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Rural–urban migration and agricultural productivity: the case of Senegal

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Abstract

This paper explores the relationship between agricultural productivity and rural–urban migration by developing an econometric model and applying it to the case of Senegal. Country level data is used covering the years 1961–1996. Policy implications of reducing rural–urban migration using agricultural output elasticities are developed. The findings support the hypothesis that rural–urban migration is a positive function of the ratio of urban per capita income to rural per capita income. Moreover, the results support a policy aimed at reducing rural–urban migration flows through increases in per capita earnings derived from increased agricultural investment.

JEL classification: F0; O1; Q1

Keywords: International agriculture; Economic development; Rural–urban migration; Investment

1. Introduction

The entry of sub-Saharan Africa into the modern economy simultaneously initiated active rural–urban migration. According to Lewis (1954) and Fei and Ranis (1961), rural–urban migration is a response to the high demand of labour by an industrial sector, which assures workers greater levels of productivity, and investors positive profits superior to the opportunities found in the traditional agricultural sector. According to these models rural regions are over-populated relative to their ability to feed themselves; labour productivity is low and approaching zero, which results in a subsistence level of production and provides incentives for migration to the cities.

However, in many African countries, significant rural–urban migration flows have coincided with limited industrialisation, high unemployment and poverty rates in urban areas. Thus, the so-called industrial sector pull for rural labour has been largely absent in many SSA countries. Nevertheless, migration has occurred at fairly high rates. According to Todaro (1969) and to Harris and Todaro (1970), rural–urban migration in less developed countries is a function of the difference between the expected wage from

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migration (urban wage) and the agricultural wage. That expected wage is equivalent to the actual industrial wage weighted by the migrant's probability of obtaining a job in the modern urban sector. Hence, rural–urban migration can coexist with high levels of urban unemployment. Johnson (1971) introduced to the Harris–Todaro model a 'wage sharing' variable to take into account urban unemployment and a lower rate of job turn over than in the Harris–Todaro model. Gugler and Flanagan (1978), Fields (1979), and Kelly and Williamson (1984) suggested inclusion in the Harris–Todaro model of information on costs of living and potential migrants' education levels when computing the probability of securing an urban job. According to Corden and Findlay (1975) it is capital mobility, workers moving to places where capital is more productive, that leads to labour migration. The purpose this research is to test the Todaro hypothesis in the African country of Senegal and to design a policy aimed at reducing rural–urban migration in that country.

The typical rural–urban migrant in LDCs is 15–30 years old, is more educated than the average rural worker, and has contacts or an initial endowment to finance the transportation and installation costs (Caldwell, 1969; Byerlee, 1974; Sabot, 1979; Lipton, 1980). Developing countries that face urban unemployment and poverty resulting from high rural–urban migration rates have employed three types of policies to solve the problem. First, the shadow pricing policy (e.g. Kenya and Tanzania) attempts to equate marginal rates of substitution between labour inputs in both sectors. Manufacturing labour markets were subsidised, in effect lowering the urban wage to the rural wage level (Harris and Todaro, 1970; Sabot, 1979). This policy is equivalent to granting subsidies to agricultural production by indirectly maintaining greater rural labour supplies and better equating the marginal rates of production in both sectors (Bhagwati and Srinivasan, 1974). But such a policy is costly and involves heavy administrative costs (Sabot, 1979). As well, it reflects an odd sort of logic, seeking lower rather than higher wages. Second, restricting labour migration into cities had been applied in many LDCs but with only short run positive results (Sabot, 1979). It also raises questions of civil liberties. Finally, attempts have been made to implement labour intensive projects in cities to reduce urban unemployment and poverty. This has led to even more rural–urban migration as rural workers interpret them as signals of higher probabilities of obtaining urban jobs (Todaro, 1994).

Therefore Stiglitz (1969), Todaro (1976), Byerlee (1974), and Sabot (1979) have suggested that the most consistent policy for decreasing rural–urban migration should be built upon the improvement of agricultural per capita earnings. In fact, rural–urban migration and agricultural performance are tied together because rural workers compare their income with what they could obtain if they migrated to the cities. We explore this relationship using a recursive equation system. The results will be used to identify those agricultural factors that have a significant impact on rural–urban migration.

We next introduce the problem of rural–urban migration, using Senegal as an example, and then present a set of equations as a model of rural–urban migration. Finally, the results of the model will be used to derive indirect elasticity indicators that could be used to design a policy aimed at reducing rural–urban migration.

2. Rural–urban migration in Senegal

Located in the sub-Saharan African zone, Senegal experiences significant rural–urban migration flows (Pison et al., 1995). The rural population decreased from 70% of the total national population in the 1960s to 57% in 1993 (FAO, 1999). In 1999, Senegal's population was estimated at 9 million, with 2.5 million living in the city of Dakar (Programme de Gestion Urbaine, 1995). Projections show that the urban population in 2030 will reach 11.7 million, increasing at 3.72% per year, while the rural population will reach 6.5 million, increasing at a rate of 1.76% a year (Fig. 1).

On the other hand, in Senegal, the per capita agricultural production index (base year 1989–1991, 3-year average) has decreased by almost 50%, falling from 176 to 96 (FAO, 2000) between 1961 and 1999. Other studies confirm the poor performance of the agricultural sector, 1% growth between 1967 and 1991 (Kante et al., 1994) and 0.7% in the 1980s (Diagne, 1995). Meanwhile the annual growth rate of the population is around 2.7%.

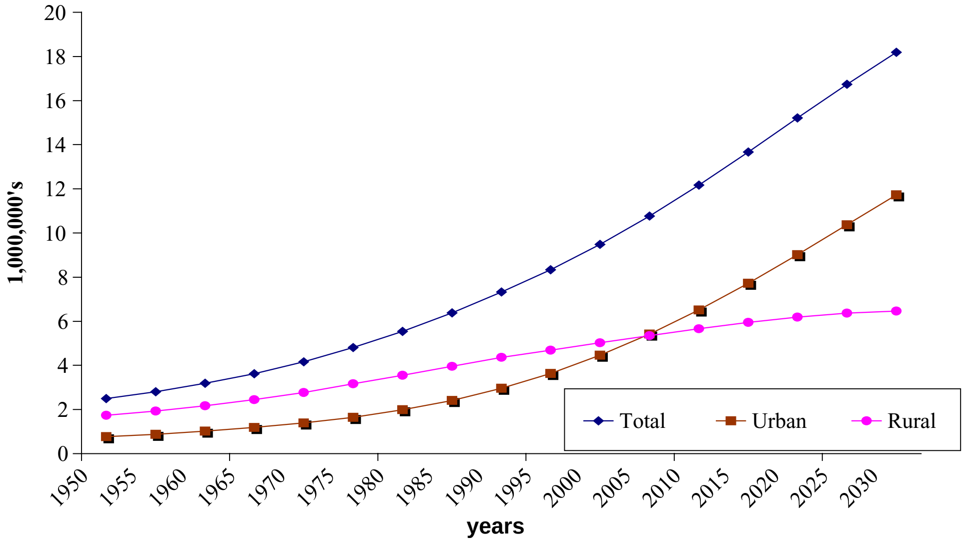

Fig. 1. Projections of Senegal's total, rural and urban population (1950–2030).

Cities in Senegal have high levels of unemployment, poverty and a deficit of infrastructure investment. The unemployment rate in the capital city of Dakar was estimated at 24.4% in 1992 (Kante et al., 1994), at 34.6% among these aged 15–29 and at 44.3% for women aged 20–24 (Programme de Gestion Urbaine, 1995). Although many factors are to blame, the high urban unemployment rate is related to the crisis in the industrial and the public sectors. The annual growth rate of real manufacturing value added (MVA) was negative (−1%) in the 1970s and (−0.8%) in the 1990s (UNIDO, 1999). During the 1985–1996 period, the growth rate of employment was negative in important manufacturing activities such as food products, textiles, petroleum, chemicals, machinery and fabricated metal products (UNIDO, 1999). Finally, the structural adjustment program adopted in 1985 led to a reduction in the number of public service workers.

Since the public and private modern sectors are no longer creating jobs for an increasing urban labour force, unemployed people are trying to make their own living by working or creating new economic activity in the 'non-official urban sector', also called the 'fringe', 'murky' or 'informal' sector. These activities generally involve services and deal with car repair, hair cutting, shoe shining, street peddling, prostitution, etc. This is enough to attract young workers from rural areas, driving down agricultural output while doing little to increase urban productivity or reduce urban poverty. The thesis on which this paper is based focuses on a policy of increasing agricultural productivity as an indirect means of reducing rural–urban migration.

3. The model

Economic theory and empirical research have shown that the foundation of rural–urban migration is the excess of the urban wage over the rural wage. Other migration determinants such as distance, age and personal contacts only really reflect the fact that wage and productivity disparities exist. The model developed below is used to identify what factors drive agricultural productivity. It is hypothesised that a rise in agricultural wages as a result of an increase in productivity will reduce, ceteris paribus, the wage differential between urban and rural sectors. This change in the wage differential can feed into a migration equation, reducing the rural–urban migration. Therefore, there is a recursive relationship between the agricultural production equation and the rural–urban migration equation, linked by the agricultural output that is common to both equations. By creating this recursive system of equations, the migration elasticities can be estimated with respect to changes in agricultural inputs. The computed elasticities can then be used to estimate the impact of agricultural inputs on rural–urban migration.

3.1. Migration models

Macro migration functions using time series data sets are used to estimate the important determinants of aggregate migration flows from rural to urban areas, calculate their relative importance, assess possible trade-offs and predict migration flows based on the estimated elasticities (Todaro, 1976). Godfrey (1973) looked at the problem from a macroeconomic perspective and specified migration as dependent on the rural–urban wage differential and on the difficulty of getting a job in the modern sector. Salehi-Isfahani (1993) similarly focused on the relationship between land use intensity and migration in Iran. Krishna (1984) specified migration as dependent on the wage differential and on the past year's migration rate. Also, when modelling migration behaviour, Levy and Wadycki (1972), Beals et al. (1967), and Sahota (1968) used the macro approach. The dependent variable (M) of the macro migration function at any period t is the number of migrants moving from rural areas to cities (Eq. (1)). The independent variables are wage or income levels defined as agricultural output (Y) divided by the population level (P), unemployment rates (U), and the age structure (G) of migrants. The subscripts A and U refer to agricultural and urban areas, respectively. This study employs the macro-economic approach:[3]

$$M_t = f(Y_{A_t}, Y_{U_t}, P_{A_t}, P_{U_t}, G_t) \quad (1)$$

The algebraic form used is generally logarithmic because the expected wage hypothesis posits multiplicative interactions between wage rates and employment that are easily specified logarithmically. Previous empirical research on migration (Schultz, 1977; Fields, 1979) has shown that the logarithmic form explains a larger share of the variance in M than other forms.

[3] An anonymous reviewer raised important criticisms of macro-economic approaches to the study of migration. While we have referenced numerous articles using aggregated data to study migration or agricultural productivity, it is important to note alternative approaches to understanding these complex issues. Excellent studies which employ a micro-level approach are: Weigel (1982), Jacob and Delville (1993), and Pison et al. (1995).

3.2. Agricultural productivity models

Empirical research has often used the Cobb–Douglas production function to measure the relationship between inputs and output, marginal products, and production elasticities (Dillon and Hardaker, 1993). Block (1995), using a time series from 1963 to 1988, measures output per worker using a unique wheat unit approach. Hayami and Ruttan (1970), using multi-year averages, employed a Cobb–Douglas meta-production function to conduct inter-country comparison of agricultural productivity per capita. The inputs they used could be classified as capital and labour. They specified agricultural output (Y_A) to be function of traditional conventional capital inputs: land (A) and livestock (S) and modern conventional capital inputs, fertilisers (F) and machinery (Mc). They also included traditional conventional labour inputs: agricultural labour force (L) and modern non-conventional labour input, education (E) (Eq. (2)). An additional non-conventional input is infrastructure capital (IK) (Schultz, 1964). Public spending on infrastructure is exogenous to the farmer's production plan, although it is correlated with agricultural growth in both developed and developing economies (Howard et al., 1998):

$$Y_{A_t} = f(A_t, L_t, F_t, \mathrm{Mc}_t, S_t, E_t, \mathrm{IK}_t). \quad (2)$$

Together, Eqs. (1) and (2) comprise the model.

Expressing (1) and (2) as double logarithmic functions creates a system of two equations (3) linked by agricultural output in the migration equation. Agricultural output, the dependent variable in (2), is an independent variable in (1):

$$\begin{cases} \ln Y_{At} = \alpha_0 + \alpha_A \ln A_t + \alpha_L \ln L_t + \alpha_F \ln F_t \\ \qquad +\alpha_{\mathrm{Mc}} \ln \mathrm{Mc}_t + \alpha_S \ln S_t + \alpha_E \ln E_t \\ \qquad +\alpha_{\mathrm{IK}} \ln \mathrm{IK}_t + \varepsilon_1 \\ \ln M_t = \beta_0 + \beta_{Y_A} \ln YA_t + \beta_{Y_U} \ln Y_{U_t} + \beta_{P_A} \ln P_{A_t} \\ \qquad +\beta_{P_U} \ln P_{U_t} + \beta_U \ln U_t + \beta_G \ln G_t + \varepsilon_2 \end{cases} \quad (3)$$

It is crucial to determine which agricultural inputs have a negative effect on rural–urban migration. The sensitivity of migration with respect to agricultural investments can be expressed by indirect agricultural input elasticities of migration, since migration is expected to decrease when the ratio of urban to rural wages is reduced by agricultural investments. This chain process can be expressed as follows:

$$M_t = f(\mathrm{WR}_t); \qquad \mathrm{WR}_t = g(Y_{A_t}, Y_{U_t});$$
$$Y_{A_t}, Y_{U_t} = h(X_{i_t}, X_{j_t}) \tag{4}$$

where WR is the wage ratio between the two sectors, X_i and X_j are agricultural inputs, *f*, *g* and *h* are functions, and all other variables are as defined above. These relationships can be derived with the chain rule, shown in Appendix A, and are interpreted as indirect elasticities of rural–urban migration with respect to individual agricultural inputs.

3.3. Definitions/derivation of variables and sources of data

The study covers the years 1961–1996. Except for education, agricultural output and inputs have been expressed per hectare. Land is expressed in hectares and is defined as the sum of land used for arable and permanent crops, permanent pasture, forest and woodland (Duruflé, 1994; FAO, 1999). Specific variables used in the model are defined below.

3.3.1. Agricultural output (Y_{A_t})

Agricultural output is measured as the total of crop, livestock, fishery and forestry production in real terms. The sources of the data are the World Bank (1995) and The Economist Intelligence Units (1998). The series are published in current local currency (CFA Francs). They are converted into US$ using the official exchange rate published by the IMF (1999 and earlier issues), and then expressed in constant US$ (1982–1984) using the US consumer price index (Statistical Abstracts of United States, 1994, 1997).

3.3.2. Labour (L_t)

Labour represents the economically active population (aged 15–64) in agriculture (see Krishna, 1984; Block, 1995, for similar approaches to labour). In many sub-Saharan African countries, the agricultural sector involves traditional means of production, mainly for subsistence purposes. In that form of agriculture, principally the family provides the labour and the workload is shared. This family farming system, characterised by work and income sharing (Ghatak and Ingerscent, 1984), explains why visible unemployment is absent in traditional agriculture. Therefore, it is reasonable to utilise the economically active population in agriculture as a measure of agricultural labour resources in Senegal. The source of the data is FAO (1999).

3.3.3. Fertiliser (F_t)

Fertiliser is measured as the quantity of nitrogen, potassium and phosphorous utilised. It is expressed in hundred grams per hectare. Increased use of fertiliser is associated with the adoption of modern capital and is one of the conditions for increasing productivity (Schultz, 1964; Hayami and Ruttan, 1985; Scoones et al., 1996; Rusike et al., 1997; Kelly et al., 1998). Fertiliser use is also a reliable index of progress in the adoption of yield-increasing technologies (Arnon, 1987). The source of the data is FAO (1999).

3.3.4. Machinery (Mc_t)

Machinery is measured as the number of tractors in use (FAO, 1999). Machinery, like fertilisers, represents capital supplied by the modern industrial sector. But unlike fertilisers, machinery is associated with large land areas where there is little access to labour (Schultz, 1964; Hayami and Ruttan, 1985). According to Binswanger and Pingali (1998), tractors have done little to increase agricultural output in SSA-countries because farming systems require varied types of operations according to the variety of crops produced. Tractors become valuable when larger tracts of land are involved and cropping becomes more specialised. Equally important in limiting the use of machinery is the lack of efficient credit markets (Arnon, 1987). Instead, tools commonly used in traditional farming systems are a hoe and a machete that allow the preparation for planting of at most 0.5 ha per worker (Arnon, 1987) or 2 ha per family (FAO, 1981). In high temperature countries such as Senegal, with a diet of 1500 kcal per day a farmer cannot work, with such tools, for many hours. Consequently, essential agricultural operations are delayed or are not well executed. On the other hand, machinery might have positive complementary effects on the usage of modern inputs such as fertilisers and irrigation (Binswanger, 1982) and thereby on agricultural production.

3.3.5. Livestock (S_t)

Livestock is represented as the number of animal units available for agricultural production. It represents a long-run capital input supplied from within the sector. Livestock contributes in many ways to agricultural production. Besides providing animal power for traction (Reardon et al., 1996) it supplies meat, milk, hides and organic fertiliser. In many developing countries, animals contribute to the farm economy by providing financial liquidity in the form of savings and investment. Due to a lack of financial means, farmers use livestock as savings, selling animals occasionally to buy agricultural inputs such as seeds, chemical fertiliser or pesticide (Banque Mondiale, 1992). By providing financial liquidity and organic manure to agricultural production, livestock represents a specific input that differs from all other production factors, whose effects are observable in the short run.

To avoid double counting, the livestock variable excludes milk, meat or skin production, which are included in agricultural output (Y_A). In order to estimate livestock's contribution to output, following Hayami and Ruttan (1985), each animal has been assigned a weight to obtain equivalent animal units: 1.1 for camels, 1.0 for horses and mules, 0.8 for cattle and donkeys, 0.1 for sheep, goats and pigs and 0.01 for poultry. The annual livestock data originate from FAO (1999).

3.3.6. Education (E_t)

The education measure attempts to capture the quality of agricultural labour (Griliches, 1970). In a study of agricultural productivity using a time series from 1947 to 1997, Schimmelpfennig et al. (2000) estimated an annual farmer education index. The literacy rate is used as a proxy for farmer's education. UNESCO defines the literacy rate as the proportion of the population over the age of 15 that can read and write a short statement about their everyday life. The data sources are UNESCO (1996), UNDP, Human Development Index (1998 and earlier issues) and UNECA (1987 and earlier issues).

3.3.7. Infrastructure capital stock (IK_t)

Infrastructure represents expenditures and investments in rural utilities, irrigation and drainage, rural markets, transport facilities, commodity storage, and processing facilities, research stations and extension services. Agricultural infrastructure is a modern capital asset that allows traditional inputs to produce at their maximum level (Scoones et al., 1996). In many LDCs, the government provides much of this infrastructure. For this reason, an index of the national agricultural budget expenditure (in 1982–1984 constant US$) is used as a proxy for net annual investment in agricultural infrastructure. The sources of these data are Ministère de l'Économie, des Finances et du Plan du Sénégal (1992) and Ba (1994). The last two years were obtained by a linear extrapolation. From that annual flow data, an infrastructure capital stock is constructed using the perpetual inventory method (Brown, 1972; Aboagye and Gunjal, 2000) (Eq. (5)):

$$\mathrm{IK}_t = \mathrm{IK}_{t-1}(1-\delta) + I_t, \qquad (5)$$

where IK_t and IK_{t-1} are capital stock at time t and time $t-1$, respectively, and δ is the depreciation rate.

The capital stock in the initial period was obtained by

$$\mathrm{IK}_0 = \frac{I_0}{g+\delta} \qquad (6)$$

where IK_0 is the infrastructure capital stock at time t_0, I_0 is investment flow at time 0 and g, set to 8%, is the estimated average growth rate of real investment I_t. Brown (1972) sets the depreciation rate δ to 7% for Ghana, while Aboagye and Gunjal (2000), in an application to the whole sub-Saharan Africa zone, use 10%. We use the higher depreciation rate, 10%. The infrastructure capital stock variable is lagged once as it takes one period for newly acquired capital to come on line. Hence stock from period $t-1$ is available for use in production at time t (Barro and Lucas, 1994).

3.3.8. Rural–urban migration (M_t)

In most countries, there is no regular collection of data related to rural–urban migration. We assume that there is zero immigration into the country and that the urban population grows at the same rate as the total population. The data originates from FAO (1999).[4] The rural–urban migration level (M_t) is estimated as the total urban population change less the portion of urban population due to the natural population increases (Eq. (7)):

[4] See Godfrey (1973), Krishna (1984), and Salehi-Isfahani (1993) for comparable approaches.

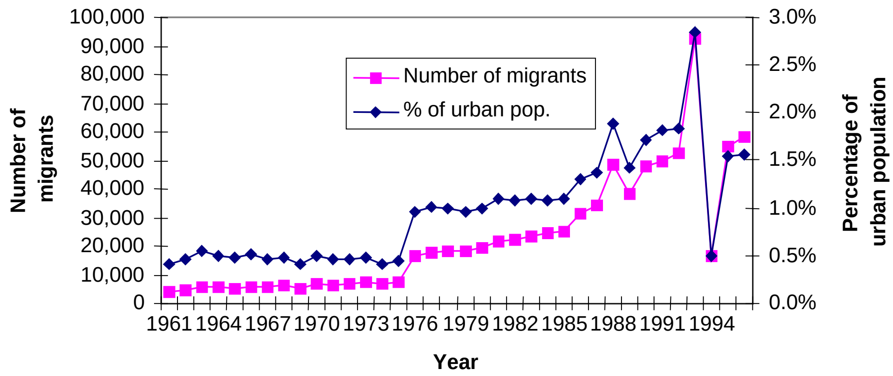

Fig. 2. Number of migrants and migrants as a percentage of the urban population in Senegal, 1961–1996.

$$M_t = P_{U_t} - (1+g)P_{U_t-1} \tag{7}$$

where g is the natural growth rate of the total population. The migration variable and migrants as a percentage of the urban population are shown in Fig. 2.

3.3.9. Implicit agricultural wage (W_{A_t})

The agricultural wage is approximated by the average productivity of the family labour force. According to Ghatak and Ingerscent (1984), traditional agriculture is characterised by work sharing with quasi-unemployment and farm income sharing. Therefore, the implicit agricultural wage is defined as the ratio of agricultural output to the total agricultural population (FAO, 1999):

$$W_{A_t} = \frac{Y_{A_t}}{P_{A_t}} \tag{8}$$

3.3.10. Implicit urban wage (W_{U_t})

The urban wage is approximated by per capita urban output, where output is equal to the sum of industrial and service production. This definition is adopted for several reasons. First, there is no published data on urban wages or specific industrial wages in Senegal. Furthermore, since there is no minimum wage policy in most SSA-countries, including Senegal, there is little data about wages at the margin of the economy. Also not measured are wages in the fringe economy, where individuals do not interact with government institutions but instead draw support from each other in the form of income sharing (Johnson, 1971). The implicit urban wage, the ratio of urban output to the urban population, is the best available proxy:

$$W_{U_t} = \frac{Y_{U_t}}{P_{U_t}} \tag{9}$$

The sources for the service and industrial output data are the World Bank (1995 and earlier issues) and The Economist Intelligence Units (1998). Data are published in current local currency, and converted into constant 1982–1984 US$ as outlined above. Population data originate from FAO (1999).

3.3.11. Age structure (G_t)

Age structure is defined as the proportion of individuals age 15–25 in the total population. It is used to account for the youth factor in the migration function. If the proportion of young people in the entire population were to increase, one would expect, ceteris paribus, rural–urban migration to rise. The data sources are UN Demographic Yearbook (1997 and earlier issues) and UNECA (1987 and earlier issues).[5] Missing values are obtained by fitting a linear trend to the existing data.

Based on the available data and the unique characteristics of the Senegalese economy, the second equation of the model (3) has been simplified to yield the following estimable model:

$$\begin{cases} \ln Y_{A_t} = \alpha_0 + \alpha_L \ln L_t + \alpha_F \ln F_t + \alpha_M \ln \mathrm{Mc}_t \\ \qquad\qquad +\alpha_S \ln S_t + \alpha_E \ln E_t + \alpha_{\mathrm{IK}} \ln \mathrm{IK}_t + \varepsilon_{1t} \\ \ln M_t = \beta_0 + \beta_{\mathrm{WR}} \ln \mathrm{WR}_t + \beta_{A_P} \ln G_t + \varepsilon_{2t}, \end{cases} \tag{10}$$

[5] Examples of studies using time series population estimations are Godfrey (1973), Krishna (1984), Salehi-Isfahani (1993), Savvides (1995), Block (1995), and Dinar and Keck (1997).

where

$$\mathrm{WR}_t = \frac{Y_{U_t}/P_{U_t}}{Y_{A_t}/P_{A_t}} \text{ and is the wage ratio.} \quad (11)$$

4. Estimated results and interpretation

In the context of a system of equations such as (10), estimation procedures such as the two-stage least squares or three-stages least squares and full information maximum likelihood (FIML) are preferred to linear regression techniques such as Ordinary Least Squares (Todaro, 1976; MacIntosh, 1977; Krishna, 1984). However, a recursive system of equations can be estimated with OLS because simultaneity bias is not of concern in such models (Kennedy, 1993; Gujarati, 1995).

Autocorrelation was found in the migration equation, which is common in lengthy time series. The autocorrelation was corrected using the Cochrane–Orcutt method following Judge et al. (1988). This transformation, creating GLS estimators (Shazam, 1997), severed the recursive relationship between the two equations rendering the FIML procedure unnecessary. All the variables were converted to natural logarithms so the parameters can be interpreted as elasticities (Table 1). The total number of observations is equal to 35, as the number of annual observations, 36 (1961–1996), is reduced by one reflecting the 1 year that was used in lagging infrastructure capital stock.

The system of equations meets the rank condition for identification and is not affected by heteroskedasticity. However, pair-wise correlation is high among agricultural independent variables. This is a common situation in studies involving a small sample and time-series, single country, macro data. Moreover, estimated coefficients in the presence of high multicollinearity are unbiased and have correct, though high standard errors (Achen, 1982).

In the agricultural production equation, the labour force coefficient is not significantly different from zero. Therefore, the model indicates that in Senegalese agriculture, additional workers do not increase aggregate output. The marginal agricultural labour productivity is statistically equal to zero. This finding is consistent with economic incentives being a key driver for rural–urban migration.

The effect of machinery on agricultural output was also not significantly different from zero. This makes sense, as the role of tractors, for example, in the agricultural economy, at 0.3 tractors for one thousand hectares, is extremely small. Also, irrigated land represents less than 2% of the total land (computed from FAO, 1999), rural education is poor (see below), and fertiliser utilisation is only about 8 kg/ha.

Surprisingly, the elasticity of education on agricultural output is not significantly different from zero. This is probably because the literacy rate used in the model was at the national level and did not capture rural literacy, which is believed to be lower. Data on

Table 1
Estimated structural elasticities

Agricultural output equation: OLS estimates		Migration equation: OLS estimates		Migration equation: GLS estimates	
Variables	Coefficients	Variables	Coefficients	Variables	Coefficients
Labour	−0.8635 (−0.5739)	Wage ratio	1.4281** (6.0020)	Wage ratio	0.6498* (1.8330)
Fertilisers	0.1889** (2.3180)	Age structure	5.4528** (2.1970)	Age structure	6.7852* (1.8130)
Machinery	−0.6659 (−1.5160)	Constant	−33.699* (−1.8310)	Constant	−42.406 (−1.5230)
Livestock	1.1866** (4.1580)				
Education	−0.6461 (−0.5138)				
Infrastructure	0.3370** (3.3890)				
Constant	7.6469 (0.4260)				
R^2	0.5699		0.7541		0.8102
Durbin–Watson statistic	1.8840		1.1256**		
Rho-estimate	0.0381		0.4322		0.7028

Figures in parenthesis are t-statistics.
* Significant at the 10% level.
** Significant at the 5% level.

farmer education, such as the number of school years attended, would have been a better measure. The proportion of agronomists or workers involved in extension services influencing farmers and their family to adopt new technologies could also have been a proxy for the role of education on production. Moreover, according to the UNESCO standard, to make the literacy rate a reliable measure of education, workers must have completed at least 4 years of schooling and also have had to maintain their basic skills in reading, writing and computing. Many times this is difficult in LDCs, because traditional rural life styles discourage reading and the availability of reading materials is low.

The estimated results for fertilisers, livestock and infrastructure elasticities on agricultural output are positive, as expected, and statistically significant. A 1% increase of fertiliser use would increase agricultural output by 0.19%. This is consistent with what is known about fertiliser use in LDC countries. Not only is productivity enhanced by the nutritive properties of the input, but fertilisers are readily adopted, requiring little capital, and can be applied by an individual worker. A 1% increase in the amount of resources devoted to agricultural infrastructure increases agricultural output by 0.34%, indicating the importance of infrastructure capital as an building block for the rural economy.

The result for livestock is similar, as a 1% increase in the stock of animals raises output by 1.19%. However by no means should the conclusion be drawn that Senegal can rely on increasing the number of animals to modernise its agricultural production. In this arid and semi-arid environment, the number of animals is limited by the quantity of pasture. Climate also limits the value of organic manure that livestock contribute to soil fertility and agricultural output. However, part of the impact of livestock on agricultural output may be due to the financial role livestock plays in the economy. Bearing this in mind, these results point to the importance of rural banking reforms and increasing financial liquidity for agricultural output.

The migration equation results are as hypothesised. The age structure elasticity of rural–urban migration is positive and significantly different from zero. This is consistent with both theory and observation that higher migration rates are found in populations containing high percentages of young people.

The wage ratio elasticity of rural–urban migration (from the GLS estimates of migration equation in Table 1) is equal to 0.65 and is significant at the 10% level. For each 1% increase in the urban-rural wage ratio, migration increases 0.65%, thus the response is inelastic. This finding supports the fundamental hypothesis of this research and is consistent with the literature; rural–urban migration is a positive function of the ratio of the urban per capita income to the rural per capita income. Importantly, it justifies the foundation of a policy aimed at reducing rural–urban migration flows by increasing per capita rural earnings through increased agricultural investment.

4.1. Reducing rural–urban migration

From the estimated results and the above interpretation, fertiliser, infrastructure and livestock/credit reform are all inputs that can exert a positive effect on agricultural output, and hence on the agricultural per capita income. It was shown earlier that livestock contributes to output by providing organic manure and financial security. The first function could also be achieved through additional use of chemical fertilisers while the second could be better realised through credit reform. In addition, the Senegalese climate is semi-arid and is subject to frequent droughts, which limits the success of any policy aimed at decreasing rural–urban migration through increasing the number of domestic animals. For these reasons, livestock is not taken into consideration when computing the impact of agricultural inputs on rural–urban migration.

The policy to reduce rural–urban migration by agricultural investments will thus be based on the improvement of fertiliser and agricultural infrastructure. By applying the chain rule formulated in Eq. (4), the indirect elasticity of rural–urban migration with respect to factor X_i, keeping all other factors constant, is (see Appendix A):

$$\eta_{M,X_i} = \eta_{W,\mathrm{WR}} \times \eta_{Y_A,X_i}. \tag{12}$$

Using the above equation, the indirect elasticity of rural–urban migration with respect to fertiliser is equal to −0.123. This implies that a 10% increase in the quantity of fertiliser used would result in 1.23% decrease in rural–urban migration, keeping all other factors including population constant. The present level of rural–urban migration in Senegal is about 55,000 migrants per year (the average over the last 5 years), representing 0.90% of the rural population and

1.64% of the urban population. The above reduction would reduce annual rural–urban migration to 54,300. Extrapolation of this result in theory would imply that a substantial increase in agricultural production through increased fertiliser use could bring down rural–urban migration in order to reach a target annual level. For example, to cut migration by 10% from the present level, fertiliser use would need to increase by 81%. This would imply increasing the current fertiliser use of 8.8 kg/ha (average of the sample period 1961–1996) to 15.9 kg/ha keeping all other factors of production constant. Applying the fertiliser elasticity of 0.189 computed in the model, agricultural output would increase by 15.4%, from its average level of US$ 747–862 million. This increase would amount to about 2.4% of Senegal's US$ 4.8 billion GDP (1998).

The indirect elasticity of rural–urban migration with respect to agricultural infrastructure is −0.219. In other words, a 10% increase in agricultural infrastructure capital stock would result in a 2.19% decrease in rural–urban migration. This is equivalent to roughly to 1200 migrants. Reducing the annual rate of rural–urban migration by 10% would require an increase in the level of agricultural infrastructure capital stock of 45.7%. The sample period average value of this stock is US$ 176.8 million, and a 45.7% increase of this input would equal US$ 81 million. Using the infrastructure elasticity of 0.337, this increase in agricultural infrastructure would raise agricultural output by 15.4%, from US$ 747 to 862 million, a little more than 1.8% of Senegal's 1998 GDP.

Equivalently, to effect a 10% reduction in rural–urban migration, both inputs would need to be increased by 29.24% (assuming that their effects are additive). This would require increasing fertiliser use to 11.37 kg/ha and infrastructure capital stock to US$ 228.5 million. Increasing these two inputs simultaneously by 29.24% would result in agricultural output increasing by 15.4% to US$ 862 million. More generally, a roughly 15% increase in agricultural output would be required through productivity improvement efforts to raise the rural–urban wage ratio sufficiently to reduce rural–urban migration by 10% from its present level. As Kelly et al. (1998) point out, though the relationship between fertiliser and productivity may be clear, effective access and utilisation by farmers is complex. Therefore, our results depend on successful implementation of fertiliser and other policies.

5. Conclusion

The focus of this paper is the apparent paradox whereby urban industrial growth is paired with growing urban poverty in less developed countries. While the industrial sector continues to grow, the wage disparity between urban and rural regions, reflecting the relative difference in marginal productivities, exacerbates the migration problem causing greater, not lower urban poverty. Rural out-migration continues despite high levels of urban unemployment and/or under employment in the fringe urban economy. Greater urban compared to rural per capita earnings plus degrading economic conditions in the rural sector play key roles in motivating rural out migration. At the same time, urban inhabitants expect to buy affordable import cereals and influence policy measures in favour of urban labour investments such as urban labour intensive projects and micro-credit measures for the fringe urban sector. These polices only worsen the situation by providing even greater incentives for migration. The urban economy cannot keep up and the situation spirals downward.

To become effective, policy designed to address urban poverty problems needs to involve rural policy issues in order to reduce rural–urban migration. A policy of narrowing the income differential between the rural and the urban sectors through agricultural investment can accomplish this. Our estimates suggest that agricultural investment targeted in key areas can reduce migration. This policy of targeted agricultural investment is preferred not only because it reduces the differences in marginal productivities, but also because it does not distort the urban economy. However, it should be noted that this response depends on the successful transmission of effects from investment, via production, to the wage differential.

Appendix A. Derivation of indirect elasticity ($\eta_{M,X}$) of migration (M) with respect to input X

Given that $M_t = f(\mathrm{WR}_t)$, $\mathrm{WR}_t = g(Y_{A_t})$, and $Y_{A_t} = h(X_{i_t})$ it follows that

$$\eta_{M_t,X_{i_t}} = \left\{\frac{\partial M_t}{\partial WR_t}\frac{\partial WR_t}{\partial Y_{A_t}}\frac{\partial Y_{A_t}}{\partial X_{i_t}}\right\}\frac{X_{i_t}}{M_t}$$
$$= \left\{\left(\frac{\partial M_t}{\partial \mathrm{WR}_t}\frac{\mathrm{WR}_t}{M_t}\right)\frac{M_t}{\mathrm{WR}_t}\left(\frac{\partial \mathrm{WR}_t}{\partial Y_{A_t}}\frac{Y_{A_t}}{\mathrm{WR}_t}\right)\right.$$
$$\left.\times\frac{\mathrm{WR}_t}{Y_{A_t}}\left(\frac{\partial Y_{A_t}}{\partial X_{i_t}}\frac{X_{i_t}}{Y_{A_t}}\right)\frac{Y_{A_t}}{X_{i_t}}\right\}\frac{X_{i_t}}{M_t}$$
$$= \left\{\left(\eta_{M_t,\mathrm{WR}}\frac{M_t}{\mathrm{WR}_t}\right)\left(\eta_{\mathrm{WR}_t,Y_{A_t}}\frac{\mathrm{WR}_t}{Y_{A_t}}\right)\right.$$
$$\left.\times\left(\eta_{Y_{A_t},X_{i_t}}\frac{Y_{A_t}}{X_{i_t}}\right)\right\}\frac{X_{i_t}}{M_t}$$
$$= (\eta_{M_t,\mathrm{WR}_t}\eta_{\mathrm{WR}_t,Y_{A_t}}\eta_{Y_{A_t},X_{i_t}})$$
$$\times\left(\frac{M_t}{\mathrm{WR}_t}\frac{\mathrm{WR}_t}{Y_{A_t}}\frac{Y_{A_t}}{X_{i_t}}\frac{X_{i_t}}{M_t}\right).$$

Since all terms in the second parentheses cancel each other and the value of $\eta_{\mathrm{WR}_t,Y_{A_t}}$ is equal to -1 as shown below:

$$\eta_{M_t,X_{i_t}} = \eta_{M_t,\mathrm{WR}_t}\eta Y_{A_t}, X_{i_t}$$

To see this, not that,

$$\mathrm{WR} = \frac{Y_{U_t}/P_{U_t}}{Y_{A_t}/P_{A_t}}$$

by assumption and

$$\eta_{\mathrm{WR}_t}, Y_{A_t} = \frac{\partial \mathrm{WR}_t}{\partial Y_{A_t}}\frac{Y_{A_t}}{\mathrm{WR}_t}$$
$$= -\left(\frac{P_{A_t}}{P_{U_t}}\frac{Y_{U_t}}{Y_{A_t}^2}\right)\frac{Y_{A_t}}{\mathrm{WR}_t} = -1.$$

References

Aboagye, A.Q.Q., Gunjal, K., 2000. An analysis of short-run response of export and domestic agriculture in sub-Saharan Africa. Agric. Econ. 23 (1), 41–53.

Achen, C.H., 1982. Interpreting and Using Regression. Sage, Beverly Hills, CA.

Arnon, I., 1987. Modernisation of Agriculture in Developing Countries. Wiley, New York.

Ba, M., 1994. La condition paysanne dans le développement agricole du Sénégal 1970–1990. Master Thesis, Université du Québec à Montréal, Montréal.

Banque Mondiale, 1992. L'Afrique Subsaharienne, De la crise à une croissance durable. Washington, DC.

Barro, J.R., Lucas, F.R., 1994. Macroeconomics. Irwin, Massachusetts.

Beals, R.E., Levey, M.B., Moses, L.N., 1967. Rationality and migration in Ghana. Rev. Econ. Stat. 49 (4), 480–486.

Bhagwati, J.N., Srinivasan, T.N., 1974. On reanalyzing the Harris–Todaro model: policy ranking in the case of sector-specific sticky wages. Am. Econ. Rev. 64 (3), 502–508.

Binswanger, H.C., Pingali, P., 1988. Technological priorities for farming in sub-Saharan Africa. World Bank Research Observer 3, Washington, DC, pp. 81–98.

Binswanger, H.C., 1982. Agricultural mechanisation: a comparative historical perspective. World Bank Staff Working Paper 673, IBRD, Washington, DC.

Block, S.A., 1995. The recovery of agricultural productivity in sub-Saharan Africa. Food Policy 20 (5), 385–405.

Brown, T.M., 1972. Macroeconomic data of Ghana, Part I. Econ. Bull. Ghana 2 (1), 42–46.

Byerlee, D., 1974. Rural–urban migration in Africa: theory, policy and research implications. Int. Migrat. Rev. 8 (3), 543–566.

Caldwell, J.C., 1969. African Rural–Urban Migration: The Movement to Ghana's Towns. Australia National University Press, Canberra.

Corden, W.M., Findlay, R., 1975. Urban unemployment inter-sectoral capital mobility and development policy. Economica, 59–78.

Diagne, A., 1995. Estimation des élasticités-prix des principales cultures au Sénégal. Document de Travail, CREA/UCAD, Dakar.

Dillon, J.L., Hardaker, J.B., 1993. Farm management research for small farmer development. FAO Farm Systems Management Series, vol. 6, Rome.

Dinar, A., Keck, A., 1997. Private irrigation investment in Colombia: effects of violence, macroeconomic policy, and environmental conditions. Agric. Econ. 16, 1–15.

Duruflé, G., 1994. Le Sénégal peut-il sortir de la crise, Karthala, Paris, 1994.

The Economist Intelligence Units, 1998. Country profile, Senegal. London High School of Economics, London.

FAO, 1981. Agricultural mechanization in development: guidelines for strategy formulation. FAO Agricultural Services Bulletin, vol. 45, Rome.

FAO, 1999. Statistical database, on-line data (http//:www.fao.org).

FAO, 2000. Statistical database, on-line data (http//:www.fao.org).

Fei, J.C.H., Ranis, G., 1961. A theory of economic development. Am. Econ. Rev., 533–565.

Fields, G.S., 1979. Place-to-place migration: some new evidence. Rev. Econ. Stat. (61), 21–32.

Ghatak, S., Ingerscent, K., 1984. Agriculture and Economic Development. John Hopkins University Press, Maryland.

Godfrey, E.M., 1973. Economic variables and rural–urban migration: some thoughts on the Todaro hypothesis. J. Dev. Study 10 (1), 66–78.

Griliches, Z., 1970. Notes on the role of education in production functions and growth accounting. In: Hansen, L. (Ed.) Studies in Income and Wealth, NEBR, vol. 35. Columbia University Press, New York, pp. 141, 148.

Gugler, J., Flanagan, W.G., 1978. Urbanization and Social Change in West Africa. Cambridge University Press, Cambridge, NY.

Gujarati, D.N., 1995. Basic Econometrics, third ed. McGraw-Hill. New York.

Harris, J.R., Todaro, M.P., 1970. Migration, unemployment and development: a two-sector analysis. Am. Econ. Rev. 60 (1), 126–138.

Hayami, Y., Ruttan, V., 1970. Agricultural productivity differences among countries. Am. Econ. Rev. 60, 895–911.

Hayami, Y., Ruttan, V., 1985. Agricultural Development: An International Perspective. John Hopkins Studies in Development, Baltimore.

Howard, J., Jeje, J.J., Tschirley, D., Strasberg, P., Crawford, E.W., Weber, M.T., 1998. Is Agricultural Intensification Profitable for Mozambican Smallholders? Policy Synthesis for Cooperating USAID OFFICES and Country Mission, Michigan State University.

International Monetary Fund, 1999. Statistic Financial Year Book.

Jacob, J.P., Delville, P.L., 1993. Les associations paysannes en Afrique: organisation et dynamiques. Hommes et sociétés. APAD, Marseille.

Johnson, G., 1971. The structure of rural–urban migration models. East. Afr. Econ. Rev. 3 (1), 21–38.

Judge, G.G., Hill, R.C., Griffths, W.E., Lutkepohl, H., Lee, T.C., 1988. Introduction to the Theory and Practice of Econometrics, second ed. McGraw-Hill, New York.

Kante, B., Kamara, M., Tano, F., 1994. Document préparatoire pour une mission d'identification d'un programme d'appui à la régionalisation au Sénégal, Bureau d'appui à la coopération Canadienne, Dakar.

Kelly, A.C., Williamson, J.G., 1984. What Drives Third World City Growth? A Dynamic General Equilibrium Approach. The Princeton University Press, New York.

Kelly, V., Reardon, T., Yanggen, D., Naseem, A., 1998. Fertilizers in Sub-Saharan Africa: Breaking the Vicious Circle of High Prices and Low Demand. Policy Synthesis for Cooperating USAID OFFICES and Country Mission, Michigan State University.

Kennedy, P., 1993. Guide to Econometrics, third ed. MIT Press, Cambridge, MA.

Krishna, R., 1984. A three-sector, time-series model of the labour market in India. World Bank Staff Working Papers No. 637, Washington, DC.

Levy, M., Wadycki, W., 1972. Lifetime versus one-year migration in Venezuela. J. Reg. Sci. 2 (3), 407–415.

Lewis, W.A., 1954. Economic development with unlimited supplies of labour. Manchester School Econ. Social Study 22, 139–192.

Lipton, M., 1980. Migration from rural areas of poor countries: the impact on rural productivity and income distribution. World Development, vol. 8. Pergamon Press, Great Britain, pp. 1–24.

MacIntosh, J., 1977. The econometrics of growth and underdevelopment: a test of the dual hypotheses. Rev. Econ. Studies, 285–298.

Ministère de l'Économie, des Finances et du Plan du Sénégal, 1992. Annual Controls Table on the Social Situation in Senegal. Statistical Annex, Dakar.

Pison, G., Hill, K.H., Cohen, B., Foote, K.A. (Eds.), 1995. Population Dynamics in Senegal. National Academy Press, Washington, DC.

Programme de Gestion Urbaine, 1995. La lutte contre la pauvreté à Dakar, bureau régional pour l'Afrique, Dakar.

Reardon, T., Kelly, V., Crawford, E., Jayne, T., Savadogo, K., Clay, D., 1996. Determinants of Farm Productivity: A Synthesis of Four Case Studies. Policy Synthesis for Cooperating USAID OFFICES and Country Mission, Michigan State University.

Rusike, J., Reardon, T., Howard, J., Kelly, V., 1997. Developing Cereal-Based Demand for fertilizer Among Smallholders in Southern Africa: Lessons Learned and Implications for Other African Regions. Policy Synthesis for Cooperating USAID OFFICES and Country Mission, Michigan State University.

Sabot, R.H., 1979. Economic Development and Urban Migration, Tanzania 1900–1971. Clarendon Press, Oxford.

Sahota, G., 1968. An economic analysis of internal migration in Brazil. J. Pol. Econ. 76 (2), 218–245.

Salehi-Isfahani, D., 1993. Population pressure, intensification of agriculture, and rural–urban migration. J. Dev. Econ. 40, 371–384.

Savvides, A., 1995. Economic growth in Africa. World Dev. 23 (3), 449–458.

Schimmelpfennig, D., Thirtle, C., van Zyl, J., Arnade, C., Khatri, Y., 2000. Short and long-run returns to agricultural R&D in South Africa, or will the real rate of return stand up. Agric. Econ. 23, 1–15.

Scoones, I., Reij, C., Toulmin, C., 1996. Sustaining the soil: indigenous soil and water conservation in Africa. In: Scoones, I., Reij, C., Toulmin, C. (Eds.), Sustaining the Soil: Indigenous Soil and Water Conservation in Africa. Earthscan. UK, pp. 1–27.

Schultz, T.W., 1964. Transforming Traditional Agriculture. Yale University Press, New Haven and London.

Schultz, T.P., 1977. A conditional logit model of internal migration, Venezuelan lifetime migration within educational strata. Discussion Paper No. 266, Economic Growth Center, Yale University.

Shazam, Version 8.0, 1997. McGraw-Hill, New York.

Stiglitz, J., 1969. Rural–urban migration, surplus of labour and the relationship between urban and rural wages. East. Afr. Econ. Rev. 2, 1–28.

Todaro, M., 1969. A model of labour migration and urban unemployment in less developed countries. Am. Econ. Rev. 59 (1), 138–148.

Todaro, M., 1976. Migration and economic development: a review of theory, evidence, methodology and research priorities. Occasional Paper No. 18, Institute for Development Studies, University of Nairobi, Nairobi.

Todaro, M., 1994. Economic Development. Longmann, New York.

United Nations Demographic Yearbook, 1997.

United Nations Development Program (UNDP), 1998. Human Development Index. New York.

United Nations Economic Commission on Africa (UNECA), 1987. Statistical Yearbook. Addis Ababa.

United Nations Educational, Scientific and Cultural Organisation (UNESCO), 1996. On line data (http//:www.unesco.org.).

UNIDO Databases 1999. Country Statistics Senegal. New York. On-line data (http//:www.unido.org).

US Bureau of Labour Statistics, 1994, 1997. Statistical Abstracts of United States. Washington, DC.

Weigel, J.Y., 1982. Migration et production domestique des Soninké du Sénégal. Travaux et documents de l'ORSTOM no. 146. ORSTOM, Paris.

World Bank, 1995. African Development Indicators. Washington, DC.