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An Econometric Analysis of the Impact of Structural Changes on the Aggregate Output of the United States Since the 2000s

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Abstract

Structural changes play an essential role in the economic development of a country. They represent the evolution of economic dynamics within the macroeconomy. As we know, the economic sectors of a country do not affect the whole economy equally and their level of output generates economic fluctuations. The purpose of this paper is to analyze the impact of the three major economic sectors on the aggregate production of the United States since the 1990s. This paper essentially argues that the service sector is the sector that has contributed the most to the development of the U.S. economy since the 2000s because technological progress increased the rapid changes in the structure of the macroeconomy. Through the use of several econometric methods, we aim to rigorously analyze how the economic policy of each sector impacted economic growth.

Keywords: Econometrics, Economic Policy, Statistical Methods, Macroeconomics, Structural Changes, Quantitative Methods

I. INTRODUCTION

It is undeniable that the United States is the most powerful economy in the world. The United States has produced more goods and services than any other nation in modern history. There are countless factors that have contributed to the economic development of the United States, such as immigration, education, and the creation of new businesses. In fact, it would be realistically impossible to quantify all the factors that intertwine in the economy within this paper. Notwithstanding, it is safe to say that economic sectors have played a significant and consequential role in the structural transformation of the U.S. macroeconomy.

Structural change shifts the assumptions used to determine courses of action, for instance, changing the way market orders are processed.[1] In the nineteenth century, the United States was essentially an agricultural society. Much of the economic output of this period was provided by the agricultural sector. As time evolved and people became more and more educated, employment began to shift from the agricultural sector to the manufacturing sector. As we could see in figure 1, employment in the agricultural sector started to plummet from the 1920s while at the same time, employment in the manufacturing sector dramatically augmented.

[1] Ganti, Akhilesh. "Structural Change" *Investopedia.* (2021).

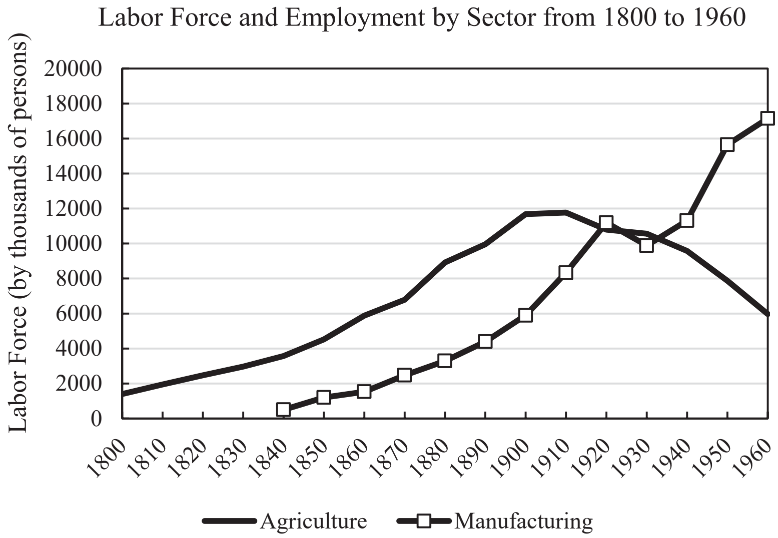

Figure 1. Source: Historical Statistics of the United States. Note: (1) There were no data available for the total number of persons engaged in the manufacturing sector before 1840. (2) The number of persons employed in the labor force was all above 10 years old. (3) The service sector was not included in this graph because there were not enough data collected.

Throughout the twentieth century, a tremendous wave of migration occurred. More and more people were leaving the agricultural sector for the manufacturing and service sectors. This drastic change was based on innovation and innovation is always driven by technological progress. Indeed, innovation is a major factor of structural change in the macroeconomy.[2] Agricultural advancements have led to the rise of factory farming and technological proliferation is causing a structural change in service industries with online shopping, self-ordering kiosks in fast-food restaurants, and voice-operated devices to access information and order products without using a phone call, or even a computer.[3]

It is clear that structural changes do profoundly affect the dynamics of the macroeconomy. It impacts to a greater extent certain factors such as labor productivity, output per capita, and

[2] Ganti, Ibid.

[3] Ganti, Ibid.

aggregate output. A flexible structure of production is an important element in the high rate of productivity increase, for it allows an economy to rapidly redistribute its resources so as to take advantage of changing patterns in productivity within industries.[4]

The second half of the twentieth century saw world-changing technological breakthroughs such as the personal computer and the internet.[5] The rise of the service sector was accompanied by much slower growth, starting in the early 1970s.[6] Figure 2 shows the rise of the service sector.

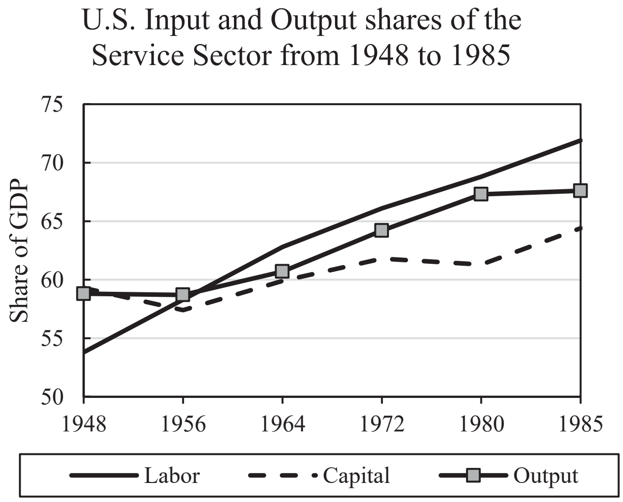

Figure 2. Source: The National Income and Product Accounts of the United States

Indeed, the rate of human capital considerably increased over the second half of the twentieth century as more individuals had access to higher education. Professional training in higher education logically leads to more service jobs such as the legal industry, the medical/healthcare

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[4] Fagerberg, Jan. “Technological Progress, Structural Change and Productivity Growth: A Comparative Study.” *Structural Change and Economic Dynamics.* Volume 11 (2000). pp. 393-411.

[5] Smith, Tyler. “The Rise of the Service Economy.” *American Economic Association.* (2020).

[6] Smith, Ibid.

industry, the financial industry, the technology industry…etc. The rise of intellectual skills due to a better education instigates the rapid growth of technological progress towards the end of the twentieth century.

Various economic policies have been consequently implemented with the aim of adjusting structural changes to the economic dynamics that transformed the American macroeconomy. Our purpose in this analysis is to investigate how economic dynamics impacted the U.S. macroeconomy. To proceed to this endeavor, we sought to analyze the impact of economic sectors on the aggregate production of the United States since the 2000s. We chose to commence our econometric analysis from the 2000s because it marked a new era. By the 2000s, the American economy has begun to increasingly depend on the internet and digital processes to make economic decisions and implement policies. Consequently, it is important to assess the pattern of those economic dynamics and fluctuations of economic sectors, and how they changed the total economic output of the macroeconomy.

II. ESTIMATION OF THE MODEL

Our analysis is not concerned with the number of industries that the U.S. economy contains, but the number of economic sectors. The United States, like a great majority of countries, has an economy essentially divided into three sectors: the agricultural sector, the manufacturing sector, and the service sector. Let us denote the agricultural sector as ($\sum_{t=0}^{\infty} X_{1t}$) The summation sign ($\sum$) represents the total number of industries that encompass the agricultural sector. (∞) represents the number of goods and services produced in each sector, and *t* represents the time, which is a discrete number. Let us apply the same reasoning for the manufacturing sector and the service sector and denote them as ($\sum_{t=0}^{\infty} X_{2t}$) and ($\sum_{t=0}^{\infty} X_{3t}$), respectively. And ($Y$) represents the aggregate economic output from all the sectors combined. Therefore, we can write the formation of the current U.S. economy as the following equation:

$$Y = \sum_{t=0}^{\infty} X_{1t} + \sum_{t=0}^{\infty} X_{2t} + \sum_{t=0}^{\infty} X_{3t}$$

Let us factorize the summation signs and rewrite our equation. The factorization of the summation would lead to the effectuation of a constant variable denoted (α_t). This constant variable, in fact, represents technological change in the economic process of each sector. Hence, we will have:

$$Y = \sum_{t=0}^{\infty} \alpha_t (X_{1t} + X_{2t} + X_{3t})$$

The fundamental characteristic that determines the structure of each economic sector is based on the two input variables that are human capital (L) and capital stock (K). These variables play a crucial role in the production process because they impact the dynamics of the economic sector. These two variables are what form the Cobb-Douglas production function, which could be written as the following:

$$Y = f(K, L)$$

In addition to the two input variables of production, there is also the total factor productivity that is also known as technological change, denoted as (A). Thus, the production function could be written as:

$$Y = AL^{\alpha}K^{\alpha}$$

In each economic sector, the production function is calculated in terms of marginal labor productivity and marginal capital stock. That being said, let us determine the marginal product of labor and the marginal product of capital.

The marginal product of labor can be written as the following formula:

$$\frac{dy}{dL} = \frac{d}{dL}(AK^{\alpha}L^{1-\alpha})$$

$$\frac{dy}{dL} = (1-\alpha)AK^{\alpha}L^{1-\alpha-1}$$

$$\frac{dy}{dL} = (1-\alpha)AK^{\alpha}L^{-\alpha}$$

$$\frac{dy}{dL} = (1-\alpha)A(\frac{K}{L})^{\alpha}$$

The marginal product of capital can be written as the following formula:

$$\frac{dy}{dK} = \frac{d}{dK} = (AL^{1-\alpha}.\alpha K^{\alpha-1})$$

$$\frac{dy}{dK} = \alpha AK^{\alpha-1}L^{1-\alpha}$$

$$\frac{dy}{dK} = \alpha A(\frac{L}{K})^{1-\alpha}$$

Labor and capital are not separate from each other. They are complementary to the production process, and the production process is what impacts the dynamic of economic sectors. As we previously assessed that aggregate output is the sum of output produced by each economic sector, we can then determine that our econometric model would be a linear statistical model that encompasses the three predictors and the dependent variable since our initial model of the American macroeconomy contain three economic sectors. We can then write our model as the following:

$$GDP = \beta_0 + \beta_1 agriculture + \beta_2 manufacturing + \beta_3 service + \varepsilon$$

III. DATA

The dataset we built to develop our test our model was based on the dataset of the World Bank from 2000 to 2018. Our dataset contains essentially one outcome variable (GDP) that depends on three predictors (Agriculture, Manufacturing, Service). We measured the aggregate output by the real GDP, which is in trillion of dollars. The three predictors are measured by the percentage of their share of the total GDP of the U.S. economy.

Years	GDP ($ Trillion)	Agriculture (% of GDP)	Manufacturing (% of GDP)	Service (% of GDP)
2000	10.252	1.5	15.12	72.82
2001	10.582	1.13	13.92	74.01
2002	10.936	0.97	13.45	74.88
2003	11.458	1.12	13.22	74.61
2004	12.214	1.26	13.18	74.16
2005	13.037	1.14	12.99	74.02
2006	13.815	1.00	12.99	73.70
2007	14.452	1.07	12.78	73.90
2008	14.713	1.07	12.26	74.53
2009	14.449	0.97	11.73	76.44
2010	14.992	1.04	11.93	76.21
2011	15.543	1.22	11.95	75.86
2012	16.197	1.16	11.85	76.15
2013	16.785	1.33	11.81	75.77
2014	17.527	1.19	11.65	75.81
2015	18.225	1.04	11.63	76.80
2016	18.715	0.94	11.20	77.51
2017	19.519	0.94	11.17	77.20
2018	20.580	0.86	11.26	76.89

Table 1. Source: World Bank, Author's computation

IV. DESCRIPTIVE STATISTICS AND TREND ESTIMATIONS

In this part of our analysis, we summarize the various parameters of each variable of our model before analyzing their trend.

GDP ($Trillion)		*Agriculture (% of GDP)*		*Manufacturing (% of GDP)*		*Service (% of GDP)*	
Mean	14.9468947	**Mean**	1.10263158	**Mean**	12.4257895	**Mean**	75.33
Standard Error	0.70883203	**Standard Error**	0.03541601	**Standard Error**	0.24104101	**Standard Error**	0.31259057
Median	14.713	**Median**	1.07	**Median**	11.95	**Median**	75.77
Mode	#N/A	**Mode**	0.97	**Mode**	12.99	**Mode**	#N/A
Standard Deviation	3.08972721	**Standard Deviation**	0.1543748	**Standard Deviation**	1.05067341	**Standard Deviation**	1.36255071
Sample Variance	9.54641421	**Sample Variance**	0.02383158	**Sample Variance**	1.10391462	**Sample Variance**	1.85654444
Kurtosis	-0.8942926	**Kurtosis**	1.08760214	**Kurtosis**	0.73639033	**Kurtosis**	-1.1494337
Skewness	0.13868424	**Skewness**	0.87343501	**Skewness**	0.95975219	**Skewness**	-0.0828845
Range	10.328	**Range**	0.64	**Range**	3.95	**Range**	4.69
Minimum	10.252	**Minimum**	0.86	**Minimum**	11.17	**Minimum**	72.82
Maximum	20.58	**Maximum**	1.5	**Maximum**	15.12	**Maximum**	77.51
Sum	283.991	**Sum**	20.95	**Sum**	236.09	**Sum**	1431.27
Count	19	**Count**	19	**Count**	19	**Count**	19
Largest (1)	20.58	**Largest (1)**	1.5	**Largest (1)**	15.12	**Largest (1)**	77.51
Smallest (1)	10.252	**Smallest (1)**	0.86	**Smallest (1)**	11.17	**Smallest (1)**	72.82
Confidence Level (95.0%)	1.48920084	**Confidence Level (95.0%)**	0.07440627	**Confidence Level (95.0%)**	0.50640837	**Confidence Level (95.0%)**	0.65672842

Table 2

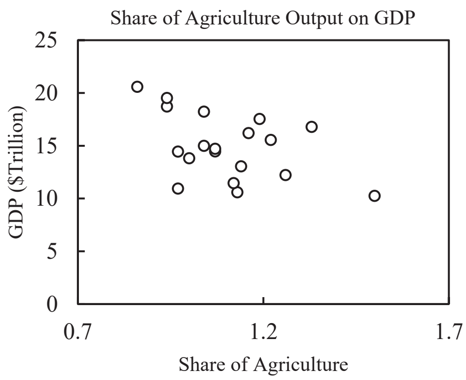

Figure 3

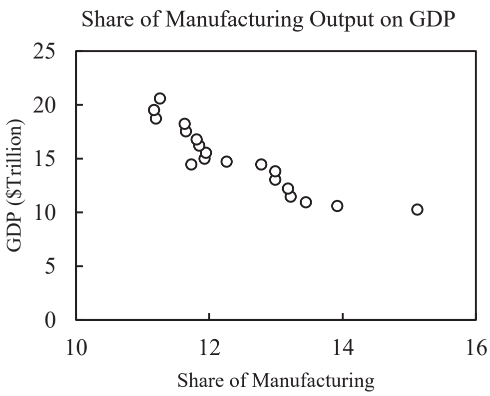

Figure 4

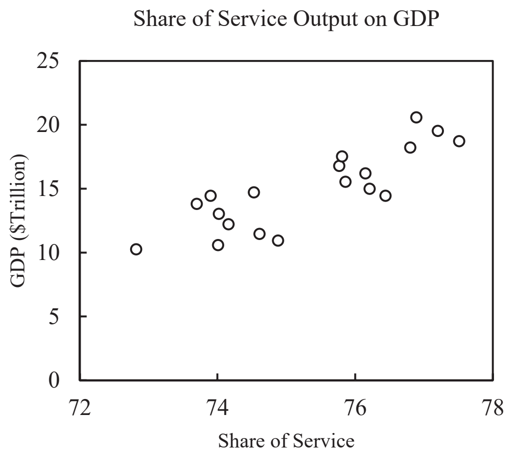

Figure 6

V. TESTING THE MODEL

After observing the trend of the scatterplot, it is clear that the whole model is not entirely linear. The second predictor, which tests the relationship between the share of manufacturing output and aggregate output, does not follow a strict linear trend. Instead, its trend is curvilinear. Hence, to test our model, it is essential to ground it on a various set of assumptions. Since our model is based on a multiple linear regression, then its assumptions must be also based on the properties of the multiple linear regression. One of the fundamental conundrums that a researcher must deal with while performing a multiple regression analysis, is the problem of multicollinearity. It is first and foremost fundamental to check for multicollinearity.

To test for multicollinearity, let us apply the Variance Inflation Factor (VIF) formula, which could be written as:

$$VIF_i = \frac{1}{1 - R^2}$$

Through a series of computation, we obtain the following results:

Multicollinearity Results

	Agriculture (% of GDP)	*Manufacturing (% of GDP)*	*Service (% of GDP)*
Agriculture (% of GDP)	1		
Manufacturing (% of GDP)	0.55765709	1	
Service (% of GDP)	-0.54400436	-0.902951172	1

Table 3

As a rule of thumb in statistics and econometrics, a correlation is considered strong when the R^2 is above 0.7. In our case, there is clearly a correlation between the manufacturing sector and the service sector. This then indicates that there is multicollinearity between the predictors. The second predictor, which is the manufacturing sector, is then considered as a dummy variable. To remedy the issue of multicollinearity, let us exclude the dummy variable from the data and re-run the multicollinearity test without it.

This time, through the same computation process, but without the dummy variable, we obtain the following results:

Multicollinearity Results without Dummy Variable

	Agriculture (% of GDP)	*Service (% of GDP)*
Agriculture (% of GDP)	1	
Service (% of GDP)	-0.54400436	1

Table 4

After re-testing the Variance Inflator Factor, we can see that there is no multicollinearity between the agriculture sector and the service sector. We can now check again and see if our model subscribes to the multiple regression assumptions. (1) there is a linear relationship between the outcome variable and the predictors, (2) there is no multicollinearity, (3) the variance of the residuals is the same at the same level of the explanatory variables. Consequently, let us reformulate our model as the following equation:

$$GDP = \beta_0 + \beta_1 agriculture + \beta_2 service + \varepsilon$$

VI. RESULTS AND DISCUSSIONS

The results of our multiple regression give us the following computational output as well as the numerical values of the model:

Regression Statistics					
Multiple R	0.83862098				
R Square	0.70328515				
Adjusted R Square	0.66619579				
Standard Error	1.78511435				
Observations	19				
ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	120.849324	60.4246619	18.9619128	6.0078E-05
Residual	16	50.9861321	3.18663325		
Total	18	171.835456			

Table 5

$$\widehat{GDP} = -127.56 - 0.12X_1 + 1.89X_2$$

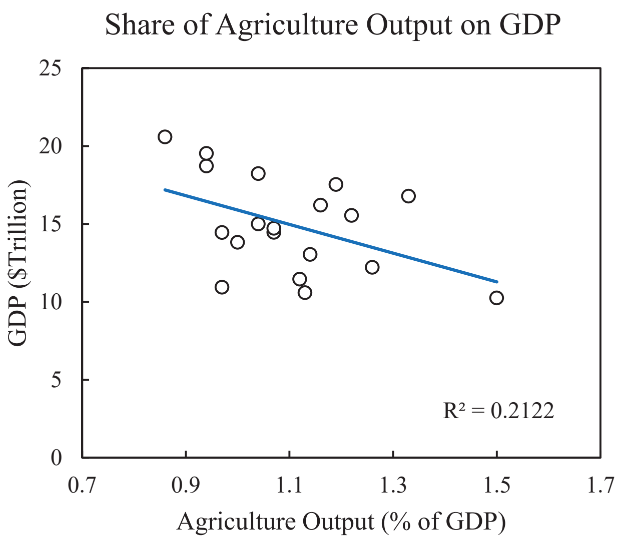

Figure 7

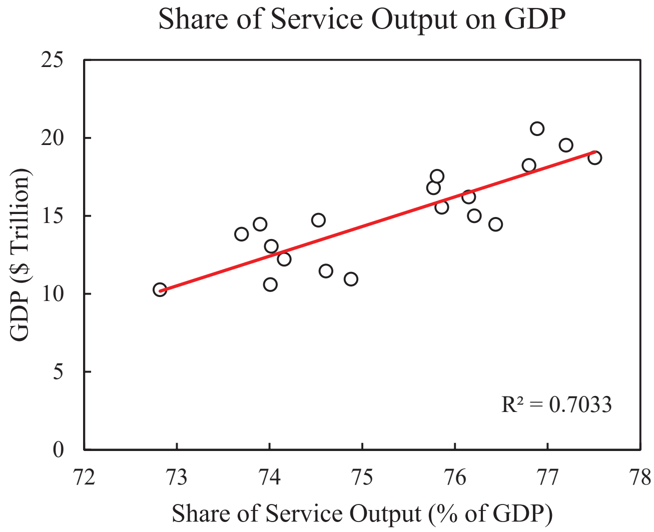

Figure 8

The results of our regressions show that the relationship between the outcome variable and the predictors is statistically significant with a p-value of 0.00006. More importantly, the regression shows that there is a strong correlation between the agricultural sector, the service sector, and the aggregate output of the macroeconomy. The aggregate output will increase every $1 trillion when the GDP of the agriculture sector decreases by 0.12% per one-unit and the GDP of the service sector increases by 1.89% per one-unit. What does this entail for the whole American economy?

It is evident that the industrialization of the United States has created a sharp decline in aggregate agricultural output and a shift in labor. As was aforementioned in the introduction of this analysis, the shift of labor commenced back in the nineteenth century. In 1870 agricultural workers comprised more than half the labor force, but by the turn of the century, their number had fallen to less than 40 percent.[7] In this twenty-first century, agriculture does not even contribute to 2 percent of the whole U.S. economy. Some industries of the agriculture sector, such as poultry and pork have evolved into a food production system.[8] A primary characteristic of a production system is that the relationships among input suppliers, producers/farmers, commodity buyers, food processors, and food distributors have grown closer.[9] The firms which comprise the various stages of the production process no longer limit their interaction to commodity marketplace transactions—instead, these businesses are establishing long-term relationships wherein the seller becomes familiar with the unique needs of the buyer's business.[10] Hence, the attempt to understand the business's needs and the long-term relationship that follows it becomes a service. In other words, it becomes a new industry that transitioned from the agricultural sector to the service sector.

Technology, as discussed, is the driver of innovation, structural changes, and adjustments. It has affected the agricultural sector in rural areas.[11] Although the development of technology has been ongoing for centuries, current technological developments are thrusting considerable changes upon agriculture.[12] As in the past, advances in production technology led to greater output, which,

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[7] Lewis, Frank. "Explaining the Shift of Labor from Agriculture to Industry in the United States 1869 to 1899." *The Journal of Economic History.* Vol. 39, No. 3 (1979). pp. 681-698.

[8] Saxowsky, David M.; Duncan, Marvin R. "Understanding Agriculture's Transition into the 21st Century." *Agricultural Economics Miscellaneous Report No. 181.* (1998). North Dakota State University. pp. 1-32.

[9] Ibid. p. 6

[10] Ibid. p. 6

[11] Ibid. p. 12

[12] Ibid. p. 12

in turn, exerts downward pressure on commodity prices.[13] But in addition, expanded communication and transportation technology allows producers to almost immediately learn about and quickly respond to market opportunities in other areas or regions.[14]

Although we did not include the manufacturing sector in our model for statistical purposes, we cannot deny however that its aggregate output has contributed to the structural changes that we are witnessing today. American cities where manufacturing used to hold sway are evidence of the reversal.[15] Pittsburgh, for example, which was once the center of global steel production, lost more than 150,000 jobs to closing factories in the 1980s.[16] The manufacturing sector accounts for $2.17 trillion of the U.S. economy, and despite popular belief, it is actually on the rise up, by more than 27 percent from just 2009.[17] From offering job cuts, manufacturing has been at the whim of economic and international trends—the latest movement involves technological advancements and the impact these advancements have on factories and workforce demographics.[18] Many changes in the manufacturing industry have come from consumer demand. Consumers want things fasters and better, personalized and unique, and newer than last year, or even the last quarter.[19]

[13] Ibid. p. 12

[14] Ibid. p. 12

[15] "The American Economy is Experiencing a Paradigm Shift." *The Atlantic.* (2020)

[16] *The Atlantic*, Ibid.

[17] Leary, Nora. "how Technology is Changing the Manufacturing Sector." *Reliable Plant.*

[18] Leary, Ibid.

[19] Leary, Ibid.

Consequently, manufacturers have had to find a way to keep up not only with the demand for products but also with finding workers to make these products.[20]

The service sector, more than ever, is the sector that contributes the most to the macroeconomy. Technology has shifted labor and capital in the service sector. The living standard of Americans has considerably improved over the last two decades to the point that the agricultural sector is almost becoming extinct, and the manufacturing sector is also on the verge to see its output being reduced to a significant degree. Productivity growth in the services industries has fueled the post-1995 expansion of labor productivity in the United States.[21] Labor productivity in services-producing industries advanced 2.6 percent a year between 1995 and 2001, exceeding the 2.3 percent growth in productivity in goods-producing industries.[22] Services now lead the way, indicating how much things have changed and they will continue to do so especially with the pandemic that has shifted everything to remote activities. With COVID-19, which has changed the way the economy operates, it is clear that the service sector will maintain its lead for a long time in this twenty-first century.

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[20] Leary, Ibid.

[21] Triplett, Jack E.; Bosworth, Barry P. "Introduction." *Productivity in the U.S. Services Sector: New Sources of Economic Growth.* Brookings Institution Press. (2004). p. 1.

[22] Ibid. p. 1

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9. Ibid. p. 6

10. Ibid. p. 6

11. Ibid. p. 12

12. Ibid. p. 12

13. Ibid. p. 12

14. Ibid. p. 12

15. "The American Economy is Experiencing a Paradigm Shift." *The Atlantic.* (2020)

16. *The Atlantic*, Ibid.

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22. Ibid. p. 1