A Global Model for Agriculture and Bioenergy: Application to Biofuel and Food Security in Peru and Tanzania

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Abstract

This paper describes a global model for agriculture and bioenergy (GLOMAB) that incorporates biomass, biofuels and bioelectricity sectors into the GTAP-Energy model by expanding the global GTAP database, production and consumption structures. Biofuels are separated between first- generation (sugar ethanol, starch ethanol) and second-generation (cellulosic ethanol) biofuels and associated biomass feedstocks (maize, sugar cane, crop residues, woody biomass). Beside biofuels, the model also incorporates bioelectricity (as separate form conventional electricity) which competes for the same biomass feedstocks with cellulosic ethanol sector (agricultural residues, woody biomass). With this broad-based representation of the bioenergy system likely to prevail over the medium term (2010-2020), the model offers a useful framework for analyzing the growing influence of biofuels on agricultural markets, the implications biofuel subsidies and tariffs on trade in biofuels and biomass, and a comparative analysis of alternative policies to mitigate role of GHG emissions (mandates versus carbon taxes).

In this paper, we apply the model to an analysis of biofuels and food security for two developing countries – Peru and Tanzania, and examine the implications on food security. Preliminary results for Tanzania show that the implications of ethanol expansion depend on the feedstock used with Cassava-ethanol draws more additional labor and land then sugar-cane based ethanol. Moreover, greater productivity of feedstocks can alleviate the pressure on new lands required to meet new biofuel needs. While sugar cane ethanol may be more efficient in terms of resource use compared to biodiesel, the latter may have better opportunities for food security in terms of labor employment. However, suggestions for further research are suggested including expanding the CGE analysis to include micro-simulations where the implications for food security are assessed for specific household types.

JEL Classification: C68, Q18, Q42, R14
Keywords: Biofuels, Renewable Energy, Biomass, Agricultural Markets, Computable General Equilibrium (CGE).

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Introduction

In recent years, there has been a rapid growth in biofuel production in the US, Brazil and EU, making biofuels a global phenomenon. Such an expansion is expected to continue broadly in the future (FAO-OECD 2008). Also, an increasing number of developing countries initiated biofuel production to meet domestic market and international demand. Those developing countries interested in biofuels are motivated by a variety of objectives; some seek to exploit their perceived comparative advantage in biomass production, especially when land, water and labour are not limiting; other countries try to diversify energy sources, alleviate dependence on imported fossil energy; foster new paths for agricultural or rural development, including opportunities stemming from global demand imperative of combating global warming and controlling green house gas emissions. Moreover, developing countries pursuing biofuels are adopting different feedstock-biofuel (bioenergy) pathways, some concentrating on one or few key biomass drivers (e.g., oil palm in Malaysia, sugar cane in Peru; cassava in Thailand), others on strictly non-food feedstocks (Jatropha in India, China) or important by-products (molasses in India).

Developments of biofuels imply new technologies for using biomass and biofuels; and increasing oil prices opens the way for a potential for new industries in developing countries (Slater, 2007). However, these biofuel opportunities have yet to be assessed in terms of cost effectiveness, resource management and sustainability criteria, including land, water and labour use requirements and competition with other activities, all of which are critical for long term economic viability of bioenergy projects in developing countries. Factors likely to play a role include: feedstock/production systems; existing crop production structure; processing industries; and patterns of land holding and access, among others.

In terms of feedstock production structures, there is evidence that bioethanol production may favour large scale production systems, given economies of scale and the need to control or reduce cost per unit of output. A review of production costs in OECD countries (RDBB, 2008; OECD 2006) shows that feedstocks represented the largest cost of biofuel production which could range from 1/3 to 2/3 of total cost (RDBB, 2008; OECD, 2006). The implication is that improving economic cost effectiveness of biofuels requires raising feedstock productivity to lower its price to biofuel plants. This may include adoption of improved varieties, intensified management, and a move to larger holding to achieve economies of scale, and shift to more capitalized production. The extent of adaptation of small farms via cooperatives or outgrowers schemes or cooperatives may be difficult, unless conditions are particularly favourable such as integrated markets or under pro-active policy support (such as in Brazil for soybean supply for biodiesel).

The impact of biofuels on labour and employment depends on the types of feedstock production systems. For examples, oilseeds for biodiesel are more amenable to job creation because they can be profitable under a labour-intensive production system.

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Policy can also play a role in favouring labor intensive production; for example Brazil policy about amount of oilseeds processors must purchase from family farms.

The potential implications of biofuels on food security play out in the expected amount of land demanded by biofuels and the degree of substitution away from food crops. At a different level, biofuels affect food security via its differential effect on income and labour markets and hence affect the household purchasing power for food and other essentials quite differently. Empirical work documented these effects is scant up to now.

Biofuels and Food Security

Soaring food prices, beginning in 2007 and peaking in 2008, have highlighted the potential implications for food security. Inevitably, the fast growth of biofuel demand was criticized for its contribution to the price hikes and heightened the need to examine the implications of biofuel developments on food security.

The linkage between biofuels development and poverty or food security is not strait forward. Food security is a multi-faceted concept. It can be approached at various levels: (i) at the global level, there is the need to secure adequate supplies and ensure sufficient global production; (ii) at the national level are strategies and policies for food production, availability, distribution, and ability to finance import requirements; (iii) at the micro or household level, food security plays out through changes in incomes and prices affect the ability to access adequate food, and (iv) finally at individual intra-household level, adequate nutrition and well being become the focus.

Needless to say that, given this multi-dimensional nature of the *food security* concept and the very short history behind the biofuel growth at the national and global levels, our understanding of the biofuel-food security links are very limited and little documented empirically. One requirement for such an assessment is to first start by identifying the major sources of income of the poor and determine how biofuel and feedstock expansion will impact these sources, particularly households whose largest income source comes from labour; hence the importance of evaluating the overall impact of biofuel expansion on real wage changes.

At the macro level, the decision to expand feedstock production for biofuels will likely induce substitution between various economic activities (agricultural and non-agricultural) via reallocation of input factors. This in turn leads to a change in relative prices of traded and non-traded goods and factors, and consequently changes in income levels, which if increased at the aggregate as a result of more efficient resource allocation, could improve food security status, at least for households whose income rises. Trade policy also could play a role, as it has implications for food exchange earnings; trade policy could also affect food security through the link of incomes and expenditures. Changes in trade regimes will have direct and indirect effect on both rural and urban incomes, and on employment, and hence income distribution. There is also the effect on government revenues through, a change in the level of revenue from import levies.

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The Case of Tanzania

Like many developing countries, the Tanzanian Government is lured by biofuels seeing in them the prospects for increased revenues from value added agriculture, export revenues, increased employment, and broader development benefits to the economy from diversified energy sources, including small scale energy developments for local or rural use. Biofuels, particularly biodiesel, could be an alternative source for rural lighting and cooking where the majority of the live.

One of the major concerns faced by the Tanzanian Government is potential large land acquisition for biofuels and diversion of land from crop utilization and negative consequences on food security. These concerns are mirrored in the following priorities, stated in a policy guideline document on bioenergy: (1) 1st priority is National Food Security, (2) 2nd priority is to secure land to resource poor farmers who may sell their land for short-term benefit, and (3) 3rd good quality land must remain with food crops. It is not known if and what extent any new land for biofuel will come from unused land; but competition for current cropland is to be expected and sustained efforts to raise yields and productivity per ha is required for long term economic viability of biofuels in Tanzania.

Food security is a major concern for Tanzania. Tanzania experiences chronic food insecurity; and even in good years there are pockets of food insecurity. Food self-sufficiency for Tanzania is around 88% - but varies by crop and region. According to the National Bureau of Statistics (NBS), in 2000/01 19% of total population was below the poverty line and 36% was below the basic needs poverty line. From the WDI in 2002, active population in agriculture account for 72% of total while 60% of rural population is below the poverty line (set at 1 dollar per day). The National Bureau of Statistics reports 38% child stunting, 35.6% poverty rate, and 18.7% food poverty.

There are about 44 million hectare of arable land and only 6-10% are cultivated. According to 1996/97 household survey, there were 4.4 million small holder households and 1038 large and medium-sized agricultural holdings (WM). The vast majority of export and crop production is carried out by small holding farms (80%). Of the export crops, tea, sisal and sugar cane are grown in large capital intensive farms, while other exports crops like cotton, coffee and cashew nuts are still produced by small scale farms. The majority of small farms however specialize in food crops (Musonga and Wanga, 2007). Maize and rice are two major staple crops.

According to 2001/2002 estimates by the MAFS, the main sources of income and employment for households are agricultural sales, which account for 65% of total household income (Musonga and Wanga, 2007). Of this food crops account for 41% (maize, rice), cash crops just under 20% while livestock account for little over 4%. Cash crops sold include coffee, cashew nuts, tobacco, as well as livestock. For poorest farms, sales of maize, sorghum and millet are often a necessity. But lack of price market information and strong seasonal variations in basic grain prices are harmful to small producers. According to the same survey, cash income from employment account for another 7.8% of household income in rural areas.

Maize is the key staple with domestic production mostly for subsistence. Maize yields are low (about 1.6 tons/hectare). Tanzania also depends on imports- a situation that was difficult to manage during last year high food prices. Maize is grown by over 80 percent of rural households, but only 26% of these sell maize (ERB, 2001). Overall 60% of maize produced is self consumed and 40% marketed; in years with good harvests, excess supply is also exported officially and unofficially to neighbouring countries (Musonga and Wanga, 2007). However, Tanzania also imports maize and imported volumes are increasingly larger than exports, pointing to internal production and marketing constraints, notably the large distance between maize production areas from domestic markets and ports.

Cassava is Tanzania's second largest crop after maize. In Tanzania, Cassava is mostly concentrated in the Lake region and in western regions. Cassava crop has many advantages including the ability to grow easily in harsh and less favourable environments to other crops. Cassava is the only crop that cut across a wide range of agroecological zones; cassava massive leaf production provide nutrients to the soil, thus requiring little fertilization and little weeding since the rich canopy quickly dominates over weeds. Cassava is normally intercropped with early maturing annuals such as maize, rice. Cassava is highly compatible as an intercrop because of slow early growth.

Cassava is rich in carbohydrates but is nutritionally highly unbalanced (80% of the root is starch) and need to be eaten with other foods for balanced nutrition (Manyong and Abass, 2007). Another disadvantage of cassava is its high perishability, so immediate post-harvest processing for preservation is critical for its marketability. Cassava is also prone to pests and diseases (e.g., bacterial blight and leaf mosaic diseases) and new resistant varieties are needed if the current low yields averaging 10 tons of fresh tons of roots per ha can be raised in Tanzania [FOOTNOTE=Zanzibar introduced new pest-tolerant varieties with yield potential up to 35 tonnes of fresh cassava roots per ha.]

Cassava is mostly self-consumed and is 2nd most important item in households' food basket. Cassava contributes to a substantial proportion of household food basket in drier and marginal agricultural areas of Lake Victoria and Western zones. Very little cassava is marketed, mostly cassava produced around the urban centers. For many areas there is no access to market due to poor infrastructure and prohibitive transportation costs. Cassava development in Tanzania also suffers from the broader weakness or lack of the institutional and regulatory framework necessary to turn cassava into a fully developed value chain (Manyong and Abass, 2007). Cassava is thought of as famine or crisis food crop. In years of drought or low national incomes, cassava consumption increases relative to alternative food staples such as yam, maize, rice and wheat.

There is some effort by the Government to encourage expanding cassava production, especially in Central Tanzania and coastal areas south of Dar Es-Salaam, where farmers have fewer alternative income opportunities and where production costs could be more

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competitive. In addition to 20 farms producing cassava seeds, the government operate a large seed cuttings facility, producing 14 million cuttings per year- for distribution to producers to encourage cassava production for ethanol.

Tanzania produces sugar for domestic consumption and for exports using sugar cane. This crop is grown largely in estates or large plantations owned by sugar processing factories (SPF) and contract growers (CG) (Tarimo and Takamura, 1998). In Tanzania, despite ample rainfall, supplemental irrigation is often needed since rains are concentrated in part of sugar cane season. About 1/3 of the country is dry (mainly the central plateau) with less than 500 mm of rainfall per year. Consequently, sugarcane farms in Tanzania are situated along river valleys to facilitate supplementary irrigation during the season in three regions: Morogoro, Kilimanjaro (under irrigation Scheme) and Kagera (River Kagera Basin). Tanzania is not self sufficient in sugar (which it also imports) despite having the potential for sugar-self sufficiency. However, more production requires greater incentives to encourage small farmers to grow SC, especially in the periphery of processing plants. The prospective of using sugar cane as a source of ethanol production must be viewed within this larger context. For Tanzania to raise sugar cane production, several challenges must be met. This includes improving irrigation, introduce rotations to improve soil fertility (move away from monocropping), introduce new varieties. There is also a need to upgrade the quality of the sugar processing mills, which continue to use outdated technologies from the 1960's (Tarimo and Takamura, 1998).

Of these various options, sugar cane–based ethanol has drawn more investors' interest perhaps because of sugar cane potential for high ethanol yield per unit of land and because sugar cane industry is already established in Tanzania. Currently, Tanzania produces 250 to 300 thousand tons of sugar (out of total consumption of 500 thousand). There are 4 sugar factories in the country, producing sugar, molasses and bagasse by-product. Sugar cane expansion for biofuels is most likely to develop on a large-scale plantation basis requiring large and contiguous lands or holdings and hence large initial investments that may not be readily accessible to small farmers. Establishment of new sugar cane plantations would however attract labour from neighbouring farms to meet added demand. As of 2008, on-going investments plans for sugarcane ethanol envisage the construction of ethanol bio-refinery supplied by sugar cane from a 7000-1000 ha plantation with the rest of plant sugar cane need (20-30%) to be provided with contracts from growers (out-growers schemes).

Tanzania is interested in developing several feedstock-bioenergy pathways including Jatropha [non-food] and palm-oil [food]. From the poverty reduction perspective, jatropha shows advantages, largely because it can be grown by small scale growers, is labour intensive and hence offer a greater scope for wide adoption by farmers. Beside not-providing competition with food crops, Jatropha has other advantages. The crop is drought resistant and can be grown in poor soils. Its leaves add nutrients to the soil, while deep roots avoid competition with other crops while help improve soil quality. However, much of jatropha crop management is still poorly understood, and the yields of current varieties are low (between 1200-3000 litre/ha) and Jatropha remains untested technology

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for some years to come. Moreover, development of Jatropha by small holders require overcoming several obstacles such as lack of credit access by small farmers to invest in jatropha oil pressing; also export prospects may be restricted by tariff escalation and NTBs. Consequently, the first movers into Jatropha-biodiesel production are made by large operators such as one Jatropha plantation in Kitomondo northeast of Bagamovo with 4000 hectares. Also a Jatropha plantation of 8200 hectares of good quality is currently under development in Kisarawi near Dar Es-salaam for the production of biodiesel.

Palm oil is grown at small scale level in western Tanzania within the rainforest areas, some of which are near wildlife conservation areas. Given the concerns over protection of biodiversity the scope for growth in this area is limited. By contrast any potential growth of large scale palm oil plantation will have to take place in areas where farming is already established. This means direct competition with current land uses. In Kilombero [Kigoma], a plan is underway to grow surface-irrigated palm oil in a 5000 hectare plantation for biodiesel production. The plantation is expected to produce 30 thousand tons of palm oil and would require 40 days of labor/year. Labor will be supplied from neighboring farms. It will take 10 years before palm generates oil.

Tanzania has no regulations or blending mandates in place and hence is still at early stages of biofuel regulatory development. Overall Tanzania is more concerned about land access issues; if the market structure of sugar cane in Tanzania is any guide, we may well see a model structure where ethanol processing plants acquiring large estates or plantations for producing and supplying their own feedstock, leaving with outgrower schemes with small farms playing only a marginal role overall.

In summary, given the above, does Tanzania has a comparative advantage in biofuel development? What are the various constraints likely to impede translating potential benefits into reality? What are the key concerns facing the Tanzania Government as it forges a policy framework for regulating biofuels? Many of these questions need a multi-pronged empirical assessment. In particular, the paper attempts to examine the plausible links between biofuel development and food security. This papers focuses on the macro-level, economy-wide assessment of biofuel development scenarios on production, trade, prices and primary factors (land, labour).

The Case of Peru

For several years, Peru has been on the path of developing liquid biofuel production. To stimulate demand for biofuel production and use, Peru established mandates in 2007 setting mandatory blending of ethanol by 7.8% in 2010 and 5% biodiesel blend with diesel by 2011. Beside diversifying its energy sources and creating growth and employment opportunities, biofuel development is also seen as part of its anti-narcotics initiatives, where the development of biofuel feedstocks especially in the Amazon region is viewed as an alternative to drug cultivation.

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Peru is divided into three topographic regions: The Pacific coast, 11 percent of the total area, the Andean Highlands (Sierra) with 31 percent, and the Amazon region about 58% of the country (Zorrillla and Cafferatta, 2006). Most of the arable land is in the coastal region and most agricultural production is derived from the river valleys along the coast. In Sierra region, agriculture is largely subsistence based, while in the Amazon basin, agriculture is only slowly developing.

Agriculture area represents 24% of total area. There is potential for further agricultural land but at an environmental cost since land expansion requires deforestation. The forest covers 70% of total land including the tropical rainforest of the Amazon region. Peru's climate is tropical only in the Amazonian region with abundant vegetation. The Andes mountains divide the country into the wet tropical forests in the east and the arid zone in the west. On the western side of the Andes, drought is a high risk, and water supply is erratic making agriculture very much dependent on irrigation systems, especially in the coast.

Peru's main crops are sugar and coffee (exportables); potatoes, alfalfa and plantains (non-tradables); and poultry, rice, milk and maize, palm oil, livestock (importables). Geographically, coastal regions produce mostly tradable products, while non-tradables are grown largely in the Sierra and to some extent in Amazonia. Small scale peasant producers (1-5 ha) represent the vast majority of farmers. The majority of these are located in the Sierra, an area of poorly developed rainfed agriculture. The commercial producers are predominantly located in the coast, where there is a concentration of financial and commercial services and better productive and institutional infrastructure. Hence, small farms grow mostly potatoes, maize and plantain; large farms and cooperative produce mostly tradables such as rice, sugar cane, maize, coffee, and alfalfa.

Food security is an important imperative for Peru. As of 2001, the proportion of the population under severe poverty rose to 24% (Zorrillla and Cafferatta, 2006), while the percent of poor people in rural areas is overall 60%; but the number of poor people in absolute terms is higher in urban areas than rural ones. The main income source for rural households is agriculture even though other sources of employment and income are growing (Zorrilla and Cafferatta, 2006). Small farmers surveys in 2003 in three representative regions of Peru show that non-agriculture income are proportionately high for small farms with less than 1 ha. Extreme poverty continues to be highest in the Sierra and Amazon and especially in rural areas of these regions. As of 2001, about 61% and 41% of the population in these regions didn't have enough income to cover their essential food needs.

For ethanol production, the main feedstock of choice is sugar cane. Peru produces over 7 million tonnes of sugar cane; and its sugar mills are concentrated in the coastal region. Sugar cane in Peru is produced year-around and yields range from 53 to 190 MT of cane per hectare. The bioethanol industry estimates that about 200,000 ha of sugar cane are under development for ethanol. For example the company Maple Energy has invested in land, biorefinery and pipeline (for exports) to produce 30 million gallons of ethanol from over 10,000 ha plantation located in dry area in Northern Peru- where sugar cane will be produced under drip irrigation using water drawn from the nearby Chira river. While drip irrigation may be water use efficient, sugar cane expansion may pose environmental sustainability concerns associated with monocropping and the resulting problems like soil erosion, nutrient runoff, and widespread crop infestation and failure.

Biodiesel production is also under development in Peru. The targeted feedstocks are palm oil and Jatropha, even though, even though soybean oil (imported from Argentina) is also considered in the biodiesel mix, at least in the short term. There are also plans to develop dedicated Jatropha plantations for biodiesel. For example the company Pure Biofuels has planted 5,000 ha of Jatropha plants to make biodiesel; Jatropha plant is grown for seed production which is crushed for the oil, used as feedstock into biodiesel production. Current palm oil production is around 48,000 tonnes per year. Palm oil production is also expanding in the Amazonian provinces of Ucayalli, San Martin and Loreto, where deforested land is being converted to palm oil plantations. Such an expansion of palm oil for biodiesel in the poorly developed Amazon region is being pushed as part of Peru’s anti-narcotics strategy by creating alternatives to drug cultivation.

In summary, Peru has clearly trusted itself into liquid biofuel production. Nevertheless, land and especially water, are important constraints to large scale biofuel development. About 38% of the land is under forest, and 42% are protected; this leaves only little “free” land for additional agricultural production, including biomass. Most of the arable land is already used by crops including sugar cane currently grown mostly for sugar. The exception may be palm oil, which can be grown in deforested lands in Amazonia. Water availability will also be a challenge, primarily in the coastal areas where existing urban centers are concentrated leading to increased competition for water use. In these regions, sugar cane expansion for biofuels will require large investments in irrigation, raising the concern for environmental sustainability in the long run.

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GLOMAB: Model and Database Description

In this section we describe a global CGE model for agriculture and bioenergy (GLOMAB) to examine biofuel production and trade and their implications on agricultural markets, energy industries, GHG emissions. GLOMAB has its origin in the GTAP-Energy model, which was first developed by Truong (1999) who incorporated a substitution between capital and fuels using a simple top-down approach was used with allowing for capital and energy to be either substitutes or complements. In order to allow for different elasticities of substitution across value added and energy, and non-energy inputs, a nested CES function has been employed in the model. Under this structure, all energy products are included into the value added components; the non-energy intermediate inputs exclude all the energy inputs, but include fossil-fuel based feedstocks. Burniaux and Truong (2002) further improved the GTAP-E model by incorporated carbon emission from the combustion of fossil fuels along with the mechanisms to trade these emissions internationally. More recently, McDougall and Golub (2007) made additional improvements to the programming of the GTAP-E model. Therefore, we view the EMH model as another milestone in the continuous improvement of this powerful modeling tool.

The GLOMAB model incorporates several new biofuels and biomass sectors. Biomass sectors include the major types of the first generation feedstocks (maize, sugarcane, oilseeds, cassava, palm oil) as well as second generation feedstocks (agricultural residues and woody biomass). Also different types of biofuels both first and second generation, are represented: sugar ethanol (sugar cane), starch ethanol (maize, cassava), cellulosic ethanol (agricultural residues, woody biomass), temperate biodiesel (oilseeds, vegetable oils) and tropical biodiesel (palm oil). The model also incorporates biopower by separating out conventional electricity from bioelectricity as two separate activities.
The substitution of biofuels is represented by intermediate demand substitution as well as household substitution, which required appropriate modifications in the production and consumption structures, respectively. Private consumption assumes constant-difference of elasticities (CDE) functional form to accommodate nonhomothetic preferences and fully flexible functional form. Since biofuels are substitutable for petroleum products at the pump, we allow for substitution in the private household demand through CES nesting.

Following on the latest version o GTAP-E (McDougall and Golub, 2007) we incorporate several biofuels by expanding the nesting structure. This production tree represents how the firm combines its individual inputs. The relative share of intermediate inputs (say agricultural residues) in the production of a given product (say cellulosic ethanol) is reflected in the cost structure within the input-output matrix. We also introduce joint production structure to allow for biomass feedstock produced jointly with a food crop (wheat and wheat straw). Under the joint production structure, the commodities combine in a single CES nest; for example AgricResidue is a CES nest combination of Rice residue, wheat residue, maize residue, and sugar cane residue.

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Biopower is an important bioenergy source in many countries. Among its advantages is a better environmental footprint (than biofuels). While current electricity generation currently relies mostly on coal and combustion technology, future routes for electric generation may include the so-called biomass co-firing (combined biomass and coal as fuel inputs). Also "biomass gasification-combined cycle is replaced to replace current combustion based technologies, technology offering a greater flexibility in fuel inputs among coal, natural gas and biomass. These considerations are reflected in the electricity CES nest.

Dataset, original aggregation and data modifications

The underlying database in the model is based on GTAP database version 7 with 2004 as the base year. The original database made of 57 sectors and 101 regions (covering the whole world) was aggregated up into 20 sectors and 24 regions. The GTAP data base (Dimaranan, ed., 2007) does not include explicitly biofuels, biomass or bioelectricity sectors. The new biomass, biofuels and bioelectricity sectors identified in the model need to be explicitly represented in the database. For this purpose we used a specially designed an extension to the utility software 'SplitCom' developed by Horridge (2005). From a subset of the initial 20 sectors, we derived several new sectors. These are maize, maize residues (from cereals), wheat residues (from wheat), rice residues (from rice), bagasse (from sugarcane), cassava (from fruit-vegetables aggregate), palm oil, temperate biodiesel, tropical biodiesel (from vegetable oil, fats), starch ethanol (from other foods), woody biomass (from forestry), bioelectricity (from electricity), and sugar ethanol and cellulosic ethanol (from other chemicals industry). This complex process of data disaggregation and rebalancing required additional data on the new sectors production, trade use and expenditure patterns. The final disaggregated dataset was 34 sectors and 24 regions. In addition the database also include 5 factors of production: two types of labor (unskilled and skilled), agricultural land, capital and n natural resources.

Another important modification to the database (not included in the original GTAP database) is the introduction of bioethanol and biodiesel tariffs and production subsidies based on estimates from the Global Subsidies Initiative (GSI), which cover the aggregate support for biofuels in US, EU, Canada, Australia and Switzerland.

This final data base aggregation enables us to focus on the sectors and regions of particular interest. Given the broad set of bioenergy related issues the model is called upon to examine with a medium term time horizon (roughly 2010-2020), the model and data aggregation are designed to allow for a balanced representation between first and second generation biofuels, first and second generation feedstocks, and between biofuels and bioelectricity- the two important pillars of biomass-derived energy. The sectors are aggregated such that we could focus on the linkages among feedstock, biofuels, energy commodities, and other food and non-food industries. The regions are aggregated to represent the major global bioenergy players (US, EU, Brazil, China) as well a host of developing countries that have either began or are set to launch into biofuel development, allowing us to analyze both global issues as well as targeted developing country biofuel options.

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Biofuel Scenarios

The biofuel scenarios in this paper are summarized in table X. For Tanzania, we compare ethanol development under 2 feedstock options: ethanol from sugar cane only (TNZ_E_SC) and ethanol from a mixture of sugar cane and from cassava (TNZ_E_MIX.). Under the latter, we assume equal share of ethanol growth in Tanzania between the two feedstock technologies. In both scenarios we set the level of ethanol expansion to roughly 5 times the amount of current (2008) investments planned for ethanol in the country. The third scenario for Tanzania combines scenario 2 with an expansion of palm oil- based biodiesel (TNZ_BE_MIX).

For Peru we compare PER_E, PER_B and PER_EB. Under PER_E scenario the model shock ethanol growth expansion to meet the mandate of 7.5% of total gasoline use domestically (to be enacted by 2010) and under scenario PER_B, we enact the realization of the biodiesel mandate for domestic use equal to 5% of total biodiesel consumption. Scenario PER_EB combines the two. (For the rest of the paper, we focus the results solely on the Tanzania case).

Preliminary Results and Discussion

In this section we focus solely on the Tanzania scenarios. So what do these scenarios tell us about Tanzania's prospects for developing ethanol? We need to sort out the results that are directly tied to the model and the scenarios and identify some broad conclusions with implications of policy advice. First let's start with some caveats and limits of the model then state some broad conclusions.

First some caveats. This quantitative analysis focused on before-and-after scenarios looking at the sectoral and aggregate changes in Tanzania when ethanol production is exogenously raised. We considered two potential options: ethanol expansion under sugar alone or a mix of sugar cane and cassava based ethanol expansion. To keep us focused on Tanzania, we ignored any changes in biofuel developments in the rest of the world. The analysis is also static, with no allowance made to productivity changes; no technology change is allowed in ethanol industry and no yield improvements factored in feedstocks.

Given the above, the preliminary results of this analysis show the following. Under the assumption of endogenous (unskilled) labor and land availability, the exogenous expansion of ethanol production induces recourse shift from away from other sectors including food crops resulting in changes in production (lower), imports (higher) and exports (lower) of non-biomass food sectors (see table 3). The choice of feedstock matters. Sugar cane being more productive per unit of land has less impacts on resource shifting than cassava which has lower yield per unit of land and hence would demand more inputs (land and labor) to generate the same level of ethanol output.

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Also given the magnitude of ethanol sector expansion, the macro-level effect on prices is relatively small, typically less than one (Table 4 et Figure 3). The magnitude of changes as currently envisioned means that the effects are generally small, but multiplying the expansion several folds show bigger effects on resource reallocation, price and production.

In terms of labor or employment effects, the analysis is very aggregate and suggests that under the above assumptions, sugar cane ethanol may draw lower growth of additional labor compared to cassava-based ethanol system. While ethanol production would create opportunities for employment, perhaps seasonal or on part-time, at the same time ethanol will create more competition for labor demand by other activities, especially for food production. A more refined analysis involving detailed labor markets may be required to further explore this critical issue.

On the land use issue, using the assumption of endogenous land, the comparison between sugar cane and cassava-based ethanol systems shows that the latter will require more additional lands to meet the new demand from biofuels. Such an outcome would work in favour of sugar cane given its greater productivity per unit of land compared to cassava. Tanzania may not have abundant and suitable lands for biofuels. This is a controversial issue. And the one concern preventing the Government of Tanzania from going full scale in allowing for large scale land acquisition for biofuels by investors. This is quite justified on the assumption that investors are also likely to acquire current agricultural land, especially in areas where infrastructure is relatively more developed.

This leaves the issue of alleviating the pressure on land through more intensive use of technologies to raise productivity per unit of land. This factor was allowed for in the analysis by including productivity shocks based on reasonable assumptions of yield increases for feedstocks, notably sugar cane and cassava. The overall effects in terms of intersectoral resource shifts, prices and direction of production for competing food crops is noticeable and in the expected direction.

Among the factors likely to inhibit biofuels expansion in Tanzania is the very limited infrastructure. Tanzania, like many African countries, do not have navigable waterways, nor functioning railways, or pipelines; and significant investments would be needed to make processing and production cost effective. Here biodiesels may better suited than ethanol, since biodiesel can use the same infrastructure as existing uses of its feedstocks, so countries with weak infrastructure, biodiesel may be more suitable than ethanol. Existing processing industries may help determine the likely development of new ethanol/biodiesel processing plants.

So what does this mean for food security? First food production may be somewhat adversely affected if land and labor are drawn away to produce feedstock for ethanol but the effects are lessened under higher productivity of feedstocks. Second, that increased food imports to compensate is not a reassuring strategy in light of recent world food crisis; At the same time, there may opportunities for greater employment benefits, more pronounced under cassava-ethanol compared to sugar cane ethanol. Moreover, there is

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another issue not fully explored is that with biofuel development, a better infrastructure and greater productive technologies may be spilled over to crop production hence having a beneficial overall impact on food production. Again these are additional qualifications to a preliminary assessment of the food security dimension in light of the present CGE analysis. In principal, a follow up microsimulation analysis using detailed household data might offer additional responses.

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Table 1. Commodity, Industry, Primary Factors, and Regional Aggregation in GLOMAB

COMMODITIES/INDUSTRIES:

1 Agric Residues
  1.1 Rice straw
  1.2 Wheat straw
  1.3 MaizeResidue
  1.4 Sugar cane bagasse
2 Rice
3 Wheat
4 Maize
5 Other Cereals
6 Cassava
7 Veg_Fruits
8 Oilseeds
9 Sugar cane/beet
10 Plant Fibers
11 Other Crops
12 Palm Oil
13 Other Veg-Oils
14 Livestock and meats
15 Processed foods
16 Forestry
17 Woody biomass
18 Coal
19 Gas
20 Oil
21 PetroProd
22 Bioethanol
  22.1 Starch Ethanol
  22.2 Sugar Ethanol
  22.3 Cellllulosic Ethanol
23 Biodiesel
  23.1 Temperate Biodiesel
  23.2 Tropical Biodiesel
24 Electricity
  24.1 Bio-Electricity
  24.1 Conventional Electricity
25 Chemicals
26 Other Manufacturing
27 Services

REGIONAL AGGREGATION

1 High income Asia
2 China
3 Cambodia
4 Indonesia
5 Malaysia
6 Thailand
7 India
8 Low Income Asia
9 West-Central Asia
10 USA
11 Rest of North America
12 Brazil
13 Peru
14 Rest Latin America
15 European Union (27)
16 Rest of Europe
17 North Africa
18 West Africa
19 Central Africa
20 Tanzania
21 Mozambique
22 Rest of East Africa
23 South Africa
24 Rest of Southern Africa

PRIMARY FACTORS

1 Land
2 Unskilled labor
3 Skilled labor
4 Capital
5 Natural resources

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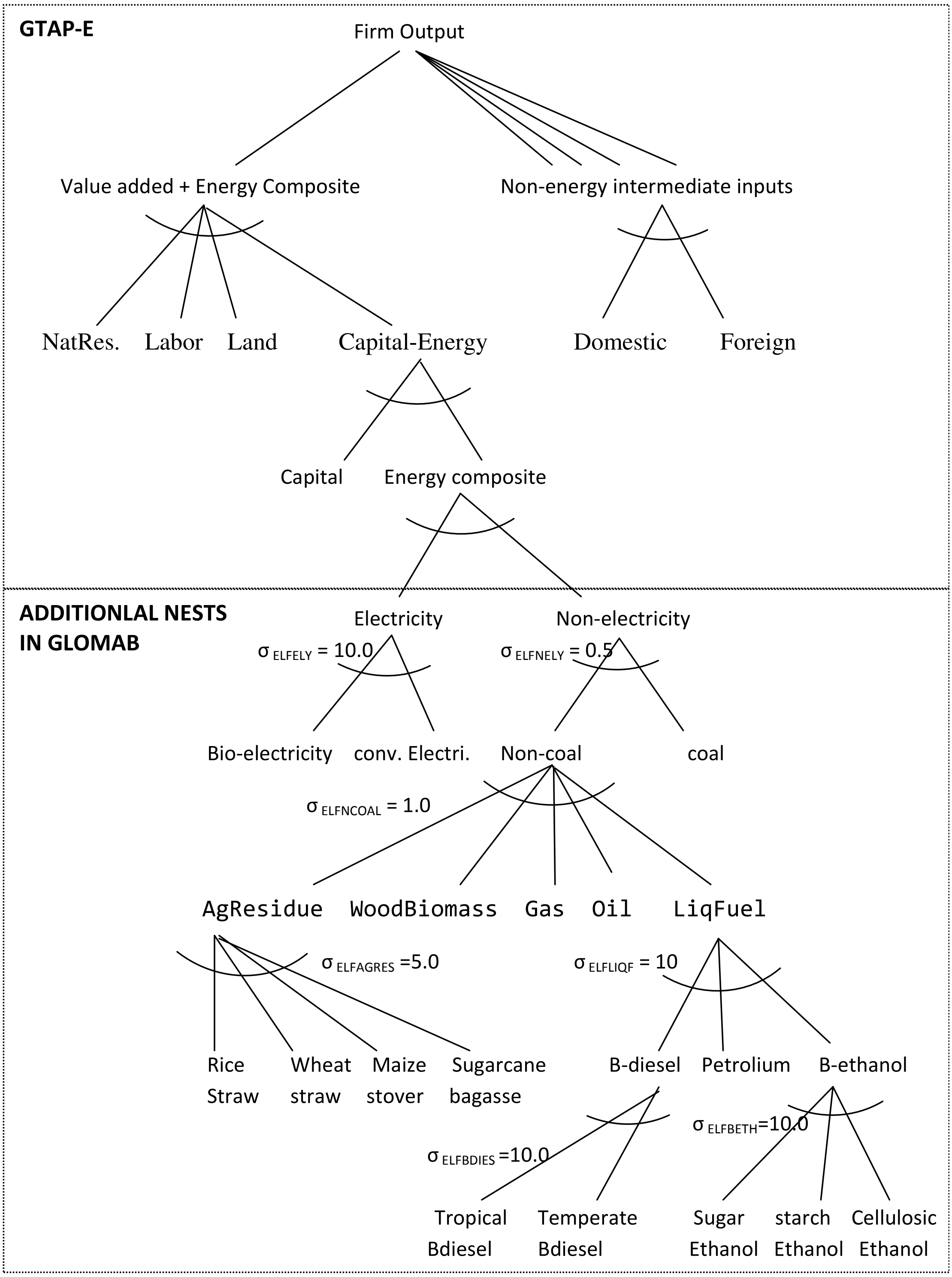

Figure 1. Production Structure in GLOMAB

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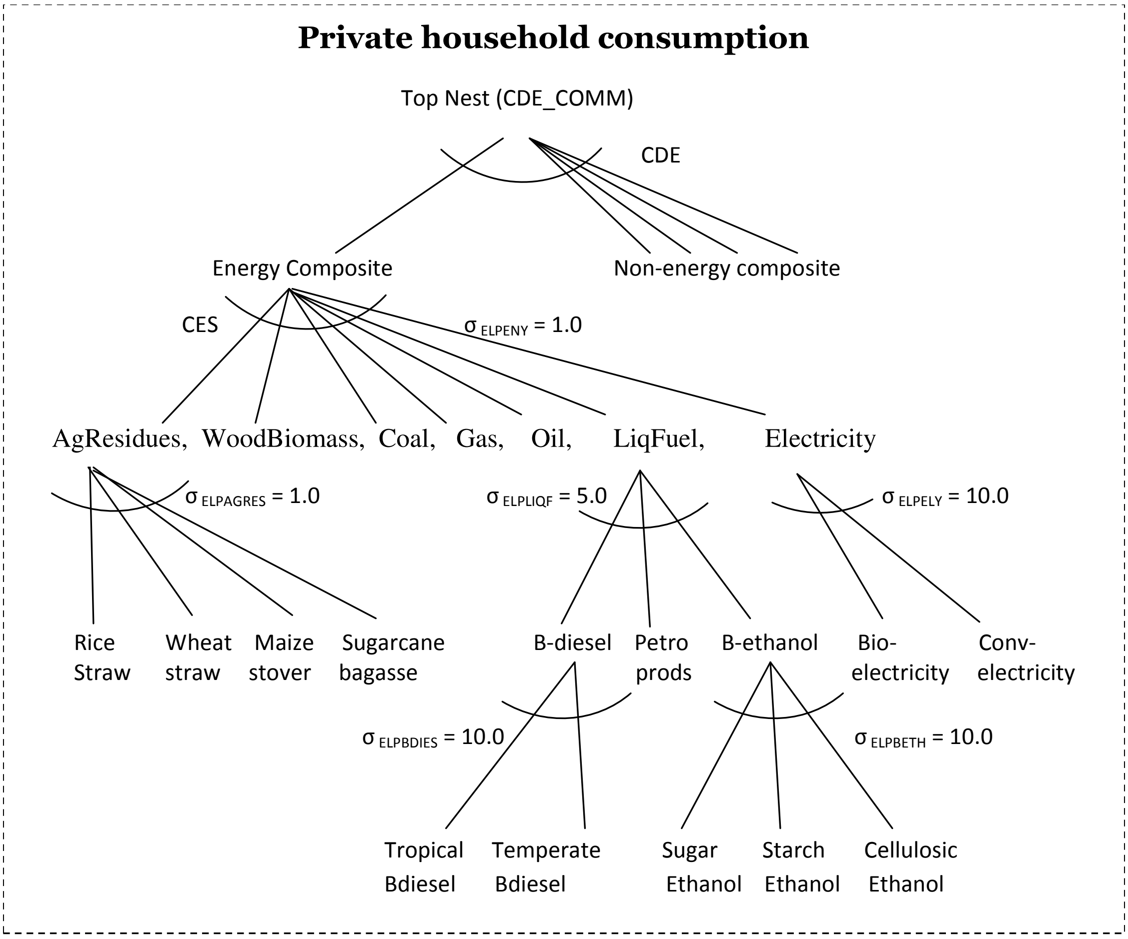

Figure 2. Private Household Consumption Structure in GLOMAB

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Table 2. Model Scenarios

Scenario name	Scenario description	Observations/Model closures
TANZANIA SCENARIOS		
Scenario 1 = TNZ_E_SC	Sugar cane ethanol output expansion (equivalent of 70,000 ha of sugar cane; 60,000 of which are plantations); plus sugar cane productivity boost	SC productivity from 44 to 70 tonnes/ha/yr (outgrowers) and from 95 to 110 tonnes/ha/yr) (plantations); Model closures: endogenous unskilled labor; endogenous land
Scenario 2 = ETH_E_MIX	Ethanol output expansion (equivalent of 70,000 ha of sugar cane)-half from sugar cane; half from cassava ; plus sugar cane and cassava productivity increases boost	Cassava productivity reflect yield increase from 10 fresh tonnes to 15 fresh tonnes/ha/yr; Model closures: endogenous unskilled labor; endogenous land
Scenario 3 = ETH BE MIX	Scenario 2 plus palm oil biodiesel output expansion (equivalent to 25,000 ha of palm oil; with 20 tonnes/ha)	Model closures: endogenous unskilled labor; endogenous land
PERU SCENARIOS		
PER_E	Supply response to reach the 7.8% mandate for ethanol by 2010 (re FAO 2003)	(production expansion equivalent to 12,000 ha of sugar cane for ethanol with yields 110 tons/ha; Model closures: endogenous unskilled labor; endogenous land
PER_B	Biodiesel supply shock to meet reach 5% blend mandate by 2011	2/3 increase from palm oil or 40,000 ha; 1/3 increase from canol oil; Model closures: endogenous unskilled labor; endogenous land
PER_EB	Combined supply shock to meet 7.8% mandate for ethanol and 5% blend for biodiesel	Model closures: endogenous unskilled labor; endogenous land

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Table 3. Production effects of ethanol production shock in Tanzania

	Initial values (USD millions)	BIOFUEL OUTPUT EXPANSION ONLY			ETHANOL EXPANSION + PRODUCTIVITY		
		tnz_e_sc Scenario 2 Ethanol (Sugar cane)	tnz_e_mix Scenario 3 Ethanol (SC/Cassava)	tnz_bemix Scenario 4 Biod/Ethanol (1+2+3 scenar)	tnz_e_sc Scenario 5 Ethanol (Sugar cane)	tnz_e_mix Scenario 6 Ethanol (SC/Cassava)	tnz_bemix Scenario 7 Biod/Ethanol (1+5+6 scenar)
Land	534.57	0.32	0.51	1.03	0.63	0.72	1.23
UnSkLab	4620.46	0.54	0.52	0.79	1.07	1.13	1.40
Rice	327.00	0.08	0.12	-0.38	0.71	0.91	0.42
Maize	995.94	0.53	0.47	0.02	1.01	1.05	0.60
Other cereals	215.42	0.16	0.62	0.19	0.61	1.16	0.74
Cassava	195.06	0.12	6.45	6.10	0.54	6.97	6.62
Veg_Fruits	489.29	-0.61	-0.35	-0.65	-0.24	0.47	0.17
Oilseeds	206.51	-0.68	-0.47	14.89	-0.06	0.22	15.58
Sugarcane-sbeet	613.59	11.93	6.12	6.61	12.98	7.31	7.80
Other crops	1337.06	-1.03	-0.74	-0.97	-0.56	-0.18	-0.41
Palm Oil	21.03	-4.18	-3.07	848.22	0.15	1.36	852.61
Livestock & meats	856.80	0.69	0.58	0.23	1.24	1.26	0.91
Other foods	2701.30	0.10	0.13	-0.38	0.79	1.00	0.48
Forestry	519.12	0.09	0.09	-0.35	0.49	0.60	0.16
Other chemicals	508.46	0.40	-0.44	-0.89	-0.31	-1.06	-1.51
Other manufacturing	2464.46	-2.29	-1.78	-2.21	-2.17	-1.61	-2.03
Services	9020.86	0.26	0.14	-0.13	0.44	0.41	0.14

Source: Authors simulations

Table 4. Prices effects of ethanol production shock in Tanzania

	BIOFUEL OUTPUT EXPANSION ONLY			ETHANOL EXPANSION + PRODUCTIVITY		
	tnz_e_sc Scenario 2 Ethanol (Sugar cane)	tnz_e_mix Scenario 3 Ethanol (SC/Cassava)	tnz_bemix Scenario 4 Biod/Ethanol (1+2+3 scenar)	tnz_e_sc Scenario 5 Ethanol (Sugar cane)	tnz_e_mix Scenario 6 Ethanol (SC/Cassava)	tnz_bemix Scenario 7 Biod/Ethanol (1+5+6 scenar)
Land	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
UnSkLab	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
SkLab	**1.13**	**0.81**	**0.91**	**1.71**	**1.58**	**1.68**
Capital	**1.02**	**0.78**	**0.93**	**1.64**	**1.57**	**1.72**
Rice	**0.20**	**0.13**	**0.07**	**0.44**	**0.45**	**0.38**
Maize	**0.15**	**0.09**	**0.02**	**0.34**	**0.36**	**0.28**
Other cereals	**0.24**	**0.21**	**0.15**	**0.50**	**0.55**	**0.49**
Cassava	**0.21**	**0.90**	**0.83**	**0.41**	**-4.72**	**-4.79**
Veg_Fruits	**0.12**	**0.13**	**0.07**	**0.30**	**-0.05**	**-0.11**
Oilseeds	**0.14**	**0.08**	**1.84**	**0.35**	**0.36**	**2.10**
Sugarcane-sbeet	**0.29**	**0.12**	**0.12**	**-4.54**	**-4.60**	**-4.59**
Other crops	**0.05**	**0.02**	**-0.03**	**0.25**	**0.29**	**0.24**
Palm Oil	**0.17**	**0.11**	**0.79**	**0.10**	**0.12**	**0.80**
Livestock & meats	**0.30**	**0.22**	**0.23**	**0.58**	**0.57**	**0.57**
Other foods	**0.13**	**0.10**	**0.10**	**-0.02**	**-0.11**	**-0.11**
Sugar ethanol	**0.20**	**0.10**	**0.12**	**-2.12**	**-2.12**	**-2.10**
Other chemicals	**-0.02**	**-0.02**	**0.01**	**0.35**	**0.45**	**0.47**
Other manufacturing	**-0.23**	**-0.18**	**-0.21**	**0.10**	**0.24**	**0.20**
Services	**0.34**	**0.26**	**0.32**	**0.74**	**0.74**	**0.79**

Source: Authors simulations

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References

To be completed

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