time series to be stationary. This means that the mean value of the series and its variance do not vary in the same manner over time (Gujarati, 1995).

A popular stationarity test used in most econometric studies is the unit root test, which is conducted to test for the order of integration. The Augmented Dickey-Fuller (ADF) test will be used to test the stationarity of the three time series ($log\ FDI, logEXP, logGDP$). The ADF test performs a regression analysis of the first-difference of the series against a first-lagged value, a constant, and time trend. This regression is presented in equations 3.4, 3.5 and 3.6:

Intercept model:

$$\Delta y_t = a_0 + \gamma y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + e_t \qquad (3.4)$$

Trend and intercept model:

$$\Delta y_t = a_0 + \alpha_2 t + \gamma y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + e_t \qquad (3.5)$$

No intercept and no trend model:

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{k} \beta_i \Delta y_{t-i} + e_t \qquad (3.6)$$

where y_t is a time series, $\Delta y_t = y_t - y_{t-k}$ is the first difference of the series y_t; $\Delta y_t = (y_{t-1} - y_{t-2})$ is the first difference of y_{t-k}, etc. a, γ and β_k are parameters to be estimated, and e_t is a stochastic error term and $e_t \sim N(0, \sigma^2)$.

The number of lagged terms is chosen to ensure that the errors are uncorrelated (Dlamani 2010; Tang 2008). The difference among the three regressions (3.4, 3.5 and 3.6) relies in the addition or deletion of the deterministic elements a_0 and α_2. Equation 3.4 includes a_0 but it does not have a time trend, equation 3.5 includes both α_0 and α_2 and equation 3.6 does not include a_0.

Another method used to check the stationarity of the time series analyzed is by looking at the autocorrelation plot for each variable. PROC ARIMA in SAS® was used to correct the data for non stationarity and to identify model orders. A time series $(X_t, t(time) = 0, \pm 1, \pm 2, \dots)$ is said to be stationary if it has statistical properties similar to those of the time-shifted series $(X_{t+h}, t = 0, \pm 1, \pm 2, \dots)$ for each integer h. Mathematically the pure ARIMA model is written as:

$$W_t = \mu + \frac{\theta(B)}{\phi(B)} a_t \tag{3.7}$$

where t is the index time, W_t is the response series y_t or a difference of the response series, μ denotes the mean term, B is the backshift operator; that is $BX_t = X_{t-1}$. $\phi(B)$ is the autoregressive operator, $\theta(B)$ is the moving average operator, and a_t is the independent disturbance, also known as random error.

Cointegration

Cointegration is used to establish long-run equilibrium relationships between agricultural FDI, agricultural exports and Mexico's GDP. It is used as a pre-test. A valid Granger causality test requires the presence of a cointegrated set of variables. The existence of cointegration implies that Granger causality must exist in at least one direction between the variables of the system. By definition, cointegration requires that the variables are integrated of the same order before they can be said to be cointegrated. This test is performed to examine any long –run equilibrium relationships between the two pairs of variables $log\ FDI$, $logEXP$ and $log\ FDI, logGDP$.

The Johansen cointegration rank test was used to test for cointegration. This test is based on the method of maximum likelihood and allows inference to be made on the cointegrating parameters using likelihood ratio tests. This method also allows the rank of the cointegrating relationship to be tested, allowing inference to be made on the number of cointegrating relationships in the set of variables.

Granger Causality (ECM)

Granger causality can have two forms: the Granger causality test is implemented using the first differences of the variables (ECM without the error-correction term), or the error-correction model.

Two variables are said to be cointegrated if they are integrated of order one, I(1), and their residuals are I(0) (Engle, 1987). Using the Granger theorem, if the variables are I(1) and their residuals I(0), then the relationship between these variables can be generated using a dynamic process (Engle 1987; Bashier 2007) from FDI to EXP and vice versa as well as from FDI to GDP and vice versa. Following the procedure developed by Bashier (2007), equations 3.8, 3.9 and 3.10 will be estimated.

$$\Delta log\ FDI_t = \alpha_1 + \sum_{i=1}^{k} \alpha_{1t} \Delta FDI_{t-1} + \sum_{i=1}^{k} \beta_j \Delta EXP_{t-1} + \delta\mu_{t-1} + \beta_1 Dum + e_t \quad (3.8)$$

$$\Delta log\ EXP_t = \alpha_2 + \sum_{i=1}^{k} \alpha_{2t} \Delta EXP_{t-1} + \sum_{i=1}^{k} \lambda_j \Delta FDI_{t-1} + \eta\gamma_{t-1} + \beta_2 Dum + e_t \quad (3.9)$$

$$\Delta log\ GDP_t = \alpha_3 + \sum_{i=1}^{k} \alpha_{3t} \Delta GDP_{t-1} + \sum_{i=1}^{k} \vartheta_j \Delta FDI_{t-1} + \rho\varphi_{t-1} + \beta_3 Dum + e_t \quad (3.10)$$

where μ_{t-1}, γ_{t-1} and φ_{t-1} are the error correction terms, δ, η and ρ are the error-correction coefficients.

The estimated error correction terms are expected to be negative and significant. They are intended to capture the adjustments of the three variables towards long-run equilibrium, while the coefficients of the change of the three variables are expected to capture the short run dynamics adjustment test, which measures the proportion of the disequilibrium from one period that is corrected in the next period. The inclusion of the error correction terms in the above equations provide another mean through which causality can be established and another way to see how the two variables return to equilibrium in the case of a shock (Bashier, 2007). The main focus in the correction-model is the sign and the statistical significance of the error term.

Data

The sample time series data used covered the period 1993: I – 2010: IV containing quarterly observations for real gross domestic product of the agricultural sector and agricultural exports. Annual agricultural FDI stock was used to derive quarterly FDI figures. The EXPAND procedure in SAS® was used to transform annual FDI data to quarterly observations; this procedure corrects the data for missing values and periodicities by interpolating the full set of time series converting the data frequency to quarterly values and correcting for periodicities.

Data was collected from the Mexican Government Statistical Agency by its Spanish acronym INEGI and from the UNCTAD. Data for GDP of the agricultural sector and agricultural exports was obtained in Mexican pesos; therefore the spot exchange rate used to convert the wage data into U.S. dollars. This was obtained from the International Financial Statistics database of the International Monetary Fund.

Results and Discussion

Stationarity (Unit Root Tests)

The stationarity of the three series was examined by testing for unit roots. As mentioned before ADF test was used to test the stationarity of the series. In each test, the significance level used is 5 percent. The ADF tests are performed on both levels and first differenced observations by estimating the three models represented in equations 3.8, 3.9 and 3.10.

Table III-1 presents the results of the ADF unit root test for the three models. The results show that the null hypothesis of a unit root is accepted for all three time series $log\ FDI, logEXP$ and $logGDP$ in all three models, meaning that the series are nonstationary. The null hypothesis is accepted because all estimates are not significant using Tau. This conclusion was also achieved by looking at the autocorrelation plots for all three series which show a slow decay trend (See Figures III-3, III-4, and III-5). As previously discussed, the series need to be stationary in order to be used for causality testing and result on real causality outcome. In order to make the series stationary first differencing was applied to the series data. For the used data all estimates for the three models are significant using Tau. The conclusion is that the three time series are all integrated of order one I(1), using Model 2. This is because equation 3.5 (trend and intercept Model) was chosen as the unit root test specification.

Cointegration Results

To test for cointegration, the Johansen cointegration rank test was used. Table III-2 shows the Johansen cointegration rank test between the series. In the cointegration rank test, the last two columns explain the drift in the model or process. Since the NOINT option is specified, the model is specified in equation 3.11:

$$\Delta y_t = \Pi y_{t-1} + \Phi_1^* \Delta \mathrm{y}_{\mathrm{t-1}} + \mathrm{e}_\mathrm{t} \qquad (3.11)$$

The column Drift In ECM means there is no separate drift in the error correction model, and the column Drift In Process means the process has a constant drift before differencing. Drift refers to the process varying or oscillating randomly about a fixed setting. H_0 represents the null hypothesis, and H_1 is the alternative hypothesis. The first row tests $r = 0$ against $r > 0$; the second row tests $r = 1$ against $r > 1$. The Trace test statistics in the third column are computed by $-T \sum_{i=r+1}^{k} \log{(I - \lambda_i)}$ where T is the available number of observations and λ_i is the eigenvalue. The trace statistic tests the null hypothesis that there are at most *r* cointegrating relations against the alternative of more than *r* cointegrating relations. The trace test does not follows a chi square distribution in general; so the asymptotic critical values (column four in Table III-2) where obtained using SAS®. The critical values at 5 percent significance level are used for hypothesis testing.

By comparing the test statistics in Table III-2 and critical values in each row we can see that there is one cointegrated processes since the Trace statistic for testing $r = 0$ against $r > 0$ is greater than the critical value (12.21), hence we reject the null hypothesis and conclude that the rank is more than zero for $log\ FDI$, and $logGDP$. Similarly for $log\ FDI$ and $logEXP$ the Trace statistic for testing $r = 0$ against $r > 0$ is greater than the critical value (12.21). Therefore we reject the null hypothesis and conclude that the rank is more than zero. The results demonstrate that the two pairs of time series are strongly linked together. We can conclude that the two pairs of variables: $log\ FDI$, and $logGDP$ and $log\ FDI$ and $logEXP$ and *vice versa* are cointegrated. This means that there exists a long-run relationship between the two sets of variables.

Granger Causality (ECM) Results

The Error Correction Model for all equations was estimated using the OLS method. The error correction term obtains the rate at which changes in the dependent variable return to equilibrium following a shock in the independent variable. It implies that the behavior of the dependent variable is tied to the independent variable. The estimated value must have a negative sign in order to indicate it moves back towards the equilibrium after a shock. A negative coefficient also indicates the model is stable. All coefficients should lie between 0 and 1. Table III-3 shows the parameter estimates (error terms) of lag one first differenced coefficients $\Delta logFDI_{t-1}$, $\Delta logEXP_{t-1}$, and $\Delta logGDP_{t-1}$ and their significance.

When $\Delta logFDI$ is used as a dependent variable, the coefficient of -0.107 suggests 11 percent movement back towards equilibrium following a change in agricultural exports, one time period later. The negative sign of the coefficient means that a small change in FDI relative to agricultural exports in period *(t-1)* indicates an upward adjustment in FDI for the next period in order to achieve equilibrium. When $\Delta logEXP$ is set as a dependent variable, the coefficient of -0.494 suggests 49 percent movement back toward equilibrium following a change in FDI a period later. Regarding GDP, there will be a 48 percent movement back in order to achieve equilibrium after a change in foreign direct investment.

The effect of FDI on EXP and *vice versa* is significant and the coefficient (error term) is negative. This suggests the validity of long-run equilibrium relationship among foreign direct investment and exports in the agricultural sector. The effect of FDI on GDP is positive and insignificant (0.00438), while the effect of GDP on FDI is negative and significant (-0.48785). This means that the causal relationship runs only from GDP to foreign direct investment and not *vice versa*.

The direction of the Granger causality for all variables is summarized in Table III-4. The results show that FDI Granger causes EXP and *vice versa*, implying that the causal relation between foreign direct investment and agricultural exports is bidirectional. On the other hand, only gross domestic product Granger causes FDI but not the other way round. The above results imply that agricultural exports and GDP are important determinants of foreign direct investment inflows to the agricultural sector of Mexico.

The results of the Granger Causality Wald test are presented in Table III-5. The null hypothesis of the Granger Wald causality test is that Group 1 is influenced only by itself, and not by Group 2. For $\Delta logFDI$ and $\Delta logEXP$ the results show that we can reject that FDI is influenced by itself and not by agricultural exports confirming the results obtained using the error correction model. On the other hand we cannot reject that agricultural exports are influenced by itself and not by FDI. In the case of $\Delta logGDP$ and $\Delta logFDI$ we cannot reject that GDP is influenced by itself and not by FDI, but we reject that FDI is influenced by itself and not by GDP, this again confirms the results of the error correction model which say that gross domestic product influences foreign direct investment but not the other way round.

Conclusions

This paper investigated the causal relation between agricultural foreign direct investment inflows and exports in the agricultural sector as well as the causal relation between agricultural foreign direct investment inflows and gross domestic product of the agricultural sector in Mexico over the period of 1993 through 2010. After performing unit root tests for stationarity, results of this study prove that the variables included are nonstationary at their levels, but when first differences are applied they become stationary. The Johansen cointegration rank test indicate that the variables are cointegrated, meaning that the variables have a stable long-run relationship. In order to confirm that this relation exists, Granger-Causality Wald test was used.

To establish the causal direction, the error correction model was used. The results of the ECM and the Granger Causality Wald test say that FDI is a determinant factor in agricultural exports; therefore an increase of foreign direct investment inflows in the sector will lead to an increase in agricultural exports in Mexico. Because the causality was determined to be bidirectional, agricultural exports also have a significant effect on FDI inflows to Mexico. Regarding the relation between gross domestic product of the agricultural sector and foreign direct investment inflows in the agricultural sector, findings indicate that GDP Granger causes FDI, but FDI does not Granger cause GDP. Unidirectional causality means that past values of GDP have a predictive ability in determining the present valued of FDI but not the other way round.

Findings of this study confirm that exports are a determinant for FDI inflows in Mexico and that policies designed to increase exports of agricultural products will have an impact on agricultural FDI inflows to Mexico. Policies to encourage agricultural production can include offering incentives to producers of commodities destined for foreign markets. Facilitating the access to credit will give farmers an incentive to produce agricultural commodities with the potential to be exported live vegetables which require higher investments.

Because the majority of the agricultural producers live in rural areas it is important to improve the infrastructure in those areas in order to increase the production of agricultural commodities for foreign markets. Improving roads, transportation and irrigation systems will not only encourage a more efficient agricultural production and increase the welfare of the rural population, but will also create the necessary conditions to attract foreign direct investment to these areas of the country.

Another important factor to be considered when policies are designed is the legal restrictions imposed by land tenure in Mexico, which directly affect ownership and investment. Finally, FDI inflow location is limited due to the geographic and climatic characteristics in Mexico, since not all the States in the country have the ideal characteristics for a large scale and highly technified agricultural production. Larger investments are needed in the northern States of Mexico, because of its arid and semiarid climate characteristics. Investors should notice that the Southern States have semi-tropical climate characteristics, which give them a natural comparative advantage in the production of agricultural commodities that require such conditions to be produced.

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APPENDICES

Table III-1. Augmented Dickey-Fuller Unit Root test results

Variable	Intercept (Model One)	Trend and Intercept (Model Two)	None (Model Three)
Log FDI	-1.09 (0.7142)	-2.98 (0.1441)	3.63 (0.9999)
Log EXP	-0.25 (0.9256)	-3.41 (0.0584)	1.39 (0.9578)
LogGDP	-0.61 (0.8622)	-3.29 (0.0757)	0.84 (0.8903)
Augmented Dickey-Fuller test for unit root on the first differenced series			
ΔLog FDI	-4.27 (0.0010)***	-4.24 (0.0067)***	-2.64 (0.0089)***
ΔLog EXP	-7.27 (0.0001)***	-7.25 (<0.0001)***	-7.06 (<0.0001)***
ΔLogGDP	-7.61 (0.0001)***	-7.59 (<0.0001)***	-7.52 (<0.0001)***

Source: Authors' estimations.
Parenthesis ( ) denote the Pr < Tau
*** Denotes significance at the 1 percent levels
Δ Denotes first difference series

Table III-2. Johansen Cointegration Rank Test

$log\ FDI$, and $logGDP$					
$H_0: rank = r$	$H_1: rank > r$	**Trace**	**Critical Value**	**Drift in ECM**	**Drift in Process**
0	0	59.6256	12.21	NOINT	Constant
1	1	7.3343	4.14		

$log\ FDI$ and $logEXP$					
$H_0: rank = r$	$H_1: rank > r$	**Trace**	**Critical Value**	**Drift in ECM**	**Drift in Process**
0	0	50.8148	12.21	NOINT	Constant
1	1	7.8490	4.14		

Source: Authors' estimations.

Table III-3. Results of causality test based on the significance of Error Correction Model coefficient, 1993:I – 2010:IV

Dependant variable is $\Delta logFDI$			
Variable	**Error Term Coefficient**	**t-value**	**Pr > |t|**
$\Delta logEXP_{t-1}$	-0.10796***	-0.85	0.001
$\Delta logGDP_{t-1}$	0.00438	0.03	0.9722
Dependable variable is $\Delta logEXP$			
$\Delta logFDI_{t-1}$	-0.49407***	5.16	0.0001
Dependable variable is $\Delta logGDP$			
$\Delta logGDP_{t-1}$	-0.48785***	5.20	0.001

Source: Authors' estimations.
*** Denotes significance at the 1 percent levels
Δ Denotes first differenced data

Table III-4. Direction of the Causality

Dependent Variable	$\Delta logFDI$	$\Delta logEXP$	$\Delta logGDP$
Conclusion	FDI $\Longrightarrow$ EXP	EXP $\Longrightarrow$ FDI	GDP $\Longrightarrow$ FDI

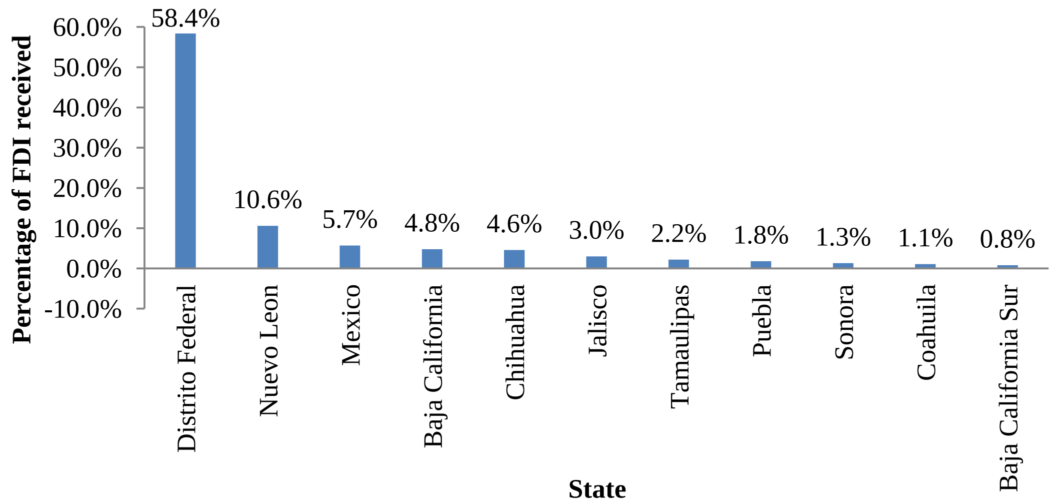
Source: Authors' estimations.
Δ Denotes first differenced data

Table III-5. Granger - Causality Wald Test

Test	**Chi-Square**	**Pr > ChiSq**
$\boldsymbol{\Delta logFDI}$ **and** $\boldsymbol{\Delta logEXP}$		
Group 1: $\Delta logFDI$ and **Group 2:** $\Delta logEXP$	8.40	0.0037***
Group 1: $\Delta logEXP$ and **Group 2:** $\Delta logFDI$	0.25	0.6190
$\boldsymbol{\Delta logGDP}$ **and** $\boldsymbol{\Delta logFDI}$		
Group 1: $\Delta logGDP$ and **Group 2:** $\Delta logFDI$	0.04	0.8432
Group 1: $\Delta logFDI$ and **Group 2**: $\Delta logGDP$	7.24	0.0071***

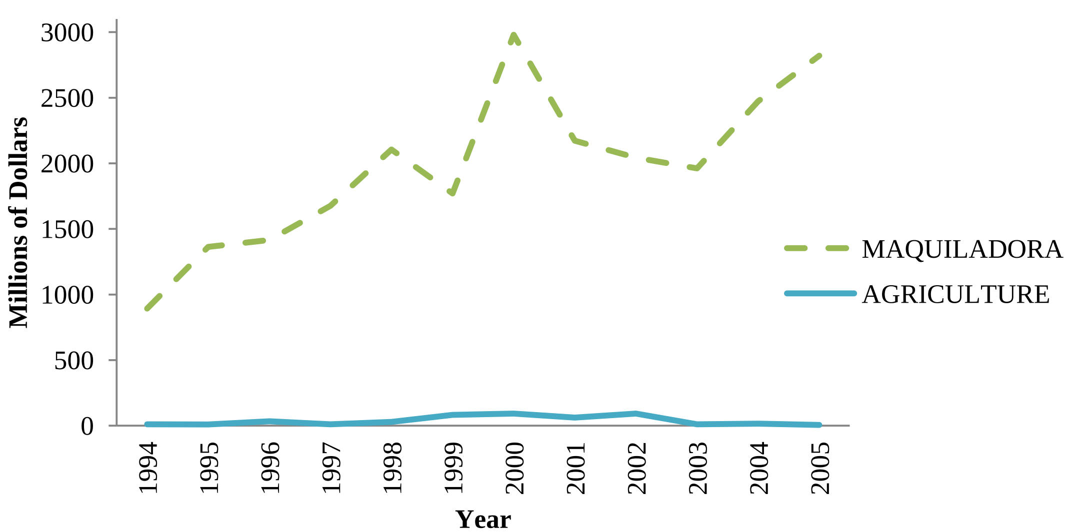
Source: Authors' estimations.
*** Denotes significance at the 1 percent levels
Δ Denotes first differenced data

Figure III-1. States with largest amount of FDI in Mexico in percentage, 1994-2006



Source: Authors' estimations with data from INEGI, 2012.

Figure III-2. Foreign direct investment flows into Mexico in millions of U.S. dollars, 1994-2005



Source: SAGARPA, 2010.

Figure III-3. Autocorrelation plot for $logGDP$.

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Source: Authors' estimations.

Figure III-4. Autocorrelation plot for $logEXP$.

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Source: Authors' estimations.

Figure III-5. Autocorrelation plot for $logFDI$.

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Source: Authors' estimations.

VITA

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Major Field: Agricultural Economics

Scope and Method of Study: This dissertation is composed of three studies aimed to analyze several aspects of the agricultural sector in Mexico including efficiency, agricultural Foreign Direct Investment (FDI) and the effects of foreign economies on Mexican agriculture. The first study, "Chinese Competition and its Effects on Mexican Agriculture" was made to determine if changes in Mexican, U.S. and Chinese economies have had a significant effect on the agricultural labor market in Mexico. The second study called "Agricultural Production Efficiency Analysis in Mexico using Data Envelopment Analysis" was designed to analyze the agricultural production efficiency for the 32 States in Mexico. The third and final study "Foreign Direct Investment in the Mexican Agricultural Sector" examined the potential causal link between agricultural FDI, agricultural exports, and agricultural gross domestic product (GDP) in Mexico.

Findings and Conclusions: Empirical results from the first study indicate that the demand for agricultural workers in Mexico is affected by the real relative manufacturing wage between Mexico and China and also by Mexico's GDP. The second study found that using both input and output-oriented analysis results show that there are only five States in Mexico that have an efficient agricultural production, these States are: Guerrero, Sinaloa, Sonora, Tabasco and Yucatán. The rest twenty seven States of Mexico present several degrees of agricultural production inefficiency. Having 27 out of 32 States with inefficient agricultural production, it was concluded that the agricultural production in Mexico is inefficient. Results of the third study show a bi-directional causality between agricultural FDI and agricultural exports in Mexico. On the other hand, results show only a one way causality from agricultural GDP to agricultural foreign direct investment.

ADVISER'S APPROVAL: Dr. Shida Henneberry