AN ABSTRACT OF THE THESIS OF

Ebru Alpay for the degree of Master of Science in Economics presented on November 11th, 1998. Title: THE COMPARISON OF PRODUCTIVITY GROWTH IN THE U.S. AND MEXICAN FOOD PRPCESSING SECTORS.

Abstract approved:

Redacted for Privacy

Joe R. Kerkvliet

In this study, the rates of technological change in food processing sectors of U.S. and Mexico are compared through econometric estimation of both the unrestricted (long-run) and restricted (short-run) profit functions with first order autocorrelation correction. Then, the dual rate of productivity growth is computed and decomposed into its sources. The impact of environmental regulations on productivity growth is also analyzed through incorporation of a pollution abatement variable into empirical models.

The hypothesis testing results on the existence of short-run equilibrium in capital markets indicated that the restricted profit function framework is the valid specification for the underlying production technologies of U.S. and Mexican food sectors during the sample period, and hence, our conclusions are based on restricted profit function models. Our results suggest that, in U.S., the average annual dual rate of technological change dropped from 0.76% during 1963-73 to 0.67% during 1974-88, increased to 0.72% between 1988-1990, and declined to 0.65% during 1990-93. In Mexico, the dual rate of technological change was sharply declining during most of the years of sample period, and the average annual rate dropped from 1.30% during 1971-74 to 0.01% between

1989-93. The dual rate of technological change was lower in U.S. than in Mexico during 1971-81 period, but the difference (dual technological change gap) was sharply declining. Starting from 1982, the dual rate of technological change became greater in U.S. than in Mexico and the difference was continuously increasing. Moreover, the decomposition of dual productivity growth into its sources reveals that technological change was the main source of productivity growth in both countries, although in Mexico, the effects of changes in output price on productivity growth outweighed the contributions of technological change during several years between 1982-94. The impact of capacity utilization had a minor impact on productivity growth in both countries.

The estimated elasticities of input demand and output supply indicated that labor demand is price inelastic, while material demand and output supply are price elastic in both countries. The own price elasticity of material and output was higher in Mexico than in U.S. In both countries, input demands are affected most significantly by output prices, while output supply is most significantly affected by its own price. The estimates for elasticity of substitution between labor and material imply that labor and material are complement of each other in both countries, with the degree of substitution between them is higher in Mexico than in U.S.

Finally, the estimated parameters corresponding to pollution abatement variable suggested that pollution abatement costs had no significant impact on the U.S. dual rate of technological change, and in turn, productivity growth rate, and this appears to be consistent with the fact that the share of pollution abatement costs is quite small in U.S. food processing sector. For the Mexico, the estimated parameters were individually significant, implying that one unit increase in pollution abatement variable reduced the dual rate of technological change by around 0.11% points during 1982-94 period.

The Comparison of Productivity Growth in the U.S. and Mexican Food Processing Sectors

by

Ebru Alpay

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented November 9th, 1998
Commencement June 1999

Master of Science thesis of Ebru Alpay presented on November 11th, 1998

APPROVED:

Redacted for Privacy

Major Professor, representing Economics

Redacted for Privacy

Head or Chair of Department of Economics

Redacted for Privacy

Dean of Graduate School

I understand that my thesis will become part of the permanent collecton of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Redacted for Privacy

Ebru Alpay, Author

ACKNOWLEDGMENT

I would like to thank to my major professor, Joe Kerkvliet, for his encouragement, guidance and support during the preparation of this research. I also thank Steve Buccola for his support and valuable comments. I am also grateful to all faculty, students and staff of Economics Department for their support and making my life in the department enjoyable and fun.

Financial support for this thesis was provided by the National Research Initiative Grants Program, Aggreement No. 96-35400-3619, US. Department of Agriculture.

Finally, I would like to thank to my husband for his endless support and encouragement.

TABLE OF CONTENTS

Page

TABLE OF CONTENTS (continued)

Page

TABLE OF CONTENTS (continued)

Page

LIST OF FIGURES

LIST OF FIGURES (continued)

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF APPENDICES

DEDICATION

TO MY HUSBAND...

THE COMPARISON OF PRODUCTIVITY GROWTH IN THE U.S. AND MEXICAN FOOD PROCESSING SECTORS

CHAPTER 1: INTRODUCTION

The food processing sector is one of the largest manufacturing sectors in both the United States and Mexico. Specifically, the food processing sector in the U.S. was the second largest manufacturing sector in terms of value of shipment in 1994 and the third largest in terms of employment in 1995. Similarly, in Mexico, the food processing sector was the top manufacturing sector in terms of gross domestic product and employment in 1995.

The food processing trade between the U.S. and Mexico has been growing rapidly since last 1980's. Mexico is the third largest export destination for the U.S. processed food products, after Japan and Canada, while the U.S. is the top destination for the Mexican exports. Furthermore, the 1994 North American Free Trade Agreement (NAFTA) has lead to major changes in food processing sector trade between U.S. and Mexico, as a result of reduced tariffs and quantity restrictions, and reductions of other type of trade barriers. Although NAFTA has resulted in increased volume of trade between countries of agreement, the increased integration of U.S. and Mexican economies puts more competitive pressures on food processing sectors of U.S. and Mexico. The competitive success of the food processors in each country is mostly determined by their ability to improve and maintain high productivity levels as well as their ability to develop and market new products. Productivity growth, which is broadly defined as the difference between growth rate of output and growth rates of total inputs, can be achieved through improvements in technology and the methods of using existing resources as well as introduction of new processes and new inputs.

To further improve our understanding of the relative competitiveness of the U.S and Mexican food sectors, this study measures the inter-country productivity differences. I employ an econometric model of total factor productivity allowing for: i) the effects of disequilibrium in capital markets ii) the effects of scale economies iii) the rates of technological change iv) the impacts of pollution abatement regulations on productivity levels.

In the literature, as to my knowledge, there are no econometric studies comparing the productivity levels in the U.S. and Mexican food processing sectors. Previously, several single-country studies that analyze the food processing productivity in U.S. or Mexico have been conducted (see section 2.2 in chapter 2). However, none of these single-country studies take into account "simultaneously" for the effects of scale economies, disequilibrium in capital markets and the impacts of pollution abatement regulations on food processing productivity levels. Several studies have found that the failure to account for any of the above effects might have cause significant biases in the measures of productivity levels. Morrison (1986 and 1992) has shown that the effects of disequilibrium in capital markets and economies of scale can have substantial impacts on productivity estimates. In addition, with increasing environmental regulations since 1970's in the U.S., the accounting for the impacts of pollution abatement regulations may have significant effects on productivity levels of food processing sector. In a survey article, Jaffe et al. (1995) summarized several empirical studies that have found significant adverse effects of environmental regulation on productivity growth levels of several individual manufacturing sectors or on whole manufacturing sector.

The impact of environmental regulations on relative competitiveness of U.S. and Mexican firms was also an important debate issue during NAFTA negotiations. The critics of the NAFTA claimed that the relatively lower level of Mexican environmental regulations and lower compliance costs in Mexico compared to those in the U.S. would impair the U.S. firm's competitiveness against Mexican firms. According to this view, with increasing trade liberalization after NAFTA, Mexican firms will have to compete with more technologically advanced U.S. firms, and therefore, they would tend to cut their costs down by limiting their investment on pollution abatement activities or by avoiding compliance with regulations. It has been also argued that U.S. firms would tend to locate their capital away from U.S. to Mexico in search of lower environmental standards and compliance costs.

With the limitations of previous studies in mind, the objectives of this study are to:

i) Develop an econometric model of total factor productivity in U.S. and Mexican food processing sectors, allowing for the effects of variable returns to scale, disequilibrium in capital markets and the impacts of pollution abatement regulations

ii) Estimate and compare productivity growth rates and rates of technological change in the U.S. and Mexican food processing sectors

iii) Decompose total factor productivity growth rates into its sources in order to examine the contributions of rate of technological change, capital adjustment, economies of scale and environmental regulations to productivity growth rates.

The study proceeds as follows: First, the characteristics of the U.S. and Mexican food processing sectors are discussed in chapter 2. In chapters 3 and 4, the theoretical framework for productivity measurement and development of econometric models are presented. In chapter 5, the impacts of environmental regulations on productivity growth and the methodology for the incorporation of pollution abatement regulations into the measure of productivity are discussed. In chapter 6, the empirical results are presented. Finally, in the last chapter conclusions based on empirical results are drawn.

CHAPTER 2: PROFILE OF THE U.S. AND MEXICAN FOOD PROCESSING SECTORS

In the following sections of this chapter, the characteristics of food manufacturing sectors in each country are discussed with particular attention to the composition of subsectors in industry, the evolution of value of shipments, and bilateral trade relationship between food sectors of two countries. In the last section, the previous studies of productivity in food manufacturing in each country are reviewed.

2.1 Characteristics of the U.S. and Mexican Food Processing Sectors

The U.S. food processing sector was the second largest manufacturing sector in terms of value of shipment after transportation equipment in 1994 while it was the largest sector during 1978-93. Specifically, in 1994, it accounted for the 12.9 % of total manufacturing shipment and 1.4% of the total U.S. GDP (Industrial Outlook, 1994 and Statistical Abstract of U.S., 1996). The U.S. food processing sector was also the third largest employer in U.S. manufacturing sector after the industrial machinery and transportation equipment industries, employing 9.2 % of total employees in manufacturing in 1995. The Mexican food processing sector was the largest manufacturing sector in terms of gross domestic product, accounting for around 28% of total manufacturing gross domestic product in 1995 (Handbook of North American Industry, 1998). In 1991, the food processing sector was the top manufacturing sector in terms of value of shipment, accounting for 25.2 % of total value of shipment in the entire manufacturing, followed by machinery and equipment industry (OECD Economic

Surveys, Mexico, 1991/1992). The Mexican food processing sector was also the largest in terms of employment, accounting for 21 % of total manufacturing employment in 1995.

The composition of the food processing sector differs between the U.S. and Mexico. In the U.S., the largest subsector in food manufacturing is the meat products, with 23.1% of total industry shipments during 1992. The next are beverages with 14.2% of total industry shipments, dairy products (13%), grain mill products (12.3%), and preserved fruit and vegetables (11.7%). With respect to employment, the meat products is again the largest subsector, accounting for 26.4% of total food processing employment in 1992, followed by preserved fruit and vegetables (14.6%), bakery products (12.5%), beverages (10.6%), and dairy products (9.1%). In Mexico, the major subsector is beverages, employing 19.3% total employees in whole food processing sector. Beverages are followed closely by bread products (18.9%) and tortilla sectors (14.5%). The meat products in Mexico accounts for only a small portion (5.7%) of the total food processing employment. In the U.S., the bread products and tortilla sectors are combined under the bakery products and they constitute around 12.5% of the U.S. food processing sector employment, while in Mexico, the bread and tortilla sectors together account for more than one third of the total Mexican food processing employment (Handbook of North American Industry, 1998).

Moreover, the disaggregation of total food processing sector costs into its components indicates that the U.S. food processing sector is material intensive. The share of material cost in total costs was between 59%-72% during 1962-1993 time period, with an annual average share of 65%. Material cost share was leveled around

65% from 1960's to early 1970's while it reached to 72% during 1972-1974. During late 1970's and 1980's it showed a decreasing trend, declining to around 59% in 1992. The labor cost share was between 20.6%-16.2% during 1962-93, with an average annual share of 18%. Labor's cost share usually experienced a declining trend, dropping from around 20% in early 1960's to around 18% during late 1980's, reflecting recent capitalization of food manufacturing. The capital cost share was between 5.2%-12.8% during period of 1962-93, averaging 8.9%. Except for the 1970's, the capital cost share showed an increasing trend, from 6% during early 1980's to 12% in the 1990's (Bureau of Labor Statistics, 1995).

The Mexican food processing sector is even more material intensive. Material cost share was around 90% during whole period of 1970-94, followed by capital (5%) and labor (4%). The relatively small share of labor cost may be due to the relatively lower wage rates in Mexico compared to those in the U.S.

The evolution of the U.S. and Mexican food processing sectors can be analyzed by looking at Table 2.1 that shows the value of shipment and its annual growth for food sector of each country over time period of 1962-1994. The average annual growth figures for selected subperiods are also given in Table 2.2 to compare the growth rates of value of shipment between two countries. In the U.S food processing, the average annual growth rate of real value of shipments was 3.03% during 1960-72 and increased to 4.09% during 1971-73. In the Mexican food manufacturing, the value of shipments grew at a higher average annual rate of 7.25% during 1971-1973. In both countries, the growth rate of value of shipment sharply dropped during 1974-82, probably reflecting effects of

Table 2.1 Real Value of Shipments (in billions of 1992 U.S. dollars) in U.S. and Mexican Food Processing Sectors

Year	U.S.	%change	Mexico	% change
1962	247.687	3.43		
1963	254.103	2.59		
1964	265.130	4.34		
1965	269.529	1.66		
1966	280.148	3.94		
1967	294.421	5.09		
1968	298.838	1.50		
1969	307.455	2.88		
1970	312.980	1.80	22.889	
1971	318.795	1.86	25.027	9.34
1972	338.794	6.27	26.027	4.00
1973	352.869	4.15	28.215	8.41
1974	354.640	0.50	32.181	14.06
1975	345.110	-2.69	35.392	9.98
1976	346.668	0.45	33.603	-5.05
1977	348.282	0.47	29.813	-11.28
1978	361.690	3.85	32.095	7.66
1979	351.381	-2.85	33.646	4.83
1980	334.158	-4.90	36.900	9.67
1981	325.547	-2.58	41.141	11.49
1982	328.739	0.98	27.519	-33.11
1983	334.762	1.83	25.803	-6.24
1984	344.261	2.84	32.114	24.46
1985	350.555	1.83	34.755	8.22
1986	372.218	6.18	27.543	-20.75
1987	375.768	0.95	26.172	-4.98
1988	387.876	3.22	31.676	21.03
1989	396.738	2.28	34.464	8.80
1990	394.593	-0.54	38.314	11.17
1991	399,886	1.34	44.852	17.06
1992	406.734	1.71	48.578	8.31
1993	415.848	2.24	54.126	11.42
1994	418.89	0.73	54.344	0.40

Source: U.S. Bureau of Census (1997), Manufacturer's Shipment, Inventories and Orders
INEGI, El Sector Alimentario (various years)

Table 2.2 Average Annual Growth in Real Value of Shipment for U.S. and Mexican Food Processing Sectors during Selected Subperiods

Period	U.S. (%change)	Mexico (% change)
1962-70	3.03	
1971-73	4.09	7.25
1974-82	-0.75	0.92
1983-88	2.81	3.62
1989-93	1.29	9.50

oil crisis in 1973. The growth rate of value of shipments in U.S. food processing sector declined from 3.29% during 1962-73 to -0.75% during 1974-82 period. In Mexico, the average annual growth rate also dropped to 0.92% during 1974-82. Between 1983-88, the annual growth rates in both countries increased to 2.81% in U.S. and to 3.62% in Mexico. After 1988, the value of shipments in food processing continued to grow at a higher average annual rate of 9.5% in Mexico, compared to 1.29% in the U.S.

Trade relationship between food sectors of two countries is also an important indicator of their performance. In the U.S. food processing sector, the exports have consistently exceeded its imports since 1991, and the exports grew more than twice as fast as imports during 1989-96 period (Handbook of North American Industry, 1998). The trade of food processing products between U.S. and Mexico grew rapidly from late 1980's until the Mexican peso crisis in 1994. In 1994, the U.S. food processing exports to Mexico rose from 1.3 billions of U.S. dollars in 1989 (accounting for 8.4% of total U.S. food processing exports in that year) to 2.4 billions of U.S. dollars in 1994 (that is 10.3% total U.S. food processing sector exports in 1994). In 1995, the U.S. exports to Mexico dropped to 1.6 millions of dollars due to the reduced Mexican demand for U.S. food sector products after 1994 peso crisis. However, almost one-half of the decrease was regained in 1996. Conversely, the U.S. is Mexico's most important trade partner, absorbing over two-thirds of Mexico's total exports. The Mexican food processing sector exports to the U.S. also grew rapidly during 1989-1996, rising from 718.7 millions of U.S. dollars (56.7% of total Mexican food manufacturing exports) to 1,218.2 millions of dollars (48.1% of total Mexican food manufacturing exports) in 1995. Overall, the U.S. food processing exports to Mexico grew at an average annual rate of 7.1% during 1989-96, while the average growth rate of Mexican food processing exports to U.S. was 12.1% during same period. The growth of U.S. food processing exports has been mostly due to increasing exports of highly processed food products. As a result of recent increases in the demand for highly processed foods, such as frozen fruits, vegetables, fruit juices and bakery products, the exports of highly processed U.S. food products grew more than 16% annually between 1989-93 period (Industrial Outlook, 1994). In 1993, the U.S. food processing sector exported 634 millions of dollar worth of highly processed food products to Mexico, 36% up from 1992. On the other hand, the exports of low processed or semi-processed U.S. food products, such as animal feed, meat, butter, cheese, flour, fats and oils, expanded at around 4% annually.

The differences in market concentration and scale of the establishments in each country are reflected in the distribution of value added according to different size of firms (Tables 2.3a and 2.3b). Table 2.3a indicates that, in 1992, the largest firms with more than five hundred employees accounted for nearly 36% of total value added in U.S. food processing sector, while they represented only 2.7% of total number of establishments in the U.S food processing. Moreover, the fifty largest U.S. food manufacturing firms accounted for 27% of total value of shipments in U.S food

Table 2.3a Distribution of Value Added in U.S. Food Processing Sector according to Employment Size, 1992

Employment Size	Establishments Number	Establishments (%)	Share in Value Added (%)
25-50	15038	72.31	8.92
51-100	2147	10.32	9.17
101-250	2139	10.29	23.55
251-500	916	4.40	22.67
>500	558	2.68	35.70
Total	20798	100	100

Source: U.S. Bureau of Census (1992), Census of Manufactures

Table 2.3b Distribution of Value Added in Mexican Food Processing Sector according to Employment Size, 1990

Employment Size	Establishments Number	Establishments (%)	Share in Value Added (%)
25-50	69	14.26	1.5
51-100	109	22.52	5.3
101-250	141	29.13	21.6
251-500	76	15.70	16.5
>500	89	18.39	55.1
Total	484	100	100

Source: Brown and Dominguez, (1994)

manufacturing in 1987 (Census of Manufacturers, Concentration Ratios in Manufacturing, 1987). Similarly, the largest firms (with more than 500 hundred employees) in Mexican food processing sector accounted for 55% of value added in food manufacturing in 1990, while this group represented only 18% of total number of establishments in that year, indicating a high degree of concentration in the Mexican food sector.

The U.S. food processing sector is characterized by a quite large number of small firms (with less than fifty employees), accounting for 72% of total number of establishments in the entire U.S. food sector, compared to 14% in Mexico. On the other hand, medium to large size firms (with employees between 101-250) in Mexican food manufacturing accounted for the highest portion (29%) of total number of establishments in Mexican food sector in 1990, compared to 10% in U.S. Overall, the share of value-added by large firms (more than 500 employees) was higher in Mexico (55.1%) than the corresponding share by large firms in U.S. (35.7%), indicating a relatively higher level of concentration in the Mexican food processing sector than in U.S. The relatively higher share of value added by small firms (less than 100 employees) in the U.S. (18.1%) than in Mexico (6.8%) is also consistent with the conclusion that the Mexican food processing sector is more concentrated than the U.S. food processing sector.

2.2 Studies of Productivity Growth in the U.S and Mexican Food Processing Sectors

In the literature, there is no previous study that compares the productivity levels of the U.S. and Mexican food processing sectors. On the other hand, several single country studies analyzed the productivity growth in the U.S. food processing sector. Since the methodology used for measuring productivity and time period of analyses are different across these studies, there has been no consensus on the level of productivity growth in food processing sector.

Table 2.4 summarizes the previous studies measuring productivity growth rates in the U.S. Heien (1983) analyzed the total factor productivity in U.S. food processing and distribution sector during 1950-1977 time period. Heien employed a growth accounting approach in measuring Total Factor Productivity (TFP), using Tornqvist indexing. He found that TFP growth averaged at 0.074 % during 1950-72 period while it dropped to -0.418% during 1972-77. Between 1950-1977, the average annual TFP growth rate was 0.007 %. Heien suggested that the sharp drop in TFP growth rate during 1972-77 might have been caused by higher energy costs, the increase in environmental and safety regulations and the erratic nature of monetary and fiscal policy practices during this later subperiod.

Jorgenson, Gollop and Fraumeni (1987) measured total factor productivity growth rate in the U.S. economy at both aggregate and SIC two-digit sector levels during 1948-1979. Their measure of TFP growth for the food processing sector was based on estimation of a translog production function, in which output is defined as a function of capital, labor, materials and technology variable (time). They found that the average annual rate of TFP growth in food manufacturing sector was 1.31 % during whole study period of 1948-1979. Annual figures of TFP growth rate were mixed in sign, indicating both declines and increases in TFP growth rate. The figures for the selected subperiods can be seen in Table 2.4. The trend in the figures of TFP growth rate for selected subperiods suggests a continuous decline, from 3.98% during 1948-53 to -3.35% during 1969-73, while it rose to 2.19% during 1973-79.

According to a study by Rao and Lempriere (1990) that compares the productivity levels of the U.S. and Canadian food processing sector, the average annual rate of total factor productivity growth was 0.75% during 1962-1985 time period (reported in Hazeldine, 1991).

Table 2.4 Studies of Productivity Growth in the U.S. Food Manufacturing Sector

Author	Study period	Methodology	Industrial Scope	Average Annual Productivity Growth Rate
Helen (1983)	1950-1977	Growth accounting approach by using Tornqvist indexing to construct the index of total factor productivity	Food manufacturing and distribution sector	1950-72......0.074% 1972-77.....-0.418% 1950-77......0.007%
Jorgenson, Gollop and Fraumeni, (1987)	1948-1979	Econometric approach: estimation of a production function	Food manufacturing as a part of economy-wide analysis	1948-53.....3.98% 1953-57.....3.90% 1957-60.....1.42% 1960-66.....0.21% 1966-69....-0.01% 1969-73....-3.35% 1973-79.....2.19% 1948-79.....1.31%
Rao and Lemprlere (1990)	1962-1985	Bilateral comparison of productivity in U.S. and Canadian food sectors. Productivity is defined as total factor productivity	Food manufacturing	1962-85.....0.75%
Gullickson (1995) Bureau of Labor Statistics	1949-1992	Growth accounting approach by using Tornqvist indexing to construct total factor productivity index.	Food manufacturing as a part of overall manufacturing sector analysis	1949-73....1.0% 1973-79....0.2% 1979-92....0.6% 1949-92....0.8%
Morrison (1997)	1965-1991	Econometric approach. A flexible cost function incorporating subequilibrium in capital markets and economies of scale is estimated. TFP growth is measured in terms of both output-side and cost-side rates of technological change	Food manufacturing sector	**Output-side** 1965-72 1.082% 1972-77 -0.526% 1977-82 2.188% 1982-87 0.547% 1987-91 -0.142% 1965-91 0.785%

The Office of Productivity and Technology of Bureau of Labor Statistics also establishes its own estimates of TFP growth. Gullickson (1995, Bureau of Labor Statistics, BLS) revised and extended these estimates to cover 1949-1992 time period for SIC two digit manufacturing sectors. TFP is defined as the difference between growth rate of gross output and weighted growth rates of capital, labor, energy and material inputs, using Tornqvist indexing. The results indicate an average annual TFP growth rate of 0.8% between 1949-1992. The figures for the subperiods show that TFP growth rate dropped from 1.0% during 1949-73 to 0.2% during 1973-79. From 1979 to 1992, TFP growth rate rose again to 0.6%.

In the most recent study, Morrison (1997) measured TFP growth during 1965-1991 using an econometric approach. She estimated a flexible dual cost function that incorporates the effects of disequilibrium in capital markets and capital adjustment costs, and allowed the isolation of scale effects from productivity changes. TFP growth is measured in terms of both output-side rate of technological change and dual cost-side rate of technological change. On the cost side, Morrison found an average annual TFP growth rate of 0.734% over the entire study period. The figures for the selected periods indicate a decline, from 1.008% during 1965-72 to -0.49% during 1972-77. During 1977-82, it rose to 2.096% while it declined again to 0.514% during 1982-87. During the most recent subperiod it was -0.13%. Output-side measures, which include also the scale effects, are quite similar to cost-side measures. Overall, Morrison concluded that the little productivity growth might be attributed to disequilibrium in capital markets, probably because of the small cost share of capital, or scale economies. Also, due to the its large cost share and the large growth rate, materials are found to have significant impact on the total factor productivity measures.

Only one study measures TFP growth in Mexican food processing sector. Brown and Dominguez (1994) analyzed TFP in the Mexican food processing sector during 1984-1990, as a part of a larger whole manufacturing wide investigation. They employed the Kendrick index based on a non-parametric approach to measure the TFP growth. Their Kendrick index is based on a production process that reflects the relationship between value added and inputs (labor and capital), and TFP growth is defined as the growth rate of output that is not explained by the growth rate of total inputs. However, their measure of TFP ignores the effects of materials and economies of scale on productivity since it is based on the assumption of constant returns to scale and contribution of materials to production process is ignored. Their results indicate that total factor productivity in Mexican food processing declined during 1984-87 and it sharply increased during 1987-90. The average annual TFP growth rate was -2.0% during 1984-87 while it jumped to high 11.6% during later subperiod of 1987-90. During whole study period it was 4.6% with a quite high standard deviation of 4.3. During 1984-90, subsectors with highest growth rates were processed animal food (11.7%), processed fruit and vegetables (9.7%), meat and dairy products (8.4%), and other food products (6.9%), while milled flour and associated products, and soft drink sectors had lowest growth rates (-1.5% and 0.3%, respectively). According to "Annual Industrial Survey", which was used as the data source for computation of Kendrick index of TFP, there was a significant reduction (-2.5%) in the growth rate of capital assets in Mexican food manufacturing during 1984-90. Brown and Dominguez argued that this significant reduction in growth rate of capital assets might explain the significant increase in TFP growth during the later years of study period. This study also analyzes how productivity growth rate in the Mexican food processing sector was differentiated across the firms with different sizes. According to their five size classifications (small: 25-50 employees, medium: 51-100 employees, large:101-250 employees, very large: 251-500 employees, and huge: more than 500), the highest TFP growth rate was achieved by large firms (6.4%), which is made up by 29.1% of total establishments and accounts for the 21.6 % of total value added in whole food sector. The second and third highest rates were achieved by huge firms (5.2%) and by very large firms (4.2%), respectively. Small and medium firms experienced the lowest growth rates (-3.0% and -2.3%, respectively).

CHAPTER 3: THEORETICAL FRAMEWORK

The productivity growth can occur in two ways: i) through the improvements in scale efficiency and ii) through the improvements in the state of technology (i.e. technological change) (Antle and Capalbo, 1988).

In this study, technical efficiency is assumed, implying that maximum level of output is produced with a given level of inputs and state of technology so that the industry operates on its production frontier. Technological change represented by the shift of production function can be achieved in two ways: through embodied technological change and through disembodied technological change. The disembodied technological change is defined as the increases in output as a result of improved methods of using existing resources and inputs. This definition implies that technological change does not require new type of inputs. In this study, the definition of disembodied technological change will be used. On the other hand, the embodied technological change represents the increases in output level through introduction of new inputs and changes in input quality, and hence, it implies changes both in the form of production technology and in the input bundle over time (Chambers, 1988, p:205).

The fundamental concept in measuring the productivity growth is total factor productivity (TFP), which is the ratio of an index of aggregate output to an index of aggregate input. TFP growth can be measured in two alternative forms: i) as the output growth induced by the increases in state of technology, holding input levels fixed (primal side measure) ii) as the profit growth induced by increase in state of technology, holding input and output prices constant (dual profit side measure). Under the assumptions of constant returns to scale, long-run equilibrium in all input levels and perfect competition, the primal and dual methods of measuring TFP growth will be equal to each other. However, when there exist varying returns to scale and disequilibrium in some quasi-fixed inputs, the dual measure may differ from the primal measure due to the economies of scale and varying capacity utilization of quasi-fixed inputs.

3.1 Measurement of Technological Change

3.1.1 Primal Measure of Rate of Technological Change

The derivation of the primal measure of rate of technological change requires postulating an aggregate production function as:

$$Y = Y(X, t) \tag{3.1}$$

where Y is total output, $X=(X_1,X_2,\ldots,X_n)$ is the vector of inputs used in production and t is the time variable which is a proxy for the state of technology. The primal rate of technological change can be derived from (3.1) by taking natural logarithm of both sides and differentiating with respect to time as following:

$$\frac{d\ln Y}{dt} = \frac{1}{Y}\left[\frac{\partial Y}{\partial t} + \sum_{i=1}^{n}\frac{\partial Y}{\partial X_i}\frac{dX_i}{dt}\right]$$

$$\frac{d\ln Y}{dt} = \frac{\partial \ln Y}{\partial t} + \frac{1}{Y}\left[\sum_{i=1}^{n}\frac{\partial Y}{\partial X_i}\frac{dX_i}{dt}\right] \tag{3.2}$$

The term, $\varepsilon_{Yt} = \partial \ln Y / \partial t$, represents the primal measure of rate of technological change. Under the assumptions of perfect competition in output and input markets, and the profit maximizing behavior, first order conditions from profit maximization imply that price of output is equal to marginal cost (P=MC, where P is the output price) and input prices are equal to the value of their marginal products ($W_i = P^* \partial Y/X_i$, where W_i is the price of input *i*). The substitution of these first order conditions into (3.2) and rearranging the terms give the primal rate of technological change as:

$$\varepsilon_{Yt} = \frac{\partial \ln Y}{\partial t} = \frac{d \ln Y}{dt} - \sum_i S_i^R \frac{d \ln Xi}{dt} \tag{3.3}$$

where $S_i^R = \frac{1}{Y}\left[\frac{\partial Y}{\partial Xi}\right] X_i = \frac{W_i X_i}{PY}$ is the cost share of i^{th} input in total revenue.

According to equation (3.3), the primal rate of technological change is defined as the total rate of change in output less the contribution to this change accounted for by the share weighted rates of change in inputs.

An equivalent expression for the primal rate of technological change can be obtained by substituting the first order conditions from cost minimization problem ($\partial C/\partial Y$=MC=P and W_i= P $^*\partial Y/\partial X_i$) into equation (3.3) as:

$$\varepsilon_{Yt} = \frac{\partial \ln Y}{\partial t} = \frac{d \ln Y}{dt} - \left(\frac{\partial \ln C}{\partial \ln Y}\right)^{-1} \sum_{i=1}^{n} S_i^C \frac{d \ln X_i}{dt} \tag{3.4}$$

where $S^C_i = W_i X_i / \Sigma W_i X_i$ is the cost share of input *i* in total cost and $\partial \ln C/\partial \ln Y$ is the elasticity of cost with respect to output. In equation (3.4), the primal measure of technological change, ε_{Yt}, is expressed as the rate of change in output minus a scale adjusted index of rate of change in inputs (Antle and Capolbo, 1988, p:35).

3.1.2 Dual Measure of Rate of Technological Change

The rate of technological change can also be measured by using a dual profit function framework. The dual measure of technological change derived from a profit function gives the rate of profit growth induced by improvements in the state of technology, holding input and output prices fixed.

In the production function framework, the production function models only the physical relationship between quantities of inputs and output. However, the use of profit function enables us to incorporate the effects of changes in input prices and the changes in output price on input demands and output supply, and in turn, on productivity growth measures (Jayne et al., 1994).

Under the assumption of profit maximizing behavior, the duality theory states that for a well behaved production function there exists a well behaved profit function with certain properties (Lau, 1978). The profit function dual to a production function is defined as:

$$H = H(P, W, t) \tag{3.5}$$

where H is the total profit, $W=(W_1,W_2,\ldots,W_n)$ is the vector of input prices and P is the output price. The dual measure of rate of technological change is derived by first taking logarithm of both sides of (3.5) and differentiating it with respect to time as follows:

$$\frac{d\ln H}{dt} = \sum_i \frac{\partial \ln H}{\partial \ln Wi}\frac{d\ln Wi}{dt} + \frac{\partial \ln H}{\partial \ln P}\frac{d\ln P}{dt} + \frac{\partial \ln H}{\partial t} \tag{3.6}$$

where $\varepsilon_{Ht} = \partial \ln H/\partial t$ represents the dual rate of technological change derived from a profit function.

Under the assumption of profit maximization and perfect competition, Hotelling's Lemma gives the profit maximizing levels of input demand and output supply (Lau, 1978):

$$\frac{\partial H(P,W,t)}{\partial W_i} = -X_i^*(P,W,t) \quad \text{and} \quad \frac{\partial H(P,W,t)}{\partial P} = Y^*(P,W,t) \tag{3.7}$$

where $X_i^*(P,W,t)$ and $Y^*(P,W,t)$ represent the profit maximizing levels of input demands and output supply, respectively. Then, the factor cost shares in total profit, S_i^P, and share of revenue in total profit, S_Y^P, can be defined as following:

$$S_i^P = \frac{\partial \ln H}{\partial \ln W_i} = \frac{\partial H}{\partial W_i}\frac{W_i}{H} = -\frac{X_i W_i}{H} \quad \text{for each input i and}$$
$$S_y^P = \frac{\partial \ln H}{\partial \ln P} = \frac{\partial H}{\partial P}\frac{P}{H} = \frac{YP}{H} \tag{3.8}$$

The substitution of equation (3.8) into (3.6) yields the following expression for the dual rate of technological change:

$$\varepsilon_{Ht} = \frac{\partial \ln H}{\partial t} = \frac{d\ln H}{dt} - \sum_i S_i^P \frac{d\ln W_i}{dt} - S_y^P \frac{d\ln P}{dt} \tag{3.9}$$

The equation (3.9) shows that the profit side dual rate of technological change is equal to the total rate of change in profit minus the rate of changes in input prices weighted by corresponding factor cost shares in profit minus the rate of change in output price weighted by the share of revenue in profit. There is no assumption of CRTS in equation (3.9).

To find the relationship between ε_{Ht} and ε_{Yt}, total profit defined as H= PY - $\Sigma W_i X_i$ is differentiated with respect to time as following:

$$\frac{d\ln H}{dt} = S_Y^P \frac{d\ln P}{dt} + S_Y^P \frac{d\ln Y}{dt} + S_i^P \frac{d\ln W_i}{dt} + S_i^P \frac{d\ln X_i}{dt} \tag{3.10}$$

in which expressions in equations (3.8) and (3.9) are used. Then, the substitution of (3.10) into (3.9) gives:

$$\varepsilon_{Ht} = \frac{\partial \ln H}{\partial t} = S_Y^P \frac{d\ln Y}{dt} + \sum_i S_i^P \frac{d\ln X_i}{dt} \tag{3.11}$$

After factoring out the term $S_Y^P = \frac{\partial \ln H}{\partial \ln P}$, at right hand side of equation (3.11), it becomes:

$$\varepsilon_{Ht} = \frac{\partial \ln H}{\partial t} = \left[\frac{d\ln Y}{dt} - \sum_i S_i^R \frac{d\ln X_i}{dt}\right]\frac{\partial \ln H}{\partial \ln P}$$

$$\varepsilon_{Ht} = \varepsilon_{Yt}\left(\frac{\partial \ln H}{\partial \ln P}\right) \tag{3.12}$$

where the expression in parenthesis is equal to the primal rate of technological change given in equation (3.3). The equation (3.12) shows that ε_{Ht} and ε_{Yt} are equal to each other only if the share of revenue in total profit is equal to 1.

3.2 The Effects of Short-Run Equilibrium

In derivations of rate of technological change in section (3.1), I assumed that firms instantaneously adjust all input levels to their long-run (LR) equilibrium levels as a response to changes in their market prices. Therefore, no distinction is made between the short-run and long-run, and firms are assumed to operate at their LR equilibrium levels (Morrison, 1986, p:51). However, firms may not be able to instantaneously adjust some of their inputs, such as capital, due to the institutional rigidities, credit issues, physical immobility of input changes or regulatory restrictions (Squires, 1987, p:559). When input levels are not instantaneously adjusted, the observed prices of such inputs do not reflect their true marginal contribution to production, causing disequilibrium in those quasi-fixed input markets. Therefore, the measure of technological change should be adjusted to reflect these effects of disequilibrium. This adjustment requires the representation of true marginal contributions of quasi-fixed inputs by reevaluating them at their shadow prices (that are derived from a short-run profit function) rather than at their observed market prices (Morrison, 1992, p:384). Hence, a short run framework is derived in following section in order to correct the measures of technological change for the disequilibrium in capital markets.

In the short run framework, a restricted (short-run) profit function defined as:

$$HR = HR\,(P, W, K, t) \qquad (3.13)$$

where HR is the restricted profit that is equal to revenue minus cost of variable inputs, W is the vector of variable input prices, P is the output price, and K is the observed level of quasi fixed input capital (assumed to be fixed in short run but variable in long run). Firms are assumed to be in short-run equilibrium with respect to variable inputs conditional on K. Then, total short run profit defined as the restricted profit minus observed cost of quasi-fixed input capital is expressed as:

$$H\,(P, W, K, W_K, t) = HR\,(P, W, K, t) - W_K K \qquad (3.14)$$

where W_K is the observed market price of quasi-fixed capital.

The shadow price of quasi-fixed input that will be used in reevaluation of its marginal product can be found by taking the partial derivative of restricted profit function with respect to observed quantity of quasi fixed input (Lau, 1978):

$$Z_k = \frac{\partial HR(P, W, K, t)}{\partial K} \tag{3.15}$$

Then, total shadow profit function is defined as:

$$H^* (P, W, K, Z_K, t) = HR (P, W, K, t) - Z_K K \tag{3.16}$$

In the short run framework where there exists disequilibrium in capital markets, the derivation of the profit side dual rate of technological change requires differentiation of equation (3.14) with respect to time as follows:

$$\frac{d \ln H}{dt} = \sum_i \frac{\partial \ln H}{\partial \ln W_i} \frac{d \ln W_i}{dt} + \frac{\partial \ln H}{\partial \ln P} \frac{d \ln P}{dt} + \frac{\partial \ln H}{\partial t} + \frac{(Z_K - W_K) K}{H} \frac{d \ln K}{dt} - \frac{W_K K}{H} \frac{d \ln W_k}{dt}$$

$$\text{where } \varepsilon_{HK} = \frac{\partial \ln H}{\partial \ln K} = \left(\frac{\partial HR}{\partial K} - W_K \right) \frac{K}{H} = \frac{(Z_K - W_K) K}{H} \tag{3.17}$$

Then, the short run dual measure of technological change, ε_{Ht}^{SR}, can be written as:

$$\varepsilon_{Ht}^{SR} = \frac{\partial \ln H}{\partial t} = \frac{d \ln H}{dt} - \sum_i S_i^P \frac{d \ln W_i}{dt} - S_Y^P \frac{d \ln P}{dt} - \frac{(Z_K - W_K) K}{H} \frac{d \ln K}{dt} + \frac{W_K K}{H} \frac{d \ln W_K}{dt} \tag{3.18}$$

The equation (3.18) shows that profit side dual rate of technological change is the rate of change in short run total profit that is not accounted for by the rate of changes in variable input prices, output price, observed level of quasi-fixed input and quasi-fixed input market price.

An equivalent expression for ε_{Ht}^{SR} can be derived by first taking the derivative of short run total profit defined as $H = PY - \Sigma W_i X_i - W_K K$ with respect to time and substituting it into equation (3.18). That is:

$$\varepsilon_{Ht}^{SR} = \frac{\partial \ln H}{\partial t} = \frac{PY}{H}\left[\frac{d\ln Y}{dt} - \sum_i \frac{W_i X_i}{PY}\frac{d\ln X_i}{dt} - \frac{Z_k K}{PY}\frac{d\ln K}{dt}\right] \qquad (3.19)$$
$$= \frac{PY}{H}\varepsilon_{Yt}^{SR}$$

where the term inside brackets represents the primal measure of technological change, ε_{Yt}^{SR}, when there exists disequilibrium in capital markets. The equation (3.19) shows that dual rate of technological change based on short run total profit function can also be expressed as the difference between share weighted rate of change in output level and the share weighted rates of change in input levels.

Moreover, the relationship between ε_{Ht}^{SR} in equation (3.19) and ε_{Ht} (derived based on LR profit function in section 3.1.2) can be expressed after adding and subtracting the share of quasi fixed factor cost in revenue and rearranging terms in (3.19) as follows:

$$\varepsilon_{Ht}^{SR} = \frac{PY}{H}\left[\frac{d\ln Y}{dt} - \sum_i \frac{W_i X_i}{PY}\frac{d\ln X_i}{dt} - \frac{W_K K}{PY}\frac{d\ln K}{dt}\right] - \frac{(Z_K - W_K)K}{H}\frac{d\ln K}{dt}$$

$$= \frac{PY}{H}\varepsilon_{Yt} - \varepsilon_{HK}\frac{d\ln K}{dt}$$
$$= \varepsilon_{Ht} - \varepsilon_{HK}\frac{d\ln K}{dt} \qquad (3.20)$$

where $\varepsilon_{Ht} = \varepsilon_{Yt}\left(\frac{\partial \ln H}{\partial \ln P}\right)$ according to equation (3.12).

In the long run, $\varepsilon_{HK}=0$ since shadow price of capital (Z_K) is equal to market price of capital (W_K), so ε_{Ht}^{SR} and ε_{Ht} will be equal to each other in the long run.

Furthermore, the dual rate of technological change is corrected for the effects of disequilibrium in capital markets by dividing short-run dual rate of technological change, ε_{Ht}^{SR}, in equation (3.19) into a ratio of total shadow profit to short run total profit, H*/H. Then, the equation (3.19) becomes:

$$\varepsilon_{Ht}^{A} = \frac{\varepsilon_{Ht}^{SR}}{\left(\frac{H^*}{H}\right)} = \frac{PY}{H*}\frac{d\ln Y}{dt} - \sum_i \frac{W_i X_i}{H*}\frac{d\ln X_i}{dt} - \frac{Z_k K}{H*}\frac{d\ln K}{dt} \tag{3.21}$$

where ε_{Ht}^{A} represents the dual rate of technological change corrected for the effects of disequilibrium in capital markets. In equation (3.21), the all of the shares are adjusted by reevaluating capital at its shadow price rather than its observed market price in order to incorporate the effects of disequilibrium.

Finally, in order to derive the relationship between the dual rate of technological change corrected for disequilibrium effects, ε_{Ht}^{A}, and the corresponding primal rate of technological change corrected for disequilibrium effects, logarithmic derivative of production function defined as Y = Y (X, K, t) with respect to time is taken as follows:

$$\frac{d\ln Y}{dt} = \frac{\partial \ln Y}{\partial t} + \sum \frac{\frac{\partial Y}{\partial X_i}X_i}{Y}\frac{d\ln X_i}{dt} + \frac{\frac{\partial Y}{\partial K}K}{Y}\frac{d\ln K}{dt} \tag{3.22}$$

Recalling that first order conditions from cost minimization require that $P\frac{\partial Y}{\partial X_i} = W_i$ and,

$P\frac{\partial Y}{\partial K} = Z_K$ and rearranging terms in (3.22) yields:

$$\frac{\partial \ln Y}{\partial t} = \frac{d\ln Y}{dt} - \sum \frac{W_i X_i}{PY}\frac{d\ln X_i}{dt} - \frac{Z_K K}{Y}\frac{d\ln K}{dt} \tag{3.23}$$

After dividing and multiplying each term at the right hand side of (3.23) by

$\frac{\partial \ln H^*}{\partial \ln P} = \frac{PY}{H^*}$ to get the expression of ε_{Ht}^{A} at the right hand side, (3.23) becomes:

$$\varepsilon_{Yt}^{A} = \frac{\partial \ln Y}{\partial t} = \frac{H^*}{PY}\left[\frac{PY}{H*}\frac{d\ln Y}{dt} - \sum_i \frac{W_i X_i}{H*}\frac{d\ln X_i}{dt} - \frac{Z_k K}{H*}\frac{d\ln K}{dt}\right]$$

$$= \left(\frac{\partial \ln H^*}{\partial \ln P}\right)^{-1} \varepsilon_{Ht}^{A} \qquad (3.24)$$

where $\frac{\partial \ln H^*}{\partial \ln P} = \frac{PY}{H^*}$ (see the appendix B for the derivation).

3.3 Approaches for Measurement of Productivity Growth

3.3.1 Growth Accounting Approach

The fundamental concept in this approach is that, given technological change, the growth in output would not be explained by only the growth in total inputs, and there would remain a "residual" output, that is not explained by growth in total inputs, reflecting productivity growth (Antle and Capalbo, 1988).

The growth accounting approach requires the construction of aggregate indexes of output and total inputs, and using them to calculate a total factor productivity (TFP) index. Construction of these aggregate indexes involves choosing an indexing method that implies certain economic assumptions about underlying production technology.

Several early studies of productivity growth used Laspeyres, Paasche or Geometric indexing procedures to construct aggregate quantity indexes for total inputs, in which factor prices assigned as weights to corresponding inputs remained as quasi-fixed relative to a base year[1] (Sudit and Finger, 1981). These indexes have been shown to be exact for certain aggregator functions, imposing several restrictions on underlying production technology. Laspeyres or Paasche indexes implies either linear production function with perfect substitutability of all inputs or Leontief production function where all inputs are used in fixed proportions. Also, the geometric index implies a Cobb-Douglas production function (Antle and Capalbo, 1988). Furthermore, these indexing methods might result in possible aggregation biases since the underlying assumption that components of an aggregate vary proportionally would not hold for the most of the industrial productions (i.e., most of the industrial production functions are characterized by varying factor intensity as a result of substitutions between inputs over time) (Sudit and Finger, 1981). Also, Fisher's reversal rule (product of factor price and quantity indexes should yield the total cost ratio between two periods) is not satisfied by the above indexing methods.

To avoid restrictions imposed by above methods, a more flexible Divisia index has been used in later studies of productivity. Divisia index has been shown to satisfy Fisher's reversal rule. It also exhibits reproductive property (a discrete divisia index of discrete divisia indexes is a discrete divisia index of the components) which is important

---

[1] A Laspeyres quantity index is defined as $Y_L(P^t, P^0, Y^t, Y^0) = \frac{\sum_i P_i^t Y_i^0}{\sum_i P_i^t Y_i^t}$, that is a weighted aggregate quantity index where weight for each item (Y_i) is its current period price (P_i^t). A Paasche quantity index is defined as

$$Y_L(P^t, P^0, Y^t, Y^0) = \frac{\sum_i P_i^0 Y_i^0}{\sum_i P_i^0 Y_i^t}$$

, that is a weighted aggregate quantity index where weights for each item is its base year price (P_i^0). Geometric index is defined as the square root of the product of Laspeyres and Paache indexes.

when aggregate variables are constructed by aggregation of subaggregates (Sudit and Finger, 1981).

Using the definition of TFP as a ratio of index of output to an index of total inputs, TFP growth is given by:

$$\dot{TFP} = \dot{Y} - \dot{X} \tag{3.25}$$

where $\dot{Y} = dY/dt$ is the growth rate of output and $\dot{X} = dX/dt$ is the growth rate of total inputs. Using divisia indexes to specify the forms for $\dot{Y}$ and $\dot{X}$ gives the following expressions:

$$\dot{Y} = \sum_j \frac{P_j Y_j}{\sum P_j Y_j} \dot{Y}_j \tag{3.26a}$$

$$\dot{X} = \sum_i \frac{W_i X_i}{\sum W_i X_i} \dot{X}_i \tag{3.26b}$$

where cost shares are used as weights in (3.26b) under cost minimizing assumption. Substitution of (3.26a) and (3.26b) into (3.25) yields the divisia index for TFP growth rate as:

$$\dot{TFP} = \sum_j \frac{P_j Y_i}{\sum P_j Y_j} \dot{Y}_j - \sum_i \frac{W_i X_i}{\sum W_i X_i} \dot{X}_i \tag{3.27}$$

The comparison of (3.27) with the definition of primal rate of technological change, ε_{Yt}, derived in section (3.1.1) reveals that expression for TFP growth in (3.27) will be equivalent to ε_{Yt}, only when production function is characterized by constant returns to scale. However, under the assumption of profit maximizing behavior for firms, the following divisia index for total inputs is used:

$$\dot{X} = \sum_i \frac{W_i X_i}{PY} \dot{X}_i \tag{3.28}$$

in which shares of factor costs in revenue instead of total cost are used as weights. The comparison of ε_{Yt} with divisia index for TFP growth based on above divisia input index reveals that they are equivalent to each other even if production function does not exhibit constant returns to scale.

Computation of expression in (3.27) requires continuous time series data on output and input price, and on output and input quantities. Since most of the economic data are in discrete form, discrete approximation of divisia indexes are required. Then, the use of a widely common Tornqvist approximation to divisia indexes, which is exact for homogenous translog production function, yields the following approximation for TFP growth index:

$$TFP = \sum_j 1/2(S_{jt} + S_{j,t-1})(\ln Y_{jt} - \ln Y_{j,t-1}) - \sum_i 1/2(S_{it} + S_{i,t-1})(\ln X_{it} - \ln X_{i,t-1}) \tag{3.29}$$

where the first term at the right hand side of (3.29) is the Tornqvist approximation to divisia output index and the second is the Tornqvist approximation to divisia input index.

In sum, the use of expression for TFP growth rate in (3.29) derived under growth accounting approach to approximate the rate of technological change requires the following assumptions on the underlying production technology: competitive output and input markets, constant returns to scale when cost minimization is assumed, input-output separability, and neutrality of technological change (Antle and Capalbo, 1988).

3.3.2 Econometric Approach

The econometric approach to productivity measurement involves the econometric estimation of the underlying production technology. Underlying production technology can be determined through either direct estimation of a production function or estimation of a dual cost or profit function using duality theory. As opposed to the growth accounting approach, the econometric estimation of production technology allows us to test for the substitution possibilities among inputs, separability of inputs and output, as well as neutrality of technological change rather than priori imposition of them. Also, the assumption of constant returns to scale can be relaxed and the effects of temporary disequilibrium in some inputs can be incorporated into the measure of technological change.

In this study, a dual profit function is used to represent the production technology. The econometric model involves the estimation of a system of equations consisting of a profit function and its associated share equations derived as the derivatives of the profit function. A flexible functional form for the profit function, in which profit is defined as a function of exogenous input and output prices, time, and a set of unknown parameters, is chosen. An appropriate estimator is used and certain statistical assumptions about random errors are established to estimate the set of unknown parameters. The detailed discussion of the econometric model and the estimation procedures used in this study are discussed in the Chapter 4.

CHAPTER 4: EMPIRICAL MODEL

In this study, separate aggregate profit functions are estimated to approximate the production technologies of U.S. and Mexican food industries. One of the advantages of estimating a dual profit function rather than a dual cost function is that output level is endogenous to the model. The profit function framework allows us to estimate the profit maximizing level of output supply as well as profit maximizing levels of factor demands. In contrast, with cost function framework where output is exogenous and not necessarily equal to its profit maximizing level, the adjustment of output level to the changes in factor prices and technology over time is ignored (Squires, 1988 and Lopez, 1985). In profit function framewok, there is no need to use endogenous variables for output, so the econometric problems of simultaneous equations are avoided.

4.1 Selection of Functional Form

A functional form must be chosen in order to construct an empirical model that represents production technologies of food industries of two countries. In the literature, a number of alternative flexible functional forms (FFF) are available. However, the results of the several studies do not conclude that any of these FFF's is unequivocally superior with respect to all theoretical and empirical criteria (Lopez, 1985 and Quiroga, 1992).

A previous analysis of several FFF's has shown that some of the FFF's impose stronger priori restrictions on underlying production technology than some of others. Linear FFF's, such as generalized Leontief and normalized quadratic, are shown to impose quasi-homotheticity and seperability restrictions while non-linear FFF's, such as translog form, do not impose them. However, when additional considerations are taken into account, (i.e., convexity and monotonicity requirements) some forms of FFF's can be seen superior to translog form. The normalized quadratic satisfies regulatory restrictions (convexity) globally while Translog form can not do so. In sum, when translog and some other forms are compared, there is a trade-off between ability of representing more complex technologies and the verification of global satisfaction of regulatory conditions.

The functional form chosen for a profit function should be consistent with the properties of a well behaved profit function at least within the range of data (Lau , 1978 chapter II.1 in Fuss, McFadden and Mundlak, 1978). The profit function, H (P,W), should satisfy the following properties :

1. Monotonicity: H (P,W) is a non-decreasing function of output price and non-increasing function of input prices

2. Convexity: H (P,W) is a convex function in input and output prices

3. Homogeneity: H (P,W) is homogeneous of degree one in prices

4. Twice differentiability: H (P,W) is twice differentiable implying following conditions:

i) Hotelling's Lemma: $\frac{\partial H(P,W)}{\partial P} = Y^*(P,W)$ and $\frac{\partial H(P,W)}{\partial W_i} = -X_i^*(P,W)$

where Y* and X_i* are profit maximizing levels of output supply and input demands, respectively.

ii) Symmetry of second partial derivatives of total profit with respect to output and input prices.

Similarly, a restricted profit function, HR (P,W,K), should satisfy the following properties:

1.Monotonicity: HR (P,W,K) is a non-decreasing function of output price, non-increasing function of variable input prices and non-decreasing function of quasi fixed input levels.

2. Convexity: HR (P,W,K) is convex in variable input prices and output price.

3. Concavity: HR (P,W,K) is concave in quasi-fixed input levels.

4. Homogeneity: HR (P,W,K) is homogenous of degree one in variable input prices and output price.

5. Twice differentiability: HR (P,W,K) is twice differentiable, implying following conditions:

i) Hotelling's Lemma:

$$\frac{\partial HR(P,W,K)}{\partial P} = Y^* \quad \frac{\partial HR(P,W,K)}{\partial W_i} = -X_i^* \text{ and } \frac{\partial HR(P,W,K)}{\partial K} = Z_K$$

where Z_k is shadow price of quasi fixed input and Y^* and X^*_i are as defined before.

ii) Symmetry of second partial derivatives of restricted profit with respect to output and variable input prices, and levels of quasi-fixed input.

4.2 Translog Profit Function

The transcendental logarithmic function (translog) form is chosen to represent the aggregate profit functions of food processing sectors of each country. Translog is a non-linear flexible functional form that provides a local second order approximation to any arbitrary twice differentiable profit function (Chambers, 1988). The translog form does not impose restrictions of homotheticity and returns to scale on underlying production technology due to its flexible nature. However, it does not globally satisfy the regularity conditions, and hence, these conditions will be checked locally. Finally, being in linear in parameters, the translog form mathematical computations easier and provides us with intuitive interpretations of parameters.

4.2.1 Unrestricted Translog Profit Function Model

Under the assumptions of profit maximizing behavior of producers and competitive input and output markets, the unrestricted profit function is defined as a function of exogenous output price and input prices, and time as following:

$$H = H(P, W_L, W_M, W_K, t) \qquad (4.1)$$

where W_L, W_M and W_K are exogenous prices for labor, material and capital, respectively, P is the exogenous output price and H is total profit defined as revenue minus total cost. Then, the unrestricted translog profit equation can be written as follows:

$$\begin{aligned} \ln H = {} & a0 + ay * \log(P) + al * \log(W_L) + am * \log(W_M) + ak * \log(W_K) + at * t \\ & + 0.5 * ayy * (\log(P))^2 + 0.5 * all * (\log(W_L))^2 + 0.5 * amm * (\log(W_M))^2 \\ & + 0.5 * akk * (\log(W_K))^2 + 0.5 * att * t^2 + aly * \log(W_L) * \log(P) \\ & + alm * \log(W_L) * \log(W_M) + alk * \log(W_L) * \log(W_K) + ayk * \log(P) * \log(W_K) \\ & + amk * \log(W_M) * \log(W_K) + amy * \log(W_M) * \log(P) + ayt * \log(P) * t \\ & + alt * \log(W_L) * t + amt * \log(W_M) * t + akt * \log(W_K) * t \qquad (4.2) \end{aligned}$$

where a0, a_i and a_{ij} i,j=L,M,K,Y,t represent the parameters to be estimated.

Symmetry and linear homogeneity of profit function in prices imply following restrictions on equation (4.2):

$$aij = aji \ , \quad \text{for all i, j} \qquad i, j = L, M, K, Y, t \qquad \text{(symmetry)}$$

and

$$ay + al + am + ak = 1 \qquad \text{(hom ogeneity)}$$
$$ayy + aly + amy + ayk = 0$$
$$all + aly + alm + alk = 0$$
$$akk + amk + alk + ayk = 0$$
$$amm + alm + amy + amk = 0$$
$$ayt + alt + amt + akt = 0 \qquad (4.3)$$

Differentiation of (4.2) with respect to logarithm of input and output prices and using Hotelling's Lemma yield the following system of share equations:

$$S_L^P = al + all * \log(W_L) + aly * \log(P) + alm * \log(W_M) + alk * \log(W_K) + alt * t$$
$$S_M^P = am + alm * \log(W_L) + amy * \log(P) + amm * \log(W_M) + amk * \log(W_K) + amt * t$$
$$S_K^P = ak + alk * \log(W_L) + ayk * \log(P) + amk * \log(W_M) + akk * \log(W_K) + akt * t$$
$$S_Y^P = ay + aly * \log(W_L) + ayy * \log(P) + amy * \log(W_M) + ayk * \log(W_K) + ayt * t$$
$$(4.4)$$

where S_i^P's i=L,M,K are the shares of expenditure on each input in total profit and S_Y^P is the share of revenue in total profit.

Because of the cross equation restrictions (symmetry and homogeneity restrictions) imposed on unrestricted translog profit equation and associated share equations, gains in efficiency can be achieved by estimating equations in (4.2) and (4.4) jointly. A classical additive error term is added to each equation to reflect the optimization errors in profit maximizing behavior.

In the system of share equations, (4.4), the sum of dependent variables is equal to one for each observation. Hence, only three out of four share equations are linearly independent and the sum of error terms across share equations is equal to zero. This implies that covariance matrix of error terms is singular. In order to handle this singularity problem, one of the four share equations, revenue share equation, is arbitrarily dropped from (4.4) for estimation. The parameter estimates obtained after eliminating one of the share equations will be invariant to the dropped equation as long as maximum-likelihood estimation techniques are used (Berndt, 1991, p: 472).

4.2.2 Restricted Translog Profit Function Model

Under the assumptions of profit maximizing behavior and competitive pricing in output and input markets, the restricted profit function is defined as a function of exogenous output price and variable input prices, quantity of quasi-fixed input capital, and time as follows:

$$HR = HR(P, W_L, W_M, K, t) \tag{4.5}$$

where HR is the restricted profit which is equal to revenue minus cost of variable inputs, and K is the quantity of quasi-fixed input capital. Then, the restricted translog profit equation is written as:

$$\begin{aligned}
\ln HR = {} & \alpha 0 + \alpha y * \log(P) + \alpha l * \log(W_L) + \alpha m * \log(W_M) + \alpha k * \log(K) + \alpha t * t \\
& + 0.5 * \alpha yy * (\log(P))^2 + 0.5 * \alpha ll * (\log(W_L))^2 + 0.5 * \alpha mm * (\log(W_M))^2 \\
& + 0.5 * \alpha kk * (\log(K))^2 + 0.5 * \alpha tt * t^2 + \alpha ly * \log(W_L) * \log(P) \\
& + \alpha lm * \log(W_L) * \log(W_M) + \alpha lk * \log(W_L) * \log(K) + \alpha yk * \log(P) * \log(K) \\
& + \alpha mk * \log(W_M) * \log(K) + \alpha my * \log(W_M) * \log(P) + \alpha yt * \log(P) * t \\
& + \alpha lt * \log(W_L) * t + \alpha mt * \log(W_M) * t + \alpha kt * \log(K) * t
\end{aligned} \tag{4.6}$$

Symmetry and homogeneity restrictions of restricted profit function in prices imply following restrictions:

$\alpha ij = \alpha ji$, for all i, j $i, j = L, M, K, Y, t$ (symmetry)

and

$\alpha y + \alpha l + \alpha m = 1$ (hom ogeneity)

$\alpha yy + \alpha ly + \alpha my = 0$

$\alpha ll + \alpha ly + \alpha lm = 0$

$\alpha mm + \alpha lm + \alpha my = 0$

$\alpha yt + \alpha lt + \alpha mt = 0$ (4.7)

Differentiation of restricted translog profit equation in (4.6) with respect to logarithms of variable input prices and output price and the use of Hotelling's Lemma yield the following system of share equations:

$$S_L^{pr} = \alpha l + \alpha ll * \log(W_L) + \alpha ly * \log(P) + \alpha lm * \log(W_M) + \alpha lk * \log(K) + \alpha lt * t$$
$$S_M^{pr} = \alpha m + \alpha lm * \log(W_L) + \alpha my * \log(P) + \alpha mm * \log(W_M) + \alpha mk * \log(K) + \alpha mt * t$$
$$S_Y^{pr} = \alpha y + \alpha ly * \log(W_L) + \alpha yy * \log(P) + \alpha my * \log(W_M) + \alpha yk * \log(K) + \alpha yt * t \qquad (4.8)$$

where S_L^{pr} and S_M^{pr} are the shares of variable input expenditure in restricted profit and S_Y^{pr} is the share of revenue in restricted profit.

In addition, differentiation of equation (4.6) with respect to logarithm of quantity of capital gives the shadow price equation for capital:

$$\varepsilon_{HRK} = \alpha k + \alpha kk * \log(K) + \alpha lk * \log(W_L) + \alpha yk * \log(P) + \alpha mk * \log(W_M) + \alpha kt * t \qquad (4.9)$$

and shadow price of capital, Z_k, can be computed as $Z_k = \varepsilon_{HRK} * \frac{HR}{K}$.

In short run framework, the estimated system of equations consists of restricted translog profit equation in (4.6), and share equations in (4.8). Again, a classical additive error term is added to each equation to construct the statistical model. In (4.8), the sum dependent variables is equal to one and so, revenue share equation is arbitrarily dropped from (4.8) to overcome the singularity problem.

4.3 Checking for Regulatory Conditions

After estimation, the estimated translog profit equations are checked to see if the regularity conditions are satisfied at the point of approximation and at each observation

The monotonicity of unrestricted translog profit function require that profit function be non-decreasing in output price, that is, $S_Y^P = \frac{\partial \ln H}{\partial \ln P} > 0$ and be non-increasing in input prices, that is, $S_i^P = \frac{\partial \ln H}{\partial \ln W_i} < 0 \quad i = K, L, M$. S_Y^P and S_i^P's are computed by using equation (4.4). The monotonicity of restricted profit function also requires the same conditions: $S_Y^{pr} = \frac{\partial \ln HR}{\partial \ln P} > 0$ and $S_i^{pr} = \frac{\partial \ln HR}{\partial \ln W_i} < 0 \quad i = L, M$, where S_Y^{pr} and S_i^{pr}'s are computed by using equation (4.8). Moreover, the condition that restricted profit function be non-decreasing in quasi-fixed input capital requires that $\varepsilon_{HRK} = \frac{\partial \ln HR}{\partial \ln K} > 0$, computed by using equation (4.9).

The convexity of profit function in prices requires that the Hessian matrix of second order partial derivatives with respect to output and input prices be positive semi-definite. For the unrestricted translog profit function, the elements of Hessian matrix are:

$$\text{Hess}_{ii} = \frac{\partial^2 \ln H}{\partial^2 \ln W_i} = (a_{ii} + S_i^2 - S_i) * H / W_i^2 \qquad i = L, M, K$$

$$\text{Hess}_{ij} = \frac{\partial^2 \ln H}{\partial \ln W_i \partial \ln W_j} = (a_{ij} + S_i * S_j) * H / (W_i * W_j) \quad i \neq j \quad i, j = K, L, M, Y \qquad (4.10)$$

where Hess_{ii} and Hess_{ij} are diagonal and off-diagonal elements of Hessian matrix, respectively. For the restricted profit function, the elements of Hessian matrix are the second partial derivatives of restricted profit with respect to output and variable input prices, and they are computed in a similar way defined in equation (4.10).

To check for the semi-definiteness of Hessian matrix, the cholesky factorization of the Hessian matrix is performed for each observation and at the point of approximation. Non-negative cholesky values implies that Hessian matrix is positive semi-definite and convexity is satisfied (Lau, 1978b).

4.4 Input Demand and Output Supply Elasticities

Own and cross price elasticities for input demands and output supply provide us with extra information on the characteristics of underlying production technology. For the translog functional form, the Marshallian own and cross price elasticities of output and input demands are as follows (Atkinson and Halvorsen, 1976, p:963):

$$E_{ii} = (a_{ii} + S_i^p * S_i^p - S_i^p) / S_i^p \qquad i = L, M, K, Y$$

$$E_{ij} = (a_{ij} + S_i^p * S_j^p) / S_i^p \qquad i, j = L, M, K, Y \text{ and } i \neq j \qquad (4.11)$$

Own and cross price elasticities in (4.11) are computed at the point of approximation. Theoretically, the expected sign of the own price elasticities is negative for input demands, and it is positive for output supply, implied by the convexity of profit function. The own price elasticities in (4.11) gives the proportional change in input demand or output supply as a response to a proportional change in its own price.

Cross price elasticities between inputs in (4.11) give the proportional change in factor demand i induced by proportional change in the price of factor j. Similarly, cross price elasticities between input demand and output supply give the proportional change in factor demand (output supply) caused by proportional change in output price (input prices). For the restricted profit function model, own and cross price elasticities do not include capital input.

Moreover, the partial elasticities of substitution are computed according to following equation:

$$Q_{ij} = -E_{ij} / S_j^p = -(a_{ij} + S_i^p * S_j^p)/(S_i^p * S_j^p) \qquad i, j = L, M, K \qquad (4.12)$$

The definition of partial elasticity of substitution in (4.12) is analogous to Allen-Uzawa elasticity of substitution used in cost function framework, but they are not exactly identical. There are two distinctions between two of them. First, when restricted profit function model is used, quantity rather than price of fixed input is held constant in (4.12). Secondly, price of output rather than its quantity is held constant in (4.12) (Atkinson and Halvorsen, 1976). For the restricted profit function model, the partial elasticity of substitution is computed for only between variable inputs (labor and material).

4.5 Computation of Primal and Dual Rate of Technological Change

4.5.1 Technological Change Based on Unrestricted Profit Function

Using the definition of the dual measure of technological change given in equation (3.9) of section (3.1.2), $\varepsilon_{Ht} = \frac{\partial \ln H}{\partial t}$, can be expressed in terms of estimated parameters and explanatory variables of unrestricted translog profit equation as follows:

$$\varepsilon_{Ht} = at + att * t + alt * \log(W_L) + amt * \log(W_M) + akt * \log(W_K) + ayt * \log(P) \qquad (4.13)$$

where this expression gives the percentage change in total profit induced by one unit change in technology variable (time), ceteris paribus.

The primal measure of rate of technological change, $\varepsilon_{Yt} = \frac{\partial \ln Y}{\partial t}$, can also be computed by using the relationship in equation (3.12) of section (3.1.2):

$$\varepsilon_{Yt} = \varepsilon_{Ht} * \left(\frac{\partial \ln H}{\partial \ln P} \right)^{-1} = \varepsilon_{Ht} / S_Y^P \qquad (4.14)$$

where ε_{Ht} and S_Y^P are computed by using equations (4.13) and (4.4), respectively. In equation (4.14), ε_{Yt} gives the rate of change in output as a response to one unit change in time, holding input levels constant.

4.5.2 Technological Change Based on Restricted Profit Function

When capital is treated as a quasi-fixed input, the short run dual measure of rate of technological change, ε_{Ht}^{SR}, based on estimation of a restricted translog profit equation given in (4.6) is computed by following equation:

$$\varepsilon_{Ht}^{SR} = \frac{\partial \ln HR}{\partial t} = \alpha t + \alpha tt * t + \alpha lt * \log(W_L) + \alpha mt * \log(W_M) + \alpha kt * \log(K) + \alpha yt * \log(P) \tag{4.15}$$

ε_{Ht}^{SR} can be interpreted as the rate of change in restricted profit during a given year, holding output and variable input prices, and capital quantity fixed. ε_{Ht}^{SR} is corrected to reflect the effects of disequilibrium in capital market as following:

$$\varepsilon_{Ht}^{A} = \frac{\varepsilon_{Ht}^{SR}}{(H*/HR)} = \frac{\varepsilon_{Ht}^{SR}}{\left(1 - \dfrac{\partial \ln HR}{\partial \ln K}\right)} = \frac{\varepsilon_{Ht}^{SR}}{(1 - \varepsilon_{HRK})} \quad . \tag{4.16}$$

where $H*$ is the total shadow profit, HR is the restricted profit and

$$\frac{H*}{HR} = \frac{HR - Z_K K}{HR} = 1 - \frac{Z_K K}{HR} = 1 - \frac{\partial \ln HR}{\partial \ln K} = 1 - \varepsilon_{HRK}$$

The term, $\partial \ln HR / \partial \ln K = \varepsilon_{HRK}$, is computed by using shadow price equation in (4.9). ε_{Ht}^{A} gives the rate of change in total shadow profit during a year, holding prices and stock of capital fixed, where marginal contribution of capital is reevaluated at its shadow price rather than its market price to reflect effects of disequilibrium in capital market.

Primal measure of rate of technological change adjusted for disequilibrium can also be computed by using the following relationship defined by equation (3.24) of section (3.2):

$$\varepsilon_{Yt}^{A} = \frac{\varepsilon_{Ht}^{A}}{\left(\frac{\partial \ln H^{*}}{\partial \ln P}\right)} = \frac{\varepsilon_{Ht}^{SR}(1-\varepsilon_{HRK})^{-1}}{\left(\frac{\partial \ln HR}{\partial \ln P}\right)(1-\varepsilon_{HRK})^{-1}} = \frac{\varepsilon_{Ht}^{SR}}{\left(\frac{\partial \ln HR}{\partial \ln P}\right)} = \frac{\varepsilon_{Ht}^{SR}}{S_{Y}^{pr}} \tag{4.17}$$

where $\frac{\partial \ln H^{*}}{\partial \ln P} = \left(\frac{\partial \ln HR}{\partial \ln P}\right)(1-\varepsilon_{HRK})^{-1}$ (see the appendix B for its derivation).

4.6 Dual and Primal Rate of Technological Change Difference

The difference in dual or primal rate of technological change between the U.S. and Mexico is defined as the difference in the rate of technological change between two countries during a given year, holding everything else fixed. Then, the dual and primal rate of technological difference based on unrestricted profit function model can be computed as:

$$\Delta\varepsilon_{Ht} = \varepsilon_{Ht,US} - \varepsilon_{Ht,mex} \tag{4.18a}$$

$$\Delta\varepsilon_{Yt} = \varepsilon_{Yt,US} - \varepsilon_{Yt,mex} \tag{4.18b}$$

Similarly, the dual and primal rate of technology change difference based on estimation of a restricted profit function computed according to following:

$$\Delta\varepsilon_{Ht}^{A} = \varepsilon_{Ht,US}^{A} - \varepsilon_{Ht,mex}^{A} \tag{4.19a}$$

$$\Delta\varepsilon_{Yt}^{A} = \varepsilon_{Yt,US}^{A} - \varepsilon_{Yt,mex}^{A} \tag{4.19b}$$

A positive (negative) dual rate of technological change difference implies that the rate of increase in profit induced by technological change is higher (lower) in U.S. food industry than it is in Mexican food industry during a given year. In other words, the U.S. food industry has a technological advantage (disadvantage) over Mexican food industry. Similarly, a positive (negative) primal technology change difference indicates that rate of increase in output induced by technological change is higher (lower) in U.S. food industry than it is in Mexican food industry, indicating a primal technological change advantage (disadvantage) of U.S. food industry over Mexican food industry.

4.7 Profit Side Dual Measure of Productivity Growth Rate

In this section, I introduce the profit side dual measure of productivity growth rate and decompose it into its sources. The dual measure of productivity growth rate is defined as the total rate of change in profit during a year, holding input prices constant.

When an unrestricted profit function, in which all input levels are assumed to be at their long run levels, is estimated, the dual measure of productivity growth rate can be derived by taking the total logarithmic differentiation of unrestricted profit function defined as H=H (P,W,t) with respect to time as:

$$\left.\frac{d\ln H}{dt}\right|_{W} = \frac{\partial \ln H}{\partial t} + \frac{\partial \ln H}{\partial \ln P}\frac{d\ln P}{dt} \qquad (4.20)$$

where the term $\left.\frac{d\ln H}{dt}\right|_{W}$ represents the dual measure of productivity growth in terms of total rate of change in profit, holding input prices fixed. The equation (4.20) shows that dual measure of productivity growth consists of not only the contributions of technological change, $\varepsilon_{Ht} = \frac{\partial \ln H}{\partial t}$, but also the rate of change in profit induced by the changes in output price (output price effects), expressed by the second term at the right hand side of equation (4.20).

In short run framework, where capital is treated as quasi-fixed input, dual measure of productivity growth rate in (4.20) should be adjusted to incorporate the effects of disequilibrium in capital markets. Then, the dual measure of productivity growth rate corrected for disequilibrium effects is given by following equation:

$$\left.\frac{d\ln H}{dt}\right|_{W_L,W_M} = \frac{HR}{H}\frac{\partial \ln HR}{\partial t} + \frac{HR}{H}\frac{\partial \ln HR}{\partial \ln P}\frac{d\ln P}{dt} + \left(\frac{HR}{H}\frac{\partial \ln HR}{\partial \ln K} - \frac{W_K K}{H}\right)\frac{d\ln K}{dt}$$

$$= \frac{HR}{H}\varepsilon_{Ht}^{SR} + \frac{HR}{H}S_Y^{pr}\frac{d\ln P}{dt} + \left(\frac{HR}{H}\varepsilon_{HRK} - \frac{W_K K}{H}\right)\frac{d\ln K}{dt} \qquad (4.21)$$

where $\varepsilon_{Ht}^{SR} = \frac{\partial \ln HR}{\partial t}$ is the rate of change in restricted profit , holding prices and capital stock fixed, $S_Y^{pr} = \frac{\partial \ln HR}{\partial \ln P}$ is the share of revenue in restricted profit (or elasticity of restricted profit with respect to output price), $\varepsilon_{HRK} = \frac{\partial \ln HR}{\partial \ln K} = \frac{Z_K K}{HR}$ is the elasticity of restricted profit with respect to capital stock (or shadow capital cost share in restricted profit), $\frac{W_K K}{H}$ is the observed share of capital cost in total profit, and finally dlnP/dt and dlnK/dt is the observed rates of change in output price and capital stock, respectively. The proof of (4.21) is given in Appendix B.

The equation (4.21) shows the components of dual productivity growth. The first term, $\frac{HR}{H}\frac{\partial \ln HR}{\partial t}$, gives the contribution of technological change to productivity growth as a result of increases in total profit induced by technological change, holding everything else constant. The second term, $\frac{HR}{H}S_Y^{pr}\frac{d\ln P}{dt}$, gives the effects of the changes in output price on productivity growth in terms of proportional change in total profit as a response to a proportional change in output price. The effects of disequilibrium (or capacity utilization) on productivity growth is given by the third term,

$\left(\frac{HR}{H}\varepsilon_{HRK} - \frac{W_K K}{H}\right)\frac{d\ln K}{dt}$, which is the proportional change in total profit induced by a proportional change in capital stock as the industry moves its capital level toward its long run equilibrium level.

4.8 Capacity Utilization

Capacity utilization (CU) measures the proportion of available productive capacity currently utilized. In short-run framework, industry may not operate at its optimal level of quasi-fixed input capital, so capital input may be underutilized or over utilized, depending on direction of variation in CU. In the profit function framework, the sources of deviation in CU from unity stem from implicit costs of disequilibrium represented by the difference between shadow price of quasi-fixed input capital, Z_K, and its market price, W_K. Then, the measure of CU based on estimation of a restricted profit function is given by following equation (Squires, 1987, p: 564 equation 12):

$$CU = 1 + \frac{(Z_K - W_K)K}{HR} \tag{4.22}$$

In order to compute the second term at the right hand side of (4.22), first we need to compute the shadow cost of capital evaluated at its shadow price. By Hotelling's Lemma

$Z_K = \frac{\partial HR}{\partial K}$ and the elasticity of restricted profit with respect to K, $\frac{\partial \ln HR}{\partial \ln K}$, gives the shadow cost share of capital in restricted profit. Then the shadow expenditure on capital is computed by following expression:

$$Z_{K,t}K_t = \frac{\partial \ln HR_t}{\partial \ln K_t} HR_t$$

$$= \frac{Z_{K,t}K_t}{HR_t} HR_t \qquad (4.23)$$

where $\frac{\partial \ln HR}{\partial \ln K} = \varepsilon_{HRK}$ is computed by using equation (4.9) and estimated restricted profit is obtained by taking exponentiation of equation (4.6).

Finally, the cost of capital evaluated at its market price, W_K*K, is computed by multiplying the observed share of capital expenditure in restricted profit with the observed restricted profit.

According to equation (4.22), when shadow price is greater than market price of capital, $Z_K > W_K$, CU will be greater than one, indicating over utilization of capital (under-capitalization of industry) and potential higher profits with further capital expansion. Similarly, when $Z_K < W_K$, CU will be less than one, implying under utilization of capital (over-capitalization of industry).

4.9 Hypothesis Testing on Production Structure

4.9.1 Homothetic Seperability of Inputs from Output

A production technology that is input-output separable requires that dual profit function be homothetically separable in input and output prices (Antle and Capalbo, 1988, p: 85). That is:

$$H(P, W_L, W_M, W_K, t) = H(G_1(P,t), G_2(W_L, W_M, W_K, t), t) \qquad (4.24)$$

Equation (4.24) implies that optimal input demands (or expenditure shares in profit) do not depend on output price, and similarly, optimal output level (or revenue share in profit) are independent of input prices. These restrictions can be expressed in terms of parameters of estimated translog profit equation as following:

aly=0, amy=0, ayk=0 (4.25a) or

αly=0, αmy=0 (4.25b)

where (4.25a) is valid if unrestricted profit function is estimated and (4.25b) is used when restricted profit function is estimated.

4.9.2 Homothetic Separability of Variable Inputs from Quasi-fixed Input

A necessary and sufficient condition for a homothetic production technology to be weakly separable in variable inputs (labor and material) from quasi-fixed input capital requires that restricted profit function should be separable in prices of variable inputs from quantity of capital. That is:

$$HR(P, W_L, W_M, K, t) = HR(G_1(W_L, W_M, t), K, t) \quad (4.26)$$

This can be represented in terms of estimated parameters of restricted profit function as:

αlk=0 and αmk=0 (4.27)

Restrictions in (4.27) is also called as linear separability restrictions and imply that elasticity of substitution between variable inputs and capital are one (Atkinson and Halvorsen, 1976).

4.9.3 Hicks Neutral Technological Change

First case of Hicks neutral technological change is the Hicks neutrality of technological change with respect to inputs. The estimated profit function will be Hicks neutral with respect to inputs if

alt=0, amt=0, akt=0 (for unrestricted profit function) (4.28a)

αlt=0, αmt=0, αkt=0 (for restricted profit function) (4.28b)

Similarly, the profit function will be Hicks neutral with respect to output if

ayt=0 (for unrestricted profit function) (4.29a)

αyt=0 (for restricted profit function) (4.29b)

Finally, the absence of technological change requires the restrictions in (4.28) and (4.29) as well as following:

at=0 and att=0 (for unrestricted profit function) (4.30a)

αt=0 and αtt=0 (for restricted profit function) (4.30b)

4.9.4 Hypothesis Testing for the Existence of Long-Run Equilibrium in Capital Market

In this study, two different specification of the profit function: unrestricted (long-run) profit function and restricted (short-run) profit function, are estimated for the food processing industry of each country. In the unrestricted profit function model, industry is assumed to be able to instantaneously adjust their all input levels without occurring any extra cost in response to changes in input prices within a year, and therefore, the industry is at its long-run equilibrium. On the other hand, in the restricted profit function model, industry is allowed to be in short-run equilibrium where variable factors (labor and material) fully adjust to their conditionally optimal levels (conditional on capital stock) within one period, while quasi-fixed input capital adjusts partially. Then, the industry can reach its long-run equilibrium by optimally adjusting the quasi-fixed input level until total profit is maximized. If the industry in fact operates at its long-run equilibrium, then the optimal long-run level of capital and the observed short-run level of capital are required to be equal to each other.

In short run framework, total profit, H, is defined as $H(P, W_L, W_M, K, W_K, t) = HR(P, W_L, W_M, K, t) - W_K K$. Then, the optimal long-run level of quasi-fixed input capital can be found by using the following first order condition of profit maximization:

$$\frac{\partial HR}{\partial K} - W_K = 0 \qquad \text{or}$$

$$Z_K(P, W_L, W_M, K^*, t) = W_K \tag{4.31}$$

where $\frac{\partial HR}{\partial K} = Z_K$ by Hotelling's Lemma, K* is the optimal long-run level of capital and W_K is observed market price of capital. However, the above equation (4.31) does not provide us with a closed form of analytical solution for K*, and hence, the following numerical solution for K* is used:

$$K^*(P, W_L, W_M, W_K, t) = \frac{\partial \ln HR}{\partial \ln K}\left(\frac{HR}{W_K}\right) \tag{4.32}$$

The difference between the observed capital level, K, and the optimal long-run level of capital, K*, might reflect the sampling error in estimation of K*. A test statistic is constructed by Kulatilaka (1985) in cost function framework based on the difference between observed and optimal LR level of capital in order to test whether a long-run (unrestricted) full equilibrium specification of the production technology is valid. Squires (1987) developed a similar test statistic for profit function framework:

$$t = \frac{(K^*_t - K_t)}{[Var(K^*_t)]^{1/2}_{tt}} \qquad (4.33)$$

which is t-distributed for each observation, and the matrix of variance for optimal long-run capital level is given as $Var(K^*) = K^*_\beta\, Var(\beta)\, K^*_\beta{}'$ where K^*_β is the vector of partial derivatives of K* with respect to vector of parameters, β, and Var(β) is the covariance matrix of estimated parameters in restricted profit function model. K^*_β is be computed by using the following expression (Squires,1987,p:567):

$$K^*_\beta = -\left[\frac{\partial^2 HR}{\partial K^2}\right]^{-1} \frac{\partial^2 HR}{\partial K \partial \beta} \qquad (4.34)$$

which is evaluated at K*.

If the computed t-statistics in (4.33) are higher than the critical value of t-distribution, the null hypothesis that optimal long-run capital level, K*, is equal to observed level of capital, K, is rejected. This implies that a long-run (unrestricted) profit function is not a valid specification for the underlying production technology. Moreover, a more powerful joint test that takes into account the intertemporal correlations between K^*_t values is performed by using following test statistic (Kulatilaka, 1985, p:260):

$$t' = (K^* - K)'\, Var(K^*)^{-1} (K^* - K) \qquad (4.35)$$

which is distributed as chi-squared with degree of freedom N, where N is the number of observations, Var(K*) is a N by N variance matrix for K* and (K*-K) is a N by 1 column vector. A t' that exceeds the critical value implies the rejection of the null hypothesis of long-run equilibrium in capital markets.

4.10 Estimation

We estimate two separate empirical models for each county: the unrestricted translog profit and restricted translog profit function models. All models are estimated by Full Information Maximum Likelihood (FIML). It is assumed that vector of additive error terms in system of equations estimated has the distribution of independent and identical multivariate normal with a mean vector of zero and a constant non-singular covariance matrix. Error terms across equations may be contemporaneously correlated but they are initially assumed to be serially uncorrelated. Later, the assumption of no serial correlation will be relaxed and error terms will be assumed to follow a first-order vector auto-regressive process (see section 4.11). FIML guarantees the invariance of parameter estimates to the share equation dropped to avoid singularity problem. During estimation of both empirical models, all right hand side variables are normalized by dividing each explanatory variable into its sample mean, so all of them have standard mean value of one. This implies that the point of approximation for both translog models is the sample mean and equations in (4.2) and (4.6) are second-order Taylor series approximation around the unit vector.

There are two approaches for comparing the production technologies of U.S. and Mexican food processing sectors (Denny and Fuss, 1983). The first one requires the pooling of the data sets of each country into one and jointly estimating the profit function for food industry of each country. In the second one, profit functions are estimated separately by running separate regressions for each country. In this study, both unrestricted and restricted profit function models are estimated separately for food industries of U.S. and Mexico. The one of the reasons for separate estimation is to avoid the possible hetereoscedasticity problems that would appear with the pooled data set since the variance of error terms would expected to be different for the data sets of each country. In addition, by separate regressions, all of the quadratic terms can be allowed to differ to reflect differences in production technologies of each country. On the other hand, when the data sets of U.S. and Mexico are pooled into one, dummy variables should be used to differentiate the parameters of profit function to reflect the differences in production technologies of two countries. However, the use of dummy variables may cause further multi-colinearity problems since dummy variables would be highly correlated with each other causing difficulties in estimation of parameters corresponding to these dummy variables.

4.11 Autocorrelation Correction

Initially, the specification of statistical models for both unrestricted and restricted translog profit functions has the assumption that additive error terms in profit function an its share equations are independently and identically multivariate normally distributed with mean vector zero and constant non-singular covariance matrix. In the following part of this section, a more general statistical model is constructed in which error terms are assumed to follow a first-order stationary vector autoregressive process. In the rest of this section, the methodology used to incorporate first order autocorrelation process into statistical models of profit function based on a study by Berndt and Savin (1975) is discussed. First, let the system of equations in section (4.2.1) or (4.2.2) be written as:

$$\begin{bmatrix} P_t \\ S_{1t} \\ S_{2t} \\ \cdot \\ \cdot \\ S_{nt} \end{bmatrix} = \begin{bmatrix} X_{pt} & & & & \\ & X_{1t} & & & \\ & & X_{2t} & & \\ & & & \cdot & \\ & & & & \cdot \\ & & & & & X_{nt} \end{bmatrix} \begin{bmatrix} \beta_p \\ \beta_1 \\ \beta_2 \\ \cdot \\ \cdot \\ \beta_n \end{bmatrix} + \begin{bmatrix} v_{pt} \\ v_{1t} \\ v_{2t} \\ \cdot \\ \cdot \\ v_{nt} \end{bmatrix} \tag{4.36}$$

or in a more compact form (4.35) becomes $Y_t = X_t \beta + v_t$. In (4.36), P_t represents the dependent variable in unrestricted translog profit equation (4.2) and S_{it}'s i=1,..n, (n is the number of share equations estimated and is equal to four in unrestricted profit function model) denotes the dependent variables in associated system of share equations in (4.4). For the restricted profit function model, P_t denotes natural logarithm of restricted profit and the number of equations in the system of share equations is three. X_{pt}, X_{1t},.....X_{nt} are the associated matrices of right hand side variables in profit function and share equations, respectively. Also, β_p, β_1,.., β_n denote the vector of estimated parameters in the profit and share equations, respectively. Finally, $v_p, v_1, \ldots, v_n$ represents the additive disturbance terms for each equation.

The singularity of the system of share equations implies the following adding up condition:

$$\sum_i S_{it} = 1 \quad \text{and} \quad \sum_i v_{it} = 0 \tag{4.37}$$

Also, the assumption that disturbance terms follow a first-order autoregressive scheme, AR(1), requires the following specification for the error term, v_t:

$$v_t = R\, v_{t-1} + \varepsilon_t \tag{4.38}$$

where R is and (n+1) by (n+1) matrix of auto correlation parameters and its general form is:

$$R = \begin{bmatrix} r_{pp} & r_{p1} & \cdots\cdots & r_{pn} \\ r_{1p} & r_{11} & \cdots\cdots & r_{1n} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ r_{np} & r_{n1} & & r_{nn} \end{bmatrix}_{(n+1)\times(n+1)} \quad (4.39)$$

ε_t is (n+1) by 1 vector of independently and identically normally distributed random error terms with mean zero. ε_t's are assumed to be contemporaneously correlated but serially uncorrelated. Then, the adding up property of share equations in (4.37) together with AR(1) specification in (4.38) impose that each column of R_s (submatrix of R consisting of autocorrelation parameters for only share equations) add to same constant, where general form for R_s is:

$$R_s = \begin{bmatrix} r_{11} & r_{12} & \cdots\cdots & r_{1n} \\ \cdot & & & \cdot \\ \cdot & & & \cdot \\ r_{n1} & r_{n2} & \cdots\cdots & r_{nn} \end{bmatrix}_{(n\times n)} \quad (4.40)$$

One of the share equations, n^{th} equation, is arbitrarily dropped from whole system due to the singularity of share equations. Then, the matrix of autocorrelation parameters, R, needs to be modified after elimination of one share equation as following:

$$R' = \begin{bmatrix} (r_{pp} - r_{pn}) & (r_{p1} - r_{pn}) & \cdots\cdots & (r_{pn-1} - r_{pn}) \\ (r_{1p} - r_{1n}) & (r_{11} - r_{1n}) & \cdots\cdots & (r_{1n-1} - r_{1n}) \\ \cdot & \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot & \cdot \\ (r_{np} - r_{nn}) & (r_{n1} - r_{nn}) & \cdots\cdots & (r_{nn-1} - r_{nn}) \end{bmatrix}_{(n+1)\times n} \quad (4.41)$$

where typical element of R' is $r_{ij}'=r_{ij}-r_{in}$. Similarly, R_s is also modified as:

$$R_s' = \begin{bmatrix} (r_{11} - r_{1n}) \ldots\ldots\ldots\ldots (r_{1n-1} - r_{1n}) \\ r_{21} - r_{2n}) \ldots\ldots\ldots\ldots (r_{2n-1} - r_{2n}) \\ . \qquad\qquad\qquad . \\ (r_{n1} - r_{nn}) \qquad\qquad (r_{nn-1} - r_{nn}) \end{bmatrix} \tag{4.42}$$

After modification of autocorrelation matrices, the equation (4.38) becomes:

$$v'_t = R_s' v_{t-1}' + \varepsilon_t' \tag{4.43}$$

where v_t', v_{t-1}' and ε_t' are also modified by dropping one of their elements corresponding to eliminated equation. Furthermore, due to the degree of freedom considerations, R' and R_s' is assumed to be a diagonal matrix with non-diagonal elements equal to zero. The diagonality of R_s' together with restriction that sum of elements in each column of R_s' should be equal to same constant lead to the following specification for R':

$$R' = \begin{bmatrix} r_{pp} & 0 & 0 \ldots\ldots\ldots 0 \\ 0 & r & 0 \ldots\ldots\ldots 0 \\ 0 & 0 & r \ldots\ldots\ldots 0 \\ . & . & . \qquad\quad . \\ 0 \ldots\ldots & \ldots\ldots & \ldots\ldots r \end{bmatrix}_{(n\times n)} \tag{4.44}$$

where r_{pp} is the autocorrelation parameter for profit function and r is the auto correlation parameter for the system of share equations.

The autocorrelation parameters, r_{pp} and r, and the structural parameters in profit function and share equations are jointly estimated by rewriting the model in section (4.2.1) or (4.2.2) as:

$$Y_t' = R' Y'_{t-1} + X'_t \beta - R' X'_{t-1} \beta + \varepsilon'_t \tag{4.45}$$

where ' denotes the elimination of one share equation from whole system due to the singularity of the system of share equations. Full information maximum likelihood technique is again used to estimate the whole system in (4.45), which treats (4.45) as a standard non-linear model under the assumption that ε_t's are normally distributed. Stationarity of AR(1) process requires that r_{pp} and r should be less than one and this condition will be checked after estimation.

CHAPTER 5: IMPACT OF ENVIRONMENTAL REGULATIONS ON PRODUCTIVITY GROWTH

5.1 Implications of Environmental Regulations

There has been a growing concern over the impact of environmental regulations on the productivity of U.S. firms beginning with the passage of major environmental legislation in the early 1970's.

There are two opposing views regarding the effects of environmental regulations on productivity growth. Critics of regulations argue that environmental regulations impose significant costs on firms and slow productivity growth. Regulations can adversely affect productivity in five ways (Jaffe et al., 1995). First, the measured productivity growth of the regulated industry can fall due to the diversion of conventional inputs, capital, labor, material and energy that are used in output production to the production of environmental quality. The latter is not included in conventional productivity measures. Second, when firms change their production activities in response to regulations, the new practices may be less efficient than the old ones. Third, environmental investments can crowd out other investments. Forth, the regulations that impose higher standards for new plants may discourage investment in new more efficient facilities. Fifth, requiring firms to use the best-available-technology for pollution abatement may initially increase the adoption of these new techniques but it may eventually reduce incentives to develop new pollution control methods.

In the literature, there are several empirical studies showing the negative effects of environmental regulations on productivity growth (see the Table 5.1). The studies covering all manufacturing sectors (Denison, 1979; Christainsen and Haveman, 1981; Gray, 1987; Robinson, 1995) suggest that the proportion of decline in productivity growth due to regulations range from 8-16%. However, there is a substantial variation among industrial sectors. For the most heavily regulated industries, this figure is much higher than it is for overall manufacturing sector. For example, for the chemical industry it is 30% (Barbera and McConnell, 1990) and 44% for electric utilities (Gollop and Roberts, 1983).

Robinson (1995) reported that the impact of environmental regulations on TFP growth rate is highly skewed. According to his study, typical (median) industry, based on the distribution of pollution abatement expenditures over industrial sectors, suffered TFP growth rate losses ranging from 0.3% in 1975 to 5.2% in 1986, while for the most heavily regulated industries (95th percentile) suffered losses between 3.2%-45.4% during 1975-1986. Also, for the food and beverage industry, which falls into the median classification, decline in TFP growth ranges from 0.3%-6.1% during 1975-1986.

On the other hand, some argue that properly designed environmental regulations can increase the productivity by encouraging innovation and development of new technologies that may partially or more than fully outweigh the cost of regulatory compliance (Porter and van der Linde, 1995). According to this view, regulations can increase the productivity for three reasons. First, regulations force firms to reduce resource inefficiencies that leads to pollution and wastes, and encourage the development of potential improvements in their production technology. Porter's technology forcing interpretation emphasizes the long run positive benefits of regulation over time;

Table 5.1 Impact of Environmental Regulations on Productivity Growth

Study	Time Period of Analysis	Industrial Scope	Percentage Decline In TFP Growth
Robinson, 1995	1974-1986	Over all 445 US manufacturing sectors	11.4 % for 1986
		Median industry	(0.3%-5.2%) during 1975-86
		Most heavily regulated industries	(3.2%-45.4%) during 1975-86
		Food industry	(0.33%-6.13%) during 1975-86
Barbera and McConnell,1990	1970-1980	Chemical; stone, clay, and glass; iron and steel	10%-12%
		Paper	30%
Gray, 1987	1958-1978	450 manufacturing sectors	12%
Haveman and Christainsen,1981	1973-1975	Over all manufacturing sector	8%-12%
Gollop and Roberts, 1983	1973-1979	Electric utilities	44%
Denison, 1979	1972-1975	Manufacturing sector	16%

productivity enhancing effects of innovations stimulated by regulations will outweigh the productivity slowing diversion of resources toward compliance in the long run.

Second, by reducing uncertainties, regulations can encourage compliance investment. Third, regulations that promote information dissemination can promote industry level cost reductions.

However, critics argue that profit maximizing firms can not be systematically ignorant of potential improvements, and whether regulators know more about the better means of production than firms do (Palmer et al., 1995). Unfortunately, the literature on possible positive effects of environmental regulation lacks systematic empirical evidence and mostly depends on case studies.

5.2 The Comparison of the U.S. and Mexican Environmental Regulations and Enforcement

The U.S. and Mexican environmental standards, policies, and their enforcement differ significantly. Especially since the passage of NAFTA, critics argue that the relatively more stringent environmental regulations in the U.S. decrease U.S. firms' competitiveness against Mexican firms. They argue that U.S. manufacturing operations are moved away from the U.S. to Mexico to take advantage of lower pollution abatement costs in Mexico. To improve our understanding of the impact of environmental regulations on the relative competitiveness of the U.S. and Mexican food processing industry, this section compares the evolution of environmental standards, policies, and their enforcement in two countries.

Two types of standards are used: technology based discharge standards and ambient environmental quality standards (Congressional Budget Office Study, 1985). Discharge standards limit the amount of pollution from specific sources. A technology based discharge standard specify the limits based on pollution levels that would result from using state-of-the-art control methods, although the use of that particular method is not required. A technology based standard may be expressed as either a performance or engineering standard. A performance standard specifies only the discharge limits and the polluter is allowed to use any control method to meet specified discharge limit. Engineering standards require an engineering based control approach rather than specifying a target discharge limit.

Ambient quality standards specify the amount of pollution allowed in a geographic region as opposed to discharge standards that specify the pollution levels from a particular source. These ambient quality standards are also used as targeted environmental quality objectives during development of discharge standards.

Starting from early 1970's, the U.S. has established several major environmental programs. The Environmental Protection Agency (EPA) generally shares the responsibility for environmental management with the states. The EPA is responsible for the designing and implementing most of the major environmental programs. States may pass their own laws, but state standards can be no less strict than federal ones.

Mexico's first environmental agency, the Subsecreteria de Mejeramiento del Ambiente (SMA) was founded in 1972, but it had very little impact from 1972-1982 (Husted and Logsdon, 1997). In 1982, a new federal agency, the Secreteria de Desarrollo Urbano y Ecologia (SEDUE), with more authority than SMA, was established, with very limited funding and staff. In 1988, the General Law of Ecological Equilibrium and Environmental Protection was passed. This law was largely patterned after the U.S. environmental programs and standards. The new law established some specific environmental standards for the first time and gave SEDUE the authority to develop other standards. It followed a "police approach" in regulatory enforcement with strict fines and jail terms. However, SEDUE's budget was still too low for the proper implementation and enforcement.

From 1990-1993, there were significant improvements in Mexico's environmental policy and enforcement. One indication of this is the increase in SEDUE's budget and personnel. The budget increased from $4.3 million in 1989 to $66.8 million in 1992 and its personnel increased from 81 in 1989 to 250 in 1992. Another indication of improvements is the increase in number of inspections after 1990. In 1992, a new agency

SEDESOL was founded. Under SEDESOL, National Institute of Ecology has been given the authority of creating regulations and approving permits while enforcement is carried out by Federal Attorney's Office for Environmental Protection (PROFEPA) with increased authority of inspections, fine and closing plants. PROFEPA had a major impact on enforcement. After its founding, the number of inspections rapidly increased and plant closing became more frequent. In 1991, the number of inspections was as twice those in 1990. Inspections peaked at 14, 387 in 1993. After 1993, PROFEPA changed its policy toward more preventive practices (such as voluntary environmental audits). With 1994 currency crisis, some argued that environmental efforts and enforcement would not be maintained. On the contrary, the 1995 budget of newly founded Secreteriat of Environment, Natural Resources and Fishing (SEMERNAP) including INE and PROFEPA, increased 48% over 1994 budget in real dollars (Husted and Logsdon, 1997).

Overall, we conclude that Mexico's environmental policy and enforcement was quite poor before 1988 and weak during 1988-1990, but improved significantly after 1990. Moreover, most of the NAFTA induced improvements have been maintained after 1994 (Husted and Logsdon, 1997).

In 1993, EPA initiated a study to compare the U.S. and Mexican environmental standards in several medias such as air, water hazardous waste, pesticides and industrial chemicals (The NAFTA: Report on Environmental Issues, 1993). In the following subsections, the comparison of U.S. and Mexican environmental practices will be discussed based on this study.

5.2.1 Water Quality

In the U.S., water quality standards are set by the states but approved by the EPA according to Federal Clean Water Act (1972 and 1977). Discharge limits are also established by the EPA for most new sources of water pollution (Congressional Budget Office, 1985).

Mexico's 1988 General Ecology Law provides quite comprehensive coverage with respect to water pollution, covering releases from industry and municipalities; agriculture and livestock activities; use of pesticides and toxic substances; infiltrations into aquifers, etc. The law also states the principles for developing water quality and other technical standards.

According to EPA's comparisons, Mexico's requirements for permitting source discharges are comparable to the permit and discharge system of U.S.'s Clean Water Act. However, unlike the EPA's water quality criteria, Mexican water quality criteria do not form the basis for discharge conditions. Another significant difference between the U.S. and Mexican practices is that the Mexican water quality standards mostly focus on conventional pollutants rather than toxic pollutants. Also, Mexico's control system for municipal waste water treatment facilities is not fully developed yet. In the U.S., municipal treatment systems must comply with secondary treatment requirement and must receive a permit for effluent discharges. In Mexico, sources that discharge into municipal systems are subject to federal pretreatment of indirect charges and standards. However, there is not yet a federal requirement that municipal systems must meet secondary requirements as those defined in the U.S. Overall, based on legal requirements, Mexico and the U.S. appear to have generally comparable water pollution control regimes but they may differ in practice depending on how permissible limits, criteria, permitting system and other requirements are implemented.

5.2.2 Air Quality

In the U.S., ambient air quality standards are set by the EPA according to Clean Air Act (1970, 1977,1990) and must be met nationwide by specified time. States may set stricter standards. Maximum limits are set for both mobile and stationary sources by the states and the EPA sets standards for new sources of air pollution.

Both Mexican and the U.S. air quality control programs require the adoption of ambient air quality standards for certain pollutants. Mexico set such standards, Maximum Permissible Levels (MPL's), for the same pollutants covered by the U.S. National Ambient Air Quality Standards (NAAQ's) with the exception of particulate matter. Moreover, all the Mexican MPL's are set at the same level or nearly at the same level as their equivalent of U.S. NAAQ's. However, Mexico does not have standards to protect public welfare, that are referred as secondary NAAQ's in the U.S.

In the U.S., the states are responsible, with the EPA oversight, for assuring NAAQs attainment. The states develop State Implementation Plans, which are submitted to the EPA for approval. On the other hand, Mexico has a source permitting program instead of state or local air planning with federal oversight. Like the U.S., Mexico has a system for further restricting emissions in highly polluted areas, called "critical zones". Two critical zones along U.S.-Mexico border have been designated: one for Tijuana and one for Ciudad Juarez.

In Mexico, a source registration and permitting program is used to control stationary source air emissions. This program uses a similar application procedure to what the EPA is requiring under Clean Air Act operating permit regulations. Also, technical norms used in controlling stationary source air emissions resemble the U.S. new source performance standards. Mexican norms apply to both new and existing sources, while U.S. standards apply to only new sources. However, Mexico's source specific standards for some industries, such as coal-fired power plants, allow much higher emission levels than EPA's program.

Like the U.S., Mexican law requires a source to submit annual emission data to government. SEDESOL reviews the data and if violations are found, it may inspect the source and close it partially or completely, or impose a fine.

Regarding hazardous air pollutants, Mexico's law seems not to contain any program comparable to one in Clean Air Act (1990), but it authorizes the development of such standards. Finally, both in Mexico and the U.S., mobile source program rely on comparable approaches; such as tail pipe emission standards, vehicle inspection, fuel content requirements and transportation controls.

5.2.3 Hazardous Waste, Pesticides and Industrial Chemicals

In the U.S., Resource Conservation and Recovery Act (RCRA) (1977) establishes requirements for the transportation, storage and disposal of hazardous waste. States are required to develop solid waste programs. Also, Comprehensive Environmental Response, Compensation and Liability Act (1980) authorizes federal government to respond to emergency hazardous spills (Congressional Budget Office, 1985).

Mexico's General Ecology Law, like U.S.'s RCRA attempts to regulate activities dealing with hazardous waste from generation, storage, treatment and transportation to final disposition. The Mexican criteria that are used for definition of what constitutes hazardous waste are very similar to the U.S. criteria. Moreover, 23 out of 27 chemicals on Mexican hazardous waste list that are also on RCRA list have maximum permissible limits lower than their U.S. equivalents.

According to Mexican law, a prior authorization from SEDESOL's INE is required to construct a facility that will generate or manage hazardous waste. The authorization procedure is similar to that of RCRA, which requires both general information about facility and extensive technical information. Moreover, Mexican law requires applicants to prepare a risk study on the dangers involved in activities, while RCRA does not require risk studies in consideration of siting a facility.

Like U.S., Mexican law also has requirements that a site must meet if it is used for controlled confinement of hazardous waste. Some of these standards (siting landfills in zones connected to aquifers) are as stringent as U.S. equivalents, and others (siting in flood and seismic zones), Mexican standards are less stringent.

Mexico does not have a program to control releases from inactive sites equivalent to U.S.'s Superfund Law or RCRA "corrective action" program, but it currently has a voluntary program. SEDESOL has been trying to build a fund that will be used for cleaning of abandoned waste sites. However, voluntary actions and fund do not appear to be adequate for cleaning up rapidly growing volume of such wastes. Furthermore, unlike EPA's lands disposal restriction program, Mexico does not impose a general ban on land disposal of untreated waste, although it is intended to do so in the near future. Finally, RCRA contains detailed requirements relating to ground water monitoring, closure, and facilities' financial ability to provide proper closure and clean up, while Mexican law does not impose any such financial requirements and does not provide enough detail about on closure and ground water monitoring of facilities.

In Mexico, the U.S. pesticide residue tolerances are usually adopted as official Mexican tolerances. Otherwise, limits are set according to international standards or limits of other developed countries are adopted. Only a few pesticides (none of them are allowed for food uses) that are banned in U.S. are registered in Mexico. Also, Mexico's requirements for registration of pesticides are almost identical to those used by EPA. For imported pesticides, Mexico relies on studies in developed countries which has approved the pesticide.

Generally, Mexico imports most of its industrial chemicals and relies on data from country of origin and from international organizations. An official list of hazardous chemicals banned for use and list of chemicals that must be controlled are published. These lists are quite similar to international equivalents.

5.2.4 Enforcement

In the U.S., environmental standards are enforced through the imposition of fines and penalties. Fines are issued for failure to meet a standard by a specified time or failure to be on compliance schedule. In the U.S., litigation plays a significant role in enforcement (Congressional Budget Study, 1985).

Mexico has a civil law as opposed to U.S. common law and enforcement largely depends on administrative mechanisms and negotiations between parties. Mexican government bodies have greater executive power and Mexico tends to use more administrative power rather than judicial authority to achieve enforcement.

Enforcement activities in Mexico generally involve permanent or temporary plant closings, the negotiation of compliance requirements, and imposition of fines and jail terms. These activities are implemented administratively by SEDESOL acting both prosecutor and adjudicator. In Mexico, two types of inspections are carried out. Multimedia (comprehensive) inspections check for total compliance with all relevant regulations and technical norms. Short inspections mostly look to see that paperwork requirements are met. Comprehensive inspections do not usually involve actual discharge sampling. They mainly consist of examining inventories of chemicals used and released or verification that required technologies are being used. The burden of analyzing and documenting releases or installment of pollution control equipment lies with the firm. The Mexican practices mirror the U.S. For example; the enforcement of the Clean Air Act in U.S. relies mostly on discharge monitoring reports submitted by facilities. Actual discharge sampling is uncommon except to verify violations discovered through review of facility reports.

In Mexico, temporary plant closures are ordered when the environmental problem is remediable and closures are intended to lead to negotiations between administrators and the facility. The plant is allowed to reopen after the firm removes the problem or an agreement is reached for full compliance by a certain time. Permanent closures are less frequently ordered, but they can serve as a major deterrent. Both Mexico's and U.S.'s environmental agencies rely on negotiated settlement to achieve compliance. However, Mexico differs from the U.S. in that the shutdowns can precede negotiations.

Mexican inspection program also allows its agency to routinely investigate citizen complaints about polluting sources, although it is not entirely comparable to formal citizen suit mechanism under the U.S. law. In addition to targeted inspections and responses to public complaints, an environmental audit program was initiated in Mexico in 1992, with the purpose of promoting compliance by encouraging facilities to discover violations in their practices and eliminate them prior to inspections and shutdowns or fines. The audit allows inspectors to evaluate compliance of the facility and develop an action plan with facility managers for full compliance. Since 1992, 541 environmental audits have been started, of which 425 were concluded and 116 still in process in early 1996 (Husted and Logsdon, 1997).

5.2.5 Empirical Studies of the Impact of Differences in the U.S. and Mexican Environmental Regulations on U.S. Competitiveness

A through search of the literature failed to uncover any empirical analysis of the effects of differences in the U.S. and Mexican environmental regulations on productivity levels (or competitiveness) for any industry. However, several studies indirectly approach this question by analyzing trade flows.

Grossman and Krueger (1993) examined the effects of U.S. pollution abatement costs on total U.S. imports from Mexican maquiladora industries. They used three different performance measures: total imports from Mexico to U.S., imports under the offshore assembly provisions of U.S. tariff codes, and sectoral patterns of maquiladora activities. They asked whether performance measures could be statistically explained by the ratio of U.S. pollution abatement costs to total value-added in selected U.S. industries. They found no evidence that pollution abatement costs have affected any performance measure.

Henderson et al. (1996) used a simulation model to analyze the impacts of trade liberalization and environmental policy changes in the U.S., Canada, Mexico, Brazil and Argentina on the U.S. exports and imports, covering food processing and other manufacturing sectors. In their simulation model, they used current estimates of pollution emissions and pollution expenditures[1] by food and other manufacturing sectors in each country as base levels and simulated the changes in pollution levels and abatement expenditures in each country, and looked at how these changes affected the U.S. exports and imports according to following three scenarios: i) elimination of import barriers for trade between the U.S. and other countries without any changes in environmental policies of developing countries (Mexico, Brazil and Argentina) ii) elimination of trade barriers with absolute harmonization of environmental standards where developing countries duplicate environmental regulations in U.S. and iii) elimination of trade barriers with relative harmonization of environmental standards in which developing countries impose standards similar to those in U.S but they are adjusted according to their own economic development level. The simulation results based on first scenario indicates that the exports and imports in the U.S. food processing sector are both increased, with a small decrease in the balance of U.S. food trade. Overall, trade liberalization without environmental policy changes generates net benefits

[1] U.S. pollution estimates are based on EPA estimates, and for other countries, they assumed similar pollution intensities as those in U.S. The U.S. abatement expenditures are based on EPA estimates, and for Canada they assumed that there are similar abatement expenditures as those in U.S. For developing countries they assumed that there are no abatement expenditures.

from increased trade for all countries but these benefits come at the cost of increasing pollution levels for developing countries. The results based on other two scenarios are very similar those from first one, implying that harmonization of environmental regulations in developing countries had very little effect on production and trade flows in U.S. food processing and other manufacturing sectors, due to the small share of environmental costs relative to total production costs in U.S. (in food processing sector, the share of environmental costs is less than 1%). The simulation results based on harmonization of environmental standards also indicate that the pollution abatement expenditures increases significantly in Mexico, Argentina and Brazil, improving environmental quality relative to pre-trade liberalization levels.

5.3 Incorporation of Effects of Pollution Abatement into Measure of Productivity Growth

Most studies that attempt to measure the impact of environmental regulations on productivity growth incorporated a measure of regulatory intensity variable into their model. The regulatory intensity variable is most often sector's private total expenditures on abatement and compliance, including pollution abatement capital costs and operating expenditures.

Pollution abatement affects productivity growth in two ways. First, abatement expenditures directly reduce productivity, since they increase total factor costs for the same output level (Barbera and McConnell, 1990). Second, abatement can affect productivity indirectly, by changing the amount and combination of conventional inputs used in production. This indirect effect can be positive or negative. Studies using the growth accounting approach for measuring TFP growth measure only the direct effect (Denison, 1979). In studies by Gray (1987), and Gray and Shadbegian (1993), TFP growth was based on growth accounting approach and the effects of regulations are measured through the regression of TFP growth levels on pollution abatement costs. In contrast, Gollop and Roberts (1983) take an econometric approach that allows indirect effects. However, they did not decompose the total effect into its direct and indirect components. Finally, Barbera and McConnell (1990) used an econometric approach in which both direct effects and indirect effects of environmental regulation on TFP growth were measured through estimation of a flexible cost function.

Following Barbera and McConnell's approach (1990), the effects of pollution abatement can be incorporated into profit function as following:

$$H^E = H^E(P, W, t, K_E) - E \tag{5.1}$$

where E is the pollution abatement expenditure and K_E is the stock of pollution abatement capital. Then, the dual measure of rate of technological change becomes:

$$\varepsilon_{pt}^E = \frac{\partial \ln H^E}{\partial t} = \frac{d \ln H^E}{dt} - \sum_i \frac{\partial \ln H^E}{\partial \ln W_i}\frac{d \ln W_i}{dt} - \frac{\partial \ln H^E}{\partial \ln P}\frac{d \ln P}{dt} - \frac{\partial \ln H^E}{\partial \ln K_E}\frac{d \ln K_E}{dt} + \frac{E}{H^E}\frac{d \ln E}{dt} \tag{5.2}$$

The term $\frac{\partial \ln H^E}{\partial \ln K_E}\frac{d \ln K_E}{dt}$ denotes the indirect effects of pollution abatement on the rate of technological change, while the term, $\frac{E}{H^E}\frac{d \ln E}{dt}$, gives the direct effects of pollution abatement. If it is assumed that abatement expenditures have no effect on allocation of conventional inputs of production (non-jointness of pollution abatement inputs with conventional inputs used in production), the profit function in equation (5.1) is redefined as:

$$H^{E'} = H(P, W, t) - E \tag{5.3}$$

The equation (5.3) yields the following expression for the dual measure of rate of technological change:

$$\varepsilon_{pt}^{E'} = \frac{\partial \ln H^{E'}}{\partial t} = \frac{H}{H^{E'}}\left[\frac{d\ln H}{dt} - \sum_i \frac{\partial \ln H}{\partial \ln W_i}\frac{d\ln W_i}{dt} - \frac{\partial \ln H}{\partial \ln P}\frac{d\ln P}{dt}\right] + \frac{E}{H^{E'}}\frac{d\ln E}{dt} \tag{5.4}$$

which includes only direct effects of pollution represented by the last term at right hand side of equation (5.4).

To implement the above approach, a variable measuring pollution abatement expenditures, E, is needed. For the U.S., there are data available to construct such a time series (see the appendix A about construction of variable E for the U.S. food industry). However, for Mexico, there are no pollution abatement expenditure data for the overall manufacturing sector or by individual sectors (OECD, Environmental Information System of Mexico, 1996) and it is not possible to construct the variable E for the Mexican food industry.

Based on the discussion of Mexican environmental regulations in section (5.2), We conclude that industry abatement efforts were zero until the passage of 1988 General Ecology Law. Yet, implementation of this law and enforcement activities did not begin until 1990 during the NAFTA negotiations. Therefore, at the beginning phase of this study, I planned to incorporate two dummy variables into profit function; one that is zero prior to 1988 and unity thereafter, and other is zero prior to 1990 and unity thereafter, to reflect the effects of regulations. Later, I was able construct a better measure to control for the effects of environmental regulations: the number inspections carried out annually in Mexico during 1982-1994 (see the appendix A for more detailed discussion of this measure). An index of number of annual inspections instead of times series of pollution abatement expenditures is added to profit function to represent environmental regulation activities in Mexican food industry. Similarly, an index of total pollution abatement expenditure is added into profit function estimated for the U.S. food industry. The empirical model of profit function that includes the regulatory variable, E, can be written as following:

$$\begin{aligned}\ln H = {} & a0 + a0pol * E + ay * \log(P) + al * \log(W_L) + am * \log(W_M) + ak * \log(W_K) + at * t \\ & + atpol * E * t + 0.5 * ayy * (\log(P))^2 + 0.5 * all * (\log(W_L))^2 \\ & + 0.5 * amm * (\log(W_M))^2 + 0.5 * akk * (\log(W_K))^2 \\ & + 0.5 * att * t^2 + aly * \log(W_L) * \log(P) \\ & + alm * \log(W_L) * \log(W_M) + alk * \log(W_L) * \log(W_K) + ayk * \log(P) * \log(W_K) \\ & + amk * \log(W_M) * \log(W_K) + amy * \log(W_M) * \log(P) + ayt * \log(P) * t \\ & + alt * \log(W_L) * t + amt * \log(W_M) * t + akt * \log(W_K) * t \qquad (5.5)\end{aligned}$$

where E is an index of number of annual inspections in Mexico for the Mexican model and E is an index of total pollution abatement expenditures for the U.S. model. In equation (5.5), the variable E is interacted only with intercept and first degree technology variable, t, to preserve the degrees of freedom. Consequently, the direct effect of pollution abatement on the dual measure of rate of technological change is represented by the parameter "atpol" (which is equal to $\frac{\partial^2 \ln H}{\partial t \partial E}$). This parameter gives us the change in the rate of technological change, and in turn productivity growth rate, as response to one unit change in index of pollution abatement.

CHAPTER 6: RESULTS

Initially, I estimated the unrestricted and restricted profit function models for the U.S. and Mexican food processing sectors without correcting for first-order autocorrelation. An analysis of the resulting error terms suggested the existence of auto correlation in both profit functions models of two countries. I conducted Likelihood Ratio (LR) tests of the null hypotheses of no first order auto-correlation. The results suggest that the null hypotheses should be rejected in all cases with the significance level of 5 % and less (see Table 6.1). Therefore, our final models contain an AR (1) correction based on the methodology in section (4.11).

Table 6.1 Likelihood Ratio Tests for Hypothesis Testing of AR (1)

Unrestricted Profit Function Model	**U.S**	**Mexico**
L^r	165.056	162.767
L^u	273.001	241.616
LR-test statistic	215.89	157.698
Restricted Profit Function Model		
L^r	115.962	91.2390
L^u	214.630	169.666
LR-test statistic	197.336	156.854

Note: L^r is the value of log-likelihood function when auto-correlation parameters are constrained to zero, and L^u is the value of log-likelihood function when all the parameters are included. LR test statistics are distributed as the chi-square with two degrees of freedom.

6.1 Parameter Estimates and Regulatory Conditions

The parameter estimates and the corresponding t-statistics for the U.S. and Mexican unrestricted and restricted profit function models are presented in Tables 6.2a and 6.2b. These tables also show generalized R^2's[1] as a measure of the goodness of fitness of whole system of equations to data (estimated equations for unrestricted and restricted profit function models are given in equations (4.2) and (4.4), and (4.6) and (4.8), respectively). The generalized R^2's for the two models of U.S. and Mexico are all quite high (above 0.9), implying a quite high degree of goodness of fitness for the whole system equations. Individual R^2's for profit equations in the both models of U.S. and Mexico are also high (above 0.8), while the share equations (especially material equation) in both models of U.S. and Mexico have relatively lower R^2's.

Monotonicity of profit function requires that output shares and factor expenditure shares should be positive and negative, respectively. Both the U.S. and Mexican estimated unrestricted and restricted profit function models satisfy monotonicity requirement for all observations. Another monotonicity condition for the restricted profit function is that the restricted profit function be non-decreasing in quasi-fixed input capital. This requires that the shadow capital expenditure shares, $\varepsilon_{HRK} = \dfrac{\partial \ln HR}{\partial \ln K}$ (computed by equation (4.9)), be positive. The estimated shadow capital expenditure shares are positive for both countries for all observations.

---

[1] Generalized R^2's are computed by using following definition: R^2_{gen}=1-exp[2(L1-L2)/T], where L1 is the max value of log-likelihood when parameters for all right hand side variables except intercept are constrained to zero, and L2 is the maximum value of log-likelihood when all parameters are included in the model.

Table 6.2a Parameter Estimates for Unrestricted Profit Function Model

Parameter	Variable	Estimate		T-statistic	
		U.S.	Mexico	U.S.	Mexico
a0	Constant	3.6953	1.4415	22.54 **	5.88 **
al	Log(W_L)	-0.2594	0.1226	-1.45	1.67
am	Log(W_M)	-0.2221	-0.3934	-0.66	-3.25 **
ak	Log(W_K)	-0.0559	-0.0691	-0.70	-1.34
ay	Log(P)	1.5373	1.3399	3.53 **	9.28 **
at	t	0.5003	1.1628	2.46 **	2.82 **
all	$[\log(W_L)]^2$	-1.0261	-0.0410	-9.64 **	-2.52 *
amm	$[\log(W_M)]^2$	-2.2829	-0.5863	-3.02 **	-2.24 *
akk	$[\log(W_K)]^2$	-0.3201	-0.1247	-16.28 **	-9.10 **
ayy	$[\log(P)]^2$	-4.4367	-0.6658	-4.57 **	-2.37 *
att	t^2	-0.0006	-0.5632	-0.0038	-1.94
alm	$\log(W_L)*\log(W_M)$	-0.3528	-0.0065	-2.35 **	-0.22
alk	$\log(W_L)*\log(W_K)$	-0.0171	-0.0049	-0.54	-0.46
aly	$\log(W_L)*\log(P)$	1.3960	0.0525	6.70 **	1.71
amk	$\log(W_M)*\log(W_K)$	-0.0340	0.0546	-0.44	1.62
amy	$\log(W_M)*\log(P)$	2.6696	0.5382	3.14 **	1.99
ayk	$\log(P)*\log(W_K)$	0.3712	0.0750	3.52 **	2.31 *
alt	$\log(W_L)*t$	0.0310	0.0131	0.26	0.25
amt	$\log(W_M)*t$	-0.4553	0.2953	-1.88 *	2.64 **
akt	$\log(W_K)*t$	-0.1068	0.0423	-1.80 *	1.72
ayt	log(P)*t	0.5311	-0.3507	1.61	-2.42 *
atpol	t*E	0.0482	0.0516	0.56	1.71
a0pol	E	-0.1402	-0.0972	-1.12	-1.74
Generalized R^2		**0.9901**	**0.9423**		
Equation R^2					
Profit		**0.81**	**0.98**		
Labor		**0.86**	**0.64**		
Material		**0.6**	**0.35**		
Capital		**0.97**	**0.95**		
Log of Likelihod		**273.001**	**241.616**		

Note: * denotes % 10 significance level and ** denotes % 5 significance level.

Table 6.2b Parameter Estimates for Restricted Profit Function Model

Parameter	Variable	Estimate		T-statistic	
		US	Mexico	U.S.	Mexico
α0	Constant	3.5782	1.7613	28.26 **	31.32 **
αl	$\log(W_L)$	0.3961	-0.0012	3.13 **	-0.03
αm	$\log(W_M)$	0.1876	-0.1974	1.43	-1.02
αk	log(K)	-1.1778	0.4627	-4.20 **	1.44
αy	log(P)	0.4163	1.1986	3.03 **	6.03 **
αt	t	0.9681	0.7946	4.99 **	7.57 **
αll	$[\log(W_L)]^2$	-0.6161	-0.0405	-10.04 **	-2.54 **
αmm	$[\log(W_M)]^2$	-2.2263	0.0051	-4.43 **	0.02
αkk	$[\log(K)]^2$	-3.9357	-0.2159	-4.40 **	-0.20
αyy	$[\log(P)]^2$	-3.4611	-0.0500	-5.32 **	-0.14
αtt	t^2	-0.6159	-0.3103	-3.26 **	-3.30 **
αlm	$\log(W_L)*\log(W_M)$	-0.3094	-0.0073	-2.76 **	-0.25
αlk	$\log(W_L)*\log(K)$	0.3127	-0.0620	2.67 **	-1.36
αly	$\log(W_L)*\log(P)$	0.9254	0.0478	7.74 **	1.51
αmk	$\log(W_M)*\log(K)$	0.7779	-0.3212	2.03 *	-0.66
αmy	$\log(W_M)*\log(P)$	2.5357	0.0022	4.41 **	0.01
αyk	log(P)*log(K)	-1.0905	0.3833	-3.82 **	0.76
αlt	$\log(W_L)*t$	-0.3367	0.0257	-3.52 **	1.10
αmt	$\log(W_M)*t$	-0.6457	0.3681	-5.87 **	1.55
αkt	log(K)*t	1.6217	-0.1709	5.31 **	-0.59
αyt	log(P)*t	0.9823	-0.3938	12.41 **	-1.58
αtpol	t*E	0.0030	-0.1092	0.08	-2.03 *
α0pol	E	-0.0472	0.2007	-1.03	2.09 *
Generalized R^2		**0.9893**	**0.9017**		
Equation R^2					
Profit		**0.94**	**0.98**		
Labor		**0.73**	**0.79**		
Material		**0.69**	**0.59**		
Log of Likelihood		**214.630**	**169.666**		

Note: * denotes % 10 significance level and ** denotes % 5 significance level

The convexity of unrestricted profit function with respect to output and input prices are checked by determining whether the cholesky values from cholesky factorization of the estimated Hessian matrix are positive (see the corresponding discussion in section (4.4.1)). For the U.S. unrestricted profit function model, the convexity in prices is satisfied for 25 observations out of 31 and at the sample mean. For the Mexican unrestricted profit function model, the convexity condition is satisfied for 11 observations out of 24 and at the mean. The U.S. restricted profit function model satisfies the convexity condition for 29 observations out of 31 but not at the sample mean. The convexity condition for the Mexican restricted profit function model is satisfied at all data points and at the mean.

6.2 Elasticities

The own and cross price elasticities of input demands and output supply, and elasticities of substitution between inputs are presented in Tables 6.3a, 6.3b, 6.3c and 6.3d for unrestricted and restricted profit function models of U.S. and Mexico. All the figures for own price elasticities of input demands and output supply have theoretically expected signs for all U.S. and Mexican models.

The results from the U.S. unrestricted profit function model show that labor and material inputs, and output are price elastic with own price elasticities of -1.14, -3.22 and 3.66, respectively (Table 6.3a). The own price elasticity of demand for capital is -0.61, implying that capital is price inelastic. The own price elasticity figures for Mexican unrestricted profit function model imply that output and only material input are price elastic with elasticities of 2.42 and -3.13, respectively (Table 6.3b). Labor and capital

Table 6.3a Elasticities for Input Demands and Output Supply, and Elasticities of Substitution for the U.S. Unrestricted Profit Function Model

Own and Cross Price Elasticities	Prices			
	Labor	Material	Capital	Output
Quantities				
Labor	-1.1439 (0.011) **	-2.6611 (0.027) **	-0.3859 (0.004) **	4.1910 (0.042) **
Material	-0.9693 (0.009) **	-3.2210 (0.031) **	-0.3903 (0.004) **	4.5805 (0.043) **
Capital	-1.0448 (0.007) **	-2.9010 (0.022) **	-0.6049 (0.005) **	4.5506 (0.034) **
Output	-0.8325 (0.007) **	-2.4979 (0.020) **	-0.3339 (0.003) **	3.6642 (0.029) **
Elasticity of Substitution	**Labor**	**Material**	**Capital**	
Labor		-0.8913 (0.008) **	-0.9608 (0.007) **	
Material	-0.8913 (0.008) **		-0.9717 (0.007) **	
Capital	-0.9608 (0.007) **	-0.9717 (0.007) **		

Table 6.3b Elasticities for Input Demands and Output Supply, and Elasticities of Substitution for the Mexican Unrestricted Profit Function Model

Own and Cross Price Elasticities	Prices			
	Labor	Material	Capital	Output
Quantities				
Labor	-0.6809 (0.027) **	-2.3060 (0.092) **	-0.0822 (0.003) **	3.0691 (0.122) **
Material	-0.0955 (0.002) **	-3.1254 (0.049) **	-0.1558 (0.002) **	3.3768 (0.527) **
Capital	-0.0608 (0.001) **	-2.7837 (0.035) **	-0.1944 (0.002) **	3.0389 (0.038) **
Output	-0.0837 (0.001) **	-2.2231 (0.027) **	-0.1120 (0.001) **	2.4189 (0.029) **
Elasticity of Substitution	**Labor**	**Material**	**Capital**	
Labor		-0.9720 (0.015) **	-0.6190 (0.007) **	
Material	-0.9720 (0.015) **		-1.1733 (0.015) **	
Capital	-0.6190 (0.007) **	-1.1733 (0.015) **		

Note: All elasticities are evaluated at the mean. ** denotes significance 5% level. Figures in parenthesis are standard errors inputs are price inelastic with own price elasticities of -0.68 and -0.19, respectively. The comparison of own price elasticities for unrestricted profit function model of two countries reveals that all elasticities are greater in absolute value for the U.S. model than those for the Mexican model, suggesting that input demands and output supply are more responsive to changes in prices in U.S. than they are in Mexico.

The own price elasticity figures for the U.S. restricted profit function model in Table 6.3c are lower in absolute value than those from unrestricted profit function model. Labor is price inelastic, with elasticity of -0.94 (as opposed to -1.14 in U.S. unrestricted profit function model). Material and output are found as price elastic as they are in unrestricted profit function model of U.S., with lower own price elasticities of -2.04 and 1.94, respectively (Table 6.3c). Similarly, the own price elasticities from Mexican restricted profit function model are also lower in absolute value than those from unrestricted model. The implications of own price elasticity figures from Mexican restricted profit function model are the same as those from unrestricted model. The output supply and material demand are price elastic with elasticities of 2.18 and -3.11, respectively and the labor demand is price inelastic with elasticity of -0.63 (Table 6.3d). Overall, the material demand has the highest own price elasticity in both countries (with the exception of U.S. unrestricted model in which output supply has the highest own price elasticity closely followed by material demand), reflecting material intensive nature of food processing sector in both countries.

The cross price elasticity values from the U.S. and Mexican unrestricted profit function models show that labor demand is more responsive to the changes in material price than it is to changes in its own price in both countries. Specifically, 1% increase in

Table 6.3c Elasticities for Input Demands and Output Supply, and Elasticities of Substitution for the U.S. Restricted Profit Function Model

Own and Cross Price Elasticities	Prices		
	Labor	Material	Output
Quantities			
Labor	-0.9364 (0.007) **	-1.6940 (0.014) **	2.6148 (0.022) **
Material	-0.6067 (0.004) **	-2.0466 (0.014) **	2.7180 (0.035) **
Output	0.9692 (0.014) **	-1.4446 (0.007) **	1.9419 (0.010) **
Elasticity of Substitution	**Labor**	**Material**	
Labor		-0.8050 (0.005) **	
Material	-0.8050 (0.005) **		

Table 6.3d Elasticities for Input Demands and Output Supply, and Elasticities of Substitution for the Mexican Restricted Profit Function Model

Own and Cross Price Elasticities	Prices		
	Labor	Material	Output
Quantities			
Labor	-0.6294 (0.013) **	-2.0241 (0.042) **	2.6535 (0.055) **
Material	-0.0848 (0.002) **	-3.1094 (0..054) **	3.1929 (0.037) **
Output	0.1112 (0.003) **	-2.1063 (0.026) **	2.1796 (0.026) **
Elasticity of Substitution	**Labor**	**Material**	
Labor		-0.9607 (0.017) **	
Material	-0.9607 (0.017) **		

Note: All elasticities are evaluated at the mean of data. ** denotes significance level of % 5. Figures in parenthesis are standard errors.

material price decreases the labor demand by 2.7 % in U.S. and 2.3% in Mexico (Table 6.3a and 6.3b). On the other hand, the responsiveness of material demand to the changes in labor price is quite poor in both countries; 1% increase in labor price reduces material demand by only 0.96% in U.S. and 0.1 % in Mexico. The capital demand is also more responsive to the changes in material price than it is to changes in its own price. Indeed, 1% increase in material price reduces the demand for capital by 2.9% in U.S and 2.8% in Mexico. The cross price elasticities between inputs and output from unrestricted profit function models of U.S. and Mexico have expected signs, implying that the changes in output price affect input demands in the same direction, and the changes in input prices affect output supply in the opposite direction. Specifically, 1% increase in output price increases the demand for inputs (labor, material and capital) by more than 4% in U.S. and 3% in Mexico. The fourth line in Tables 6.3a and 6.3b shows that the output supply is inversely related with input prices as expected, the output supply being most responsive to changes in material price after its own price in both countries. Overall, the cross price elasticity figures from the U.S. unrestricted profit function model are greater in absolute value than those from Mexico, suggesting that the input demands and output supply in the U.S. food sector is more responsive to the changes in other input prices or output price than those in Mexican food sector.

The cross price elasticity figures from the U.S. and Mexican restricted profit function models again imply that labor demand is more sensitive to the changes in material price than it is to changes in its own price in both countries. Specifically, the labor demand is reduced by 1.69% in U.S and 2.02% in Mexico as a response to 1% increase in material price. On the other hand, the material demand is less responsive to changes in labor price than labor demand is to the changes in material price in both countries. In addition, all of the input demands are most significantly affected by output price in both countries. Specifically, the labor demand is increased by 2.6% in both U.S. and Mexico as a response to 1% increase in output price. Also, 1% increase in output price raises the material demand by 2.7% in U.S. and 3.2% in Mexico. As in unrestricted profit function models of U.S. and Mexico, the output supply is again inversely related with material price as expected. However, the changes in labor price affect the output supply in the same direction.

Overall, the comparison of cross price elasticities in restricted profit function models of U.S. and Mexico reveals that the input demands and output supply are more responsive to the changes in labor price in U.S. than they are in Mexico. On the other hand, the input demands and output supply are less responsive to the changes in material price or output price in U.S. than they are in Mexico.

The values for the partial elasticities of substitution based on both unrestricted and restricted profit function models indicate that all inputs are complements of each other in both countries. According to the unrestricted profit function model, the degree of substitution between labor and material, and between material and capital are less in U.S. than they are in Mexico, while the elasticity of substitution between labor and capital is higher in U.S. than in Mexico. According to restricted profit function model, elasticity of substitution between labor and material is less in U.S. than it is in Mexico.

The previous estimates of factor demand elasticities for U.S. food sector by Goodwin and Brester (1995) and Huang (1991) are presented in Table 6.4. Elasticities in both of these studies are based on cost function framework, and Huang's study does not include material inputs. Goodwin and Brester reported elasticities for two periods (1972-1980 and 1980-1990) to analyze the structural changes in food sector during early 1980's. Our estimates of own price elasticities of labor and material demand are much higher than those reported by Goodwin and Brester (1995). Our own price elasticity of labor demand is also higher than the one estimated by Huang (1991). On the other hand, our own price elasticity of demand for capital is lower than those reported by both Goodwin and Brester (1995) and Huang (1991). Our cross price elasticity estimates are also higher in absolute value than those of Goodwin and Brester (1995) and Huang (1991).

Moreover, both of these previous studies reported that all inputs in U.S. food sector are substitutes of each other, while our estimates for the partial elasticities of substitution imply that they are complements. Overall, the estimated elasticities in this study substantially differ from those in previous studies. These differences might be caused by the fact that profit function framework with underlying profit maximizing behavior assumption is used in our study as opposed to cost function framework with cost minimizing assumption used in those previous studies. Our estimated elasticities for input demands and output supply derived from profit function models are Marshallian elasticities that consist of both substitution and output scale (expansion) effects. On the other hand, elasticities based on cost function framework consist of only substitution effects. Therefore, our negative cross price elasticities implying that all inputs are complements might be explained by the expansion effects outweighing substitution effects. It has been reported that inputs might be Marshallian complements of each other due to the expansion effects (Sakai, 1974).

Table 6.4 Previous Estimates of Factor Demand Elasticities for U.S. Food Sector

Goodwin and Brester (1995)						
	Prices					
Quantity	Labor		Material		Capital	
	1st period	2nd period	1st period	2nd period	1st period	2nd period
Labor	-0.77	-0.47	0.29	0.07	0.02	0.02
Material	0.07	0.02	-0.29	-0.67	0.02	0.02
Capital	0.10	0.09	0.43	0.42	-0.97	-0.99
Morishima Substitution Elasticities						
Labor			0.84	0.49	0.87	0.56
Material	0.58	0.73			0.72	1.08
Capital	0.99	1.01	0.99	1.01		

Huang (1991)		
	Prices	
Quantity	Labor	Capital
Labor	-1.05	1.12
Capital	1.78	-2.08
Allen Partial Elasticities of Substitution		
Labor		3.31
Capital		
Morishima Substitution Elasticities		
Labor		2.83
Capital	3.20	

Sources: Goodwin, B.K. and Brester, G.W. (1995) " Structural Change in Factor Demand Relationships in the U.S. Food and Kindred Products Industry" Amer. J. of Agr. Econ.,77: 69-79.
Huang, K.S. (1991)"Factor Demands in U.S. Food Manufacturing Industry"
Amer. J. of Agr. Econ. 73:615-20.

6.3 Estimates for Primal and Dual Rate of Technological Change

6.3.1 Primal and Dual Rate of Technological Change Estimates based on Unrestricted Profit Function Model

The estimates of dual and primal rate of technological change derived from the U.S. and Mexican unrestricted profit function models are given in Table 6.5. The second and third columns present the estimates of dual rate of technological change, $\varepsilon_{Ht} = \frac{\partial \ln H}{\partial t}$, (computed by equation (4.13) in section 4.5.1) for U.S. and Mexico, respectively. The estimates of primal rate of technological change, $\varepsilon_{Yt} = \frac{\partial \ln Y}{\partial t}$, (computed by equation (4.14) are also given in the last two columns. In addition, Figures 6.1-6.4 illustrate the trends in these estimates of rate of technological change. Finally, Table 6.6 presents the average annual rates of dual and primal technological change for U.S. and Mexico during selected subperiods.

Table 6.6 and Figure 6.1 reveal that, in U.S., the dual rate of technological change shows a rather steady trend with quite small drops and rises. The average annual rate was around 0.530% during whole study period of 1963-93. The estimates for selected subperiods also indicate that rate of dual technological change followed a steady trend during 1963-73, with an average annual rate of 0.516%. The average annual rate rose to 0.551% during next period of 1974-81 although the sharpest decrease was observed between 1974-75 period. It declined to 0.530% during 1982-88 in spite of an increasing trend during 1984-86. During last subperiod of 1989-93, the trend in dual rate of technological change was steady with average annual rate of 0.523%. Unfortunately, the observed trend in dual rate of technological change in U.S. based on unrestricted profit function model is not plausible in the sense that it shows a rising trend with higher average annual rate during 1974-81 period during which U.S. economy in general faced dramatic increases in fuel and energy prices, and in turn productivity slowdown, suggesting that a declining trend with a lower average annual rate should be expected during this subperiod. Also, considering the tax cuts and increased investment incentives that were introduced by 1981, the relatively lower level of average annual rate during 1982-88 than the one during 1974-81 is not as we expected.

The primal rate of technological change, ε_{Yt}, shows a similar trend as the dual rate of technological change. The Figure 6.2 and Table 6.6 indicate that the primal rate of technological change was following an almost steady trend with an average annual rate of 0.098% during 1963-73 while it rose to 0.105% during next period of 1974-81. For the next two subperiods average annual rate was falling.

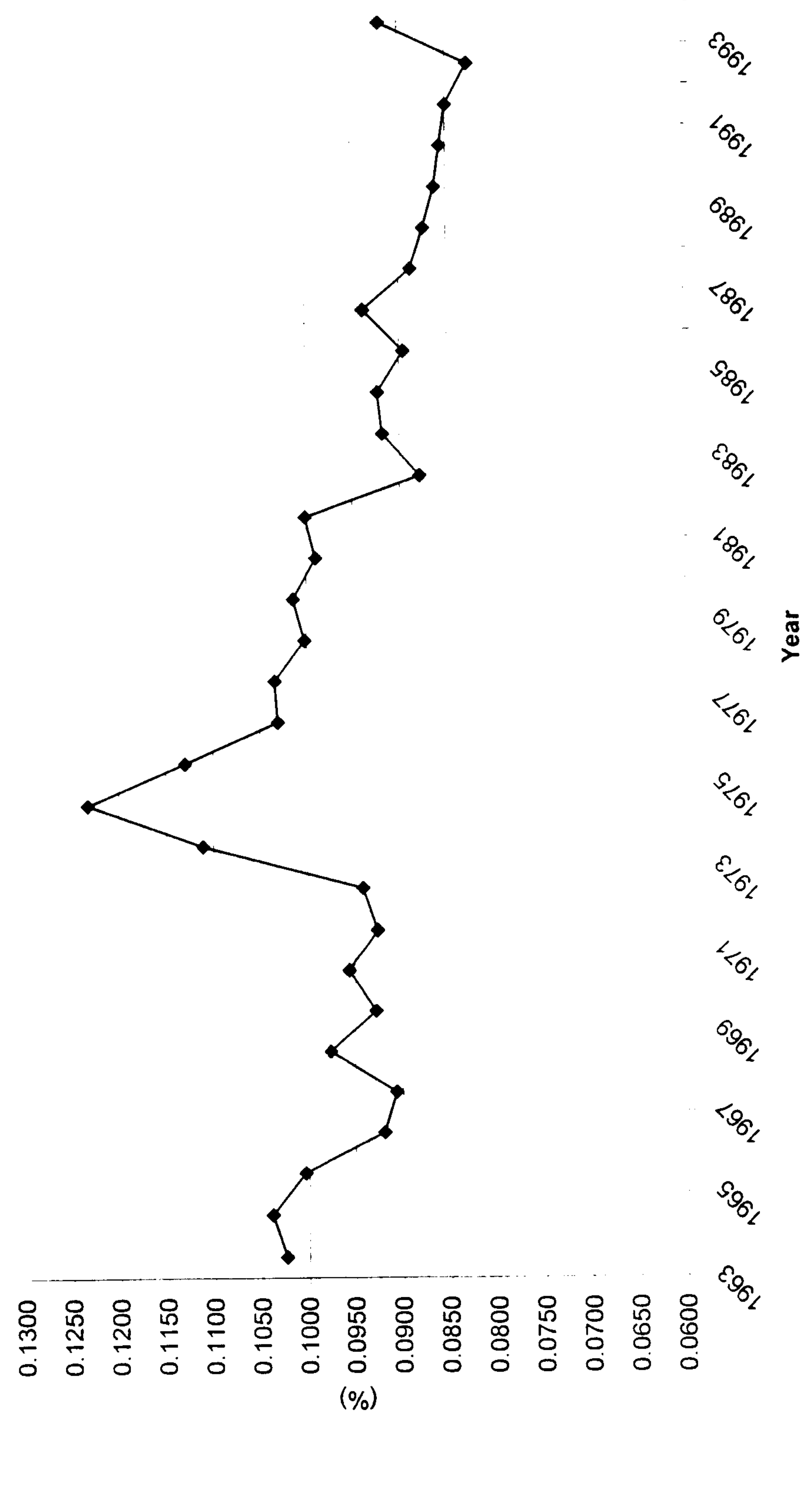
For the Mexico, Figure 6.3 and 6.4, and Table 6.6 suggest that both dual and primal rate of technological change generally follow a declining trend during whole study period. Specifically, the average annual rate of dual technological change in Mexico declined from 0.921% during 1971-74 to 0.338% during 1989-93. Similarly, the primal rate of technological change also follows a declining trend during most of the years in study period. Indeed, average annual rate of primal technological change fell from 0.254% during 1971-74 to 0.102% during 1989-93.

Table 6.5 Estimates of Dual and Primal Rate of Technological Change for Unrestricted Profit Function Model

YEAR	ε_{Ht} (%)		ε_{Yt} (%)	
	U.S.	Mexico	U.S.	Mexico
1963	0.5146		0.1024	
1964	0.5221		0.1039	
1965	0.5125		0.1004	
1966	0.5016		0.0920	
1967	0.5129		0.0907	
1968	0.5148		0.0976	
1969	0.5116		0.0928	
1970	0.5162		0.0956	
1971	0.5213	1.0019	0.0926	0.2534
1972	0.5182	0.9565	0.0941	0.2691
1973	0.5299	0.9074	0.1111	0.2579
1974	0.5664	0.8163	0.1233	0.2344
1975	0.5332	0.8477	0.1130	0.2289
1976	0.5379	0.8411	0.1031	0.2240
1977	0.5597	0.7992	0.1034	0.2157
1978	0.5506	0.7824	0.1002	0.2205
1979	0.5523	0.7632	0.1014	0.2119
1980	0.5494	0.7130	0.0990	0.1904
1981	0.5598	0.6891	0.1001	0.1918
1982	0.5282	0.6470	0.0879	0.1750
1983	0.5305	0.5936	0.0918	0.1580
1984	0.5221	0.5579	0.0923	0.1455
1985	0.5305	0.5506	0.0896	0.1428
1986	0.5458	0.5113	0.0938	0.139
1987	0.5269	0.4485	0.0888	0.1323
1988	0.5268	0.4445	0.0874	0.1304
1989	0.5173	0.404	0.0862	0.1198
1990	0.5186	0.3316	0.0856	0.095
1991	0.5296	0.3024	0.085	0.0924
1992	0.5177	0.254	0.0827	0.0772
1993	0.5342	0.3997	0.092	0.1264
1994		0.2108		0.0598

Figure 6.1 Dual Rate of Technological Change, U.S. Unrestricted Profit Function Model

Figure 6.2 Primal Rate of Technological Change, U.S. Unrestricted Profit Function Model



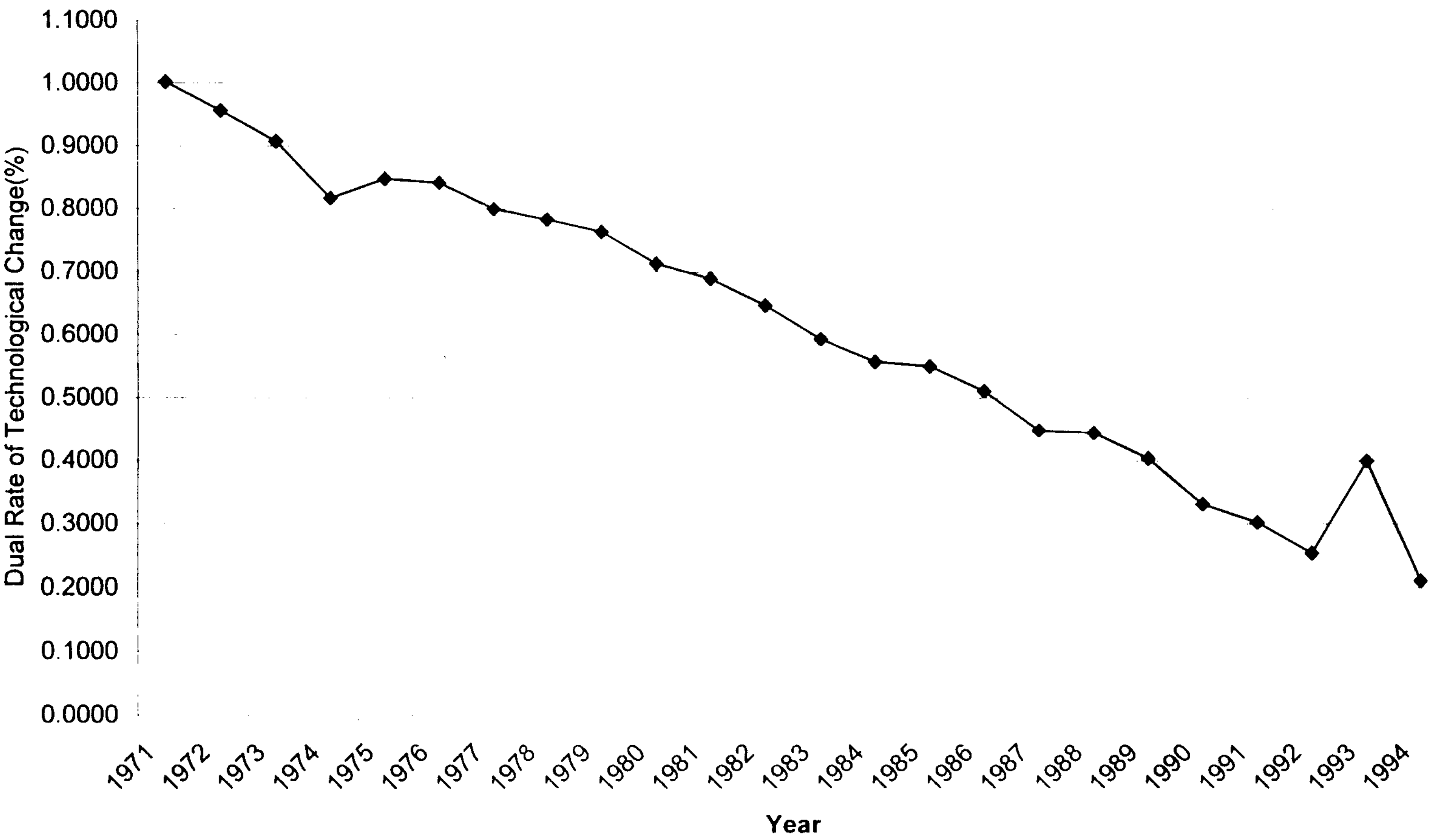


Figure 6.3 Dual Rate of Technological Change, Mexican Unrestricted Profit Function Model

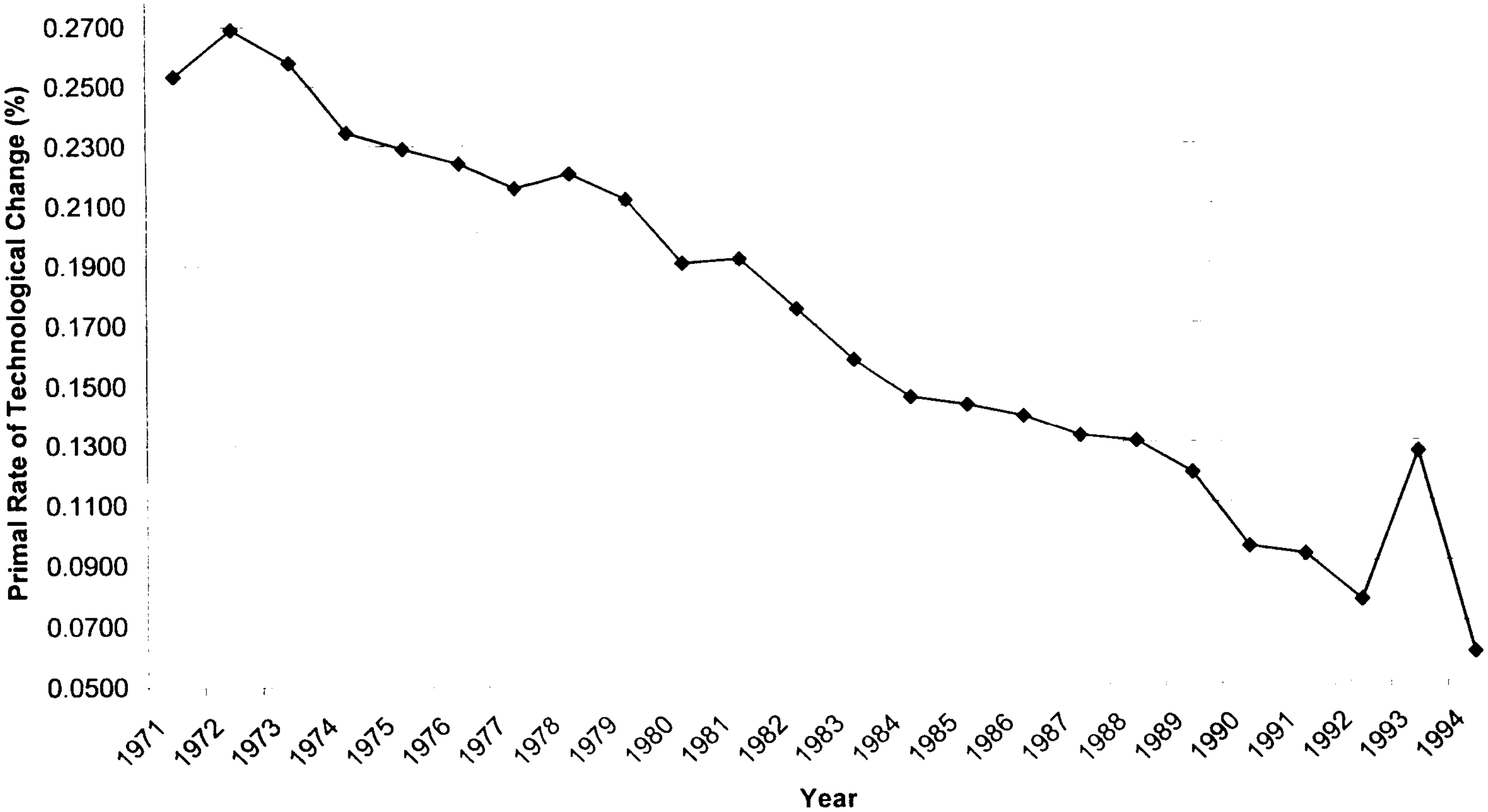


Figure 6.4 Primal Rate of Technological Change, Mexican Unrestricted Profit Function Model

Table 6.6 Average Annual Rates of Dual and Primal Technological Change for Selected Subperiods, Unrestricted Profit Function Model

Subperiod	U.S.		Mexico	
	ε_{Ht}	ε_{Yt}	ε_{Ht}	ε_{Yt}
1963-73	0.516	0.098		
1971-74	0.534	0.105	0.921	0.254
1974-81	0.551	0.105	0.782	0.215
1982-88	0.530	0.090	0.536	0.146
1989-93	0.524	0.086	0.338	0.102
1963-93	0.530	0.096		
1971-93	0.535	0.096	0.633	0.175

6.3.2 Primal and Dual Rate of Technological Change Estimates based on Restricted Profit Function Model

The estimates of dual and primal rate of technological change derived from restricted profit function models for U.S. and Mexico are presented in Table 6.7. The second and third columns of this table give the dual rate of technological change, ε^{A}_{Ht} (computed by equation (4.16) in section 4.5.2). The last two columns present the estimates for the primal rate of technological change, ε^{A}_{Yt} (computed by equation (4.17).

Figure 6.5 and table 6.8 illustrate that the average annual rate of dual technological change in U.S. was around 0.76% during first subperiod of 1963-73, while it dropped to 0.67% during next period of 1974-81, probably reflecting the general slowdown in U.S. economy during this time. The highest reduction in dual rate of technological change was observed between 1975-76, which might be considered as a lagged response to 1973 oil crisis. Between 1982-88, although the dual rate of technological change was increasing from its low levels during late 1970's, the average annual rate of technological change was stayed around 0.67% as it was during 1974-81. The dual rate of technological change continued to follow an increasing trend during 1988-1990 with an average annual rate of 0.72%. However, it showed a declining trend after 1990 until the end of study period, with an average annual rate of 0.65%.

Figure 6.6 and Table 6.8 reveal that primal rate of technological change in U.S. based on restricted profit function generally followed opposite of the trends that observed for the dual rate of technological change. During 1963-73 period, the primal rate of technological change declined (with the exception of 1966-68 period) and the average annual rate was 0.079%. It started to increase during early years of 1974-81 period, while it followed a decreasing trend during late years of 1974-81 period, with sharpest reduction between 1977-78. During 1982-88, the primal rate of technological change had a steady trend and the average annual rate of technological change had its lowest level of 0.065%. After 1988, the primal rate of technological change started rising again, with an average rate of 0.075%.

For the Mexican sector, Figures 6.7 and 6.8, and Table 6.8 indicate a generally declining trend in the dual rate of technological change during whole study period with the exception between 1986-87 and 1993-94. Specifically, the dual rate of technological change dropped from 1.43% in 1971 to -0.25% in 1994, with the sharpest reduction between 1992-1993. According to Figure 6.8 and Table 6.6, the Mexican primal rate of technological change showed relatively steady trend during 1971-81, with average annual rate of 0.19%. During the next two periods of 1982-88 and 1989-93, the primal rate of technological change was dropping and average annual rate was 0.12% and 0.03%, respectively. Overall, the generally declining trend in the Mexican dual and primal rate of technological change is consistent with the conclusions of previous studies of TFP growth in Mexican economy. These previous studies suggested that Mexican economy experienced a dramatic fall in productivity growth during 1970 and 1980's after high levels of productivity growth during 1950-1970 period (Fuess and Berg, 1997). It has been also argued that the roots of the Mexican debt crisis in 1982 and Mexico's economic problems during 1980's would be linked to dramatic reductions in the productivity growth rates of Mexican economy during 1970's. In sum, the generally declining trends observed in rate of technological change can be seen as consistent with dramatic slowdown of Mexican economy during 1970's and 1980's.

Table 6.7 Estimates of Dual and Primal Rate of Technological Change for Restricted Profit Function Model

YEAR	ε^{A}_{Ht} (%)		ε^{A}_{Yt} (%)	
	U.S.	Mexico	U.S.	Mexico
1963	0.7602		0.0915	
1964	0.7520		0.0913	
1965	0.8018		0.0807	
1966	0.8110		0.0769	
1967	0.7456		0.0783	
1968	0.7220		0.0801	
1969	0.7329		0.0743	
1970	0.7484		0.0739	
1971	0.7574	1.4342	0.0721	0.1959
1972	0.7222	1.3170	0.0668	0.2053
1973	0.7712	1.2579	0.0852	0.2011
1974	0.7752	1.1946	0.0886	0.1723
1975	0.7604	1.0982	0.1004	0.1838
1976	0.6587	1.0351	0.0976	0.1897
1977	0.6328	0.9922	0.1055	0.1833
1978	0.6423	0.9414	0.0874	0.1922
1979	0.6383	0.8823	0.0862	0.1903
1980	0.6357	0.8028	0.0804	0.1677
1981	0.6446	0.7090	0.0809	0.1681
1982	0.6220	0.5933	0.0673	0.1452
1983	0.6433	0.5636	0.0664	0.1393
1984	0.6821	0.5476	0.0639	0.1356
1985	0.6717	0.4449	0.0624	0.1120
1986	0.6872	0.4246	0.0664	0.1104
1987	0.6744	0.4463	0.0645	0.1232
1988	0.7029	0.3591	0.0618	0.1001
1989	0.7285	0.3534	0.0653	0.1005
1990	0.7396	0.3348	0.0745	0.0938
1991	0.7049	0.1973	0.0752	0.0571
1992	0.6361	0.1046	0.0726	0.0296
1993	0.6164	-0.5084	0.0851	-0.1476
1994		-0.2523		-0.0677

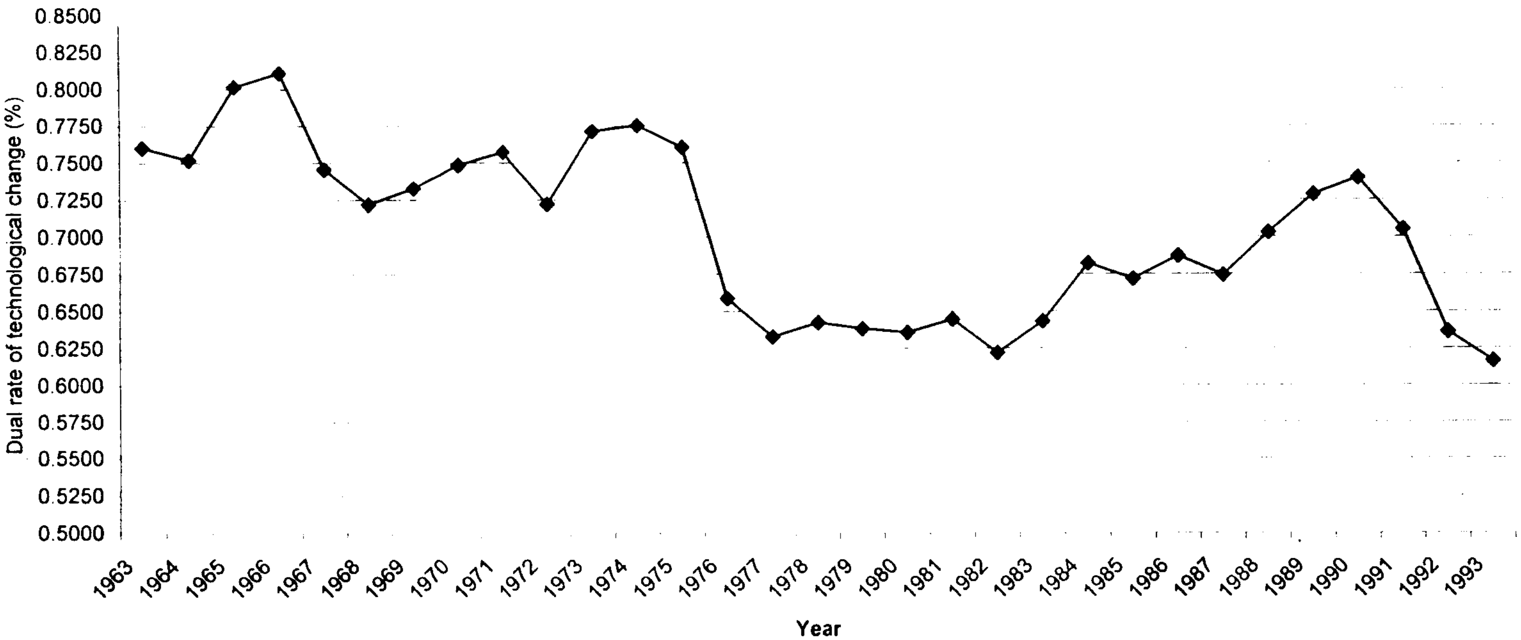
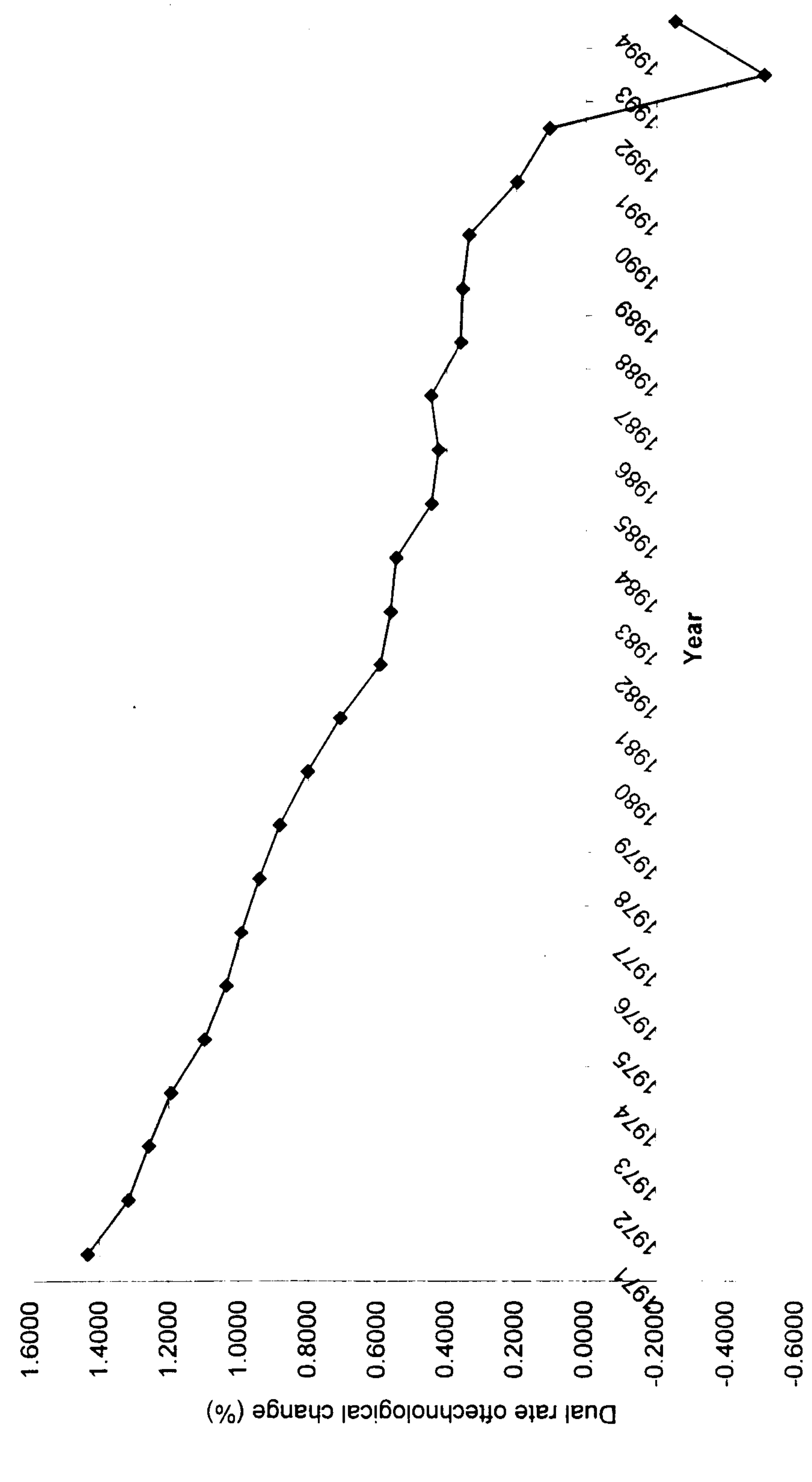


Figure 6.5 Dual Rate of Technological Change, U.S. Restricted Profit Function Model

Figure 6.6 Primal Rate of Technological Change, U.S. Restricted Profit Function Model

Figure 6.7 Dual Rate of Technological Change, Mexican Restricted Profit Function Model



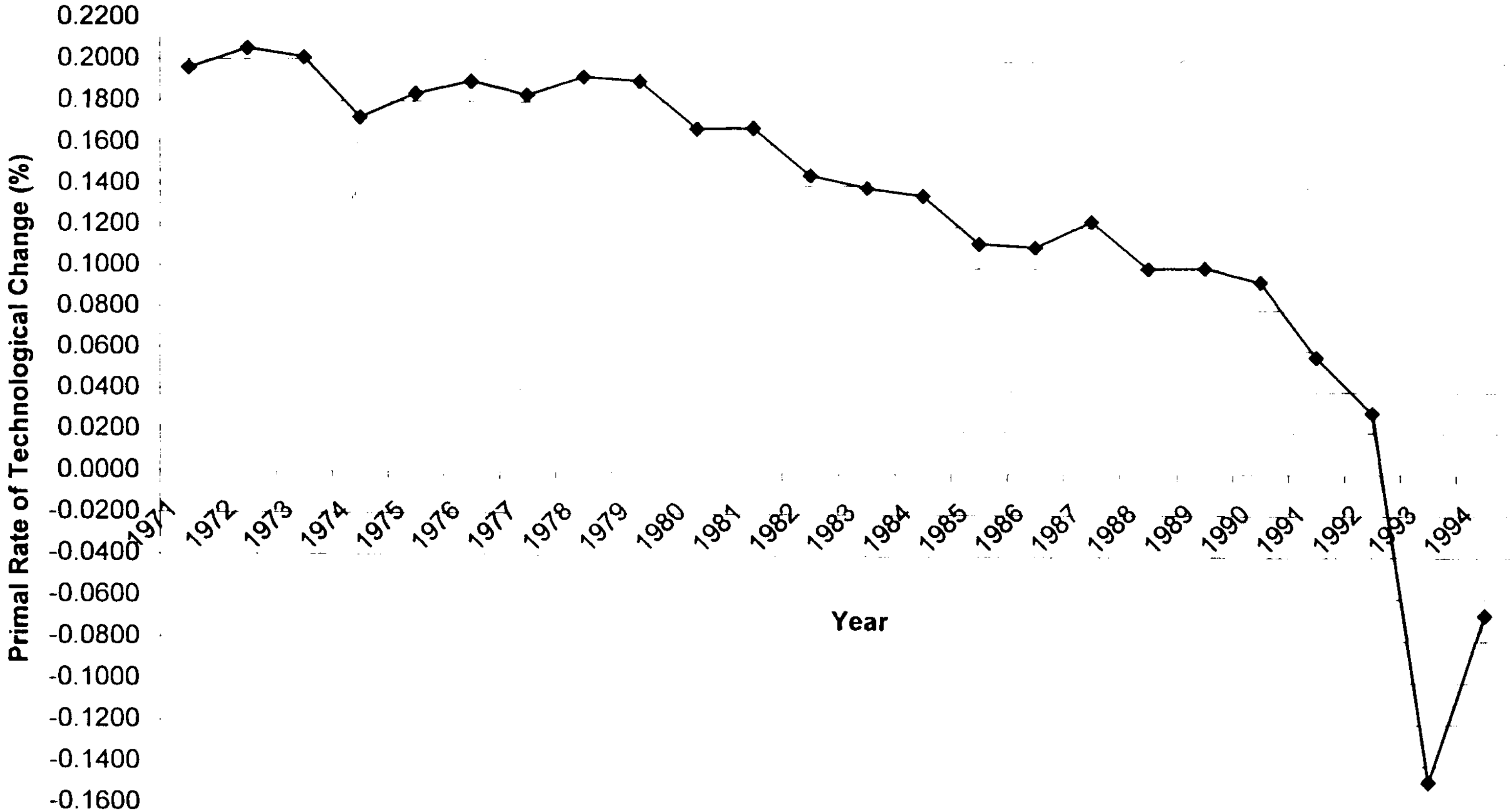


Figure 6.8 Primal Rate of Technological Change, Mexican Restricted Profit Function Model

Table 6.8 Average Annual Rates of Dual and Primal Technological Change for Selected Subperiods, Restricted Profit Function Model

Subperiod	U.S.		Mexico	
	ε^{A}_{Ht}	ε^{A}_{Yt}	ε^{A}_{Ht}	ε^{A}_{Yt}
1963-73	0.757	0.079		
1971-74	0.757	0.078	1.301	0.194
1974-81	0.674	0.091	0.957	0.181
1982-88	0.669	0.065	0.483	0.124
1989-93	0.685	0.075	0.096	0.027
1963-93	0.704	0.078		
1971-93	0.685	0.077	0.675	0.133

6.4 Dual and Primal Rate of Technological Change Difference between U.S. and Mexico

6.4.1 Primal and Dual Rate of Technological Change Difference based on Unrestricted Profit Function Model

Tables 6.9a and 6.9b present the dual and primal technological change difference between U.S. and Mexico (defined in section 4.6). A positive (negative) difference implies a better (worse) performance of the U.S. food processing sector than its Mexican counterpart in terms of rate of increase in total profit or rate of increase in output level induced by technological change, holding everything else fixed.

Figure 6.9 reveals a wide negative dual technological change difference between U.S and Mexico during 1970's, indicating that Mexican food sector performed better in terms of rate of increase in total profit induced by technological change, ceteris paribus. The difference continuously narrowed during 1970's and early 1980's and eventually reached it lowest level by 1985. After 1985, an increasing positive dual technological change difference was observed, indicating that U.S. food processing sector had a net technological advantage over Mexican food sector during 1986-1993 period. This positive difference that is in favor of U.S. was continuously widening, while it narrowed only between 1992-93.

Table 6.9a Dual Rate of Technological Change Difference between U.S. and Mexico based on Unrestricted Profit Function Model

YEAR	$\varepsilon_{Ht,U.S.}$	$\varepsilon_{Ht,Mexico}$	$\varepsilon_{Ht,U.S} - \varepsilon_{Ht,Mexico}$
1971	0.5213	1.0019	-0.4806
1972	0.5182	0.9565	-0.4383
1973	0.5299	0.9074	-0.3775
1974	0.5664	0.8163	-0.2499
1975	0.5332	0.8477	-0.3145
1976	0.5379	0.8411	-0.3032
1977	0.5597	0.7992	-0.2395
1978	0.5506	0.7824	-0.2318
1979	0.5523	0.7632	-0.2109
1980	0.5494	0.713	-0.1636
1981	0.5598	0.6891	-0.1293
1982	0.5282	0.647	-0.1188
1983	0.5305	0.5936	-0.0631
1984	0.5221	0.5579	-0.0358
1985	0.5305	0.5506	-0.0201
1986	0.5458	0.5113	0.0345
1987	0.5269	0.4485	0.0784
1988	0.5268	0.4445	0.0823
1989	0.5173	0.404	0.1133
1990	0.5186	0.3316	0.1870
1991	0.5296	0.3024	0.2272
1992	0.5177	0.254	0.2637
1993	0.5342	0.3997	0.1345

The estimates of primal technological change difference (Table 6.9b and Figure 6.10) reveals a wide negative gap for most of the years in study period, implying that Mexico had a net primal technological advantage in terms of rate of increase in output. The difference continuously narrowed during 1970's and 1980's, reaching its lowest in 1991.The only positive difference was observed during 1992, after which it became negative again.

Table 6.9b Primal Rate of Technological Change Difference between U.S. and Mexico based on Unrestricted Profit Function Model

Year	$\varepsilon_{Yt,U.S.}$	$\varepsilon_{Yt,Mexico}$	$\varepsilon_{Yt,U.S} - \varepsilon_{Yt,Mexico}$
1971	0.0926	0.2534	-0.1608
1972	0.0941	0.2691	-0.1750
1973	0.1111	0.2579	-0.1468
1974	0.1233	0.2344	-0.1111
1975	0.1130	0.2289	-0.1159
1976	0.1031	0.2240	-0.1209
1977	0.1034	0.2157	-0.1123
1978	0.1002	0.2205	-0.1203
1979	0.1014	0.2119	-0.1105
1980	0.0990	0.1904	-0.0914
1981	0.1001	0.1918	-0.0917
1982	0.0879	0.1750	-0.0871
1983	0.0918	0.1580	-0.0662
1984	0.0923	0.1455	-0.0532
1985	0.0896	0.1428	-0.0532
1986	0.0938	0.1390	-0.0452
1987	0.0888	0.1323	-0.0435
1988	0.0874	0.1304	-0.0430
1989	0.0862	0.1198	-0.0336
1990	0.0856	0.0950	-0.0094
1991	0.0850	0.0924	-0.0074
1992	0.0827	0.0772	0.0055
1993	0.0920	0.1264	-0.0344

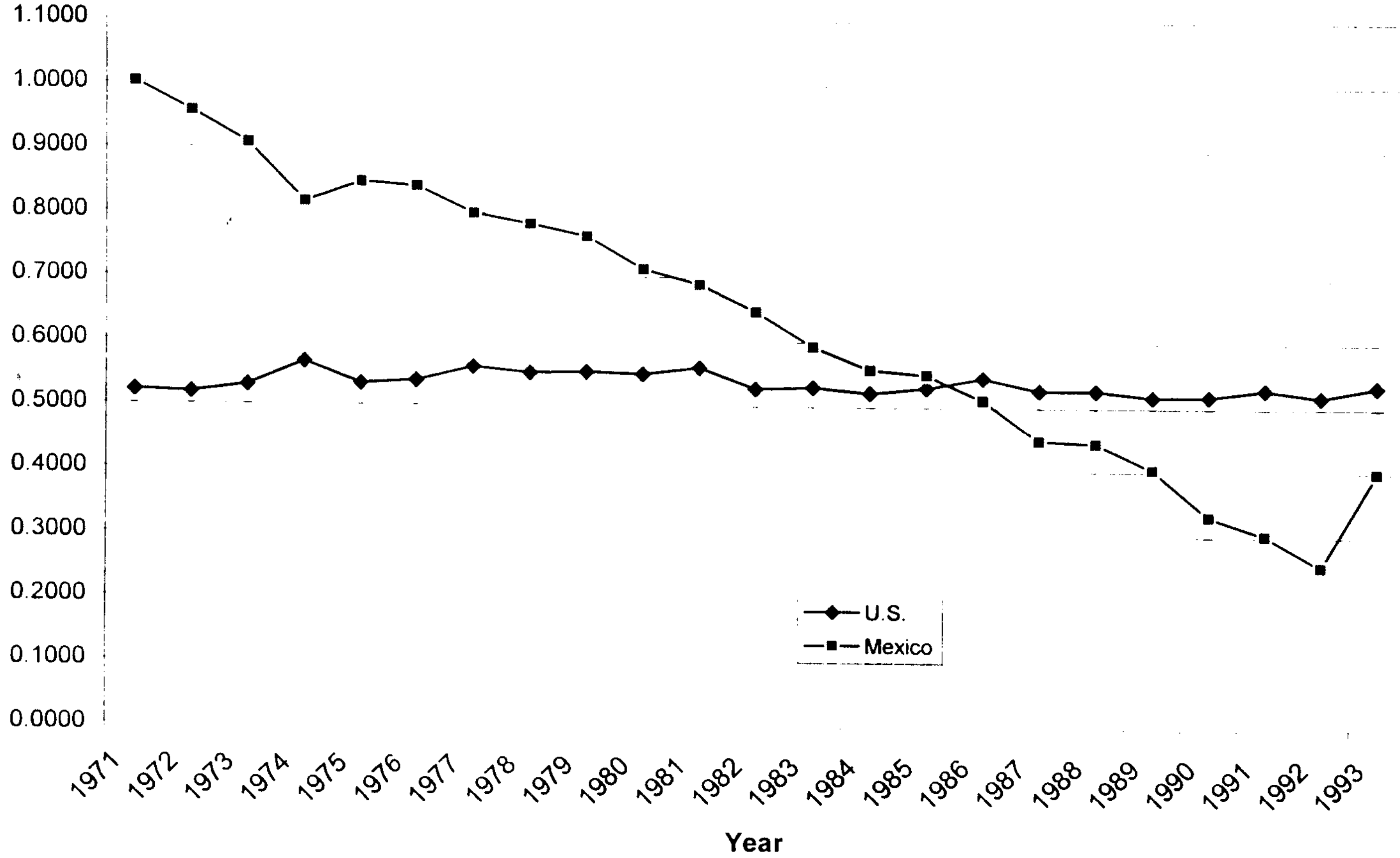


Figure 6.9 Dual Rate of Technological Change Difference between U.S. and Mexico, Unrestricted Profit Function Model

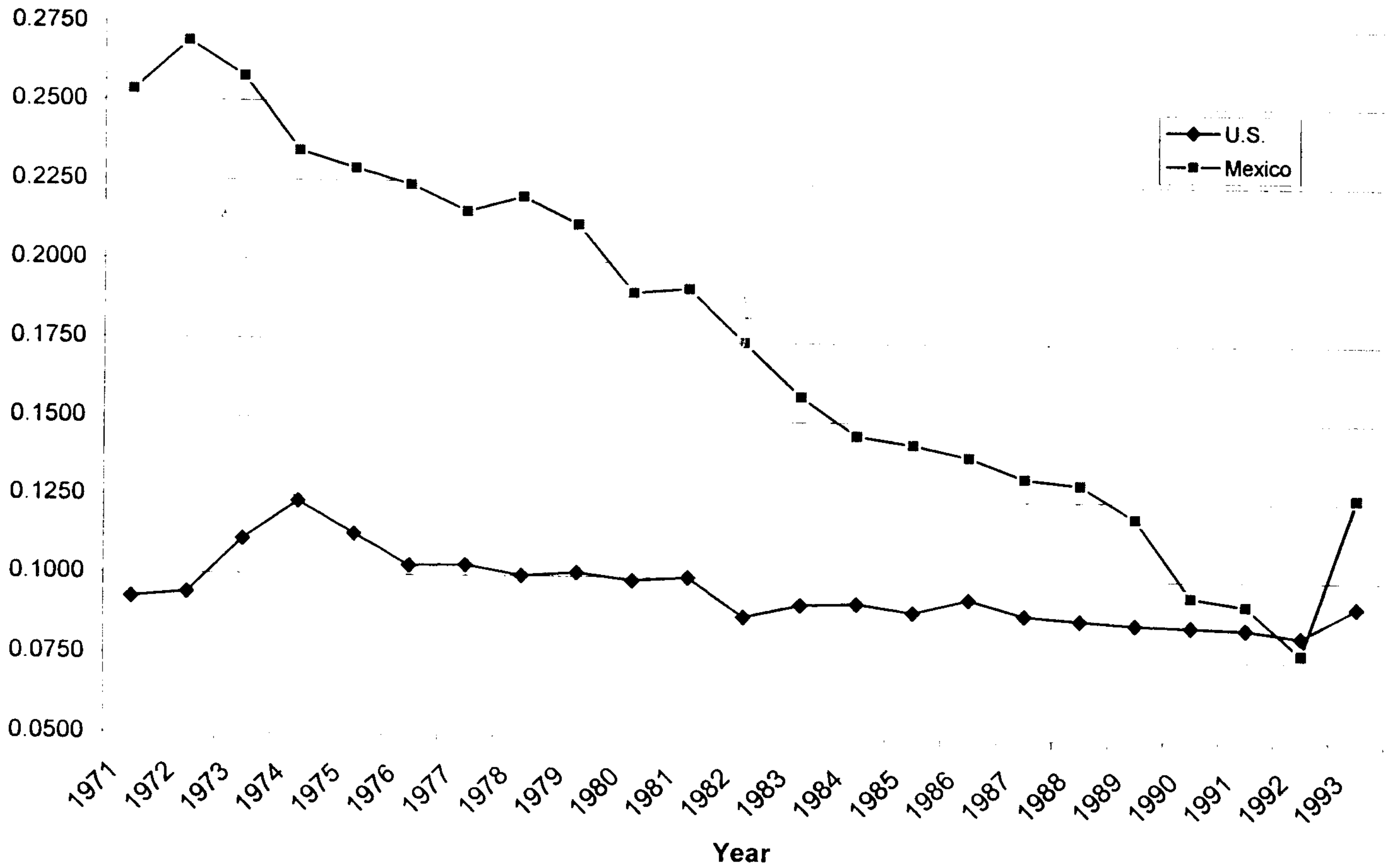


Figure 6.10 Primal Rate of Technological Change Difference between U.S. and Mexico, Unrestricted Profit Function Model

6.4.2 Primal and Dual Rate of Technological Change Difference based on Restricted Profit Function Model

The estimates of primal and dual rate of technological change difference derived from restricted profit function model are presented in Tables 6.10a and 6.10b, and illustrated in Figures 6.11 and 6.12.

Figure 6.11 reveals a declining negative difference in favor of Mexican food sector during 1971-81 period. After 1981, the difference was positive and it was widening for the rest of the study period. The comparison of results for dual technological change difference from unrestricted and restricted profit function models (see Figures 6.9 and 6.11) indicates that both models suggest a declining negative difference with implication of Mexican technological advantage over U.S. during 1970's. However, the magnitude of the difference derived from restricted profit function is smaller and becomes positive more quickly than the one from unrestricted profit function. After early 1980's, both unrestricted and restricted models reveal an increasing positive dual technological change difference, implying a net technological change advantage for U.S. food sector over Mexican sector.

The estimates of primal technological change difference (Table 6.10b) and their illustration (Figure 6.12) also indicate a net technological change advantage for Mexico over U.S. during most of the years as those from unrestricted profit function (Figure 6.10). However, in Figure 6.12, the negative difference is smaller in absolute value and the reduction in the difference is much smoother.

Overall, the results provide evidence that Mexico had a declining technological advantage over U.S. in terms of rate of increase in total profit induced by technological change during 1970's and 1980's. However, after early 1980's, dual technological change difference became positive and was widening throughout the rest of the study period, implying a net technological change advantage of U.S. over Mexico. On the other hand, the results for the primal technological change difference suggest that Mexican food sector had a declining net technological advantage in terms of rate of increase in output induced by technological change during most of the years and U.S. was able to outperform Mexico only after 1990.

Table 6.10a Dual Rate of Technological Change Difference between U.S. and Mexico based on Restricted Profit Function Model

Year	$\varepsilon^{A}_{Ht,U.S.}$	$\varepsilon^{A}_{Ht,Mexico}$	$\varepsilon^{A}_{Ht,U.S} - \varepsilon^{A}_{Ht,Mexico}$
1971	0.7574	1.4342	-0.6768
1972	0.7222	1.3170	-0.5948
1973	0.7712	1.2579	-0.4867
1974	0.7752	1.1946	-0.4194
1975	0.7604	1.0982	-0.3378
1976	0.6587	1.0351	-0.3764
1977	0.6328	0.9922	-0.3594
1978	0.6423	0.9414	-0.2991
1979	0.6383	0.8823	-0.2440
1980	0.6357	0.8028	-0.1671
1981	0.6446	0.7090	-0.0644
1982	0.6220	0.5933	0.0287
1983	0.6433	0.5636	0.0797
1984	0.6821	0.5476	0.1345
1985	0.6717	0.4449	0.2268
1986	0.6872	0.4246	0.2626
1987	0.6744	0.4463	0.2281
1988	0.7029	0.3591	0.3438
1989	0.7285	0.3534	0.3751
1990	0.7396	0.3348	0.4048
1991	0.7049	0.1973	0.5076
1992	0.6361	0.1046	0.5315
1993	0.6164	-0.5084	1.1248

Table 6.10b Primal Rate of Technological Change Difference between U.S. and Mexico based on Restricted Profit Function Model

Year	$\varepsilon^{A}_{Yt,U.S.}$	$\varepsilon^{A}_{Yt,Mexico}$	$\varepsilon^{A}_{Yt,U.S} - \varepsilon^{A}_{Yt,Mexico}$
1971	0.0721	0.1959	-0.1238
1972	0.0668	0.2053	-0.1385
1973	0.0852	0.2011	-0.1159
1974	0.0886	0.1723	-0.0837
1975	0.1004	0.1838	-0.0834
1976	0.0976	0.1897	-0.0921
1977	0.1055	0.1833	-0.0778
1978	0.0874	0.1922	-0.1048
1979	0.0862	0.1903	-0.1041
1980	0.0804	0.1677	-0.0873
1981	0.0809	0.1681	-0.0872
1982	0.0673	0.1452	-0.0779
1983	0.0664	0.1393	-0.0729
1984	0.0639	0.1356	-0.0717
1985	0.0624	0.1120	-0.0496
1986	0.0664	0.1104	-0.0440
1987	0.0645	0.1232	-0.0587
1988	0.0618	0.1001	-0.0383
1989	0.0653	0.1005	-0.0352
1990	0.0745	0.0938	-0.0193
1991	0.0752	0.0571	0.0181
1992	0.0726	0.0296	0.0430
1993	0.0851	-0.1476	0.2327

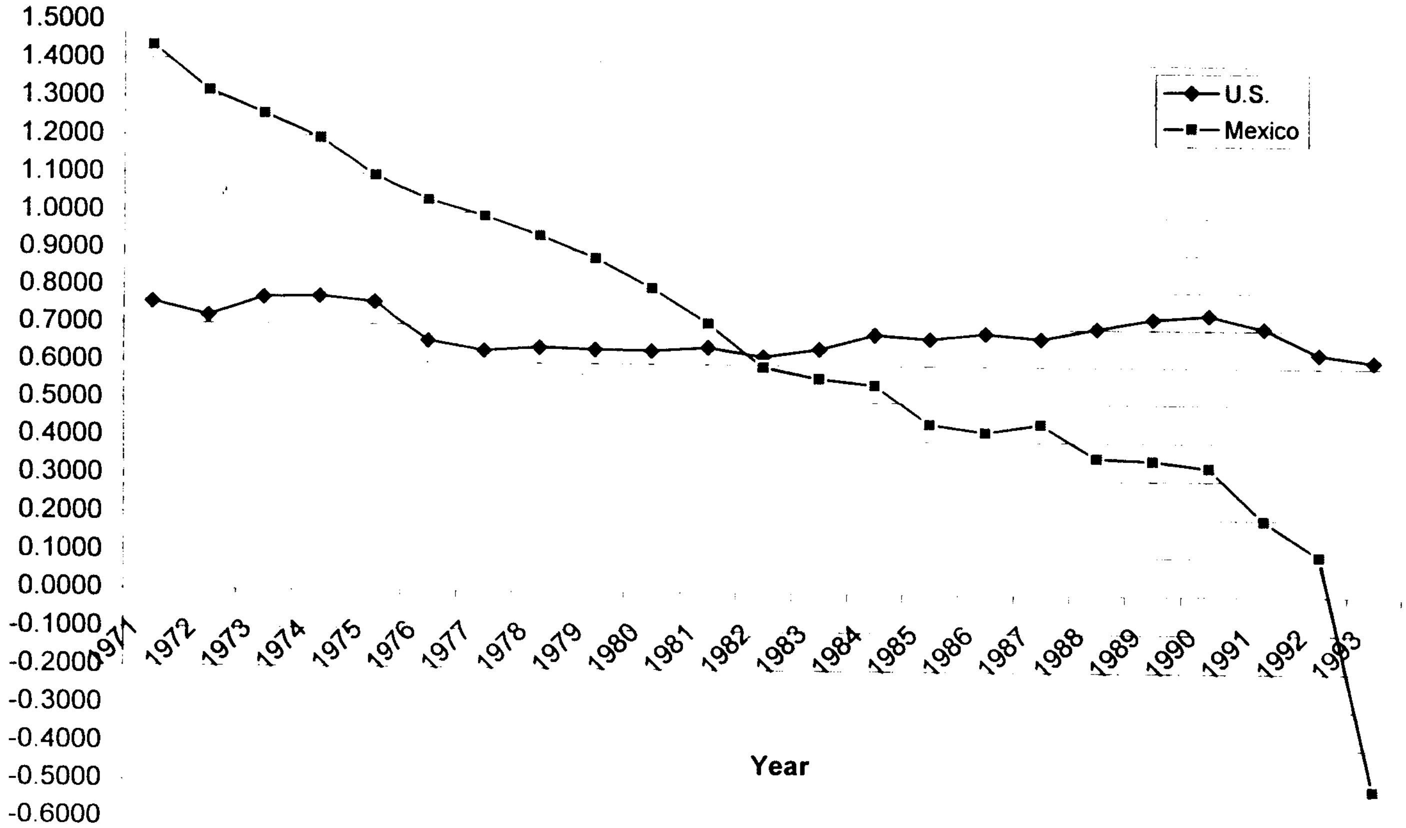


Figure 6.11 Dual Rate of Technological Change Difference between U.S. and Mexico, Restricted Profit Function Model

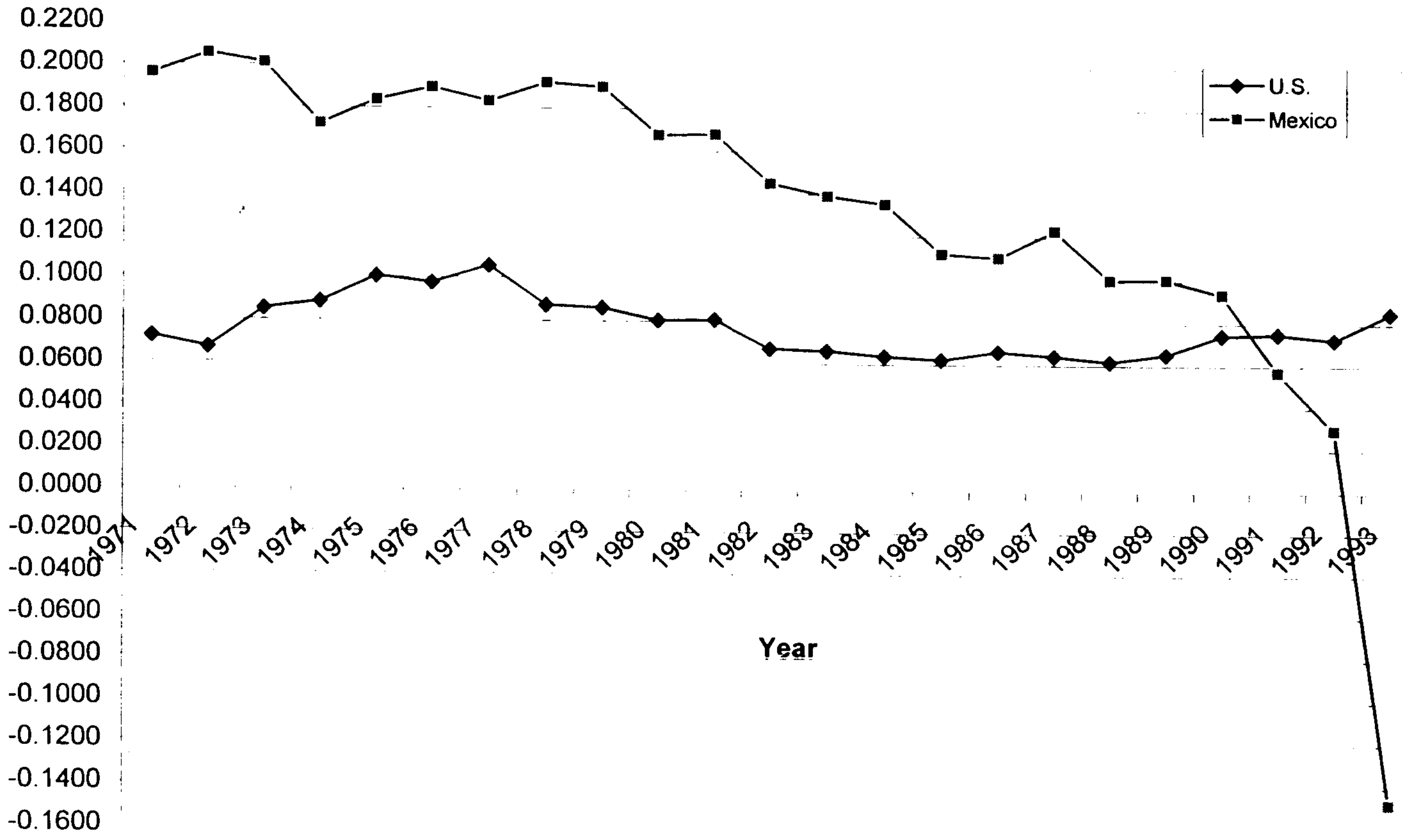


Figure 6.12 Primal Rate of Technological Change Difference between U.S. and Mexico, Restricted Profit Function Model

6.5 Capacity Utilization

The estimates of capacity utilization (computed by equation (4.22) in section 4.8) based on restricted profit function model are presented in Table 6.11.

For the U.S. food processing sector, the CU estimates are greater than one during whole study period, implying under-capitalization of industry. However, this implication of continuous under-capitalization does not seem to be plausible, since it suggest that firms continuously ignoring the opportunities of increasing their profits that can be achieved with expansion of capital stocks. Interestingly, the highest CU estimates were observed in 1973 and 1974, coinciding with 1973 oil crisis. The CU estimates for Mexico are also found greater than one with implication of under-capitalization. The highest level of CU was observed in 1974, and after 1974 it was following a downward trend. Between 1981-1994, the level of CU was steady with average close to unity, implying that capital levels in Mexican food processing sector were almost at their long-run equilibrium levels. However, the Mexican CU estimates should be interpreted cautiously due to the caveats in the measurement of observed capital price. Our Mexican observed capital price does not include capital gains and taxes on capital stock and this might lead to biases in Mexican CU estimates.

Table 6.11 Capacity Utilization in U.S. and Mexican Food Sectors

Year	U.S.	Mexico
1963	1.2958	
1964	1.3032	
1965	1.3696	
1966	1.3438	
1967	1.3145	
1968	1.3195	
1969	1.3333	
1970	1.3458	
1971	1.3340	1.4279
1972	1.3952	1.4097
1973	1.4587	1.4146
1974	1.4127	1.4602
1975	1.2286	1.3518
1976	1.2019	1.2983
1977	1.0971	1.2939
1978	1.2084	1.2471
1979	1.2236	1.1995
1980	1.2344	1.1724
1981	1.2060	1.0890
1982	1.2063	1.0384
1983	1.2875	1.0595
1984	1.3074	1.0680
1985	1.2903	1.0422
1986	1.3049	1.0301
1987	1.2652	1.0577
1988	1.3062	1.0779
1989	1.2954	1.0228
1990	1.2220	1.0509
1991	1.2042	1.0661
1992	1.1664	1.0494
1993	1.1549	1.0498
1994		1.0384

6.6 Dual Rate of Productivity Growth and its Sources

6.6.1 Based on Unrestricted Profit Function Model

The dual rate of productivity growth (defined by equation (4.20) based on unrestricted profit function) consists of technological change and the effects of output price changes on total profit (defined as the rate of change in total profit induced by the changes in output price, ceteris paribus)

The estimates of dual productivity growth rate for U.S. and Mexico and decomposition into its sources can be seen in Tables 6.12a and 6.12b. Table 6.12a, and Figures 6.13 and 6.15 reveal that, in U.S., the average annual dual rate of productivity growth derived from unrestricted profit function model was around 0.56% during first subperiod of 1963-73, reaching its peak in 1973. Between 1974-81, the productivity growth rate sharply declined (with the exception of 1974-75 and 1976-78), and average annual rate of productivity growth dropped to 0.38%. During next subperiod of 1982-88, it followed an upward trend (except between 1984-85 and 1987-88) and average annual rate was again around 0.56%. During last subperiod of 1989-93, it showed a steady trend with a slightly reduced average annual rate of 0.50%. Table 6.12a also suggest that major source of productivity growth was the rate of increase in total profit induced by technological change while the output price effects has been minor during most of the years in study period.

Turning to Mexico, Table 6.12b and Figure 6.14 indicate that the dual rate of productivity growth was sharply declining between 1974-77 while it followed an upward trend between 1977-81. After 1981, rather high reductions lead to negative growth rates in 1982 (coinciding with Mexican foreign debt crisis) and in 1986 (during which Mexican oil prices collapsed and Mexican economy experienced a major slowdown). During 1982-88, the average annual rate was at its lowest level of 0.34% while it improved to 0.60% during last period of 1989-93. In addition, the figures for proportion of components of productivity growth in Table 6.12b suggest that major source of productivity growth rate was mostly due to the contributions of technological change with the exception of years 1982, 1984,1986 and 1988. Indeed, in 1982 and 1986, the rather sharp reductions in output prices in Mexican food sector were observed, causing output contractions, and hence significant reductions in productivity growth rate. In contrast, in 1984 and 1988, the output expansions induced by improved output prices during these years lead to significant increases in productivity growth rate.

Table 6.12a Dual Productivity Growth Rate based on Unrestricted Profit Function Model, U.S.

YEAR	Productivity Growth Rate	Decomposition of Productivity Growth Rate			
		Technological Change		Output Price Effects	
			Proportion (%)		Proportion (%)
1963	0.4981	0.5146	103.31	-0.0165	-3.31
1964	0.5128	0.5221	101.81	-0.0093	-1.81
1965	0.5543	0.5125	92.46	0.0418	7.54
1966	0.6359	0.5016	78.88	0.1343	21.12
1967	0.4231	0.5129	121.22	-0.0898	-21.22
1968	0.4953	0.5148	103.94	-0.0195	-3.94
1969	0.5756	0.5116	88.89	0.0640	11.11
1970	0.5428	0.5162	95.10	0.0266	4.90
1971	0.4714	0.5213	110.59	-0.0499	-10.59
1972	0.5652	0.5182	91.68	0.0470	8.32
1973	0.8433	0.5299	62.84	0.3134	37.16
1974	0.3911	0.5664	144.82	-0.1753	-44.82
1975	0.4841	0.5332	110.14	-0.0491	-10.14
1976	0.1766	0.5379	304.59	-0.3613	-204.59
1977	0.5003	0.5597	111.87	-0.0594	-11.87
1978	0.5978	0.5506	92.10	0.0472	7.90
1979	0.4081	0.5523	135.33	-0.1442	-35.33
1980	0.1800	0.5494	305.22	-0.3694	-205.22
1981	0.3162	0.5598	177.04	-0.2436	-77.04
1982	0.4401	0.5282	120.02	-0.0881	-20.02
1983	0.5762	0.5305	92.07	0.0457	7.93
1984	0.5925	0.5221	88.12	0.0704	11.88
1985	0.4147	0.5305	127.92	-0.1158	-27.92
1986	0.8183	0.5458	66.70	0.2725	33.30
1987	0.4923	0.5269	107.03	-0.0346	-7.03
1988	0.5718	0.5268	92.13	0.0450	7.87
1989	0.5231	0.5173	98.89	0.0058	1.11
1990	0.4881	0.5186	106.25	-0.0305	-6.25
1991	0.4947	0.5296	107.05	-0.0349	-7.05
1992	0.4879	0.5177	106.11	-0.0298	-6.11
1993	0.5262	0.5342	101.52	-0.0080	-1.52
	Average Annual Productivity Growth Rate				
1963-73	0.56				
1974-81	0.38				
1982-88	0.56				
1989-93	0.50				

Table 6.12b Dual Productivity Growth Rate based on Unrestricted Profit Function Model, Mexico

YEAR	Dual Productivity Growth Rate (%)	Decomposition of Productivity Growth Rate			
		Technological Change		Output Price Effects	
			Proportion (%)		Proportion (%)
1971	1.3255	1.0019	75.59	0.3236	24.41
1972	0.9098	0.9565	105.13	-0.0467	-5.13
1973	1.0165	0.9074	89.27	0.1091	10.73
1974	1.1689	0.8163	69.83	0.3526	30.17
1975	0.9900	0.8477	85.63	0.1423	14.37
1976	0.4945	0.8411	170.09	-0.3466	-70.09
1977	0.2573	0.7992	310.61	-0.5419	-210.61
1978	0.8335	0.7824	93.87	0.0511	6.13
1979	0.6802	0.7632	112.20	-0.0830	-12.20
1980	0.8198	0.7130	86.97	0.1068	13.03
1981	0.9046	0.6891	76.18	0.2155	23.82
1982	-0.9579	0.6470	-67.54	-1.6049	167.54
1983	0.3864	0.5936	153.62	-0.2072	-53.62
1984	1.3294	0.5579	41.97	0.7715	58.03
1985	0.6626	0.5506	83.10	0.1120	16.90
1986	-0.4107	0.5113	-124.49	-0.9220	224.49
1987	0.2523	0.4485	177.76	-0.1962	-77.76
1988	1.1067	0.4445	40.16	0.6622	59.84
1989	0.4958	0.4040	81.48	0.0918	18.52
1990	0.5853	0.3316	56.65	0.2537	43.35
1991	0.7052	0.3024	42.88	0.4028	57.12
1992	0.4651	0.2540	54.61	0.2111	45.39
1993	0.7348	0.3997	54.40	0.3351	45.60
1994	0.2485	0.2108	84.83	0.0377	15.17
	Average Annual Productivity Growth Rate				
1971-73	1.11				
1974-81	0.77				
1982-88	0.34				
1989-93	0.60				

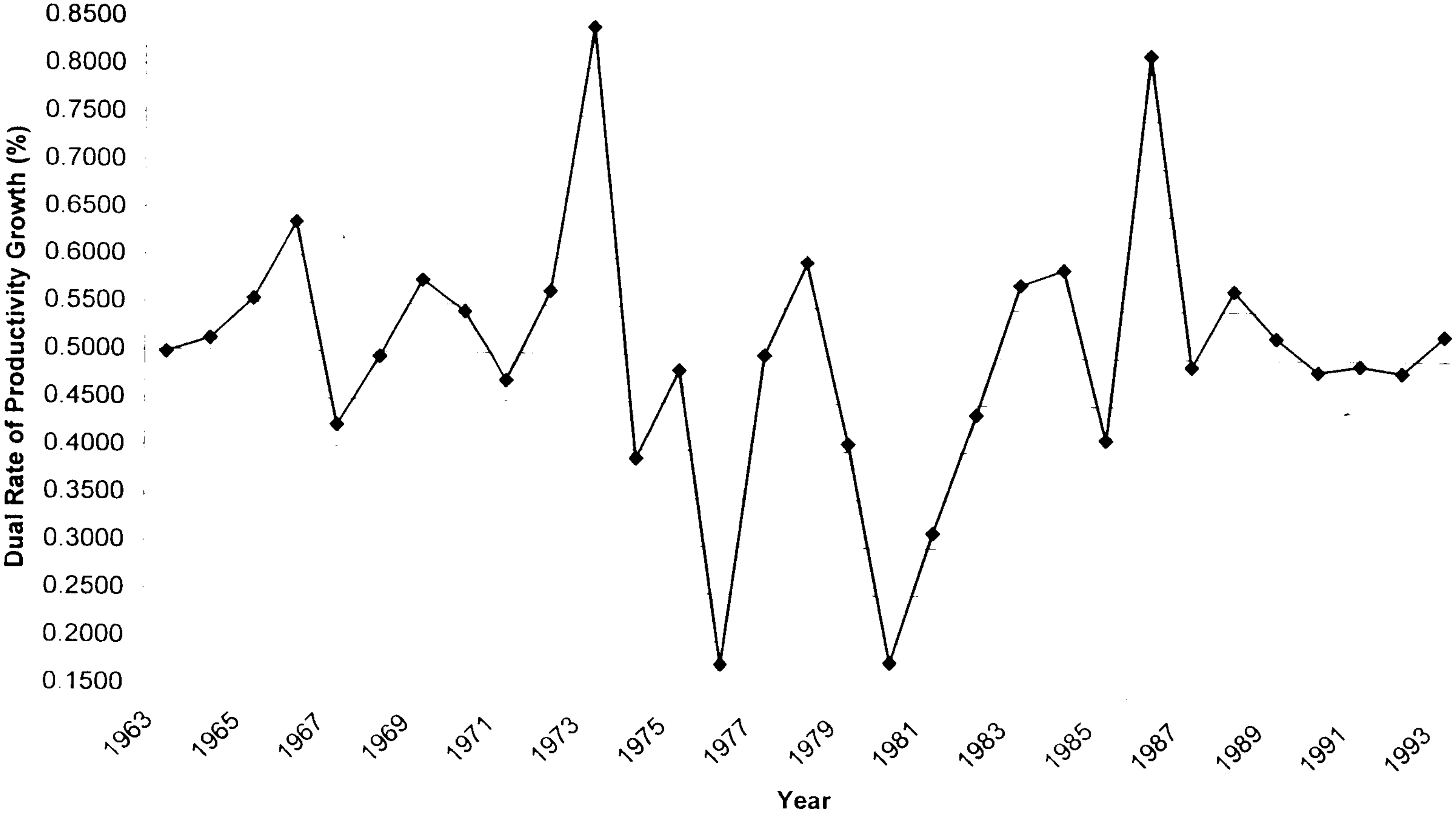


Figure 6.13 Dual Rate of Productivity Growth, Unrestricted Profit Function Model, U.S.

Figure 6.14 Dual Rate of Productivity Growth, Unrestricted Profit Function Model, Mexico

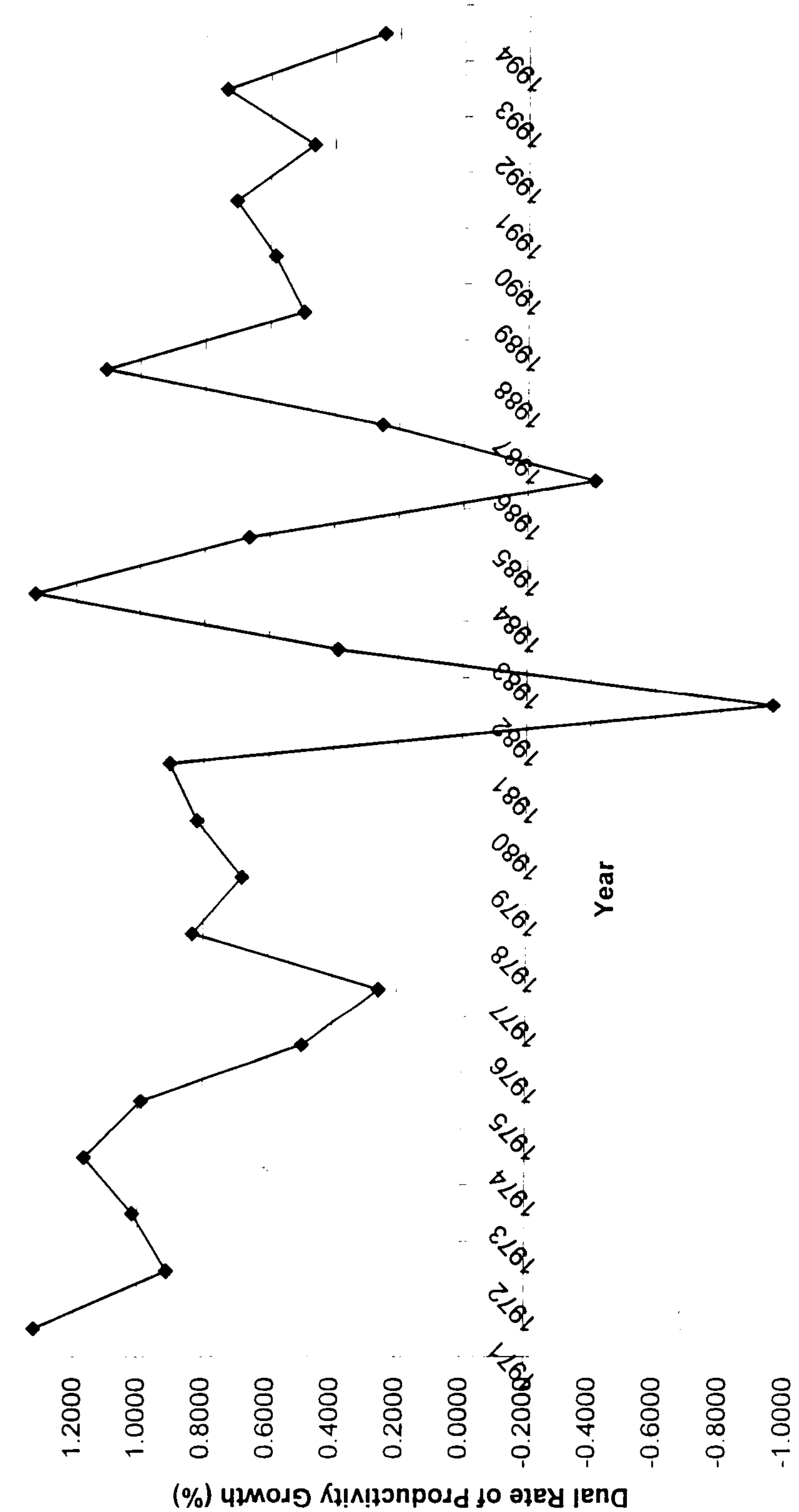
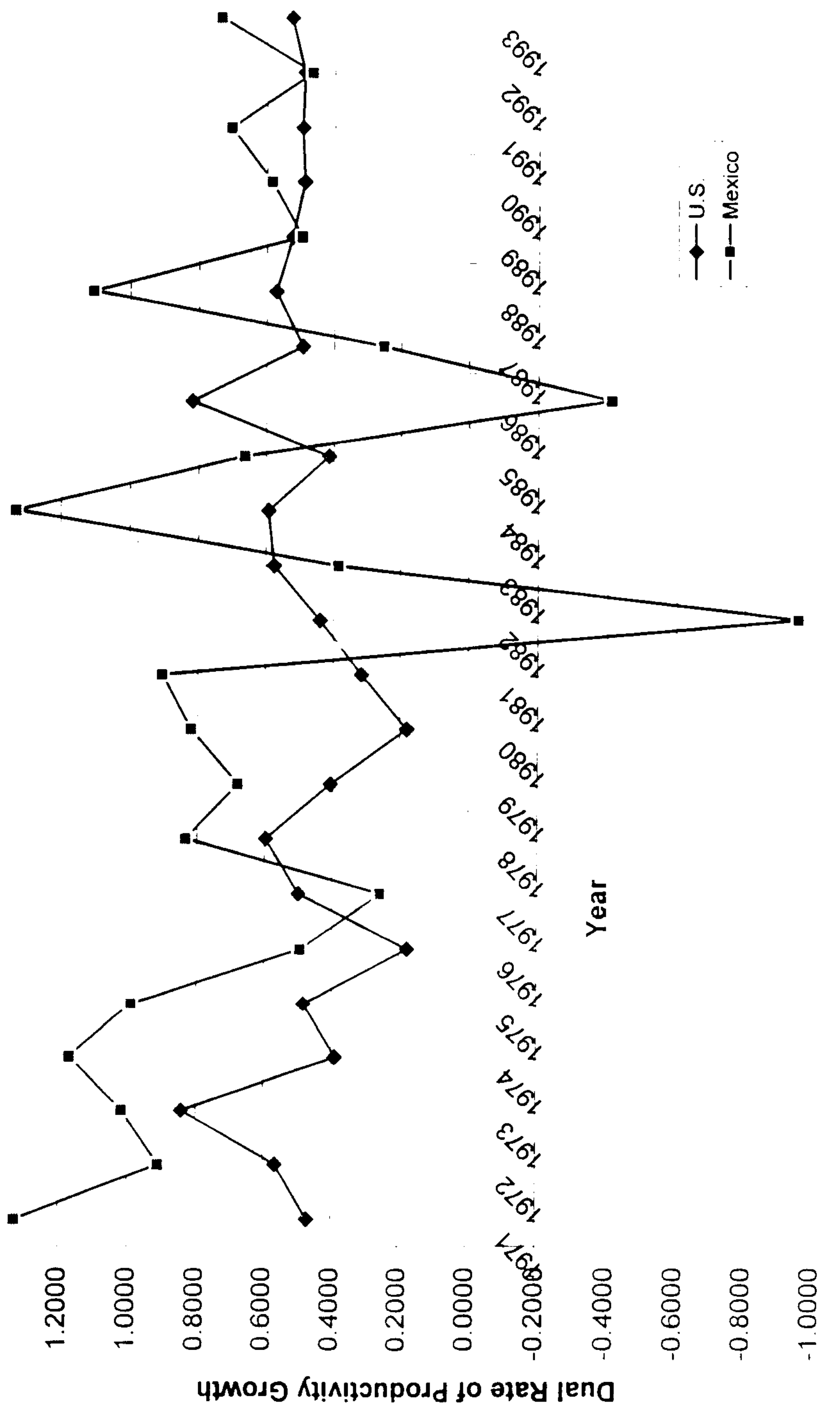


Figure 6.15 Comparison of Dual Rate of Productivity Growth between U.S. and Mexico, Unrestricted Profit Function Model



6.6.2 Based on Restricted Profit Function Model

Dual rate of productivity growth derived from restricted profit function model (defined by equation (4.21) in section 4.7) consists of the effects of capacity utilization (CU) (or effects of diseqilibrium in capital markets), technological change and effects of output price changes on productivity growth. The effects of capacity utilization are defined as the proportional change in total profit induced by a proportional change in capital stock as the industry moves it short-run capital level toward its long-run equilibrium.

The estimates of dual rate of productivity growth and its decomposition based on restricted profit function model for U.S. and Mexico are given in Tables 6.13a and 6.14a, and illustrated in Figures 6.16, 6.17 and 6.18. Table 6.13a and Figure 6.16 indicate that the average annual dual rate of productivity growth in U.S. was around 0.46% during 1963-73 and dropped to 0.32% during next subperiod of 1974-81 (with the sharpest reduction observed between 1973-74 period). During the next two subperiods of 1982-88 and 1989-93, the dual rate of productivity growth was rising (with the exception of reductions between 1984-85 and 1986-87) and the average annual rate of productivity growth reached to 0.42% and 0.44%, respectively. In addition, Table 6.13b suggests that major source of productivity growth was due to the contributions of technological change followed by the output price effects, with the largest negative output price effects (induced by declines in output prices) observed in 1974,1976 and 1980, and the highest positive output price effects (induced by increase in output price) observed in 1986. The effects of capacity utilization had the smallest impact on productivity growth.

For Mexico, Table 6.14a and Figure 6.17 suggest similar trends in dual productivity growth rate as those derived from unrestricted profit function model. However, the figures derived from restricted profit function model are smaller. Table 6.14b reveals that major source of productivity growth was due to the contributions of technological change during 1971-81. However, beginning from 1982, the output price effects became larger. Indeed, in 1982 and 1986, negative output price effects induced by declines in output price outweighed the positive effects of technological change, leading negative productivity growth rates.

Table 6.13a Dual Rate of Productivity Growth based on Restricted Profit Function Model, U.S.

YEAR	Dual Productivity Growth Rate	Decomposition of Productivity Growth Rate		
		Technological Change	Output Price Effects	CU Effects
1963	0.4521	0.4604	-0.0166	0.0083
1964	0.4535	0.4522	-0.0091	0.0104
1965	0.4649	0.4165	0.0423	0.0061
1966	0.5741	0.4259	0.1363	0.0119
1967	0.3529	0.4210	-0.0855	0.0174
1968	0.4165	0.4229	-0.0195	0.0131
1969	0.4762	0.4029	0.0630	0.0103
1970	0.4395	0.4031	0.0268	0.0096
1971	0.3615	0.3996	-0.0491	0.0110
1972	0.4063	0.3440	0.0440	0.0183
1973	0.6230	0.3453	0.2663	0.0114
1974	0.2386	0.3941	-0.1697	0.0142
1975	0.4752	0.5181	-0.0536	0.0107
1976	0.1592	0.4981	-0.3532	0.0143
1977	0.5049	0.5575	-0.0580	0.0054
1978	0.5198	0.4703	0.0462	0.0033
1979	0.3287	0.4629	-0.1421	0.0079
1980	0.0836	0.4453	-0.3687	0.0070
1981	0.2202	0.4649	-0.2505	0.0058
1982	0.3353	0.4187	-0.0911	0.0077
1983	0.4310	0.3803	0.0453	0.0054
1984	0.4526	0.3743	0.0729	0.0054
1985	0.2661	0.3707	-0.1161	0.0115
1986	0.6626	0.3825	0.2699	0.0102
1987	0.3711	0.3946	-0.0357	0.0122
1988	0.4240	0.3708	0.0448	0.0084
1989	0.4130	0.3965	0.0059	0.0106
1990	0.4480	0.4698	-0.0318	0.0100
1991	0.4415	0.4646	-0.0347	0.0116
1992	0.4309	0.4467	-0.0292	0.0134
1993	0.4858	0.4854	-0.0079	0.0083
	Average Annual Productivity Growth Rate			
1963-73	0.46			
1974-81	0.32			
1982-88	0.42			
1989-93	0.44			

Table 6.13b Proportions of Components of Dual Productivity Growth Rate based on Restricted Profit Function Model, U.S.

YEAR	Dual Productivity Growth Rate	Proportion of Components		
		Technological Change (%)	Output Price Effects (%)	CU effect (%)
1963	0.4521	101.84	-3.67	1.84
1964	0.4535	99.71	-2.01	2.29
1965	0.4649	89.59	9.10	1.31
1966	0.5741	74.19	23.74	2.07
1967	0.3529	119.30	-24.23	4.93
1968	0.4165	101.54	-4.68	3.15
1969	0.4762	84.61	13.23	2.16
1970	0.4395	91.72	6.10	2.18
1971	0.3615	110.54	-13.58	3.04
1972	0.4063	84.67	10.83	4.50
1973	0.6230	55.43	42.74	1.83
1974	0.2386	165.17	-71.12	5.95
1975	0.4752	109.03	-11.28	2.25
1976	0.1592	312.88	-221.86	8.98
1977	0.5049	110.42	-11.49	1.07
1978	0.5198	90.48	8.89	0.63
1979	0.3287	140.83	-43.23	2.40
1980	0.0836	532.66	-441.03	8.37
1981	0.2202	211.13	-113.76	2.63
1982	0.3353	124.87	-27.17	2.30
1983	0.4310	88.24	10.51	1.25
1984	0.4526	82.70	16.11	1.19
1985	0.2661	139.31	-43.63	4.32
1986	0.6626	57.73	40.73	1.54
1987	0.3711	106.33	-9.62	3.29
1988	0.4240	87.45	10.57	1.98
1989	0.4130	96.00	1.43	2.57
1990	0.4480	104.87	-7.10	2.23
1991	0.4415	105.23	-7.86	2.63
1992	0.4309	103.67	-6.78	3.11
1993	0.4858	99.92	-1.63	1.71

Figure 6.16 Dual Rate of Productivity Growth, Restricted Profit Function Model, U.S.

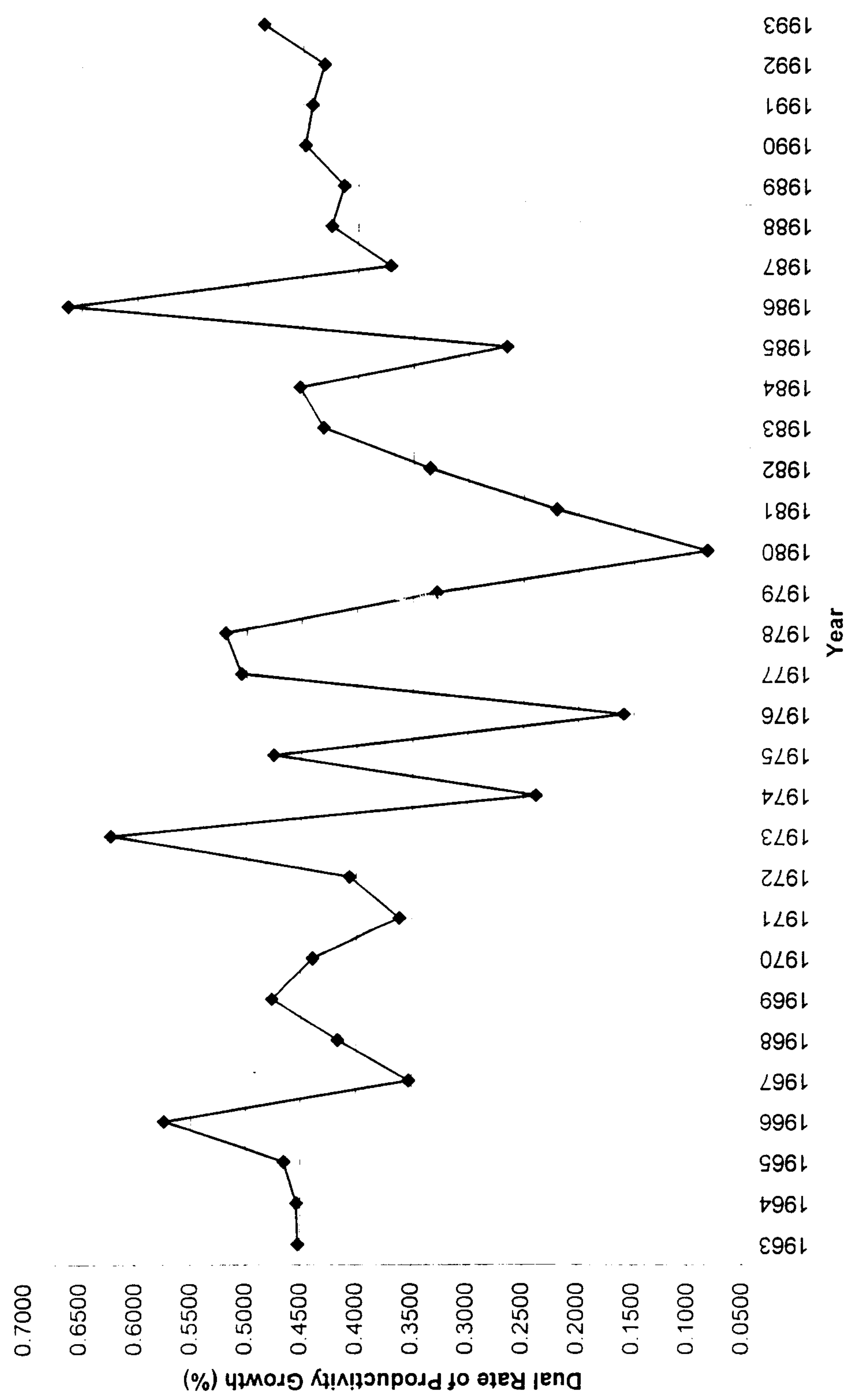


Table 6.14a Dual Rate of Productivity Growth based on Restricted Profit Function Model, Mexico

YEAR	Productivity Growth Rate (%)	Decomposition of Productivity Growth Rate		
		Technological Change	Output Price Effects	CU effect
1971	1.0979	0.7692	0.3213	0.0074
1972	0.7006	0.7342	-0.0470	0.0134
1973	0.8027	0.7017	0.1082	-0.0072
1974	0.9703	0.6126	0.3599	-0.0022
1975	0.8296	0.6780	0.1418	0.0098
1976	0.3594	0.7009	-0.3410	-0.0005
1977	0.1291	0.6743	-0.5382	-0.0070
1978	0.7329	0.6837	0.0512	-0.0020
1979	0.6096	0.6881	-0.0834	0.0049
1980	0.7582	0.6404	0.1089	0.0089
1981	0.871	0.6331	0.2259	0.0120
1982	-1.1209	0.5661	-1.6916	0.0046
1983	0.3154	0.5262	-0.2083	-0.0025
1984	1.268	0.5116	0.7593	-0.0029
1985	0.5328	0.4244	0.1101	-0.0017
1986	-0.516	0.4036	-0.9167	-0.0029
1987	0.2131	0.4104	-0.1927	-0.0046
1988	0.9589	0.3276	0.6361	-0.0048
1989	0.4394	0.3450	0.0935	0.0009
1990	0.5592	0.3147	0.2438	0.0007
1991	0.5826	0.1836	0.3960	0.0030
1992	0.3167	0.0988	0.2143	0.0036
1993	-0.1333	-0.4829	0.3466	0.0030
1994	-0.2011	-0.2417	0.0382	0.0024
	Average Annual Rate of Productivity Growth			
1971-74	0.89			
1974-81	0.66			
1982-88	0.24			
1989-94	0.26			

Table 6.14b Proportions of Components of Dual Productivity Growth Rate based on Restricted Profit Function Model, Mexico

YEAR	Productivity Growth Rate	Proportion of Components		
		Technological Change (%)	Output Price Effects (%)	CU Effect (%)
1971	1.0979	70.06	29.26	0.67
1972	0.7006	104.80	-6.71	1.91
1973	0.8027	87.42	13.48	-0.90
1974	0.9703	63.14	37.09	-0.23
1975	0.8296	81.73	17.09	1.18
1976	0.3594	195.02	-94.88	-0.14
1977	0.1291	522.31	-416.89	-5.42
1978	0.7329	93.29	6.99	-0.27
1979	0.6096	112.88	-13.68	0.80
1980	0.7582	84.46	14.36	1.17
1981	0.871	72.69	25.94	1.38
1982	-1.1209	-50.50	150.91	-0.41
1983	0.3154	166.84	-66.04	-0.79
1984	1.268	40.35	59.88	-0.23
1985	0.5328	79.65	20.66	-0.32
1986	-0.516	-78.22	177.66	0.56
1987	0.2131	192.59	-90.43	-2.16
1988	0.9589	34.16	66.34	-0.50
1989	0.4394	78.52	21.28	0.20
1990	0.5592	56.28	43.60	0.13
1991	0.5826	31.51	67.97	0.51
1992	0.3167	31.20	67.67	1.14
1993	-0.1333	362.27	-260.02	-2.25
1994	-0.2011	120.19	-19.00	-1.19

Figure 6.17 Dual Rate of Productivity Growth, Restricted Profit Function Model, Mexico

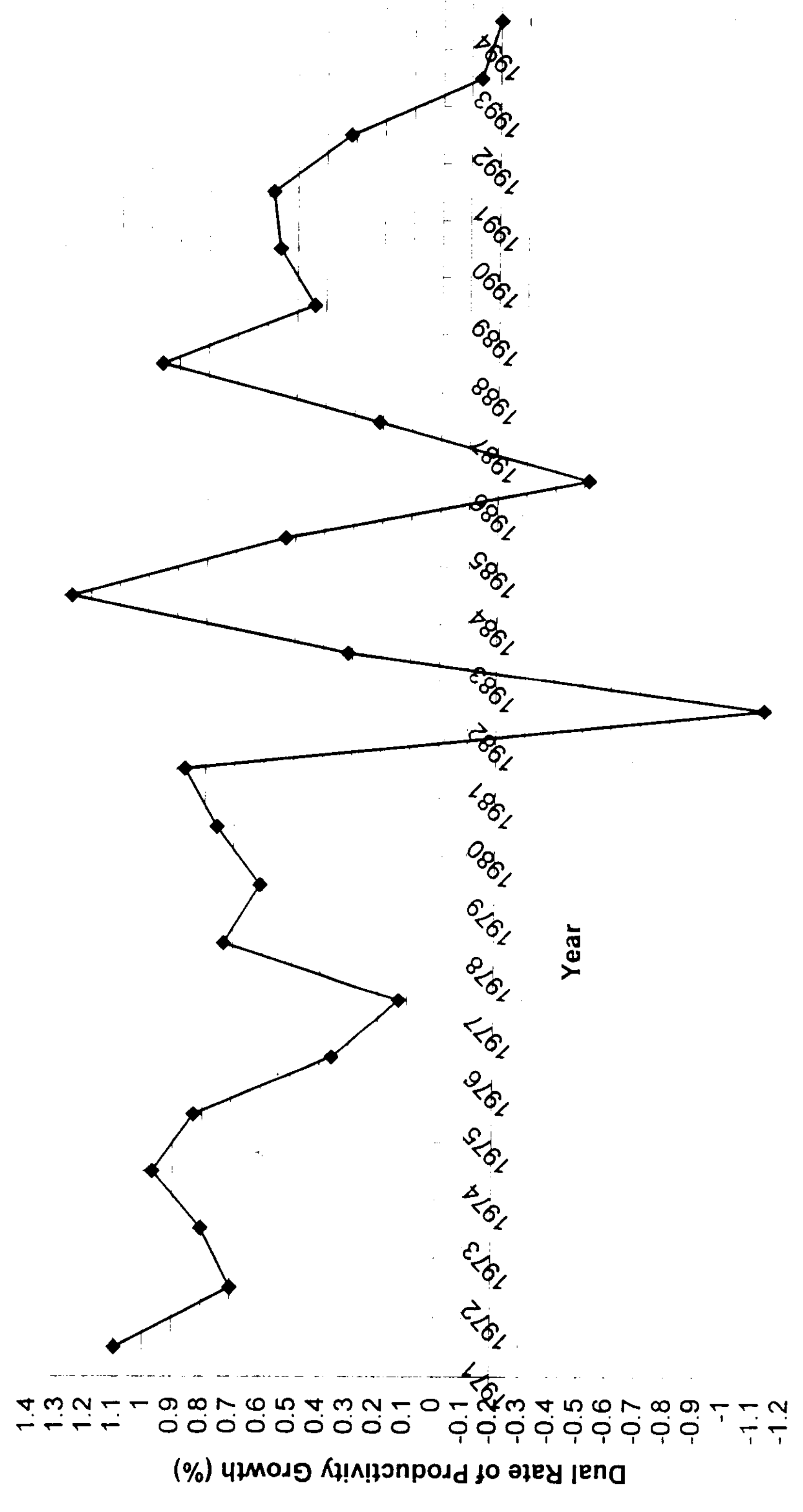
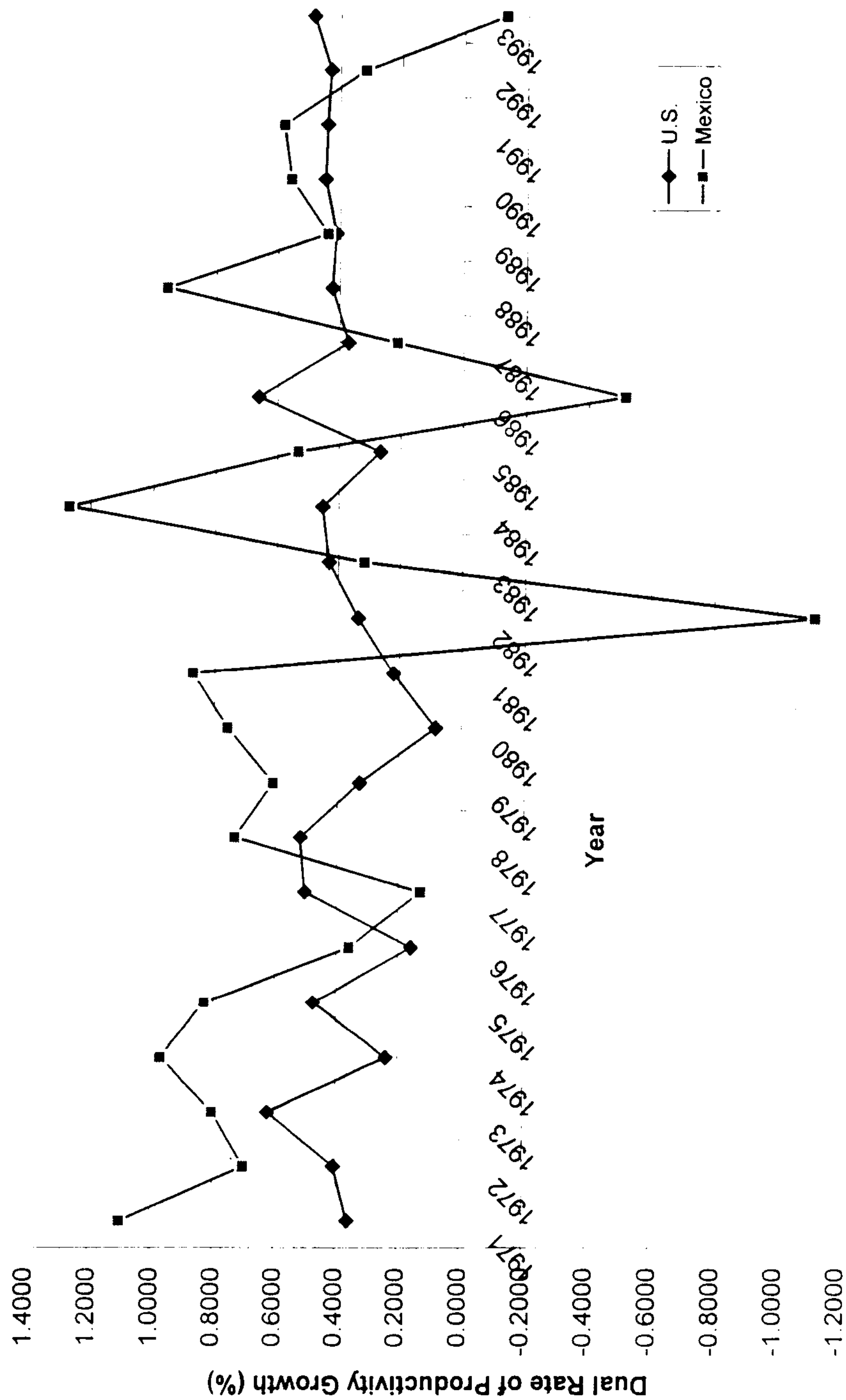


Figure 6.18 Comparison of Dual Rate of Productivity Growth between U.S. Mexico, Restricted Profit Function Model



6.7 Results of the Hypothesis Testing

6.7.1 Hypothesis Testing for the Existence of Long-Run Equilibrium in Capital Markets

The estimated joint test statistics (computed by using equation (4.34) in section 4.9.4) are found to be much higher than the 95 percent chi-squared critical values for both U.S. and Mexican models ($t'_{US} = 4.78053D{+}09 > \chi^2_{(31),\alpha=0.05} = 43.77$ and $t'_{Mexico} = 1.37779D{+}12 > \chi^2_{(24),\alpha=0.05} = 36.42$).Therefore, optimal long-run levels of capital derived from restricted profit function models of U.S. and Mexico are significantly different from their observed levels, and a restricted profit function specification rather than an unrestricted (long-run) specification is valid for the underlying production technology of U.S. and Mexican food sectors during the studied sample periods.

6.7.2 Hypothesis Testing on Production Structure

The results of the hypothesis testing concerning several characteristics of production structure are summarized in table 6.15. Hypothesis tests are performed by using LR test statistics[2].

Input-output separability is rejected for U.S. based on both unrestricted and restricted profit function models. In contrast, for Mexico, it is not rejected based on either unrestricted or restricted profit function models.

Table 6.15 Summary of the Results from the Hypothesis Tests on Production Structure

		Restrictions	LR test statistics		Cqi-square critical value at 5 % significance level
			U.S.	Mexico	
Separability of inputs from output	Unrestricted profit function model	aly=0,amy=0, ayk=0	37.07	7.05	7.82
	Restricted profit function model	αly=0, αmy=0,	20.16	2.98	5.99
Linear separability of variable inputs from quasi-fixed input	Restricted profit function model	αlk=0, αmk=0	0.90	1.49	5.99
Hicks Neutrality of technological change	Unrestricted profit function model	alt=0,amt=0, akt=0	1.85	8.41	7.82
	Restricted profit function model	αlt=0, αmt=0, αkt=0	0.46	7.64	7.82
Absence of technological change	Unrestricted profit function model	alt=0, amt=0, akt=0, at=0, att=0, atpol=0	66.25	23.70	12.59
	Restricted profit function model	αlt=0, αmt=0, αkt=0, αt=0, αtt=0, αtpol=0	11.50	98.39	12.59
Joint significance of "a0pol"and "atpol"	Unrestricted profit function model	atpol=0, a0pol=0	14.01	4.32	5.99
	Restricted profit function model	αtpol=0, α0pol=0	6.46	1.46	5.99

Linear separability of variable inputs (labor and material) from quantity of capital (based on restricted profit function model) is not rejected for either U.S. or Mexico.

[2] LR= -2 (L_C - L_U) ~ $\chi 2_{(df = \#\ of\ restrictions)}$, where L_C is the value of maximum log-likelihood function when some of the parameters are restricted and L_U is the value of maximum log-likelihood function without any restrictions.

Hicks neutrality of technological change with respect to inputs and output is not rejected for U.S. based on both unrestricted and restricted profit function models. For Mexico, the results of the test for hicks neutral technological change is mixed; based on unrestricted profit function model, hicks neutrality of technological change is rejected, while it is not rejected for restricted profit function model. In addition, test results for the absence of technological change show that, for Mexico, the null hypothesis of zero technological change is rejected based on both unrestricted and restricted models, while for U.S. it is only rejected for unrestricted profit function model.

Finally, the results of the test for joint significance of parameters corresponding to pollution abatement variable (see the equation 5.5 in section 5.3 for the discussion of pollution abatement variable) show that, for U.S., pollution abatement parameters ("a0pol" and "atpol" or "α0pol and "αtpol") are jointly significant based on both unrestricted and restricted profit function models. However, the estimates of these parameters are quite close to zero, and they are individually non-significant (see table 6.2a and 6.2b), implying that pollution variable had no significant impact on the rate of technological change in U.S. food processing sector. This implication appears to be consistent with the fact that the share of pollution abatement cost in total production costs in U.S. food sector is quite small (less than %1 of total production costs). For Mexico, the parameters corresponding to pollution variable are jointly non-significant based on both unrestricted and restricted profit function models, but they are individually significant based on restricted profit function model (although t-statistics are only slightly higher than the critical values). The parameter "αtpol" is found negative (-0.1092) and significant based on Mexican restricted profit function model (tables 6.2a and 6.2b), indicating that the dual rate of technological change is inversely affected by increases in pollution abatement variable E in Mexican food sector. Specifically, when the index of pollution variable E (for Mexico, it is an index of annual number of environmental inspections) is increased by one unit, the dual rate of technological change is reduced by around 0.11 percentage points.

CHAPTER 7: CONCLUSIONS

In this study, the primal and dual rates of technological change in food processing sectors of U.S. and Mexico are compared through econometric estimation of both unrestricted (long-run) and restricted (short-run) profit functions with first order autocorrelation correction. Then, the dual rate of productivity growth is computed and decomposed into its sources.

The results of the hypothesis testing on the existence of short-run equilibrium in capital markets indicated that the restricted profit function framework is the valid specification for the underlying production technologies of U.S. and Mexican food sectors during the sample period, and hence, our conclusions are based on the results from restricted profit function models.

Our estimates of dual rate of technological change suggest that:

i) In U.S., the average annual dual rate of technological change dropped from 0.76% during 1963-73 to 0.67% during 1974-88, increased to 0.72% between 1988-1990, and declined to 0.65% during 1990-93. In Mexico, dual rate of technological change was sharply declining during most of the years of sample period, and the average annual rate dropped from 1.30% during 1971-74 to 0.01% between 1989-93.

ii) Dual rate of technological change was lower in U.S. than in Mexico during 1971-81 period, but the difference (dual rate of technological gap) was sharply declining. Starting from 1982, dual rate of technological change became greater in U.S. than in Mexico and the difference was continuously increasing.

On the other hand, in U.S., the estimates of the primal rate of technological change exhibits a different pattern from the one in dual rates:

i) In U.S., primal rate of technological change was declining between 1963-73, averaging at 0.079%. The average annual rate was increased to 0.091% between 1974-81, declined to 0.065% during 1982-88 and increased again to 0.075% between 1989-93. In Mexico, the primal rate of technological change was continuously declining as the dual rate but downward trend was relatively smoother.

ii) Primal rate of technological change was lower in U.S. than in Mexico during 1971-1990, but the difference was declining, implying that Mexican food sector had a declining technological change advantage in terms of rate of increase in output induced by technological change over U.S. food sector. U.S. food sector was able to outperform Mexico only after 1990.

Furthermore, the estimates of dual rate of productivity growth reveals that, in U.S., the average annual rate of productivity growth was its highest level (0.46%) during 1963-73 and dropped to 0.32% during 1974-81, coinciding with oil crisis. After 1982, it increased to 0.42% between 1983-89, during which U.S economy experienced significant tax cuts and increased investment incentives. Between 1989-93, average annual rate of productivity growth continued to increase, reaching 0.44%. In Mexico, the average annual rate of productivity growth was declining, dropping from 0.89% between 1971-74 to 0.26% during 1989-94. The sharpest reductions in productivity growth rate were observed between 1981-82 and 1984-86, coinciding with 1982 Mexican debt crisis and Mexican oil price collapse in 1986. In addition, the decomposition of dual rate of productivity growth reveals that technological change was the main source of productivity growth in both U.S. and Mexico, although, in Mexico, output price effects outweighed the contributions of technological change during several years between 1982-94. The effects of capacity utilization had a minor impact on productivity growth in both countries.

Our estimates for elasticities of input demand and output supply indicated that labor demand is price inelastic, while material demand and output supply are found as price elastic in both countries. The own price elasticity of material demand and output supply was higher in Mexico than in U.S. In both countries, input demands are affected most significantly by output prices, while output supply is most significantly affected by its own price, closely followed by material price. Also, input demands and output supply are more responsive to the changes in labor price in U.S. than they are in Mexico, reflecting relatively higher share of labor cost in U.S food sector than in Mexico. On the other hand, the input demand and output supply are more responsive to changes in material price or output price in Mexico than they are in U.S. Finally, our elasticity of substitution between labor and material imply that labor and material are complement of each other in both countries, with degree of substitution between labor and material is higher in Mexico than it is in U.S.

Finally, the hypothesis tests on estimated parameters corresponding to pollution abatement variable suggested that pollution abatement costs had no significant impact on the dual rate of technological change, and in turn, productivity growth rate in U.S. food processing sector, and this appears to be consistent with the fact that share of pollution abatement costs in total costs is quite small in U.S. food processing sector. For the Mexico, estimated parameters were individually significant (although t-statistics were slightly higher than the critical values), implying that one unit increase in pollution abatement index reduced the dual rate of technological change by around 0.11% points (which is about 16% of the Mexican average annual dual rate of technological change during 1971-93). However, it should be noted that pollution abatement variable in Mexican models was based on the number of total inspections performed in whole Mexican economy and it does not reflect the pollution abatement activities in food processing sector alone.

BIBLIOGRAPHY

Antle, J. M. and S. M. Capalbo. "An Introduction to Recent Developments in Production Theory and Productivity Measurement" in S. M. Capalbo and J. M. Antle (eds), *Agricultural Productivity: Measurement and Explanation*, Washington, D.C.: Resources for the Future, 1988.

Atkinson S. E. and R. Halvorsen. "Interfuel Substitution in Steam Electric Power Generation," *Journal of Political Economy*, vol. 84 (5) (1976): 959-977.

Banco de Mexico. *Indicadores Economicos*, various years.

Banco de Mexico. *Informe Annual*, 1977.

Banco de Mexico. *Mexican Data Bank*, 1995.

Banco de Mexico. *Survey of Capital Formation and Capital Assets*, annual issues.

Barbera, A. J. And V. D. McConnell. " The impact of Environmental Regulations on Industry Productivity: Direct and Indirect Effects "*Journal of Environmental Economics and Management*, vol. 18 (1990): 50-65.

Berndt, E. R. *The Practice of Econometrics: Classic and Contemporary*. Addison-Wesley Publishing Company, 1991.

Berndt, E. R. and N. E. Savin. "Estimation and Hypothesis Testing in Singular Equation Systems with Autoregressive Disturbances," *Econometrica*, vol. 43 (5-6) (September-November, 1975): 937-957.

Brown, F. and L. Dominguez. "The Dynamics of Productivity Performance in Mexican Manufacturing, 1984-1990." *The Developing Economies*, vol.32 (3) (September, 1994): 279-298.

Bureau of Economic Analysis. " Expenditures in Pollution Abatement and Control by Sector and by Type, in Current Dollars and Chain-type Quantity and Price Indexes, 1972-1994," in Vogan, C. R. *Pollution Abatement Control Expenditures 1972-1994, Survey of Current Business*, September, 1996.

Chan-Kang, C. "R&D Investment and Productivity in the U.S. and Canadian Food Processing Sectors", M.S. Thesis Submitted to Agricultural and Resource Economics Department of Oregon State University, 1997.

Chambers, R. G. *Applied Production Analysis*. Cambridge: Cambridge University Press, 1988.

Christainsen, G. B. and R. H. Haverman. " The Contribution of Environmental Regulations to the Slowdown in Productivity Growth," *Journal of Environmental Economics and Management*, vol.8 (1981): 381-390.

Christensen, L. R. and D. W. Jorgenson. " The Measurement of U.S. Real Capital Input, 1929-1967," *Review of Income and Wealth*, vol. 15 (4) (1969):293-320.

Congressional Budget Office. *Environmental Regulation and Economic Effiency, CBO Study*, Congress of the United States, 1985.

Conrad, K. "Productivity and Cost Gaps in Manufacturing Industries in U.S., Japan and Germany," *European Economic Review*, vol. 33 (1989): 1135-1159.

Denison, E. F. " Explanation of Declining Productivity Growth," Survey of Current Business, part II, August, 1979.

Fuess, S. M. and H. van den Berg. "Transaction Activities and Productivity Growth in Mexico," *The Journal of Developing Areas*, vol. 31 (spring, 1997): 387-398.

Goodwin, B. K. and G. W. Brester. " Sructural Change in Factor Demand Relationships in the U.S. Food and Kindred Products Industry," *American Journal of Agricultural Economics*, vol. 77 (February, 1995): 69-79.

Gray, W. B. " the Cost of Regulation: OSHA, EPA and the Productivity Slowdown," *The American Economic Review*, vol.77 (5) (December, 1987): 998-1006.

Gray, W. B. and R. J. Shadbegian. *" Environmental Regulation and Manufacturing Productivity at the Plant Level,"* Discussion Paper, U.S. Department of Commerce, Center of Economic Studies, Washington, D.C., 1993.

Gollop, F. M. and M. J. Roberts. " Environmental Regulations and Productivity Growth: The Case of Fossil-Fueled Electric Power Generation," *Journal of Political Economy*, vol. 91 (4) (1983): 654-674.

Grossman, G. M. and A. B. Krueger. " Environmental Impacts of North American Free Trade Agreement," in *The U.S.-Mexico Free Trade Agreement*, ed. Garber, P. Cambridge MA: MIT Press, 1993: 13-56.

Gullickson, W. "Measurement of Productivity Growth in U.S. Manufacturing". *Monthly Labor Review* (July 1995): 13-28.
Handbook of North American Industry: NAFTA and the Economies of its Member Nations, 1998, *John E. Cremeans, ed., Bernan Press.*

Hazledine, T. "Productivity in Canadian Food and Beverage Industries: An interpretive Survey of Methods and Results", *Canadian Journal of Agricultural Economics*, vol.39 (1991): 1-34.

Heien, D. M. " Productivity in U.S. Food Processing and Distribution" *American Journal of Agricultural Economics*, vol.65, (May 1983): 297-302.

Henderson et al. *Globalization of the Processed Foods Market*, Agricultural Economic Report, no.742 Washington, D.C.: U.S. Department of Agriculture, Economic research Service, Food and Consumer Divison, 1996

Huang, K. S. "Food Factor Demands in the U.S. Food-Manufacturing Industry," *American Journal of Agricultural Economics*, vol. 73 (August, 1991): 615-620.

Husted, B. W. and J. M. Logsdon. " The Impact of NAFTA on Mexico's Environmental Policy," *Growth and Change*, vol. 28 (Winter, 1997): 24-48.

International Monetary Fund (IMF). *International Financial Statistics Yearbook*, 1996.

International Monetary Fund (IMF). *International Financial Statistics, Supplement on Price Statistics*, 1986.

Instituto Nacional de Estadistica, Geografia, e Informatica (INEGI), *El Sector Alimentario,* various years.

Instituto Nacional de Estadistica, Geografia, e Informatica (INEGI*), Encuesta Industrial Manual*, various years.

Jaffe, A. B., S. R. Peterson, P. R. Portney and R. N. Stavins. " Environmental Regulation and Competitiveness of U.S. Manufacturing: What does the Evidence Tell Us?," Journal of Economic Literature, vol. 33 (March, 1995): 132-163.

Jayne, T. S., Y. Khatri, C. Thirtle and T. Reardon. "Determinants of Productivity Change Using a Profit Function: Smallholder Agriculture in Zimbabwe" *American Journal of Agricultural Economics*, vol. 76 (August, 1994): 613-618.

Jorgenson, D.W., F. M. Gollop and B. Fraumeni. *Productivity and U.S. Economic Growth.* Newyork: North Holland, 1987.

Jorgenson, D. W. and M. Kuroda. "Productivity and International Competitiveness in Japan and the United States, 1960-1985," in C. R. Hulten (ed.), *Productivity Growth in Japan and the United States*, The University of Chicago Press, 1990.

Kravis, I. B., A. Heston and R. Summers. *World Product and Income International Comparisons of Real Gross Product*, The Unite Nations International Comparison Project, phase III, The John Hopkins University Press, 1982.

Kulatilaka, N. "Tests on Validity of Static Equilibrium Models", *Journal of Econometrics*, vol. 28 (1985): 253-268.

Lau, L. J. "Applications of Profit Functions" in M. Fuss and D. McFadden (eds.), *Production Economics: A Dual Approach to Theory and Applications*. Vol.1 North Holland Publishing Company, 1978.

Lau, L. J. "Testing and Imposing Monoticity, Convexity and Quasi-Convexity Constraints" in M. Fuss and D. McFadden (eds.), *Production Economics: A Dual Approach to Theory and Applications*. Vol.1 North Holland Publishing Company, 1978.

Lopez, R. E. "Estimating Substitution Expansion Effects Using a Profit Function Framework" *American Journal of Agricultural Economics*, vol.66 (1984): 358-367.

Lopez, R. E. "Structural Implications of a Class of Flexible Functional Forms for Profit Functions," *International Economic Review*, vol.26 (3) (October, 1985): 593-601.

Morrison, C. J. "Productivity Measurement with Non-Static Expectations and Varying Capacity Utilization". *Journal of Econometrics*, vol.33 (1986): 51-74.

Morrison, C. J. "Unraveling the Productivity Growth Slowdown in the U.S., Canada and Japan: The Effects of Subequilibrium, Scale Economies and Markups". *The Review of Economics and Statistics*, vol.74 (3) (1992): 381-393.

Morrison, C. J. "Structural Change, Capital Investment and Productivity in the Food Processing Industry". *American Journal of Agricultural Economics*, vol.79 (1997): 110-125.

Organization for Economic Co-Operation and Development (OECD), *OECD Economic Surveys: Mexico, 1991/1992, 1995 and 1997*

Organization for Economic Co-Operation and Development (OECD), *The Environmental Information System of Mexico*, 1996 (http://www.semarnap.gob.mx/ingles/diffusion.htm).

Quiroga, R. E. and B. E. Bravo-Ureta. " Short- and Long-Run Adjustments in Dairy Production: A Profit Function Analysis," *Applied Economics*, vol.24 (1992):607-616.

Palmer, K., W. E. Oates and P. R. Portney. " Tightening Environmental Standards: The Benefit-Cost or the No-Cost Paradigm?" *Journal of Economic Perspectives*, vol.9 (4) (Fall,1995): (119-132).

Porter, E. M. and C. van der Linde. " Toward a New Conception of the Environment-Competitiveness Relationship," *Journal of Economic Perspectives*, vol. 9 (4) (Fall, 1995): 98-117.

Robinson, J. C. " The Impact of Environmental and Occupational Health Regulation on Productivity Slowdown in U.S. Manufacturing," *The Yale Journal on Regulation*, vol.12 (2) (Smmer, 1995): 387-434.

Sakai, Y. "Substitution and Expansion Effects in Production Theory: The Case of Joint Production," *Journal of Economic Theory*, vol. 9 (1974): 255-274.

Secreteria de Programacion. *Manual de Estadisticas Basicas Sector Industrial Informacion de la Estadistica Industrial Annual*, 1982.

Squires, D. "Long-Run Profit Functions for Multiproduct Firms", *American Journal of Agricultural Economics*, vol.69 (1987): 558-569.

Squires, D. "Production Technology, Costs, and Multiproduct Industry Structure: An Application of the Long-Run Profit Function to the New England Fishing Industry," *Canadian Journal of Economics*, vol.21 (2) (1988): 359-378.

Statistical Abstract of U.S., 1996

Sudit, E. F. and N. Finger. "Methodological Issues in Aggregate Productivity Analysis," in A. Dogramaci and N. R. Adam (eds.) *Aggregate and Industry-Level Productivity Analysis, Studies in Productivity Analysis* vol.2, Martinus Nijhoff Publishing,(1981): 7-30.

The NAFTA: Report on Environmental Issues, November, 1993.

U.S. Bureau of Labor Statistics, 1995, *Multifactor Productivity in U.S. Manufacturing and in Twenty Manufacturing Industries, 1949-1993*

U.S. Bureau of Census, *Census of Manufacturer's, Concentration Ratios in Manufacturing*, 1987.

U.S. Bureau of Census, *Pollution Abatement Costs and Expenditures*, U.S. Department of Commerce, annual issues.

U.S. Bureau of Census, *Manufacturer's Shipments, Inventories, and Orders, 1997* (http:\\www.census.gov\ftp\pub\indicators\www\m3\index.htm).

U.S. Department of Commerce, *U.S. Industrial Outlook, 1994*

APPENDICES

Appendix A: Data

A.1: U.S. Data

The U.S. Bureau of Labor provided us with series of total cost, expenditures on capital, labor, material, energy and services, and quantity and price indexes of output, capital, labor, material, energy and services for the years between 1962-1992 (Bureau of Labor Statistics, Multi-factor Productivity in U.S. Manufacturing and in Twenty Manufacturing Industries, 1995). Total cost and expenditure figures are in current dollars, and quantity and price indexes are Tornqvist indexes. In order to have consistency between Mexican and U.S. data, the quantity and price index of services are combined with the those of labor by forming a weighted average of separate series, in which the expenditure shares of labor and service in total cost are used as weights. Energy price and quantity indexes are combined with material price and quantity series in a similar way. Time series for profit are constructed as the difference between value of shipment and total cost. Time series of value of shipment are obtained from U.S. Bureau of Census (1997), Manufacturer's Shipment, Inventories and Orders.

A.2: Mexican Data

A.2.1: Capital Data

Annual series of capital stock, new investment and depreciation amounts for the time period of 1960-1994 for each of the 13 Mexican food and beverage sub-industries (including tobacco sector) were obtained from Bank Of Mexico. The values were given in both current new pesos and 1980 new pesos.

Total capital stock series for the entire Mexican food industry are obtained by summing up capital stocks in each sub-industry. Then, the total capital stock series is converted into an index with base year 1980. Implicit service price of capital is derived from acquisition price of capital in conjunction with interest rate and depreciation rates (Christensen and Jorgenson, 1969, p:304). Capital acquisition prices are approximated as the ratio of new annual investment in current prices to new annual investment in constant prices. The series of depreciation rate is constructed by taking the ratio of depreciated amount to total capital stock in each year for each subsector. Then, the depreciation rate series for entire food industry is obtained by taking weighted average of depreciation rate series of each subsector, where capital stock shares of each subsector are used as weights. Average cost of fund figures, which are obtained from IMF International Financial Statistics Yearbook, 1996, are used as interest rates. The following formula is used to construct service price of capital;

$$W_{kt}= P^{a}_{t-1}*r_t + P^{a}_{t}*u_t - [P^{a}_{t} - P^{a}_{t}] \qquad (A.1)$$

where W_k , P^a , r and u are service price for capital, acquisition price for capital, interest rate and depreciation rate, respectively. The first term at the right side of the equation (A.1) represents opportunity cost for using one unit of capital service and the second term denotes depreciation cost incurred. Finally, last term represents the capital gains due to the rising value of capital services already purchased. However, the implicit price of capital computed by using the formula in equation (A.1) resulted in some negative values for some years due to the quite high levels of capital gains. These high levels of capital gains might be caused by high inflation rates experienced in Mexican economy during 1970's and 1980's. Thus, the implicit price of capital is calculated again after eliminating the capital gains form the formula in (A.1). The new implicit price of capital series are used in estimation of unrestricted profit function for Mexico, which requires the use of capital prices instead of series of capital quantity.

The annualized total cost of capital series are constructed by multiplying the series of service price of capital by the total capital stock series.

A.2.2: Labor data

The series of total remuneration and worker hours for the time period of 1976-1996 are obtained from Encuesta Industrial Manual (various years) published by Instituto Nacional de Estadistica, Geografia, e Informatica (INEGI). Total remuneration includes wages, salaries and social benefits. The source of the figures of total remuneration and worker hours for the years between 1970-1975 is the Manual de Estadisticas Basicas Sector Industrial Informacion de la Estadistica Industrial Annual (MEBSIIEI), 1982, Secretaria de Programacion. The raw data from this source contains total remuneration as the sum of wages, salaries and benefits, the number of hourly workers and employees with salary, and average number of working days per employee per year for each subsectors of Mexican food manufacturing sector. The total worker hours are computed by multiplying the number of total employees with average number of working days. Then, The time series of wage rate is constructed by dividing total worker hours into total remuneration. Finally, wage rate series are converted into an index with base year 1980.

A.2.3: Material Data

Material expenditure series covering time period of 1970-1994 for the each subsector in Mexican food manufacturing industry is obtained from El Sector Alimentario en Mexico (1984,1991 and 1994), published by INEGI. Subsector level material price series for the years between 1980-1995 are obtained from Indicadores Economicos (August 1996, November 1989 and 1991), published by Banco de Mexico. The material price series for the entire food and beverage industry is constructed by forming a weighted average of subsector level material price series, where the ratio of material expenditure in each subsector to total material expenditure for entire industry is used as weights. The source of the figures for material price series for the years between 1970-1975 is MEBSIIEI, 1982, Secretaria de Programacion. The raw data from this source contains quantities and expenditures on each type of material used by each subsector of food manufacturing industry. First, material price series for each type of material in each subsector is constructed by dividing quantity series into expenditure series. Then, subsector level material price series is formed by taking weighted average of material price series over each type of material used in that subsector, where the expenditure shares of each type of material are used as weights. Finally, the material price series for the entire food and beverage industry is constructed by taking weighted average of subsector level material series, using the material expenditure shares of each subsector as weights. Furthermore, time series of material quantity are formed by dividing the material price series into series of material expenditure.

A.2.4: Output data

The index of output quantity for the entire Mexican food manufacturing industry (including tobacco) for the time period of 1970-1975 is obtained from Informe Annual (1977), published by Banco de Mexico. The figures of output quantity index for the years between 1975-1995 are obtained from Indicadores Economicos (1987, 1989, 1991 and 1996), published by Banco de Mexico. The index of output prices for the time period 1970-1995 are taken from Indicadores Economicos (April 1992 and August 1996), Banco de Mexico. The value of production (revenue) series in current prices for the entire food manufacturing industry for the years between 1970-1994 is obtained from El Sector Alimentario (1984, 1991 and 1996), INEGI. The value of production series is used as revenue series for the entire food manufacturing industry.

All series of factor expenditures and indices of prices for inputs and output are deflated by using Producer Prices Index (PPI) for Mexico. PPI series for Mexico, covering time period of 1980-1994 is obtained from Mexico Data Bank (1995), published by Banco de Mexico. The source of the figures for years between 1970-1980 is IMF, International Financial Statistics, Supplement on Price Statistics (1986).

A.3: Pollution Abatement Data

In order to estimate the effects of environmental abatement activities on productivity, a regulatory variable is constructed. For the U.S. model, regulatory variable is an index of total abatement expenditure in U.S. food sector, which is constructed by using total abatement expenditure series for the 1962-93 time period prepared by Connie Chan-Kang (1997). In her computations, total abatement expenditure was defined as the sum of pollution abatement expenditure and pollution abatement operating cost. The series for pollution abatement capital expenditure was computed by multiplying the stock of pollution abatement capital with service price of pollution abatement capital. The stock of pollution abatement capital for US food industry for the time period of 1962-91 was obtained from Bureau of Economic Analysis (BEA). Service price of pollution abatement capital was computed by using the same formula in equation (A.1). This formula requires the acquisition price of pollution abatement capital, opportunity cost of capital, and depreciation rate of pollution abatement capital. Acquisition price of pollution abatement was obtained from BEA (Survey of Current Business, 1996), and opportunity cost of pollution abatement capital was approximated by AAA corporate bond yield. Finally, the depreciation rate of pollution abatement capital was computed by dividing the amount of depreciation in stock of pollution abatement capital to net stock of pollution abatement capital, published by BEA. The series of pollution abatement operating costs was obtained from Bureau of Census for the years between 1973-1992. The figures for earlier years, 1962-1972, were approximated by multiplying the series of expenditure on pollution abatement capital for those years with an estimated ratio of pollution abatement operating expenditures to pollution abatement capital expenditures.

For Mexican model, regulatory variable is an index of numbers of annual inspections in Mexico, since there is no other available pollution abatement expenditure data for Mexican food manufacturing. The number of annual inspections in Mexico during 1982-1994 time period were obtained from a study by Husted and Logsdon

(1997). The number of inspections before 1982 are taken as zero since the environmental activities during this earlier period were reported by several sources as quite unsignificant or even not existing at all (Husted and Logsdon, 1997).

A.4: Purchasing Power Parities

Comparison of productivity growth rates of food sectors in two countries requires comparable measures of quantity and price for inputs and output. To achieve comparability in these measures, Purchasing Power Parities (PPP's) have to be developed for input and output prices for two countries. Indices of quantity and price for inputs and output constructed for U.S. and Mexico are equal to one in the base year. However, this misleadingly implies that both countries faced the same input and output prices, and produced (or used) the same amount of output (or inputs). Therefore, PPP's are used as conversion factors to adjust the Mexican data set for the differences in input and output prices across two countries, and for differences in quantities of inputs and output that can be purchased by the same amount of money in the U.S.

Purchasing Power Parity between two countries at a point in time represents the relative price of the same bundle of commodities in two countries. If U.S. output (or input) price is measured relative to Mexican output (input) price, the PPP for output (input) price represents the price of one dollar's worth of output (or input) in terms of Mexican pesos (Jorgenson and Kuroda, 1990). The unit of PPP is the same as peso-to-dollar exchange rate, namely peso per U.S. dollar. The PPP's for output and inputs are divided by peso-to-dollar exchange rate to convert PPP's into relative prices in terms of dollars.

Kravis, Heston and Summers (1982) developed PPP's between U.S. dollar and currency of wide variety of countries (including Mexican peso) for GDP's, for detailed components of aggregate consumption goods output (such as for outputs of food industry, clothing and footwear industry, etc..), and investment goods output for the year 1975. In this study, PPP for sectoral output of food manufacturing between U.S. and Mexico developed by Kravis, Heston and Summers (1982) is used.

In several previous studies of international comparisons, researchers have estimated their own estimates of PPP's as a ratio of price of inputs in two countries during base year. Following the approach in Jorgenson and Kuroda (1990), and Condrad (1989), PPP for input i at the base year is constructed as a ratio of price of that input in Mexico to the one in U.S. , that is:

$$PPP_i = \frac{W^i_{0,mex}}{W^i_{0,US}} \tag{A.2}$$

where $W^i_{0,US}$ and $W^i_{0,mex}$ are the price of input i at the base year in U.S. and Mexico, respectively. To convert PPP's into relative prices in terms of dollars, PPP's are divided by market exchange rate in the base year as:

$$PPP_i^{adj} = \frac{\left(\frac{W^i_{0,mex}}{W^i_{0,US}}\right)}{E} \tag{A.3}$$

PPP_i^{adj} represents the number of U.S. dollars required in Mexico to purchase the amount of input costing one dollar in U.S.

PPP for capital is not estimated by using equation (A.3) due to the unreliability of data used for computation of service price of capital. Instead, PPP for capital goods estimated by Kravis, Heston and Summers, (1982) is used. Also, due to the lack of data in order to compute PPP for material by using (A.3) (only the index of material price for Mexico rather than price figures is available), PPP for food industry output is also used as PPP for material input.

After, PPP's for inputs and output are constructed for the base year, Mexican input and output price indices comparable with corresponding indices for U.S. are constructed by using PPP's as following:

$$\frac{W^i_{t,mex}}{W^i_{0,US}} = \left(\frac{W^i_{t,mex}}{W^i_{0,mex}}\right) * PPP^{adj}_i \tag{A.4}$$

where $\frac{W^i_{t,mex}}{W^i_{0,US}}$ is index of input (or output) price comparable the one for U.S. and $\frac{W^i_{t,mex}}{W^i_{0,mex}}$ is the index of input (or output) price before conversion. The U.S. comparable Mexican input and output price indices are then deflated by U.S. Producer Price Index (PPI).

Following, Kravis, Heston and Summers (1982), the U.S. comparable index of capital quantity for Mexico is constructed by using following equation:

$$\frac{K_{t,mex}}{K_{0,US}} = \frac{\frac{(W^K_0 K_0)_{mex}}{(W^K_0 K_0)_{US}} * \left(\frac{K_{t,mex}}{K_{0,mex}}\right)}{PPP^{adj}_i} \tag{A.5}$$

where $W^K_0 K_0$ is capital expenditure in the base year, $\left(\frac{K_{t,mex}}{K_{0,mex}}\right)$ is index of capital quantity for Mexico before conversion, and $\frac{K_{t,mex}}{K_{0,US}}$ is the U.S. comparable index of capital quantity for Mexico.

where $W_0^K K_0$ is capital expenditure in the base year, $\left(\frac{K_{t,mex}}{K_{0,mex}}\right)$ is index of capital

quantity for Mexico before conversion, and $\frac{K_{t,mex}}{K_{0,US}}$ is the U.S. comparable index of

capital quantity for Mexico.

Appendix B: Derivations

B.1: Derivation of $\frac{\partial \ln H^*}{\partial \ln P} = \frac{S_Y^{pr}}{(1-\varepsilon_{HRK})}$

First recall that total shadow profit is defined as

$$H^*(P, W_L, W_M, K, Z_K, t) = HR(P, W_L, W_M, K, t) - Z_K K \quad \text{(B.1)}$$

Taking derivative of (A.1) with respect to P yields:

$$\frac{\partial H^*}{\partial P} = \frac{\partial HR}{\partial P} \quad \text{(B.2)}$$

Then, the expression for the $\frac{\partial \ln H^*}{\partial \ln P}$ can be derived as follows:

$$\begin{aligned}
\frac{\partial \ln H^*}{\partial \ln P} &= \frac{\partial H^*}{\partial P}\frac{P}{H^*} \\
&= \frac{\partial HR}{\partial P}\frac{P}{H^*} \\
&= \frac{\partial HR}{\partial P}\frac{P}{HR}\frac{HR}{H^*} \\
&= \frac{\partial \ln HR}{\partial \ln P}\left(\frac{HR}{H^*}\right) \\
&= S_Y^{pr}/(1-\varepsilon_{HRK}) \quad \text{(B.3)}
\end{aligned}$$

where $\frac{H^*}{HR} = \frac{HR - Z_K K}{HR} = 1 - \varepsilon_{HRK}$

B.2: Derivation of Equation (4.21)

In short run framework total profit is defined as $H=HR-W_K K$. Logarithmic differentiation of total profit with respect to time, holding variable input prices fixed:

$$\left.\frac{d\ln H}{dt}\right|_W = \frac{1}{H}\left(\frac{dHR}{dt} - W_K \frac{dK}{dt}\right)$$

$$= \frac{HR}{H}\frac{d\ln HR}{dt} - \frac{W_K K}{H}\frac{d\ln K}{dt} \tag{B.4}$$

Also, recall that restricted profit is a function of output price, variable input prices, capital stock and time, HR=HR(P,W,K,t). Then, logarithmic differentiation of restricted profit with respect to time, holding variable input prices constant gives:

$$\left.\frac{d\ln HR}{dt}\right|_W = \frac{\partial \ln HR}{\partial t} + \frac{\partial \ln HR}{\partial \ln P}\frac{d\ln P}{dt} + \frac{\partial \ln HR}{\partial \ln K}\frac{d\ln K}{dt} \tag{B.5}$$

Then, the substitution of (B.5) into (B.4) yields the following expression in (4.21) for the dual measure of productivity growth adjusted to incorporate the effects of subequilibrium:

$$\left.\frac{d\ln H}{dt}\right|_{W_L, W_M} = \frac{HR}{H}\left(\frac{\partial \ln HR}{\partial t} + \frac{\partial \ln HR}{\partial \ln P}\frac{d\ln P}{dt} + \frac{\partial \ln HR}{\partial \ln K}\frac{d\ln K}{dt}\right) - \frac{W_K K}{H}\frac{d\ln K}{dt}$$

$$= \frac{HR}{H}\varepsilon_{prt} + \frac{HR}{H}S_y^{pr}\frac{d\ln P}{dt} + \left(\frac{HR}{H}\frac{Z_K K}{HR} - \frac{W_K K}{H}\right)\frac{d\ln K}{dt}$$

$$= \frac{HR}{H}\varepsilon_{prt} + \frac{HR}{H}S_y^{pr}\frac{d\ln P}{dt} + \left(\frac{HR}{H}\varepsilon_{HRK} - \frac{W_K K}{H}\right)\frac{d\ln K}{dt} \tag{B.6}$$