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THE WORLD WHEAT GLUTEN INDUSTRY, AN ECONOMETRIC INVESTIGATION OF THE U.S. IMPORT DEMAND FOR WHEAT GLUTEN

by François Ortalo-Magné and Barry K. Goodwin

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Department of Agricultural Economics

Kansas State University

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An Econometric Investigation of the U.S. Import Demand for Wheat Gluten

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François Ortalo-Magné

and

Barry K. Goodwin*

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*Graduate Research Assistant and Assistant Professor, Department of Agricultural Economics, Kansas State University, respectively.

ABSTRACT

This paper discusses the international market for wheat gluten, an important protein supplement in processed grain products. A brief description of wheat gluten composition, properties, and uses provides the necessary technical background for this study. Raw material availability, growth of the corn wet milling industry, and political decisions are identified as the main factors influencing the development of the wheat gluten industry. An international market has been established in which the U.S. is the major importer, and Australia, Canada, and the E.C. are the main exporters. An econometric analysis of the U.S. import demand for wheat gluten is undertaken. The price of flour, income, and protein amount for the domestic wheat harvest are found to be important determinants of wheat gluten imports.

Key words: international trade, processed agricultural products, wheat gluten

ABBREVIATIONS

c.i.f.	cost, insurance and freight
E.C.	European Community
E.S.A.P.	Ecole Supérieure d'Agriculture de Purpan
GATT	General Agreement on Tariffs and Trade
I.M.F.	International Monetary Fund
IWGA	International Wheat Gluten Association
O.E.C.D.	Organization for Economic Cooperation and Development
PRC	People's Republic of China
ROC	Republic of China
ROK	Republic of Korea
U.S.	United States of America

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TABLE of CONTENTS

TABLE of CONTENTS (following)

INTRODUCTION

The European Community (E.C.) has made considerable investments in the wheat wet milling industry over the past few years. The implied overcapacity of production leads the E.C. producers to turn to the export market. This overcapacity of production is now higher than the quantity exchanged on the international market. With almost no exports until 1983, the E.C. ranked second in exports bound for the U.S. in 1988, holding approximately 17.5 percent of the U.S. import market share. The U.S. is the major importer of wheat gluten, with more than 60 percent of world imports. In light of the wheat wet milling industry's development in the E.C. and of the prominent role U.S. imports play in the international market for wheat gluten, it is of interest to empirically examine factors that are related to the demand for imported wheat gluten in the U.S.

An abundance of literature is available attempting to explain the unique structure and properties of "vital" wheat gluten. Nevertheless, very little has been written about the wheat gluten market. This is largely due to one single factor: the wet milling industry as a whole is considered to be a particularly secretive industry, reluctant to make production figures public (Bailey, 1985).

Leuck (1990) reviews the effect of the E.C.'s Common Agricultural Policy on the wheat wet milling industry and the trade of grain in the E.C. After noticing the increase in fractionation of wheat flour into wheat gluten and starch, Leuck explores the causes and effects of this growth. Favorable agricultural policies and the adaptation of better fractionation techniques have lead to this development. The two main implications have been a decline in the

E.C. hard wheat imports and a significant limitation of the increase in the E.C. wheat exports. He notes that "significant additional impacts on E.C. wheat trade may occur if E.C. agricultural policies continue to favor the expansion of this industry".

Because the U.S. is the major importer in the international wheat gluten market, the objective of this paper is to identify and analyze the factors affecting the U.S. import demand for wheat gluten. An econometric analysis of this import demand is presented.

Chapter 1 opens with a brief description of wheat gluten composition, properties, and uses. It provides the necessary technical background for this product. Chapter 2 first presents the wheat gluten production process. This is followed by an overall review of the wheat wet milling industry and the factors that have led to the current international situation. After a presentation of the economic theory relevant to such a demand function, Chapter 3 provides the equation, the basis of the econometric analysis. Factors affecting the U.S. import demand for wheat gluten are deducted from the first three chapters and presented in Chapter 4. This chapter then provides an a priori estimation of the coefficients, the empirical methodology adopted, and lastly the estimated models.

CHAPTER 1

THE UNIQUE WHEAT GLUTEN

It is not the intention of this study to go into detail on technical data. However, a minimum knowledge of wheat gluten composition, properties, and uses is essential for the econometric analysis. This is what is presented below.

1.1. Composition and General Properties:

Wheat gluten is primarily the water insoluble protein fraction of wheat flour. Eric E. McDermott (1985) analyzed the composition of over 30 commercial wheat glutens from the United Kingdom and Europe and a few from Australia and Canada. The results of this study provide a valuable indication of the composition of products on the market (cf Table 1). Consisting of approximately 75 percent protein, commercial wheat gluten also contains 6 percent lipids and 0.7 percent ash on a dry matter basis.

The protein fraction can be separated into two parts on the basis of solubility in aqueous alcohol. The gliadin are a large group of proteins with similar properties. They have an average molecular weight of about 40,000 and are single chained. They are extensible but have low elasticity and polarity. The glutenin are a heterogeneous group of multichained proteins. Their molecular weights ranges from 100,000 to several millions with an average of 3,000,000. Unlike the previous group they are elastic, having a low extensibility and a high polarity.

Table 1. Composition of Commercial Glutens.

Component	Average (percent)	Range (percent)
Protein	77.4	66.4-84.3
Moisture	7.5	5.3-10.2
Lipid	5.8	4.2-7.6
Ash	0.69	0.44-0.94
Chloride	0.08	0.01-0.28

Source: McDermott, 1985.

The amino acid compositions of gluten proteins presented in Table 2 show a lack of certain essential amino acids, such as lysine and tryptophan, and high levels of methionine and cysteine. This results in a lower nutritional quality compared to that of high-quality proteins founds in milk, eggs, and meat (Finley and Hopkins, 1985). On the other hand, wheat gluten can be a fairly good complement for blending with protein sources high in lysine such, as soy flour.

This low nutritional quality does not prevent wheat gluten from being a unique vegetable protein of considerable commercial value. "Its specific property of forming an elastic mass when hydrated and its thermosetting ability account for its unique baking characteristics" (Hesser, p.116, 1989(b)).

The viscoelasticity of wheat gluten results from the interaction between its two major protein components forming a viscoelastic mass in an aqueous system.

Like most hydratable protein, wheat gluten undergoes irreversible denaturation and insolubilization when heated to critical temperatures. This thermosetting property can result in elegant structures of high dimensional stability, when protein percentages are high enough.

Wheat gluten is also notable for its film forming property, a direct outcome of its viscoelasticity. "In addition to its film forming potential in food systems, cast or floated films of wheat gluten can be made" (IWGA, p.4, 1989).

Quality powdered vital wheat gluten has the ability to rapidly absorb and hold approximately twice its weight in water. "The combination of speed of water absorption and the degree of viscoelasticity produced are evidence of 'vitality'; hence the commonly used term Vital Wheat Gluten" (Hesser, p.5, 1989(b)).

Table 2. Proportions and Amino Acid Contents of Gluten Proteins.

Amino Acid	Gliadin	Glutenin	Residue Protein
		(g/16g of N)	
Tryptophan	0.7	2.2	2.3
Lysine	0.5	1.5	2.4
Histidine	1.6	1.7	1.8
NH_3	4.7	3.8	3.5
Arginine	1.9	3.0	3.2
Asparagine	1.9	2.7	4.2
Threonine	1.5	2.4	2.7
Serine	3.8	4.7	4.8
Glutamic acid	41.1	34.2	31.4
Proline	14.3	10.7	9.3
Glycine	1.5	4.2	5.0
Alanine	1.5	2.3	3.0
Cysteine	2.7	2.2	2.1
Valine	2.7	3.2	3.6
Methionine	1.0	1.3	1.3
Isoleucine	3.2	2.7	2.8
Leucine	6.1	6.2	6.8
Tyrosine	2.2	3.4	2.8
Phenylalanine	6.0	4.1	3.8

Source: Pomeranz, 1989.

Finally, wheat gluten exhibits a flavor note frequently described as "bland" or "slight cereal". It improves the overall flavor when blended with meats or other food proteins.

1.2. Uses:

The unique properties of wheat gluten provide a special place for it in the food industry. On the other hand, industrial uses are still not very developed even if prudent foresight, planning and evaluation could uncover interesting potentialities for it.

1.2.1. Food Applications:

1.2.1.1. Milling and Baking Products:

"Probably no area of food processing enjoys greater benefit from wheat gluten than does the baking industry. To the baker, the most valuable properties of wheat gluten are: (1) dough strengthening, (2) gas retention and controlled expansion resulting in uniform shaped products, (3) structural enhancement due to the thermosetting, (4) water absorption and retention allowing improved yield, product softness and extended shelf life, and (5) natural flavor enhancement" (IWGA, p.9, 1981).

The most important use of wheat gluten is in the enhancement of flour protein levels in order to reach the requirements of the baking industry. This has become a common practice, mainly in Europe, for two main reasons: (1) the development and cultivation of high yield and low protein wheat and (2) the import levies on high protein wheat from North America. These points will be developed later in this study.

Another reason for using wheat gluten as a protein enhancer in the flour is that it is often cheaper to use one single flour blended with different amounts of gluten depending on the level of protein needed than different flours.

The different uses of wheat gluten today in the U.S. milling and baking sector are for hard rolls and multigrain, high fiber, and other specialty breads at levels ranging from 2 to 10 percent. Another very important outlet lies in hot dog and hamburger bun production. Wheat gluten improves the strength of the hinge and provides desirable crust characteristics. In this case, it is used approximately at a 2 percent level (Hoseney, 1989).

1.2.1.2. Breakfast Cereal:

Wheat gluten is used in breakfast cereals not only as a protein complement to meet nutritional requirements but also as a binder for vitamin and mineral enrichment components. It also contributes to the strength of product. A known example is "Special K" from Kellogs with a gluten content of about 7-10% (IWGA).

1.2.1.3. Nutritional Snacks:

"In extruded snacks, wheat gluten provides nutritional value, crispness and desired texture. Use levels in this country (the U.S.) are generally 1-2 percent" (Magnuson, p.180, 1985).

1.2.1.4. Meat, Fish and Poultry Products:

The unique adhesive, cohesive, and film forming characteristics of hydrated wheat gluten and its thermosetting properties can be used in preparing meat, fish, and poultry products. In such cases, wheat gluten is commonly used at a level of 2-3.5 percent (IWGA).

1.2.1.5. Other Applications:

There are many others applications of wheat gluten. As previously described, wheat gluten is favored for its protein content as well as for its unique properties. For example, wheat gluten is used in the production of:

-Petfood

-Aquaculture Feed

-Pasta

-Cheese Analogs and Pizza

-Beverage fortification

-Chewing gum base

-Cosmetic products

-Pharmaceutical tablets

-Biodegradable surfactants

-Paper coating and wall paper adhesives, and

-Pressure-sensitive adhesive tapes

1.2.2. Wheat Gluten Amount per End Usage:

Table 3 has been compiled from various editions of the "Product Application Bulletin" published by the International Wheat Gluten Association (IWGA). This table summarizes the gluten amount used in different recipes of products manufactured in the U.S.

Because the percentages are not calculated on the same base, it is difficult to compare the different end uses. However, they clearly demonstrate that wheat gluten is used in relatively small amounts, whatever the final product may be.

Table 3. Examples of Production Applications

Application	Wheat gluten percentage	Calculation Basis
French bread	2	Ingredient
Hamburger buns	2	Sponge
Kaiser (hard) rolls	2.1	Sponge
Multigrain bread	4	Dough
Wheat bread with bran	1	Dough
Wholemeal fiber increased bread	6	Ingredient
Batters for coated foods	3	Ingredient
Crab analog	1	Finished Product
High protein pasta	1.6	Ingredient
Imitation american cheese	6.3	Ingredient
Pizza	1.2	Flour
Sausages, meat products	3.2	Ingredient
Aquaculture		
Catfish diet	5-10	Ingredient
Shrimp diet	10	Ingredient

Source: IWGA, Product Application Bulletin.

1.2.3. Wheat Gluten End Usage per Percentage:

Data provided by the IWGA show slight variations in the end usage percentages of wheat gluten since 1981 (Figure 1).

The milling and baking sector utilizes about 75 percent of the wheat gluten consumed every year followed by petfood (almost 10 percent) and breakfast cereals (approximately 5 percent).

Information obtained in interviews by the author implied that before 1981, the pattern of wheat gluten end usage showed slight variation, as is the case for the period covered by the data provided. Furthermore, the IWGA membership is considered representative of the wheat gluten industry. Hence, the milling and baking sector is considered as having always been the primary consumer of wheat gluten.

1.2.4. Wheat Gluten Substitutes:

Wheat gluten is used mainly for its unique properties and not just as a protein supplier. This use positions it apart from other protein sources.

Research is underway to find substitutes having properties similar to those of wheat gluten. For example, one led by Satin, a food technician with the United Nations, has resulted in the discovery of boiled cassava, maize or sorghum flour as possibly replacements for gluten (Anonymous, 1989). However, wheat gluten is still a unique product because of its vitality, and no substitute is available on the market.

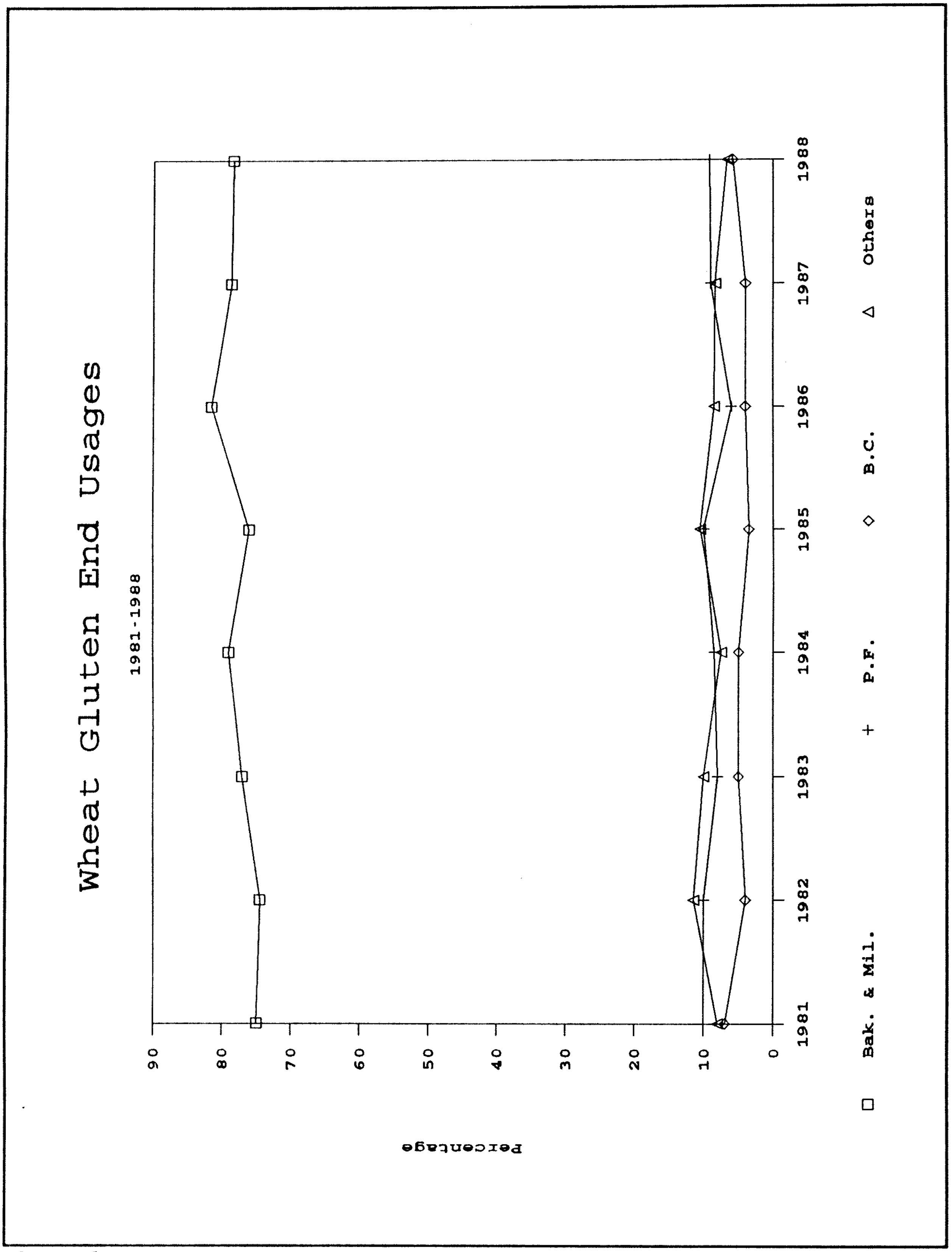

Figure 1. Source: IWGA. **(Bak.: Baking; Mil.: Milling; P.F.: Pet Food; B.C.: Breakfast Cereals)**

1.3 Summary:

Wheat gluten is primarily the water insoluble protein fraction of wheat flour. In spite of a low nutritional quality, wheat gluten is a unique vegetable protein of considerable commercial value. Viscoelasticity and thermosetting ability are its most valuable properties. It is mostly utilized in the milling and baking sector (75 percent of wheat gluten end usage) where it complements the flour. Its unique properties position wheat gluten apart from other protein sources; thus, no substitutes exist.

CHAPTER 2

THE WHEAT WET MILLING SECTOR

The production of wheat gluten first began in the mid-20s. Frank Howker, a New Zealand technician, was carrying out a traditional test of dough and flour quality when he discovered that gluten, the residue from this test, was successful in making a good loaf of bread. Then, in 1936, two Australians, J.B. Regan and Harry Flather, successfully dried gluten without devitalizing it (Sosland, 1986). Since then, industrial wheat gluten processes have been developed. In 1988, the world production and consumption reached more than 250,000 tons, with the main players in this market being Australia, Canada, the E.C., and the U.S.

2.1. The Wheat Gluten Production Process:

A grain of wheat contains approximately 70 percent starch and 8 to 15 percent gluten. It is from the separation of these two components from the rest of the kernel that commercial wheat gluten is produced.

A straight-grade roller-milled flour of 75 to 80 percent extraction is most commonly used. About half of the companies operate their own flour mills. This allows them to process flour with less starch damage than would occur in processing for bread-making. Although this damaged starch provides the advantage of enhancing baking performances for the bread-making industry, it has a negative effect on yields of gluten.

The wet separation of gluten from starch is accomplished through very similar processes in different firms. "There are many variations in the plant and equipment used but each variation can be traced back to its origins either in the dough system or the batter system" (Grace, p.113, 1989).

2.1.1. Dough Process:

The so-called dough or Martin process was first developed in Paris in 1835. Wheat flour is mixed with water and kneaded to form a dough with a 55-60 percent dry basis. Then ribbon blenders, twin screw troughs, or rotating screens are used to wash away the starch from the gluten.

2.1.2. Batter Process:

The batter process is a variant of the dough process, which was developed during World War II at the Northern Regional Research Laboratory, USDA. As in the dough process, flour is mixed with water. Then the batter obtained is developed by mechanical means. After 30 minutes of rest, the batter is vigorously mixed with additional water. Finally, gyratory screens, sieve bends, or rotary screens are used to separate it from the starch liquor.

2.1.3. Gluten Drying:

"After additional dewatering by roller compression, the gluten may be dried to about 8 percent moisture in vacuum, spray, flash or drum dryers" (Knight and Olson, p.496, 1984). Because of its sensitivity to heat damage, rapid drying at controlled temperature is needed. More than 90 percent of world gluten output is flash dried in specially designed equipment (Grace, 1989).

2.1.4. Wheat Starch and Effluent:

The production of wheat gluten is associated with that of wheat starch and a liquid effluent. An output of 1 ton of wheat gluten corresponds to the recovery of 5.25 tons of wheat starch and up to 30 tons of liquid effluent containing 1.1 tons of soluble starch and fiber. (Grace, 1989).

2.2. The wheat Wet Milling Industry:

2.2.1 Recent Evolution of the Industry:

Starch and gluten are the two main co-products of the wheat wet milling industry. Therefore, the production of wheat gluten is influenced by the demand for wheat starch. With wheat and corn being the most important raw materials used in the production of starch, the production of wheat gluten is also dependent upon the evolution of the use of corn relative to that of wheat.

2.2.1.1. Factors Influencing this Evolution:

The wheat wet milling industry was the first major source of starch at the end of the previous century, but much has changed since then. In countries where corn is available, the wheat wet milling industry has developed at a slower rate than the dominating corn industry.

Another important factor has been the agricultural policies set up by each main player. These policies have affected the wheat wet milling industry through their influence on the price ratio of wheat to corn and of high protein wheat to low protein wheat. The first ratio influences the development of the use of corn relative to wheat as a raw material for starch production. The second influences the use of high protein flour relative to low protein flour enhanced with wheat gluten (Leuck, 1990).

Table 4. Trends in Flour Use and Export for Australia

Year	Starch /Gluten	Bread	Export	Total
	(thousands of tons)			
1979	208	551	92	851
1980	218	570	78	866
1981	229	568	100	897
1982	209	567	102	878
1983	193	570	91	854
1984	232	545	63	841
1985	259	540	61	859
1986	274	523	61	859
1987	270	541	73	884
1988	300	563	86	949

Source: Wrigley and McMaster, 1989.

Finally the development of the wet milling industry has been influenced by diverse policies concerning it directly.

2.2.1.2.: Evolution in the Main Areas:

Australia, Canada, the E.C. and the U.S. are the areas that dominate the wheat gluten market as will be seen below. Hence, the following review is focused on these areas.

2.2.1.2.1. Australia:

Wheat is the major cereal in Australia and, therefore, the primary source of starch. As shown in Table 4, the wet milling industry absorbs a significant amount of wheat flour. From approximately 25 percent in 1979-80, wheat flour usage has shot up to more than 30 percent within the past years. In absolute value, the use of wheat flour for starch and gluten production has increased at a rate of approximately 50 percent during the last decade.

"The great increase in gluten use has been largely due to the increased popularity of wholemeal bread (e.g., from 20 percent of bread consumption 15 years ago, in Australia to about 50 percent at present) and the need to increase protein content to maintain bread quality" (Wrigley and McMaster, p.33, 1989).

Australian wheat gluten producers are assisted by subsidies for domestic cereal grains. These subsidies somewhat offset the 8.3 percent U.S. tax on wheat gluten imports.

2.2.1.2.2. Canada:

The federal government provides financial assistance for the transport of grain destined for export. Other components of the Canadian grain program are input subsidies and income stabilization.

The development of the Canadian wheat gluten industry, as in Australia, has been dependent upon agricultural and market factors more than anything else. Canada produces high protein wheats that lower the demand for wheat gluten, thus explaining why this country has only one company that exports a large amount of its production (estimated at 60 percent in 1988).

2.2.1.2.3. The E.C.:

In the mid-60s, the European Community's Common Agricultural Policy was developed on three basic cornerstones: (1) common prices for agricultural products in all member countries, (2) absolute preferences for E.C. producers over outside producers, and (3) common funding of its agricultural programs (Hathaway, 1987).

Its primary feature has been to provide income support to farmers by maintaining high domestic support prices. A price system was set up to artificially keep internal E.C. grain market prices above world grain market prices. A minimum market floor price for grains in the E.C. is established annually: the intervention price. It is maintained through a mechanism of purchases by public agencies when the market price falls below its level. The E.C. price regime also prevents the entry into the E.C. of lower priced grain imports from third countries. This has involved the establishment of a variable import levy. The import levy is calculated daily in order to compensate the difference between the lowest c.i.f. offer price and the so-called threshold price, the minimum price at which third country imports can enter the E.C. market. This threshold price is also set annually like the intervention price.

Self-sufficiency in most agricultural products was reached by the E.C. in 1974-75, and that status has since been maintained. Hence, the price of domestic wheat has developed in a manner similar to the intervention price since 1974-75.

On the other hand, the required quality standards of corn for the wet milling industry as well as high protein wheat have always been insufficient. Imports have been necessary. Therefore, prices have developed close to the threshold price, which, by political decision, has increased more rapidly than the intervention price.

In addition to this situation, another important factor affecting the evolution of the wet milling industry in the E.C. must be considered: the system of production refunds. Production refunds have been given since 1967 to starch producers to allow them to obtain starch at world market prices. Briefly, these refunds are a payment made by the E.C. to starch producers in order to cover the gap between the threshold and c.i.f. prices of the raw material used in starch production, either corn or wheat.

"The amount of the refunds changed little over the years, with the result that net price paid by the wheat washing industry for E.C. wheat declined relative to both the corn net price paid by the wet milling industry for corn and the threshold price for hard wheat. These shifting price ratios encouraged both a shift from corn starch to wheat starch and from hard wheat flour to gluten-fortified E.C. flour" (Leuck, p.7, 1990). Variable import levies and export subsidies for starch and wheat gluten protect these industries. However, during the past two years, no export subsidy has been granted for wheat gluten.

In addition, the gradual spread of modern commercial bakery practices to Western Europe has prompted the extraordinary growth in wheat gluten production in recent years.

2.2.1.2.4. The U.S.:

A study conducted by B.F. Stanton (1986) over a 7-year period (1977-1984) concluded that the costs of corn production are lower in the U.S. than in the E.C. Conversely, the study shows that costs of production of wheat are lower in the E.C. Hence, the U.S. is believed to have a comparative advantage in corn production. The effects of climate, of the non-need of irrigation and, therefore, of drying costs could explain this American advantage. As a consequence, the U.S. has placed more emphasis on the valorization of corn than wheat (Debatisse, 1987).

The corn starch industry in the U.S. is far more developed than the wheat starch industry. This development has been amplified by great efforts in research leading to a near perfect knowledge of the corn wet milling process, a process that has still not been completely mastered for wheat. Furthermore, the corn starch industry has profited from a better reputation of its products.

2.2.2. The Wheat Wet Milling Industry Today:

Most of the data used here and in the following part (The Wheat Gluten Market) are provided by the International Wheat Gluten Association. The key position of this organization and personal interviews with people in the industry confirm the validity of these data. Although they concentrate only on the year 1988, they provide a good image of what the condition of the world wheat gluten market has been recently. The only noticeable difference in recent development has been the increasing role of the E.C. in the international market.

2.2.2.1. Orientation of the Companies:

From the previous discussion about the recent evolution of the wet milling industry, a major difference between companies comes to light: depending on location, the major product of the wheat wet milling companies is not the same. The North American companies are wheat gluten producers, and starch is the by-product of their activity. On the other hand, Australian and European are primarily wheat starch producers, with wheat gluten being a by-product of starch production.

2.2.2.2. Repartition of the Companies:

The international wheat gluten industry is relatively small. It consists of 43 companies located throughout 19 countries. Out of these 43 companies, 35 are located in four main areas:

-Australia:	4
-Canada:	1
-The E.C.:	26
-The U.S.:	4

2.2.2.3. Size of the Companies:

Depending upon location, the average company has a production capacity estimated at:

-Australia:	12,600 tons per year
-Canada/USA:	13,900 tons per year
-The E.C.:	6,800 tons per year

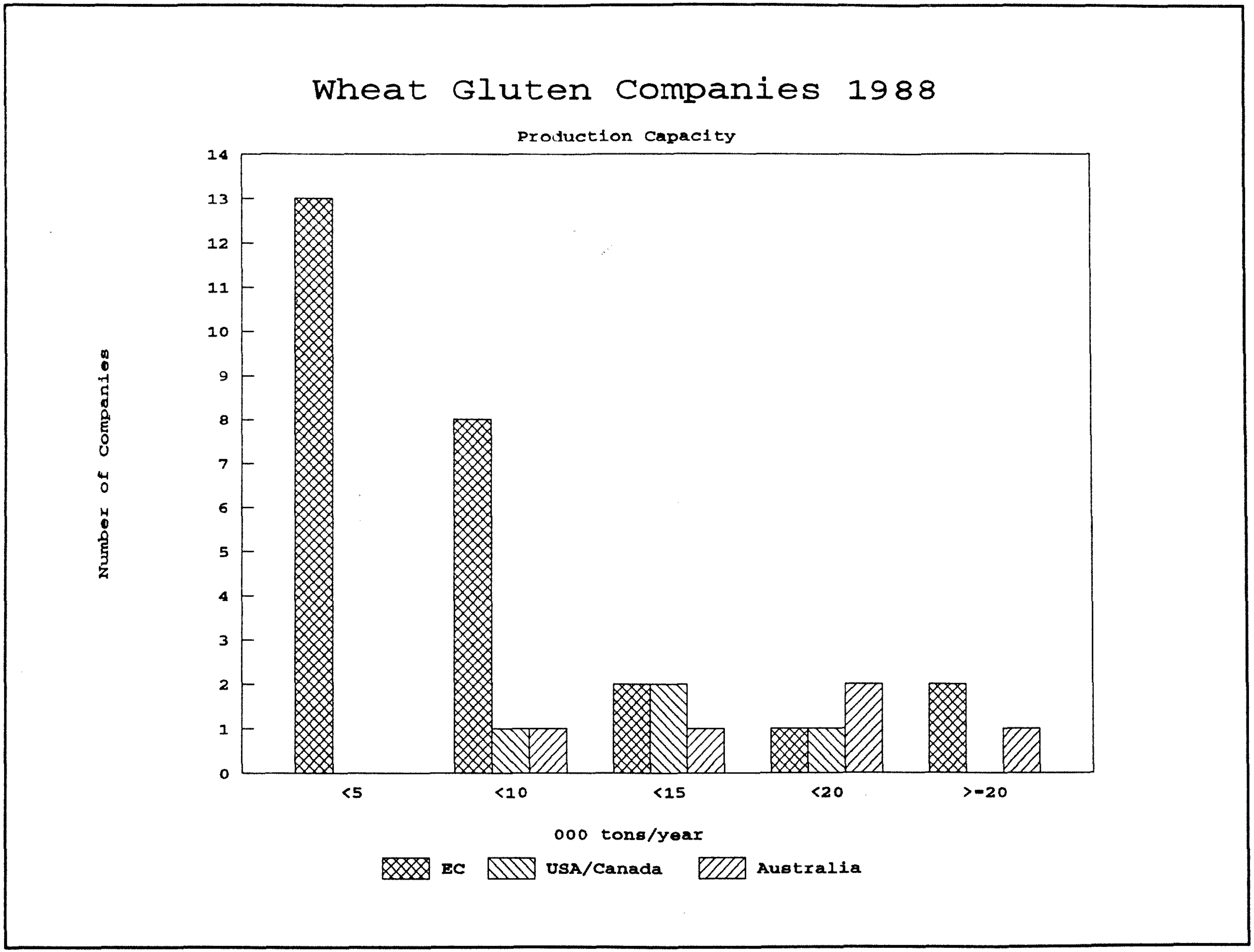

Figure 2. Source: IWGA.

The average European company appears to have half the production capacity of the others. A look at the distribution per production capacity of these companies confirms this statement (cf Figure 2).

Apart from two major companies with a capacity between 25,000 and 30,000 tons per year, most European corporations are not able to produce more than 10,000 tons per year. On the other hand, almost all the Australian and North American firms have a production capacity ranging between 10,000 and 20,000 tons per year.

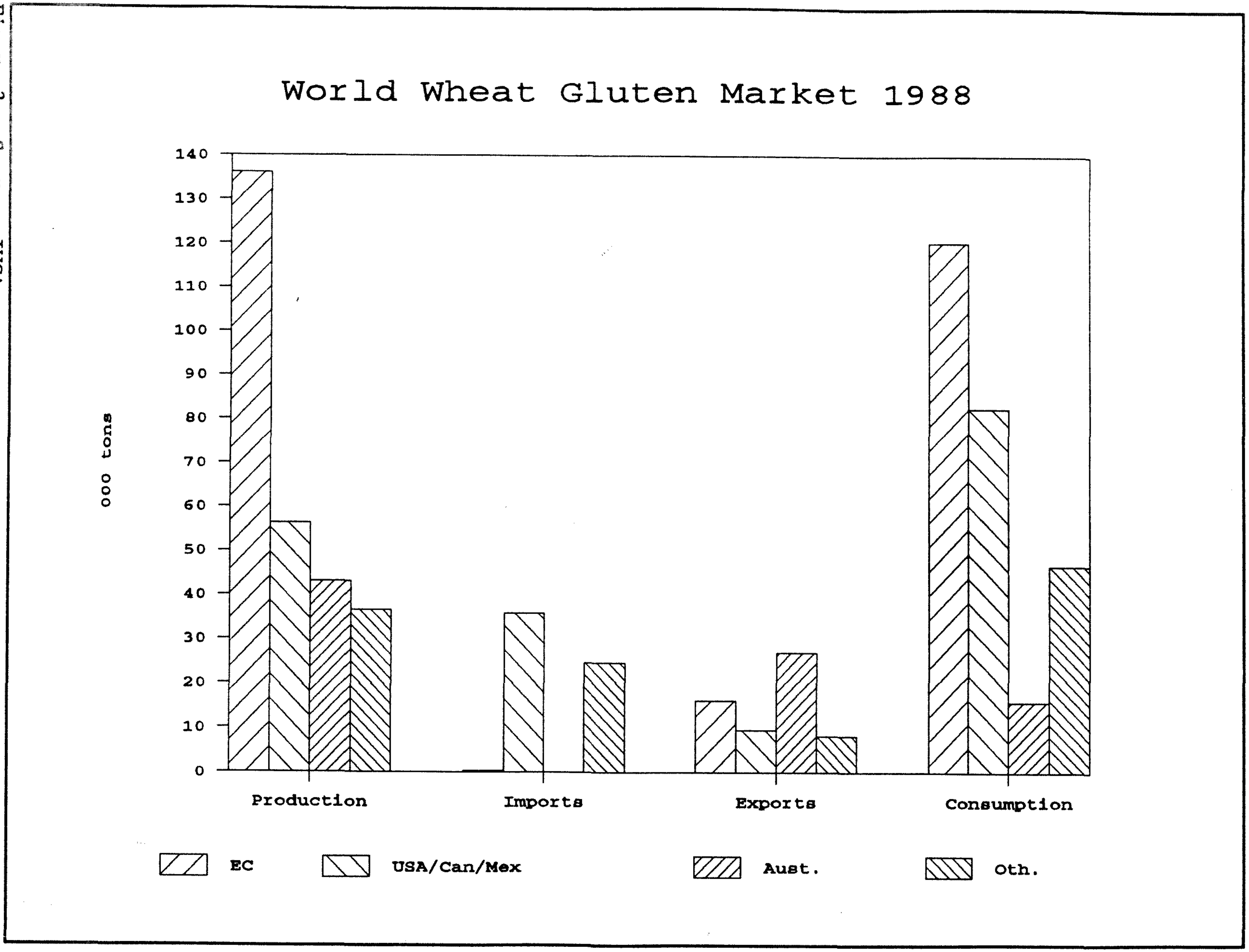

Figure 3. Source: IWGA.

2.3. The Wheat Gluten Market:

2.3.1. World Situation:

The data shown in Figure 3 provide a global image of the world situation in 1988. In that year, a total of 271,800 tons of gluten was produced from an estimated production capacity of 330,100 tons. Only about 80 percent of the production capacity was used in 1988. World consumption was almost equal to production at 265,000 tons. The international market represented a little more than 20 percent of this intake. In 1988, approximately 60,000 tons were traded between countries.

2.3.2. Output and Production Capacity per Main Area :

2.3.2.1. The E.C.:

In 1988, the E.C. was clearly the main producer of wheat gluten (cf Figure 3). Producing 136,100 tons, the E.C. accounted for half of world production. Its production capacity, 176,300 tons, represented approximately the same proportion of the world production capacity (53 percent). Hence, utilization of the production capacity was close to the world average: 80 percent.

Within the E.C., production was dispatched in a highly irregular way. A first group of countries produced between 20,000 and 30,000 tons: the Netherlands, Germany, France, the United Kingdom, and Belgium. A second group had outputs between 500 and 6,000 tons: Ireland, Italy, Spain, and Denmark. The other E.C. nations (Greece, Luxembourg, and Portugal) did not participate in wheat gluten production.

2.3.2.2. USA/Canada/Mexico:

After the E.C., the USA/Canada/Mexico group ranked second, with a production level of 56,200 tons.

Note that both Canada and Mexico account for only one wheat gluten plant each. For this reason, no individual data are available for each of these countries. The data concerning Canada and Mexico are considered confidential.

It is assumed that the U.S. represents 80 percent and Canada 20 percent of the production capacity and production. The part owned by Mexico is so minor that it will not be considered.

In 1988, USA/Canada/Mexico used approximately 80 percent of their production capacity, nearly 72,000 tons. This percentage is once again the world average.

2.3.2.3. Australia:

The third position is held by Australia. In 1988, the output of this country was estimated at 43,000 tons for a production capacity estimated at approximately 50,000 tons. 86 percent of the production capacity was used that year.

2.3.2.4. Others:

The remaining 13.4 percent of production was contributed by more than 20 countries. They produced slightly less than 7,000 tons.

2.3.3. Consumption:

As in the previous discussion, the same areas are dominant in consumption levels:

-the E.C.:	120,300 tons
-USA/Canada/Mexico:	82,600 tons
-Australia:	16,000 tons
-Others:	46,700 tons

The importance of the amount consumed by "others" shows that consumption was not as concentrated as production in 1988. A few countries not previously considered came to light:

-Japan:	10,200 tons
-Korea, ROK:	4,200 tons
-China, ROC:	4,500 tons
-China, PRC:	3,500 tons

However, the E.C., USA/Canada/Mexico, and Australia still proved to be the most important players as far as consumption was concerned. The consideration of Mexico can again be eliminated. Its participation in consumption is very minor.

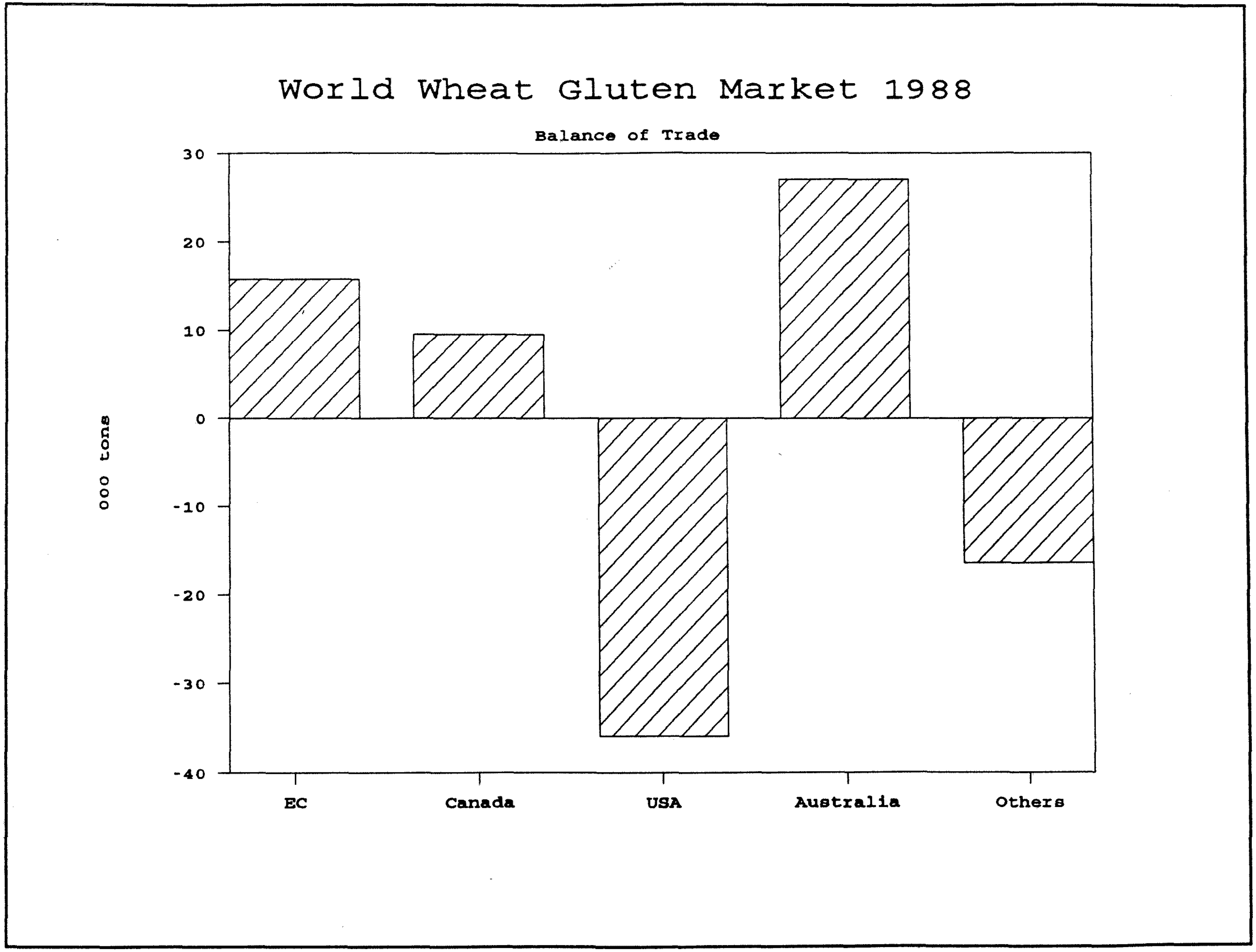

Figure 4. Source: IWGA.

2.3.4. The International Market:

Previous discussions about consumption and production reflect the state of the international market (cf Figure 4). Two of the main players were in a surplus situation in 1988: the E.C., +15,800 tons and Australia, +27,000 tons.

As shown by the data provided by the IWGA, surpluses found in these areas have given rise to exports. On the other hand, the USA/Canada/Mexico group experienced a production deficit of 26,400 tons. This deficit, of course, was completed by imports.

The pattern of U.S. imports, as will be seen below, shows that Canada exported a significant amount of gluten to this country. Bearing in mind the minor role held by Mexico, it can be assumed that: all the exports of the group are from Canada and all the imports of the group are from the U.S.

Hence, Canada must be listed among the main exporters, with an estimated amount of 9,500 tons exported in 1988. On the other hand, the U.S. is the main importer in the international market, with imports of approximately 36,000 tons representing 60 percent of the international market imports.

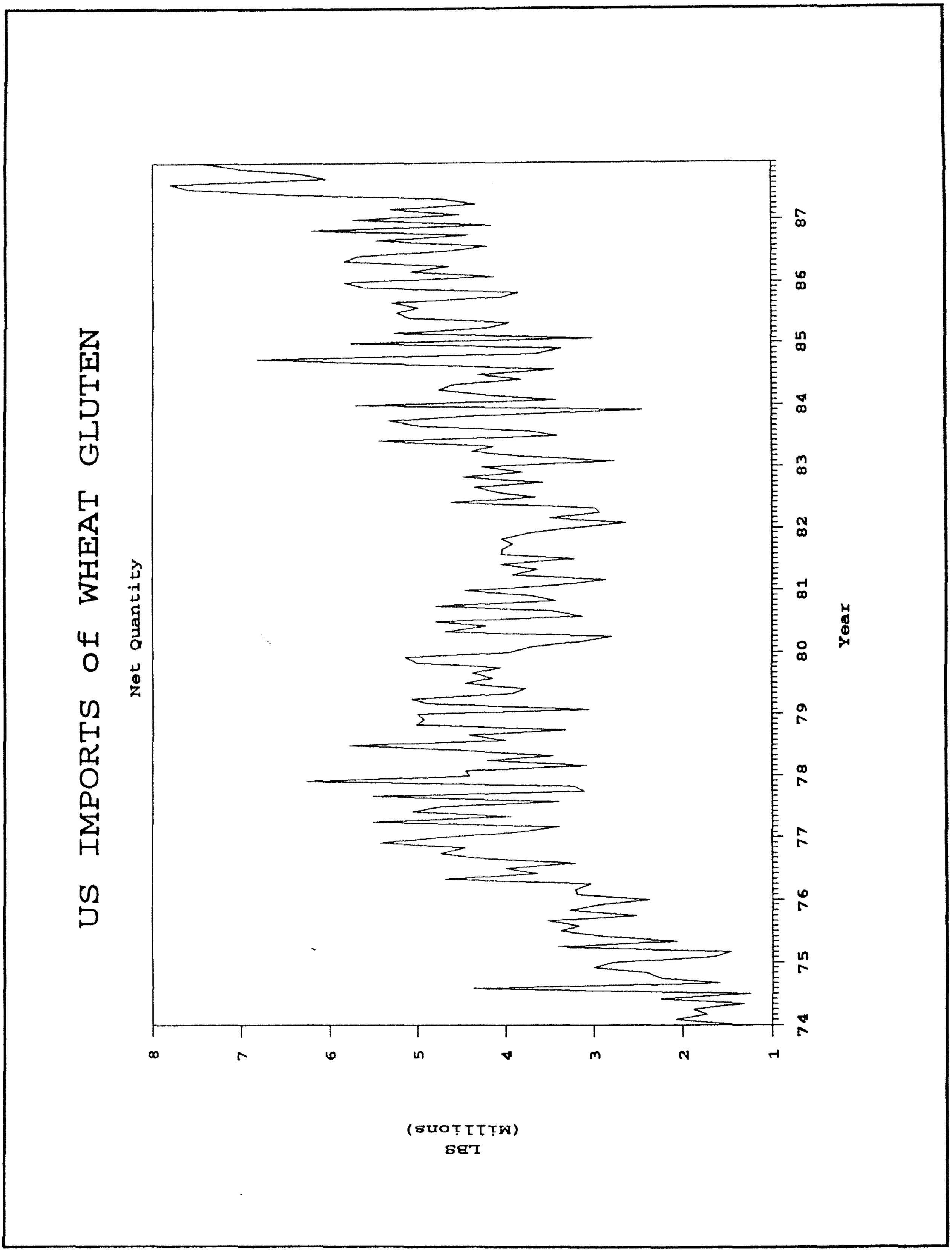

Figure 5. Source: Department of Commerce, Bureau of the Census.

2.3.5. U.S. Imports:

Because the U.S. is the main importer, our study focuses on this country. The evolution of wheat gluten imports by the U.S. is illustrated in Figure 5. The figure displays a general upward trend in the quantity of gluten imported since 1974. However, after a sharp increase from 1974 to 1978, imports showed a slight recession before increasing again after 1982. Since then, the same trend has been observed, with an acceleration after 1986.

Figure 6 breaks down U.S. imports into relative market shares among the important exporting markets. The main origin of U.S. imports has historically been Australia, with a 14-year average of approximately 60 percent of the U.S. import market. Its exports to the U.S. have been most important in 1975 and between 1980 and 1982. Since then, they have decreased slightly.

Canada ranked second in importance as a supplier of U.S. imports of wheat gluten. Since 1975, its market share has slowly decreased from about 30 percent to 25 percent. Canada is now ranking third.

In 1983, trade in wheat gluten between the E.C. and the U.S. began to attain significance. After a slowdown in exports from the E.C. to the U.S. in 1985, its market share has grown to such an extent that the E.C. is now the second largest supplier of wheat gluten to the U.S., providing 22 percent of imports in 1987. The recent prominence of the E.C. as an exporter of wheat gluten parallels its new role as a net exporter of grains.

Other countries have represented an average of 8.7 percent of the U.S. import market for wheat gluten, having a maximum of 14.5 percent in 1978 and a minimum of 2.5 percent in 1982.

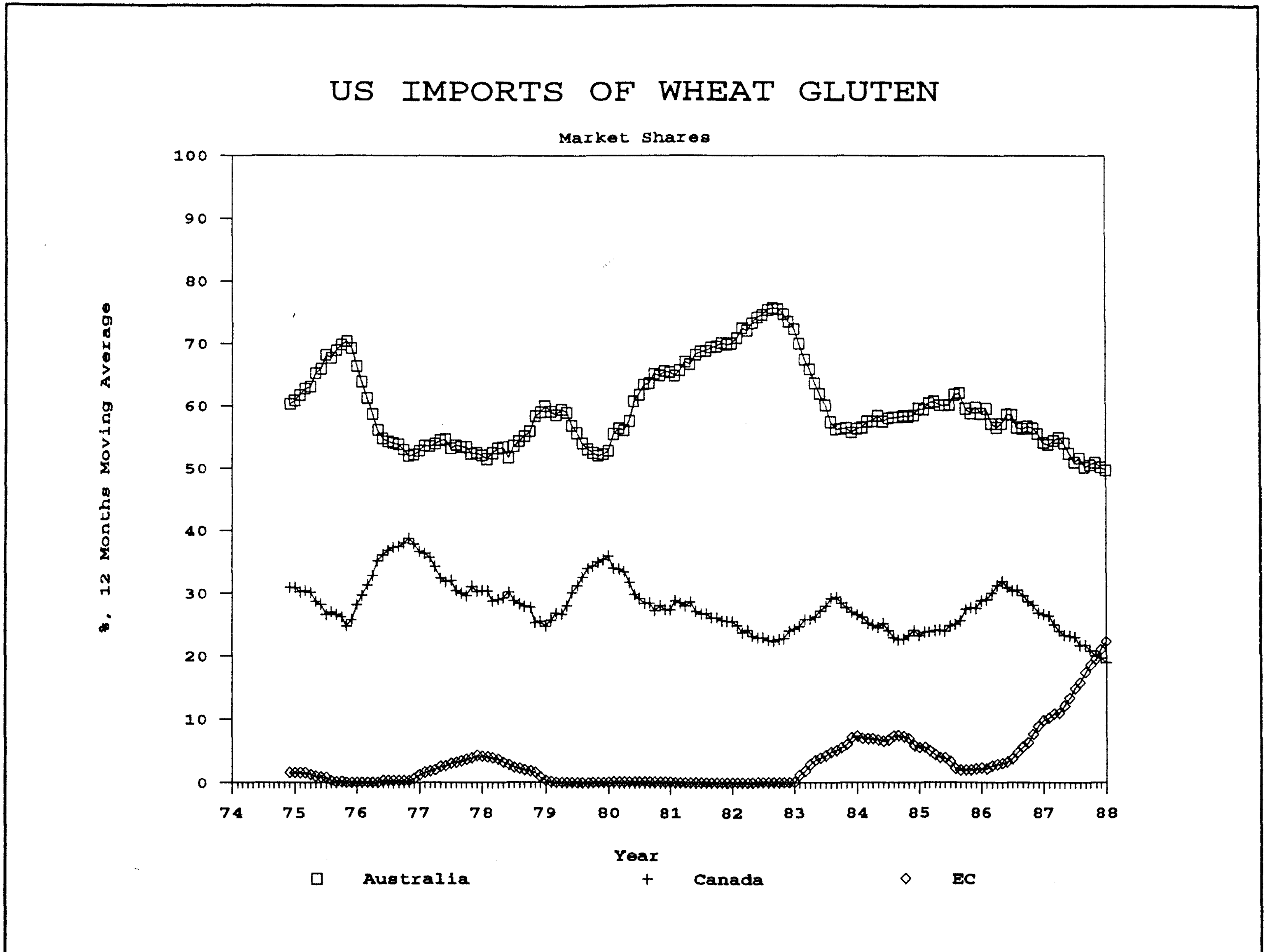

Figure 6. Source: Department of Commerce, Bureau of the Census.

2.4. Summary:

A grain of wheat contains approximately 70 percent starch and 8 to 15 percent gluten. Commercial wheat gluten is obtained by separation from starch through a wet milling process based on the dough or batter method. After careful drying, gluten can be stored; rehydration will restore its initial properties when needed.

Raw material availability, growth of the corn wet milling industry, and political decisions have been the main factors influencing the development of the wheat gluten industry. An international market has been established, in which the U.S. is the major importer and Australia, Canada, and the E.C. are the main exporters.

The wheat wet milling industry is relatively small and mainly developed in four areas: Australia, Canada, the E.C., and the U.S. The U.S. can be distinguished by having companies that are gluten producers, with starch being the by-product of their operation.

CHAPTER 3

ECONOMIC REVIEW

Before touching on the econometric analysis itself, the economic theory underlying this study must be explained. This leads to the setting up of the theoretical equation adapted to the case of U.S. wheat gluten import demand.

3.1. Theoretical Economic Review:

The point here is to study the import demand, or excess demand, for a single commodity. From economic theory, we have the following identity:

$$ED_t = M_t - E_t = (D_t - H_t) + \Delta I_t$$

where:

ED_t = quantity representing the excess demand within period "t"

M_t = quantity imported within period "t"

E_t = quantity exported within period "t"

D_t = quantity demanded within period "t"

H_t = quantity produced within period "t"

ΔI_t = inventory variation within period "t"

The theoretical domestic demand function can be expressed as:

$$D_t = f(D_{t-1}, p_t, p^s{}_t, p^c{}_t, Y_t, z^D{}_t)$$

where:

D_t = quantity demanded within period "t"

D_{t-1} = quantity demanded within the previous period

p_t = commodity price within period "t"

$p^s{}_t$ = price of substitutes within period "t"

$p^c{}_t$ = price of complements within period "t"

Y_t = income within period "t"

$z^D{}_t$ = other explanatory and policy variables within period "t"

The domestic supply function for a single commodity can be expressed as:

$$H_t = f(H_{t-1}, p^e{}_t, z^H{}_t)$$

where:

H_t = quantity produced within period "t"

H_{t-1} = quantity produced within the previous period

$p^e{}_t$ = expected price within period "t"

$z^H{}_t$ = other explanatory and policy variables within period "t"

3.2. Demand Equation for U.S. Wheat Gluten Imports:

It is assumed that there is no inventory adjustment in the import demand for wheat gluten. This assumption is made on two grounds. First, relevant data on inventories of wheat gluten in the U.S. are nonexistent. Second, industry personnel (Hesser, 1989(a)) have advised that, because of the stability and flexibility of foreign supplies of wheat gluten , domestic inventories are very small and are restricted to their monthly utilization levels. Therefore:

$$\Delta I_t = 0$$

This results in the following expression for the previous equation:

$$ED_t = M_t - E_t = D_t - H_t$$

Hence, it is deduced that the excess demand function is affected by factors relevant to domestic supply and demand functions.

As seen before, wheat gluten is a manufactured product that has a short production cycle. It is assumed that agents have perfect foresight regarding contemporaneous prices. In this case:

$$p^{e}_{t} = p_{t}$$

In addition, the fact that wheat gluten has no substitute eliminates the variable p^{s}_{t} in our model.

Therefore, the Demand (D) and the Supply (H) functions are expressed in the following form:

$$D_t = f(D_{t-1}, p_t, p^{c}_{t}, Y_t, z^{D}_{t})$$

$$H_t = f(H_{t-1}, p_t, z^{H}_{t})$$

The U.S. does not export any wheat gluten. It is a strict importer and has always been. Therefore:

$$ED_t = M_t - E_t \rightarrow ED_t = M_t$$

$$ED_{t-1} = M_{t-1} - E_{t-1} \rightarrow ED_{t-1} = M_{t-1}$$

This results in the following expression of the import demand function, which will be used for the econometric analysis of U.S. imports of wheat gluten:

$$M_t = f(M_{t-1}, p_t, p^{c}_{t}, Y_t, Z_t)$$

3.3. Summary:

Economic theory provides the typical equation for an import demand function. The adaptation of this equation to the case of the wheat gluten leads to the following identity:

$$M_t = f(M_{t-1},\ p_t,\ p^c_t,\ Y_t,\ Z_t)$$

where:

- M_t = quantity imported within period "t"
- M_{t-1} = quantity imported within the previous period
- p_t = commodity price within period "t"
- p^c_t = price of complement within period "t"
- Y_t = income within period "t"
- Z_t = other explanatory and policy variables within period "t"

CHAPTER 4

ECONOMETRIC ANALYSIS

Now that the basis of the econometric analysis of the U.S. imports of wheat gluten has been considered, the next step is assigning a precise definition to each variable suggested by economic theory. An expected relation between independent and dependent variables is presented before a description of the methodology and the theoretical statistical notions used. This chapter ends with a presentation of the results obtained.

4.1. Factors Affecting the U.S. Import Demand for Wheat Gluten:

The previous discussion of general economics related to the wheat gluten sector in the U.S. provides indicators for choosing the specific variables that influence the U.S. import demand for wheat gluten.

4.1.1. The Dependent Variable, M:

The dependent variable, M, is the quantity of wheat gluten imported by the U.S.

Source: Bureau of the Census, Department of Commerce.

4.1.2. The Independent Variables:

4.1.2.1. Lagged Imports, M_{-1}:

Source: Idem M.

4.1.2.2. Commodity Price, p:

Because no market price is directly available, the unit value of the imports is used. It was obtained by dividing the quantity imported within one period by the c.i.f. value of imports during this same period.

Source: Idem M.

4.1.2.3. Price of Complement, p^c:

Flour is the main complementary product. The Consumer Price Index for flour is used for this variable. The seasonally unadjusted index has been chosen because no other data were seasonally adjusted.

Source: Bureau of Labor Statistics, Department of Labor.

4.1.2.4. Income, Y:

Since wheat gluten is an industrial product, the income evolution is accounted for by the Index of the Industrial Production. Hence, the variable reflects more upon the overall economy's industrial health rather than exact income.

Source: O.E.C.D.

Note: The figures for the variables p, p^c, and Y have been transformed into a constant dollar value, using a 1975 base, by removing the effect of inflation. This effect has been taken into account through the U.S. Index of the Producer Price for Industrial Goods provided by the I.M.F.

4.1.2.5. Other Explanatory and Policy Variables, Z:

The objective is to incorporate within the model the various factors specific to the wheat gluten market that influence the U.S. import demand for this commodity. The previous analysis of this market leads to consideration of an average protein amount of the wheat harvest. This factor has been identified as the main factor influencing the demand for wheat gluten (Hesser, 1989(a); Pudden, 1989).

The chosen indicator is a weighted average of the protein amount of the wheat harvest in North Dakota and Kansas. North Dakota is the main state for the production of Hard Red Spring Wheat, the strongest wheat in protein produced in the U.S. Kansas is the main state for the production of Hard Red Winter Wheat, which ranks second as far as protein level is concerned. The weights are the amounts of each one of these wheat categories harvested. The value taken is the one calculated for the previous season. The value of "Pa" is calculated as:

$$Pa = ((Pnd * HRSW) + (Pks * HRWW)) / (HRSW + HRWW)$$

where:

Pnd = Protein percentage of the wheat harvest in North Dakota

HRSW = Amount of the harvest of Hard Red Spring Wheat

Pks = Protein percentage of the wheat harvest in Kansas

HRWW = Amount of the harvest of Hard Red Winter Wheat

Source: U.S. Wheat Associates, Inc.

4.1.3. Relation Between the Dependent and Independent Variables:

Before considering any statistical analysis, the expected sign of the coefficient relating the dependent variable to each of the independent ones is presented below.

4.1.3.1. Lagged Imports, M_{-1}:

Positive.

International wheat gluten trade requires many large fixed assets, which may be difficult to quickly adjust (capital in shipping institutions, flour manufacturing, etc...). Thus, it may be difficult to quickly alter trade levels. Generally, this is called a "partial adjustment model"; the higher the coefficient on M_{-1}, the slower the adjustment. This coefficient should be between 0 and 1, 0 signifying an immediate adjustment and 1 an absence of adjustment.

4.1.3.2. Commodity Price, p:

Negative.

The coefficient relating the quantity imported and the price of the commodity is the price elasticity. This coefficient is expected to be negative because of the implications of neoclassical demand theory.

4.1.3.3. Price of Complement, p^c:

Negative.

As the price of the complement increases, the quantity of the commodity purchased decreases.

4.1.3.4. Income, Y:

Positive.

For a normal good, the income effect is positive since the variation of quantity purchased to the variation of income ratio is positive. Here, the factor tested is similar to a measure of the income. Therefore, the estimated coefficient should be positive. This effect is also generated by neoclassical demand theory.

4.1.3.5. Protein Amount of the Wheat Harvest, Pa:

Negative.

Wheat gluten is mainly used as a protein complement in flour. As the protein amount of the wheat harvest increases, the need for gluten, and therefore, the quantity imported decrease.

4.2. Empirical Methodology:

4.2.1. Data Base:

The model is estimated using monthly data over a 14-year period, from 1974 to 1987. The time series data start in 1974 because it represents the year of change in the presentation of import data. Before this time, no c.i.f. values were provided from the available publication of the Bureau of the Census, Department of Commerce. The reason for the termination in 1987 is due to the unavailability of certain data for 1988.

Therefore, the model is based on 168 monthly observations (cf Appendix 1).

4.2.2. First Transformation:

For convenience, elasticities are assumed to be relatively constant in response to changing factors. This is mathematically revealed by a demand equation, linear in logarithms (denoted by "ln"). The different elasticities expressed through this type of function are constant and may be read directly from the mathematical form of the curve.

From:

$$\ln(Q) = \ln(B_0) + B_1 \ln(F)$$

is deducted, by derivation:

$$dQ / Q = B_1 * dF / F$$

From this last identity, the price elasticity is derived since the identity is equivalent to:

$$B_1 = (dQ / Q) / (dF / F)$$

$$B_1 = (dQ / dF) * (F / Q)$$

$$B_1 = \epsilon_{Q,F}$$

where:

Q = quantity

F = factor

$\epsilon_{Q,F}$ = elasticity of demand with respect to factor F

"This feature may make such curves more suitable for empirical work, since demand functions of this form seem to fit historical data rather well" (Nicholson, p.197, 1989).

Because the import quantities are reported in pounds, they reach high numbers. In order to avoid disturbances by the logarithmic transformation of high numbers, these figures are divided by 1,000,000.

4.2.3. Multiple Regression Analysis:

The linear in logarithms form of the factor demand model is estimated because there is no theoretical basis pertaining to this particular model that would suggest examining non-linear forms of regression estimation. This type of relation between one variable and "n" others is described by a multiple linear regression equation in the form of:

$$\ln(Y_i) = B_0 + B_1 \ln(X_{i1}) + B_2 \ln(X_{i2}) + \ldots + B_n \ln(X_{in}) + e_i$$

where:

Y_i	= dependent variable
$B_{0,1,2,\ldots,n}$	= parameters to be estimated
$X_{i1,2,\ldots,n}$	= independent explanatory variable
e_i	= stochastic disturbance

To complete the specification of the regression model, certain basic assumptions must be added:

1: e_i is i.i.d. normally distributed,

2: $E(e_i) = 0$,

3: $Var(e_i) = S^2$,

4: $Cov(e_i, e_j) = 0 \quad (i \neq j)$,

5: each of the explanatory variables is non stochastic,

6: the number of observations exceeds the number of coefficients to be estimated,

7: no exact linear relation exists between any of the explanatory variables.

These assumptions are taken to apply to all observations (Kmenta, 1986).

Although all of these assumptions may not be met completely by the model and its corresponding data, the model is set up in such a way as to try and minimize any violations of the assumptions.

4.2.4. Autocorrelation Disturbance:

Our statistical analysis is made from the time series on a monthly basis. Thus the effect of the factors operating at one period may be partly carried over into the following period. This would be a violation of assumption No.4 which, combined with assumption No.1, implies that the disturbance occurring at one period does not carry over into another period.

Hence, the presence of linkages between residual errors must be considered. A link is not taken into consideration by the Ordinary Least Squares Method which leads to the obtainment of inefficient regression coefficients estimates. The presence of autocorrelation is determined by applying the Durbin-Watson test.

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4.3. Results:

The model is estimated with the six dependent variables revealed by the previous parts of this study. This estimation results in the equation:

$$\ln(M) = \underset{(-0.532)}{10.5092} + \underset{(1.143)}{0.0905}\ln(M_{-1}) + \underset{(-0.545)}{-0.1042}\ln(p) + \underset{(-7.273)^*}{-1.8689}\ln(p^c)$$

$$+ \underset{(3.993)^*}{0.9411}\ln(Y) + \underset{(-2.773)^*}{-1.8279}\ln(Pa)$$

Adjusted r-square : 0.4931

The complete output of this regression is provided in Appendix 2.

The numbers in parentheses are t-values for the respective parameters with 167 degrees of freedom. A "*" denotes significance at the 5 percent level. The adjusted r-square signifies that 49.31 percent of the variation in the dependent variable is explained by the changes in the independent variables. The Durbin-Watson test is not applicable when one of the explanatory variables is a lagged dependent variable, which is the case here. For this situation, Durbin developed two tests: the "h" test and the "m" test. The "h" test cannot be used because it leads to the calculation of the square root of a negative number.

The "m" test consists of calculating the least squares residuals (e_t) and applying the least squares method to:

$$e_t = \beta_0 + \beta_1 M_{t-1} + \beta_2 p_t + \beta_3 p^c{}_t + \beta_4 Y_t + \beta_5 Pa_t + \beta_6 e_{t-1} + \text{error}$$

and testing the significance of the estimated coefficient of e_{t-1} by the standard *t* test (Kmenta, 1986). The *t*-value obtained here is -1.427. Hence, the "m" test does not indicate the presence of autocorrelated disturbances.

The own-price effect for the import demand for wheat gluten is not significantly different from zero. The corresponding elasticity has a value of -0.10, which indicates a very inelastic import demand. This finding is in agreement with the views of individuals familiar to the industry (Hesser, 1989(a); Pudden, 1989; Hoseney, 1989) who confirm that changes in price have little effect on imports of wheat gluten by the U.S. This statement seems relevant because wheat gluten is used in very small amounts whenever it is needed. In addition, its prices are not high enough to compensate the low percentage at which it is incorporated. Consequently, its contribution to the cost of production of the final product is very small. Since there is no substitute for wheat gluten, its price is not a major factor in its use.

The estimated coefficient for the variable M_{-1} is also not significant, with a t-statistic at a level of only 1.143. In addition, the parameter estimated is very small: 0.09. This indicates that, no significant degree of lagged adjustment exists, and therefore, that short-run and long-run elasticities are quite similar.

The coefficients related to variables "p^c", "Y", and "Pa" are consistent with the expectations previously presented and are highly significant. The price of flour appears to be a significant factor in the determination of imports of wheat gluten. Its coefficient is highly significant with a negative sign, which reflects flour's role as a complementary product of wheat gluten. The index of wheat protein availability also appears to be a significant determinant of U.S. imports of wheat gluten. The protein variable has a significantly negative sign, indicating that a greater availability of domestic wheat protein decreases the demand for imports of wheat gluten. The elasticity estimated indicates a very elastic response to increased supplies of domestic protein.

4.4. Summary:

An Ordinary Least Square regression has been run on monthly data between 1974 and 1987. No correction for autocorrelation has been needed. All the estimated coefficients are in keeping with the hypothesis deducted from knowledge of the reality and presented before the analysis. In all, the results indicate that the U.S. import demand for wheat gluten is significantly influenced by the price of a complementary product (flour), by income, and by the domestic availability of wheat protein. The results also reveal that the import demand for wheat gluten is very price inelastic. In particular, changes in the price of imported wheat gluten did not appear to exhibit a significant effect on imports. Finally, a non-significant degree of partial adjustment was revealed indicating a fast adjustment process.

CONCLUSIONS

The international wheat gluten market is dominated by four main players: Australia, Canada, the E.C., the U.S. The three first are net exporters, with the E.C. being a recent and fastly growing exporter. Considerable investment in the wheat wet milling industry has been made recently in the E.C. This implies a growing importance on the international market to such an extent that the E.C. has become the second major exporter to the U.S. since 1987. The U.S. is the major buyer on the international market.

In light of the wheat wet milling industry's development in the E.C. and of the prominent role U.S. imports play in the international market for wheat gluten, the import demand of the U.S. has been evaluated in this paper. Through a brief description of wheat gluten composition, properties, and uses, a global outlook of the wheat wet milling industry, and a review of economic theory, five factors likely to affect the U.S. import demand for wheat gluten have been revealed: (1) lagged imports, (2) price of wheat gluten, (3) price of flour, (4) income, and (5) protein amount of the previous wheat harvest.

The influence of these factors is investigated by econometric analysis using a database consisting of monthly observations between 1974 and 1987. The results of the econometric analysis indicate that the U.S. demand for imported wheat gluten is influenced by the price of flour, a measure of national income, and the domestic availability of wheat protein. The import demand for processed wheat gluten was shown to be very price inelastic. This may suggest that decreased international prices would not be effective in boosting U.S. imports of wheat gluten.

Another comment, suggested by Pudden (1989), is that research has been and still is being done to obtain increasingly stronger wheat varieties. In addition, incentives have been set up in order to stimulate the cultivation of high protein wheat varieties. Therefore, on a long-term basis, the protein amount of the wheat harvest has followed an upward trend. The empirical results obtained tend to show that, in the long run, a decreased import demand of wheat gluten can be expected.

Additional research into production interrelationships between wheat gluten and wheat starch and corn sweeteners, corn starch, and corn gluten might provide additional insights into factors which that shaped the international market for wheat gluten. In addition, a clearer understanding of these relationships might clarify knowledge of the impacts of trade policy on international trade in processed agricultural products.

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APPENDIX 1

DATABASE

VARIABLES:

- -M: U.S. Wheat Gluten Import Quantity (000,000 LBS)

- -p: U.S. Wheat Gluten Import Unit Value (US$)

- -p^c: Consumer Price Index for Flour

- -Y: Industrial Production Index

- -Pa: Indicator of the Protein Amount of the Wheat Harvest

- -Deflator: Producer Price Index for Industrial Goods

No.	Month	M	p	p^c	Y	Pa	Deflator
1	7401	1.38627	0.334577	163.5	110.3	11.9581	78.9
2	7402	2.07966	0.383409	171.8	110.0	11.9581	80.6
3	7403	1.73139	0.413879	179.2	110.4	11.9581	83.0
4	7404	1.88148	0.416326	183.2	110.3	11.9581	85.5
5	7405	1.31527	0.430970	181.9	111.5	11.9581	87.8
6	7406	2.24845	0.425675	172.9	112.0	11.9581	89.6
7	7407	1.25320	0.402215	170.8	111.9	11.9581	92.0
8	7408	4.37915	0.406382	169.9	111.8	11.9581	94.2
9	7409	1.59225	0.410300	169.7	111.9	12.2955	95.0
10	7410	2.24063	0.402688	169.0	109.9	12.2955	96.1
11	7411	2.41025	0.380048	169.1	106.0	12.2955	96.7
12	7412	3.00647	0.385416	171.1	101.3	12.2955	96.9
13	7501	2.79530	0.370157	174.7	97.8	12.2955	97.7
14	7502	1.65024	0.369821	174.5	95.7	12.2955	98.2
15	7503	1.46891	0.380843	170.5	94.8	12.2955	98.5
16	7504	3.40555	0.360063	170.9	95.5	12.2955	99.0
17	7505	2.06961	0.359930	169.3	96.5	12.2955	99.3
18	7506	2.89344	0.374296	166.1	98.8	12.2955	99.5
19	7507	3.37389	0.356158	161.0	100.5	12.2955	99.8
20	7508	3.17088	0.353748	157.3	102.7	12.2955	100.4
21	7509	3.51964	0.348815	157.1	103.7	12.0731	100.9
22	7510	2.51984	0.351650	160.0	103.7	12.0731	101.9
23	7511	3.27884	0.340175	162.4	104.8	12.0731	102.3
24	7512	2.92461	0.361969	161.1	105.6	12.0731	102.7
25	7601	2.38600	0.355111	161.1	107.1	12.0731	103.4
26	7602	3.18970	0.356354	157.8	108.7	12.0731	103.9
27	7603	3.21543	0.379063	157.3	109.3	12.0731	104.4
28	7604	3.04163	0.379276	155.3	109.5	12.0731	105.0
29	7605	4.69132	0.390699	155.7	110.4	12.0731	105.3
30	7606	3.64492	0.399144	154.8	111.0	12.0731	105.8
31	7607	4.00029	0.416410	155.2	111.4	12.0731	106.5
32	7608	3.21410	0.443493	155.1	112.1	12.0731	107.2
33	7609	4.34870	0.446221	153.7	111.5	12.3157	107.8
34	7610	4.74274	0.475568	152.4	111.5	12.3157	108.6
35	7611	4.46551	0.473824	150.3	112.6	12.3157	109.1
36	7612	5.42556	0.462065	147.2	113.4	12.3157	109.3
37	7701	4.75728	0.452229	147.8	113.5	12.3157	109.9
38	7702	3.89421	0.480963	144.7	114.2	12.3157	110.8
39	7703	3.39897	0.490364	145.6	115.7	12.3157	111.8
40	7704	5.50991	0.449689	144.0	116.4	12.3157	112.7
41	7705	3.94335	0.482432	144.8	117.2	12.3157	113.2
42	7706	5.06213	0.476994	145.4	117.9	12.3157	113.5
43	7707	4.73900	0.481808	143.4	118.0	12.3157	114.2
44	7708	3.39864	0.476049	140.4	118.3	12.3157	114.8
45	7709	5.51601	0.469618	137.7	118.5	13.0930	115.3

No.	Month	M	p	p^c	Y	Pa	Deflator
46	7710	3.10462	0.480912	137.5	118.9	13.0930	116.1
47	7711	3.22607	0.481613	135.8	119.1	13.0930	116.2
48	7712	6.26051	0.463561	134.9	119.3	13.0930	116.6
49	7801	4.41472	0.465261	137.2	118.9	13.0930	117.6
50	7802	4.45663	0.443160	140.0	119.1	13.0930	118.3
51	7803	3.07898	0.435209	141.1	120.6	13.0930	119.0
52	7804	4.20748	0.439930	142.2	122.6	13.0930	120.2
53	7805	3.46039	0.429143	144.1	122.9	13.0930	120.9
54	7806	4.56415	0.403142	147.0	124.0	13.0930	121.7
55	7807	5.77865	0.416879	148.7	124.9	13.0930	122.9
56	7808	3.99863	0.396136	150.8	125.6	13.0930	122.8
57	7809	4.42186	0.385358	151.2	126.2	12.4576	123.9
58	7810	3.32122	0.382991	151.2	127.1	12.4576	125.3
59	7811	5.01616	0.376084	150.8	127.8	12.4576	125.8
60	7812	4.92972	0.378520	151.6	128.9	12.4576	126.8
61	7901	4.99854	0.384052	153.9	128.6	12.4576	128.3
62	7902	3.05567	0.397948	155.3	129.0	12.4576	129.7
63	7903	4.88114	0.384746	155.4	129.9	12.4576	131.4
64	7904	5.06580	0.392633	155.8	128.0	12.4576	133.5
65	7905	3.92586	0.409592	157.8	129.4	12.4576	135.0
66	7906	3.77590	0.435393	159.7	129.5	12.4576	136.2
67	7907	4.46183	0.438161	162.3	129.7	12.4576	136.4
68	7908	4.14764	0.469665	166.3	128.7	12.4576	140.3
69	7909	4.36863	0.491001	168.8	129.4	12.6022	142.4
70	7910	4.04824	0.512568	168.6	129.2	12.6022	144.9
71	7911	4.99897	0.506504	168.1	129.1	12.6022	145.9
72	7912	5.14436	0.530484	168.8	129.2	12.6022	147.4
73	8001	3.96903	0.533380	171.2	129.6	12.6022	151.8
74	8002	3.73108	0.532822	171.7	129.5	12.6022	154.8
75	8003	3.12593	0.555994	172.0	129.1	12.6022	156.4
76	8004	2.80172	0.555373	173.9	125.9	12.6022	158.2
77	8005	4.69101	0.550202	175.2	122.2	12.6022	158.5
78	8006	4.22113	0.536112	177.3	120.1	12.6022	159.5
79	8007	4.80022	0.537059	179.1	119.2	12.6022	161.0
80	8008	3.13426	0.522612	180.6	120.4	12.6022	161.7
81	8009	3.47826	0.520374	180.9	122.3	12.8556	162.2
82	8010	4.79267	0.513284	180.5	124.7	12.8556	164.0
83	8011	3.43007	0.516899	180.2	126.8	12.8556	164.8
84	8012	3.72624	0.519357	181.3	128.1	12.8556	166.8
85	8101	4.46040	0.541431	184.5	128.5	12.8556	170.0
86	8102	3.42418	0.557505	186.0	128.9	12.8556	172.4
87	8103	2.86345	0.564004	188.1	129.1	12.8556	174.7
88	8104	3.93166	0.559052	187.8	128.9	12.8556	177.0
89	8105	3.64484	0.538020	189.3	129.6	12.8556	177.7
90	8106	4.06058	0.524801	190.7	129.8	12.8556	177.9

No.	Month	M	p	p^c	Y	Pa	Deflator
91	8107	3.22072	0.512308	191.4	130.6	12.8556	178.5
92	8108	4.04991	0.513345	191.6	130.4	12.8556	179.0
93	8109	4.03786	0.504227	190.3	128.7	13.4086	179.1
94	8110	3.91720	0.510824	190.1	126.7	13.4086	181.1
95	8111	4.04712	0.522841	189.1	124.3	13.4086	183.2
96	8112	3.74192	0.515778	186.7	121.6	13.4086	183.8
97	8201	3.30654	0.510201	188.3	119.4	13.4086	181.8
98	8202	2.63703	0.508622	188.3	121.3	13.4086	181.7
99	8203	3.49635	0.473065	188.3	120.3	13.4086	181.3
100	8204	2.93481	0.462722	189.0	119.0	13.4086	180.7
101	8205	2.98040	0.454050	191.7	118.2	13.4086	180.5
102	8206	4.62643	0.421059	192.2	117.7	13.4086	181.1
103	8207	3.65945	0.412971	194.3	117.8	13.4086	182.4
104	8208	4.05024	0.410593	191.7	117.5	13.4086	182.6
105	8209	4.35649	0.414554	191.3	116.6	12.1651	182.3
106	8210	3.58516	0.416159	189.3	115.3	12.1651	183.3
107	8211	4.49211	0.441663	188.2	114.4	12.1651	183.7
108	8212	3.80615	0.489996	188.6	114.3	12.1651	183.7
109	8301	4.27102	0.509011	189.7	116.2	12.1651	183.1
110	8302	2.77135	0.530067	189.0	116.7	12.1651	183.1
111	8303	3.83470	0.539547	188.7	118.3	12.1651	182.8
112	8304	4.39129	0.531279	189.4	120.5	12.1651	182.1
113	8305	4.14183	0.525613	191.2	122.0	12.1651	182.9
114	8306	5.44243	0.529726	192.5	123.7	12.1651	183.9
115	8307	3.41249	0.523371	193.3	126.5	12.1651	184.5
116	8308	3.73337	0.537851	195.1	128.3	12.1651	185.0
117	8309	4.94823	0.535545	193.4	130.2	12.1797	184.9
118	8310	5.32033	0.523276	191.4	130.9	12.1797	185.8
119	8311	4.30499	0.526830	190.6	131.9	12.1797	185.7
120	8312	2.45423	0.530105	189.4	132.6	12.1797	185.7
121	8401	5.70528	0.540201	193.3	133.9	12.1797	186.1
122	8402	3.43009	0.544301	194.0	135.2	12.1797	186.8
123	8403	4.26061	0.543818	195.7	135.9	12.1797	187.7
124	8404	4.75723	0.537708	194.4	137.0	12.1797	188.1
125	8405	4.61568	0.547915	195.3	137.5	12.1797	188.5
126	8406	3.82685	0.553980	197.6	138.9	12.1797	188.9
127	8407	4.31691	0.498504	199.0	140.3	12.1797	188.9
128	8408	3.45159	0.488761	200.5	140.3	12.1797	188.5
129	8409	5.20923	0.527333	197.8	139.4	12.1305	187.9
130	8410	6.81434	0.520960	196.4	139.0	12.1305	188.5
131	8411	3.66390	0.532492	194.8	139.6	12.1305	188.9
132	8412	3.36323	0.524199	193.7	140.5	12.1305	188.4
133	8501	5.75523	0.513793	198.0	141.4	12.1305	188.2
134	8502	3.00873	0.511180	200.2	141.5	12.1305	187.9
135	8503	5.25907	0.501229	201.1	141.9	12.1305	188.1

No.	Month	M	p	p^c	Y	Pa	Deflator
136	8504	4.23122	0.492057	199.4	142.0	12.1305	188.9
137	8505	3.95760	0.471498	203.6	142.0	12.1305	189.7
138	8506	5.09365	0.470585	205.3	142.3	12.1305	189.3
139	8507	5.22986	0.460051	205.7	142.0	12.1305	189.2
140	8508	4.99609	0.448751	206.9	143.2	12.1305	188.7
141	8509	5.29360	0.458667	204.0	143.0	12.1420	187.9
142	8510	4.04078	0.453626	204.2	142.5	12.1420	189.2
143	8511	3.85783	0.457770	201.1	143.1	12.1420	189.5
144	8512	5.61522	0.453589	200.6	144.1	12.1420	189.7
145	8601	5.83036	0.469782	204.0	144.4	12.1420	188.9
146	8602	4.12597	0.499035	204.4	143.4	12.1420	186.0
147	8603	5.07887	0.499521	204.1	141.4	12.1420	183.1
148	8604	4.64089	0.529424	204.0	142.6	12.1420	181.7
149	8605	5.83036	0.469782	206.1	142.1	12.1420	181.7
150	8606	5.68066	0.521946	208.2	142.1	12.1420	181.8
151	8607	4.61466	0.523548	208.3	142.9	12.1420	179.9
152	8608	4.20852	0.548887	208.8	143.1	12.1420	179.6
153	8609	5.48070	0.531319	206.4	142.9	12.4445	180.1
154	8610	4.42153	0.555690	204.5	143.4	12.4445	180.4
155	8611	6.21078	0.568689	200.5	144.1	12.4445	180.7
156	8612	4.16626	0.603899	200.6	144.9	12.4445	180.4
157	8701	5.74040	0.612501	204.4	144.4	12.4445	182.8
158	8702	4.52304	0.625686	206.1	145.4	12.4445	183.6
159	8703	5.30644	0.615479	203.4	145.7	12.4445	184.1
160	8704	4.34036	0.622989	204.1	145.7	12.4445	185.0
161	8705	4.73536	0.621494	207.7	146.6	12.4445	185.5
162	8706	6.45995	0.607900	209.5	147.7	12.4445	186.5
163	8707	7.59590	0.607564	210.0	149.5	12.4445	187.7
164	8708	7.80222	0.583808	210.0	150.1	12.4445	188.9
165	8709	6.03812	0.588760	208.4	149.8	12.3603	188.4
166	8710	6.34228	0.563835	206.1	151.6	12.3603	189.3
167	8711	7.03710	0.599821	204.4	152.3	12.3603	189.7
168	8712	7.43180	0.514411	203.0	153.2	12.3603	189.5

APPENDIX 2

REGRESSION OUTPUT

ORDINARY LEAST SQUARE REGRESSION

DEP VARIABLE: M

ANALYSIS OF VARIANCE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PROB>F
MODEL	5	9.39186293	1.87837259	33.485	0.0001
ERROR	162	9.08766707	0.05609671		
C TOTAL	167	18.47953000			

ROOT MSE	0.2368474	R-SQUARE	0.5082
DEP MEAN	1.362792	ADJ R-SQ	0.4931
C.V.	17.37957		

PARAMETER ESTIMATES

VARIABLE	DF	PARAMETER ESTIMATE	STANDARD ERROR	T FOR H0: PARAMETER=0	PROB > |T|
INTERCEP	1	10.50921309	2.41162893	4.358	0.0001
M_{-1}	1	0.09046040	0.07912059	1.143	0.2546
p	1	-0.10422478	0.19109738	-0.545	0.5862
p^c	1	-1.86894567	0.25696049	-7.273	0.0001
Y	1	0.94118682	0.23567994	3.993	0.0001
Pa	1	-1.82794125	0.65918785	-2.773	0.0062

KSU
KANSAS STATE UNIVERSITY

Agricultural Experiment Station, Kansas State University, Manhattan 66506

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