Emergence of the Biofuel Sector in Brazil and in the US

– The Role of Innovation Policy with focus on Public Procurement

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1 Introduction

Biofuel[1] is an issue that currently receives much attention worldwide due to its potential for lowering greenhouse gas (GHG) emission rates from transport and because the currently high, and still rising, oil prices have (in some regions) made ethanol production cost-competitive with fossil fuel. A longer-term perspective on energy sources also seems to be in favour of biofuels - in 2007, fossil fuels made up about 80% of the total world energy supply. At constant (continuation of recent growth in consumption) production and consumption, presently known reserves of oil will last about 41 years, natural gas 64 years and coal 155 years (Goldemberg, 2007). As a reaction to the latter, policies requiring ethanol blended with gasoline (in various proportions) are becoming widespread in OECD countries which is estimated to result in a demand for about 26 billion litres of ethanol in the short run (CREM, 2006, 27). It seems undeniable that the demand for biofuel will surge in both the near and medium-term future – the remaining question is who will produce it?

Currently a wide range of countries are currently launching public funded ethanol programs in order to get a foothold in the sector for both strategic, environmental and economic reasons. Even though it will not be dealt with in this paper, the framework governing international trade will have a decisive impact on who will produce and thus export ethanol (Matthews, 2007).

The idea with writing this paper is to take a first step towards understanding my main research interest which is fairly encapsulated in the question:

What are the "potentials" for poor countries to benefit from the up-coming market for bio-ethanol as both producers and users?

That several poor countries have the possibility to produce ethanol is unquestionable. This possibility mainly consists of the right resource endowment inter alia including available arable land, favourable climate and low wage level. Twidell and Weir (2006) estimate that Latin America and Africa are the continents with the largest potential for producing biofuel. Still, to benefit (short or long term) from this will depend on whether a given country is capable of gardening such a production sector through policy measures. Several scholars are of the opinion that other countries, developed and developing, can learn important lessons from Brazil's history (Goldemberg, 2007; ESMAP, 2005).

In the light of my main research interest, this paper considers the policy management that has taken place in the world's two largest bio-ethanol producers – the US and Brazil. If any lessons can be learned it is likely to be from them. Therefore the paper is a step towards getting a firmer grasp on my future research.

My focus in the policy analysis will be on innovation policy because establishing an ethanol sector per se may only be a matter of investments and thus reallocation of resources. Making the sector competitive/sustainable is another issue - an issue which in this case concerns productivity, technological development and how to manage the sector's broader impact on society through inter alia institutional innovation.

[1] Biofuels covers a range of energy forms. In this paper I am only concerned with bio-ethanol. Thus, when biofuel is mentioned it should be read as ethanol.

I do not consider the climatic aspect of biofuels per se. Instead I observe that there is a growing demand for the product and that it is currently produced most efficiently (in terms of price) in countries with arable land, low wage level and tropical climate. These observations make me wonder whether biofuels can support development and poverty alleviation in poor countries with the abovementioned characteristics.

The structure of the paper will be as follows. In the following section (2) I will give an introductionary overview of ethanol as a biofuel including production process, feedstocks, fuel use and its potential benefits and costs in terms of sustainability. I hope to give a convincing argument for why ethanol is worthwhile studying.

Section 3 will make up my theoretical considerations regarding the role of the state with respect to establishing an ethanol sector. I focus on demand-oriented innovation policies but emphasise the potential synergy effects between supply and demand-side policies. I outline how the state by creating and stimulating demand (public and private) can induce innovation by use of various policy instruments.

In section 4 I analyze Brazil's experience with ethanol production. I start by summarizing the history of the sector where after I explicitly focus on the policies used – innovative as well as more standard industrial policies. In section 5 the US's experience is analyzed in an identical manner. Lastly, section 6 will conclude on similarities, differences and possible lessons to be learned from the two cases.

2 Ethanol as a Biofuel

Not so long ago renewable energy sources were thought of as a possibility for the far future without present relevance and potential due to cost and inefficiency in production. Renewable energy, and especially bio-ethanol, has during the last decade become increasingly cost-competitive vis-à-vis fossil fuels. The term biofuels includes both bio-ethanol and bio-diesel that can function as complete or part substitutes for petrol and diesel oil respectively. Bio-ethanol and bio-diesel are produced from different feedstocks and processed differently. I will only focus on ethanol since the countries in question are ethanol producers. Since ethanol is used in combustion engines, the following considerations mainly concern the transport sector. The world transport sector may seem insignificant with respect to global warming but the transport sector is actually responsible for 1/5 of total world GHG emissions and this share is only expected to rise (ESMAP, 2005, 18). Furthermore, estimations show that the largest increases in demand for oil will on a short/medium term come from transport in inter alia large emerging markets as China and India (Girard et al., 2006). Since Brazil's and the US's main feedstocks for ethanol are sugarcane and maize, respectively, I will only focus on these in the following.

Moreover, one must distinguish between anhydrous and hydrous ethanol. Hydrous ethanol can be used in pure form in motors designed for it while anhydrous ethanol is blended with gasoline. The factor separating the two is the water content. Anhydrous ethanol has a water content of 0.5% (by volume) while hydrous ethanol contains about 5% water (by volume). Hydrous ethanol comes directly from the distillation process while anhydrous requires additional processing to remove more water (UNICA, 2007, 13).

Cost Structure of Ethanol

Biofuels are available in every country albeit in varying quantities and at different costs. Given the commercially available technology, the potential for producing biofuels in industrialized countries is small compared to import of petroleum due to high cost of feedstocks (ESMAP, 2005, 13).

Ethanol as a fuel is a special type of product since it builds directly on agricultural production. The feedstock used to produce ethanol therefore determines how production and technological development take place in the sector. Hence, ethanol production can be clearly separated into agricultural production and ethanol production that use different technologies. Also, the production of ethanol requires feedstock-specific technology. The cost of producing biofuel depends on the movements of both the price of the feedstock in question and the price of oil. Hence, it is profitable to produce ethanol when feedstock prices are low and oil prices are high and vice versa (ESMAP, 2005, 14). Feedstock costs are a major component of biofuel production cost – in Brazil it accounts for as much as 2/3 of the cost producing ethanol (ESMAP, 2005, 15). Hence, productivity improvements in the agricultural part of production are crucial for efficiency and competitiveness.

2.1 Production Process for Ethanol

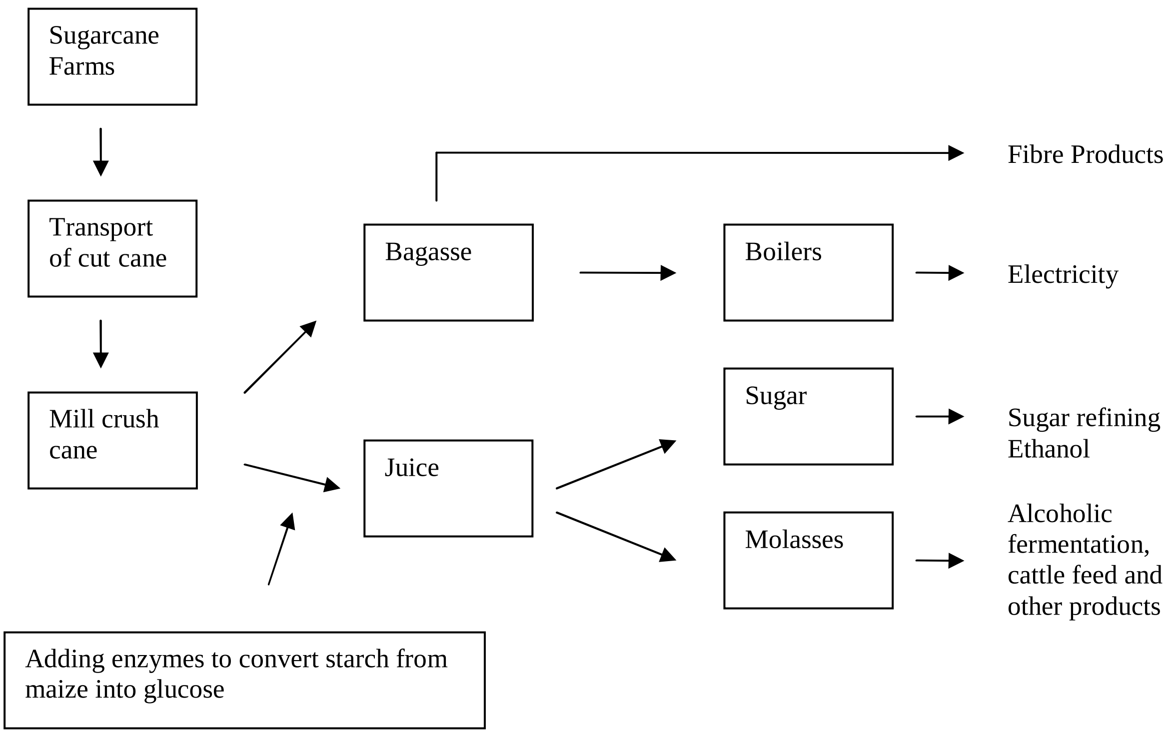
It is possible to distinguish between two very different methods/technologies to convert biomass into biofuel. One is converting traditional agricultural products like sugar and starch-rich crops. Another is to convert lignocellulosic products and residues. The former is known as 1st generation technology for biofuel and the latter is known as 2nd generation. The 2nd generation technology is not yet commercially developed but heavy investments are currently made in R&D. Potentially the latter can convert all sorts of biomass including garbage, grass and wood into biofuel at low cost.

My focus will be on 1st generation since it represents the production process used so far in Brazil and the US.

Ethanol can be produced from a wide range of organic material inter alia corn, sunflower, weed, grain, beet and sugar cane. The various feedstocks contain different amounts of starch from which ethanol is produced – sugar cane is a top scorer in this respect. Likewise, these feedstocks grow differently across climate zones. The standard is that plantation grows faster in tropical climate than in temperate zones.

Ethanol is an alcohol produced by biological fermentation of carbohydrates derived from plant material. Much ethanol is produced from sugar-rich feedstocks - in 2003 as much as 61% of world ethanol was produced from sugar crops (cane, beet and molasses). Molasses is a sugar-rich residue from ethanol production from sugarcane which can be used both for creating electricity and for ethanol through further processing. The production process of ethanol from sugar rich crops follows the process illustrated in figure 1 below. The process of getting from sugar to ethanol involves fermentation of glucose (sugar) by adding yeast where after it undergoes a process of distillation. A by-product from ethanol production is bagasse which contains a lot of fibre. It can be burnt in order to create heat that can be transformed into electricity through steam turbines (Twidell and Weir, 2006, 353).

Production of ethanol from starch-rich crops as maize is similar to the one described above. The only difference in technical terms is that another process is added to the production process. Starch needs to be transformed into glucose which is done by adding enzymes and yeast, cf. figure 1. By-products from maize are animal feed, gluten and fructose maize syrups (Girard et al., 2006, 6).



Figur 1: Ethanol Production Process

2.2 Energy Efficiency

The chemical composition of and hence the energy content in feedstocks naturally varies. Therefore it is relevant to consider how energy efficient the production of sugarcane and maize is[2].

Brazilian sugarcane is one of the most energy efficient forms of ethanol with an energy balance averaging 8.0 (WWI, 2007, 162) Brazil's natural conditions mean that soil productivity is very high and that photosynthesis is strong. The sugar fields are also rain fed which means that production does not need many additional inputs. Moreover, in Brazilian plants the residues from ethanol production (bagasse) is used for generating electricity (by burning) which implies that fossil fuels requirements are close to zero.

Maize - the production in the US yields about 1.5 units of energy for every energy input (WWI, 2007, 162). The lower energy balance stems from that corn cultivation in the US requires higher quantities of petrochemical fertilizers and toxic pesticides plus the corn processing needs additional fossil fuel (Dufey, 2006, 40). Also, the process of hydrolysis demands extra resources.

2.3 Benefits and costs of Ethanol

In this section I will outline the basic costs and benefits related to producing and using ethanol. I will do this with respect to economic, environmental and social aspects. In general ethanol has two advantages over other biofuels. One, it works with existing engines blended with conventional fuel. Two, it can be used and distributed with the existing equipment and infrastructure (Girard et al., 2006). This straight forward advantage of technological interrelatedness seems vital for the development of an international ethanol market in the short and medium term.

2.3.1 Economic Aspects

Ethanol production can serve as diversification of energy supply that entails less dependence on the increasingly expensive oil imported from instable regions. The replacement of oil imports will also mean saved foreign currency that can be applied elsewhere (it has been estimated that Brazil saved about USD 43.5 billion between 1976 and 2000) (Dufey, 2006, 38). The ethanol sector further provides a possibility for creating more value-adding to agricultural products. It can also function as a diversification of agricultural products and thereby stabilize prices. A negative aspect is that ethanol often is more expensive (price) than fossil fuels. Still, this depends on the country, the feedstock and the technology used. Also, foregone government revenue in the form of fuel tax collected from conventional fossil fuel can mean a loss of sizeable finance to public budgets (Dufey, 2006, 39). The international up-coming market could make export a profitable activity.

2.3.2 Environmental Aspects

The use of ethanol undoubtedly lowers GHG emissions - it is rather the issue of the production process that has been debated extensively (UNCTAD, 2006A, 5). When measuring GHG emission one looks at the entire production chain wherefore it matters greatly which feedstock, production

[2] Energy efficiency indicates how much energy is used to produce (input) one unit of ethanol as compared how much energy is produced (output) - if it is less than 1, it is inefficient and vice versa. Energy efficiency is unrelated to economic and environmental efficiency.

process and climate zone one is considering. One of the more optimistic reports has shown that Brazilian ethanol yields a 92% reduction in GHG as compared to standard fossil fuel (Dufey, 2006, 42). This percentage varies significantly across both reports and production processes. Still, it is possible to say that under the most efficient presently-known production terms, ethanol can be considered a green fuel (CO_2 neutral). Furthermore, the lower emission naturally helps to improve air quality locally.

The large expected expansion of ethanol production will put pressure on the agricultural frontier and threaten biodiversity. There are several conflicting estimates on the market – policy makers say that there is enough land available to expand production considerably while NGOs and some researchers claim that biodiversity will be harmed. At this moment there is no conclusion on the matter for a global perspective (Dufey, 2006, 44). There exist several reports with a local focus but they often reach opposing conclusions. Likewise, the large expected expansion furthermore requires investments in infrastructure which by nature may harm biodiversity.

2.3.3 Social Aspects

One of the often-heard social benefits of ethanol production is the creation of employment (rural) since production in the agricultural sector is normally labour intensive. Still, the latter often results in migration of workers to the expanding regions where they lead a “hard” life (CREM, 2006).

A large-scale production of ethanol can possibly increase price for the ethanol-feedstock agricultural products which can raise living standards and stabilize income for rural farmers.

The fuel-versus-food debate regarding ethanol has been intense in recent years. The argument is that if demand and hence price for ethanol increases enough then farmers will only sell their agricultural products to ethanol distilleries and thereby create a food shortage. This debate is similar to the one on the expanding agricultural frontier noted above; there are many opinions on the matter but so far no decisive estimates (Dufey, 2006, 49). Also, lacking definitions of land rights may lead to a further concentration of land ownership in the hands of the elites as the agricultural frontier expands – especially in developing countries.

3 Public procurement

In this section I will outline my theoretical approach which is founded on Edler (2006), Edquist and Hommen (1999) and Edquist et al. (2000).

The main goal is to develop a framework for analysing the role of government in stimulating innovation activity. A government has many different policy instruments at disposal but regarding innovation policy it is possible to make a distinction between demand and supply-oriented policy. In this paper focus will be put on demand-oriented policy but especially the complementary interaction between demand and supply-oriented innovation policies is interesting wherefore supply side measures also will be included.

3.1 Conceptual Issues

In this section I will give an argument for why it is relevant and necessary to consider the demand side in technological development which will pivot around the idea of the technology life cycle.

The technology life cycle is a classic model describing the development of new technology. It contains three phases – infant, mature and senile phase. The starting point in this context is that the supply-side creates a universe of technological possibilities where after the demand-side "chooses" (politically) a technological trajectory[3]. In the infant stage there are many product innovations (stemming from same core technology) and firms are producing different designs. The phase is characterised by uncertainty regarding the viability of the technology, product design and existence of demand – no one knows which design will win. In the mature phase there is more market security as a few designs have emerged as winners. It is also a phase where product innovation declines and process innovation increases – incremental innovation and adjustment processes. In the senile phase we see a market concentration and a shift of focus away from innovation activity towards cost-reduction strategies and improvement of product quality. In this framework producing the design chosen is what counts for producers (Edquist et al., 2000, 43-44). It is obvious that demand will be influential regarding choice of design in the early stages of development when uncertainty is largest as compared to the mature phase (Edquist and Hommen, 1999, 57). Demand is not only influential regarding choice of design. In the absence of demand, it is unlikely that commercialization of a given new technology would take place. Hence, demand can deliver both direction and promotion. Still, demand is not always present.

Demand-oriented innovation policy is needed when demand for innovations is "insufficient" or absent - even though technologies are ready for a market, they may lack demand. Demand for an innovation may be insufficient or absent for several reasons. The argument here is that the "market mechanism" alone is not able to induce this demand[4].

The paramount reason for the latter paradox is what can be called *path-dependency*. Evolution of technology often follows a technological trajectory which has a core technology which undergoes incremental improvements (innovations) through diffusion and learning by doing. When a new core (radical innovation) appears or if an innovation does not "fit" with the current core technology, then it will have problems getting users because to leave the current trajectory can both be and seem very

[3] The parameters for choice of technology are not universal but normally include economic, social, environmental and ideological considerations. Also, who chooses depends on mode of governance.
[4] A similar argument can be found for supply-side-oriented policy.

costly - especially if you are the only one doing it, irrespective of its superior performance (Edler, 2006). There are several reasons for why a technology switch as a user may be and/or seem costly.

One aspect could be *high entry cost* for consumers. Early users must be prepared to take on part of the producers' development and learning costs that will be higher at the early phase of a product's life cycle. On the other hand first users may get an advantage in terms of productivity or lower expenditure vis-à-vis other users. Hence, risk, cost and potential benefits are shared between producers and users (Edquist and Hommen, 1999, 45). Also, early potential users may have a *lack of information* about the innovation with respect to benefits, safety, reliability and its complementarities vis-à-vis other products. Hence, early users bear a higher risk which may detain them from using the product – the latter encompasses learning and adjustment costs. Government policy then has a possibility for socialising the risk through inter alia diffusing information or by setting quality standards. One can say that the more accumulated user experience that exists, the lower is the cost of and risk involved in product/technology switch for new users. The government can lower these costs by using the innovation and thereby demonstrating its qualities or by supplying financial incentives. In a similar fashion the absence of *network effects* will make potential users hesitate to switch[5].

Furthermore, a lack of *user-producer interaction* will hinder users in communicating their needs to producers. This can be a result of users' lack of voice, competences to formulate needs or an institutional set-up detrimental to user-producer interaction. The influence of users may be limited inter alia due to limited user competence (cf. section promotion of private demand) or if market structure hinders users to have influence.

Regarding market structures the market for ethanol is characterized by oligopoly or close-to monopoly on the supply side while demand is made up by individual consumers who need fuel for their car. The latter is a case of polypsony (many small buyers) where there is no concentration of demand/buying power. Still, cooperatives and consumer organizations are possible if strong common interests are present. In such a situation supply-push is more likely than demand-pull in terms of inducing innovation. Producers will try to obtain users' preferences through market surveys, but demand will not have a *functional role* to play once it is fragmented (relative to market size – e.g. developing computer games). Polypsony is often seen in consumer goods markets with individuals as users. It is likely that such a structure is characterised by a lack of user competence. Thus, the quality of demand is low because users are amateurs. In this situation the government could play a coordinating role – one example is minimum government standards on refrigerators (Edquist et al., 2000).

The above illustrates the relevance of demand-oriented innovation policy. In the next section I will give a more detailed presentation of public procurement.

3.2 Public Procurement

Demand-oriented innovation policy, henceforth denoted public procurement, refers to that government stimulates or creates demand to promote technological development.

[5] Network effects are characterized by that the use-value of a product increases with the number of users (mobile phones are one example).

I will follow Edler (2006) and define public procurement as *a set of public measures to induce innovations and/or speed up diffusion of innovations through increasing the demand for innovations, defining new functional requirements for products and services or better articulating demand*. Still, Edquist et al. (2000, 5) operates with the term public technology procurement which they define as *when a public agency places an order for a product or a system which does not exist at the time, but which could (probably) be developed within a reasonable period*. In their terms public procurement is an order for a simple and already existing product or system. Edler's definition seems broader by emphasizing diffusion which does not necessarily involve a new product and neither a non-existing one. Still, diffusion can easily necessitate innovation during the process. With Edquist et al.'s more "developmental" definition in mind, I will stick with Edler (2006).

Public Procurement often targets development and diffusion of technology relatively equal. Edquist et al. (2000; 21) make a distinction between the two elements with the terms developmental and adaptive procurement. Developmental procurement refers to technologies that are new to the world and radical where procurement has targeted technology development. Adaptive procurement refers to technologies that are new to the country (not the world), incremental by nature and that involves some innovation in production through adaption processes.

Innovation policy can be defined as *all public policy influencing technical development in its speed, direction or diversity so that socio-economic problems could be solved and societal needs could be met*. The latter can be distinguished in two – direct and indirect innovation policy. Indirect policy primarily regards framework conditions while direct policy refers to those situations where public agencies are directly involved. Public procurement can likewise be both direct and indirect. In the former the government or a governmental organisation solely buys products from a private supplier. In the latter the government plays a coordinating role that induces private users to demand certain products. There are naturally several intermediaries between the two extremities (Edquist and Hommen, 1999, 9). A combination of the two positions is most likely to yield the better outcome (Edquist et al., 2000, 24). Hence, when discussing innovation policy, regardless of level, it is wise to have a holistic innovation system framework in mind such that one is capable of seeing the interactions and feedback mechanisms between demand and supply-side measures and between strategic policy and framework conditions – an integrated approach.

Additionally, Edquist et al. (2000) argue that public procurement must be targeted at finding solutions to generic social needs that are unlikely to be addressed by the market. The latter leads us to the classical issue of diverse "welfare functions" – a private and a social. The social welfare function should thus be the point of departure for public procurement which then in turn can be complementary to the private welfare function. The focus on generic and practical problem-solving gives procurement a natural bias towards product innovation over process innovation (Edquist et al., 2000, 23).

Public procurement may seem more suitable especially for certain sectors - sectors where public demand traditionally makes up the lion's share of total demand as e.g. construction, energy and health care (in some countries).

Edler (2006) indicate that public procurement is at least as effective as R&D subsidies in terms of promoting innovation. Public procurement seems to create a linkage between innovation and production that is not possible to the same extent for supply-side measures as e.g. R&D subsidy. One can argue that demand-oriented innovation policy induces both *technological and production capacity* while R&D subsidy mainly affects the former.

3.2.1 General versus Strategic Public Procurement

Considering the coordination of public procurement one can distinguish between general and strategic policy. With respect to *general procurement* you basically only have minor agencies within ministries to implement procurement targeting innovation. The latter implies that there will most likely be a lack of coordination and willpower to change status quo which will result in an uncoordinated outcome. Execution of public procurement policy in a *strategic* manner implies having innovation policy higher up the ranking of political priorities such that specific technologies, products, services or sectors are targeted in terms of public demand (Edquist et al., 2000).

3.2.2 Promotion of Private Demand and Regulation

Indirect demand-oriented policy is when the government promotes private demand for innovations. Promotion of this nature normally focuses on *changing cost structures* inter alia through financial subsidies or tax reliefs. Such an intervention can align prices according to the social welfare function. The primary aim of changing cost structure is to stimulate diffusion of innovation.

Diffusion of innovation can also be stimulated through “soft” steering (as opposed to “hard” pecuniary measures). The idea is to affect private users’ willingness to accept, demand and apply innovations through inter alia awareness building, competence building and information campaigns. Creating awareness of a new product with for example an information campaign will reduce potential users’ uncertainty and increase their information about it. Campaigns could also in a complementary manner help to build user competencies that would also reduce uncertainty plus increase both the real and the perceived use value of the innovation. Following the above, user competence (skill, information, knowledge and perception of newness) of users (the quality of demand) are vital to the successful diffusion of innovations

Within a framework of user-producer interaction in the narrow (individual consumer needs) and in the broad sense (societal needs/visions), government can manoeuvre with its policy instruments and discursive intelligence. The logic with soft steering is that the government through policy measures can affect the preferences of users which will put pressure on producers to apply to new standards which again will push them to innovate (safety in automobiles) (Edquist et al., 2000).

“Hard” and “soft” steering as outlined above are examples of how regulation of the institutional framework can stimulate demand for an innovation. Changing the institutional set-up towards stricter regulation can influence demand conditions positively. Regulation of industry that forces firms to apply to certain standards can simultaneously inform potential users about the products - e.g. regulations that determines which materials to use in production, quality of products and consequences of production as environmental impact.

This concludes my theoretical considerations so far. In the following section I will move on to look at the Brazilian experience with ethanol production in terms of the above.

4 The Ethanol Sector in Brazil

Brazil has a long history of ethanol production which I will outline in this section. The ethanol production became a serious political target as a response to the oil crises in the 1970s where the government launched a massive public-funded program to promote ethanol production and use. Still, the production and use of ethanol started much earlier as will be shown below. After going through the various phases of ethanol production in Brazil I will reconsider the history in the light of demand-oriented innovation policy.

Brazil currently produces 45% of world ethanol. In 2005 Brazil produced 14.5 billion litres and plans to produce 30 billion litres of ethanol by 2015. The sugarcane industry makes up 2.35% of Brazilian GDP (CREM, 2006, 29). The largest importers of Brazilian ethanol are US, India, Korea, Japan, Sweden and Holland (ESMAP, 2005, 29).

Ever since production of sugar was introduced in the northeast region of Brazil in the 17th century it has been an important agricultural activity in the country[6]. Sugar production was established (by the Portuguese) in order to break down France's world monopoly in sugar supply which was produced at the Caribbean Islands (Moreira and Goldemberg, 1999, 229). Ethanol was first used as a fuel in Brazil in 1903 when the first national congress on industrial applications of alcohol proposed to establish an infrastructure to promote ethanol production and use. Also, the use of ethanol was compulsory many places in the country during World War 1 and production amounted to 150 million litres by 1923. The first policy demanding ethanol (5%) blended with gasoline came by a federal decree in 1931 which also put forward guidelines for its transportation and commercialization – ethanol production reached 650 million litres in 1941 (Moreira and Goldemberg, 1999, 231).

After World War 2 Brazil experienced a high-growth period, but the economic policies at the time reached their limits in the early 1960s which partly served as the basis for a military coup in 1964. The coup introduced a new approach to policy making and a new strategy for economic development which involved foreign capital that was to help the country achieve economic independence. The multinational car industry soon became the flagship of this industrialization model – between 1960 and 1976 the country's car fleet increased tenfold and consumption of oil (80% imported) increased at an average rate of 16.2% p.a. (while the economy grew at an average of 11.2%). Hence, the dependency on oil imports put the country in a very vulnerable situation with respect to the coming oil crises in the 1970s (Lehtonen, 2007).

Ethanol was produced as a niche product and a by-product from the sugar industry until the 1970s. It had functioned as an auxiliary market in the sugar sector helping to dampen the influences of price fluctuations. The technology for producing ethanol at a large scale was already present and the sugar industry was loosely tied to the transport system. During the 1960s the government had supported the sugar industry intensely in order to modernize and increase production so that Brazil could be competitive at the world market and increase its market shares. Hence, the capacity of the sector nearly doubled during the first half of the 1970s. There was a sudden collapse of the sugar world market prices in 1975 which threatened the now politically powerful sugar and alcohol industry because it was struggling with overcapacity (Lehtonen, 2007, 8).

[6] There are two main regions for ethanol production in Brazil – the north east of Brazil and the Sao Paulo region (south-centre). Significant differences exist between these regions in terms of ownership structure, productivity, employees, wage, technology and management. Still, these will not be explored further in this paper.

The above describes the context in which the Brazilian military dictatorship/government initiated a large-scale program for promoting ethanol. The program, called Proalcool, was launched in 1975 in response to the 1973 oil crisis. The support mechanisms in the program were gradually phased out during the 1990s. During its lifetime it underwent several changes as reactions to other external events that will be used to structure the below account of Proalcool into five phases.

4.1 History of Proalcool

4.1.1 Phase 1: 1975-1979

When the first oil crisis hit in 1973 the government (whose legitimacy rested upon persistent economic growth), car manufacturers and sugar producers came under pressure. In the presence of fuel shortage and overproduction of sugar, expansion of the production and use of ethanol seemed as a satisfactory solution. Hence, the sugar-alcohol sector became an integral part of the transport regime. Proalcool was launched on the basis of the following *objectives*: save foreign currency, reduce regional disparities and income inequality, increase GDP and capital goods production. The aim was to increase production fivefold by 1980 which was more than achieved (in 1979) due to prevailing overcapacity in sugar production. One policy measure to reach the goal was to use blending regulation – the maximum was 20% of ethanol to be blended with gasoline because engines at the time would suffer damage at a higher ratio (Lehtonen, 2007, 11). Thus, the goal was to produce anhydrous ethanol. Investment-friendly policies stimulated construction of distilleries that were annexed to existing sugar cane mills (Walter and Cortez, 1999).

4.1.2 Phase 2: 1979-1985

When the second oil crisis hit in 1979 the consumption of ethanol could be pushed no longer under the given technological possibilities – the max limit of about 20% ethanol blend had been reached. Thus, technological development was necessary in the form of cars purely running on ethanol. There had been successful experimentation in government labs that were now put to commercial use and the government persuaded the car industry to heavily invest in production of 100% ethanol cars. Also, the former overcapacity in the sugar sector was now fully exploited and new investments had to be made if further expansion was to take place – especially there was a need for support for autonomous ethanol distilleries. New production targets were set – the production in 1979 (3.4 billion litres of ethanol) was to triple and make up 10.7 billion litres by 1985. Several autonomous distilleries were constructed on the basis of extensive public subsidies. In the period 1983-86 more than 90% of car sales were ethanol cars and in the mid-1980s ethanol amounted to 50% of Brazil’s fuel supply (Lehtonen, 2007). The sale of cars meant that demand for and production of hydrated ethanol to a large extent replaced production of anhydrous ethanol (Walter and Cortez, 1999).

4.1.3 Phase 3: 1985-1990

World oil prices fell sharply in 1985-86 while at the same time Brazil experienced serious inflation and started a series of reforms. The latter meant that subsidies and support were phased out. As a result hereof production of ethanol stagnated and eventually started to decline – an augmenting factor was that the price of sugar on the world market was increasing. Still, these downward trends did affect the production of cars – automakers undaunted continued to produce ethanol-only cars (and even increased production). In late 1980s nearly all sold cars were only running on ethanol. This mismatch in trends resulted in a serious shortage of ethanol by 1990 which caused protests and loss of credibility for ethanol as a fuel. Ironically, Brazil was forced to import methanol from the US due to the shortage. Gradually political support for the ethanol program weakened. Automakers soon restructured production to build gasoline cars (Sandalow, 2006).

In spite of the phasing out of public subsidies to the sector, more investments in R&D focusing on improving productivity were undertaken. One key point was the use and development of by-products from the production process (e.g. bagasse to produce electricity and heat). The alcohol programme was kept alive due to (lets say lock-in conditions) employment and clean air benefits. Also, substantial R&D had been conducted which amounted to a significant capacity in biotechnology. The state of Sao Paulo and some firms continued to invest heavily in R&D on sugarcane crop improvements (Lehtonen, 2007).

4.1.4 Phase 4: 1990-1999

Since 1997 the role of the state has solely been to regulate framework conditions and not to intervene as forcefully as earlier. Subsidies for the ethanol sector ended in 1997 where the sector was fully competitive vis-à-vis fossil fuel. In the period 1990-1999 sales of ethanol cars declined due to incidents of the latter period and a relatively low price of oil. The ethanol sector's role in relation to the fuel transport regime gradually diminished but it found a stable position as an integrated, but minor, part of the regime. An important point in this period is that due to technical development producers had the opportunity to switch production between sugar and ethanol depending on price movements on the world market. This strategy was followed throughout the 1990s with some success since price of sugar was good while demand for ethanol declined. During the end of this period world price of sugar fell though and overproduction was a significant problem which gradually detoriated the competitiveness of the industry. Overproduction meant that ethanol was produced in large quantities – that were not demanded in the market. This led to complete use of existing storage facilities and the construction of new. In the late 1990s Brazil had a high interest rate and an overvalued currency. The former meant low investment activity (especially in agricultural and industrial segments of ethanol production) which made it difficult for Brazil to compete on the world sugar market. These factors combined gave a dim outlook for the future of the program at the end of the 1990s (Walter and Cortez, 1999).

4.1.5 Phase 5: 1999-present

A range of factors have recently brought renewed interest to ethanol production. The main factor has been the rising oil prices but also the fear of terrorism (and hence instability in oil supply and prices) and the surge in the political interest in global warming have revitalized the ethanol sector. Brazil's plans are big: one goal is to produce 30 billion litres in 2015 which would require extra 3 million hectares of new land into cane cultivation. A bit more ambitious plan made by the ministry says that Brazil should aim at producing 200 billion litres by 2025 which would require an increase of cultivated area from 6 million hectares to 30 million. The latter would put significant pressure on the potential conflicts with environmental damage and food scarcity.

Another important event in the revitalization of ethanol production and use was the introduction of the flex-fuel vehicle (FFV) in 2003. The FFV is able to drive on any blend of pure ethanol (E100) and E20 (20% ethanol) and with E100 significantly cheaper than E20, the FFVs have been a massive success. In December 2005, 70% of new light-duty vehicle sales were FFVs and the cumulative sales since 2003 amounts to 1.3 million vehicles (WWI, 2007, 253). The FFV has allowed Brazilians to tank fuel according to the changing relative prices of fuels.

Following the revitalization of interest in and production of ethanol, the presence of foreign firms and FDI is currently increasing in the sector – the participation of foreign capital is about at 4.5% in production of sugar and ethanol. Firms are attracted by the low production costs which are among the lowest in the world.

The role of the state has gradually diminished as deregulation increased. Today, there are state organs monitoring and managing the sectors further deregulation on its way to becoming a free market. An area where the state is still active involves the sector's environmental impact as for example waste management, soil quality, biodiversity, and ground water quality. These areas are still recipients of public R&D investments and support – here it can be possible find productivity increases and lessen negative effects of ethanol production. Hence, the competitive edge now concerns R&D which inter alia is coordinated by the ministry of science and technology (Lehtonen, 2007). The sector still enjoys some policy support since the blending policy (min. 20%) and import tariffs on ethanol (30%) and sugar (20%) are still in use.

4.2 Policy analysis

4.2.1 Policy

In this section I will analyse the Brazilian experience, as outlined above, on the basis of this paper's theoretical section. I will start with some general observations and then structure the analysis according to the different phases of Proalcool since policy objectives gradually changed.

Some parameters changed during the course of Proalcool while others remain the same. The latter concerns the structure of demand. Demand consists of individual consumers who (when unorganized) do not posses the capability/power to change fuel production and use radically which makes a case for public procurement.

During the history of ethanol production in Brazil, the state has played a vital role from the very beginning both when it constituted a niche market and once it became large-scale production. In the following I will focus on the latter part. When Proalcool was launched in 1975 there was already a minor production, an overproduction of sugar and available technology for large-scale production, but both large-scale demand and supply were absent. Since technology existed it only had to be "politically chosen" and thereafter diffused. Diffusion policies targeted both demand and supply.

In the first phase of Proalcool where anhydrous ethanol was to be blended with gasoline, the primary demand-oriented policy instrument was the blending policy (20% ethanol). Mandatory blending policy automatically created a huge demand for and use of ethanol. On the supply side several policies were enacted to support production of domestic ethanol – inter alia investment subsidies, credit guarantees and favourable interest rates on loans in order to promote investment in ethanol distillation equipment. Also, a minimum price for ethanol was set by the state. Moreover, public investments were made in a distribution system including installation of alcohol pumps in nearly all gas stations (Lehtonen, 2007). Moreover, public investments were made in R&D in collaboration with universities to improve productivity. Besides, public marketing campaigns were initiated trying to link ethanol with feelings of nationalism which reflects "soft" steering of users. Lastly, also import restrictions on ethanol were enacted to protect domestic producers.

The second phase of the program shifted attention from anhydrous to hydrous ethanol which entailed a reorganization of ethanol production. New types of distilleries were necessary which lead to further investment subsidies. Still, at this point no cars could run on pure ethanol wherefore demand was absent. The state initiated four actions to solve the problem. Firstly, it made contracts with multinational car producers to make assembly line production facilities and produce 250.000 cars by 1980 and 350.000 in 1982. Secondly, special tax incentives were given to purchasers of ethanol cars. Thirdly, the price of ethanol was kept below those of gasoline. Lastly, the state purchased a significant number of cars for the public car fleet inter alia for taxies. The latter action both functioned as a demonstration project and forced the companies to start large-scale production. The second and third action represents hard steering (regulation) through pecuniary incentive structures of consumers. To place an order of 250.000 ethanol cars that were not yet in production comes close to Edquist et al.'s (2000) definition of public procurement. The order forced through commercialization of new technology.

In the period 1985-1990 ethanol production faced dire conditions with the price of sugar rising and the price of oil falling which led to a significant fall in production. Also, the first tendencies to liberalize the country's economy through public deregulation appeared which put subsidy policies under pressure. Still, the state continued, and even increased, subsidy support in order to help the industry survive. One important reason for the continued support to ethanol production in spite of unfavourable cost structures and public dissatisfaction was that Brazil at this point had developed an idiosyncratic experience in sugarcane ethanol production. The country had built a capability base in biotechnology regarding ethanol production through years of R&D, which the state was not willing to lose because of current market prices. For the same reasons public support for R&D has been sustained since the start of Proalcool (now focused on environmental impacts) which has contributed to the technological development and thus competitiveness of Brazilian ethanol.

From 1990 onwards the industry was "liberalized" and public support was gradually removed. Minimum blending policies and import tariffs were not dismantled though and still persist.

Considering the technology life cycle as an approach to the Brazilian experience one can argue that the ethanol technology, which was quite simplistic, was politically chosen where after the state was concerned with diffusion. In the process of diffusion some policy measures targeted supply, others demand. The main instrument during the first and second phase of the Proalcool was regulation through "hard" steering. The situation at the initial phase of Proalcool was special in that the cost and uncertainty, which is normally related to switching products as a user, must have been lessened by the need-driven aspect of the oil crisis. What remained of uncertainty and cost regarding the switch to ethanol (2nd phase) was dampened by price control, tax incentives and demonstration projects.

The issue of user competence has not been explicit in the story of Proalcool. Consumers naturally had expectations to both fuel and ethanol cars on the basis of fossil fuels. Hence, the functional specificities of both fuel and car were known to producers. Likewise, user-producer interaction (in the ethanol market) has not been present which is probably also related to the polysonic market structure. It is possible that user-producer interaction was more significant between sugar producers and ethanol producers, but this I do not have information about.

On overall the Brazilian state primarily conducted indirect public procurement by stimulating private demand by use of regulation. The only exception was the order of ethanol cars for the public car fleet. With respect to the distinction between general and strategic public procurement, then I will argue that the policy approach regarding ethanol has been very strategic even though it has changed to a more general character during the 1990s. The necessity (national crisis) of developing the sector in the 1970s made ethanol production an explicit political priority.

4.3 Technological Development

Here I will explore the link between the policy analysis and technological development to see if there are any indications that public procurement has a positive effect.

Firstly, technological development must be divided into at least two parts of the production chain - sugarcane production and ethanol production.

4.3.1 Productivity Improvements

There has been substantial productivity improvements in both sugarcane and ethanol production. Sugarcane productivity has increased 2.3% p.a. between 1975 and 2004 while ethanol productivity has increased 1.17% p.a. on average in the same period (Matines-Filho et al., 2006). Furthermore, the following results have been achieved in the state of Sao Paulo since the start of Proalcool (UNICA, 2007, 67): 33% increase in tons of sugar per ha; 8% more sugar extracted from cane; 14% efficiency improvement in conversion of cane sugar into ethanol and 130% productivity increase in the fermentation process. Moreira and Goldemberg (1999) interpret Brazil's falling cost per unit as reflecting a learning curve.

The Technological developments that lie behind the above improvements can be divided into two phases and summarized as below:

- 1980-1990: introduction of new cane varieties; new grinding systems, fermentation with larger capacity; use of vinasse (by-product of sugar production) as fertilizer; biological control of sugarcane beetle; optimization of agricultural operations; autonomy in energy.

- 1990 – 2000: start of energy surplus sales; improved technical, agricultural and industrial management; new sugarcane harvesting and transportation systems; advanced industrial automation (UNICA, 2007, 66).

Energy co-generation in the production of ethanol has emerged as an important element in reducing cost and making ethanol more sustainable in terms of necessary fossil-fuel inputs. On average, one tonne of cane leaves about 280 kg of bagasse behind whereof 90% is burned to produce steam which in turn is used to generate electricity and mechanical power for the distillery mills (Moreira and Goldemberg, 1999, 237). By investing in inter alia larger steam turbines the latter technology can be made much more efficient though and even more electricity can be sold to the electrical grid (sale of electricity).

4.3.2 R&D

The productivity improvement and technological development that have created the competitive advantages of Brazilian ethanol production described above were results of continuous public investments in and support to R&D on both sugarcane and ethanol production. Still, private R&D also played an important role – especially in the later years.

The first public organization related to ethanol was the Instituto do Acucar e do Alcool (IAA) which was established in the 1930s. IAA regulated the production of ethanol until the 1980s in cooperation with the various governments. The first efforts to conduct R&D in the sector were initiated by Instituto agronomico de campinas (IAC) and Instituto Biológico where the former was under the control of Sao Paulo state government – hence it was a public initiative. In 1970 a private cooperative, called Copersucar, of sugar and sugarcane producers established the Center for Technological Research which was an important contributor to the expansion of sugarcane production. By 1971 the federal government created the Programa Nacional de Melhoramento da Cana-de-Acucar (Planalsucar) whose primary focus area was the development of new cane varieties. Much of the public funded R&D was stopped with the deregulation of the industry in the late 1980s, but public R&D still exists. For example significant investments in basic research and molecular genetics have recently been made by the state of Sao Paulo plus an 8 million USD investment in breeding improvements (Martines-Filho et al., 2006). Public R&D is now coordinated by the ministry of science and technology.

Instead the private share of R&D in sugarcane and ethanol production has increased since the early 1990s. The Copersucar cooperative metamorphosed into center for sugarcane technology (CTC) which carried on the R&D section. CTC is a private non-profit research centre financed by 152 sugar and ethanol producers. CTC conducts R&D in most parts of the production process – results are reserved for the financing members. CTC has developed an extensive collaboration with both domestic and foreign universities and research centres – here among four Brazilian universities from the state of Sao Paulo. The R&D performed by CTC is at times competing with strictly private R&D conducted internally by the largest firms in the industry (e.g. Dedini). Moreover, partnerships among private firms and universities are common. Especially the interuniversity network for development of the sugarcane sector (Ridesa) which consists of seven domestic universities. Ridesa was established as a reaction to the closure of Planalsucar in 1991 where after Ridesa absorbed Planalsucar’s R&D capacity (Fontana, 2007).

The sugarcane and ethanol sectors seem to be the exception to the otherwise weak ties between industry and universities in Brazil (Fontana, 2007). Currently R&D is being done on transgenic sugarcane but legislation necessary for commercialization is slowing down the process (Martines-Filho et al., 2006).

4.4 Conclusion

The link between technological development and public procurement is of an indirect nature. The demand-oriented policies made it possible to sell the production of ethanol which in turn made continuous and incremental technological improvements possible. Public procurement was only one part of an integrated approach to industrial policy where demand and supply-side measures (here infrastructure investments, investment subsidy, R&D subsidy) are each others' prerequisites in order achieve technological development.

5 Ethanol Sector in the US

5.1 History of Ethanol production in the US

Ethanol engines were built already in the late 1800s by inter alia Henry Ford and Nicholas Otto. The Ford Model T in 1908 was a flex fuel vehicle (FFV)[7]. It had carburetors that could be adjusted to use gas, ethanol or a mix of them. World War 1 meant a surge in demand for ethanol and production increased. After the war demand decreased but car manufactures were still interested (since it was not decided yet which fuel with be the dominant). Engines of the time had problems of "engine knocking"[8]. A solution to this was found in the form of tetraethyl lead in 1921 which was then added to gasoline despite health concerns. Thus, gasoline became the preferred fuel. Ethanol mixed with gasoline experienced a revival in the 1930s due to low corn prices – government launched a support plan for farmers in trouble. After World War 2 gasoline totally dominated the market due to low price plus several new oil discoveries reduced the perceived urgency in finding replacements for petroleum (Solomon et al., 2007, 417).

The US interest in ethanol (also) experienced a revival as a response to the oil crises during the 1970s. The initial outcome was the 1978 energy tax act which was supposed to promote production of fuels alternative to gasoline. It included a subsidy policy to make a 10%-ethanol fuel cheaper. The wars and instability in the Middle East helped keep the ethanol industry alive even when oil prices were low. Several policy initiatives to support the ethanol industry were accepted in congress during the 1980s with reference to energy security (CFDC, 2007). Among the policies were for example tax benefits, loan and price guarantees to support producers and blenders. Still, the industry faced difficult terms due to low oil prices.

The rise of ethanol production and use started in the early 1990s even though ethanol-promoting policies can be found back in the 1970s. The 1990 clean air act was the beginning. It continued with the 1992 energy policy act which encouraged the use of alternative fuels. Also, it was made mandatory that a minimum percentage of the US federal state fleet of vehicles and the fleets of alternative fuel providers ran on alternative fuels. Average ethanol consumption grew around 2.5% p.a. during the 1990s (OECD, 2004, 148). That policy support has been significant can be seen from a report from the US treasury which estimates that the lost revenue from giving tax exemptions to ethanol producers between 1980 and 2000 is about 11 billion USD (ESMAP, 2005, 66).

One of these policies was the "alternative motor fuels act" of 1988 which provided auto companies with tax credits for every flex fuel vehicle or alternative-fuel vehicle they produced. The initiative proved inefficient though, partly because it was very difficult to get E85[9]. Today there are about 5 million flex fuel vehicle s in the US but only around 1000 retail outlets that sell E85, wherefore the majority rely on gasoline. The latter reflects the importance of infrastructure for distribution (Solomon et al., 2007).

[7] Vehicles capable on running on any blend of gasoline and ethanol.
[8] Early ignition of the fuel that causes the motor to "jump".
[9] E85 is a fuel containing 15% ethanol and 85% gasoline.

Despite inefficiency, ethanol production continued to rise during the 1990s. Continued low oil prices and bad harvests that doubled the price of corn brought ethanol producers into trouble. The latter led several Midwestern states to accept more subsidies in order to help the industry survive. The last decade has been very different (1997-2007) which is reflected by that the 2005 production level is triple that of 1997. Besides the importance of the influence of terrorism, instability of oil supply and global warming, the public health problems with leaded gasoline led to its prohibition in the 2002 which greatly resurrected interest in and production of ethanol.

Furthermore, a federal "renewable fuel standard" was implemented in 2005 which is to support increases in production to 2012. The "renewable fuel standard" contains a mandatory blending policy based on use-targets for ethanol. In 2006 2.78% of transportation fuel sold must be ethanol which makes up 15.14 billion litres that should increase to 28.39 billion litres by 2012 (UNCTAD, 2006B, 15).

Currently much support is given to commercialization of 2nd generation technology in the form of R&D funding plus grant and loan guarantees to overcome uncertainty of finance. These policies both have a short-term commercialisation focus but also a longer term aspect that could make the sector much bigger.

5.2 Policy Analysis

In this section I will analyse the US experience in ethanol production, as outlined above, on the basis of this paper's theoretical section

Regarding market structures, then demand structure is similar to Brazil's since users primarily are individuals, which in itself makes a sound case for procurement.

On the supply side concentration is relatively high both in maize and ethanol production. The maize sector is in general the sector in the US that receives most government support and it is given on terms mainly benefitting large corporations. A similar picture emerges regarding concentration can be seen in the ethanol sector - the four largest firms produce 58% and the eight largest produce 71% of production (ESMAP, 2005, 35).

It is helpful to constantly distinct between policy at the state level and at the federal level – these may compliment or conflict with each other. Still, policy instruments at both federal and state level have been present for the last 30 years targeting both the supply and demand. At the federal level excise taxes for producers have been the most-used instrument. It is simple and easy to use but it has had and still has great influence on the sector (Solomon et al., 2007, 422).

The state furthermore established demonstration projects to promote the use of ethanol. As part of the alternative motor fuels act of 1988 programs for R&D were created and demonstration projects of both vehicles and fuel took place. The latter is clearly intended to reduce potential users' uncertainty and increase their competences. Additionally, financial incentives were given to car manufacturers for producing flex fuel vehicles (CFDC, 2007).

Moreover, the "energy policy act" of 1992 required parts of the car fleet belonging to federal and state authorities and to ethanol producers should be alternative/flex fuel vehicles that had to be able to run at E85 (85% ethanol). The latter is an example of direct public procurement where the state acts as a buyer for a not fully commercialized product.

More recently, the mandatory blending policy (cf. “renewable fuel standard”) has been increasingly used to increase demand. Also, subsidies for supporting R&D in both feedstock and ethanol production have grown recently.

At the state level the picture is naturally more blurred since there are 51 states that act independently. Still, policies on state level seem to have supplemented the federal policies – more in some states than others. For example an exemption on road-use tax and producer credits were offered in 11 states. Minnesota is accentuated as a successful example of good state policy on the area. The state has managed to combine both demand and supply side policies plus it has the best infrastructure for ethanol/E85 in the country (300 retail outlets) (Solomon et al., 2007, 423).

Regarding the distinction made between general ands strategic public procurement, it seems that general public procurement has been the dominant form in the US. Ethanol production has received continuous support, but there have not been any strategic attempts to go large scale. In general one can say that public procurement has not been widespread in the ethanol sector besides the recent mandatory blending policies – it is clearly the supply-side that has gotten the most attention. With respect to Brazil’s experience, a consistent and favourable price regulation could probably help. Having Brazil in mind, then the situation was clearly very different in the 1970s in the two countries – the US was having an economic cold while Brazil was seriously ill regarding energy.

5.3 Technological Development

Even though the political attention to ethanol production has not been as intense in the US as in Brazil, productivity improvements have still been significant – especially in the agricultural production. Maize yields in the US increased from 86 bushels per acre in 1975 to 142 bushels per acre in 2003. A large part of the productivity increase comes from the use of genetically engineered crop varieties that hold large potential but are still politically controversial (ESMAP, 2005, 55).

Productivity improvements between 1970 and 2000 in ethanol production (ESMAP, 2005, 57):

- Costs on energy and water fell from 0.22 USD per gallon to 0.14 USD per gallon (36% improvement)
- Labour cost fell from 0.24 USD per gallon to 0.04 USD per gallon due to use of computer automation and increased plant size.
- Chemical cost increased and is now about 0.09 USD per gallon.

The focus of R&D in the US is inter alia on efficient use of residue products, in this case corn stover which can be dried and used as (animal) fodder. The sale of by-products amounted to 24% of total revenue in 2004. Still, R&D is mainly concentrated on developing 2nd generation technology because basically US feedstocks are too expensive to compete with Brazilian ethanol production. It is actually cheaper to import Brazilian ethanol to the US than internal production in spite of import tariffs (UNCTAD, 2006B, 16).

5.4 Conclusion

In general the development of the sector in the US has been far more gradual that in Brazil whose strength of emphasis changed radically and quickly. In a similar fashion the development of the US ethanol sector has been far less driven by necessity which has probably kept the issue from being a national priority (until recently). Policies supporting the sector have mainly concerned regulation on incentive structures (hard steering). Still, it seems that these policies have been most focused on the supply side. One reason for the latter could be the work of US's powerful agricultural lobby. Still, it might hold importance that the US has applied mandatory production policy instead of mandatory blending policy (as in Brazil). One could argue that the latter puts stronger emphasis on market development (demand-pull) and thus development of infrastructure. It is unclear how large a price difference between E85 (E15) and gasoline that exists (and has existed), but it seems to have been negligible (authors responsibility). Moreover, the lacking investments in infrastructure have certainly dampened the effect of the price difference. It appears that demand or public procurement has not been instrumental in developing the ethanol sector in the US – not in quantity nor in technological development.

Moreover, nearly all US productivity improvements have come from feedstock production which benefit agricultural production in general but not ethanol particularly. One can deduct from the latter that focus has not been explicitly on developing technology for improving ethanol production which may be related to the lack of consistent promotion of ethanol and political will hereto.

6 Conclusion

Brazil and the US have experienced very different development paths with respect to their ethanol sectors. One main difference can be attributed to the "policy-mode" which refers to my earlier distinction between general and strategic policy. The policies supporting ethanol production in the US can be characterized as general since it has been applied inconsistently at various policy levels and at changing areas of the agriculture-ethanol-transport complex. Induced by the necessity characterizing the situation at the time, Brazil opted for strategic policy – it became a national priority which produced some consistent policies and some less consistent. Both the US and Brazil have subsidised the supply side in terms of tax breaks and investment support but only Brazil made serious use of demand-side policies. The mandatory blending policy, even though simplistic, stands out as an indicator of the latter. Also, the emphasis given to investments in distribution infrastructure and auto production (market supporting/creating investments) reflects the Brazilian political dedication.

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