Marginal Cost Versus Average Cost Pricing with Climatic Shocks in Senegal: A Dynamic Computable General Equilibrium Model Applied to Water

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Summary

The model simulates on a 20-year horizon, a first phase of increase in the water resource availability taking into account the supply policies by the Senegalese government and a second phase with hydrologic deficits due to demand evolution (demographic growth). The results show that marginal cost water pricing (with a subsidy ensuring the survival of the water production sector) makes it possible in the long term to absorb the shock of the resource shortage, GDP, investment and welfare increase. Unemployment drops and the sectors of rain rice, market gardening and drinking water distribution grow. In contrast, the current policy of average cost pricing of water leads the long-term economy in a recession with an agricultural production decrease, a strong degradation of welfare and a rise of unemployment. This result questions the basic tariff (average cost) on which block water pricing is based in Senegal.

Keywords: Computable General Equilibrium Model, Dynamic, Imperfect Competition, Water, Pricing, Sub Saharan Africa

JEL Classification: C68, O13

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Water is a scarce natural resource in many countries, in particular in sub-Saharan Africa areas including Senegal. With strong demand growth, the government initially tried to address the scarcity by engaging in many investment plans to increase production capacity. Then, the idea of resource use rationalization by demand management developed. Water demand policies has been combined with supply policies. This is why we observe a drinking water price increase in most developing countries. This increase leads us to ask about its consequences on different sectors in particular agricultural sectors that employ a great part of the working population. It also leads us to ask about access to drinking water of the poorest households. Therefore, a new tariff policy has to be studied by taking account of the direct and indirect repercussions on the whole economy, the water-user sectors (agricultural, industrial and services), household incomes and total welfare.

To understand all the resource feedback effects and the water pricing policies consequences in the long term, we propose a sequential dynamic computable general equilibrium model, which take into account long-term resource availability (supply) and demographic growth (demand).

The model simulates a 20-year horizon, a first phase of increase in the water resource availability (policies of supply increase by the Senegalese government) and, a second phase with hydrologic deficits (demand and demographic growth) in accordance with projections (Management system consultants corp, 1998). This *scenario* presents two cases of water pricing policies: average cost (the current policy) *versus* marginal cost pricing. The model shows how the economy subjected to future risks of water shortages, absorbs the long-term shock if the government maintains average cost pricing (current policy in order to ensure budget equilibrium) or if it practices marginal cost pricing (with a subsidy to ensure the sector survival). It describes the mechanisms by which the evolutions of the different water prices (connection private, standpost and informal) affect on the one hand, the resource sector users (agricultural, industrial and services) and on the other hand, households (Dakar, other urban and rural areas). It presents the substitution effects between the different drinking water modes of supply. Lastly, the model evaluates the water pricing impacts (short and the long term) on production (in particular agricultural), unemployment, investment and on total welfare.

The first section presents the long-term evolution of drinking water supply and demand in Senegal. The second section describes the water pricing policy adopted by the government and the third section explains the water pricing *scenarios* simulated by the CGE model. After a short review of the literature in the fourth section, we present the data (Social Accounting Matrix) and the model. The last section presents the results of climatic shocks combined with two cases of water demand management (average cost *versus* marginal cost pricing).

1. The long-term evolution of the drinking water supply and demand in Senegal

In September 2000, Senegal adhered to the Millennium International Declaration objectives. Among its objectives, access to basic social services appears and in particular, access to drinking water. One of the important objectives is to reduce by half the population not having access to a drinking water distribution point by the year 2015. Indeed, the UNDP[2] report notes that 73% of the population had access to drinking water (2001). However, strong geographical disparities persist. The 35 liters per person a day objective has not been reached. The Senegal Poverty Reduction Strategy (SPRS, 2003-2005) confirms the aim of increasing drinking water service quality to the households. Lastly, the Letter of Sectoral policy (2003) validates the SPRS objectives by engaging an important investment plan through the "Water Sectoral Project" (WSP). This one aims at increasing drinking water availability and at improving service to users.

1.1 The policy of supply increase

The WSP was elaborated in 1996 to continue the first programme of production capacity reinforcement in Dakar and in eleven urban areas, completed in 1993. The objectives of this plan consist of improving management and covering costs in order to reduce subsidies, increase drinking water access, and engaging the private sector in drinking water urban service management. The strategy aims to promote a water resource integrated management to coordinate the investment projects, to reinforce the capacity of the realization of the investments and to increase the production capacity of 34% (271 000m3/J). Ten backers finance the investments (119 billion FCFA) (at August 31, 2003). 75% of these investments are mobilized for the production capacity extension and 25% for rehabilitation, reinforcement and extension of the distribution networks (1 100km) and connections (60 000, including 14 000 rehabilitated).

Since 2003, a new investment plan, the Long-term water Sectoral Plan (LSP) is in effect. Its aim is to ensure drinking water demand satisfaction with financial autonomy for the sector. This plan envisages investments of about 116 billion FCFA over one 5-year period for the production capacity reinforcement. In the LSP project, the KMS project will lead, in two phases, to a treatment capacity of 130 000 m3 a day, a first section allowing the treatment, from 2003, of 65 000 m3 a day and a second section the additional treatment, from 2007, of 65 000 m3 a day.

1.2 The hydrologic deficits taking into account the long-term demand evolution

Investments have been realized for the reinforcement of production capacity of drinking water. However, it is important to take account of resource availability (ground water and surface water) and demand evolution (population growth).

A study (Management system consultants corp, 1998) presents this long-term evolution (see the following tables).

[2] UNDP : United Nations Development Programme

1.2.1 The long-term demand evolution

Water demand study for Dakar - assumptions

	growth	1996	2000	2010	2020	2030
Demography						
Population (low assumption)	2,0%	1.917.100	2.132.000	2.696.000	3.220.000	3.674.000
Population (average assumption)	2,4%	1.917.100	2.161.000	2.832.000	3.570.000	4.335.000
Population (high assumption)	2,8%	1.917.100	2.190.000	2.969.000	3.869.000	4.880.000

Source: Management system consultants corp, 1998

Water access rate in 1996 and 2030 (in % of the total population)

Assumptions	*1996*	Low	Average	High
Private connections	*65%*	70%	80%	85%
Standposts	*26%*	20%	15%	10%
Others	*9%*	10%	5%	5%

Source: Management system consultants corp, 1998

Domestic consumption in 1996 and 2030 (in liters per person a day)

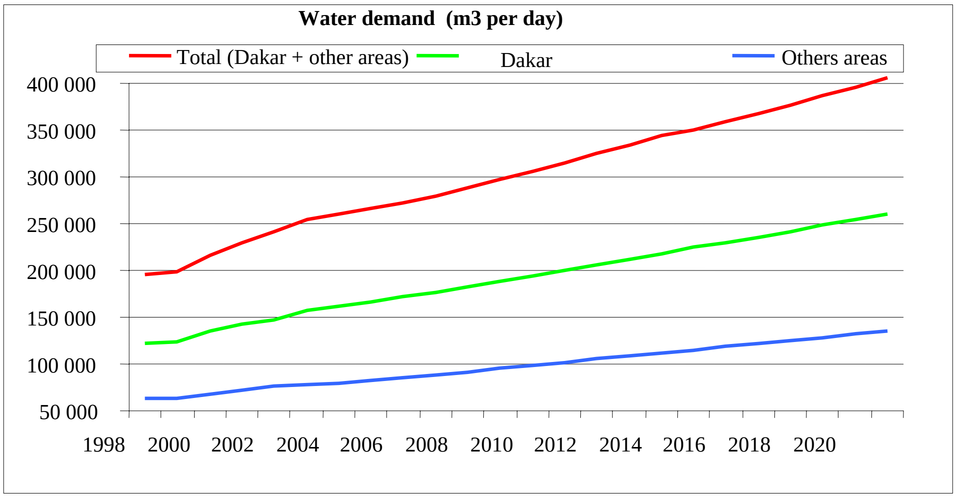
Assumptions	*1996*	Low	Average	High
Private connections	*50*	45,2	71,2	123,1
Standposts	*20*	18,1	28,5	35
Others	*11*	9,9	15,7	27,1
All	*39*	*36,2*	*62*	*109,5*

Source: Management system consultants corp, 1998

Non domestic water demand (in m3 per day in 1996 and 2030)

Assumptions	*1996*	Low	Average	High
Industrial	*16 700*	37 000	74 300	125 100
Commercial	*8 000*	15 600	30 900	57 900
Administrations/municipal	*24 400*	28 600	38 300	55 000
Total excepted irrigation	*49 100*	*81 200*	*143 500*	*238 000*

Source: Management system consultants corp, 1998



Source: Management system consultants corp, 1998

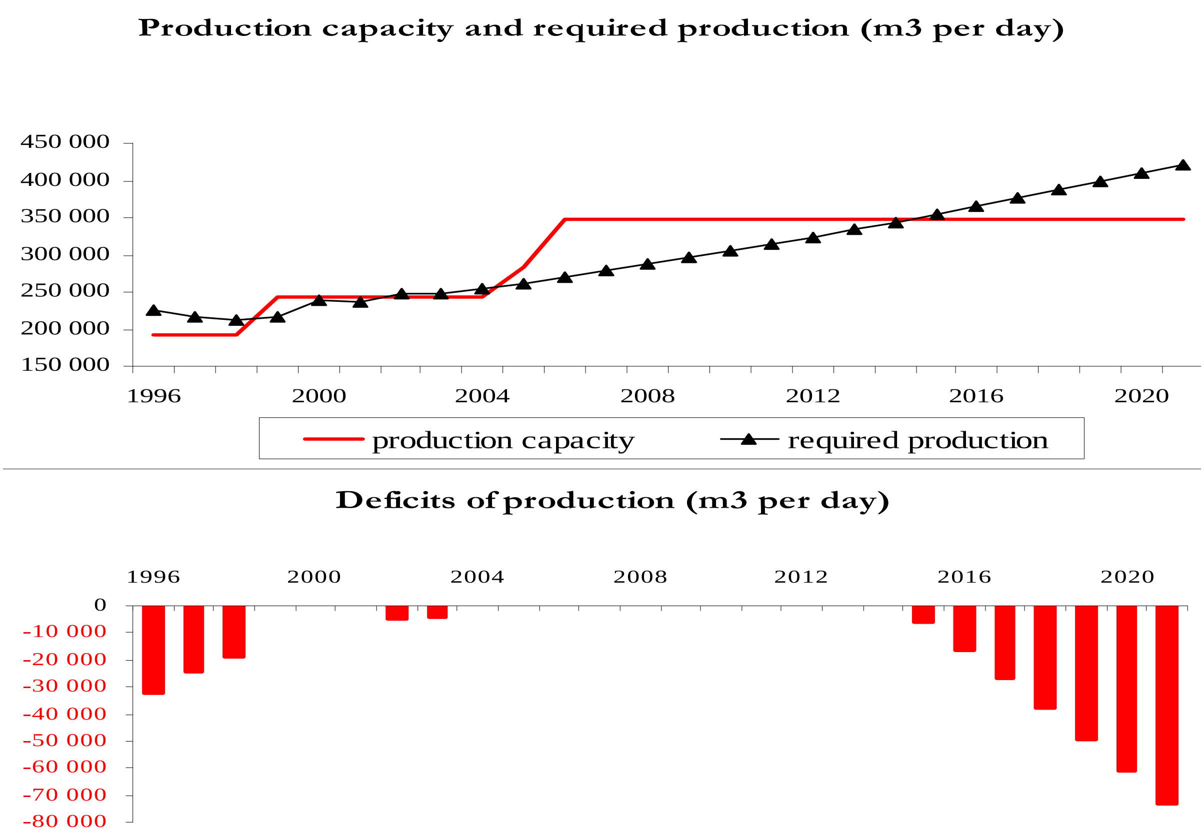
We can summarize the water demand evolution in this graphic:

We wonder about the long-term equilibrium question of water demand and resource availability. The study (Management system consulting corp, 1998) presents projections in terms of future shortages. The assumptions of the study are:

1) An availability of the production capacity of 100%
2) A water consumption by the market-gardeners of 14 000 m3 a day
3) An invoicing rate in Dakar of 79% in 2003, 80,5% in 2004 and 81,5% beyond
4) The average assumption of the water demand evolution
5) The priority use of the surface water production capacity

1.2.2 The future hydrologic deficit

Since 2006, the ground water withdrawals have been approximately reduced to the third of the current withdrawals (173 000 m3 a day in 2002 and 50.000 m3 a day in 2006) with a rise of the surface water use. Then, ground water withdrawals will increase gradually to satisfy the water demand until reaching the maximum fixed withdrawal. This maximum withdrawal, which will be reached in 2015, remain lower by approximately 31% than the annual average withdrawal of the year 2002 (173 000 m3 a day in 2002 and 117.000 m3 a day in 2015). Thus, these changes lead to the following results in terms of long-term equilibrium between water supply and demand.



Source : Management system consultants corp, 1998

According to the same study, water shortages happen, in particular from 2015. This means that new resources will have to be mobilized. The government indicates that these resources could come from sites not yet exploited: the lake Guiers, the Maastrichtien aquifer, desalination of Seawater, etc.

2. The demand management policy

In spite of the current investment plans aiming at increasing storage capacities, studies find disequilibrium between the long-term supply and demand. This is why, following the sector privatization (1996), the supply policy needs to be combined with a demand side management policy. But this latter remains difficult to implement because it often implies a rise in water prices, unpopular for several reasons. Mainly, Senegal pursued in parallel a campaign against poverty. This program was accompanied by the introduction of an increasing block tariff structure. The majority of the developing countries use an increasing block water tariff, which depends on the volume of drinking water consumption. This is justified by the will to pursue a social objective, that of the access for all to drinking water.

The Senegalese government objectives through its water pricing policy are:

- To target a balanced budget;
- To allow the poorest households to consume a water *minimum* in good hygiene conditions; to give them access to private connections, with a social tariff for low consumption;
- Not to handicap the rest of the economy while supporting the firms for which the tariff increases necessary;
- To simplify the tariff;
- In a scarcity context of the water resource, the aim is to incite the consumer to anticipate the level of its consumption.

We present the results of a first assessment of the pricing policy following the privatization of the sector (1996). This assessment was established in 2003, when the Water Sectoral Project ends.

2.1 The objective of the average tariff for water

The tariff objective defined by the SONES after the privatization was to reach budget equilibrium in 2003 (except the Long-Term Project). Financial projections by the Government show that this objective would be achieved with an annual increase in the average water tariff of 1998 from 2,72% to 2,96% in current money. The following table presents the targeted average tariff of water over the period 1999-2003 in current FCFA per cubic meter and net of tax.

Objective of average tariff for water (current FCFA HT)

Average Tariff 1998	Targeted average tariff HT (FCFA) except market-gardeners				
	1999	2000	2001	2002	2003
372,26	383,28	394,62	406,3	418,33	430,71

Source: Castalia, 2002.

2.2 The structure of water increasing block pricing

The tariff structure introduced after the sector privatization is as follows:

- Reduction for three of the consumers categories except market-gardeners: standposts, domestic consumers, non-domestic consumers (category with single block);
- Removal of the blocks in the non-domestic category;
- Maintenance of three consumption blocks for the domestic consumers, with a third block starting at 40 m3 a 60 days. This threshold of 40 cubic meters per two months exists in order that consumption of this block is not negligible: they should account for approximately 20% of the domestic consumer's consumption.

This tariff structure introduction used the idea of allowing a better knowledge of the consumption structure and of facilitating the budget projection. It envisaged the exemption of taxes for the social tariff. It was designed according to the "targeted average tariff" which corresponds to the tariff objective to reach in 2003. This latter was given by increasing annually by 2,96% in current money the average tariff of 1998 except market-gardeners.

The table presents, in current FCFA HT, the drinking water pricing project, which was adopted in 1998.

Water increasing block pricing (in current FCFA HT)

Water price (FCFA per m3)	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
Standposts			196,00	196,00	196,00	196,00	196,00
Domestic consumers							
- Social block (20 m3 a 60 days)			157,51	170,28	177,34	184,69	192,34
- Intermediate block (20-40m3)			508,46	468,14	480,19	490,43	499,65
- Full block (+40m3)			589,40	618,98	642,88	663,44	682,15
Non domestic consumers			508,46	533,98	547,72	559,40	569,92
Average tariff	352,73	372,26	383,28	394,62	406,30	418,33	430,71
Target average tariff			383,28	394,62	406,30	418,33	430,71

Source: Castalia, 2002.

2.3 The assessment of the increasing block water tariff

We can say that the policies based on an increasing block tariff structure (with social block) did not make it possible to the low-income populations to durably profit from a water service in residence. Rather, these instruments appeared ineffective in sub-Saharan Africa, or sometimes even generated the opposite result to the aim (Morel à l'huissier, 1990). We wonder about the question of the validity of this increasing block tariff such as it exists today. Indeed, the first block (social) was designed in order to subsidize the poorest household consumption by that of the richest. This principle rests on the correlation usually observed between levels of consumption and incomes. However, empirical examples (Collignon, Valfrey 1998) show that indirect effects take part in an opposite redistribution of the incomes of poorest in richest, contrary to the aim in view. A survey (Diagne, Briand, Cabral, 2004) that we conducted in the dense districts of Dakar shows that several households living in the same court divide the private connection and the amount of the water bill. The increasing block tariff implies that these households pay the water at a higher price than a richest household having its own private connection.

In this case, the increasing block water pricing is not enough to fight against poverty. Then, we have to wonder about the basic tariff (target) on which the increasing block pricing is based. More precisely, the problem could stem from the choice of a targeted tariff at the average cost. Indeed, the targeted average price, which was introduced in 1996 and was gradually reached in

2003, appears high compared to other countries. It is close to that of the European countries. Such an average tariff is seldom met besides in West Africa (Castalia, 2002). Therefore, the switch to a targeted tariff at the marginal cost could decrease the price and make it possible to increase the access to drinking water and the household's welfare.

Although the question of the choice of the increasing block tariff structure is important in term of income redistribution, we focus in this paper on the choice of the basic tariff on which this structure is designed (average cost *versus* marginal cost). Our results concentrate on the sectoral and macroeconomic impacts and on the household's welfare.

3. *Scenarios* of water pricing in the CGE model: average cost *versus* marginal cost

The water sector is characterized by the existence of scale economies. More precisely, it is an activity with increasing returns to scale, a particular case of natural monopoly. The economic theory teaches us that in the case of a monopoly, which produces only one type of good, the increasing returns to scale imply that the average cost in the long run is decreasing (scale economies). Therefore, the marginal cost is always lower than the average cost. The optimal pricing, which equalizes the price and the marginal cost, leads ineluctably to a deficit of the monopoly. This one must be financed by subsidies (generally financed by a tax). However, these subsidies aiming at reabsorbing the public monopoly deficit are badly received, even if this deficit is justified by the collective optimally criterion represented by the marginal cost pricing. Moreover, the tax levy, which makes it possible to finance the subsidies, can have negative consequences in terms of equity and can distort the household's behaviour. This is why it is usually considered more reasonable to constrain the public monopoly with respect to budget equilibrium: to finance the production costs by at least equivalent receipts. We have seen previously that water pricing in Senegal takes note of this budget equilibrium constraint. So, we consider in our CGE model that the water pricing at the base run is an average cost pricing (budget equilibrium of the drinking water production sector).

But as it is also well known from the literature, in a stylized economy (without pre-existing taxation), marginal cost pricing is a simple economic principle which makes it possible to ensure an optimal allocation of the resource between all the users. The marginal cost pricing, by giving maximum surplus to the consumers makes disappear the social loss and maximizes the total welfare. We want to simulate this water pricing *scenario* in our CGE model. To ensure the survival sector, we consider that this water pricing is accompanied by the payment of a Government subsidy to the water company to finance this deficit. Taking into account the pre-exiting taxation in our model, we don't introduce a new tax to finance this subsidy.

We examine the effects in general equilibrium (with distorsive pre-existing taxes) of both these water pricing cases (average cost *versus* marginal cost). The first allows the budget equilibrium of the water sector without the Government intervention *via a* subsidy (potential source of distortions). The second makes it possible to increase the total welfare of the economy.

We propose a comparison of these water pricing *scenarios* in a sequential dynamic CGE model (with pre-existing taxation) taking into account the resource scarcity evolution and the water demand increase (population growth). We wonder about their reallocative and redistributive effects in the Senegalese economy. Which of these two policies is better to the drinking water access, better to the fight against food insecurity (by an agricultural production growth) and better to conserve long-term water resources? Finally, which of these two policies generates the higher household welfare and total welfare?

4. Review of the literature on the CGE models applied to water

The water management question in CGE models is little studied by the economic literature. Berck, Robinson and Goldman (1991) presented a first model. It was built to evaluate the investment policies in the water distribution in the area of San Joaquim in California. This model, with fourteen sectors (six agricultural sectors), was developed in order to analyze the impact of a water stock variation on the economy. The authors treat water like an exogenous stock, and the only resource consumer is the agricultural sector. The results indicate a modification in the production structure, with a substitution of agriculture towards the breeding. They note a fall of the GDP, of agricultural employment and agricultural incomes, when the quantity of available water decreases.

The second study is that of Goldin and Roland-Holst (1995). The authors examine the relations between water management policies and foreign trade in Morocco using a CGE model with four sectors (two agricultural sectors). The two agricultural sectors are different according to area by distinguishing an arid region and a non-arid region. The authors examine three simulations: an increase of the water tariff for the farmer, a total tariff cut and the third one is a combination of both the previous. In the first simulation, GDP, income and household consumption, and, water quantity used decrease. In the second simulation, the reverse occurs. In the last simulation, the authors note a reduction in water quantity used and an increase in GDP, the income and the household consumption. In spite of interesting results, the authors impose constraining assumptions on their model. They use a very restrictive agricultural production function with no substitution between the water factor water and the intermediate consumptions. A modification of the water irrigation cost does not affect the farmer's consumption decisions. However, like Berck *et al.* (1991), water is not produced, the available water quantity is fixed. Finally, water is not a component of household consumption. As households do not consume water, they are not in competition with the farmers.

A third study is that of Decaluwé, Patry and Savard (1999). The authors, using a CGE framework, study the impact on the Moroccan economy of three water pricing systems (a 10% arbitrary water tariff increase, the marginal cost pricing and the Ramsey-Boiteux pricing). They explicitly model drinking water production with different production technologies for ground water or surface water (with a Weibull function). The model gives a more complete vision of Moroccan reality than the CGE model of Goldin and Roland-Holst (1995) because the farmers, industries and the households consume water. However, the authors do not concentrate on the specific characteristics of the water market structure (natural monopoly with increasing returns to scale). The model accounts for the conflict between the different water uses (domestic, agricultural and industrial) which appear following the pricing shocks. Their study shows that Ramsey-Boiteux pricing has a better impact on the water conservation in Morocco. The equivalent variation with the Ramsey-Boiteux pricing is much lower than that induced by the marginal cost pricing. Indeed, the Ramsey-Boiteux water tariff for domestic use is significantly higher than the marginal cost water tariff in the north of the country where the majority of the population lives. Moreover, the Ramsey-Boiteux pricing has a depressive effect on the agricultural production, which results in a strong reduction in the sector exports (agrums).

A fourth study is that of Thabet (2003). He built a CGE model applied to the Tunisian agricultural sector in order to test two *scenarii*. The first comprises three simulations: a uniform water pricing, a 30% increase in the non-agricultural water demand and, one combination of both the previous. The second type of *scenario* consists in comparing the efficiency and the equity of alternative second best irrigation water pricing. Firstly, the model simulates "traditional" binomial average cost pricing, made up of a proportional tariff to volumetric water consumption and of a fixed subscription. Secondly, the model simulates binomial "personalized" pricing where the fixed part of the tariff is applied to the irrigated land. The results show that a binomial personalized pricing of the irrigation water has positive effects on the urban household's welfare and negative effects on the rural household's welfare. However, the two other modes of pricing present negative impacts on the rural and urban household's welfare. In terms of irrigation water management, a binomial personalized pricing appears the more adapted instrument if the government aims to make contribute the farmers to the financing of the hydraulic infrastructure without blocking the irrigation, not to affect the agricultural and food trade balance. However, if the water maintenance is the more important objective, average cost pricing seems to be most suitable.

The majority of the studies, which deal with the water pricing, are concentrated on the agricultural water tariff question because it is generally denounced as too low. Moreover, there are only static models not taking into account the scale economies of the drinking water production sector.

This is why we propose a sequential dynamic model in imperfect competition (the natural monopoly) which introduces an unemployment function. In an economy subjected to hydrologic deficits future risks, the model shows how the water pricing policies (demand management) affect the Senegalese economy in the short and long-term. More precisely, it describes the mechanisms by which evolution of the different water prices (private connection, standpost and informal) affects on the one hand, the sectors users of the resource (agricultural, industrial and services) and on the other hand, the households (Dakar, other urban and rural areas). It highlights the new water allocation between the different uses and more particularly, the substitution effects between the different modes of drinking water provisioning for intermediate or final consumption, by activity and household. It evaluates the impacts in short and long-term on unemployment, investment and total welfare of average cost *versus* marginal cost water pricing.

5. The Social Accounting Matrix of Senegal (SAM, 1996)

The model calibration requires construction of a Social accounting matrix (SAM) for the Senegalese economy.

We consider that the Government holds the primary water stock, and sells it to the irrigated rice sector and to the drinking water production sector. The drinking water production sector combines this resource with labour and capital to produce higher quality water, drinking water. This drinking water is distributed by three channels (private connection, standposts and informal carters) and consumed as input by the other sectors (agricultural, industrial and services) and as a final good by the households.
The SAM is composed of fifteen activities (1996) and is the database for the model. It is an aggregated and disaggregated version of the SAM built by Dansokho, Diouf (1999) and Cabral (2005). The macroeconomic data are provided by the DPS[3], by the input-output table. Incomes and consumption data are taken from the Senegalese Income Expenditure Household Survey (ESAM[4], 1996). The water data come from the SONES and the SDE (2003, 2004). The disagregation of the energy sector in electricity-gas, drinking water production, formal drinking water distribution *via* the private connection, formal drinking water distribution *via* the standpost

[3] DPS: Direction de la Prévision et de la Statistique (Senegalese Direction of Statistics).
[4] ESAM: Enquête Sénégalaise Auprès des Ménages (Senegalese Income Expenditure Household Survey).

and informal drinking water distribution, stems from data resulting from surveys (Hydroconseil, 1998; Diagne, Briand, Cabral, 2004).
Taking into account the choice of a water intensity criterion (Appendix A1.3), the SAM distinguishes the intensive agricultural water sectors such as irrigated rice, rain rice, the market gardening, fishing, of the non-intensive agricultural water sectors. It describes a drinking water production sector with a public utility mission (SONES). Taking into account the importance of the informal operators, it integrates three drinking water distribution sectors (private connection, standposts and carters). Further, it distinguishes water intensive industries and services (water is an important input) and water non-intensive industries and services. The last sector is non-tradable services.

There are four factors of production in the economy: labour, capital, land and primary water.
We propose to have eight households' categories. They are defined according to their geographical location and according to the drinking water supply in their areas: Dakar, Other Urban areas (ACU), the groundnut Basin (BA), Niayes (NIAY), Casamance (CASA), the sylvo-pastoral area (ZSP), Eastern Senegal (SO), and the Delta River (FLEUV). Six rural households' categories are distinguished according to agro-ecologic areas characteristics. Indeed, rural areas are characterized by strong disparities in terms of agro climatic potentialities, infrastructure, cultivation methods, intensity in the use of production factors, sources of households income (Cabral, 2005) and in terms of drinking water consumption structure.
The other agents taken into account are firms, the Government and the Rest of the world.

Tables presented in Appendix 1 make it possible to synthesize the important elements of the SAM structure to the base run and allow to understand the different variables evolutions after the shock. In particular, the weight of each sector in the value added of the Senegalese economy, the share of the production factors in each sector, and the water intensity of the different sectors are important informations for the results justifications. It is the same for the structure of income and expenditure by household's category.

6. The model

Our Senegalese model is inspired by the neo-classic model EXTER developed by Decaluwé, Martens and Savard (2001) but differs in many aspects. Firstly, our model is represented by four production factors (labour, capital, land and primary water) contrary to EXTER (labour and capital). The household's typology differs. The model integrates a linear expenditure system (LES) in which each commodity has a *minimum* consumption (subsistence) whereas in EXTER, consumption is a fixed proportion of the available income. The transfers within households and between the households and the Rest of the World are explicitly taken into account.
Taking into account the characteristics of the drinking water production sector, we integrate a natural monopoly with increasing returns to scale. We introduce an efficiency wage and a unemployment function. Lastly, it is a sequential dynamic model.

The model is composed of eight blocks of equations (Appendix 2): drinking water production with increasing returns to scale, others sectors production in perfect competition, incomes and saving, taxes, demand, prices, foreign trade, and equilibrium conditions.

The drinking water production (natural monopoly) is modelled in two levels. Firstly, labour is combined with capital by a Cobb-Douglas function to give a composite factor. Secondly, this composite factor is combined with the primary water by a Cobb-Douglas function with increasing returns to scale to give the added value. We assume that the added value is equal to the drinking water production, which means that there are no intermediate consumptions (negligible). We compute an average cost function and a marginal cost function of drinking water production (see equations in Appendix 2).

The other sectors' production is modelled in two levels. At the top level, sectoral output is defined by a Leontief function of value added and total intermediate consumption. Then, the added value is represented by a Cobb-Douglas function of labour, capital, land and primary water for the irrigated rice sector; labour, capital and land for the other agricultural sectors; labour, capital and primary water for the drinking water production sector; labour and capital for all the other sectors excepted non tradable services (only labour). The intermediate consumption of each sector is a fixed proportion of the production of each sector. The intermediate demand for a product is the sum of the intermediate consumptions of this product used by the different sectors. A linear function connects the intermediate demand for a product to the sector intermediate consumption of the same product.

The primary water, land, capital, and labour factors demand are determined by the first order conditions of profit maximization of the Cobb-Douglas production for tradable services. For non-tradable services, the labour factor demand is the ratio between the value added and the income from labour factor to the unit.

Each household earns his income from production factors: labour, land, capital, and primary water. He also receives dividends (by firms), intra-households transfers, government transfers and foreigner's transfers. The household's disposable incomes are derived by subtracting the direct taxes collected by the government. We specify saving and total consumption as fixed proportions of disposable income.
Firm's income is composed by capital income. Their saving is the difference between their income, the direct taxes paid and the transfers paid to the other agents.
The government receives direct taxes from households and firms, indirect taxes on domestic and imported goods, the remuneration of the primary water sale and transfers from households, firms and the Rest of the World.

For each group of households, the consumption expenditure is obtained by withdrawing available income, saving and transfers. Domestic consumption is determined by the linear expenditure system (LES), in which each good has a *minimum* consumption (subsistence) level.
The public consumption is the nominal production of non-tradable services.
The nominal investment by origin is a fixed proportion of the nominal total investment.

Value added price for activity is equal to the report between the nominal production net of the intermediate consumptions and the added value volume.
Domestic price of imported and exported good depend on import and export world prices, the nominal exchange rate and receipts from import duties.

The total demand (value) is the sum of demand for domestic good tax included, and the imports in good receipts from import duties included.
The total production (value) is equal to the sum of the demand for domestic good and the exports in good evaluated at the export price. The general prices index is the GDP deflator.

Domestic production is supplied to the domestic economy and export market. We assume that there are simultaneous export and import at the sectoral level. However, external trade shall be structured such that imperfect substitution characterise the foreign markets. On the import side, Armington (1969) approach is followed by supposing an imperfect substitution between domestic and imported goods. What is being demanded is the composite consumption good, which is a constant elasticity of substitution (CES) aggregate of imports and domestically produced goods. For exports, the allocation of domestic output between exports and domestic sales is determined on the assumption that domestic producers maximise profits subject to imperfect transformability between both alternatives. The composite production good is thus a constant elasticity of transformation (CET) aggregate of exports and domestic sales.

The current account balance is equal to the trade balance plus capital income received, plus exogenous transfer's payments from firms and government to the Rest of the World less exogenous transfers from the Rest of the World to households and government.

The composite commodity is equal to the total domestic absorption of consumption demand, intermediate demand and investment demand.
The total supply of production factors (labour, capital, land and primary water) is equal to the total demand for primary factor.
The total investment is equal to the sum of total household savings, firms savings, government savings and foreign savings (as represented by current account balance converted at nominal exchange rate), which corresponds to the neoclassical macroeconomic closure.

Following Annabi (2003), we introduce an efficiency wage and an involuntary unemployment in the CGE model (Shapiro and Stiglitz (1984)). The equilibrium wage rate is negatively related with the unemployment rate (un). The labor market equilibrium is characterized by the presence of involuntary unemployment. The non-shirking condition (NSC) depends on the disutility of the effort (ee), the exogenous quit rate (bb), the probability to be caught (qq), and the discount rate (rr). The NSC is included in the model with the calibration of the parameter (ee). Parameters bb, qq, rr are respectively fixed at 0,1 ; 0,3 et 0,05.

As we say above, to compare the short-term effects with the long-term effects of the average cost *versus* marginal cost pricing, we propose a dynamic approach. Indeed, the short-term effects can be under-estimated compared to the long-term effects.
Dynamic general equilibrium can be classified as truly dynamic ("intertemporal") or sequential dynamic ("recursive") models. Truly dynamic models are based on optimal growth theory where the behaviour of economic agents is characterized by perfect foresight. Economic agents know all about the future and react to future changes in prices. Households maximize their intertemporal utility function under a wealth constraint to determine their consumption programm over time. Investment decisions by firms are the result of cash flow maximization over the whole time horizon. However, these models are still little used for the developing countries problems. We choose the construction of a sequential dynamic model (Annabi, Cockburn, Decaluwé (2004) and Annabi, Cissé, Cockburn and Decaluwé (2005)).

This kind of dynamic model is not the result of intertemporal optimization by economic agents. Indeed, these agents have myopic behaviour. A sequential dynamic model is basically a series of static CGE models that are linked between periods by an exogenous and endogenous variable updating procedure. Capital stock is updated endogenously with a capital accumulation equation and population (total labour supply) is updated exogenously between periods. The crucial question concerns the distribution of new investments between sectors and the capital stock calibration.

The sequential dynamic model is formulated as a static model, which is solved sequentially over time. We use the static model, index all variables in time (t) and introduce the following equations.

The capital accumulation equation (69)[5] described the law of the motion for the sectoral capital stock. It supposes implicitly that the stocks are measured at the beginning of the period and that the flows are measured at the end of the period.
The investment demand function (71) determines how the new investment will be distributed between different sectors. It is a rate of investment by sector of destination. The investment demand function[6] used is similar to the one proposed by Bourguignon, Branson and De Mello (1989). Parameters γ_{1TR} et γ_{2TR} are positive parameters calibrated on the bias of the investment elasticity and the investment equilibrium equation (74). The investment rate (ratio between the investment by sector destination $IND_{TR,T}$ and the capital stock $KD_{TR,T}$) is increasing with the respect to the ratio of the rate of return to capital $r_{TR,T}$ and its user cost[7] U_T.
In introducing investment by destination, we have to respect the equality condition with total investment by origin in the original SAM. The parameters γ_{1TR} et γ_{2TR} are positive only if the value of the elasticity of $\frac{IND_{TR,T}}{KD_{TR,T}}$ with respect $\left(\frac{r_{TR,T}}{U_T}\right)$ is between 1 and 2. Following Annabi *et al.* (2004), we fixed it at 1,5. We obtain the following equation:

$\gamma_{2i} = \gamma_{1i}\frac{R_{it}}{U_t}$ this relation, taken together with the investment demand equation, makes it possible to calibrate γ_{1TR} et γ_{2TR}. We make assumptions on the sectoral growth rates of capital as data is not generally available on investment by destination in developing countries. Possible assumptions include (Annabi *et al.* (2004)):

1) It is equal to the production growth rate
2) It is equal to the sum of population growth rate and capital depreciation rate[8].

In our application, we fixed the sectoral growth rates of capital at 5% in order to calibrate the capital stock.
The capital user cost (72) is equal to the replacement capital price (price index of investment) multiplied by the sum of capital depreciation rate and real interest rate (exogenous). Total labour supply (70) is an endogenous variable although it simply increases at the exogenous population growth.

The model is solved simultaneously as a system of non linear equations on a 20-period time horizon.

There are some equilibrium conditions to be satisfied in the model (closure). The nominal exchange rate is chosen as *numeraire*. It is fixed taking into account the West African Economic and Monetary Union agreements. Since this "small country" has no impact on international markets, the world prices with the import and export are exogenous. The public expenditure is fixed. The other exogenous variables of the model are dividends, land supply, primary water demands and transfers between the different agents.

Calibration is usual step in the construction of CGE models. In order to make the model operational, it is necessary specify the parameters value. Elasticities of the household's

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[5] See Appendix 2 (Model equations).
[6] See Bchir, Decreux, Guerin and Jean (2002) and Jung and Thorbecke (2000) for other examples of investment functions.
[7] Hall and Jorgenson (1967).
[8] This assumption takes again the final condition $\frac{Id_{it}}{K_{it}} = (n+\delta)$ which is used in intertemporal dynamic models.

consumption functions and elasticity of the import and export demands are taken from Decaluwé *et al.* (2001), and Cabral (2005). All the other parameters come from the Senegalase SAM. The model counts 13 306 equations for 13 306 endogenous variables and 2 255 exogenous variables. The model is solved (calibration and simulations) using Gams[9].

In static models, counterfactual analysis is made with respect to the base run that is represented by the initial SAM. But in the dynamic models, the economy grows even without a policy shock and the analysis should be done with respect to the growth path in the absence of any shock. (see graphs in Appendix 9). Sectoral and macro effects are presented in tables of Appendix 7 and 8. These tables report the percentage variation between the base path and the after simulation path for each variable.

7. Simulation results of climatic shocks combined with average cost *versus* marginal cost pricing

The same climatic shock is simulated in two *scenarios*. It represents the long-term evolution of the water resource availability, which we describe in section 1. We simulate a first phase of resource availability increase (policy of water supply increase), followed by a stability phase, and a third phase characterized by hydrologic deficit (water demand increase and population growth). More precisely, we simulate a 30% water resource increase for the first three periods followed by a 30% decrease of the resource availability over periods 7, 8 and 9. The other periods are characterized by climatic stability. We observe the impacts on a 20-year horizon (1996-2015) of this climatic variability, by comparing the results to the long-term trend without shock (see graphics in Appendix 9, 10 and 11).

The simulations are distinguished by the water pricing policy (water demand management) combined with climatic shocks. The first *scenario* is with average cost pricing. The second is a marginal cost pricing combined with a subsidy financed by the Government to the drinking water production sector. We compare the short and long-term effects of these two policies on the Senegalese economy. We wonder about the water policy which gives the most welfare.

7.1 Climatic shocks combined with average cost pricing (see Appendix 7)

In the short run (1996):

In the short run, the rise of the primary resource availability (allowed by the supply increase) benefits directly drinking water production and the irrigated rice sectors. Firstly, it involves a decrease of the average cost, marginal cost, producer and consumer prices of - 35,6%. The fall of the drinking water input cost profits directly to the drinking water sectors. Indeed the producer and consumer water prices (private connection and standpost) decrease respectively by - 10,82% and - 9,24%.
The rise of the quantity of primary water available generates a production increase of irrigated rice (+8,92%), drinking water produced (+2,9%), drinking water distribution *via* private connection (+1,78%) and *via* standposts (+9,38%). Taking into account the Leontief production function of these sectors, their respective intermediate consumptions increase in the same proportions. There is an effect on the other sectors. Nevertheless, their production increases lower (except fishing and water intensive industry). There is an expansion of the sectors, which answers a demand rise *via* its three components: intermediate demand, final consumption and

[9] General Algebraic Modeling System, Brooke, Kendrick and Meeraus, (1996).

investment demand. This demand increase is illustrated by an imports increase (except for irrigated rice whose local production is enough to answer the demand). Firstly, it is explained by the intermediate demand rise related to the sectors expansion and the drinking water price decrease. Secondly, it is explained by an income rise of the agents. The agent's income increases taking into account the factor remunerations rise. Wages and the rate of return to agricultural land increase respectively by +0,67% and +0,43%. Rate of return to capital also increases in all the sectors (except in irrigated rice and drinking water production). In these two last sectors, primary water replaces the other factors (labour, capital and land) absorbed by the other sectors, which can ensure their expansion. Drinking water distribution sectors profit largely from the labour transfer, in particular the labour intensive sector (standposts). The other agricultural sectors profit from the land release by irrigated rice. After the irrigated rice, market-gardening is the agricultural sector which is the most in expansion, taking into account the fall of the water input cost. It monopolizes most of the land (+1,1%, +0,86% and +0,3% respectively for the market gardening, rain rice and other agriculture). The export demand for irrigated rice and market gardening grow respectively of +23,9% and +0,37%.
The intensive water sectors expansion results in a rise of their investment by destination: +1,61%, +2,48%, +15,79% and +42,22%, respectively for the market gardening, energy, private connection and standposts.

In the short run, the climatic shock combined with the maintenance of the current water pricing policy (average cost) generates a welfare rise for all the households except those of the River (-0,07%). The welfare increase for the urban households is more important (+0,51% for Dakar and +0,23% for the other urban areas) than for rural (+0,02% on average).

In terms of macroeconomics impacts, although government saving drops (because the shock generates a primary water remuneration fall), total investment increases by +1,03%. This is explained by the rise of the other agents savings (households and firms), related to their income rise, resulting from the other factors remuneration increase. Thus, the total welfare increases by +0,81% (incomes and consumption rise) and the unemployment rate decreases by - 0,9% thanks to the Senegalese economy expansion. In terms of drinking water distribution, the policy of supply increase generates, in the short run, a substitution of the standposts (+9,38%) to the private connection (+1,78%) and, a substitution of the formal to informal (+0,56%).

In the long-term (2015):

Ten years after the hydrologic deficit shock, the average cost, marginal cost and the producer and consumer prices of drinking water increase by +17,88%. This results in an increase of the drinking water input cost for the users sectors. This fall of the resource availability generates a production decrease of drinking water (-3,61%) and irrigated rice (-13,9%). The drinking water production decrease combined with the drinking water price increase generates a production fall of the intensive water sectors (-0,54%; -0,58%; -0,77%; -0,79%; -0,99%; -2,48% and -10,1% respectively for intensive water industry and tradable services, energy, drinking water informal distribution, market-gardening, private connection and standposts). The drinking water distribution is very affected. Taking into account the fall in the same proportions of their intermediate consumptions, the other sectors slow down. The production decrease of irrigated rice is partly compensated by the imports rise (+6,63%). The same does not hold for the other goods and services whose imports decrease. This implies a domestic demand contraction that must be explained. In the irrigated rice, the primary water availability decrease is compensated by an increase in the other factors demand. Labour, capital and land replace primary water. Their respective demand increases by +0,83%, +0,44% and +0,61%. The demand rise for land by irrigated rice is possible to the detriment of the other agricultural sectors, especially of the market-gardening because it is very water intensive (very affected by the water price increase). After irrigated rice, the agricultural sector is the most affected. In the drinking water production sector, the primary water availability decrease is compensated by an increase in labour and capital factors demand (+24,35% and +23,38%) to the detriment of the other sectors. This decrease in the factors demand by the other sectors is made possible by their contraction.

In the long-term, we observe a household's welfare loss except Niayes (constant) and River, which increases slightly. The welfare loss of the urban households (-0,44% for Dakar and -0,21% for the other urban areas) is stronger than that of rural (- 0,03% on average).

In terms of long-term macroeconomics impacts, we observe a sectors contraction. The primary water remunerations increase involves a rise of the governmental saving. However, the other factors' remunerations decrease (wages, rate of return to capital) generates a decrease of the other agent's income and saving. Thus, the investment and the total welfare decrease (-1,06% and -0,77%). The unemployment rate increases (+0,85%). In term of drinking water distribution, the distribution *via* standposts are more affected by the hydric deficit (-10,1%) than the distribution *via* private connection (-2,48%). The informal water distribution is less affected (-0,79%) because it is a regulation sector of the scarcity.

7.2 Climatic shocks combined with marginal cost pricing (see Appendix 8)

We suppose that the Government decides to practice marginal cost water pricing. Indeed, we have seen that the producer is in natural monopoly and at the base year, the water price is an average cost tariff. We suppose that the drinking water production price is not equal any more to its average cost (1 at the basic year) but equal to its marginal cost. This policy poses problem because for the monopoly it implies a loss. This loss (equal to the difference of sales between the average cost and the marginal cost on total volume) risks making it disappear in the long-term. This is why, to maintain the survival of the monopoly, the Government subsidies it to compensate for this loss. Through this simulation, we want to observe whether the total welfare of the Senegalese economy increases (although it undergoes climatic shocks).

In the short run (1996):

The resource availability rise, allowed by the policies of supply increase combined with marginal cost pricing, involves a fall of the drinking water average and marginal production costs of -32,36%. The drinking water producer and consumer prices decrease more than in the first *scenario* (-47,97% against -35,6%). It follows from there a stronger fall of the drinking water input cost for the users sectors. Indeed, the prices of drinking water distributed by the private connection and on the standposts drop more than in the first *scenario* (respectively -14% against - 10,82% and -12% against -9,24%). The rise of the drinking water sectors production is also accentuated (+4,01% against +2,9% for the drinking water production, +2,45% against +1,78% for the distribution *via* the private connection, +13% against +9,38% for the distribution *via* the standposts). This means that the rise of their intermediate consumptions has moved in proportion stronger than in the first *scenario* with a driving effect on the other sectors more important too. This is why the other sectors production increase is more important.
This supply rises because demand rises. Indeed, the intensive water sectors' expansion, *via* the intermediate demand rise and the drinking water price decrease, explains the total demand increase. This increase in total demand is possible because the agent's income increases. Indeed, rise in factorial remunerations is more important than in the first *scenario*: The wage rate and the rate of return to agricultural land grow respectively at +1,13% against +0,67% and +0,88% against +0,43%. The rate of return of capital increases more in all the sectors except in irrigated

rice and in the drinking water production sectors where it decreases with the first *scenario*. These changes in factorial remunerations are explained by the fact that in the irrigated rice and drinking water production sectors, primary water replaces the other factors absorbed by the other sectors growth. The labour demand increases in the drinking water distribution sectors (private connection and standposts) are more important (respectively +13,9% and +36,53% against +9,95% and +25,65%). In the agricultural sectors, the released land by irrigated rice (-1,38% against -1,29% in the first *scenario*) is more monopolized by rain rice (+1,21% against +0,86%) and the market-gardening (+1,4% against +1,1%) than in the first *scenario*.
The increase in investments by destination is also more important for rain rice, market-gardening, other agricultural sectors, non-intensive water industry, energy, drinking water distribution *via* private connection and standposts, and services. More particularly, the investment in the private connection sector increases by +22,4% against +15,79% and, +62,26% against +42,22% in standposts sector. The effect of a marginal cost pricing is more beneficial in terms of investments in the drinking water distribution sectors.
In the short-run, the climatic shock combined with the marginal cost pricing generates an improvement of all the households welfares except that of the River (-0,05%). This welfare increase is, as in the first *scenario,* stronger for the urban (+0,68% for Dakar and +0,31% for the other urban areas) than for the rural (+0,4% on average), but in greater proportions. This means that a marginal cost pricing accentuates the short run beneficial effects of the shock (policy of water supply increase) on the household's welfare.
In terms of macroeconomics impacts, marginal cost water pricing induces lower primary water remunerations. The Government's subsidy ensuring budget equilibrium of the drinking water production sector generates a Government saving degradation from -5,82% against -1,89% when it does not intervene in the first *scenario*. However, this does not stop the total investment. On the contrary, the total investment increases more (+1,84% against +1,03%) than in the first *scenario*. This is explained by the other agents' savings increase, which more than compensates for the fall of the Government saving. With marginal cost pricing, the more important economy expansion generates a more important increase in total welfare (+1,11% against +0,81%) and a more important reduction in unemployment rate (-1,5% against -0,9%). In terms of drinking water distribution, we observe the same results as in the first *scenario* even if those are accentuated. Following the policy of supply increase, we observe a substitution of standposts (+13%) to the private connection (+2,45%), which means strong development of the standposts network and, a substitution of formal for informal (+0,74%).

In the long-term (2015):

In the long-term, marginal cost water pricing makes it possible to absorb the negative effects on the economy of the hydrologic deficit shock. The average and marginal costs of drinking water production increase by +19,59%. But the producer and consumer prices of drinking water production decrease by -7,82% while they increased by +17,88% in the first *scenario*. The long-term trends of the economy are completely reversed according to the water pricing government policy (average cost *versus* marginal cost). This result is interesting because it shows that in the long-term, a marginal cost water pricing is still much more beneficial than in the short run. The analysis of the evolution of the other aggregates demonstrates it.
In spite of the resource scarcity shock, the drinking water production price decreases. Therefore, we observe a fall of the drinking water input cost for water intensive sectors. Indeed, the drinking water distribution prices *via* private connection and standposts decrease respectively by -2,96% and -2,91% while in the first *scenario* (average cost pricing), they increased respectively by +7,36% and +7,4%.
In consequence, sectoral effects become completely different. Outputs of the drinking water production sector, drinking water distribution sectors (private connection, standposts) and

market-gardening increase respectively by +1,36%, +0,8%, +4,63% and +0,11% while they decreased respectively by -3,61%, -2,48%, -10,1% and -0,99% in the first *scenario*. These results are very interesting because we observe a positive driving effect on the majority of the other sectors whose production increases *via* intermediate consumptions. The irrigated rice production decreases as in the first scenario (-13,9%). Only the productions of fishing, other agriculture and intensive water industry decrease but, in less proportions.
The expansion of most of the sectors explains the increase in factorial remunerations. The wage rate and the rate of return to agricultural land respectively increase (+0,29% and +0,5%) while they respectively decreased (-0,55% and -0,89%) in the first *scenario*. This rise in factorial remuneration justifies the expansion of the sectors by rise in the three demand components (intermediate, final and investment demands). In fact, the agents' income and saving increase except government saving which falls (-9,74% against a rise of +0,08% in the first *scenario*) because of the subsidy to the drinking water production sector. But this government saving fall is more than compensated by the other savings increase. So, the long-term total investment increases (+0,79%) whereas it decreased (-1,06%) in the first *scenario*.
In the long-term, the hydrologic shock combined with marginal cost pricing allows households to maintain welfare in the sylvopastoral area. It permits the household's welfare of River (+0,04%) to increase. The rise is more important than in the first *scenario*. As in the first *scenario*, the shock generates a decrease of all the other household's welfare, stronger for the urban (-0,1% for Dakar and -0,07% for the other urban areas) that for the rural (-0,15% on average), but in less proportions. This means that marginal cost pricing mitigates the negative effect of the water shortages on the household's welfare.

Finally in the long-term, the resource scarcity shock combined with the marginal cost water pricing, affects the total welfare less than in the average cost water pricing (-0,18% against -0,77%). The expansion of most of the sectors, allowed by the water price decrease, reopens the economic activity and decreases the unemployment rate (-0,43%) while this last increased by +0,85% in the first *scenario*. In terms of drinking water distribution, we observe an opposite trend to the first *scenario*. Indeed, the hydrologic deficit combined with a marginal cost pricing allows in the long-term an expansion of the drinking water distribution with a substitution of the standposts (+4,63%) to the private connection (+0,8%). It is explained by the investment dynamic. Contrary to the first *scenario*, investments in the water sectors increase (respectively +33%, +2,06% and +7,26% for the drinking water production, distribution *via* the private connection and standposts against +24,17%, - 2,25% and - 10,7%). Contrary to the first simulation, the informal water sector is not the regulator sector of the water shortage: it decreases (-0,06%).

Conclusion

Our dynamic CGE model applied to the Senegalese economy makes it possible to simulate in the short run a first phase of resource availability increase (policy of supply increase), followed by a phase of hydrologic deficits in accordance with the above projections. These climatic shocks are combined with two cases of water demand policy (average cost *versus* marginal cost pricing).

The results show that if in the short run, marginal cost pricing is more beneficial than average cost pricing, it positively amplifies the effects without reversing them. In fact, in both cases, the increase in the short term of the primary resource availability generates an economy expansion with a decrease of the unemployment rate, a rise of total investment and welfare. In both cases, the drinking water distribution *via* the standposts grows more than that with the private connection and, the formal one replaces the informal one. The agricultural sectors expansion is stronger when the policy of supply increase is accompanied by a marginal cost pricing. This

pricing policy is better for the fight against the food insecurity. Finally, the household's welfare increases more in this second *scenario*.
In the long-term, the results are more interesting because they show that the effects of a marginal cost water pricing are more beneficial. Indeed, in the presence of hydrologic deficits, it makes it possible to better manage the water scarcity by completely reversing the long-term economic trend induced by an average cost water pricing More precisely, the total investment increases whereas it decreased in the first *scenario*. Following the resource scarcity shock, the total welfare falls less than in the first case. More particularly, marginal cost water pricing makes it possible to mitigate the negative effects of the water shortages on the household's welfare. The expansion of most of the sectors allowed by marginal cost pricing reopens the economic activity by decreasing the unemployment rate while this latter increased with an average cost pricing. In spite of the water shortage, marginal cost pricing makes it possible to increase in the long-term the agricultural production of rain rice and market gardening whereas all the agricultural sectors production decreases with average cost pricing. This reform would also be better for the fight against food insecurity in the long-term. In term of supply drinking water, we observe an opposite trend to the first *scenario* when the hydrologic deficit is combined with marginal cost pricing. It allows an expansion of drinking water distribution (private connection and standposts) thanks to the investments dynamics, which increases the household's access to the service. Finally, the informal water sector does not play the role of shortage regulator any more.

To sum up, in the long-term, marginal cost water pricing allows better management of resource scarcity and permits reduction of food insecurity even if the government subsidises the drinking water production sector. It mitigates the negative effects of water shortages because it decreases the water input cost (related to the passage of average cost pricing with marginal cost pricing). Combined with the total investment rise, it reopens the economy and improves the household's welfare. This result goes against the directives of international organizations that impose budget equilibrium to the water companies. These directives could be negative for a long-term economy subjected to future hydrologic deficit. Lastly, it questions the basic tariff (average cost) on which the increasing block water pricing is based in Senegal.

Appendices:

Appendix 1: Table A1 .1: Share of value-added in the sectors production

Sectors	Production (XS)		Value-added (VA)		Rate of Value-added
	Value (in million FCFA)	Share (%)	Value (in million FCFA)	Share (%)	VA/XS (%)
Irrigated rice	92328	1,89	84148	3,23	91,14
Rain rice	4168	0,09	1847	0,07	44,31
Market gardening	89348	1,83	76328	2,93	85,43
Fishing	150585	3,09	119474	4,58	79,34
Other agriculture	452156	9,27	348243	13,36	77,02
Water intensive industry	573445	11,76	243892	9,36	42,53
Water non intensive industry	979654	20,09	237378	9,11	24,23
Other energy	70079	1,44	31114	1,19	44,40
Drinking water production (SONES)	29618	0,61	29618	1,14	100,00
Water distribution by private connection (SDE)	78880	1,62	36261	1,39	45,97
Water distribution by standposts (SDE)	13311	0,27	5157	0,20	38,74
Water informal distribution	7593	0,16	7513	0,29	98,95
Water intensive tradable services	980868	20,12	598784	22,97	61,05
Water non intensive tradable services	1041775	21,37	617927	23,70	59,31
Non tradable services	311910	6,40	169076	6,49	54,21
Total	4875718	100,00	2606760	100,00	53,46

Source: SAM, 1996

A1.2 table: Share of factors in Value-added (%)

Sectors	VA (million FCFA)	Share of factors				
		Labour (%)	Capital (%)	Land (%)	Primary water (%)	Total
Irrigated rice	84148	12,28	44,48	9,46	33,78	100
Rain rice	1847	57,34	30,54	12,13	0	100
Market gardening	76328	59,29	35,83	4,88	0	100
Fishing	119474	53,72	46,28	0	0	100
Other agriculture	348243	61,43	32,75	5,81	0	100
Water intensive industry	243892	18,63	81,37	0	0	100
Water non intensive industry	237378	32,91	67,09	0	0	100
Other energy	31114	17,91	82,09	0	0	100
Drinking water production (SONES)	29618	14,82	53,16	0	32,02	100
Water distribution by private connection (SDE)	36261	18,55	81,45	0	0	100
Water distribution by standposts (SDE)	5157	39,25	60,75	0	0	100
Water informal distribution	7513	88,65	11,35	0	0	100
Water intensive tradable services	598784	44,20	55,80	0	0	100
Water non intensive tradable services	617927	22,88	77,12	0	0	100
Non tradable services	169076	100	0	0	0	100
Total	2606760	40,62	56,69	1,23	1,45	100

Source: SAM, 1996

A1.3 table: Water intensity of sectors

Sectors	**Water produ-ced input (million FCFA)**	**Water distribu-ted by private connection input (million FCFA)**	**Water distribu-ted by standposts input (million FCFA)**	**Informal water input (million FCFA)**	**Total input of sectors (million FCFA)**	**Water input/ Total input (%)**
Irrigated rice	0	0	0	0	8180	**0**
Rain rice	0	0	0	0	2321	**0**
Market gardening	0	4771	1443	1443	13020	**58,8**
Fishing	0	222	0	44	31111	**0,86**
Other agriculture	0	0	0	0	103913	**0**
Water intensive industry	0	17380	0	0	329553	**5,3**
Water non intensive industry	0	10380	0	0	742276	**1,4**
Other energy	0	1791	0	0	38965	**4,6**
Drinking water production (SONES)	0	0	0	0	0	**0**
Water distribution by private connection (SDE)	32969	0	0	0	42619	**77**
Water distribution by standposts (SDE)	5742	0	0	0	8154	**70,4**
Water informal distribution	0	0	80	0	80	**100**
Water intensive tradable services	0	10051	0	0	382084	**2,6**
Water non intensive tradable services	0	4459	0	0	423848	**1,05**
Non tradable services	0	2040	0	0	142834	**1,43**
Total	38711	51094	1523	1487	2268958	**4,1**

Source: SAM, 1996

A1.4 table: Households income according to the source (in %)

	Dakar	**ACU**	**BA**	**NIAY**	**CASA**	**ZSP**	**SO**	**FLEUV**
Factors								
Labour	39,35	36	13,64	40	22,85	16,70	61,83	14,97
Capital	35,47	40,5	43,21	27,22	36,81	34,60	15,37	33,98
Land	0	0	6,61	2,94	7,31	3,9	3,32	3,60
Primary water	0	0	0	0	3,48	0	0	22,29
Transfers								
Households	17,45	15,3	17,85	17,45	15,18	30,16	13,36	15,92
Firms	5,14	4	7,70	5,03	5,74	5,11	2,32	3,64
Government	0,45	0,85	0,09	0,23	0,50	2,28	0,51	0,44
Rest of World	2,14	3,35	10,90	7,13	8,13	7,25	3,29	5,16
Total	100	100	100	100	100	100	100	100

Source: SAM, 1996

A1.5 table: Household's expenses (in %)

	Dakar	ACU	BA	NIAY	CASA	ZSP	SO	FLEUV
Total income	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**
Households transfers	**17,07**	**23,96**	**4,21**	**1,58**	**0,17**	**0,00**	**41,65**	**1,07**
Direct taxes	**2,31**	**2,49**	**1,97**	**1,29**	**0,00**	**0,00**	**0,60**	**0,00**
Final Consumption	**41,25**	**45,58**	**93,82**	**97,13**	**96,35**	**100**	**57,75**	**76,65**
Irrigated rice	9,98	10,74	13,90	16,29	17,76	13,19	13,95	15,05
Rain rice	0,00	0,00	0,12	0,00	2,31	0,00	1,92	0,00
Market gardening	5,18	5,34	6,51	6,31	5,57	6,11	5,29	5,61
Fishing	5,24	4,77	5,26	4,68	4,80	4,34	5,96	4,06
Other agriculture	8,89	9,30	20,84	14,58	25,42	17,48	15,01	25,35
Water intensive industry	16,72	15,46	10,94	16,38	14,45	21,73	17,00	11,86
Water non intensive industry	22,39	20,70	16,62	21,92	10,41	18,34	18,29	19,17
Other energy	1,78	1,65	2,27	1,74	1,54	2,31	1,81	2,16
Drinking water production	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Water *via* private connection	2,68	0,66	2,54	1,20	0,81	2,67	1,00	0,28
Water *via* standposts	0,05	0,05	0,23	0,29	0,01	0,29	0,06	0,01
Water informal	0,55	0,14	0,55	0,30	0,16	0,60	0,21	0,06
Water intensive tradable service	5,97	7,01	5,48	3,95	3,77	5,94	4,38	3,68
Water non intensive trad service	20,57	24,18	14,74	12,36	12,99	7,00	15,12	12,71
Non tradable service	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Saving	**39,37**	**27,97**	**0,00**	**0,00**	**3,48**	**0,00**	**0,00**	**22,28**

Source: SAM, 1996

Appendix 2: Model equations

Production

Production of drinking water (natural monopoly with increasing returns to scale)

(1) $$XS_{WAT} = VA_{WAT}$$

(2) $$KL_{WAT} = \left(\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}\right)\left(\frac{CM_{WAT}}{P_{KL}}\right)VA_{WAT}$$

(3) $$ED_{WAT} = \left(\frac{s_{WAT} - \alpha^{KLE}{}_{WAT}}{s_{WAT}}\right)\left(\frac{CM_{WAT}}{re_1}\right)VA_{WAT}$$

(4) $$LD_{WAT} = \left(\alpha^{KL}{}_{WAT} P_{KL} KL_{WAT}\right)/w$$

(5) $$P_{KL} = \left(\frac{1}{A^{KL1}{}_{WAT}}\right)\left(\frac{r_{WAT}}{\beta^{KL}{}_{WAT}}\right)^{\beta^{KL}{}_{WAT}}\left(\frac{w}{\alpha^{KL}{}_{WAT}}\right)^{\alpha^{KL}{}_{WAT}}$$

(6) $$PV_{WAT} = P_{WAT}$$

(7) $$PV_{WAT} = CM_{WAT}$$

(8)

$$Cm_{WAT} = \left(\frac{1}{s_{WAT}} \right) VA_{WAT}^{\frac{1}{s_{WAT}}-1} A^{KLE}{}_{WAT}^{\frac{-1}{s_{WAT}}} P_{KL}^{\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} re_1^{1-\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} \left(\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT} - \alpha^{KLE}{}_{WAT}} \right)^{1-\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} \left(\frac{s_{WAT}}{\alpha^{KLE}{}_{WAT}} \right)$$

(9)

$$CM_{WAT} = VA_{WAT}^{\frac{1}{s_{WAT}}-1} A^{KLE}{}_{WAT}^{\frac{-1}{s_{WAT}}} P_{KL}^{\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} re_1^{1-\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} \left(\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT} - \alpha^{KLE}{}_{WAT}} \right)^{1-\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} \left(\frac{s_{WAT}}{\alpha^{KLE}{}_{WAT}} \right)$$

(10)

$$CT_{WAT} = \left(\frac{VA_{WAT}}{A^{KLE}{}_{WAT}} \right)^{\frac{1}{s_{WAT}}} P_{KL}^{\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} re_1^{1-\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} \left(\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT} - \alpha^{KLE}{}_{WAT}} \right)^{1-\frac{\alpha^{KLE}{}_{WAT}}{s_{WAT}}} \left(\frac{s_{WAT}}{\alpha^{KLE}{}_{WAT}} \right)$$

(11) $SUB_{WAT} = \left(CM_{WAT} - Cm_{WAT} \right) VA_{WAT}$

Production of the other sectors (perfect competition)

(12) $XS_K = \dfrac{VA_K}{v_K}$

(13) $VA_{NWAT} = A^{KL}{}_{NWAT} \left[LD_{NWAT}{}^{\alpha_{NWAT}} KD_{NWAT}{}^{1-\alpha_{NWAT}} \right]$

(14) $VA_{NIRG} = A^{KLT}{}_{NIRG} LD_{NIRG}{}^{\alpha_{NIRG}} KD_{NIRG}{}^{\beta_{NIRG}} TD_{NIRG}{}^{1-\alpha_{NIRG}-\beta_{NIRG}}$

(15) $VA_{IRG} = A^{KLTE}{}_{IRG} LD_{IRG}{}^{\alpha_{IRG}} KD_{IRG}{}^{\beta_{IRG}} TD_{IRG}{}^{\chi_{IRG}} ED_{IRG}{}^{1-\alpha_{IRG}-\beta_{IRG}-\chi_{IRG}}$

(16) $VA_{NTR} = LD_{NTR}$

(17) $CI_K = io_K XS_K$

(18) $DI_{TR,K} = aij_{TR,K} CI_K$

(19) $LD_{NWAT} = \left(\alpha_{NWAT} PV_{NWAT} VA_{NWAT} \right) / w$

(20) $LD_{NIRG} = \left(\alpha_{NIRG} PV_{NIRG} VA_{NIRG} \right) / w$

(21) $LD_{IRG} = \left(\alpha_{IRG} PV_{IRG} VA_{IRG} \right) / w$

(22) $LD_{NTR} = \left(P_{NTR} XS_{NTR} - \sum_{TR} DI_{TR,NTR} Pc_{TR} \right) / \mathrm{w}$

(23) $TD_{NIRG} = \left((1 - \alpha_{NIRG} - \beta_{NIRG}) PV_{NIRG} VA_{NIRG} \right) / r_T$

(24) $TD_{IRG} = \left(\chi_{IRG} PV_{IRG} VA_{IRG}\right) / r_T$

(25) $ED_{IRG} = \left(\left(1-\alpha_{IRG} - \beta_{IRG} - \chi_{IRG}\right) PV_{IRG} VA_{IRG}\right) / re_2$

Income and saving

(26) $$YM_H = \lambda_{w_H} w \sum_j LD_j + \lambda_{r_H} \sum_{TR} r_{TR} KD_{TR} + \lambda_{l_H} \sum_{AGR} r_T TD_{AGR} + \lambda_{WAT_H} \left(re_1 ED_{PE} + re_2 ED_{RI}\right) + \sum_H RTF_{H,H} + DIV_H + TGM_H + TWM_H$$

(27) $YDM_H = YM_H - TDM_H - \sum_H RTF_{H,H}$

(28) $YE = \lambda_{re} \sum_{TR} r_{TR} KD_{TR}$

(29) $SM_H = \phi_H YDM_H$

(30) $SE = YE - \sum_H DIV_H - TDE - TEW$

(31) $YG = \lambda_{WAT} \left(re_1 ED_{PE} + re_2 ED_{RI}\right) + \sum_{TRX} TIM_{TRX} + \sum_{TR} TI_{TR} + \sum_H TDM_H + TDE + TWG$

(32) $SG = YG - G - \sum_H TGM_H - TGW - SUB_{PE}$

Taxes

(33) $TI_{TRX} = tx_{TRX} (P_{TRX} XS_{TRX} - Pe_{TRX} EX_{TRX}) + tx_{TRX} (1 + tm_{TRX}) ePwm_{TRX} M_{TRX}$

(34) $TI_{NTRX} = tx_{NTRX} P_{NTRX} XS_{NTRX}$

(35) $TDM_H = ty_H YM_H$

(36) $TDE = ty_e YE$

(37) $TIM_{TRX} = tm_{TRX} Pwm_{TRX} eM_{TRX}$

Demand

(38) $CTM_H = YDM_H - SM_H$

(39) $C_{TR,H} = \dfrac{Pc_{TR} \bar{C}_{TR,H} + \gamma_{TR,H} (CTM_H - \sum_{TR} Pc_{TR} \bar{C}_{TR,H})}{Pc_{TR}}$

(40) $INV_{TR} = \dfrac{\mu_{TR} IT}{Pc_{TR}}$

(41) $DIT_{TR} = \sum_K DI_{TR,K}$

(42) $G = P_{SNM} XS_{SNM}$

International trade

(43) $$XS_{TRX} = B_{TRX}{}^{e}\left[\beta_{TRX}{}^{e} EX_{TRX}{}^{-\kappa_{TRX}{}^{e}} + (1-\beta_{TRX}{}^{e}) D_{TRX}{}^{-\kappa_{TRX}{}^{e}}\right]^{-\frac{1}{\kappa_{TRX}{}^{e}}}$$

(44) $XS_{NTRX} = D_{NTRX}$

(45) $$D_{TRX} = \left[\left(\frac{1-\beta_{TRX}{}^{e}}{\beta_{TRX}{}^{e}}\right)\left(\frac{Pe_{TRX}}{Pl_{TRX}}\right)\right]^{\tau_{TR}{}^{e}} EX_{TRX}$$

(46) $$Q_{TRX} = A_{TRX}{}^{m}\left[\alpha_{TRX}{}^{m} M_{TRX}{}^{-\rho_{TRX}{}^{m}} + (1-\alpha_{TRX}{}^{m}) D_{TRX}{}^{-\rho_{TRX}{}^{m}}\right]^{-\frac{1}{\rho_{TRX}{}^{m}}}$$

(47) $Q_{NTRX} = D_{NTRX}$

(48) $$M_{TRX} = \left[\left(\frac{\alpha_{TRX}{}^{m}}{1-\alpha_{TRX}{}^{m}}\right)\left(\frac{Pd_{TRX}}{Pm_{TRX}}\right)\right]^{\sigma_{TRX}{}^{m}} D_{TRX}$$

(49)

$$SR = e\sum_{TRX} Pwm_{TRX} M_{TRX} + \lambda_{row} \sum_{TR} r_{TR} KD_{TR} + TEW + TGW - e\sum_{TRX} Pwe_{TRX} EX_{TRX} - \sum_{H} TWM_{H} - TWG$$

Prices

(50) $$PV_{K} = \left(P_{K} XS_{K} - \sum_{TR} DI_{TR,K} Pc_{TR}\right) / VA_{K}$$

(51) $Pm_{TRX} = ePwm_{TRX}(1+tm_{TRX})(1+tx_{TRX})$

(52) $Pe_{TRX} = ePwe_{TRX}$

(53) $$Pd_{TRX} = \frac{Pc_{TRX} Q_{TRX} - Pm_{TRX} M_{TRX}}{D_{TRX}}$$

(54) $$Pd_{NTRX} = \frac{Pc_{NTRX} Q_{NTRX}}{D_{NTRX}}$$

(55) $$Pl_{TR} = \frac{Pd_{TR}}{(1+tx_{TR})}$$

(56) $$P_{TRX} = \frac{Pl_{TRX} D_{TRX} + Pe_{TRX} EX_{TRX}}{XS_{TRX}}$$

(57) $$P_{NTRX} = \frac{Pl_{NTRX} D_{NTRX}}{XS_{NTRX}}$$

(58) $$P_{index} = \sum_{j} PV_{j} \delta_{j}$$

(59) $r_{WAT} = \dfrac{P_{KL} KL_{WAT} - wLD_{WAT}}{KD_{WAT}}$

(60) $r_{NWAT} = \dfrac{PV_{NWAT} VA_{NWAT} - wLD_{NWAT}}{KD_{NWAT}}$

(61) $r_{NIRG} = \dfrac{PV_{NIRG} VA_{NIRG} - wLD_{NIRG} - r_T TD_{NIRG}}{KD_{NIRG}}$

(62) $r_{IRG} = \dfrac{PV_{IRG} VA_{IRG} - wLD_{IRG} - r_T TD_{IRG} - re_2 ED_{IRG}}{KD_{IRG}}$

Equilibrium conditions

Labour market (unemployment)

(63) $LS = \sum_j LD_j + unLS$

(64) $w = ee + (ee / qq) * (bb / un + rr)$ Efficiency wage

Other equilibrium conditions

(65) $Q_{good} = DIT_{good} + \sum_H C_{good,H} + INV_{good}$

(66) $Q_{SMNIE} = \sum_H C_{SMNIE,H} + DIT_{SMNIE} + INV_{SMNIE}$

(67) $TS = \sum_{AGR} TD_{AGR}$

(68) $IT = \sum_H SM_H + SE + SG + SR$

Dynamic equations

(69) $KD_{TR,T+1} = (1-\delta) KD_{TR,T} + IND_{TR,T}$ Capital accumulation

(70) $LS_{T+1} = (1+n) LS_T$ Labour force growth

(71) $\dfrac{IND_{TR,T}}{KD_{TR,T}} = \gamma_{1TR} \left(\dfrac{r_{TR,T}}{U_T} \right)^2 + \gamma_{2TR} \left(\dfrac{r_{TR,T}}{U_T} \right)$ Investment demand

(72) $U_T = Pk_T (ir + \delta)$ Capital user cost

(73) $Pk_T = \sum_{TR} \left(Pc_{TR,T} \mu_{TR} \right)$ Capital replacement price

(74) $IT = Pk_T \sum_{TR} IND_{TR,T}$ Investment equilibrium

Appendix 3: Endogenous Variables

SUB_{WAT} : Government subsidy to drinking water production sector WAT
KL_{WAT} : Composite capital-labour in the drinking water production sector WAT
P_{KL} : Composite factor price in the drinking water production sector WAT
CM_{WAT} : Average cost of the drinking water production WAT
Cm_{WAT} : Marginal cost of the drinking water production WAT
CT_{WAT} : Total cost of the drinking water production WAT

Price
w : Wage rate
r_{TR} : Rate of return to capital TR
U_T : Capital user cost
Pk_T : Capital replacement price (price index of investment)
r_T : Rate of return to agricultural land
re_1 : Rate of return to primary water in the irrigated rice sector
re_2 : Rate of return to primary water in the drinking water production sector
P_i : Producer price of good I
PV_i : Value added price for activity J
Pd_{TR} : Domestic price of good TR including taxes
Pc_{TR} : Consumer price of composite good TR
Pe_{TRX} : Domestic price of exported good TRX
Pm_{TRX} : Domestic price of imported good TRX
Pl_{TR} : Domestic price of good TR (excluding taxes)
P_{index} : GDP deflator

Production
VA_I : Value added for activity J (volume)
XS_j : Output of activity J (volume)
CI_K : Total intermediate consumption of activity K (volume)
$DI_{TR,K}$: Intermediate consumption of good TR in activity K

Factors
LD_I : Activity J demand for labour (volume)
LS_T : Total labour supply (volume)
un : Unemployment rate
KD_{TR} : Activity TR demand for capital (volume)
TD_{AGR} : Agricultural activity AGR demand for land (volume)

Demand
$C_{TR,H}$: Household H's consumption of good TR (volume)

CTM_H : Household H's total consumption (value)
DIT_{TR} : Intermediate demand for good TR (volume)
INV_{TR} : Investment demand for good TR or by origin (volume)
$IND_{TR,T}$: Demand for capital in activity TR (volume)
IT : Total investment
D_{tr} : Demand for domestic good TR (volume)
Q_{tr} : Demand for composite good TR (volume)

International trade
EX_{TRX} : Exports in good TRX (volume)
M_{TRX} : Imports in good TRX (volume)

Income and saving
YM_H : Household H's income
YDM_H : Household H's disposable income
YE : Firm's income
YG : Government's income (value)
SM_H : Household H's savings
SE : Firms' savings
SG : Government's savings
TDE : Receipts from direct taxation on firms' income
TDM_H : Receipts from direct taxation on household H's income
TI_{TR} : Receipts from indirect tax on TR (value)
TIM_{TRX} : Receipts from import duties TRX (value)

Appendix 4: Exogenous variables

DIV_H : Dividend paid to households H
G : Public consumption (value)
TS : Total supply of land
ED_{WAT} : Activity WAT demand for primary water (volume)
ED_{IRG} : Activity IRG demand for primary water (volume)
TGM_H : Public transfers to household H
TGW : Public transfers to the rest of the world
$RTF_{H,H}$: Household H's transfers to household H's
TWM_H : Rest of the world transfers to household H's
TWG : Rest of the world transfers to government
TEW : Dividends paid to the Rest of the world
Pwm_{TRX} : World price of import TRX
Pwe_{TRX} : World price of export TRX
e : Nominal exchange rate

Appendix 5: Parameters

Unemployment function

ee : Effort disutility
bb : Exogenous probability to be fired
qq : Probability of detection of shirking
rr : Discount rate

Production functions

${A_{TRX}}^m$: Scale coefficient (CES function between imports and domestic production)
${\alpha_{TRX}}^m$: Share parameter (CES function between imports and domestic production)
${\sigma_{TRX}}^m$: Substitution elasticity (CES function between imports and domestic production)
${\rho_{TRX}}^m$: Substitution parameter (CES function between imports and domestic production)
${B_{TRX}}^e$: Scale coefficient (CET function between domestic production and exports)
${\beta_{TRX}}^e$: Share parameter (CET function between domestic production and exports)
${\tau_{TRX}}^e$: Transformation elasticity (CET function between domestic production and exports)
${\kappa_{TRX}}^e$: Transformation parameter (CET function between domestic production and exports)
$aij_{TR,j}$: Input-output coefficient
$A^{KL}{}_{NWAT}$: Scale coefficient (Cobb-Douglas production function) NWAT (capital-labour)
$A^{KL}{}_{WAT}$: Scale coefficient (Cobb-Douglas composite production function) WAT (capital-labour)
$A^{KLT}{}_{NIRG}$: Scale coefficient (Cobb-Douglas function of value added) NIRG (capital-labour-land)
$A^{KLE}{}_{WAT}$: Scale coefficient (Cobb-Douglas function of value added with increasing returns to scale) WAT (capital-labour composite and primary water)
s_{WAT} : Scale parameter mesuring increasing returns to scale WAT
$A^{KLTE}{}_{IRG}$: Scale coefficient (Cobb-Douglas function of value added) IRG (capital-labour-land-primary water)
A_{NTR} : Scale coefficient (production function of non tradable services) NTR
$\alpha^{KL}{}_{WAT}$: Share of labour (Cobb-Douglas production function of the composite factor capital-labour) WAT
$\alpha^{KLE}{}_{WAT}$: Share of the composite factor capital-labour (Cobb-douglas production function) WAT
α_I : Elasticity (Cobb-Douglas production function) I
$\beta^{Kl}{}_{WAT}$: Share of capital (Cobb-Douglas production function of the composite factor capital-labour) WAT
β_{TR} : Share of labour (Cobb-Douglas function of value added) TR
χ_{IRG} : Share of primary water (Cobb-Douglas function of value added) IRG
io_{TR} : Technical coefficient (Leontief production function) (intermediate consumption coefficient)
v_{TR} : Technical coefficent (Leontief production function) (value added coefficient)

Tax rates

tx_{TR} : Tax rate on good TR

tm_{TRX} : Import duties on good TR

ty_{H} : Direct tax rate on household H's income

ty_{e} : Direct tax rate on firms' income

Other parameters

$\overline{C}_{TR,H}$: Household H's minimum consumption of good TR

$\gamma_{TR,H}$: Marginal share of good TR

λ_{w_H} : Share of labour income received by household H

λ_{r_H} : Share of capital income received by household H

λ_{l_H} : Share of land income received by household H

λ_{WAT} : Share of primary water income received by government

λ_{WAT_H} : Share of primary water income received by households

λ_{re} : Share of capital income received by firms

λ_{row} : Share of capital income received by foreigners

ϕ_{H} : Propensity to save by household H

μ_{TR} : Share of the value of good TR in total investment

δ_{j} : Share of activity J in total value added

n : Population growth rate

δ : Capital depreciation rate

ir : Real interest rate

γ_{1TR} : Parameter in the investment demand function

γ_{2TR} : Parameter in the investment demand function

Appendix 6: Sets

$$i, j \in I = \{RI, RP, MA, PEC, AA, IIE, INIE, EG, PE, BP, BF, DIE, SMIE, SMNIE, SNM\}$$

All activities and goods (RI : Irrigated rice, RP : Rain rice, MA : Market gardening, PEC : Fishing, AA : Other agriculture, IIE : Water intensive industry, $INIE$: Water non-intensive industry, EG : Other energy, PE : Drinking water production (SONES), BP : Drinking water distribution *via* the private connection (SDE), BF : Drinking water distribution *via* the standpost (SDE), DIE : Informal drinking water distribution, $SMIE$: Water intensive tradable services, $SMNIE$: Water non-intensive non-tradable services, SNM : Non-tradable services).

$$K \in I = \{RI, RP, MA, PEC, AA, IIE, INIE, EG, BP, BF, DIE, SMIE, SMNIE, SNM\}$$

All activities and goods of I except PE

$$TR \in I = \{RI, RP, MA, PEC, AA, IIE, INIE, EG, PE, BP, BF, DIE, SMIE, SMNIE\}$$

Tradable activities and goods

$$Good \in TR = \{RI, RP, MA, PEC, AA, IIE, INIE, EG, PE, BP, BF, DIE\}$$

Tradable goods

$NAG \in TR = \{PEC, IIE, INIE, EG, PE, BP, BF, DIE, SMIE, SMNIE\}$

Non-agricultural tradable activities and goods

$AGR \in TR = \{RI, RP, MA, AA\}$

Agricultural activities and goods

$IRG \in AGR = \{RI\}$

Irrigated activity and good

$NIRG \in AGR = \{RP, MA, AA\}$

Non-irrigated agricultural activities and goods

$WAT \in NAG = \{PE\}$

Non-agricultural activity and good using primary water as input

$NWAT \in NAG = \{PEC, IIE, INIE, EG, BP, BF, DIE, SMIE, SMNIE\}$

Non-agricultural activities and goods no using primary water as input

$TRX \in TR = \{RI, MA, PEC, AA, IIE, INIE, SMIE, SMNIE\}$

Importable and exportable activities and goods

$H = \{Dakar, ACU, BA, NIAY, CASA, ZSP, SO, FLEUV\}$

Households ($Dakar$, ACU : Others urban areas, BA : groundnut basin, $NIAY$: Niayes, $CASA$: Casamance, ZSP : sylvopastoral area, SO : Eastern Senegal, $FLEUV$: Delta River)

Appendix 7: Results of the climatic shocks combined with the average cost water pricing (percent variation from the base path)

	RI		RP		MA		PEC		AA		IIE		INIE		EG		PE		BP		BF		DIE		SMIE		SMNIE	
	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015
CM																	-35,6	17,88										
Cm																	-35,6	17,88										
CT																	-33,8	22,4										
P	-8,23	12,4	0,55	-0,35	0,13	0,02	0,58	-0,39	0,65	-0,48	0,15	-0,05	0,35	-0,21	0,72	-0,06	-35,6	17,88	-10,82	7,36	-9,24	7,4	0,64	-0,47	0,59	-0,3	0,72	-0,31
PVA	-8,99	13,5	0,83	-0,58	0,97	-0,56	0,66	-0,46	0,67	-0,53	0,63	-0,41	0,68	-0,43	1,85	-0,35	-35,6	17,88	8,76	-0,2	15,65	-0,71	0,74	-0,54	0,88	-0,48	1,01	-0,45
PL	-8,24	12,4	0,55	-0,35	0,13	0,01	0,72	-0,5	0,67	-0,49	0,23	-0,08	0,46	-0,28	0,72	-0,06	-35,6	17,88	-10,82	7,36	-9,24	7,4	0,64	-0,47	0,64	-0,33	0,82	-0,37
PC	-4,13	5,46	0,55	-0,35	0,12	0,01	0,66	-0,47	0,59	-0,44	0,11	-0,04	0,28	-0,18	0,72	-0,06	-35,6	17,88	-10,82	7,36	-9,24	7,4	0,64	-0,47	0,62	-0,32	0,77	-0,34
R	-0,87	-0,26	1,29	-0,54	1,54	-0,54	0,64	-0,37	0,72	-0,43	0,62	-0,39	0,69	-0,36	2,11	-0,31	-33,8	0,26	10,69	-0,12	26,49	-0,81	1,31	-0,53	1,04	-0,44	1,12	-0,42
M	-4,27	6,63			0,76	-0,87	1,29	-1,48	1,08	-1,41	0,45	-0,73	0,87	-1,08											1,21	-1,25	1,48	-1,39
D	8,9	-13,9	0,46	-0,72	0,57	-0,99	0,2	-0,46	0,08	-0,35	0,11	-0,6	0,17	-0,47	0,25	-0,77	2,9	-3,61	1,78	-2,48	9,38	-10,1	0,56	-0,79	0,24	-0,55	0,25	-0,65
EX	23,9	-27,8			0,37	-1,11	-0,87	0,85	-0,91	0,86	-0,23	-0,43	-0,52	0,25											-0,72	0,28	-0,96	0,27
XS	8,92	-13,9	0,46	-0,72	0,56	-0,99	-0,02	-0,17	0,05	-0,3	-0,01	-0,54	0,01	-0,29	0,25	-0,77	2,9	-3,61	1,78	-2,48	9,38	-10,1	0,56	-0,79	0,16	-0,48	0,1	-0,52
Q	1,97	-3,96	0,46	-0,72	0,58	-0,98	0,29	-0,55	0,19	-0,47	0,29	-0,66	0,46	-0,73	0,25	-0,77	2,9	-3,61	1,78	-2,48	9,38	-10,1	0,56	-0,79	0,28	-0,58	0,32	-0,49
KD		0,44		-0,78		-1,02		-0,32		-0,44		-0,58		-0,39		-0,85		23,38		-2,62		-10,1		-0,81		-0,56		-0,57
LD	-1,53	0,83	0,62	-0,95	0,86	-1,01	-0,03	-0,05	0,05	-0,26	-0,05	-0,3	0,02	-0,08	1,43	-0,45	-34,2	24,35	9,95	-1,86	25,65	-10	0,63	-0,79	0,37	-0,38	0,44	-0,37
TD	-1,29	0,61	0,86	-0,47	1,1	-0,64			0,3	-0,12																		
KL																	-8,72	23,63										
INV			0,48	-0,55					0,43	-0,41	0,92	-1,03	0,75	-0,83	0,31	-1,02					11,31	-11,9			0,41	-0,6	0,25	-0,56
IND	-1,98	0,26	1,24	-1,48	1,61	-1,7	0,27	-0,7	0,39	-0,97	0,23	-1,04	0,34	-0,8	2,48	-1,04	-45,3	24,17	15,79	-2,25	42,22	-10,7	1,27	-1,47	0,86	-1,11	0,98	-1,08
DIT	2,1	-3,51	0,46	-0,72	0,14	-0,48	0,01	-0,31	0,04	-0,35	0,03	-0,4	0,1	-0,45	0,09	-0,49	2,9	-3,61	0,08	-0,49	0,56	-0,98	0,55	-0,97	0,1	-0,47	0,13	-0,54

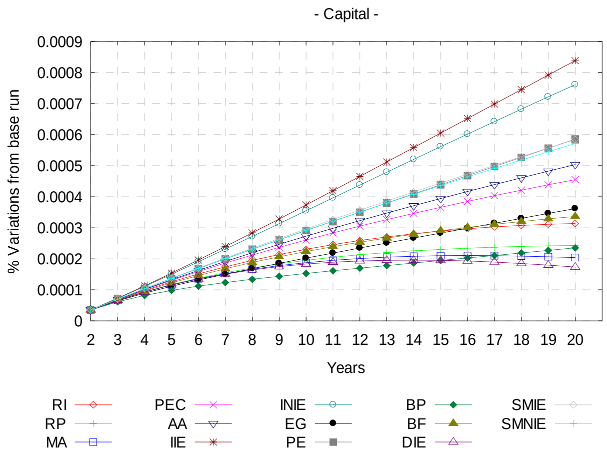
	1996	2015
w	0,67	-0,55
rt	0,43	-0,89
re1	-49,04	95,28
re2	-23,75	57,98
Pkl	-27,42	0,08
SG	-1,89	0,08
IT	1,03	-1,06
EV	0,81	-0,77
un	-0,9	0,85

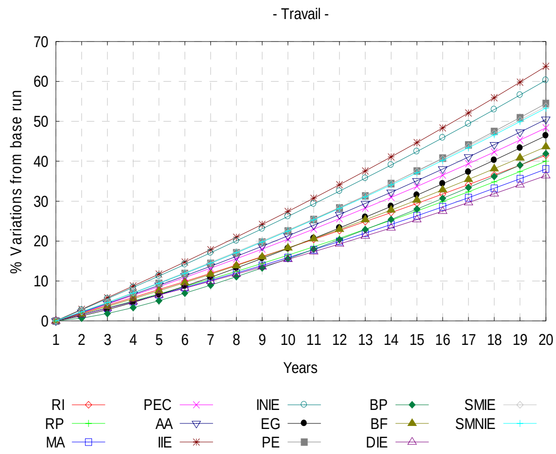
Appendix 8: Results of the climatic shocks combined with the marginal cost water pricing (percent variation from the base path)

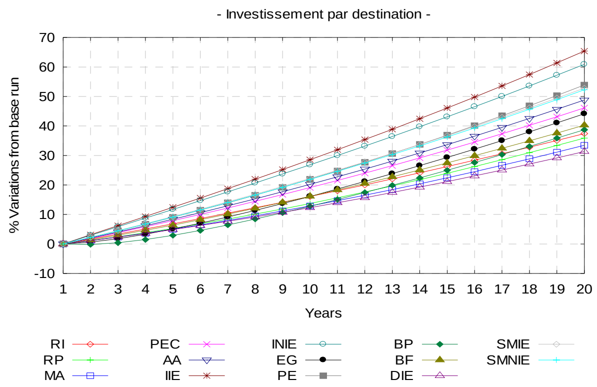
	RI		RP		MA		PEC		AA		IIE		INIE		EG		PE		BP		BF		DIE		SMIE		SMNIE	
	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015	1996	2015
CM																	-32,36	19,59										
Cm																	-32,36	19,59										
CT																	-29,65	30,79										
P	-7,88	13,2	0,92	0,16	0,4	0,02	0,93	0,18	1,08	0,22	0,23	0,07	0,61	0,12	1,14	0,08	-47,97	-7,82	-14	-2,96	-12	-2,91	1,08	0,23	1,03	0,16	1,2	0,14
PVA	-8,64	14,4	1,39	0,24	1,53	0,25	1,05	0,21	1,12	0,24	0,74	0,24	1,05	0,21	2,73	0,22	-47,97	-7,82	12,4	0,66	22,19	1,16	1,22	0,27	1,44	0,2	1,65	0,16
PL	-7,9	13,2	0,92	0,16	0,41	0,01	1,16	0,23	1,11	0,24	0,36	0,11	0,8	0,16	1,14	0,08	-47,97	-7,82	-14	-2,96	-12	-2,91	1,08	0,23	1,12	0,17	1,37	0,16
PC	-3,95	5,8	0,92	0,16	0,38	0,01	1,07	0,21	0,99	0,21	0,17	0,06	0,48	0,09	1,14	0,08	-47,97	-7,82	-14	-2,96	-12	-2,91	1,08	0,23	1,08	0,16	1,3	0,16
R	-0,51	0,23	2,1	0,08	2,3	0,17	0,95	0,11	1,16	0,14	0,65	0,23	1,01	0,18	3,08	0,21	-29,65	1,25	15,2	0,74	38,07	1,7	1,97	0,11	1,7	0,14	1,8	0,12
M	-3,76	8,21			1,38	0,14	2,01	0,44	1,76	0,47	0,64	0,07	1,46	0,47											2,08	0,59	2,47	0,58
D	8,88	-13,8	0,7	0,03	0,76	0,11	0,26	-0,06	0,08	-0,04	0,1	-0,2	0,25	0,12	0,34	0	4,01	1,36	2,45	0,8	13	4,63	0,74	-0,06	0,39	0,23	0,4	0,23
EX	23,2	-28,6			0,15	0,08	-1,47	-0,69	-1,57	-0,61	-0,44	-0,53	-0,95	-0,3											-1,27	-0,2	-1,62	-0,18
XS	8,9	-13,9	0,7	0,03	0,75	0,11	-0,09	-0,19	0,03	-0,06	-0,09	-0,33	-0,04	0,01	0,34	0	4,01	1,36	2,45	0,8	13	4,63	0,74	-0,06	0,25	0,19	0,15	0,18
Q	2,24	-3,17	0,7	0,03	0,8	0,11	0,4	-0,02	0,27	0,02	0,38	-0,05	0,74	0,27	0,34	0	4,01	1,36	2,45	0,8	13	4,63	0,74	-0,06	0,45	0,23	0,51	0,23
KD		0,78		0,27		0,23		-0,05		0,11		-0,3		0,08		0,02		30,33		0,67		3,77		0,16		0,3		0,24
LD	-1,62	0,68	0,96	-0,2	1,16	0,06	-0,17	-0,31	0,03	-0,13	-0,47	-0,4	-0,12	-0,1	1,94	-0,08	-30,43	31,55	13,9	1,36	36,53	5,88	0,83	-0,09	0,56	0,06	0,67	-0,03
TD	-1,38	0,4	1,21	-0,1	1,4	-0,02			0,27	-0,15																		
KL																	-7,61	30,63										
INV	0	0	0,91	0,56	0	0	0	0	0,84	0,48	1,66	0,72	1,36	0,66	0,69	0,71	0	0	0	0	15,71	5,6	0	0	0,75	0,57	0,54	0,58
IND	-1,97	1,01	1,91	0,18	2,22	0,35	0,2	-0,03	0,5	0,16	-0,25	0	0,28	0,24	3,4	0,26	-40,76	32,99	22,4	2,06	62,26	7,26	1,72	0,17	1,31	0,36	1,47	0,25
DIT	2,14	-2,96	0,7	0,03	0,18	0,11	-0,03	0,02	0,02	-0,01	-0,03	-0,16	0,12	0,08	0,08	-0,06	4,01	1,36	0,08	-0,05	0,75	0,1	0,73	0,1	0,11	0,02	0,13	-0,11

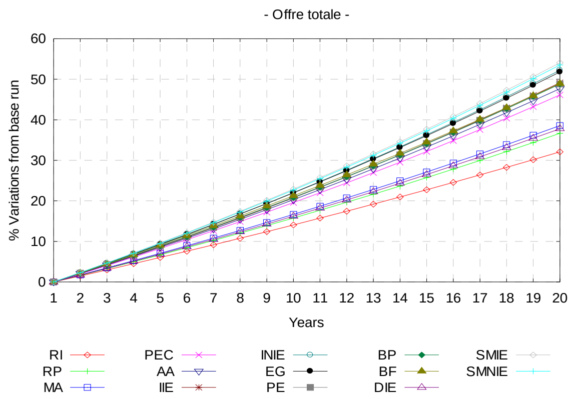
	1996	2015
w	1,13	0,29
rt	0,88	0,5
re1	-45,88	107,27
re2	-23,47	59,48
Pkl	-23,86	1,04
SG	-5,82	-9,74
IT	1,84	0,79
EV	1,11	-0,18
un	-1,5	-0,43

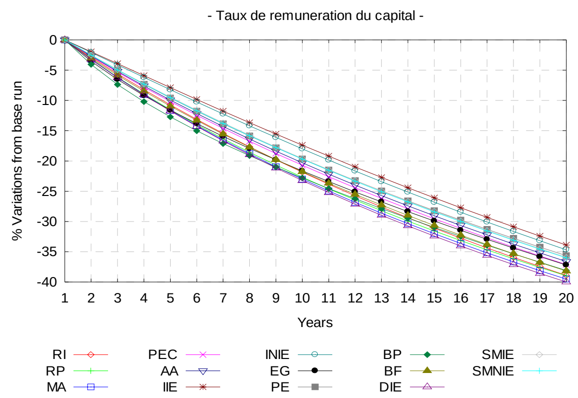
Appendix 9: The long-term tendencies (no shock: base path)

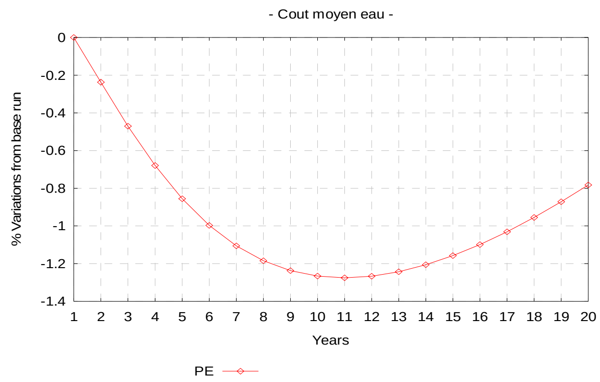


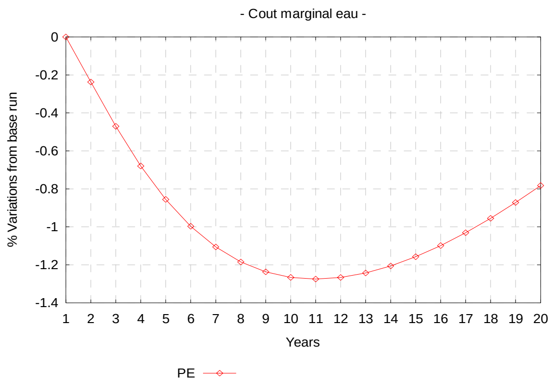




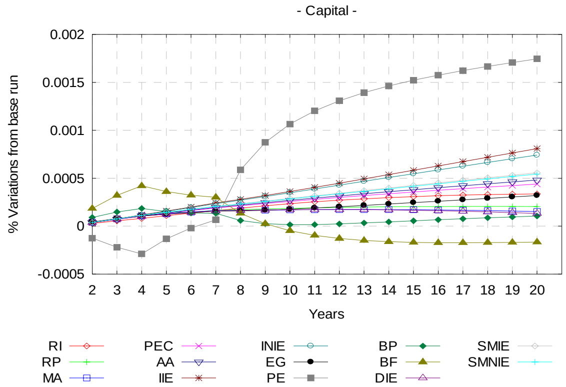


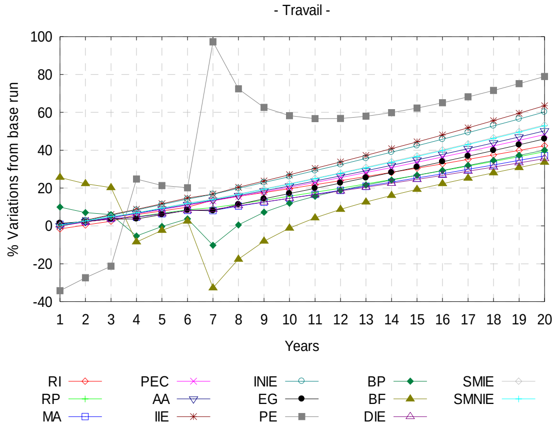


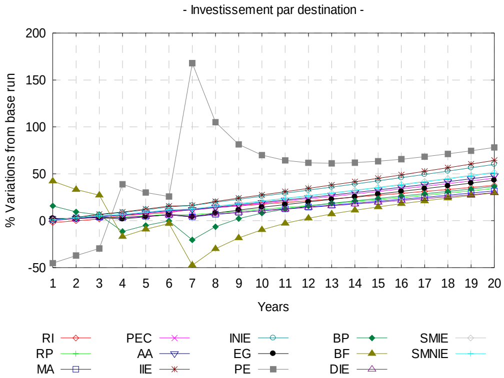


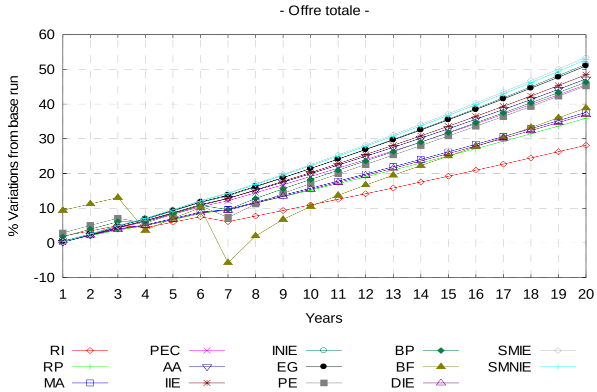


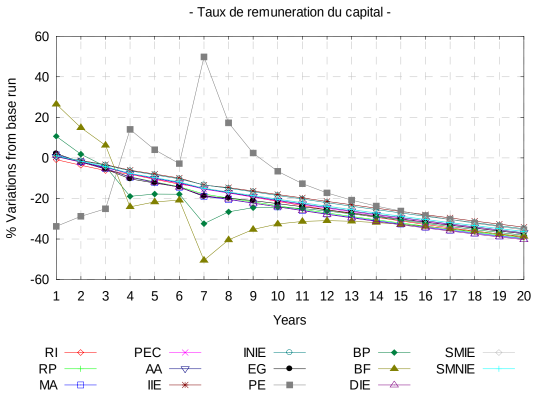
Appendix 10: Results of the climatic shocks combined with the average cost water pricing

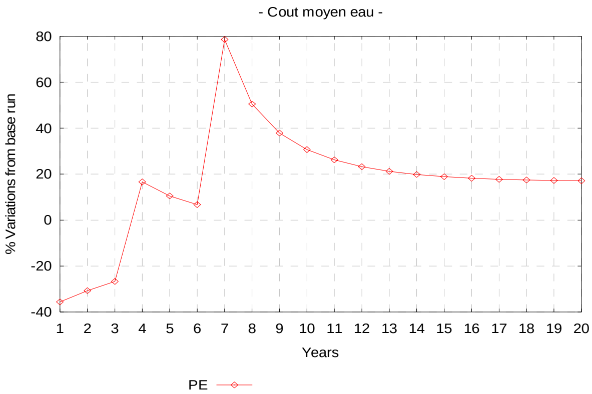


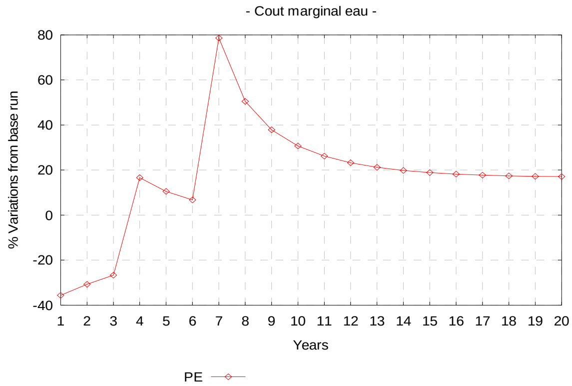




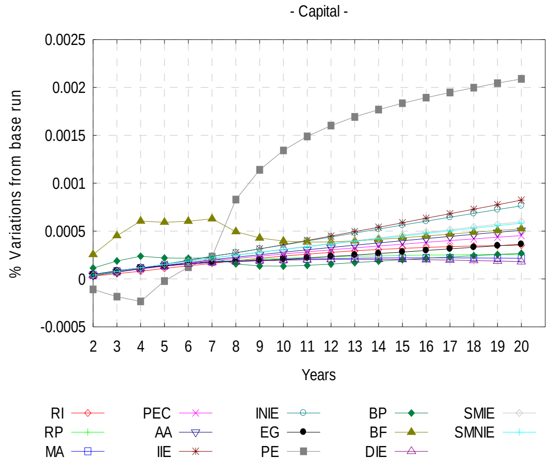


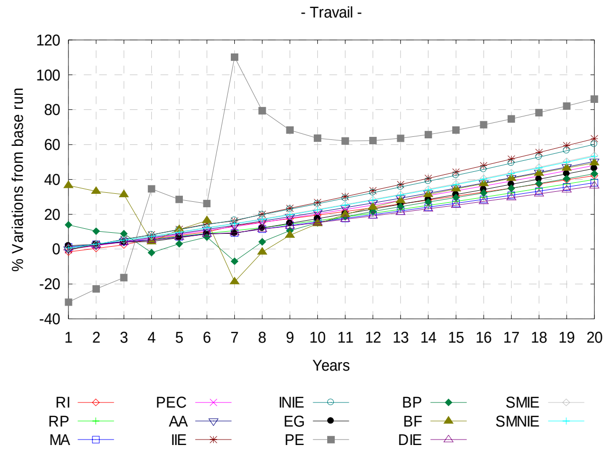


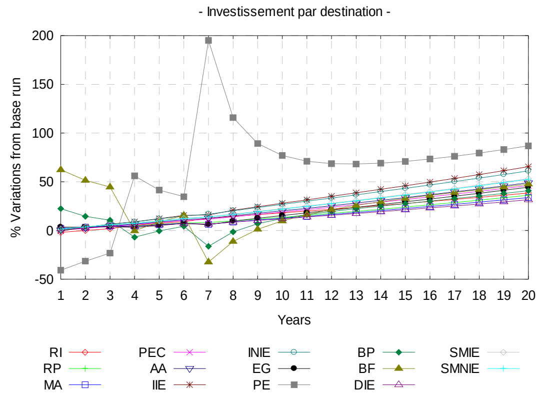


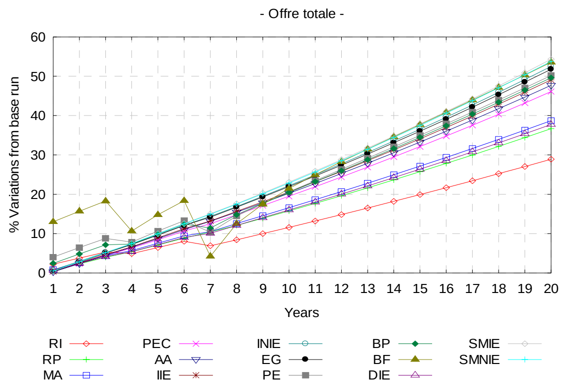


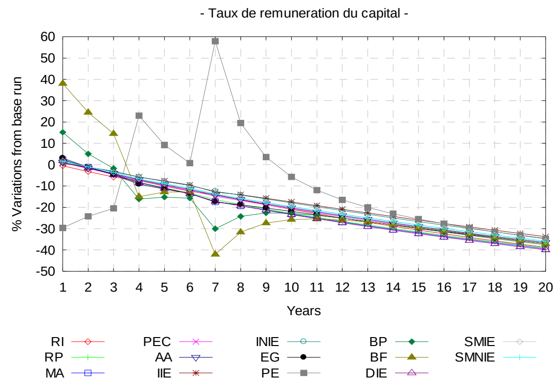
Appendix 11: Results of the climatic shocks combined with the marginal cost water pricing

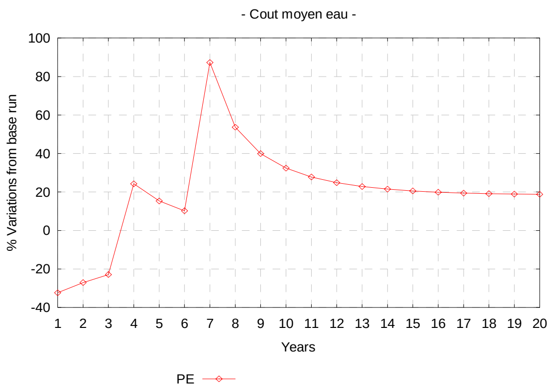


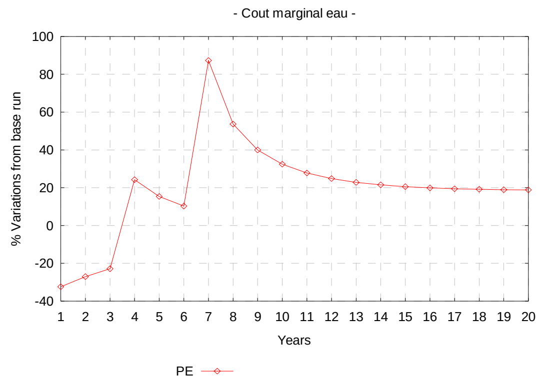












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