Simulating Government Policies for the Ethanol Market in Brazil

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Abstract

Sugarcane ethanol is now established as an important component in the Brazilian energy matrix. This status was achieved through a long lasting, expensive incentive program that started in the 1970s and with ongoing research and development. But the industry has had ups and downs and during 2011/12 it went through a major crisis with a shortage in supply, surge in prices and a shift in demand from ethanol to gasoline. This paper explores recommended policies by the government to deal with this and future crises. A System Dynamics model is used to replicate the current and possible future scenarios and to test appropriate strategies. The simulations show that a policy to allow gasoline prices to grow, adjusting to international prices, would have a highly positive impact for the industry while also contributing to public savings. The dosage of the policies can be tested under different scenarios with the presented model and flight simulator.

1. Introduction

In the 1970s Brazil started a national program for sugarcane ethanol as a response to rising oil prices. As the technology evolved, ethanol produced from sugarcane was added to gasoline in an increasing proportion (fixed by the government). In 1979 the industry started producing ethanol vehicles, boosting the market still further (Moreira & Goldemberg, 1999; Martines-Filho et al, 2006).

While the market for pure ethanol vehicles did not endure, repeated incentive programs and the launch of "flex" vehicles (with engines that run both with gasoline and ethanol) in 2003 contributed to boost demand for ethanol throughout the 2000s. The sugarcane industry also witnessed a surge in sugar production and exports. From 2000 to 2009 the exported volume grew almost four times and the Brazilian share went from 10 to more than 40% of global sugar exports (FAO, 2012). The recent growth in exported volume has also benefited from an upward trend in global prices, despite the appreciation of the real.

But despite the considerable growth in sugar and ethanol production, the industry went through major crises and faced a particularly severe one in 2011 and 2012. Supply did not keep pace with the potential demand, a large volume of ethanol had to be imported in 2011 and the volatility in prices escalated (Folha de Sao Paulo, 1994-2012).

The bio-fuel industry is considered highly strategic for Brazil, even after new oil fields were discovered. A considerable part of the goal for reducing greenhouse gases emissions depends on the use of ethanol, as its production cancels out the vehicles emission thanks to carbon sequestration in the crops (Estadão, 2012). Concerns on sustainability, climate change and all the instabilities related to petroleum supply also contribute to increase ethanol's importance as an alternative fuel not only for Brazil but for many countries (Goldemberg, 2007). But even with this importance, the market has not being able to self regulate to a satisfactory level, and the supply is now threatened even for domestic consumption, not to mention for exports.

In February 2012 the ministry of agriculture published a note communicating the government plan to revamp the sector (Brazil, Ministry of Agriculture, 2012). The plan consisted mostly in the financing of sugarcane production with an estimated spend of R$60 billion in 3 years. The concrete actions involved renovating a large part of the crops in order to increase the productivity and expanding the total crop area. The government also planned to establish a line of credit to be invested in storage capacity so the mills can increase inventories in order to smooth the supply between the harvest seasons. The industry estimated that an investment of R$156 billion would be necessary until 2020 in order to increase production to 1.2 billion tonnes of sugarcane and attend the expected demand for sugar and ethanol (Valor, 2011). But a question remains on what is the best strategy for the government to spend funds and help the industry through the crisis.

The problem with unstable supply and price volatility is highly complex. Ethanol is a commodity that behaves as other similar products, with a price being defined in a national market, the demand depending on several factors, mainly connected to economic activity and the supply depending on long term expectations of price and with long time constants. That would cause oscillations by itself, but apart from that this market also depends on other commodities such as gasoline and sugar, both also inserted in highly complex markets. All this built in complexity make this a highly suitable problem to be approached using system dynamics.

This paper builds on a system dynamics model developed for the ethanol market (Santos E. R., 2012) and uses simulations to test the best strategies for the government with a particular focus on the price of gasoline. Evidence shows that the gasoline and sugar markets are highly important in defining the ethanol dynamics. The gasoline price is particularly sensitive for policy development since the government has a major influence on it via the state owned oil company Petrobras.

The model presented here implies that a policy to allow the price of gasoline to adjust to the market (which currently means to grow without subsidies) would help to solve the crisis in the ethanol industry without the need for direct incentives to producers (a palliative which is being considered today). That would represent a double cutback on government spend with the suppression of subsidies both for gasoline and ethanol. Even though this proposed policy is not new, the model and flight simulator presented here allow the testing of different policies with varied degrees of strength and for different future scenarios for global spot price of gasoline and other uncertainties.

The paper is organized as follows: section 2 presents a review of the market; section 3 discusses the model structure. Section 4 describes the simulations and results. Section 5 presents the conclusions.

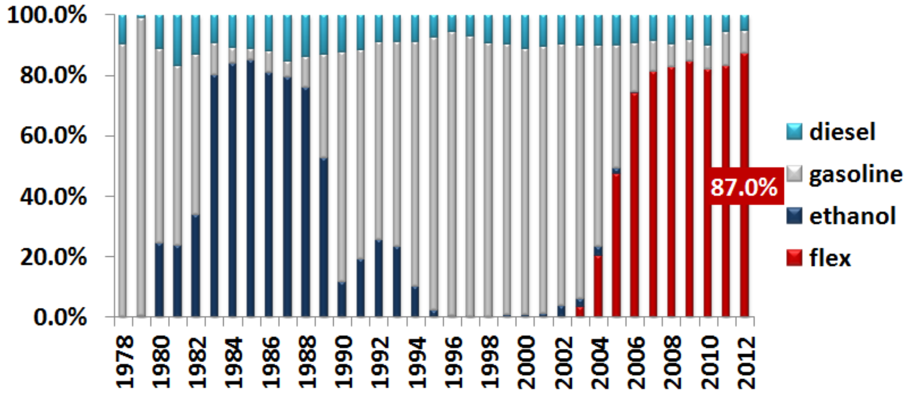
2. The Ethanol market

Brazil has produced sugarcane since the 17th century and sugar was the country's first large scale economic activity. In the 1970s, as a response to rising oil prices, the National Programme for Ethanol (PROALCOOL in Portuguese) was launched to promote the use of ethanol as an alternative fuel (Moreira & Goldemberg, 1999).

2.1. Demand

Ethanol is produced in two varieties: **hydrous** ethanol is used purely in vehicles designed specifically for this kind of fuel, while **anhydrous** ethanol is mixed with gasoline. In the beginning of the PROALCOOL, ethanol was used exclusively as the anhydrous variety. In 1979 the first ethanol vehicles (that run on pure hydrous ethanol) started being produced and demand for ethanol soared throughout the 1980s. But the market for ethanol vehicles did not hold (see Figure 1).

Figure 1. Distribution of vehicles licensed in Brazil by fuel type from 1978 to 2012



Source: (ANFAVEA, 2012)

The demand for these cars diminished drastically as a result of a lower price of oil and changes in the government incentive policy among other reasons (Martines-Filho et.al, 2006; Goldemberg, 2008). Lack of guarantee for ethanol supply and a shortage in 1990 ignited a crisis that would bring the market for neat ethanol vehicles to a collapse. But the problem would be tackled later on with the introduction of flex-fuel vehicles.

Flex-fuel is a new technology that allows vehicles to run with any blend of gasoline and (hydrous) ethanol (Goldemberg, 2008). That eliminates the trust issue: if the price and supply for ethanol are unstable the consumer can immediately shift to gasoline. The decision is now made at the pump each time the tank needs to be topped up. There is no more long term commitment to one single fuel. The results have been highly positive (see Figure 1). The demand for flex-fuel vehicles soared throughout the 2000s. By the end of 2012, close to 90% of all light vehicles sales were of flex-fuel and they already represented more than 50% of the fleet, which contributed to boost the ethanol and sugarcane market.

It is important to point out that a large fleet of flex vehicles does not necessarily translates into high demand for ethanol as the vehicles can run on 100% gasoline[1]. With the consolidation of flex cars on the fleet, the demand for hydrous ethanol will be fundamentally connected to that of gasoline and the relative price of both fuels will steer the demand. Ethanol delivers ca. 70% of the efficiency of gasoline, hence the consumer should expect a proportionately smaller price (per volume) for it (Ferreira et al, 2009).

Apart from hydrous ethanol, two other components form the demand: anhydrous ethanol and exports. Anhydrous ethanol has to be mixed to gasoline in a fixed proportion. The government actually uses this ratio as an instrument to regulate the market. The consumption of hydrous and anhydrous ethanol are correlated as gasoline "uses" anhydrous ethanol. As the demand for hydrous ethanol shifts to gasoline (when the price of ethanol rises), the demand for anhydrous ethanol grows proportionately via the increased demand for gasoline (ANP, 2011). This mechanism creates a localized reinforcing dynamic: the bigger the hydrous price, the lower its demand and the higher the demand for gasoline and anhydrous ethanol, which drains yet further the hydrous inventory and further pressures its price.

Exports also increased during the 2000s as Brazil sought to develop the market for ethanol internationally. But starting in 2009 the exported volume shrunk and the country had to import a large volume in 2011 due to a constraint in supply.

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[1] That is gasoline "C" which contains added anhydrous ethanol.

2.2. Supply

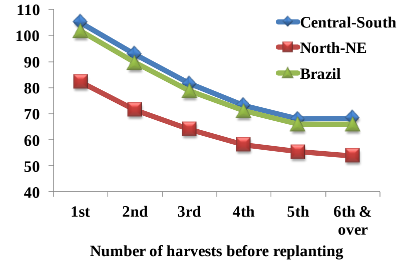
The production process starts with the sugarcane harvest. Once harvested the sugarcane is perishable and has to be transported and crushed rapidly, before losing the usable sucrose. The juice can then be destined for sugar or ethanol production. For the ethanol process the first product of the fermentation is hydrous ethanol which contains 4% more water than anhydrous ethanol. Hydrous ethanol is then dehydrated to produce anhydrous ethanol with 99.6 Gay-Lussac (GL). The whole production process takes about one day (UNICA, 2012).

The volume of ethanol to be produced depends therefore on the total amount of sucrose from the sugarcane crushing and on the fraction of that sucrose that will be used to produce ethanol instead of sugar. The total sugarcane production in Brazil has grown nine fold since 1970 and especially in the last decade. By 2010 Brazil was the largest global producer, accounting for more than 40% of worldwide production (FAO, 2012). The increase in production is the result of both an increase in the harvested area and in productivity.

Productivity depends on technology, on random factors (especially weather) and on the average age of the crop. Technology is related to the accumulated learning, or the experience curve (Bake et al, 2009) and its expected effect is to continually increase the productivity with time (knowledge can also depreciate, but presumably very slowly). But the aging and random effects may cause the productivity to oscillate.

Sugarcane can be harvested several times before it has to be planted again. On average the replanting takes place every 6 years in Brazil (Andrade, 2012). If it is replanted often it will potentially yield a higher productivity. Figure 2 shows an estimate of land productivity varying negatively with the age of the crop. The total average productivity on this setup was 81.4 tonnes/ha.

Figure 2. Land productivity according to crop age (tonne/ha)



source: (CONAB, 2008)

Apart from the land productivity there is also the sugarcane productivity. Once harvested the sugarcane may yield different amounts of usable sucrose to be transformed in sugar or ethanol. This exploitable amount is called Total Recoverable Sugar (TRS)[2]. TRS also depends on technology, or the experience curve (Goldemberg, 2008), and on various effects which may cause it to oscillate.

Both productivity indices show a long term improvement since the inception of the PROALCOOL but there has been a persistent loss in land and sugarcane productivity since 2010. The aging of the crops and the influence of the weather have been extensively mentioned in reports accounting for the lost productivity (CONAB, 2011). The weather is exogenous to the system, but the aging crops may be caused by the system itself (lack of investments, pressure to produce etc.).

Another important factor determining supply is the mills capacity, or the total capacity for processing sugarcane. Most of the capacity in Brazil is from multipurpose mills, that is, they can produce both sugar and ethanol. Another particularity is that the Brazilian mills own a big share of the sugarcane crops (typically close to 70%) so the supply

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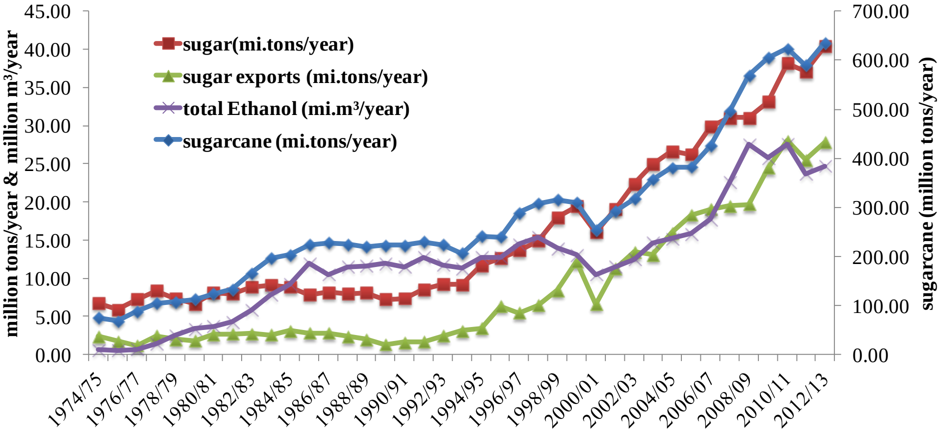
[2] In Portuguese the term is ATR (*Açúcar total recuperável*)

chain is strongly integrated (CONAB, 2008). In the 2007/08 season a total of 343 units offered a total capacity of 551 million tons/year of which 88.6% were in use (CONAB, 2008). By 2012 there were 425 units with a total capacity close to 700 million tons/year of which 16% were idle (Brazil, Ministry of Agriculture, 2012).

Together with the sugarcane yield and the mills capacity, demand for sugar is fundamental in defining the supply for ethanol. Sugar is a direct competitor for raw materials and resources. Brazil has vastly increased its sugar production in the last decade, mostly for the foreign market as its domestic consumption only grows slowly with the population. From 2000 to 2009 the exported volume grew almost four times and the share went from 10 to more than 40% (FAO, 2012).

The combined effect of the land use, productivities, supply of sugarcane and demand of sugar and ethanol are summarized in Figure 3. Apparently the forces driving the enormous growth in sugarcane production are the global demand for sugar and the domestic demand for ethanol fuelled by the flex vehicles. In the last three years, ethanol production stopped growing and all the extra sugarcane is being absorbed by the sugar market. In 2011 the situation gets even worse with a drop in production (due to the decreased productivity as we saw previously) and then even the exported volume of sugar falls despite the high prices.

Figure 3. Production of sugarcane, sugar and ethanol (1974-2011)



source: (Brazil, Ministry of Agriculture, 2007); (UNICA, 2012); (FAO, 2012). Data for 2012/13 is estimated.

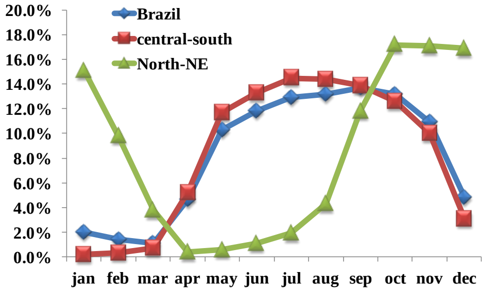
2.3. Costs and Price

The costs to produce ethanol and sugar have dropped considerably since the inception of the PROALCOOL program. Goldemberg et.al. (2004) use the learning cuve concept to analyse the cost reduction from 1980 to 2002. They found that the progress ratio for the prices in US dollars was of 93% until 1985 and 71% until 2002. That means that costs were being reduced in 29% for each doubling of cumulative production. Bake et.al. (2009) use the same concept to assess cost reduction but they separate feedstock (the sugarcane production) from industrial production costs, which, according to the authors, "would provide more insights into the factors that lowered costs in the past" (page 645). The authors find a progress ratio of 68% for the feedstock and 81% for the industrial costs from 1975 to 2004.

Another important technological development is in the use of self generated electricity from the bagasse (the residual from the sugarcane crushing process). Currently the mills produce large amounts of electricity from the bagasse. There is actually a surplus that is sold to the grid increasing the mills potential turnover with yet another byproduct.

The dynamics of the fuel and sugar markets become more complicated when we look at the production data through the year. The sugarcane is seasonal and the harvest is mostly done in the dry months, from April to November for most of the country (see Figure 4). This seasonality has an influence on price, though its magnitude is uncertain.

Figure 4. Monthly distribution of sugarcane volume



Source: (CONAB, 2010)

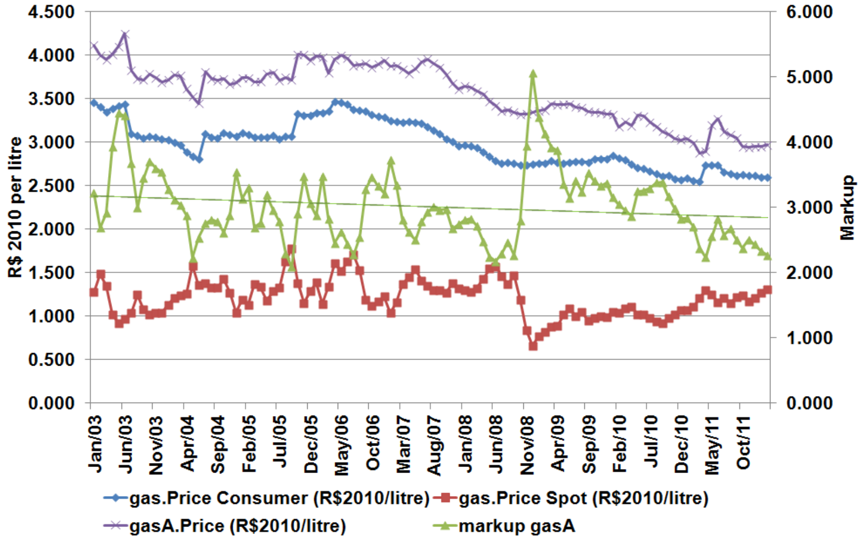
A plausible hypothesis for the price behaviour is that it responds to the dynamics of supply and demand via a perceived inventory coverage as is common for commodities (Sterman, 2000). If the level of inventories depletes or grows slower than demand the coverage will start falling. With time the agents in the market perceive this gap and respond by increasing the price (or vice-versa). The size of the gap will depend on a reference value, which can change with time as the economic agents adjust expectations. In this specific market the reference value will probably vary with the season. It is fair to assume that the market will expect a higher level of inventories at the end of the harvest and a much smaller level at the beginning of the next harvest after months of low production.

Government intervention can be equally important in determining prices. Up to the 1990s ethanol and gasoline prices were fixed by the government. The sector was gradually deregulated until 2002 when all prices, including gasoline, were (in theory) set free to adjust to market dynamics (Marjotta-Maistro, 2002). Consequently the price adjustment theory described previously would not hold before 2002. Furthermore, gasoline prices are set free in theory only because the government has a big influence on the market via Petrobras and can still "indirectly" control gasoline prices. This control can have a crucial influence in ethanol prices.

Figure 5 shows how gasoline prices have evolved since january 2003. Prices are supposed to be deregulated during this whole period but the gasoline prices to the consumer do not oscillate according to the international spot price. If we assume the cost to be proportional to the spot price (only part of the production is imported, but we could also consider an opportunity cost) and derive a mark-up as the ratio between gasoline A prices and the spot price, data shows that the mark-up varies widely while the price to the consumer changes more smoothly. Petrobras seems to filter fluctuations in price.

It is clear that the price of gasoline to consumers is much lower in 2012 than it used to be in 2003 when the flex vehicles were introduced, even though the international spot price for gasoline is approximately at the same level. The "mark-up" seems to have a long term negative trend (with an average of approximately 3) and since the beginning of 2011 it stays below the trend line, which indicates that Petrobras has been sustaining losses to keep gasoline prices down. As the analysis will show, this policy has a negative effect on the ethanol industry.

Figure 5. Gasoline prices evolution



Consumer prices are reported by ANP (2011). The spot price is reported by IndexMundi (2012) and corrected by the IGP-DI index. The gasoline "A" price is calculated as a component of the price to consumers together with the anhydrous price to producers reported by UNICA (2012). The anhydrous blend is assumed to be 25% for the whole period. The mark-up is calculated as the ratio between gasoline A and the spot price.

3. The Model

This study uses the model presented in Santos E. R. (2012) with a few tweaks to account for the government's modus operandi regarding the gasoline price setting. Figure 6 shows a simplified diagram for the demand sector. The gasoline "A" price is now formed by the spot price times a mark-up. The "cost to the government" is the spot price times a fixed mark-up of 3. The profits are accumulated into stocks to measure the accumulated effect of the policies.

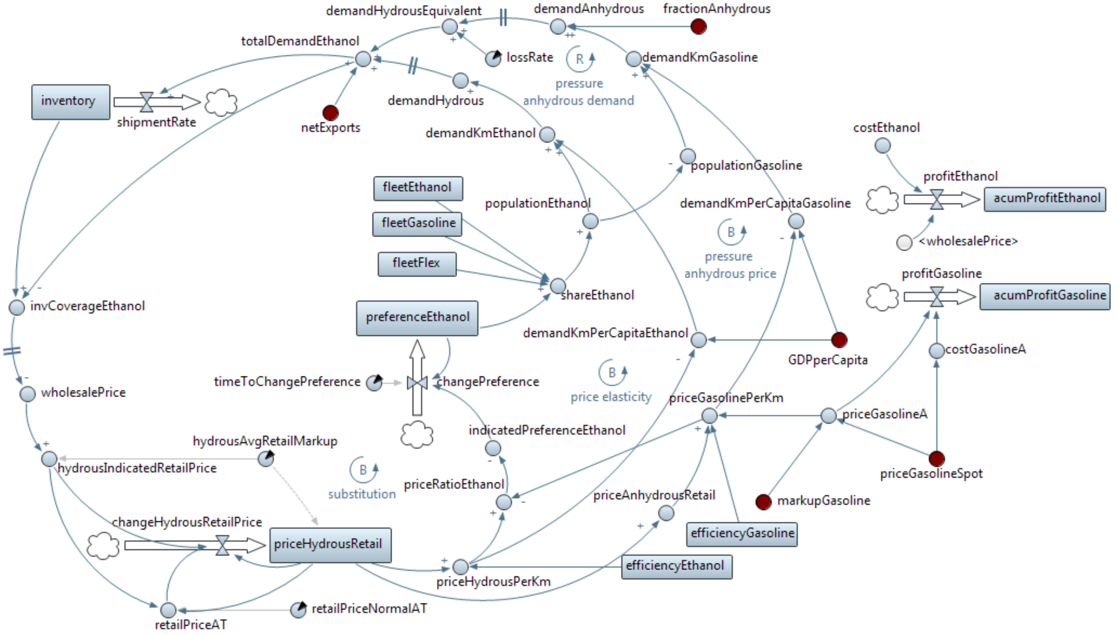
Demand for ethanol and gasoline are highly connected thanks to the flex-fuel vehicles. The demand for hydrous ethanol depends on what proportion of the population drives flex vehicles times the preference they have for ethanol instead of gasoline. This preference is a central variable in the demand sector and is modelled as a stock because there is inertia for changing it.

The demand for fuel is fundamentally driven by the income per capita and price. The demand is calculated from these variables according to the following equation: $D = K.Y^{\propto}.\mathrm{P}^{\beta}$, where D is demand of Km per capita, Y is the income per capita and P is the price per Kilometre. The constant term K and the income and price elasticities (α and β respectively) were obtained statistically from historical data.

The model is concerned with demand for Kilometres instead of demand for fuel volume because the efficiency (e.g. in Km/litre) is different between ethanol and gasoline and because the efficiency changes over time. A similar approach is used by Ferreira et.al. (2009). The efficiency is modelled as a stock adjusting to an arbitrary maximum value with a fixed time constant (a rough simplification).

The total demand for each fuel is calculated based on the total population assigned to it. This assignment is based on the fleet size and on preference for ethanol. The fleet is modelled separately (not shown in the diagram) but it is only used to measure the proportion of vehicles of each type. The model is not concerned with "consumption per vehicle" as this concept is dubious: an increase in income may lead one household, for instance, to acquire another car; in the new setup the household will likely consume more Kilometres for the same price but the consumption per vehicle will probably be lower. The size of the fleet will also be highly correlated with income, which would advise against using both variables in the model. Losekann (2010) also seems to find that the size of the fleet might not be a good parameter to estimate total demand for fuel.

Figure 6. Simplified diagram for the demand sector



Once the total demand in Kilometres is calculated for each type of fuel, the total demand in volume is calculated according to the efficiency. The demand for gasoline drives the demand for anhydrous ethanol depending on the fraction to be mixed. This fraction is defined by the government and exogenous to the model. Total demand for ethanol is the sum of hydrous and anhydrous (hydrous equivalent) demand, plus total net exports, which is also exogenous and defined in different possible scenarios. The other sectors of the model (Production, Price and Cost, Crops, Mills capacity) are described with detail in Santos E. R. (2012).

4. Simulations and Results

The full model analysis and validation is thoroughly described in Santos E. R. (2012). The study here relies on the validated model and uses a modified simulator in which the user can play the role of the government and decide whether it targets a fixed price for gasoline or a fixed mark-up. The simulator is available online at "http://www.runthemodel.com/models/1065/"[3] so the reader can follow the simulations discussed here and test different scenarios.

The simulations start at the beginning of 2003. Historical data is displayed until march 2012 and from then on the charts show the defined scenarios and simulation results. Income per capita on the base scenario is assumed to grow at an average rate of 4% per year, which will continuously feed a growing domestic demand for fuel. External demand is assumed to grow even faster, at an average rate of 10% per year. Productivity is assumed to continue to grow with the historical experience index.

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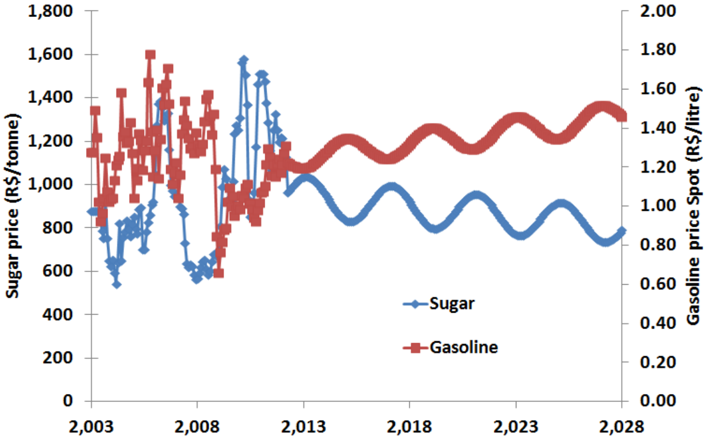
[3] Retrieved in March 2013. It has been tested in Google Chrome,V19 and Firefox,V12.

In the base scenario, the price of sugar starts at the historical average from 2003 to 2012 and the average value is assumed to decrease 1% per year on average due to learning effects on cost. The price of gasoline in the base scenario starts at the last year average and is assumed to grow 1% per year on average as oil tends to become scarce. Both prices are assumed to oscillate with a 4 year period and amplitude of 5% for gasoline and 10% for sugar. Figure 7 shows the curves for the prices.

Figure 7. Sugar and gasoline prices (historical and defined scenarios)



The market behaviour depends on the scenarios and on the implemented policies. The blend of anhydrous ethanol in gasoline is shown to be inefficient as a policy to regulate the market (Santos E. R., 2012) so this paper explores two other policies: the subsidies to the industry, defined as a fraction of the production cost given by the government to the producers (most likely in the form of a tax waiver) and the gasoline price setting. The government cannot influence the international spot price, but it can decide to subsidise the gasoline price or not. The simulator allows the user (playing the role of the government) to either set a target for the gasoline price (resulting in a profit or loss as the spot price is considered a proxy for the cost to produce gasoline), or to set a fixed mark-up, in which case an increase in the spot price (or the cost to produce gasoline) will be transferred to the consumer price.

Simulations are run for three different policy combinations. First the government sets a target price of gasoline to the consumer of 3 R$/litre. This policy is harmful for the industry as the low price of gasoline keeps ethanol demand, prices and profits down, so on the second policy the government decides to also subsidise the ethanol industry with a tax waiver amounting to 10% of the production costs (similar to what is being proposed today). On a third policy the government decides to apply a fixed mark-up of 3 instead of a fixed price for gasoline, which means that the price to the consumer will grow and oscillate according to the international spot price.

Figure 8 shows the results of the simulations for hydrous ethanol demand. Drops in demand or too much oscillation are undesirable for the industry. Most of the costs are fixed which means that a drop in demand will quickly put pressure on the producers' cash accounts and generate a debt crisis. This problem is indeed happening since 2011 (a valley in the demand can be seen on the curve) and the simulation shows it is likely to happen again under the base scenario and the policy with a fixed target price. The subsidy of 10% alleviates the problem, as does the change in policy to a fixed mark-up. Interestingly both policies are quite similar regarding their effect on demand.

The effects on profits for the ethanol producers are similar up to 2023. From then on the results for the industry are better when the government opts for the fixed mark-up, with the accumulated profit reaching almost R$ 90 billion on the 25 years simulation (see Figure 9). But the real difference between the policies is on the government's accumulated loss with gasoline. Figure 10 shows an accumulated loss of circa R$ 500 billion at the end of the 25 years period for the policies in which the government is targeting a fixed price of gasoline to the consumer. The deficit grows with the international spot price when the government insists in maintaining a low price to the consumer. And apart from the gasoline deficit, the government would also be spending circa R$ 500 million per month on subsidies. According to the simulation, the total savings for the public budget for going from the policy 2 to 3 (which are equivalent regarding the effects on the ethanol industry) would amount to circa R$ 4.5 billion per month by 2028.

Figure 8. Hydrous Ethanol Demand (m³/month)

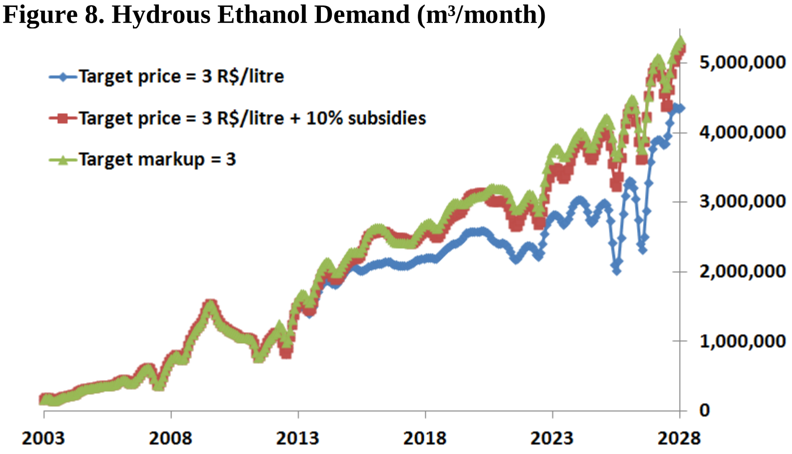


Figure 9. Accumulated Profit Ethanol (million R$)

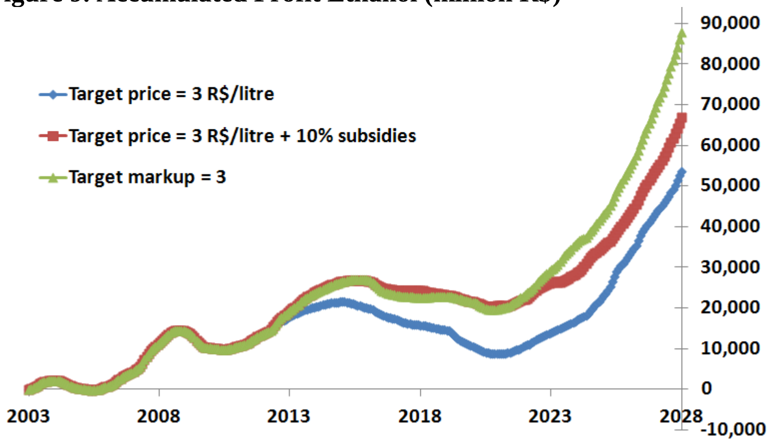
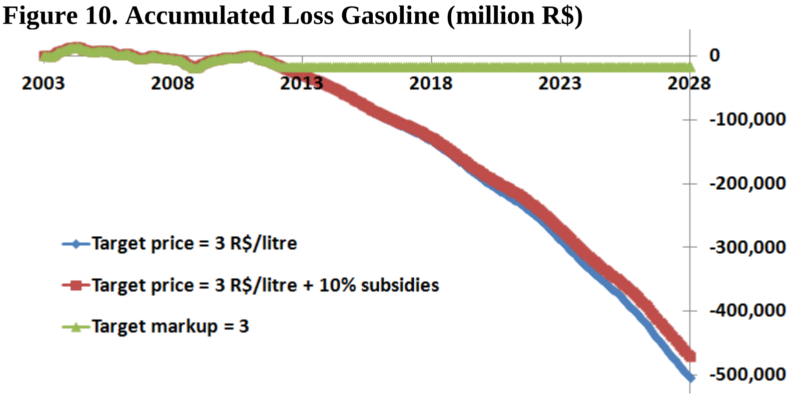


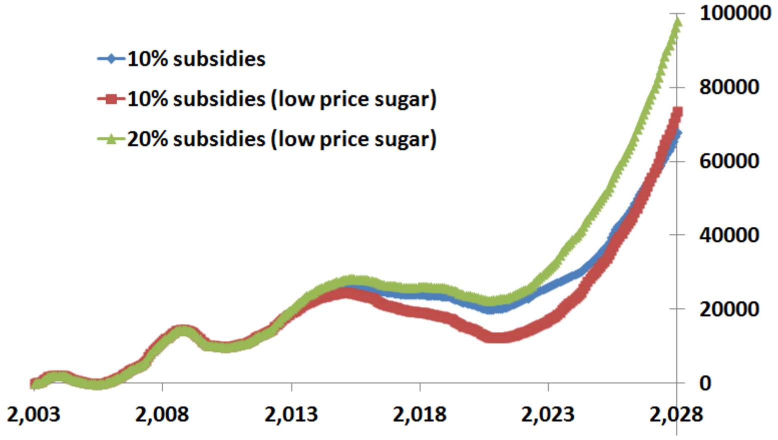
Figure 10. Accumulated Loss Gasoline (million R$)



One could argue that the scenario for gasoline prices is too pessimistic. There is a chance it may even drop in the future with more diversified energy sources, efficient vehicles, shale exploration etc. The simulator includes an optimistic scenario for gasoline prices ("low price") which indeed yields more positive results even when the government targets a fixed price for gasoline. But this scenario is improbable.

The government strategy should also be dependent on the sugar market. Santos E. R. (2012) shows how the sugar and ethanol markets can influence each other. Simulations shown in Figure 11 show how sugar prices can also change the effectiveness of government policies. In this new scenario sugar prices start with a value 5% lower than before and decrease 2% per year. The 10% subsidies are no longer as effective in alleviating the crisis in the industry. In this new scenario, subsidies of twice the amounts are necessary to keep the profitability levels similar to the previous scenario of normal sugar prices. It would probably be even more important in this case that the government avoids keeping gasoline prices low for too long.

Figure 11. Accumulated Profit Ethanol (million R$) with target price = 3 R$/litre



5. Conclusions

The evolution of the ethanol industry in Brazil can be considered highly successful despite the many crisis it went through. Consumption has grown dramatically and is expected to grow further with the consolidation of flex vehicles in the fleet. But the oscillations in supply, demand and price reveal a highly unstable and possibly immature market, which still seems to require government intervention.

In this study we investigate what the ideal policies are to foster the market while also controlling the public budget. Due to the complexity involved, simulation can be a crucial tool for sound policy development, so the study is supported by a sufficiently complex system dynamics model in which several variables related to supply, demand and price of ethanol, together with prices and demand for sugar and gasoline, are determined endogenously.

Dynamics in the sugar and gasoline markets are shown to be very tightly coupled with the ethanol market. This result is especially novel regarding sugar. Few previous studies relate sugar and ethanol dynamics and when they do, it is suggested that the relationship is weak (Bacchi, 2005). The model used in this study shows a strong causal effect, especially in the short to medium terms.

Evidence suggests that at least part of the intervention required by the ethanol industry has its origins on the government itself when it intervenes on the gasoline prices. Low gasoline prices are used by the government as a tool to curb inflation and that has a negative side effect on the ethanol market. The simulations suggest that a policy to simply let the gasoline price oscillate with the market by keeping a fixed mark-up would be equivalent (for the ethanol industry) to subsidising the producers with 10% of the ethanol production costs. According to the simulations, the government would save circa R$4.5 billion per month by 2028 without subsidising both the gasoline and ethanol prices.

This result assumes a scenario where gasoline prices grow slightly with a small oscillation and sugar prices diminish slowly, also oscillating. Of course the government would probably abandon the fixed price policy in case the spot price kept growing too much. The policy would also have to be dependent on the sugar price.

The simulation interface allows the user to test this and several other policy combinations and also to test different scenarios which makes it a powerful tool for policy development.

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