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Résumé – À l'aide d'un modèle d'équilibre général dynamique, l'article simule l'impact du programme d'insémination artificielle du Sénégal sur la croissance économique et le bien-être des ménages. Les résultats attestent d'une hausse de l'offre de bovins, de viande, de lait transformé et de cuirs. Les effets prix semblent l'emporter sur les effets revenus. En effet, les ménages gagnants de ce programme sont ceux des zones sylvo-pastorales, urbaines et du bassin arachidier.

Mots-clés – Insémination artificielle, évolution technologique, croissance endogène, équilibre général calculable, Sénégal

Cabral (François Joseph), « Artificial insemination and economic growth in Senegal »

Abstract – Using a general dynamic equilibrium model, this article simulates the impact of Senegal's artificial insemination program on economic growth and household wellbeing. The results attest to a rise in the supply of cows, meat, processed milk, and leather. The price effects seem to override the revenue effects. Indeed, the households benefitting from this program are those in silvopastoral and urban zones, and in the groundnut-growing belt.

Keywords – Artificial insemination, technological change, endogenous growth, computed general equilibrium, Senegal

ARTIFICIAL INSEMINATION AND ECONOMIC GROWTH IN SENEGAL

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INTRODUCTION

In Sub-Saharan Africa, the potential benefit from an increase in the productivity of livestock and livestock production is enormous. The production of meat per animal is twice less than the average in developing countries –and it is five times less than the average in developed countries, according to various species. The production of milk from local breeds is itself up to 10 times lower than that achieved by the European breeds (Boly and Leroy, 1999). Increasing productivity in the livestock sector in Senegal could provide an answer to many challenges (for example, the issue of market supply, food security and poverty), which also requires acquiring technologies to improve weight and livestock productivity.

In Senegal, the sub-sector livestock has the greatest contribution to agricultural value added. In comparison to the crops and fishery sector, a sustained growth in the livestock sector will ensure the highest reduction of poverty headcount from agricultural growth (République du Sénégal, 2009). Therefore, livestock sector plays a key role in increasing growth rate in the agricultural sector, in order to halve poverty.

The number of animals in the Senegalese livestock sector was estimated at 14,971,039 heads in 2010 and 15 354 685 heads in 2011. This herd was dominated by sheep (37.4%), goats (31.9%), cattle (21.9%),

pigs (2.38%), horses (3.4%), donkeys (2.9%) and camels (0.03%). Meat production was estimated at 193,311 tons in 2011, and 176,844 tons in 2010, which meant an increase of 9.3% in production. Milk production was estimated at 231,597 thousand litres in 2011 and 227,904 thousand litres in 2010, which lead to an increasby 1.6%. Milk product includes bovine milk (62%), goats (23%) and sheep (15%). At 0.12%, livestock & hunting is the twelfth (out of 42 sectors), in terms of contribution to the gross domestic product (GDP) growth that is estimated to 4.5% in 2011 (République du Sénégal, 2012).

Under the livestock component of former Senegalese "Great offensive for agriculture, food and nutrition" (GOANA) program, it was agreed that livestock production will be boosted through the implementation of the National Program for the Development of Local Dairy Die. From 2008 to the end of 2011, the program has allowed a successful insemination of 107,000 cows, which is equal to 1/5 of the target of 500,000 cows[1]. Also, only 7.33 million FCFA was devoted to this program. The budget allocated was about 18% of the required funds and this was the major constraint to the achievement of objectives (République du Sénégal, 2013). As a result, disbursing the required funds for the implementation of the National Program of Agricultural Investment (NPAI) can significantly increase the performance of the livestock sector in the upcoming years –and this will subsequently have an impact on agricultural productivity, overall GDP growth and wellbeing of households.

Given that the livestock sector is a significant segment of the agricultural sector as well as directly linked to the rest of the economy, artificial insemination can stimulate economy-wide effects due to inter-sectoral linkages. This type of shock will have important effects on the total factor productivity (TFP) valued added and the demand of factors. This will ensure feedback effects on the rest of the economy and drive microeconomic effects.

The aim of this research is to assess the effects of the cattle artificial insemination program on livestock productivity, overall GDP growth and household wellbeing. For this reason, an analytical framework that takes the relevant feedback effects into account will be developed.

1 This represents 3.4% of the total number of cows in Senegal, which is estimated at 3,127,109 by average, during the period 2005–2007 (République du Sénégal, 2012).

Moreover, a dynamic computable general equilibrium (CGE) is built to assess the effects of the shock on TFP, sectorial reallocation of resources and growth.

1. LITERATURE REVIEW

Several studies have been made on livestock economy. This paper and many others have attempted to quantify the effects of artificial insemination programs on livestock productivity and growth. Through the literature review, we will try to discuss, firstly, the main technical processes used in this sector; secondly, the key factors of livestock productivity; thirdly, the type of reproduction biotechnology.

Generally, studies on technical processes for livestock systems can be classified in three categories. In the first category, the main objective of farmers is to carry on the breeding the herd in the long term. The second category involves regular and consistent production, coupled with moderate expectations in terms of productivity objectives (for example, the number or weight of animals). The third category involves expecting a high level of production, with a distribution of calving on one or more annual campaigns. Traditional farming is often characterized by the coexistence of two systems: the transhumant system, which is characterized by high mobility and the sedentary system which can be mixed and combined with different food crops or annuity (Douhoux and Hounsou, 1993; Chentouf et al., 2004).

The literature on livestock remains divided because of the numerous factors that explain productivity. These variables include age at first calving and calving intervals (Sow et al., 1988; Dehoux and Hounsou, 1993) and lactation (Dehoux and Hounsou, 1993); the rate of withdrawal (Dekhili, 2003); the fertility rate (Senussi, 2004). The increase in productivity has to go through the adoption of pertinent techniques that improve these different variables.

Traditionally, animal reproduction biotechnology includes four generations: an artificial insemination, the embryo transfer, in vitro fertilization and transgenesis (Thibier and Guerin, 1993). However, only two genetic

improvement techniques are used in Senegal: artificial insemination (AI) and embryo transfer (Beye et al., 2013). The embryo transfer is a method of reproduction that involves removing embryos female elite, called donor, and transplant it into the uterus of recipient females, where they can develop until the end of the reproduction (Massip and Dessy, 2005). Artificial insemination is a technique of fertilization without coupling, which involves depositing the seed harvested first in the genital tract of a female in estrus.

The AI is the biotechnology breeding most widely used worldwide and is one of the effective tools for disseminating genetic material (Lofti et al., 1996). It enables large-scale screening and is a way of accelerating the pace of milk productivity. In Senegal, from 1999, AI was used in a development program covering the extent of the country, through the NAIP (Beye et al., 2013). The objective of this program was to increase milk production through the introduction of the genetic improvement of local breeds, using the genes of improved breeds. However, the largest program of AI in Senegal was launched in 2008 with the GOANA livestock program to cope with the threat of national food crisis. But the rate of success of AI is still low in Senegal. These rates have never reached 50% while in Burkina Faso, for example, the rate is 70% (Ouedraogo, 2012). This low level of AI success rate in Senegal is due to several factors such as the high cost and low availability of nitrogen; mix livestock with a high risk of protrudes of bulls before AI; nutritional deficiency that may cause embryonic mortality after insemination; the wrong track heats and starts or late warning (Faye, 2012).

Attempts to endogenously integrate innovation in economic analysis have been made through several models. For Arrow (1962), knowledge on the TFP is the accidental product of experience in the production of new capital goods. He qualifies this phenomenon as a process of "learning by doing". For Frankel (1962), the accumulation of capital leads to an increase of knowledge. Romer (1986) considers that the producers do not internalize the externalities of knowledge growth. In this context, knowledge is treated as an investment good which is combined with other factors that produce a final product.

In another model, Romer (1990) takes into account the specificity of technological knowledge as an economic good. Technology is a non-rival good: the knowledge used by an agent does not preclude the simultaneous use by another. It is also a partially exclusive good: it

is possible to prohibit the use of knowledge by an agent to produce a good. It is, however, difficult when this knowledge is used to produce another knowledge. The ownership of a discovery cannot be partial.

For Romer (1990), technical progress and innovation is at the heart of economic growth. It incites to capital accumulation and the combination of factors explains much of productivity gains. The author assumes that technical progress comes from decisions by individuals who meet the incentives issued by the market. The model therefore includes a rather endogenous technical progress. An additional assumption considered that modalities to implement technological innovations differ from the other technological assets. There was a fixed sunk cost for the first innovation, used as an input, which provides a monopoly rent to the innovative firm. Romer found that the increase in innovation depends on both the staff working in research and the number of existing innovations. The total labour supply is a sum of the labour given to the production of goods and the one allocated to research. This expresses the existence of dynamic externalities related to research.

From literature review, we found that artificial insemination is the biotechnology breeding most widely used in Senegal and worldwide. From growth endogenous theory, one can also denote that growth relies on innovation as shown by Romer (1990). Therefore, it will be interesting from the perspective of Senegalese AI experience to measure the extent of the impact setting endogenously TFP can have on livestock sector productivity, growth and wellbeing.

2. BACKGROUND

Several lessons can be drawn from the analysis of the livestock industry and its related sectors from the 2005 Social Accounting Matrix (SAM). Crops account for 9.9% of GDP, and livestock being an important subsector of Senegalese agriculture contributes to the GDP about a quarter of this amount. This sector has inter-relations with processing sectors like meat, milk and leather. In total, the livestock sector and its related sectors (meat, milk and leather) account for about 4.8% of GDP (Fig. 1).

	Value added of sector j/ Production j	Value added of sector j/ Total Value added
Crops	84.5%	9.9%
Fishery	56.8%	1.8%
Cow	49.8%	0.1%
Ovine	89.7%	0.9%
Goat	86.8%	0.5%
Cameline-porcine	86.8%	0.3%
Equine	85.3%	0.1%
Traditional poultry	85.3%	0.0%
Industrial poultry	83.3%	0.4%
Other type of livestock	60.7%	0.3%
Processed meat	67.7%	0.3%
Processed fish	58.3%	1.5%
Leather	41.3%	1.7%
Processed milk	56.1%	0.2%
Other industries	4.8%	0.1%
Tradable services	18.7%	17.4%
Non traçables services	59.6%	46.8%
Total	77.3%	17.8%

FIG. 1 – Relative weight of value added in production and share of sectors in total value added (in %). Sources: SAM.

Livestock raw products are mainly non-tradable in Senegalese economy. By contrast, with regard to the SAM data, for the sectors of processed meat, processed milk and leather, respectively 86.5%, 39.4% and 31% of the production in these sectors is geared towards the international market. On the import side, one can denote that up to 15%, 65%, and 40% of the demand for processed meat, milk, and leather come from the world market.

With regards to the consumption basket structure, raw and processed livestock products account for almost 8 % of consumption in urban areas and 0.1% in rural areas (Fig. 2).

	Dakar	Other cities	Groundnut belt	Niayes area	Southern Senegal	Sylvo-pastoral area	Eastern Senegal	River area
Crops	6.96%	8.48%	3.61%	0.23%	1.60%	0.61%	0.20%	0.54%
fishery	6.38%	5.49%	1.47%	0.15%	0.50%	0.01%	0.04%	0.17%
Crossbred cow	0	0	0	0	0	0	0	0
Traditional cow	0.16%	0.12%	0.04%	0.00%	0.02%	0.24%	0.00%	0.01%
Ovine	0.06%	0.05%	0.02%	0.00%	0.01%	0.00%	0.00%	0.00%
Goat	0.03%	0.02%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Cameline-porcine	0.03%	0.03%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%
Equine	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Traditional poultry	0.44%	0.33%	0.11%	0.01%	0.05%	0.02%	0.01%	0.02%
Industrial poultry	0.36%	0.27%	0.09%	0.01%	0.04%	0.02%	0.00%	0.01%
Egg	0.52%	0.39%	0.13%	0.01%	0.06%	0.02%	0.01%	0.02%
Raw milk	1.54%	1.16%	0.39%	0.03%	0.17%	0.07%	0.02%	0.06%
Other livestock products	0.24%	0.18%	0.06%	0.00%	0.03%	0.01%	0.00%	0.01%
Processed meat	3.86%	3.78%	1.11%	0.12%	0.39%	0.16%	0.04%	0.13%
Processed fish	2.57%	2.52%	0.74%	0.08%	0.26%	0.10%	0.03%	0.09%
Leather	0.85%	0.61%	0.22%	0.02%	0.08%	0.03%	0.01%	0.03%
Processed milk	0.86%	0.84%	0.25%	0.03%	0.09%	0.03%	0.01%	0.03%
Other industry	35.34%	26.82%	12.07%	1.27%	4.49%	1.49%	1.16%	1.52%
Tradable services	39.81%	23.28%	4.56%	0.59%	1.91%	0.49%	0.16%	0.65%
Total	100%	100%	100%	100%	100%	100%	100%	100%

FIG. 2 – Consumption basket structure. Sources: SAM.

3. METHODOLOGY

In this paper, a recursive dynamic general equilibrium model is built to assess the effects of an artificial insemination program on livestock productivity and economic growth.

3.1. MODEL DESCRIPTION

The dynamic model of the Senegalese economy has been developed based on a Pep model (B. Decaluwe, A. Lemelin and V. Robichaud, 2013). This model applies to a small open economy for which world prices are given. The model is designed as a set of simultaneous linear and non-linear equations, which define economic agents' behaviour as well as the economic environment in which these agents operate. It belongs to the strand of dynamic recursive CGE literature which implies that agents' behaviour is based on adaptive projections, rather than on the forward-looking projections that underlie alternative inter-temporal optimization models.

The model integrates seven factors: non-skilled labour, skilled labour, crop capital, cow capital, other livestock capital type, public capital and land. The institutions selected are households in Dakar; households in other urban centres; rural households in the groundnut belt; rural households in the sylvo-pastoral area; rural households in Southern Senegal; Eastern Senegal; Senegal River Basin; and the Niayes area; firms; the Government; and the rest of the world. The added value of the agricultural sector is expressed as a Constant Elasticity Substitution (CES) function of land and a composite factor. The latter is expressed as a CES function of composite labour and composite capital. Labour is specified as a CES function of skilled and non-skilled labour, while the composite capital is expressed as a Leontief function specifying fixed shares of public and private capital. The value added of the non-agricultural sector is expressed, instead, as a CES function of composite labour and non-agricultural capital.

In the recursive dynamic model, it is assumed that current economic conditions, such as the availability of capital is endogenously influenced by past economic conditions, but remain unaffected by forward-looking

expectations. The dynamic model is also exogenously updated to reflect demographic changes that are based on observed or inferred projected trends. The process of capital accumulation is endogenous.

3.2 SPECIFIC FEATURES

A number of features have been added to the model. The stock of sectorial private capital of the period t is equal to the stock in the previous period, minus capital depreciation, plus the capital accumulated during that period. Private capital accumulated during a period depends on the ratio between return to capital and the cost of this factor. For a given sector j, the stock of public capital of the period is also equal to the stock of the previous period, minus capital depreciation, plus the volume of investment accumulated. Public investment is a complement of private investment. This relation defines the one that links the public capital and the private capital in the tradable sector. Public investment includes research and development, and infrastructure. In the public sector, the investment at period t depends on the available Government income.

A specific feature of the model is that artificial insemination is treated as a process of innovation diffusion.

Based on Romer's model, one can try to endogenously introduce diffusion of innovation in livestock sector technology through artificial insemination. The artificial insemination program, as it comes from government R&D efforts, is also viewed as a non-rival good and it is quite non-exclusive. For producers who have access to artificial insemination program, productivity gains tend to be high, and hence it increases sectorial growth. Similar to the process of innovation, the decision to adopt insemination technology involves sunk costs. Expenditures for that purpose are given, whereas the percentage of unsuccessful inseminations can be sometime high[2].

Even if the added value of the cattle sector, like in the other agricultural sectors, is expressed as a CES function of land and a composite factor. In this function, the TFP is endogenous. Total factor productivity is endogenously determined. As the program of artificial insemination relies mainly on budgetary efforts, the rate of increase of insemination is supposed to be a function of expenditures devoted to R&D:

2 It is equal to 44.16 % for Senegalese artificial insemination program.

$$\frac{\hat{AI}}{AI} = \lambda RD$$

Thereafter, TFP in the livestock sector is supposed to depend on artificial insemination rate of growth:

$$TFP = \frac{\hat{AI}}{AI} = \lambda RD$$

More specifically, in the dynamic CGE model, the TFP in the specific cattle sector is supposed to be endogenous. As we distinguish two sub-sectors in the cattle sector: crossbred cattle and traditional cattle. We presume that for crossbred cow sector, TFP is a function of R&D and the stock of the total public capital, which creates a positive externality that also affects the sector. Therefore, the TFP depends on R&D and on the ratio between the total public capital and private capital of the cattle sector and a scale parameter[3]:

$$A^t_{cow} = \overline{A^t_{cow}} * (\mathrm{RD}_{\mathrm{cow}})^{\lambda} \left(\frac{\mathrm{KDpubG}^{\mathrm{t}}}{\mathrm{KDpriv}^{\mathrm{t}}_{\mathrm{tr}}} \right)^{\theta}$$

For the traditional cow sector, we also suppose that TFP is endogenous. However, only externalities coming from flows of R&D in the crossbred cattle sector through the ratio between total public capital and private capital, has an effect on TFP.

Another feature of this model is the segmentation of the labour market and the introduction of endogenous unemployment. The wage curve approach developed by Blanchflower and Oswald (1994) is used to model

3 According to policy makers, only 18% of the budget of the artificial insemination program has been mobilized, which represents an amount of 7.33 million. So the cost of the program is supposed to be 40.72 million. From this total amount, one can increase the TFP by 400% though 500,000 crossbred cows. By producing 107,000 crossbred cows, this rate is divided by four. So by using production as a proxy, the elacticity λ can be derived from the ratio between changes in production and changes in R&D. It is estimated equal to 0.095. The elasticity of the TFP in cow sector to the ratio between public and private capital is the same than the one used for CAADAP scenarios for Senegal. It is supposed equal to 0.012.

the labour market where we assume the existence of unemployment in the segment of skilled labour. Workers in this segment are traditionally used in the modern sector, or formal sector, where there is relative rigidity in the wage determination. The wage rate evolves according to the behaviour of the labour market and the situation described by the wage curve, which shows a negative relationship between levels.

We assume that the cow sector uses a specific type of capital. Therefore, endowments in terms of this type of capital are more important in the pastoral rural areas where livestock is the main activity.

3.3. DATA

The dynamic general equilibrium model is built based on a 2005 SAM of the Senegalese economy, which focuses on livestock. Data on the program of artificial insemination is collected from Ministry of Livestock. This Senegalese SAM is built, based in 2005 input-output table, so as to make the focus on the livestock sector, especially the cattle subsector. The SAM includes 18 sectors: crops, fisheries, crossbred cows, traditional cows, ovine, goats, cameline-porcine, equine, traditional poultry, industrial poultry, other types of livestock, processed meat, processed fish, processed leather, processed milk, other industries, tradable services, non-tradable services. There are 20 outputs in the SAM and it takes into account the fact that livestock activity is a multiproduct one: crops, fisheries, crossbred cows, traditional cows, ovine, goats, cameline-porcine, equine, traditional poultry, industrial poultry, eggs, raw milk, other types of livestock, processed meat, processed fish, leather, processed milk, other industries, tradable services, non-tradable services. The SAM also includes 10 institutions: government, firms; households from Dakar; households from other urban cities; households from rural areas of Niayes; households from rural Groundnut basin; households from rural Casamance; households from rural pastoral areas; households from rural Eastern Senegal; and households from the rural Senegalese's River Basin.

4. SIMULATIONS AND RESULTS

The simulation made is based on a shock on R&D in crossbred cow sector. The rate of accumulation of R&D in the crossbred cattle sector, measured by the ratio of the stock of R&D on the public stock capital, has increased by 307 %, between 2008 and 2011. We assume that changes in value added, factors, economic growth, household income and prices will pass through total factor productivity that is a function of R&D. Due to the fact that it contributes to delivering several products like raw milk, leather, processed milk and processed meat, any shock on the subsectors of cows can have an economy-wide effects and feedback effects due to inter-sectorial linkages.

4.1. SECTORAL EFFECTS

The simulation has been implemented in the sub-period 2008–2011. Due to an increase in R&D and TFP in the crossbred cattle sector resulting from the effects of the AI program, the value added in this sector observes an increase from 2008 to 2011 (Fig. 4). It increases from 0.257 to 0.179 percentage points, with respect to the Business as usual (BAU) scenario (Fig. 4). This result is close to the one found by Nadeem et al. (2012) in India who indicates that the performance of livestock sub-sector in Punjab over 39 years has been mainly driven by productivity growth.

Due to the fact that crossbred cattle sector is a multi-output one and products from this sector serves as input in the sectors of processed meat, processed milk and leather, supply also increases for processed meat (from 0.002 to 0.005 percentage points, with respect to the BAU scenario), leather (from 0.003 to 0.007 percentage points, with respect to the BAU scenario) and processed milk (from 0.001 to 0.004 percentage points, with respect to the BAU scenario). Increasing TFP is drawn up by R&D, and hence, public investment which is a complement of private capital in this sector. Value added and production also increase for services and industries. For crops, fisheries, cameline-porcine, processed fish, after a slight decrease, it increases at the end of the period. However, an

eviction effect seems to occur from the fact that government is shifting public investment in the sub-sector of crossbred cattle, as value added decreases in the other livestock sectors (Fig. 3).

Sectors	2005	2006	2007	2008	2009	2010	2011
Crops	0	0	0	−0.003	−0.001	0	0.002
Fishery	0	0	0	−0.001	0.002	0.003	0.004
Crossbred cow	**0**	**0**	**0**	**0.257**	**0.225**	**0.199**	**0.179**
Traditional cow	0	0	0	−0.017	−0.015	−0.013	−0.011
Ovine	0	0	0	−0.008	−0.006	−0.004	−0.002
Goat	0	0	0	−0.008	−0.006	−0.003	−0.002
Cameline-porcine	0	0	0	−0.002	−0.001	0	0.002
Equine	0	0	0	0	0	0	0
Traditional poultry	0	0	0	−0.003	−0.002	−0.001	0
Industrial poultry	0	0	0	−0.004	−0.003	−0.001	−0.001
Other type of livestock	0	0	0	−0.002	−0.001	0	0
Processed meat	**0**	**0**	**0**	**0.002**	**0.002**	**0.003**	**0.005**
Processed fish	0	0	0	−0.001	0.001	0.002	0.004
Leather	**0**	**0**	**0**	**0**	**0.003**	**0.005**	**0.007**
Processed milk	**0**	**0**	**0**	**0.001**	**0.003**	**0.004**	**0.004**
Other industries	0	0	0	−0.001	0.001	0.002	0.004
Tradable services	0	0	0	0.004	0.006	0.007	0.008
Non traçables services	0	0	0	0.023	0.023	0.021	0.02

FIG. 3 – Changes in value added growth, w. r. t. the BAU (in %).
Sources: simulations.

4.2. IMPACT ON THE RETURNS ON FACTORS

We assume that the cattle sector uses a specific type of capital. Therefore, endowments in terms of this type of capital are more important in the pastoral rural areas where livestock is the main activity. Between the two types of labour (skilled and non-skilled), the crossbred cattle sector is more intensive in skilled labour, while the local cattle

sector is more intensive in non-skilled labour. Also, in Senegal, the local cattle sector uses land as a factor, while this factor is weakly used by the crossbred sector.

Due to an increase in TFP driven by the artificial insemination program, the rate of returns of cow capital decreases from 11.9 to 5.8 percentage points after the implementation of the program (Fig. 4). As for skilled and non-skilled labour, wage rates decreased slightly. Due to a decreasing value added in the crop sector, except the last period, the rate of return of land and agricultural capital decreases. These effects for non-agricultural capital is positive at the first period, but tend to decrease by the end of the period.

Periods	Agricultural capital	Cow capital	Other livestock type capital	Non agricultural capital	Public capital	Land	Skilled labour	Unskilled labour
2005	0	0	0	0	0	0	0	0
2006	0	0	0	0	0	0	0	0
2007	0	0	0	0	0	0	0	0
2008	−0.005	−11.928	−0.008	0.003	−0.002	−0.008	−0.001	−0.001
2009	−0.006	−9.527	−0.009	0	−0.003	−0.008	−0.001	−0.002
2010	−0.007	−7.514	−0.009	−0.004	−0.002	−0.009	−0.001	−0.001
2011	−0.008	−5.864	−0.011	−0.006	−0.002	−0.009	−0.001	−0.001

FIG. 4 – Changes in the return on factors, w. r. t. baseline (in %).
Sources: simulations.

4.3. IMPACT ON GDP

Changes in GDP growth goes from a range of 0.001 to 0.091 percentage points, with respect to the BAU, as soon as the program is implemented (sub-period 2008–2011). This change in GDP comes from the variation in the crossbred cattle sector's TFP but also from factor reallocation effects (Fig. 5). Thus, the artificial insemination program can have wide effects on Senegal's GDP.

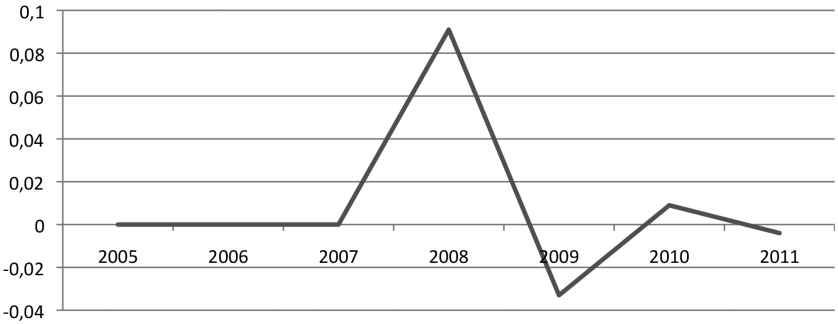

Fig. 5 – Changes in GDP growth w. r. t. baseline (in %).
Sources: simulations.

4.4. IMPACT ON NOMINAL INCOME AND CONSUMER PRICES

Changes in returns to factors that are redistributed to households affect their nominal income depending on their endowments. As mentioned previously, capital used in the cow sector is most importantly used in sylvo-pastoral rural area. Hence, the return to this type of capital goes mainly to the households of this area. Crossbred cattle sector mainly uses skilled labour, while the local cattle sector is more intensive in non-skilled labour. Like agriculture and the other livestock sectors, local cattle sector also uses a large amount of land.

Households will also be affected differently by the change in consumer prices, according to the structure of their basket consumption. Consumer price is an average of import and domestic prices, weighted by shares of imports and domestic sales in the composite good. Changes in prices of goods and services consumed will affect the real consumption of households. The combined income and price impacts will determine a priori, the effects of artificial insemination program on households wellbeing, measured by the equivalent variation.

Households have experienced a decline in their income due to decreasing rate of returns to factors, but also in consumption prices in their districts. However, price effects seem to offset income effects in urban areas. Therefore, wellbeing has increased for households living in Dakar and other cities while it decreases for rural households. Local cattle

activity is more rural activity, like the one practiced in the pastoral area, the wellbeing decreased in this area. It also decreases other rural households (Fig. 6 in appendix).

CONCLUSION AND POLICY LESSONS

Contribution of livestock Senegal in agricultural growth is very important. While the cattle sector is very important in some areas like the sylvo-pastoral region, livestock combined with crops is important for households in all rural areas. Outputs coming from livestock, in particular, from the cattle sector can also have relatively important impacts in the basket of consumption of households in urban and rural areas.

The aim of this paper was to assess the effects of Senegalese artificial insemination program, implemented from 2008 to 2011 in the cattle sector, in order to boost the production of milk, meat and leather. However, only 107,000 crossbred cows have been delivered, with a target of 500,000, as an output of the program in 2011.

In this paper, we first build a dynamic general equilibrium recursive model in which we endogenize the TFP for the cattle sector. In the cattle sector, TFP is supposed to depend on the effort of R&D and on externalities of public capital given by the ratio between private and public capital. Thereafter, the rate of accumulation of R&D is supposed to be a fixed ratio of public capital in the cattle sector. However, even if the value added in those two sub-sectors of cattle depends on an endogenous TFP, for local cattle sector, there is no investment in R&D. This approach is an innovative one in the field of livestock researches in Senegal as it tends to assess livestock policies by taking into account interactions between this sector and the rest of the economy and agents, in particular households. However, the results of this research should be analysed bearing in mind that the tool used to rely on a framework for which statistical tests are not common.

We then simulate and assess the effects of the artificial insemination program in Senegal, on sectors, factors remuneration–and hence GDP and wellbeing. We assume that R&D for the artificial insemination

program coming from flows of public capital increased from 2008 to 2011.

The results show that production of crossbred has increased while the one of traditional cow decreased in Senegal. Increasing supply in crossbred sector induces increase in several outputs (processed meat, processed milk and leather). However, increase in TFP seems to have a depressive effect on returns to factors as income for all households tends to decrease. On the other hand, consumption prices decrease. Households from urban cities (Dakar and other cities) where price impacts seem to overshadow impacts in income are major beneficiaries of this program. Wellbeing of these two groups of households has increased. And as local cattle activity is more rural activity, like the one practiced in the pastoral area, the wellbeing decreased in this area as well as for other rural households.

Therefore, the challenge will be to increase the size of the program, which is at its earlier stage and has a small magnitude. The aim should be to cover more than 3% of the total population of cattle that the program effectively covers. Another challenge is to reduce the number of areas that are not benefiting from this program. This can be done by extending the scope of the program beyond the objective of 500,000 cows, in order to enhance the income effects and make it more significant than price effects. In addition, it can also be achieved through the development of other livestock sectors in other rural areas–for example: poultry, ovine, goat and equine.

As a result, a more intensive artificial insemination livestock program with a reduction of the inefficiency level in the allocation of artificial insemination resources could be a strong policy tool to boost the contribution of livestock to agricultural GDP growth, economic growth and household wellbeing.

APPENDIX

		Dakar	Other cities	Groundnut basin	Niayes	Casamance	Pastoral area	Eastern Senegal	Senegalese River Basin
2005	Nominal income	0	0	0	0	0	0	0	0
	Consumer price	0	0	0	0	0	0	0	0
	Wellbeing	0	0	0	0	0	0	0	0
2006	Nominal income	0	0	0	0	0	0	0	0
	Consumer price	0	0	0	0	0	0	0	0
	Wellbeing	0	0	0	0	0	0	0	0
2007	Nominal income	0	0	0	0	0	0	0	0
	Consumer price	0	0	0	0	0	0	0	0
	Wellbeing	0	0	0	0	0	0	0	0
2008	Nominal income	−0.156	−0.126	−0.254	−0.468	−0.378	−0.424	−0.392	−0.331
	Consumer price	−0.232	−0.23	−0.219	−0.18	−0.235	-1.158	−0.158	−0.235
	Wellbeing	0.069	0.101	−0.009	−0.142	−0.089	0.3	−0.024	−0.019
2009	Nominal income	−0.023	0.002	−0.068	−0.341	−0.214	−0.24	−0.262	−0.167

	Consumer price	−0.146	−0.15	−0.148	−0.108	−0.162	-1.083	−0.097	−0.162
	Wellbeing	0.099	0.135	0.086	−0.116	−0.021	0.346	−0.017	0.005
2010	Nominal income	−0.063	−0.039	−0.131	−0.406	−0.275	−0.308	−0.309	−0.227
	Consumer price	−0.169	−0.171	−0.167	−0.128	−0.181	-1.104	−0.113	−0.181
	Wellbeing	0.092	0.127	0.056	−0.135	−0.046	0.345	−0.019	−0.004
2011	Nominal income	−0.047	−0.025	−0.113	−0.411	−0.265	−0.296	−0.3	−0.216
	Consumer price	−0.158	−0.161	−0.158	−0.119	−0.171	-1.095	−0.105	−0.171
	Wellbeing	0.098	0.133	0.067	−0.141	−0.043	0.361	−0.019	−0.001

FIG. 6 – Changes in nominal income, consumer prices and wellbeing according to areas w. r. t. the baseline (in %).
Sources: simulations.

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