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Issue Analysis

The Brazilian Sugarcane Ethanol Experience

by Marcus Renato Xavier

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EXECUTIVE SUMMARY

Biofuels are attracting increasing interest around the world. Governments have announced strong commitments to biofuel programs as a way to both reduce greenhouse gas emissions and diversify energy sources. Advocates of biofuel subsidies and mandates frequently cite Brazil's experience with sugarcane-based biomass ethanol as a success story and model for increasing energy security. Today, Brazil is the world's largest biofuel market and Brazilian ethanol from sugarcane is arguably the first renewable fuel to be cost-competitive with petroleum fuel for transport. The United States, where most ethanol is produced from corn, is the second largest biofuel market.

However, ethanol production is more economical in Brazil than in the United States. This is due to several factors, including the superiority of sugarcane to corn as an ethanol feedstock, Brazil's large unskilled labor force (sugarcane production is very labor intensive), and a climate ideally suited to growing sugarcane. While the U.S. and Brazil make about the same volume of ethanol, the U.S. uses almost twice as much land to cultivate corn for ethanol as Brazil does to cultivate sugarcane for the same purpose, and ethanol fuels a greater share of Brazil's cars—there are simply a lot more cars in the United States.

Given Brazil's natural and acquired advantages for ethanol production, it is difficult to imagine the United States matching Brazil's level of ethanol consumption—40 percent of the motor fuel market—at a reasonable economic cost. In the U.S., corn-based ethanol would be viable only if it were to compete in the market on the same basis as other fuels. American taxpayers today pay twice for ethanol: once in crop subsidies to corn farmers and again in a 51-cent subsidy for every gallon of ethanol. Without such a subsidy, ethanol simply would not be cost-competitive with gasoline.

Moreover, corn-based ethanol produced in quantities large enough to displace a significant percentage of U.S. petroleum consumption could have significant environmental impacts. According to the Worldwatch Institute, ethanol may damage the environment when it is produced on a large scale from low-yielding crops such as corn. In these cases it may generate as much or more greenhouse gas emissions than do petroleum fuels. Also, corn-based ethanol production processing consumes more non-renewable fuels compared to the production of sugarcane ethanol.

Finally, Brazil's ethanol infrastructure model did not arise from free market competition: It required huge taxpayer subsidies over decades before it could become viable. The ethanol program became uneconomical when petroleum prices fell in the late 1990s. The country's Congress even resorted to drastic measures by passing a law forcing oil companies to add small quantities of ethanol to their gasoline (in Brazil, gas sold at the pumps is 25 percent ethanol). Even today, during a period of high oil prices, volatile ethanol prices have not freed Brazilians from losing money on the E20 blend mandated by their government. And depending on the price fluctuations, sugar growers prefer to make even more money by selling their product as sugar on the world market rather than fermenting it into alcohol. Therefore, the Brazilian ethanol program is not a suitable model for U.S. energy policy reform.

INTRODUCTION

Biofuels are attracting increasing interest around the world. Governments have announced strong commitments to biofuel programs as a way to both reduce greenhouse gas emissions and diversify energy sources. Advocates of biofuel subsidies and mandates frequently cite Brazil's experience with sugar cane-based biomass ethanol as a success story and model for increasing energy security. Today, Brazil is the world's largest biofuel market and Brazilian ethanol from sugarcane is arguably the first renewable fuel to be cost-competitive with a petroleum fuel for transport. The United States, where most ethanol is produced from corn, is the second largest biofuel market.

The productivity and efficiency of Brazilian sugarcane ethanol production are virtually unmatched by any other country.

These two countries share some important characteristics. Geographically, both have continental dimensions. Both have great agricultural capabilities and well-developed domestic automobile industries. In absolute terms, the Brazilian and U.S. fuel ethanol markets are comparable in size. In 2005, Brazil produced 4,227 million gallons of ethanol; the United States produced 4,264 million gallons.[1] However, in biofuels' market share, the difference is striking. In the United States, ethanol supplied only 3 percent of total motor fuel consumed in 2005, while in Brazil, it supplied 40 percent[2].

One reason for this difference is simply the larger overall size of the U.S. motor fuel market—quite simply, there are a lot more cars in the United States. In Brazil, there are 23 million vehicles and 49.1 million households, an average of 0.47 vehicles per household. In the United States, there are 204 million vehicles for 107 million U.S. households, an average of 1.9 vehicle per household.[3] Cultural attachment to the automobile is also different in each country. Unlike in the United States, in Brazil, cars with small motors of up to 1.4 liters dominate the market.

Ethanol production is more economical in Brazil than in the United States. This is due to several factors, including the superiority of sugarcane to corn as an ethanol feedstock, Brazil's large unskilled labor force (sugarcane production is very labor intensive), and a climate ideally suited to growing sugarcane. While the U.S. and Brazil make about the same volume of ethanol, the U.S. uses almost twice as much land to cultivate corn for ethanol as Brazil does to cultivate sugarcane for the same purpose.

Given these advantages, the productivity and efficiency of Brazilian sugarcane ethanol production are virtually unmatched by any other country. So it is far from clear that the United States can or should attempt to replicate Brazil's biofuel policies or achievements.

Even in Brazil, where climate and labor market conditions favor ethanol production, ethanol is cost-competitive with gasoline only during periods when oil prices are high.

One objective of this paper is to review the factors that have contributed to the success of the Brazilian bioethanol industry. The evolution of this industry offers some valuable lessons for other countries considering ethanol production. The paper will show that even in Brazil, where climate and labor market conditions favor ethanol production, ethanol is cost-competitive with gasoline only during periods when oil prices are high. For the United States, it seems implausible for ethanol production to have a significant impact on the market for oil, helping reduce America's dependence on petroleum.

A Brief History of Brazil's Ethanol Program

Brazil's National Alcohol Program, PROALCOOL, was launched in 1975 as a policy to reduce the country's dependence on oil imports. At the time, Brazil was importing 80 percent of its oil and the 1973 OPEC oil embargo and production cutback had raised concerns that oil dependency could endanger national security.[4]

PROALCOOL was both an energy security program and an agricultural price support program. It aimed to increase production of sugarcane alcohol for use as a gasoline substitute, but it also sought to guarantee the profitability of the sugar industry after the sharp fall in sugar prices in 1974. The program allowed the excess production to be converted into alcohol (ethanol) in special distilleries close to the sugar mill. The ethanol thus produced would be blended with gasoline in a proportion of up to 24 percent.

As a first step, PROALCOOL aimed to increase the number of distilleries in the existing mills with the federal government offering extremely attractive credit guarantees and low-interest loans for construction of new refineries. These initial incentives accounted for nearly $2 billion in loans (nominal dollars) which represented 29 percent of the total investment needed.[5] The principal beneficiaries of the credit programs were the large producers.[6]

Next, the government began using the state oil company PETROBRAS to make infrastructure investments for ethanol distribution and to keep the cost of ethanol to consumers significantly cheaper than the cost of gasoline. The distribution of ethanol by PETROBRAS was based on a cross-subsidy scheme whereby gasoline prices were artificially boosted to keep the price of ethanol at a competitive level. Through its involvement in the National Alcohol Program, PETROBRAS accumulated losses of around $4 billion[7].

These incentives were key to the rapid expansion of ethanol consumption in Brazil. In less than four years, ethanol production more than tripled[8].

When the Iranian Revolution triggered a second oil crisis in 1979, the Brazilian government expanded PROALCOOL to promote the production of vehicles especially designed for ethanol use. In the early 1980s, it signed agreements with major automobile manufacturers—including Fiat, Volkswagen, Mercedes Benz, General Motors, and Toyota—to increase the production of ethanol-fueled vehicles. Taxi drivers were given tax breaks to convert their car engines to run on 100 percent ethanol, and the government mandated the use of ethanol-fueled vehicles in its own fleet. As a result, between 1983 and 1988, ethanol-fueled cars accounted for over 90 percent of total auto sales. In 1984, ethanol-powered cars accounted for 94.4 percent of automobile production for the Brazilian market[9].

During the second half of the 1980s, Brazil's ethanol program began to experience problems. Huge fiscal deficits and high inflation led Brazil to start economic reforms that included a cutback on ethanol production subsidies.

During the second half of the 1980s, however, Brazil's ethanol program began to experience problems. Huge fiscal deficits and high inflation led Brazil to start economic reforms that included a cutback on ethanol production subsidies. At the same time, world oil prices dropped sharply during 1985-1986, obviating the consumer benefit of replacing oil with ethanol. The economics became even more unfavorable in 1988 when the world sugar price rose considerably, and, at the same time, the government liberalized the sugar export market. As a result, sugarcane planters diverted crops to sugar exports, leading to a severe ethanol shortage during the second quarter of 1989. In response, the government authorized ethanol imports, and, ironically, Brazil turned into a net *importer* of ethanol. Drivers stopped buying ethanol-fueled cars, and car manufacturers stopped producing them. By the mid-1990s, only taxis and rental cars were being produced to run on ethanol.[10]

PROALCOOL First Incentives

- Guaranteed alcohol price lower than gasoline price
- Guaranteed remuneration to the producer
- Loans for alcohol producers to increase their capacity
- Tax reduction for alcohol cars
- Mandatory alcohol selling in gas stations
- Maintenance of strategic alcohol stocks

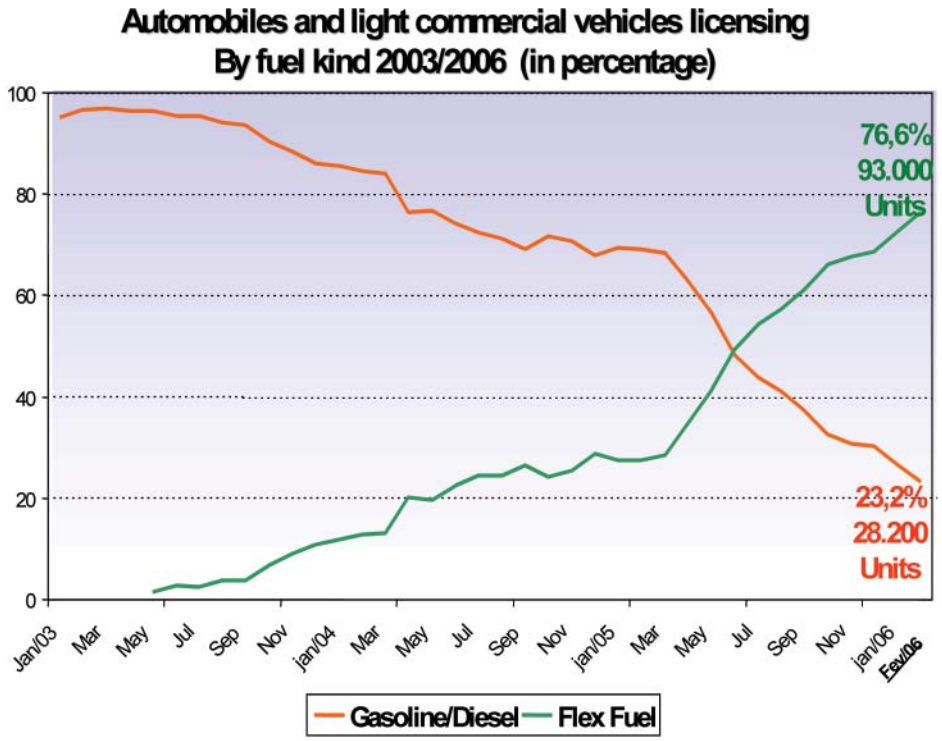
During the 1990s, the Brazilian economy experienced profound transformation. Economic policy emphasized stabilization, privatization, and liberalization—priorities into which an industrial policy program like PROALCOOL did not fit. There was little political support for continued

taxpayer-funded subsidies for sugar growers or distillers. The government gradually rescinded PROALCOOL's incentives and subsidies and freed alcohol prices to fluctuate with the market. Nevertheless, throughout this period, the federal government continued to require that all gasoline sold in Brazil contain roughly 20 percent ethanol. The government's rationale was environmental—ethanol would reduce emissions of lead and other pollutants. This helped sustain the industry through hard times.

An official evaluation of the total amount of investments in both the agricultural and industrial sectors for the production of ethanol for automotive use found that during 1975-1989 the government had spent a total of $12.3 billion in the National Alcohol Program.[11]

Towards the end of 1990s, some Brazilian engineers and policy makers sought to revive the ethanol fuel program. Ford launched its first flex-fuel prototype in 2002, with Volkswagen following in 2003. Flex-fuel cars able to run on ethanol, gasoline, or any mixture of the two caught on quickly. By March 2004, flex-fuel vehicles represented 16 percent of new cars sold in Brazil. By February 2006, the figure was 73 percent. (See Figure 1). The success of flex-fuel cars has led some automakers to announce plans to extend the technology for the production of all light vehicles in Brazil.

FIGURE1



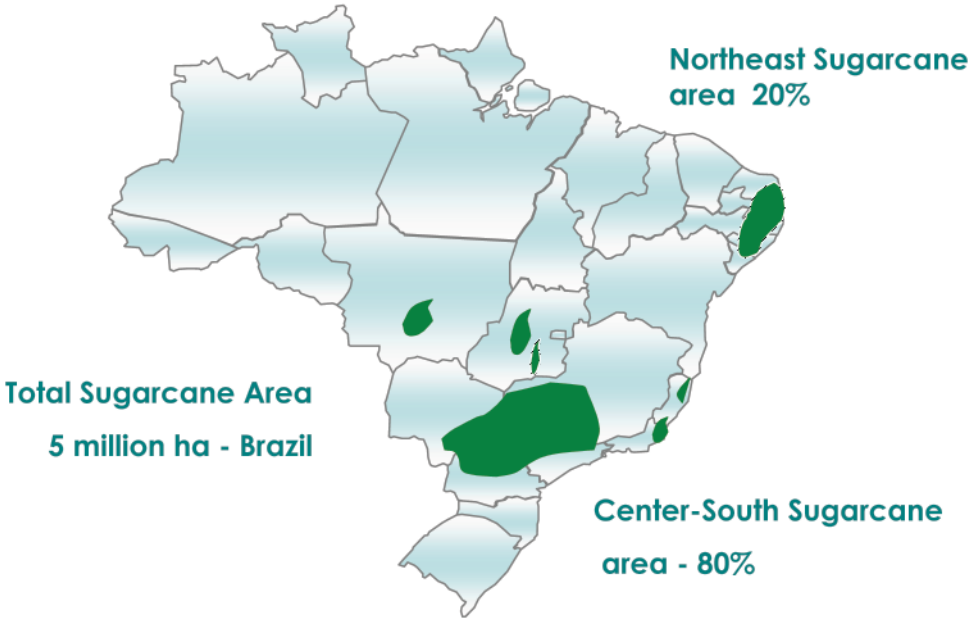
Source: Anfavea, 2006

Ethanol in Brazil Today

The dramatic increase in flex-fuel vehicles has helped fuel the Brazlian sugarcane industry's recent expansion. Today, Brazil is the world's biggest sugar producer and exporter, as well as the world's largest producer and consumer of sugarcane ethanol as a transportation fuel. In 2006, Brazil produced 4.2 billion gallons of ethanol. About 85 percent of the domestic production is concentrated in the Center South of the country and more than half of it is located in the state of São Paulo.[12]

Today, Brazil is the world's biggest sugar producer and exporter, and the world's largest producer and consumer of sugarcane ethanol as a transportation fuel.

Figure 2



About 80 percent of the country's total ethanol production is for domestic consumption, but exports have been growing for several years. By 2010, Brazilian companies are expected to invest about $10 billion in dozens of new sugar mills to boost ethanol production, while aiming to double exports.

In Brazil, sugar and ethanol are produced on an integrated basis. Currently, there are 306 operational mills producing 55 million tons of sugar or ethanol. The option to produce more or less of each product is influenced by the relative prices. When sugar prices increase, for example, producers can divert sugarcane production from ethanol to sugar. The production process also generates 100 million tons of waste—bagasse and straw— that can be used as fuel for heat and power generation. This is one significant advantage of sugarcane-based ethanol. Today, Brazilian mills and distilleries are nearly entirely self-sufficient in energy supply, and a few even sell surplus electricity.

Under conditions in Brazil, sugarcane's productivity is roughly twice that of corn-based ethanol.

Another advantage of sugarcane is its highly favorable energetic balance when compared with other ethanol sources. Under conditions in Brazil, sugarcane's productivity is roughly twice that of corn-based ethanol. As long as raw material accounts for roughly 60 percent of production costs, the comparative advantages of sugarcane is crucial to Brazilian ethanol's commercial feasibility. It is also worth noting that almost all sugarcane production, which is water-intensive, grows in rain-fed cultivated areas. Brazilian scientists have produced cane varieties that are genetically resistant to the main crop diseases. There are more than 500 commercial varieties of cane, of which 20 varieties are used in 80 percent of the cane area[13].

Physical Productivity Comparison

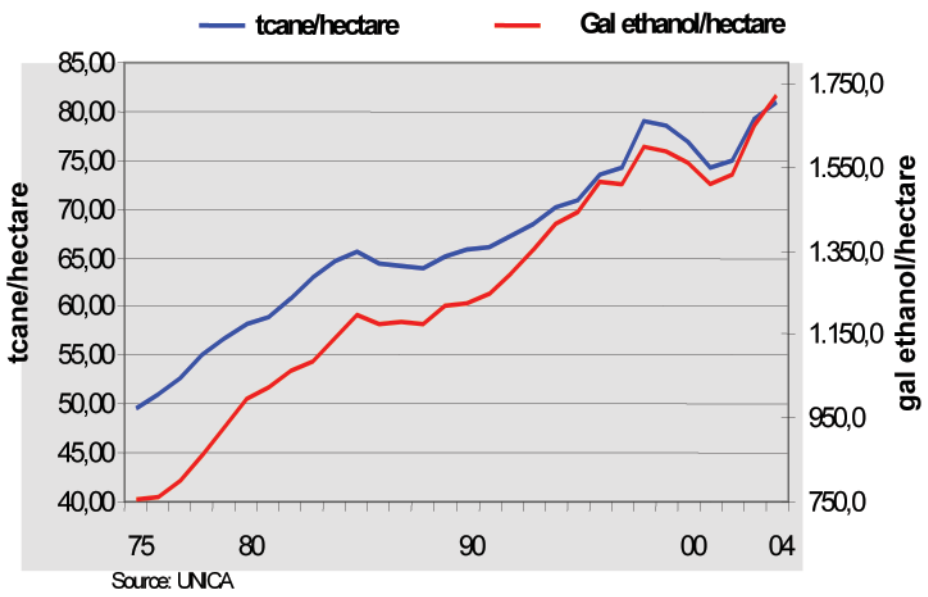
Raw Material	Production / ha (kg)	Quantity of Product (liter of Ethanol)	Quantity of Ethanol / ha
SUGAR CANE	85,000	12 kg	7,080 liter
CORN	10,000	2.8 kg	3,570 liter

Source: Ministry of Agriculture - Brazil

Production costs for ethanol in Brazil are the world's lowest. The average production cost is approximately $ 0.75 per gallon, according to UNICA, the industry association. Factors contributing to Brazil's competitiveness include favorable climate conditions, low labor costs, and mature infrastructure built over at least three decades. As Figure 3 shows, productivity gains have been substantial. Between 1975 and 2000, modernization of the sugarcane yield per hectare increased by 33 percent and ethanol yield from sugar rose by 14 percent. If ethanol could also be produced efficiently from cane bagasse, a process that is under development in Brazil, future productivity increases could be even greater[14]. These efficiency gains achieved over a three-decade learning curve, combined with the aforementioned factors unique to the country, allow Brazil to sell ethanol close to or below the market price of gasoline.

Unlike the Brazilian Alcohol Program's early days, today the Brazilian sugar program does not rely on any governmental price support mechanism. There are currently no production subsidies and no indirect costs paid by other sectors. The government's main intervention is the aforementioned requirement for all gasoline sold to contain a minimum percentage of ethanol. This is partly due to environmental rather than economic concerns. The introduction of ethanol as a substitute for lead additives has helped improve air quality in large cities, particularly São Paulo.

Figure 3 - Productivity Gains



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As ethanol provides fewer miles per gallon than gasoline, Brazilian drivers know that ethanol is price-competitive only when it costs no more than 70 percent of the price of gasoline. In March 2006, the blending ratio was reduced from 25 percent to 20 percent after ethanol prices soared to all-time highs. Brazilian drivers stopped using pure ethanol as the price reached $0.90, about 85 percent of the price of gasoline. Since both sugar ethanol and oil prices remain volatile, analysts diverge about the trajectory of ethanol as a fuel in Brazil. The beginning of the sugarcane crop season turned ethanol cost-competitive with gasoline, at least in the regions near the production areas. In the North and Northeast of Brazil, high transportation costs still limit the economic viability of using ethanol as fuel.

Ethanol, Gasoline, and Consumer Choice in Two Major Cities in Brazil

São Paulo	**Rio de Janeiro**
Ethanol price = US$2.70 Gasoline price (E20) = US$4.20	Ethanol price = US$3.30 Gasoline price (E20) = US$4.40

Currently, ethanol price is 64 percent of the price of gasoline in São Paulo and 75 percent in Rio de Janeiro. Ethanol is not cost competitive with gasoline in this latter. Price instability is still a problem to be faced, even near production areas like São Paulo.

Brazil: World's Lowest-Cost Sugar Producer – Summary of Advantages

Favorable climate, abundance of fertile land, and plentiful rainfall in the Center-South region

Production areas near major consumption centers

Use of bagasse for plant energy use and surplus electricity sales

During 1975-2000, sugarcane yield per hectare increased by 33 percent, sugar content of cane by 8 percent, ethanol yield from sugar by 14 percent, and fermentation productivity by 150 percent

More than 500 commercial varieties of cane (each plant processes around 15 varieties)

Hybrid sugar mill/distillery complexes

State-of-the-art computerized planting, harvesting, and plant operations

At the prevailing exchange rate of U$1 = R$2.15, average price of gasoline (E20) in São Paulo was US$4.20 per gallon while ethanol was US$2.70. At these prices Brazilian drivers still benefit using ethanol. In Rio de Janeiro, gasoline is still more economical than ethanol.

Conclusion and Some Lessons from Brazil

Given Brazil's natural and acquired advantages for ethanol production, it is difficult to imagine the United States matching Brazil's level of ethanol consumption—40 percent of the motor fuel market—at a reasonable economic cost. In the U.S., corn-based ethanol would be viable only if it were to compete in the market on the same basis as other fuels. American taxpayers today pay twice for ethanol: once in crop subsidies to corn farmers and again in a 51-cent subsidy for every gallon of ethanol. Without such a subsidy, ethanol simply would not be cost-competitive with gasoline.

Corn-based ethanol produced in quantities large enough to displace a significant percentage of U.S. petroleum consumption could have significant environmental impacts. According to the Worldwatch Institute,[15] ethanol may damage the environment when it is produced on a large scale from low-yielding crops such as corn. In these cases it may generate as much or more greenhouse gas emissions than do petroleum fuels.

A point rarely noted in discussions of the Brazilian biofuel program is that, along with ethanol, oil self-sufficiency has been a long-term goal of the Brazilian government. After the crisis with PROALCOOL during the late 1980s, the Brazilian government, through PETROBRAS, has put much more emphasis on increasing oil production. Based on its excellent performance on offshore exploration, PETROBRAS increased oil production by an average of 9 percent per year since 1980, in the range of 1.8 million barrels per day. In 2006, Brazil achieved self-sufficiency in oil and expects to export an estimated 500,000 bpd by 2010.

If ethanol were truly key in displacing oil imports, the Brazilian ethanol program also shows that biofuels should not be considered a panacea for the world's energy challenges. Brazil's ethanol infrastructure model required huge taxpayer subsidies over decades before it could become viable. The ethanol program became uneconomical when petroleum prices fell in the late 1990s. Even today, during a period of high oil prices, ethanol volatile prices have not freed Brazilians from losing money on the E20 blend mandated by their government. The Brazilian ethanol program is not a suitable model for U.S. energy policy reform.

Brazil's ethanol infrastructure model required huge taxpayer subsidies over decades before it could become viable.

NOTES

[1] F.O. Licht Database 2006, http://www.agra-net.com/portal

[2] Masami Kojima and Todd Johnson. *Potential for Biofuel for Transport in Developing Countries*. Energy Sector Management Assistance Programme. World Bank, October 2005. Pg. 1.

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[5] J. R. Moreira and J. Goldemberg. "The Alcohol Program." *Energy Policy 27* (1999) 229-245. Pg. 232

[6] Masami Kojima and Todd Johnson. Op cit. Pg. 48.

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About the Author

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