An Economic Analysis of U.S. Total Fiber Demand and Cotton Mill Demand

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Abstract: This article presents an economic analysis of factors that influence total U.S. fiber demand (cotton, wool, and manmade) and cotton mill demand. The study examines changes that have occurred in U.S. cotton consumption since the early 1960s and provides insights for future demand, particularly in the context of expanding textile trade. A system of simultaneous equations is developed to explain the structural relationships of U.S. per capita demand using annual data for 1962-97. The equations are used to project future levels of total fiber demand, cotton mill demand, and subsequently cotton fiber demand.

Keywords: Cotton, fiber demand, mill demand, textile trade, per capita consumption.

Cotton, wool, and manmade fibers are among the most important textile fibers in the world. Over the past decade, these three fibers collectively accounted for 98 percent of the world's annual textile fiber production, reaching about 100 billion pounds of fiber in 1997. Although demand for fibers by the textile and apparel industry has generally risen over time with population, changes in demand for specific fibers, such as cotton, are normally dictated by changes in fashion trends, product acceptance, and consumers' lifestyles.

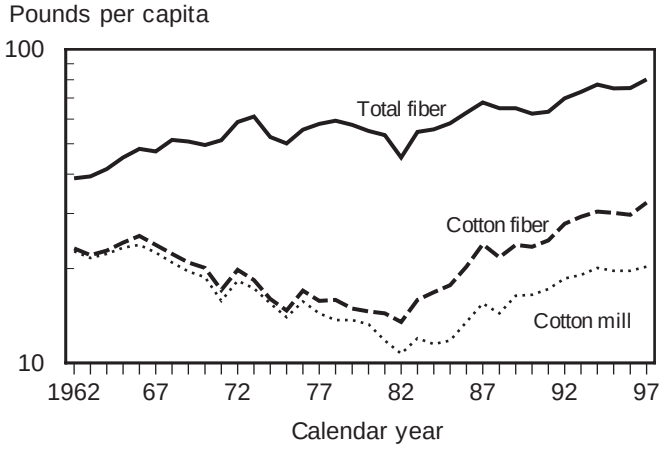
This article examines the changes that have occurred in U.S. fiber demand—particularly for cotton—since the early 1960s. The analysis measures the effects of principal factors that help determine U.S. demand on a per capita basis. This study also provides insights for future cotton demand—by mills and end-users—particularly in the context of expanding trade associated with the liberalization of textile and apparel products.

Background

In this analysis, total fiber demand is defined as the sum of annual mill demand for cotton, wool, and manmade fibers plus the net textile trade balance (raw-fiber equivalent basis) in manufactured products for these fibers. On a per capita basis, U.S. total fiber demand doubled during 1962-97, ranging from a low of about 39 pounds in 1962 to more than 80 pounds in 1997, or an average increase of slightly over one pound per year (figure B-1). While the increase shows a general upward trend, per capita demand also tends to follow economic cycles. For example, contractions of the U.S. economy during 1974-75 and 1981-82 are clearly reflected in falling demand, while subsequent expansion has moved total per capita fiber demand to its highest level to date.

Also illustrated in figure B-1 is cotton's contribution to total fiber demand. As a major raw material of the U.S. textile and apparel industry, cotton has seen its popularity decline and rebound since the early 1960s. In 1962, cotton accounted for 60 percent of total fiber demand. However, over the next 20 years, cotton's share was cut in half because of manmade fibers' popularity. Demand for cotton reversed its downward trend in the early 1980s when consumer preferences shifted back to natural fibers. Over the past 15 years, U.S. consumer demand for cotton products has risen a dramatic 20 pounds per person, to over 32 pounds in 1997. To illustrate this level of cotton demand in terms of apparel products, the 32 pounds is equivalent to

Figure B-1
U.S. fiber demand and cotton mill demand



Total fiber demand includes cotton, wool, and manmade.

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each person in the United States purchasing one pair of jeans and one sport shirt every month or two pair of dress trousers and one dress shirt or blouse every month. While cotton has many uses other than clothing, these examples give some perspective to the magnitude of consumer end-use demand for cotton in the United States today.

Cotton now accounts for 40 percent of U.S. total fiber demand, up from 35 percent just 10 years ago. Contributing to this increase are imported textile products that became more readily available as various bilateral agreements provided relatively inexpensive foreign-produced products to U.S. consumers. While bilateral textile and apparel agreements have been in existence to some extent for several decades, more recent liberalization in the 1990s under the North American Free Trade Agreement (NAFTA) and the World Trade Organization (WTO) has expanded the trend. And although U.S. cotton textile exports have also increased, imports have grown faster, as shown by the gap between cotton fiber demand and cotton mill demand (figure B-1). This divergence also represents cotton's textile trade deficit, which has nearly doubled over the last 10 years. Whereas per capita cotton fiber demand has surpassed the level reached during the early 1960s, cotton mill demand remains a few pounds below this earlier period.

Model Specification

The models developed for this analysis are based on the assumption outlined in Studenmund (1997) that most econometric applications are by nature inherently interdependent. Applying the concept in this analysis means that total fiber demand and cotton demand are interrelated and each influences the quantity demanded of the other.

Following this econometric argument, a system of simultaneous equations was developed to capture this interdependence. To this end, structural relationships among the three demand equations were first determined and are listed in their functional form below:

1) Total Fiber Demand $= f_1$ (Economic Activity, z_1, $\in_1$)
2) Cotton Mill Demand $= f_2$ (Total Fiber Demand, Textile Deficit, z_2, $\in_2$)
3) Cotton Fiber Demand = Cotton Mill Demand + Textile Deficit

Similar past analyses by Evans (1977) and Sanford (1988) found that total fiber demand is influenced by economic activity as well as other exogenous variables (z_1), including fiber prices. These studies used ordinary least squares (OLS) to estimate total fiber demand, as is achieved in this analysis. Evans and Sanford continued by estimating cotton mill demand separately using OLS, with total fiber demand given.

However, expanding on these previous works and taking into account the interdependence discussed earlier, a system of equations was established in this study to determine cotton mill demand, which is influenced not only by total fiber demand, but also the cotton textile deficit. Other predetermined variables (z_2), like substitutes, also affect demand. As a result, the first two equations listed above are solved simultaneously as a system.

The use of OLS in simultaneous systems produces coefficient estimates that are biased. Therefore, a two-stage least squares approach is employed—assuming interaction via the error terms—with total fiber demand and cotton mill demand jointly determined. The third equation—cotton fiber demand—is solved outside the system as an identity once the cotton mill demand equation is estimated.

Although the cotton demand equations will be the main focus in this article, a brief discussion of the following total fiber demand equation is in order:

$$\text{Ln (TFD)} = a + b\,\text{Ln (DPI)} - c\,\text{Ln (Fiber Price)} + d\,\text{NAFTA} + \in_1$$

where Ln represents natural logs and the parameters a, b, c, and d are to be estimated. The dependent variable (TFD) is U.S. total fiber demand for cotton, wool, and manmade fibers and is reported in pounds per capita.

Total fiber demand is hypothesized to be influenced by income, prices, and other exogenous variables. As previously mentioned, total fiber demand tends to emulate the general economy and is positively related to demand. This is captured by the variable DPI, which is the per capita real disposable personal income. If the economy is growing, consumers are expected to have a larger disposable income. And as a result, U.S. consumers tend to use this purchasing power, raising demand for various products like clothing.

In addition, economic theory suggests that fiber prices are inversely related to demand. In this study, nominal prices were used as a result of past research that found analysis of "real" prices inadequate. Consequently, nominal cotton mill prices lagged one year are used as a proxy for fiber prices, as cotton accounts for an increasing share of total fiber demand in the United States. The final variable in this equation takes into account the positive effect that NAFTA has had on per capita fiber demand. This variable is a dummy variable equal to one beginning in 1994 (NAFTA's inception) and zero in prior years.

The cotton demand equation is represented by the following functional form:

$$\text{Ln (CMD)} = a + b\,\text{Ln (TFD)} - c\,\text{Ln (Ratio)} - d\,\text{Ln (Deficit)} + e\,\text{Ln (1 + TradeLib)} + \in_2$$

The Estimated Regression Equations

Total Fiber Demand

Ln (TFD) = 2.121 + 0.980 Ln (DPI) - 0.178 Ln (Fiber Price) + 0.128 (NAFTA)

(0.080) (0.038) (0.033)

t = 12.21 t = -4.68 t = 3.85

Adjusted R-squared = 0.9096

Standard error of the estimate = 0.0559

Durbin-Watson statistic = 1.253

Degrees of freedom = 32

Cotton Mill Demand

Ln (CMD) = -2.448 + 1.315 Ln (TFD) - 0.494 Ln (Ratio) - 0.252 Ln (Deficit) + 0.136 Ln (1 + TradeLib)

(0.186) (0.035) (0.024) (0.025)

t = 7.05 t = -14.31 t = -10.68 t = 5.38

Adjusted R-squared = 0.9312

Standard error of the estimate = 0.0592

Durbin-Watson statistic = 1.672

Degrees of freedom = 31

where once again Ln represents natural logs and the parameters a, b, c, d, and e are to be estimated. The dependent variable (CMD) is U.S. cotton mill demand and is reported in pounds per capita.

Cotton mill demand is hypothesized to be influenced mainly by three variables: total fiber demand, the ratio of the cotton mill price lagged one year divided by the polyester staple mill price lagged one year, and the per capita cotton textile deficit. The Ratio variable represents the substitutability of fibers, while the Deficit variable accounts for the net trade balance of cotton textiles entering the United States. These will be discussed in more detail in the next section.

The final variable included in the model specification for cotton mill demand attempts to capture the effects of trade liberalization. TradeLib is a trend variable (1984=1) multiplied by a dummy that is equal to one beginning in 1984 and zero in previous years. This variable is constructed so that the change in value becomes smaller in subsequent years. It is theorized that cotton mill demand has been positively affected by the opening of foreign markets to U.S. products. The rise in textile exports since the early 1980s can be attributed to trade agreements like the Caribbean Basin Initiative. However, the positive effects are expected to diminish over time as more of these products are further processed in the foreign country and returned to the United States as imports, contributing to the cotton textile deficit. Liberalization of textiles under the WTO will also reduce benefits further as additional foreign products are allowed to compete in the U.S. market in the future.

Model Results

The U.S. per capita cotton mill demand model was estimated in a system of equations using annual data for calendar years 1962 through 1997. As shown in the box above, over 93 percent of the variation in (the log of) annual per capita cotton mill demand is explained by the equation. All variables are significant at the 1-percent level, with the standard errors and t-statistics shown below each coefficient. Also, the Durbin-Watson statistic suggests no autocorrelation problem. In addition, because the equation is in log form, elasticity measures are captured by the estimated coefficients.

Cotton mill demand (CMD) is positively related to total fiber demand and the TradeLib variable, and, as expected, negatively related to the price ratio and the textile deficit. The price ratio is specified to capture the competitiveness of cotton with respect to polyester. An increase (decrease) in the ratio indicates that cotton is becoming more (less) expensive relative to polyester. The negative sign of the coefficient indicates that if cotton becomes relatively higher priced, fiber substitution may occur and less cotton is likely to be used by mills. Based upon the price ratio coefficient, a 10-percent increase in the ratio would be expected to lower per capita cotton mill demand by about 5 percent.

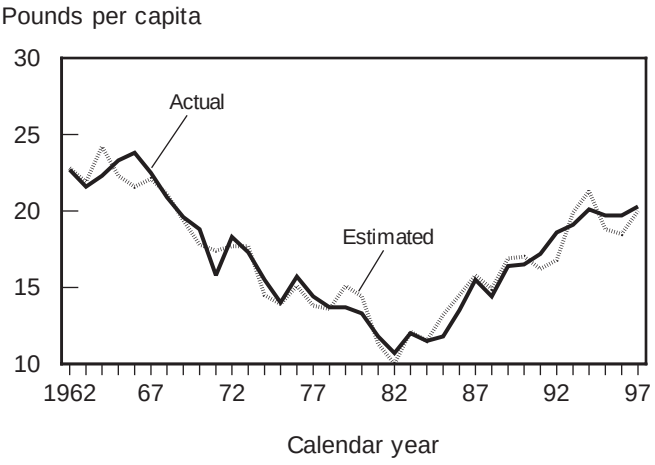
Similarly, a 10-percent rise in the cotton textile deficit would be expected to reduce per capita mill demand by about 2.5 percent, all other things being equal. Furthermore, current levels suggest that a 10-percent increase in the deficit equates to 1.5 pounds per capita and a 2.5-percent decline in cotton mill demand is approximately half a pound. Therefore, given the specified structural form of the estimated system of equations, the 1-pound increase in per capita total fiber demand is expected to raise cotton mill demand by approximately one-third of a pound. In sum, the net effect of a 10-percent rise in the cotton textile deficit is a decrease in cotton mill demand of approximately 0.2 pounds per capita or about 1 percent.

Model Performance

Figure B-2 illustrates the estimated U.S. per capita cotton mill demand along with the actual values for 1962 through 1997. The derived values from the system estimation track in-sample demand fairly well, especially the rebound that occurred in the early 1980s. Most differences between the actual per capita mill demand and the model's estimates are 1 pound or less. The largest difference occurred in 1966 when the model underestimated actual cotton mill demand by 2.2 pounds per capita. However, the 1966 underestimation can be partially attributed to the dramatic jump in the cotton textile deficit, a 70-percent increase over the previous year. While a change of this magnitude would be expected to reduce mill demand, an overabundance of U.S. cotton at relatively inexpensive prices kept per capita mill demand from falling that year.

Mean absolute errors and mean absolute percentage errors were calculated for the estimation period. The mean absolute error was determined to be approximately three-quarters of a pound, while the mean absolute percentage error was 4.5 percent. In addition, these measurement errors were also determined for the rebound period (1982-97) with similar results. These statistical measures indicate the good performance and fit of the cotton mill demand model.

Figure B-2
U.S. cotton mill demand--actual and model estimate



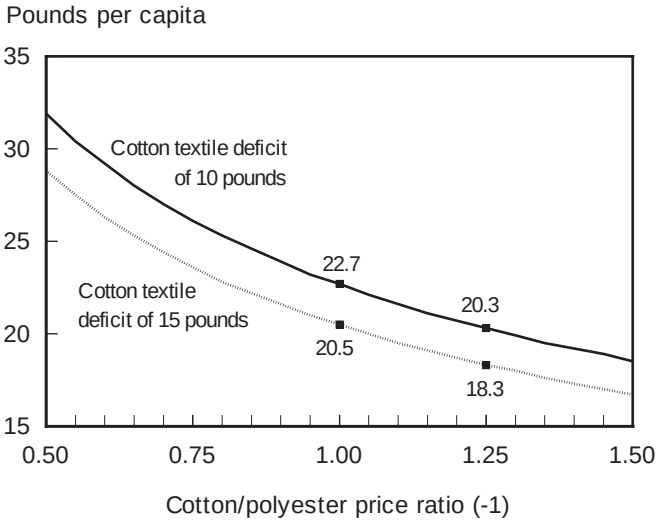
Sensitivity Analysis

A sensitivity analysis was then conducted to capture the effects of changing total fiber demand, textile trade deficits, and price ratios. Several features presented in this article illustrate the effects on per capita cotton mill demand at different textile trade deficits as well as at various total fiber demand levels. Specifically, per capita mill demand curves are determined for assorted lagged price ratios, with other exogenous variables held constant.

Figure B-3 shows total fiber demand of 80 pounds per capita and is illustrated at two cotton textile deficit levels (10 and 15 pounds). For example, if the price ratio were equal to one—meaning cotton and polyester prices were the same—cotton mill demand would be expected to total 22.7 pounds per capita with a textile deficit of 10 pounds or 20.5 pounds if the deficit were 15 pounds. On the other hand, if the cotton price were 25 percent higher than polyester, cotton mill demand would be expected to fall to 20.3 and 18.3 pounds, respectively. Similar differences along these curves would be noted at other price ratios. Accordingly, adding the appropriate per capita deficit to the mill demand estimate produces a total cotton fiber demand estimate as highlighted earlier.

Another feature of this analysis illustrates the effect of differing total fiber demand levels on cotton mill demand. Figure B-4 shows total fiber demand at 80, 85, and 90 pounds, while holding the cotton textile deficit constant at 15 pounds

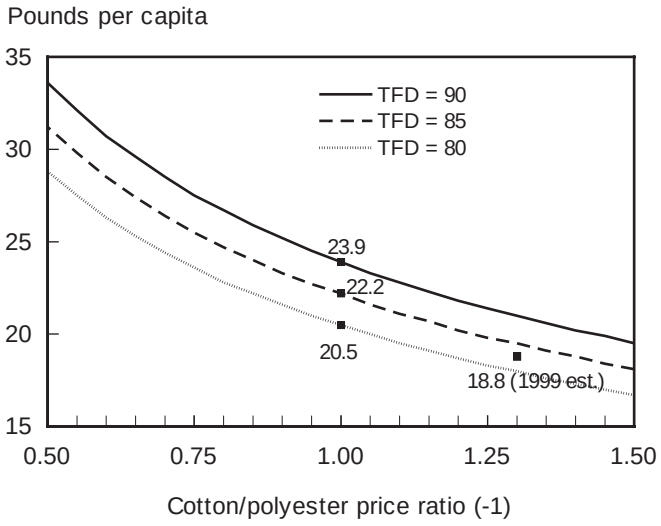
Figure B-3
U.S. cotton mill demand--effect of two cotton textile deficit levels with total fiber demand of 80 pounds



Each curve based on the estimated per capita mill demand equation for 1999.

Figure B-4

U.S. cotton mill demand--effect of three total fiber demand levels with a cotton textile deficit of 15 pounds



Each curve based on the estimated per capita mill demand equation for 1999.

per capita. If the price ratio were equal to one using these examples, cotton mill demand would be expected to range between 20.5 and 23.9 pounds per capita based on the estimated equation. Similar ranges along these demand curves would be noticed at various price ratio scenarios.

Out-of-Sample Forecast

Since this analysis uses data through calendar year 1997, the effective performance of the cotton mill demand model can be evaluated by comparing the out-of-sample estimate for 1998 given actual 1998 data. In addition, estimates for U.S. total fiber demand, cotton mill demand, as well as cotton fiber demand are made using the latest available data for calendar years 1999 and 2000.

For 1998, total demand for cotton, wool, and manmade fibers was 83 pounds per capita and the cotton textile deficit equaled 15 pounds. Using these numbers along with the cotton/polyester price ratio (1.19) and the trend variable, the cotton mill demand equation provided a per capita estimate of 19.5 pounds for 1998. A 90-percent confidence interval for this estimate would range from 17.6 to 21.6 pounds per capita. Examination of the actual data indicated that 1998 U.S. cotton mill demand exceeded 19.3 pounds per capita, slightly below the 19.5-pound estimate. Subsequently, the addition of the textile deficit to the mill demand estimate yielded a 1998 U.S. cotton fiber demand total of about 34.4 pounds per capita, the highest since 1943.

Based on the latest available data, the tentative estimates for calendar 1999 indicate a slight increase in total fiber demand and cotton fiber demand, but a decrease in the cotton mill demand. Based on the estimated equation for total fiber demand, a figure of 84 pounds was calculated. Inserting this 1-pound gain in total fiber demand and an estimated 1-pound increase in the cotton textile trade deficit into the cotton mill demand equation yields an estimate of only 18.8 pounds per capita for 1999 (see figure B-4). Based on population estimates, this projection would cause U.S. cotton mill demand to fall to approximately 5 billion pounds this calendar year, the lowest since 1993. However, total cotton fiber demand would continue to rise to 34.8 pounds per capita.

For calendar year 2000, U.S. per capita total fiber demand is projected to climb above 85 pounds to a record high, with cotton mill demand perhaps returning close to the 1998 level and cotton fiber demand moving closer to the 1943 level of 36.6 pounds per capita. Assumptions about the cotton textile deficit will play a vital role in the outcome, however. On the one hand, a decline in the U.S. dollar relative to foreign currencies may reduce the recent double-digit gains in cotton textile imports. On the other hand, the continued liberalization of cotton textiles and apparel—and the associated U.S. industry adjustments in preparation for these changes—may keep the import pace on a similar track as the last 2 years, resulting in a rising per capita cotton textile deficit.

Because of this uncertainty, a table was developed to provide insights into various scenarios that could develop for 2000 and beyond. Holding the trend variable (TradeLib) constant at the 2000 level, estimates for future demand can be determined using the model for various levels of total fiber demand, cotton textile deficits, and lagged cotton/polyester price ratios. Table B-1 presents these per capita mill demand estimates at three selected levels of total fiber demand and cotton textile trade deficits.

For example, if the lagged cotton/polyester price ratio equaled 1.20 for 2000 and total fiber demand totaled 85 pounds per capita with a cotton textile deficit of 17.5 pounds, cotton mill demand could be expected to reach 19.6 pounds per person based on the model presented in this analysis. On the other hand, if total fiber demand increased to 90 pounds, the model indicates that per capita cotton mill demand would reach 21.2 pounds. While there are a wide range of estimates presented in the table, cotton/polyester price ratios have only varied from 0.9 to 1.3 during the last 15 years and are likely to remain in this range in the near future. Consequently, the likely outcome for U.S. per capita cotton mill demand in 2000 and beyond would result in a much narrower range than what the table presents.

Conclusions

This analysis examined the changes that have occurred in U.S. fiber consumption since the early 1960s and provides some insight for future demand. The effects of factors that

Table B-1--U.S. per capita mill demand scenarios for calendar 2000 and beyond

Cotton/ polyester price ratio	Textile deficit - - - 15 pounds - - - Total fiber demand 80 lbs	85 lbs	90 lbs	- - -17.5 pounds- - - Total fiber demand 80 lbs	85 lbs	90 lbs	- - - 20 pounds - - - Total fiber demand 80 lbs	85 lbs	90 lbs
	Pounds per capita								
0.50	29.0	31.5	33.9	27.9	30.3	32.6	27.0	29.3	31.5
0.60	26.5	28.7	31.0	25.5	27.7	29.8	24.7	26.7	28.8
0.70	24.6	26.6	28.7	23.7	25.6	27.6	22.9	24.8	26.7
0.80	23.0	24.9	26.9	22.2	24.0	25.9	21.4	23.2	25.0
0.90	21.7	23.5	25.4	20.9	22.6	24.4	20.2	21.9	23.6
1.00	20.6	22.3	24.1	19.8	21.5	23.2	19.2	20.8	22.4
1.10	19.7	21.3	23.0	18.9	20.5	22.1	18.3	19.8	21.4
1.20	18.8	20.4	22.0	18.1	19.6	21.2	17.5	19.0	20.5
1.30	18.1	19.6	21.1	17.4	18.9	20.3	16.9	18.2	19.7
1.40	17.5	18.9	20.4	16.8	18.2	19.6	16.2	17.6	19.0
1.50	16.9	18.3	19.7	16.2	17.6	19.0	15.7	17.0	18.3

Note: These estimates are based on the per capita cotton mill demand model equation using the trend variable appropriate for the 2000 calendar year. Estimates for subsequent years would rise approximately 0.1-0.2 pounds per year from the levels listed here.

determine both U.S. per capita total fiber demand and U.S. per capita cotton mill demand were measured using ordinary least squares and two-stage least squares equations. Given the results of ongoing trade liberalization, U.S. cotton textile trade has expanded substantially over the past decade and will continue to play a major role in the quantity of cotton demanded by U.S. consumers.

Estimates of U.S. per capita total fiber demand and per capita cotton mill demand were made for calendar years 1998, 1999, and 2000. Subsequently, U.S. per capita cotton fiber demand was then estimated. For 1998, actual cotton mill demand confirmed the effectiveness of the model presented. The initial analysis displayed here also provides insights into future alternative cotton demand scenarios in light of global liberalization of the textile industry and furnishes a reference point for further study concerning U.S. fiber and textile demand in the new millennium.

References

Barlowe, R.G. and J.V. Lawler. "The Impact of Cotton Textile Imports on the Domestic Market," *Cotton and Wool Situation*, CWS-5, May 1976, pp. 24-31.

Evans, S. "Factors Affecting Domestic Mill Demand for Cotton and Apparel Wool," *Cotton and Wool Situation*, CWS-12, September 1977, pp. 25-28.

Sanford, S. "Factors Influencing Total Fiber Consumption and Domestic Mill Demand for Cotton and Wool," *Cotton and Wool Situation and Outlook*, CWS-51, March 1988, pp. 24-28.

Studenmund, A.H. *Using Econometrics: A Practical Guide*. New York: Addison-Wesley, Third Edition, 1997.

U.S. Department of Agriculture. Economic Research Service. *Cotton and Wool Situation and Outlook Yearbook*, Various issues.

U.S. Department of Commerce. Bureau of Economic Analysis and Bureau of the Census. Various reports.