OIL AND ETHANOL IN LATIN AMERICA AND ASIA-PACIFIC

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ABSTRACT

Oil prices have escalated dramatically in recent years. As a result, observers have renewed interest in the possibility of producing ethanol. For some time, oil experts have been predicting the exhaustion of oil supplies. To date, reality has contradicted that position. However, there is consensus of the urgency to search for oil-substitutes including ethanol. Additionally, ethanol is an environmentally acceptable alternative. This study concludes that the growth of oil prices has the same critical importance for Latin America as for Asia-Pacific. The study examines the potential of substituting ethanol for petroleum in selected countries of Latin America and Asia-Pacific. The conclusion is that only Colombia, Peru, Malaysia, and Thailand have the potential because they cultivate sugarcane; Chile and South Korea do not have sugarcane production. The country with the greatest potential is Colombia, with a potential ethanol output greater than the equivalent fuel imports. The countries with medium potential are Thailand and Peru and the country with the smallest potential is Malaysia. Korea and Chile do not have the potential to replace oil imports, because they are located in a temperate region of the world; they must look for alternatives in other agricultural raw materials or in foreign trade.

INTRODUCTION

The objectives of this study are as follows: (a) to present the current situation with respect to the magnitude of and projections for petroleum imports for selected countries of Latin America and Asia-Pacific; and (b) to measure the potential to replace ethanol instead of petroleum in the energy consumption of the selected countries.

The price of crude petroleum and the value of oil imports have increased dramatically in the last two years. Crude petroleum and fuel imports of three selected countries of Latin America (Chile, Colombia, and Peru) reached $9.1 billion in 2005. The value of imports has increased 250% from the level of year 2001 (Table 1).

Table 1: Petroleum Imports and Fuels, Selected Countries, Latin America 2001-2005, Million $

	2001	2002	2003	2004	2005
Chile	2589	2463	3131	4469	6229
Colombia	198	189	239	262	544
Peru	908	975	1376	1753	2324
Totals	3695	3627	4746	6484	9107

Source: Central Bank of Chile (2006), DANE (2006), Central Bank of Peru (2006)

Petroleum and fuel imports of three selected nations of Asia-Pacific (Korea, Malaysia, and Thailand) reached U.S. $42 billion in 2004 and grew by 30% in 2005, reaching approximately $55 billion. These imports have doubled from the levels of 2001 (Table 2).

Table 2: Petroleum Imports and Fuels, Selected Countries, Asia-Pacific 2001-2005, Billion $

	2001	2002	2003	2004	2005
Korea	21.2	20.7	24.1	31.5	41.4
Malaysia	1.3	1.1	1.5	1.9	2.6*
Thailand	4.6	4.8	5.8	8.8	14.0*
Total	27.1	26.6	31.4	42.2	58

*Source: ADB (2006). *Estimated from growth rates of imports of fuels.*

It is clear that the demand for petroleum imports is much greater in the industrialized nations of Asia-Pacific than in the mid-industrialization countries of Latin America. The combined imports of these three countries of Asia-Pacific are nearly six times the combined imports of Chile, Colombia, and Peru, in the whole period 2001-2005. Table 3 presents oil imports of the selected countries Korea, Malaysia, and Thailand in terms of physical volumes. The imports of Korea are much greater than those of Malaysia and Thailand and represent three-quarters of the imports of the three countries combined in the period 2000-2003 (Table 3).

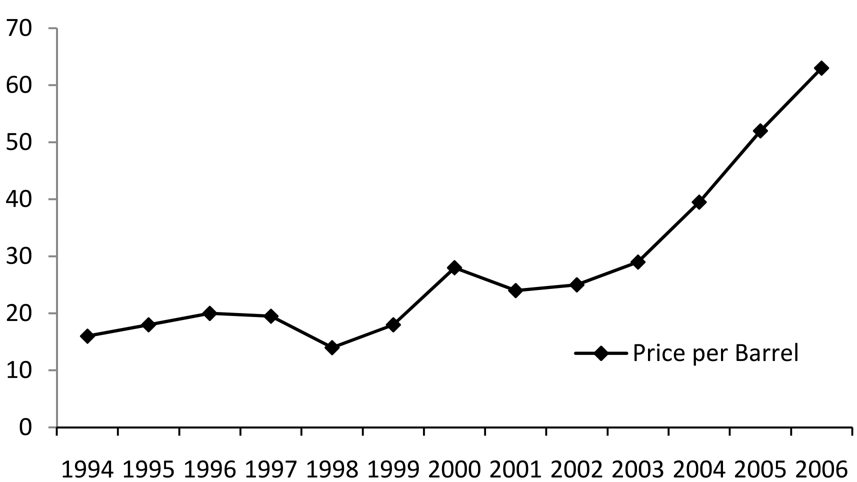
Table 3: Petroleum Imports and Fuels, Countries Selected Asia-Pacific 2001-2005, Million Metric Tons

	2001	2002	2003	2004	2005
Korea	138.5	132.0	132.5	133.8	
Malaysia	8.5	6.8	8.0	7.9	9.1
Thailand	29.8	30.8	32.1	37.0	
Totals	176.8	169.6	172.6	178.7	

Source: ADB (2006).

The conclusion is that oil imports and oil price growth have a critical and similar importance for the countries of Latin America as for those of Asia-Pacific. In both groups of countries, a high dependency on petroleum imports exists. This high dependency on petroleum may continue to grow in the future, with future growth depending on the growth tendencies of the international price of oil that currently exceeds $60 per barrel and is on an upward trend. (Figure 1).

Figure 1: Evolution of Petroleum Price 1999-2006 ($/Barrel)



Source: IMF, 2006

The high price of petroleum is the main reason that observers have begun to examine ethanol production now. The current level of petroleum price has resulted in a consensus of the urgent need to look for oil substitutes, including ethanol. The main use of ethanol at present is as an additive to gasoline, but in the future, ethanol may be the primary fuel.

Additionally, preoccupation with the environment makes a turn to bio-fuels an acceptable alternative of renewable energy. The main bio-fuel, with accessible and efficient technology and low costs that can compete with petroleum, is ethanol. Consequently, the thesis of this study is that ethanol is the fuel of the future.

The scenario of the petroleum price and its impact on fuel imports in the selected countries of Latin America (Colombia, Peru, and Chile) and of Asia-Pacific (Korea, Thailand, and Malaysia) has already appeared in previous tables. The numbers demonstrate that the situation regarding oil imports is critical and similar in regard to both Latin America and Asia-Pacific, because both groups of countries have a high dependency on petroleum.

The following sections present an analysis of the potential to replace petroleum with ethanol in energy consumption of the selected countries. First, we present the possibilities of sugarcane production in specific countries of Latin America and Asia-Pacific. Then a comparative analysis is made of sugar and ethanol markets. Finally, we display the calculation of the potential to replace petroleum imports.

SUGARCANE PRODUCTION IN LATIN AMERICA AND ASIA-PACIFIC

The situation of petroleum imports is similar in regard to both Latin America and Asia-Pacific because both regions have a high dependency on petroleum imports. The possibilities of ethanol production can also be seen as similar in Latin America and Asia-Pacific. This is because in both regions some countries are located mainly in the tropical zone of the globe: between the Tropic of Cancer and the Tropic of Capricorn, to the north and the south of the equatorial line. The exceptions in the sample are Korea in Asia-Pacific and Chile in Latin America, because these countries are located mainly in the temperate zones of the world.

In the selected Latin countries, only Colombia and Peru cultivate sugar cane; Chile does not have significant production. In the selected countries of Asia-Pacific sugarcane production takes place only in Malaysia and Thailand; South Korea does not have significant sugarcane production (Table 4).

Table 4: Sugarcane Production in Latin America and Asia-Pacific (Million Metric Ton)

	2001	2002	2003	2004	2005
Colombia	33	37	39	40	39.8
Peru	8	9.1	9.7	9.7	7.1
Malaysia	1.6	1.5	1.3	1.2	1.2
Thailand	49.6	60	74.3	65	49.6
Totals	92.2	107.6	124.3	115.9	97.7

Source: FAOSTAT, 2006

In Colombia and Peru, the cane is cultivated exclusively for sugar production. No ethanol-from-cane production has developed in these countries. Colombia produced four times the output of Peru in 2001-2005. In Asia-Pacific the cane-producing country is basically Thailand, while the production of Malaysia represents only 2% of the Thai production, and Korea does not have any sugarcane production.

On the other hand, areas and yields of sugarcane production in all Latin America have had a slow but continuous growth in the recent period. Brazil is, by far, the main sugarcane producer in Latin America. Information of areas and yields in Brazil appears in the following table (Table 5).

Table 5: Sugarcane Area, Yields and Production in Brazil 2000-2005

	2000	2001	2002	2003	2004	2005
Area (Million hectares)	4.8	5.0	5.1	5.3	5.6	5.8
Brazil Yield (MT/Ha)	67	70	71	74	74	73
Production (Million MT)	322	350	362	396	416	420

Source: FAOSTAT, 2006

Average productivity in Brazil is 74 Mt/Ha at the end of the period, somewhat greater than the average for all Latin America. The importance of Brazil is preponderant; thus, in 2005, Brazilian output reached 420 million MT or two-thirds of the Latin America total. Sugarcane production in Brazil is more than 10 times the production in Colombia and more than 40 times the production in Peru.

Next, this paper presents sugarcane prices in the main producing countries. The competitive countries have a sugarcane price less than $15/Mt., Brazil had a price of $12.50/Mt in 2000 and Central America had an average price of $15.20 (Sugar Journal, reported in FAO, 2000).

THE INTERNATIONAL MARKET FOR SUGAR

The international sugar market is dominated by the agricultural policies of the United States and the European Union. In the U.S.A., the guarantee prices and producer subsidies are combined with a quota on sugar imports. The result is a domestic price of sugar that is near double the price of the world-wide market. Nevertheless, domestic supply does not exceed internal demand and the country holds an import position.

In order to maintain the price at their objective level, the U.S.A. applies a quota on sugar imports. A special characteristic of the quota is that the rights to sell sugar in the U.S.A. are assigned, for political reasons, to foreign governments, who transfer those rights to their residents. As a result, the rents generated by the sugar quota are credited to foreign producers.

The sugar quota illustrates the tendency of protection to give benefits to a small group of producers, each of whom receives a large benefit, at the expense of a great number of consumers each of whom bears only a small cost. The cost to the North American consumer is only $6 per year. This explains why the average American is not conscious that a quota exists and so there is little opposition to it. On the other hand, the sugar quota is a life-or-death issue for the sugar producers in Louisiana and Hawaii. The industry employs only 12 thousand workers, so that the gains of the producers represent an implicit subsidy of about $90.000 annually per employee. It is not surprising that the sugar producers and their representatives in the Congress of the U.S.A. mobilize themselves as soon as they fear that their interests are affected (Krugman, 1997).

An important result of the subsidized prices and the quotas is that the price of the world-wide market is depressed. That is, the international price would be greater than the present one if these mechanisms of protection in the U.S.A. did not exist. However, the probability that the sugar quota and the subsidies to sugar producers stay in the U.S.A. in the short term is high. Thus, there is no provision for the clearing of these mechanisms in the Free Trade Agreement (FTA) of the U.S.A. with CAFTA (Central American countries) nor in the FTA recently signed with Colombia and Peru. The U.S.A. has made clear that these subjects will be negotiated at the multilateral level in the negotiations of the Doha Round. Consequently, the possibility of a free and ordered trade of sugar between Latin America countries and the U.S.A. does not exist in the short term. As a result, under most foreseeable conditions, producing countries will continue to face depressed prices and excess supply.

The situation described for the segment of the world-wide sugar market dominated by the U.S.A. is repeated for the segment of the market dominated by the policies of the European Union. The depressed scenario of internal subsidies, prices, and restrictions on imports is also reproduced in that segment of the market.

One solution for the sugar industry of Colombia, Thailand, and Peru is its shift to ethanol production, because for this product there are no subsidized prices nor tariffs, quotas, or restrictions to imports.

To measure the degree of competitiveness of the sugar countries, some figures of the production costs in the main sugar producing countries are provided in Table 6. All competitive countries have a cost of sugar inferior to 10 cents a pound. The conclusion is that Colombia is a competitive country in sugar production. Peru does not appear in the list because its costs are above the average of Latin America.

Table 6: Production Cost of Crude Sugar in Selected Countries (1997)

Country	Cost of crude sugar (cents/lb)
Brazil	8.85
Cuba	13.60
Guatemala	9.98
Colombia	9.07
Mexico	14.23
Dominican R.	12.50

Source: GEPLACEA; reported in FAO (2000).

ETHANOL PRODUCTION IN LATIN AMERICA AND ASIA-PACIFIC

A crucial and elementary issue is to investigate which is the most efficient vegetable matter for ethanol production. Although theoretically the alcohol can be produced from grains (maize, sorghum, wheat), from tubers (potatoes), or from sugar cane, technical studies demonstrate that it is more efficient to produce ethanol from sugar cane. The leader in the production of ethanol at a world-wide level is Brazil: its cane production reached 420 million MT in 5.8 million hectares in the year 2005. Of the cane harvest, 60% is destined to ethanol production, and ethanol production has reached 100 million barrels annually. Until today, there has been no sugarcane production for ethanol in Colombia and Peru. Consequently, the costs of a possible production are only estimates made by agricultural technicians.

With the new level of petroleum prices equal to $60 to $70 a barrel, ethanol already is highly competitive as a direct substitute of petroleum. The increase in the petroleum price has already meant an increase in the ethanol price to over $100 a barrel in the year 2005. The costs and benefits of a typical plant for ethanol production are described next. The data apply to a small pilot plant in Peru that will produce 188 barrels of ethanol a day (Torres-Zorrilla, 2004). Regarding benefits or income, for project evaluation purposes, a price of $100 a barrel is assumed. A use of 80% of the installed capacity and therefore a value of the annual sales of $5.5 million it is also assumed (see Table 7 below).

Table 7: Pilot Plant for Ethanol Production: Capacity and Output

Concept	Value
Installed Capacity (Thousand Barrels)	68.6
Use Level of Installed Capacity	80%
Annual Production (Thousand Barrels)	54.9
Value of Sales (Million $)	5.5

Source: Torres-Zorrilla, 2004

The production costs assume a price of sugarcane equal to the international price of 13.20 $/Mt and a transformation ratio of 2.55 MT of sugarcane for one ethanol barrel (alcohol content equal to 6.2%).

Therefore, the cost of the raw material is $33.7 for an ethanol barrel. The cost of manufacture in the plant pilot is equal to $5.14 per ton of processed cane, that is to say, $13.1 for an ethanol barrel. The average cost of the ethanol barrel is equal to $46.8, well below the international price of ethanol (Table 8).

Table 8: Pilot Project of Ethanol: Production Costs

Concepts	Price-Cost ($/Mt)	Amount MT	Values ($)
Raw Material:sugarcane	13.20	2.55	33.70
Cost of manufacturing	5.14	2.55	13.10
Total cost			46.80

Source: Torres-Zorrilla, 2004

The pilot plant produces an annual profit of $2.9 million (sales $5.5 and costs $2.6 million annually). Consequently, the ethanol pilot plant is highly profitable. Although the cost-benefit analysis comes from a case-study for Peru, the results illustrate that ethanol production can be equally or more competitive in Colombia and Thailand.

Finally, a crucial issue is the comparative advantage of ethanol production of Colombia and Peru and Thailand with respect to other countries or other regions like Latin America, Asia, or Africa. The questions that arise are the following: why should re-engineering to ethanol only occur in Colombia and Peru? Why could other countries like Brazil, Cuba, Mexico, Central America, Indonesia or Nigeria not also initiate a re-engineering program to ethanol? The answer to the previous questions is that the fuel market at the present time is incommensurable. If all the sugar producing countries produced ethanol instead of sugar, it would be only sufficient to cover a part of the gasoline market of the United States, whose consumption reaches nearly 10 million barrels per day.

The conclusion is that the possible ethanol competition of Colombia, Peru and Thailand with the production of the rest of the world will be minimal. The fuel market will have, in the future, a magnitude much larger than the combined production of all the developing nations. Moreover, the cost-benefit analysis for ethanol demonstrates an economic feasibility and high rates of return to investments in the production of ethanol. That is, Colombia, and Thailand, and Peru can be competitive in ethanol production.

In the specific case of Peru, this contrasts with the situation in the sugar market where the country is not competitive. The conclusion of the previous analysis was that Peru was not competitive in sugar and its present production was only maintained by the high levels of internal protection and by the greater price of the export quota towards the U.S.A. Peru is not competitive because their costs exceed those of the world-wide market and they can only sell in the subsidized market of the U.S.

POTENTIAL FOR THE SUBSTITUTION OF PETROLEUM IMPORTS

The analysis of the potential for the substitution of petroleum imports should be estimated, in the first instance, at the level of each country separately. The method used here consists of comparing the maximum potential production of ethanol in each country with the physical volume of crude oil imports or the equivalent, if refined fuels are imported. This method is only applied to the sugarcane-producing countries of the sample, that is to say, Colombia, Peru, Thailand, and Malaysia.

The maximum potential production of ethanol in each country is obtained from the sugarcane production in the respective country. First, it is assumed that the historical record of sugarcane production (in metric tons) is what defines the potential production of ethanol. Second, one assumes that all the raw material will be used in the production of the alcohol and that there will be no sugar production. Third, the factor that is used to consider the maximum physical production of ethanol is a standard level of 6.5% of alcoholic content in the cane. The results of this exercise appear in the following Table 9.

The comparison of the potential ethanol production must be with refined fuel imports, since ethanol directly replaces the gasoline. Alternatively, we estimate that 1.37 barrels of crude petroleum are required to produce 1 barrel or 42 gallons of refined fuels. That is to say, a volume of equivalent refined fuel import can be calculated by dividing the crude petroleum imports by a factor of 1.37 (see Table 9).

The country with the greatest potential to replace crude petroleum imports is Colombia: the maximum production potential of ethanol (2.6 million MT) is much greater than the equivalent in refined fuel imports. This implies that by only diverting 40% of the cane production from sugar to ethanol, Colombia can replace its present crude petroleum imports.

Table 9: Potential of Substitution of Petroleum Imports

Country	Maximum Sugarcane Output	Ethanol Potencial Output	Crude Oil Imports	Equivalent Fuel Imports	Import Substitution Potencial
	Million MT	Million MT	Million MT	Million MT	Percentage
Malaysia	1.6	0.1	8.0	5.8	2%
Thailand	74.3	4.8	32.1	23.4	20%
Colombia	40	2.6	1.5	1.1	236%
Peru	9.7	0.6	6.5	4.7	13%

Source: estimated by author. Note: The ratio between volume of crude petroleum and equivalent volume of gasoline is 1.37. See appendix.

The countries with medium potential to replace crude petroleum imports are Thailand and Peru. In Thailand, if all sugarcane production is dedicated to ethanol extraction (production of sugar equal to zero) 20% of the imports of crude petroleum can be replaced. In Peru, if the total of the sugarcane production is dedicated to ethanol, that is, if the Peruvian sugar production is equal to zero, 13% of the crude petroleum imports can be replaced. In other word if the area of sugarcane production in Thailand is multiplied by five, petroleum imports could be replaced completely. In addition, in Peru, if the area of sugarcane production is multiplied by 7, crude petroleum imports could be almost totally replaced. In both countries, this increase of productive areas seems viable.

The country with a smaller potential for replacing crude petroleum imports is Malaysia: if all sugarcane production is dedicated to ethanol extraction (production of sugar equal to zero) only 2% of the imports of crude oil can be replaced.

The case of Korea in Asia-Pacific is different for two reasons. First, the volume of the import needs is immense; imports of crude oil of Korea represent more than 75% of the combined imports of the three countries of Asia-Pacific in the sample. Second, all the territory of Korea is located north of the 30th parallel of the northern hemisphere: that is to say, it is a territory with a temperate climate not appropriate for sugarcane production. The alternatives to petroleum imports in Korea must be looked for in other agricultural raw materials (maize for example) or in foreign trade with its neighbors (Thailand).

The case of Chile in Latin America is also different for several reasons. First, the import needs of Chile are for two different uses. In Chile crude petroleum for refineries is imported and is of primary importance, but with almost equal importance, gas is imported from Argentina for the generation of electrical energy. This can be seen in the following table that summarizes those two types of imports of Chile (Table 10).

Table 10: Petroleum Imports and Gas Imports of Chile, 2001-2005, Million $

	2001	2002	2003	2004	2005
Petrolean	1727	1615	2126	2875	3779
Gas	862	848	1006	1594	2449
Total	2589	2463	3131	4469	6229

Source: Central Bank of Chile (2006)

Petroleum imports of Chile represented 60% of the total import in 2005. The potential for ethanol is greater as a direct substitute for gasoline for transport vehicles, but the potential of ethanol is smaller as a substitute for gas for electricity generation. In addition, all the territory of Chile is located below the 20th parallel of the southern hemisphere, and thus the climate is not appropriate for sugarcane production. By the previous analysis, the alternatives to petroleum in Chile must be looked for in the foreign trade with their neighbors (Colombia and Peru) or in other agricultural raw materials.

CONCLUSIONS

Petroleum prices and the value of imports have increased dramatically in recent years. The high price of petroleum has caused researchers to reconsider ethanol production. Petroleum imports and the growth of the price of petroleum have a critical and similar importance for the countries of Latin America and Asia-Pacific. This similarity is because both groups of countries have a high dependency on petroleum imports.

This study presents conclusions on the potential to replace petroleum with ethanol in selected countries of Latin America and Asia-Pacific. This potential is calculated for the cane-producing countries. The conclusion is that only Colombia, Peru, Malaysia, and Thailand cultivate the sugarcane; Chile and South Korea do not have significant productions.

Given the existing distortions in the sugar market, a solution for the sugar industry of Colombia, Thailand, and Peru is its conversion to ethanol production, because in this product there are no subsidized prices nor tariffs, quotas, or import restrictions. Another conclusion of this study is that the cost-benefit analysis of ethanol demonstrates an economic feasibility and high rates of return to investments to produce ethanol. That is, Colombia, and Thailand, and Peru can be competitive in ethanol production.

It is demonstrated that the country with the greatest potential to replace crude petroleum imports is Colombia, with a maximum potential production of ethanol that is much greater than the equivalent refined fuel imports. The countries with a medium potential to replace crude petroleum imports are Thailand and Peru. The country with a smaller potential to replace crude petroleum imports is Malaysia.

Korea and Chile do not have potential to replace crude petroleum imports because they are located in temperate regions of the globe. The alternatives to petroleum in Korea and Chile must be looked for in other agricultural raw materials or in foreign trade with their neighbors.

RECOMMENDATIONS ON POLICIES OF COOPERATION

This study proposes a program of cooperation between Latin America and Asia-Pacific on the subject of energy. Our proposal is that a future study must explore the conditions under which a productive, commercial, and financial cooperation on the issue of alternative energies to petroleum could be developed, with special reference to the production and trade of ethanol.

This commercial and financial cooperation must place emphasis in two areas. In the first area, one must investigate the possibility of developing investment projects of Asia-Pacific in Latin America and its potential for the energy sector. Secondly, one must develop strategic lines of cooperation in technology, especially with respect to technological possibilities of alternative petroleum options. This subject must be reviewed at the level of universities or institutes of applied research. It is also hoped that cooperation will flow from countries of Asia-Pacific towards Latin America.

These instances of cooperation between Latin America and Asia-Pacific should be implemented within the new frame of a world-wide organization for trade and investments, through agreements of economic and commercial complementation between the two groups of countries. The approval of Free Trade Agreements between the U.S.A., the countries of Central America, Chile, and the Andean countries (Colombia and Peru) opens an opportunity to reorganize the markets in the region, especially the markets of sugar and ethanol. These negotiations also create conditions to divert the existing sugarcane plantations towards ethanol production.

The following sections develop the proposals of cooperation between Latin America and Asia-Pacific in the energy sector, which can be made at the level of investment policies or at the level of technological policies.

Among the policies that could help to promote the development of ethanol production in the countries of Latin America, it is important to emphasize the policy of attraction to new direct foreign investment. These investments can occur in new companies or complementary industries in the production chain of ethanol. This objective can also be achieved with direct investments or with joint ventures.

The policies of investment promotion require the active participation of the central and regional governments of the countries. This public support can also be given through physical infrastructure provision (access roads to the ports and the market) and through direct promotion to the establishment of international subsidiaries in the countries of Latin America. For example, the Brazilian company Petrobras could participate in an investment for sugarcane plantations and ethanol refineries in Colombia and Peru. Energy companies of Asia-Pacific could also participate. The organization of road-shows that promote the investment opportunities should be considered.

The development of ethanol production in Latin American countries could be promoted through technological policies. In the first place, the transfer of technology towards regional companies in the countries of Latin America should be considered. A form of support to this process of technology transfer may be the formation of qualified human resources that support the transfer of technology in the future.

The policies of promotion of technological development also require the active participation of the central and regional governments of the countries. This public support may be given through the development of a technological infrastructure via the improvement of technical education and laboratories for research in regional universities (for example, at the University of Trujillo in Peru or the University of Cali in Colombia). There should be a direct policy to promote the sugarcane-producing areas, the raw material for ethanol.

APPENDIX: RELATIONSHIPS BETWEEN CRUDE AND REFINED PETROLEUM

The economic and productive relationships between crude and refined petroleum (gasoline and others) appear in this appendix. Our analysis is limited to gasoline, but it is important to notice that crude oil is also used to produce diesel, kerosene, industrial petroleum and others.

The international prices of crude petroleum and gasoline appear in the following table (Table A1), for the period 1994-2005. The price of gasoline is actually the before-tax average price in the United States, which it is possible to assimilate as the international price.

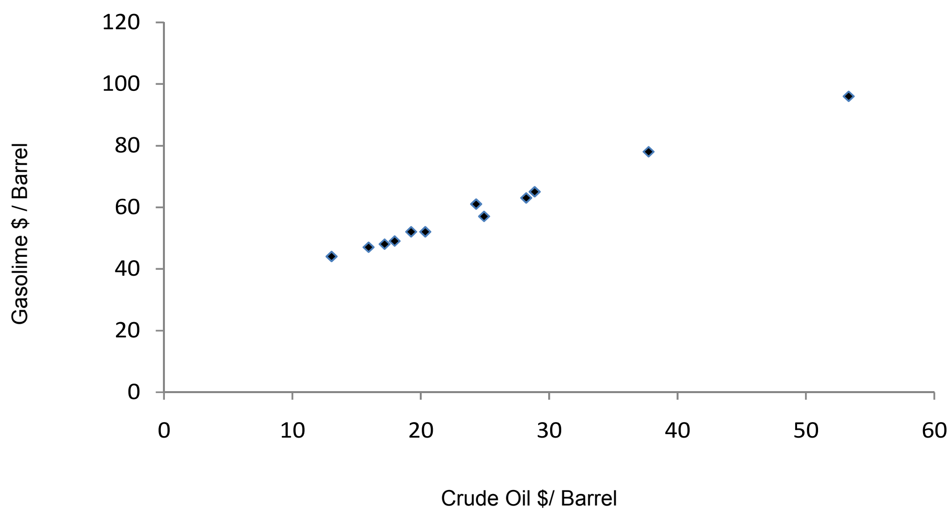
Table A1: International Prices of Crude Petroleum and Gasoline

Year	Petroleum $/barrel	Gasolina Cents/Gallon	Gasoline $/barrel
1994	15.95	112	47
1995	17.20	114	48
1996	20.37	123	52
1997	19.27	123	52
1998	13.07	106	44
1999	17.98	116	49
2000	28.23	150	63
2001	24.33	144	61
2002	24.95	135	57
2003	28.89	155	65
2004	37.76	185	78
2005	53.35	228	96

Sources: Price of Gasoline: EIA, 2006. Price Crude Petroleum: IMF, 2005.

The relationship between the price of the petroleum barrel and the price of the gasoline barrel (42 gallons) is direct and can be appraised in the following figure (Figure 2).

Figure 2: Price of Crude Petroleum and Price of Gasoline



Source: Estimated by author, from data of previous table

To predict the price of gasoline, we use data from 1994-2005. The linear regression for predicting the price of gasoline (dependent variable) from the price of crude petroleum (independent variable) with 12 observations has the following result:

GAS = $\alpha + \beta$ (crude price)

Table A2: Linear Regression for Predicting the Price of the Gasoline from the Price of Crude Petroleum

	Coefficient	t-Statistic
C(1)	25.89273	23.38136***
C(2)	1.328314	32.75528***
R-squared	0.990766	
Adjusted R^2	0,989842	
Log likelihood	-28.85496	

*Source: E-Views Econometric program. Dependent variable is the GAS price and the independent variable is crude price. *** indicates significance at the 1 percent level.*

The interpretation of this regression is that the cost of gasoline has two components: a fixed cost of \$25.89 per gasoline barrel and a variable cost that is equal to 1.33 times the price of the barrel of crude oil. Thus, if the price of the petroleum barrel were the price for the year 2000 (\$28.20), the price (or cost) of gasoline would be \$63.40 a barrel or \$1.50 a gallon.

In order to find a physical relation between the crude petroleum that is required to produce a gasoline barrel, the input-output model (Leontief, 1966) has been used. According to the Leontief model, the input-output coefficient between two industries (input i, output j) is equal to the following equation:

$$a_{ij} = \frac{\alpha_{ij}}{p_j} \times p_i$$

Where: a_{ij} is the input-output coefficient, α_{ij} is the physical coefficient (how many barrels of crude are required by a gasoline barrel), p_i is the price of input of crude petroleum; and p_j is the price of the final product: gasoline. From the previous equation the price of gasoline is written as a function of the input price of crude petroleum. This is the basic model of determination of the gasoline-price that is to be used in this study.

$$p_j = \frac{\alpha_{ij}}{a_{ij}} \times p_i = \beta \times p_i$$

The basic model interprets that the gasoline-price is a direct function of the crude oil-price multiplied by a factor β. This second equation can be estimated by econometric methods using the data from table A1. Note that the estimation must be a linear equation without a constant term.

For this analysis, the input-output coefficient from the input-output table of the economy of U.S.A. for 1997 has been used, which is equal to 0.526. The input-output table of the American economy is the most recent matrix estimated by the Bureau of Economic Analysis (2006). With this value, it is interpreted that 53% of the production cost of gasoline is the cost of crude petroleum.

The direct estimation of the model gives as a result the following equation where the number of observations is again 12 and the resulting R^2 is 0.486:

Table A3: Estimation of the Price Model of Gasoline

	Coefficient	t-Statistic
C(1)	2.200261	20.92***
R-squared	0.485932	
Adjusted R^2	0.485932	
Log likelihood	-44.97148	

Source: E-Views Econometric program

The result is that the model is $p_j = 2.2\ p_i$. That is, the price of the refined gasoline barrel is equal to 220% of the price of the crude oil used.

The estimated equation has, nevertheless, some limitations: The R^2 coefficient of the estimation is relatively low (48%) and the Durbin-Watson statistic reflects a high auto-correlation of the residuals of the equation.

In fact, some authors argue that although a clear relation between the output price and the input price always exists, sometimes this relation occurs with a certain statistical lag. That is, the price of gasoline may be reflecting the expectations of the agents about such an important price as the price of petroleum.

Often, the oil refineries are state-owned and they base their production costs of gasoline on the imported oil price of the previous shipment. If the oil price increases, it is clear that this attitude is unsuitable and that the input always must reflect its opportunity cost. The usual behavior is, however, to freeze the price of gasoline for political reasons, in the expectation that oil prices will return to previous levels.

By this argument, the model of the previous equation can be reframed as follows:

$$p_j = \beta \times p_{i,t-1}$$

Where the subscript (t-1) indicates that the price of crude oil is the price of the previous period. This re-estimation appears in the following table. The result is that the new model is $p_j = 2.61\ p_i$. That is, the price of the refined gasoline barrel is equal to 261% of the price of crude oil used.

The re-estimated equation corrects the limitations of the previous equation. First, the R^2 coefficient is greater, equaling 65%. Second, the Durbin-Watson statistic, 1.785 is at an acceptable level indicating that there are no auto-correlation problems. After controlling for the endpoints, the number of observations in this analysis is 11.

Table A4: Re-Estimation of the Price Model of Gasoline

	Coefficient	t-Statistic
C(1)	2.609365	22.67639
R-squared	0.648837	
Adjusted R^2	0,648837	
Log likelihood	-39.24018	

Source: E-Views Econometric program

Finally, we remember that the Beta coefficient of this new equation (equal to 2.61) is the ratio between the physical coefficient and the monetary input-output coefficient. Since the input-output coefficient for our period of analysis is 0.526 (from the input-output table), the physical coefficient is that we require 1.37 barrels of crude oil to produce a refined gasoline barrel. This is the ratio that was used to calculate the potential for ethanol to replace imports of crude oil in the four countries of Latin America and Asia-Pacific.

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