Environment and Development Economics

http://journals.cambridge.org/EDE

Intersectoral labor mobility and deforestation in Ghana

Victor Owusu, K. Yerfi Fosu and Kees Burger

Environment and Development Economics / *FirstView* Article / September 2012, pp 1 - 22
DOI: 10.1017/S1355770X12000253, Published online: 06 September 2012

Environment and Development Economics, page 1 of 22. © Cambridge University Press 2012
doi:10.1017/S1355770X12000253

Intersectoral labor mobility and deforestation in Ghana

VICTOR OWUSU

Department of Agricultural Economics, Agribusiness and Extension, Kwame Nkrumah University of Science and Technology, Kumasi, Ashanti Region, Ghana. Tel: +233 24 2832330. Email: vowusu.agric@knust.edu.gh

K. YERFI FOSU

University of Ghana, Legon, Accra, Ghana. Email: fozetta@yahoo.co.uk

KEES BURGER

Wageningen University, Wageningen, The Netherlands. Email: kees.burger@wur.nl

Submitted July 21, 2010; revised June 27, 2011; accepted June 2, 2012

ABSTRACT. This paper quantifies the effects of the determinants of intersectoral labor mobility and the effect of intersectoral labor mobility on deforestation in Ghana over the period 1970–2008. A cointegration and error correction modeling approach is employed. The empirical results show that labor mobility from the agricultural to the non-agricultural sector exerts negative effects on deforestation in Ghana in the long run and short run. Relative agricultural income exerts a significant negative effect on intersectoral labor mobility in the long run. Deforestation is influenced positively by population pressure, the price of fertilizer and rainfall, whereas access to irrigation infrastructure exerts a negative effect in the long run. In the short run, real producer prices of cocoa and maize exert significant positive effects on deforestation whereas access to irrigation infrastructure exerts a negative significant effect. Fruitful policy recommendations based on the empirical magnitudes and directions of these effects are made in this paper.

1. Introduction

The relationships between people and the environment tend to change over time. Environment and development are interlinked. Excessive deforestation and reduction in soil quality induced by rapid population growth tend to contribute to low rural income. The deforestation problem in tropical developing countries is a significant one, given the high biodiversity of such forests. It is also of special interest because of the high dependency of the population on forest resources for their livelihoods. Both direct and indirect causes have been identified as driving deforestation rates, and efforts are being made to mitigate the deforestation problem. In spite of these, the problem still persists. Better understanding of both types of causes is useful for policy. One important potential cause is labor mobility, driven, for instance, by high population trends and relative incentives. It is therefore crucial to identify policies which are likely to enhance such incentives, if the rate of deforestation is to be controlled.

Intersectoral labor mobility in Ghana is seen as internal migration, where domestic labor supply is reallocated between the agricultural and non-agricultural sectors. While migration may occur from rural to urban employment, there may be periodic brief interruptions marked by episodes of reverse migration from industry to agriculture due to sharp economic downturns characterized by limited employment opportunities in industry, as happened during Ghana's adjustment period in the 1980s (Ewusi, 1987; Fosu, 1989).

Agriculture has generally been the driver of the economy of Ghana. For example, about 60 per cent of Ghana's total labor force is predominantly agricultural (GSS, 2010; ISSER, 2010). While there was a decline in the share of agriculture in total employment from 63 per cent to 53 per cent between 1960 and 1970, in absolute terms there was an increase in the number of persons employed in the agricultural sector (Ewusi *et al.*, 1983; Fosu, 1989). The share of agriculture in total employment decreased from 61 per cent during 1970–1980 to 57 per cent during 1980–1990. It however increased from 55 per cent during the period 1990–2000 to 59 per cent during the period 2000–2008 (GSS, 2005, 2007; ISSER, 2010). Between 1970 and 1975, the share of agriculture in total gross domestic product (GDP) was 52 per cent. The average shares of agriculture however declined from 51 per cent during 1976–1982 to 49 per cent during 1995–2000 (GSS, 2005). Agriculture's share in GDP increased from 35.1 per cent in 2001 to 36.6 per cent in 2004, but declined to 33.9 per cent in 2008 (GSS, 2005, 2010). The share of agriculture in total GDP increased from 33.9 per cent in 2008 to 34.5 per cent in 2009 (GSS, 2010; ISSER, 2010).

Given the dominance of agriculture in the Ghanaian economy over the years and the increased rural population pressure, deforestation and land degradation coupled with persistent excess rural labor force constitute a significant problem. The inability of the non-agricultural sector to expand adequately to absorb the excess rural labor is likely to exacerbate this pressure on the forest. Ghana lost an average of 135,400 ha of forest per year between 1990 and 2000, which amounts to an average annual deforestation rate of 1.82 per cent. Between 2000 and 2005, the rate of deforestation increased by 4.2 per cent to 1.89 per cent per annum. In total, Ghana lost 25.9 per cent of its forest cover (approximately, 1,931,000 ha) between 1990 and 2005. At least 70 per cent of the original closed forests in Ghana have been destroyed due to the demand for agricultural lands (Ampadu-Agyei *et al.*, 1994; FAO, 2000, 2005). Future agricultural land expansion in Ghana for tree crop production such as cocoa and for food crops such as maize is likely to occur, and if there is shortage of land, the degradation is likely to be exacerbated as agricultural producers overexploit the land.

The links between rural population pressure, unavailability of non-agricultural employment, intersectoral labor mobility and deforestation have not been rigorously analyzed. Some literature has analyzed deforestation in developing countries in general (see for instance, Angelsen, 1999;

Barbier and Burgess, 2001; Benhin and Barbier, 2004; Scrieciu, 2007) and the determinants of labor mobility (Todaro, 1969; Harris and Todaro, 1970; Banerjee and Kanbur, 1981; Mundlak and Larson, 1997). These studies have tended not to consider the potential linkages between intersectoral labor mobility and depletion of forests due to agricultural land expansion. A few attempts have been made to analyze some aspects of this phenomenon (Carr, 2009); however, the effect of intersectoral labor mobility on deforestation has not been rigorously analyzed. Indeed, rigorous empirical evidence has been very scanty or virtually non-existent in the literature on Africa. The contribution of the present paper therefore is to bridge this knowledge gap by building on the existing literature by rigorously investigating the linkages between intersectoral labor mobility (coupled with its determinants) and deforestation in Ghana. Two important research questions which arise regarding Ghana and which are addressed in this paper are the following: (1) What were the effects of the determinants of intersectoral labor mobility in Ghana during the period 1970–2008? (2) To what extent has the transfer of labor between the agricultural and non-agricultural sectors contributed to deforestation in Ghana over the same period? The primary objective of this paper is to analyze the long-run and short-run effects of intersectoral labor mobility and its determinants on deforestation in Ghana.

This paper is structured into seven sections. In section 2, a review of the relevant literature is undertaken. The theoretical foundation of the study is presented in section 3. Section 4 presents the structure and method of estimation of the empirical model employed. In section 5, a description of the variables and the sources of the data employed are indicated. The empirical results are presented in section 6 and concluding remarks are made in section 7.

2. Review of literature

This section first reviews the relevant general literature on the determinants of intersectoral labor mobility and deforestation. This is followed by the literature relevant to the potential linkages between institutions, intersectoral labor mobility and deforestation due to agricultural land expansion in Ghana.

2.1. Determinants of intersectoral labor mobility and deforestation

Various push and pull factors (Lee, 1966) have been postulated as determinants of labor mobility from the agricultural sector (rural) to the non-agricultural sector (urban) of the economy and vice versa. An important pull factor as noted by Mundlak and Larson (1997) is the existence of income differences between the two sectors. Labor tends to move from the agricultural sector to the non-agricultural sector when non-agricultural income is higher than agricultural income and vice versa. In addition, Todaro (1969) postulated that labor tends to be pulled from the agricultural sector to the non-agricultural sector as the probability of securing a job in the latter sector increases. Access to urban employment can be a major source of funds to the household, and such funds can be invested in agricultural technologies. Better living conditions and income prospects in the urban sector where the bulk of non-agricultural activities take place tend to pull labor into the non-agricultural sector. As labor leaves agriculture, labor productivity in the agricultural sector increases, leading to a decline in both income differential and labor mobility from the agricultural sector to the non-agricultural sector.

Rural population pressure can push labor out of the agricultural sector into the non-agricultural sector (Boserup, 1965; Angelsen, 1999). As population levels increase for a given land area, the land:man ratio decreases, likewise the availability and access to fertile agricultural lands and other resources required to provide food and other means of sustenance in the rural areas. In response to this, the rural population tends to migrate out of agriculture. Thus, the population-induced scarcity of resources tends to push labor out of the agricultural sector. Other push factors like inadequate rural infrastructure including poor road networks, lack of access to markets and the incidence of natural disasters in the rural sector also tend to encourage labor movement out of the agricultural sector (EPA, 2002; Nkamleu and Louise, 2006).

It is important to note that the use of farm machinery, irrigation infrastructure and other technological inputs, land fertility and climatic conditions constitute other determinants of intersectoral labor mobility (Quaye *et al*., 2010; Armah *et al*., 2011). Moreover, higher rates of labor mobility out of the agricultural sector into the non-agricultural sector are influenced by the nature of land use, land ownership rights and inequality of land holdings (Banerjee and Kanbur, 1981).

As already indicated, some studies have identified some determinants of deforestation. For example, empirical evidence provided by Quaye *et al.* (2010) indicates that the steady increase in food production in Ghana over the past two decades is highly correlated with cropped area and population movements. This has tended to precipitate deforestation. Furthermore, climatic conditions are important for the fertility of the land, as prolonged periods of heavy rain separated by prolonged dry periods tend to contribute to the reduction of vegetative cover. Gibbs *et al*. (2010) argue that global demand for agricultural products such as food, feed and fuel would be a major driver of expansion of cropland and pasture across much of the developing world. A number of studies have argued that agriculture's contribution to forest destruction in Africa is greater than that of the use of firewood (Barbier, 2004; Kangalawe and Lyimo, 2010). Kangalawe and Lyimo (2010), for example, note that increasing demand for food, energy and other environmental services have contributed to expansion of agriculture, including marginal areas, and deforestation. In addition to non-agricultural activities such as logging and mining, Ruf and Zadi (1998) contend that cocoa cultivation has been an important agent of deforestation in Ghana and Côte d'Ivoire, especially during the 20th century.

The impact of agricultural expansion on forest cover may be captured through the relative rates of return to forest and to the alternative uses of the land (Blackman *et al.*, 2008). On the empirical front, the directions of the effects of changes in agricultural input prices on forest clearing have tended to be mixed, especially in the case of fertilizer. For example, with Ghanaian data, Benhin and Barbier (2004) found a positive relationship between fertilizer prices and area cleared for agriculture. The removal of subsidies on inputs like insecticides and fertilizer under the Structural Adjustment Programme (SAP) in Ghana discouraged the use of these inputs (Fosu, 1997, 1998) and this tended to increase agricultural land expansion and deforestation. On the contrary, a study on Latin America by Barbier and Burgess (1996) indicates a reduction in deforestation as a result of increases in fertilizer prices, the reason being that agriculture becomes less profitable when there is a higher cost associated with the acquisition of fertilizer.

On the effect of population pressure on deforestation in developing countries, empirical evidence provided by Benhin and Barbier (2004) showed a positive relationship between population density and maize land expansion in both the pre- and post-adjustment periods in Ghana. Population density, however, had no statistically significant effect on area cleared for cocoa production. Similarly, Cropper and Griffiths (1994) did not find any significant effect of population pressure on deforestation. Greater access to forests and markets accelerates deforestation, and higher rural wages and greater off-farm employment opportunities reduce deforestation by making agricultural and forestry activities more costly (Bluffstone, 1995).

It is intuitively plausible that, as the rate of outflow of labor from the agricultural sector to the non-agricultural sector increases, the volume of labor available for the conversion of forestland to agriculture is likely to decline, *ceteris paribus*. This, in turn, is likely to lead to a reduction in deforestation. On the other hand, a reduction in the rate of outflow of agricultural labor is likely to increase pressure on land and stimulate deforestation. Furthermore, the relevant existing literature is characterized by scanty rigorous research on labor mobility and deforestation. Hence, the theme of the present study is very relevant.

2.2. Institutions, labor mobility and agricultural deforestation in Ghana

As already indicated, deforestation due to agricultural land expansion is the dominant form of deforestation in tropical countries like Ghana where deforestation due to timber extraction, mining of minerals, road and railway construction, *inter alia*, also occur. The deforestation rate in Ghana during the 20th century has been phenomenal (see, for instance, Ampadu-Agyei *et al.*, 1994; Fosu, 1997; FAO, 2000, 2005; Tutu and Akol, 2009). In Ghana, the Department of Forestry of the Ministry of Lands and Forestry, the Forestry Commission, Ministry of Environment, Science and Technology, Ministry of Food and Agriculture as well as the Environmental Protection Agency are the key institutions responsible for conserving Ghana's forests and controlling deforestation. These institutions collaborate with other public and private organizations in this exercise. These organizations play key roles relative to the formulation, implementation, monitoring and evaluation of policies, programs and strategies in this regard. The parliament of Ghana enacts the relevant legislation to regulate the use of forests with the relevant provisions in consonance with Ghana's 1992 constitution.

The link between labor mobility and agricultural land expansion is significant in sub-Saharan Africa, where about 80 per cent of the population live in rural areas and practice subsistence agriculture (Nkamleu and Louise, 2006). Changes in the agricultural sector in particular could lead to changes in labor mobility which, in turn, could affect food production and agricultural development. In Ghana, Caldwell (1969) indicates that, in the 1960s, labor flow from rural to rural areas of Ghana was 59.8 per cent and in the 1970s it was 51.7 per cent. Labor flow from rural to urban locations in Ghana in the 1960s was 11.5 per cent and 16.7 per cent in the 1970s. During the 1963/64 to 1969/70 period, the policy of import-substituting industrialization (ISI) which emphasized mechanization of agriculture and rapid industrialization with the aim of modernizing the Ghanaian economy was implemented. During the 1960–1965 period, the real value of total payments which the Ghana Cocoa Board (COCOBOD) made to cocoa producers declined, and the budgeted government expenditure on the cocoa industry also dropped (Armah, 1993). The lower prices received by cocoa producers compared with the existing world market prices discouraged investments in cocoa cultivation technologies (Asare and Wong, 2004). There was a dramatic decline in the index of the 'quantity of insecticide sales to farmers' during the five-year period (Armah, 1993). Notably, the period of import substitution was associated with relatively lower employment growth rates in the cocoa-oriented regions of Ghana compared with non-cocoa-oriented regions (Armah, 1993). This policy, in effect, encouraged labor movement from rural agriculture to urban manufacturing and the non-traded-goods sector.

In 1972, Ghana initiated the 'Operation Feed Yourself Programme' (OFY) which was directed at self-reliance and increased food crop production (Girdner *et al.*, 1980; Armah 1993). With the encouragement of domestic agriculture, both imports and exports generally declined during this period. However, rice production recorded a significant increase from 11,000 tons in 1971 to over 61,000 tons in 1973, and maize output increased from 53,000 tons in 1971 to over 430,000 tons by the end of 1973 and maize was exported during the OFY period. Ghana's Economic Recovery Programme (ERP) and the SAP were pursued during the 1980s and 1990s. The ERP was launched in April 1983 and was aimed at addressing the infrastructure bottlenecks while reviving the economic downturn including the moribund productive sectors such as agriculture, mining and timber, *inter alia*. Moreover, the ERP emphasized a restructuring of Ghana's productive activities to ensure increased efficiency and effective agricultural pricing policies so as to provide incentives to farmers for them to increase food production, and also to promote export commodities (Ewusi, 1987; Fosu, 1997).

The deteriorating economic conditions were further worsened by the severe drought in early 1983, and the expulsion of an estimated 1 million Ghanaians from Nigeria who, upon arrival, had to be absorbed into the Ghanaian labor market with a chunk of them finding their way into the agricultural sector. Armah (1993) notes that the volume of exports during the period from 1984 to 1987 rose steadily from $622 million to $984 million (in constant 1985 dollars) while the total import volume increased from

$695 million to $935 million. Correspondingly, cocoa producers received an increasing share of the world market price for their exports. This share was increased from 22 per cent in 1983 to 41 per cent in 1987. The volume of forest exports, particularly timber, also steadily increased from 113.9 thousand metric tons in 1983 to 269.3 thousand metric tons in 1986 (Armah, 1993). Episodes of labor mobility from cash crop to food crop production in the 1970s and early 1980s and the reverse mobility in the 1980s and early 1990s may have had significant implications for agricultural land expansion in Ghana. In addition, the increase in the prices of fertilizers due to the subsidy withdrawal policy under Ghana's Structural Adjustment Programme resulted in a decline in fertilizer demand which, in the face of higher agricultural producer prices, resulted in agricultural land expansion and deforestation during the 1990s (Fosu, 1997, 1998). In addition, the economy-wide reforms and land management decisions of rural farmers in Ghana have tended to precipitate a decline in biomass as a result of the increased area cultivated (Benhin and Barbier, 2004). Barbier and Burgess (2001) pointed out that increased timber production and agricultural expansion constitute the main causes of forest loss in the tropics. Ghana's forest cover has decreased from 8.2 million ha since the beginning of the 20th century to 1.7 million ha in the 21st century. It has been postulated that deforestation rates in Ghana are caused mainly by the interaction of social, cultural, political and economic factors (Benhin and Barbier, 2004).

From 1992 to date, Ghana has experienced a more stable democratic system. From 2001 to 2005, the economy maintained a relatively high average growth rate of about 5.1 per cent, driven largely by the agricultural sector. By the year 2008, annual economic growth (specifically, the GDP growth rate) had increased further to 7.3 per cent. The main agricultural policy initiatives and interventions of the Government in 2009 focused on food security, the Youth in Agriculture Programme, sustainable land and environmental management, as well as agricultural mechanization. The Youth in Agriculture Programme has implemented block farming in six regions of Ghana and provided employment to some youth who cultivate maize, rice and soya beans. It is likely that these government interventions, like the aforementioned factors, have influenced labor mobility and deforestation due to agricultural land expansion in Ghana. This paper provides rigorously derived empirical evidence of this.

3. Theoretical foundation

The impact of intersectoral labor mobility on the rate of forest decline due to agricultural expansion is analyzed in this paper in the context of aggregate demand for forestland for agricultural production and aggregate supply of labor to the agricultural and the non-agricultural sectors. The theoretical studies on aggregate demand for forestland for conversion to agricultural land include, *inter alia*, Lopez (1997), Angelsen (1999) and Barbier (2000). In such models, the rural agricultural household is assumed to be a price-taker in all markets for the commodities and services it buys, consumes and produces. By virtue of their chosen focus, the relevant existing studies generally do not consider agricultural households' allocation of labor to the non-agricultural sector. They assume that household labor endowment is allocated to the agricultural sector for cultivation and for forestland conversion. The present paper, by virtue of its focus on the impact of labor mobility, contributes to the existing literature by considering the allocation of agricultural household labor to both the agricultural sector and the non-agricultural sector.

A dynamic profit-maximizing decision of the agricultural household is assumed in the present study. Maximizing the net present returns from the allocation of agricultural household labor over an infinite time horizon, the relevant optimization problem is stated as:

$$\text{Maximize} \quad Q = \int_0^\infty [pAs(F, D - L - M^A; Z) + \pi(M^A) - wF - c(L)]e^{-rt}dt \tag{1}$$

$$\text{subject to} \quad \dot{A} = m(L) - gA; \quad m_L > 0, \quad m_{LL} < 0 \text{ and } A(0) = A_0 \text{ at } t = 0, \quad g \neq 0; \pi_{M^A} > 0, \pi_{M^A M^A} < 0 \tag{2}$$

where r is the discount rate. The agricultural gross revenue of the household is the algebraic product of the aggregate output price p, the stock of arable land A (in ha) and agricultural productivity per ha $s(\cdot)$. The agricultural land productivity function $s(\cdot)$ is assumed to have the vector of the amounts of purchased inputs F, amount of labor allocated to the agricultural sector L^* and a vector of non-price factors Z as the relevant arguments. Notably, $s_F > 0$, $s_{FF} < 0$, $s_{L^*} > 0$ and $s_{L^*L^*} < 0$ where s_F denotes the first-order partial derivative of $s(\cdot)$ with respect to F, and s_{FF} denotes the second-order partial derivative of $s(\cdot)$ with respect to F. It is assumed here that the non-agricultural activity does not use forestland. The total household labor endowment D is assumed to be allocated to agriculture L^*, the non-agricultural sector M^A and forestland land conversion L. Thus, labor allocation to the agricultural sector is given by $L^* = D - L - M^A$. Here, $\pi(M^A)$ denotes the function which describes the net returns to labor which flow from the agricultural sector to the non-agricultural sector ($\pi_{M^A} > 0$; $\pi_{M^A M^A} < 0$ are the a priori signs of the relevant first- and second-order partial derivatives of $\pi(\cdot)$ with respect to M^A). The cost of purchased agricultural inputs and forest conversion are given by wF and $c(L)$ respectively, where $c_L > 0$ and $c_{LL} < 0$. The time subscript t has been suppressed here for ease of exposition. $\dot{A}$ is the rate of agricultural land expansion, $m(L)$ is the stock of new forestland converted to agricultural land by allocating some household labor, and g is the proportion of agricultural land taken out of production at each time period t at a constant rate. In view of the focus of the present paper on deforestation, re-cultivation of fallow land is not considered here. $Z = [R^{PP}, RF, IR]$ represents a vector of 'non-price' factors which could influence agricultural productivity and could, in turn, influence deforestation due to agricultural expansion, such as rural population pressure R^{PP}, climatic conditions (for example rainfall) *RF* and access to irrigation infrastructure *IR*.

The current value Hamiltonian for the solution of the optimal control problem in (1)–(2) is

$$\mathrm{H} = pAs(F, D - L - M^A; Z) + \pi(M^A) - wF - c(L) + \lambda[m(L) - gA] \quad (3)$$

where F, L and M^A are the control variables, A is the state variable and λ is the corresponding co-state variable representing the shadow value of land.

The following first-order conditions (Pontryagin's Maximum Principle) give the solution of the problem in equations (1)–(2):

$$\partial H/\partial F = pAs_F - w = 0 \qquad \Rightarrow w = pAs_F \quad (4)$$

$$\partial H/\partial L = -pAs_{L^*} - c_L + \lambda m_L = 0 \qquad \Rightarrow \lambda m_L = c_L + pAs_{L^*} \quad (5)$$

$$\partial H/\partial M^A = -pAs_{L^*} + \pi_{M^A} = 0 \qquad \Rightarrow pAs_{L^*} - \pi_{M^A} = 0 \quad (6)$$

$$-\partial H/\partial A = -[ps(F, D - L - M^A; Z) + \lambda(-g)] = \dot{\lambda} - r\lambda$$

$$\Rightarrow ps(F, D - L - M^A; Z) = \dot{\lambda} + \lambda(g - r) \quad (7)$$

$$\partial H/\partial \lambda = m(L) - gA = \dot{A}. \quad (8)$$

Rearranging equation (4) as $A = w/ps_F$ and substituting it into equation (8) gives

$$\dot{A} = m(L) - g(w/ps_F). \quad (9)$$

Differentiating (9) with respect to w, p and w/p yields $\partial \dot{A}/\partial w = -g/ps_F < 0$, $\partial \dot{A}/\partial p = gw/p^2 s_F > 0$ and $\partial \dot{A}/\partial(w/p) = -g/s_F < 0$ respectively. Making the variable A the subject of (6), substituting the result into (8) and differentiating the resulting equation with respect to M^A gives:

$$\partial \dot{A}/\partial M^A = -g(\partial \pi_{M^A}/\partial M^A)/ps_{M^A} < 0 \quad (10)$$

where $\partial \pi_{M^A}/\partial M^A = \pi_{M^A M^A} < 0$ and $s_{M^A} < 0$, $p > 0$ and $g > 0$. Equation (10) implies that, theoretically, the rate at which land area is cleared for agricultural production decreases as labor flows from the agricultural sector to the non-agricultural sector. Obtaining the derivative of equation (4) with respect to time, equating the resulting function to equation (8) and rearranging terms gives the optimal land use in each period $A(t)$ as:

$$A(t) = g^{-1}\{m(L) + (w/p)[s_{FF}/(s_F)^2]\dot{F}\} \quad (11)$$

where $\partial A/\partial(w/p) = -[s_{FF}/(s_F)^2]\dot{F} \leq 0$ if $F \geq 0$ or $\partial A/\partial(w/p) > 0$ if $F < 0$. (12)

Demand for agricultural land for conversion as indicated in equation (11) depends upon the rate of land conversion, $m(L)$, the proportion of land under fallow, g, agricultural returns p/w, the rate of marginal productivity of purchased inputs s_{FF}/s_F and the rate of input use over time $\dot{F}$. The impact of an increase in agricultural returns on land use $\partial A/\partial(p/w)$ is determined by equation (12). If input use is growing over time, then agricultural land use will increase with rise in agricultural returns and vice versa. If $\partial F/\partial t > 0$ then $\partial A/\partial(p/w) > 0$ or if $\partial X/\partial t < 0$ then $\partial A/\partial(p/w) < 0$. Equations (11)–(12) provide useful insights into how input use and prices influence demand for land. The direct increase in the relative prices of agricultural products and decrease in the relative price of agricultural inputs stimulate agriculture producers to increase output, resulting in increasing demand for land for conversion to agriculture. Similarly, obtaining the derivative of equation (6) with respect to time, equating it to equation (8) and rearranging terms yields

$$A(t) = g^{-1}\{m(L) + (1/p)[\pi_{M^A} s_{M^A M^A}/s_{M^A}^2 - \pi_{M^A M^A}/s_{M^A}]\dot{M}^A\}. \qquad (13)$$

Equation (13) thus indicates that the demand for agricultural land for conversion also depends upon the rate of marginal productivity of labor mobility from the agricultural sector to the non-agricultural sector $s_{M^A M^A}/s_{M^A}$, the marginal net returns to labor from the agricultural sector to the non-agricultural sector π_{M^A} and the rate at which labor flows from the agricultural to the non-agricultural sector over time $\dot{M}^A$.

The optimal path of the steady-state equilibrium could be derived from (4)–(8) but, because of the chosen primary focus of the present paper on the effect of labor mobility on deforestation, the steady-state analysis is not conducted. The essence of the theoretical analysis in this section of the paper is to provide a plausible theoretical basis for the empirical model estimated in this paper. Land area demanded for agriculture, following equations (1)–(13), can thus be expressed as a function of output and input prices, labor mobility from the agricultural sector to the non-agricultural sector and the vector of other non-price factors, as follows:

$$A^C = A(p, w, M^A, RF, IR, R^{PP}). \qquad (14)$$

In particular, $\partial A^C/\partial p > 0$, $\partial A^C/\partial w < 0$, $\partial A^C/\partial M^A < 0$, $\partial A^C/\partial RF > 0$, $\partial A^C/\partial IR < 0$ and $\partial A^C/\partial R^{pp} > 0$ where A^C is the area deforested due to area cleared for agriculture, w is vector of input prices (for example, prices of insecticides and fertilizer), p is a vector of output prices (for example, producer prices of cocoa and maize). M^A is labor mobility from the agricultural sector to the non-agricultural sector, *RF* and *IR* are non-price factors representing rainfall and access to irrigation infrastructure respectively, and R^{PP} is rural population pressure. These a priori effects emanate from the analysis embodied in equations (1)–(13), and they are also characterized by intuitive plausibility. As the non-agricultural income rises relative to the agricultural income, the relative agricultural income variable falls and labor flow out of agriculture increases, and vice versa. In addition, as non-agricultural employment opportunities decline, labor outflow from agriculture declines.

It is intuitively plausible that agricultural household labor allocated to the non-agricultural sector M^A is indeed endogenous. In the Harris and Todaro (1970) framework, labor mobility from the agricultural sector to the non-agricultural sector occurs in response to income differential between the two sectors and the unemployment rate in the non-agricultural sector. As already indicated in the literature review in sections 2.1 and 2.2, there is the possibility of a direct effect of higher rural population pressure on labor mobility from the agricultural sector to the non-agricultural sector due to higher fertility and lower mortality rates in the rural sector and of policies such as the SAP supported by the World Bank and the International Monetary Fund. Labor mobility from the agricultural sector to the non-agricultural sector is thus specified theoretically as

$$M^A = M^A(W^A, R^{PP}, U^{NA}, S^D) \tag{15}$$

where $\partial M^A/\partial W^A < 0$, $\partial M^A/\partial R^{PP} > 0$, $\partial M^A/\partial U^{NA} < 0$ and $\partial M^A/\partial S^D < 0$, and M^A is the labor mobility from the agricultural sector to the non-agricultural sector, W^A is the income in agriculture relative to that in the non-agricultural sector, R^{PP} is rural population pressure, U^{NA} is rate of unemployment in the non-agricultural sector and S^D denotes the implementation of structural adjustment. Equations (14) and (15) constitute the source of the empirical model employed in the present study.

4. Empirical model

The structure of the empirical model including the cointegration and error correction modeling procedures employed in this study are presented in this section. Notably, the Dynamic Generalized Least Squares (DGLS) estimator is used. The model comprises a system of simultaneous equations involving a function which describes intersectoral labor mobility and its determinants (specifically, equation (15)) as well as a function which describes area deforested and its determinants (specifically, equation (14)). Having checked the identifiability status of the two equations and found them to be over-identified, the Iterative Three Stage Least Squares approach is used to estimate the model. With the presence of cointegration established, the relevant Error Correction Models which incorporate the relevant long-run equilibrium and short-run dynamics are estimated.

Various researchers have applied the classical Engle and Granger (1987) approach in analyzing the existence of long-run and short-run relationships between economic variables but the DGLS estimator proposed by Stock and Watson (1993) is employed in this paper. The DGLS estimator provides efficient estimates of long-run parameters and also eliminates the serial correlation in the model. The empirical simultaneous equation model explaining the long-run relationships between intersectoral labor mobility and its determinants and deforestation and its determinants are specified as:

$$M_t^A = \phi_{01} + \phi_1' Z_{t1} + \sum_{i=0}^{p} \phi_{i1}' \Delta Z_{t-i,1} + \mu_{t1} \tag{16}$$

$$A_t^C = \phi_{02} + \phi_2' Z_{t2} + \sum_{i=0}^{P} \phi_{i2}' \Delta Z_{t-i,2} + \mu_{t2} \tag{17}$$

where Z_{t1} is the vector $(W_t^A \ R_t^{PP} \ U_t^{NA} \ S_t^D)'$ and Z_{t2} is the vector $[P_t^{INS} \ P_t^{FT} \ P_t^{CO} \ P_t^{MZ} \ M_t^A \ RF_t \ IR_t \ R_t^{PP}]'$. The parameters ϕ_{01} and ϕ_{02} are the intercept terms, ϕ_1' and ϕ_2' are vectors of long-run coefficients. Sufficient lags of $\Delta Z_{t-i,1}$ and $\Delta Z_{t-i,2}$ are chosen to enhance the efficiency of the estimation. M_t^A denotes labor mobility from the agricultural sector to the non-agricultural sector, A_t^C denotes area deforested, W_t^A denotes income in the agricultural sector relative to that in the non-agricultural sector, R_t^{PP} denotes rural population pressure, U_t^{NA} denotes the unemployment rate in the non-agricultural sector, S_t^D is a structural adjustment dummy ($S_t^D = 1$ for 1983–1999, and $0 =$ otherwise) and t denotes current time period , P_t^{INS} denotes the real price of agricultural insecticides, P_t^{FT} denotes the real price of fertilizer, P_t^{CO} is the real producer price of cocoa, P_t^{MZ} denotes the real producer price of maize, RF_t denotes the mean annual national rainfall, and IR_t represents access to irrigation infrastructure (specifically, the proportion of agricultural land under irrigation). μ_{t1} and μ_{t2} are white noise error terms. The a priori expectation of the effect of R_t^{PP} on labor mobility is positive whereas those of W_t^A, U_t^{NA} and S_t^D are negative. Regarding the deforestation equation, the a priori signs of $R_t^{PP} P_t^{CO}$, P_t^{MZ} and RF_t are positive whereas $M_t^A P_t^{INS}$, P_t^{FT} and IR_t are negative. These a priori signs are intuitively plausible, as already indicated in the theoretical foundation.

The system of error correction equations are specified as:

$$\Delta M_t^A = \delta_0 + \sum_{i=0}^{k} \delta_{i1}' \Delta Z_{t-i,1} + \gamma_1 ect_{t-1,1} + \varepsilon_{t1} \tag{18}$$

$$\Delta A_t^C = \delta_1 + \sum_{i=0}^{k} \delta_{i2}' \Delta Z_{t-i,2} + \gamma_2 ect_{t-1,2} + \varepsilon_{t2} \tag{19}$$

where k is the chosen lag length, δ_0 and δ_1 are constant terms, δ_{i1}' and δ_{i2}' are vectors of estimated coefficients which capture the relevant short-run effects, $\Delta Z_{t-i,1}$ and $\Delta Z_{t-i,2}$ are vectors of explanatory variables, $ect_{t-1,1}$ and $ect_{t-1,2}$ are the error correction terms and γ_1 and γ_2 are their coefficients. Notably $ect_{t-1,1}$ are the lagged residuals from equation (16) whereas $ect_{t-1,2}$ are the lagged residuals from equation (17).

5. Description of variables and sources of data

The data employed in this paper cover the period from 1970 to 2008. They are annual time series data on Ghana. Labor mobility rate is measured as the magnitude of labor contributed by the agricultural sector to the rest of the economy, following the approach of Johnston and Kilby (1975) and Fosu (1989). The time series data on labor employed in agriculture and the whole economy (proxied by the respective economically active population) were obtained from various issues of the *UN Food and Agriculture Organization (FAO) Production Yearbook* and the *Quarterly Digest of Statistics* published by the Ghana Statistical Service, Accra (see appendix A1 in the online appendix, available at http://journals.cambridge.org/EDE, for details of the relevant computations). The deforestation rate used in the present paper is based on deforestation due to agricultural land expansion. This variable is computed as the difference between the total area under agricultural cultivation for consecutive years. Ready availability of data suggested the deforestation measure employed in the present study. These data were obtained from various issues of the *FAO Production Yearbook*.

Due to data availability, agricultural and non-agricultural GDP are used to proxy agricultural and non-agricultural income in the present paper. Both GDP in current and constant 1985 prices were obtained and the relevant computations undertaken (see online appendix A1). Agricultural population and non-agricultural population data were obtained from various issues of the *FAO Production Yearbook*. The time series data on the GDP originating in the agricultural and non-agricultural sectors were obtained from the Ghana Statistical Service and various issues of the *International Financial Statistics* (*IFS)* published by the *International Monetary Fund*. Rural population pressure is defined as the ratio of rural population (millions) to area cultivated (ha). Data on rural population were obtained from various issues of the *FAO Production Yearbook*. Time series data on annual arable (cultivated) land were also obtained from this source. The rate of non-agricultural unemployment is computed as unity minus the employment rate in the non-agricultural sector. The economically active population in the non-agricultural sector was used as a proxy for the labor force in the non-agricultural sector. Data on economically active population were obtained from various issues of the *FAO Production Yearbook*. The sources of the employment data were the *ILO Yearbook of Labor Statistics.*

Annual time series data on the real price of cocoa insecticides measured in Ghana cedis per liter are employed. The relevant data are from the Ghana COCOBOD and the Ghana Statistical Service. Annual time series data on the real price of fertilizer measured in Ghana cedis per kg of NPK (15-15-15) are employed. The relevant fertilizer data are from the Ministry of Food and Agriculture. The annual time series data on the producer price of cocoa in Ghana cedis per kg and the rural consumer price index (CPI) were obtained from the Ghana COCOBOD and various issues of the *Quarterly Digest of Statistics* (*QDS*) published by the Ghana Statistical Service.

The real producer price of maize was obtained by deflating the nominal producer price of maize (Ghana cedis per 50 kg) by the rural CPI (1997 = 100). Data on the nominal producer price of maize were obtained from the Ministry of Food and Agriculture, Accra, Ghana. The mean annual rainfall data covering Ghana measured in mm were obtained from the Ghana Meteorological Service in Accra, Ghana. The proportion of arable land under irrigation was used to proxy access to irrigation infrastructure. It was computed as the ratio of agricultural land under irrigation (ha) to the total arable land (ha) in Ghana. Annual time series data on arable land under irrigation and total arable land in the whole economy were obtained from various issues of the *FAO Production Yearbook*. The detailed description of all the variables and the sources of data employed in the present paper have been provided in online appendix A1.

6. Empirical results

The empirical results of the present study are presented in this section. Results of the relevant stationarity tests are discussed first, followed by the results of the cointegration and error correction modeling. The descriptive statistics of the variables used in the analysis and the definitions of the variables are presented in online appendix A2.

6.1. Stationarity tests

The empirical results relating to the Augmented Dickey Fuller (ADF) tests are presented in online appendix A3. All the series are stationary when a deterministic trend and a drift term are included. The hypothesis of unit root could not be rejected for the levels data for all the series because none of the ADF t-statistics exceeded its asymptotic critical value even at the 10 per cent level, using the relevant Mackinnon critical values. However, after first differencing, the hypothesis of a unit root was rejected at the 5 per cent level for all the series. Thus, whereas the level of each of the series is non-stationary, the first difference is stationary, indicating that each of the series is integrated of order one (online appendix A3). The Breusch–Godfrey Lagrange Multiplier (LM) test for second-order autocorrelation shows no autocorrelation in the residuals of the error term of each ADF equation.

6.2. Long-run relationships

The empirical results of the Iterative Three Stage Least-Squares estimation of the long-run relationships are shown in table 1. Convergence was achieved after 100 coefficient iterations. The estimated coefficient of determination of the labor mobility function indicates that about 49 per cent of the variation in intersectoral labor mobility from the agricultural to the non-agricultural sector is explained by the independent variables. The independent variables in the deforestation function explain about 69 per cent of the variation in the area deforested (table 1). The Box–Pierce *Q-statistic* from the correlogram of the residuals of the labor mobility model is not significant even at the 10 per cent level, indicating that autocorrelation is not present in the residuals. The Breusch–Godfrey LM test gave a BG (2) value of 1.1841 and a probability of 27.65 per cent, indicating a non-rejection of the null hypothesis of no second-order autocorrelation in the labor mobility model. Similarly, a BG (2) value of 0.8969 with a probability of 34.36 per cent shows no second-order autocorrelation in the deforestation model (table 1). See online appendix A4 for the detailed long-run empirical results.

The estimated coefficient of income in agriculture relative to the income in non-agriculture in the long-run labor mobility model exhibits the postulated negative sign and it is significantly different from zero at the 5 per cent level (table 1). Thus, a 1 per cent decrease in the relative agricultural income tends to stimulate a 1.84 per cent increase in labor flow out of agriculture (and vice versa), *ceteris paribus*. The coefficient of rural population density has the expected positive sign, albeit insignificant even at the 10 per cent level. This may be due to the fairly high correlation coefficient of 0.75 between rural population and the relative agricultural income variable

Table 1. *Empirical cointegration results of the long-run relationships*

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Probability*
Dependent variable: $\ln M_t^A$				
CONSTANT	2.3269	2.8838	0.8069	0.4247
$\ln W_t^A$	−1.8431	0.7814	−2.3587	0.0236
$\ln R_t^{PP}$	1.5275	2.0657	0.7395	0.4642
$\ln U_t^{NA}$	−2.3989	0.6003	−3.9963	0.0003
S_t^D	0.4939	0.3286	1.5030	0.1411
R^2	0.4897		Mean	0.0263
Adjusted R^2	0.2855		S.D.	1.0812
S.E.R	0.9139		RSS	20.8802
Observations	36		BG(2)	1.1841 (0.2765)
Dependent variable: $\ln A_t^C$				
CONSTANT	−46.3912	24.7604	−1.8736	0.0687
$\ln M_t^A$	−0.7970	0.1370	−5.8171	0.0000
$\ln R_t^{PP}$	10.4541	5.6213	1.8597	0.0707
$\ln P_t^{CO}$	0.0612	0.9919	0.0617	0.9512
$\ln P_t^{MZ}$	0.0370	0.6191	0.0597	0.9527
$\ln P_t^{INS}$	−0.2414	0.2382	−1.0133	0.3173
$\ln P_t^{FT}$	0.7639	0.3995	1.9124	0.0634
$\ln RF_t$	4.7292	2.6071	1.8140	0.0776
$\ln IR_t$	−6.6244	3.7207	−1.7804	0.0830
R^2	0.6931		Mean	0.9827
Adjusted R^2	0.1738		S.D.	1.1840
S.E.R	1.0762		RSS	15.0577
Observations	36		BG(2)	0.8969 (0.3436)

Notes: With the exception of the structural adjustment dummy, all the variables are in natural logarithms. Δ denotes difference of the respective variable. The instruments used in the relevant equations are $\ln R_t^{PP}$, $\ln U_t^{NA}$, $\ln P_t^{CO}$, $\ln P_t^{FT}$, $\Delta \ln U_t^{NA}$, $\Delta \ln W_t^A$, $\Delta \ln P_t^{MZ}$, $\Delta \ln P_t^{CO}$, $\Delta \ln P_t^{INS}$, $\Delta \ln IR_t$, $\Delta \ln RF_t$, $\Delta \ln R_{t-1}^{PP}$, $\Delta \ln U_{t-1}^{NA}$, $\Delta \ln W_{t-1}^A$, $\Delta \ln P_{t-1}^{MZ}$, $\Delta \ln P_{t-1}^{CO}$, $\Delta \ln P_{t-1}^{FT}$, $\Delta \ln P_{t-1}^{INS}$, $\Delta \ln IR_{t-1}$, $\Delta \ln RF_{t-1}$, $\Delta \ln R_{t-2}^{PP}$, $\Delta \ln U_{t-2}^{NA}$, $\Delta \ln W_{t-2}^A$, $\Delta \ln P_{t-2}^{MZ}$, $\Delta \ln P_{t-2}^{CO}$, $\Delta \ln P_{t-2}^{FT}$, $\Delta \ln P_{t-2}^{INS}$, $\Delta \ln IR_{t-2}$, $\Delta \ln RF_{t-2}$. M_t^A denotes labor mobility out of the agricultural sector, A_t^C denotes area deforested, W_t^A denotes relative agricultural income, R_t^{PP} denotes rural population pressure, U_t^{NA} denotes non-agricultural unemployment rate, S_t^D denotes structural adjustment program dummy (equal to 1 for 1983–1999 and 0 otherwise), P_t^{CO}, P_t^{MZ}, P_t^{INS}, P_t^{FT} denote the respective real prices of cocoa, maize, cocoa insecticides and fertilizer; RF_t denotes the mean annual rainfall, and IR_t denotes access to irrigation infrastructure (proportion of arable land irrigated). See online appendix A2 for the detailed definitions and descriptive statistics of the variables, and online appendix A4 for the detailed long-run econometric results.
Source: Authors' computations.

as well as the fairly low variation of rural population pressure (notably, the coefficient of variation is 0.1288). The coefficient of the unemployment rate in the non-agricultural sector exhibits the hypothesized negative sign and it is significantly different from zero at the 1 per cent level. This result suggests that in the long run, intersectoral labor mobility declines by 2.3989 per cent when the unemployment rate in the non-agricultural sector increases by 1 per cent, *ceteris paribus*, and vice versa.

The coefficient of intersectoral labor mobility in the long-run deforestation model exhibits the postulated negative sign and it is significant at the 1 per cent level (table 1). A 1 per cent increase in intersectoral labor mobility from the agricultural to the non-agricultural sector leads to a 0.797 per cent decline in the area deforested due to agriculture and vice versa, *ceteris paribus*. Rural population pressure and the real producer prices of cocoa and maize exhibit the hypothesized positive signs. However, whereas the rural population pressure variable is significant at the 10 per cent level, the producer prices of maize and cocoa are not significantly different from zero even at the 10 per cent level. The insignificant coefficients of the prices of cocoa and maize may be due to the very high correlation of 0.94 between these two variables.

Moreover, farmers may have expected to receive relatively low profit margins from increasing the areas under cocoa and maize cultivation in the long run, *ceteris paribus*; this may have resulted in the insignificant coefficients of the prices of cocoa and maize. In addition, as prices of agricultural products (specifically, cocoa and maize) increase, non-agricultural product prices also tend to increase in the long run, since all prices tend to be flexible in the long run. Relative prices may therefore not change significantly and resource allocation (including forest land) may not change significantly in the long run.

Ceteris paribus, a 1 per cent increase (decrease) in rural population density leads to a 10.5 per cent increase (decrease) in the area deforested in the long run (table 1). This is consistent with the neo-Malthusian hypothesis concerning the effect of growing human population on natural resource use (Sunderlin and Resosudarmo, 1999). This empirical result further concurs with Barbier and Burgess (2001) and Scrieciu (2007) that, with increasing population pressure on land, the natural tendency is for people to clear more land so that they can feed themselves and also earn an income. The estimated coefficient of the price of insecticides has the postulated negative sign, albeit statistically insignificant even at the 10 per cent level. This may be due to the high correlation coefficients of 0.89 and 0.87 between price of insecticides and price of fertilizer, and between the price of insecticides and price of cocoa respectively. A positive relationship is observed between fertilizer prices and area cleared for agriculture in the long run, the level of significance being 10 per cent. This is consistent with Benhin and Barbier (2004). As Fosu (1997, 1998) also pointed out, the removal of subsidies on inputs like insecticides and fertilizer under the SAP in Ghana tended to stimulate phenomenal increases in agricultural input prices which tended to discourage the use of these inputs leading to agricultural extensification and deforestation. The significant negative coefficient of the irrigation variable indicates that, in the long run, a 1 per cent increase in the proportion of arable land under irrigation results in a 6.6 per cent decrease in the area deforested (table 1). This negative effect is consistent with the a priori expectation. The positive cointegration coefficient of 4.7292 concerning annual national rainfall suggests that, in the long run, a 1 per cent increase in mean annual national rainfall leads to a 4.73 per cent increase in the area deforested for agricultural production.

The long-run effects of relative agricultural income and the unemployment rate in the non-agricultural sector (viz., the two significant long-run determinants of labor mobility) on deforestation can be obtained by taking the algebraic product of the relevant coefficients in the labor mobility and deforestation equations. Thus a 1 per cent increase in the relative agricultural income leads, in the long run, to a 1.47 per cent ($-1.8431 \times -0.797 = 1.4689$) increase in deforestation, *ceteris paribus*, and vice versa. Furthermore, a 1 per cent increase in non-agricultural unemployment leads to a 1.91 per cent ($-0.792 \times -2.3989 = 1.9119$) increase in deforestation in the long run, *ceteris paribus*, and vice versa. These two responses are therefore elastic.

6.3. Short-run effects

The empirical results concerning the short-run relationships between intersectoral labor mobility and its determinants and the short-run relationships between area deforested and its determinants are presented in table 2. Convergence of the Iterative Three Stage-Least Squares estimation procedure was achieved after 36 iterations. The Breusch–Godfrey LM test with a BG (2) value of 1.9217 and a p-value of 0.1656 suggests no second-order autocorrelation in the labor mobility model. A BG (2) value of 2.6244 with a p-value of 0.1226 indicates the absence of second-order autocorrelation in the residuals of the deforestation model. The detailed short-run empirical results have been provided in online appendix A5.

Table 2 shows that income in agriculture relative to that in non-agriculture is not statistically significant even at the 10 per cent level, although it exhibits the postulated negative sign. The rural population density variable in the intersectoral labor mobility model exhibits the expected positive sign but it is not significantly different from zero in the short run, even at the 10 per cent level. The coefficient of unemployment rate in the non-agricultural sector is significantly different from zero at the 1 per cent level and has the a priori negative sign. This is consistent with the proposition that, as the unemployment rate in a sector increases, labor inflow into that sector decreases, *ceteris paribus* (Binswanger and Rosenzweig, 1984). A 1 per cent increase in non-agricultural unemployment leads to a 3.1734 per cent decrease in labor mobility in the short run (table 2). The SAP dummy is statistically insignificant even at the 10 per cent level.

The short-run dynamics further show that intersectoral labor mobility exhibits the hypothesized negative sign in the error correction modeling results relating to deforestation, and it is significantly different from zero at the 10 per cent level. The estimated coefficient of -0.3872 indicates that a 1 per cent increase in labor flow from the agricultural sector to the non-agricultural sector decreases the area cleared for agriculture by approximately 0.39 per cent in the short run. Rural population pressure

Table 2. *Empirical Error Correction Modeling results of the short-run relationships*

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Probability*
Dependent variable: $\Delta \ln M_t^A$				
CONSTANT	−0.0881	0.1365	−0.6451	0.5221
$\Delta \ln W_t^A$	−1.2062	1.1197	−1.0773	0.2871
$\Delta \ln R_t^{PP}$	4.6256	3.2745	1.4126	0.1646
$\Delta \ln U_t^{NA}$	−3.1734	1.0867	−2.9202	0.0054
ΔS_t^D	0.9082	0.7887	1.1515	0.2556
$ect_{1,t-1}$	−1.2571	0.1793	−7.0115	0.0000
R^2	0.7379		Mean	−0.05862
Adjusted R^2	0.6602		S.D	1.4689
S.E.R.	0.8563		RSS	19.7964
Observations	36		BG (2)	1.9217 (0.1656)
Dependent variable : $\Delta \ln A_t^C$				
CONSTANT	−0.0321	0.1934	−0.1661	0.8688
$\Delta \ln M_t^A$	−0.3872	0.1970	−1.9650	0.0543
$\Delta \ln R_t^{PP}$	0.7985	5.7116	0.1398	0.8894
$\Delta \ln P_t^{CO}$	1.0495	0.3703	2.8340	0.0069
$\Delta \ln P_t^{MZ}$	0.5709	0.2746	2.0792	0.0433
$\Delta \ln P_t^{INS}$	−0.0488	0.3054	−0.1597	0.8739
$\Delta \ln P_t^{FT}$	0.4124	0.4049	1.0186	0.3138
$\Delta \ln RF_t$	1.1734	1.0963	1.0703	0.2902
$\Delta \ln IR_t$	−4.3698	2.6125	−1.6727	0.1003
$ect_{2,t-1}$	−0.9273	0.2463	−3.7646	0.0005
R^2	0.5937		Mean	0.0552
Adj. R^2	0.2101		S.D	0.9374
S.E.R.	0.8331		RSS	12.4930
Observations	36		BG (2)	2.6244 (0.1226)

Notes: *ect* denotes error correction term. The instruments used in the equations are $\ln R_t^{PP}$, $\ln P_t^{MZ}$, $\ln IR_t$, $\Delta \ln P_t^{FT}$, $\Delta \ln R_{t-1}^{PP}$, $\Delta \ln U_{t-1}^{NA}$, $\Delta \ln W_{t-1}^{A}$, $\Delta \ln P_{t-1}^{MZ}$, $\Delta \ln P_{t-1}^{INS}$, $\Delta \ln IR_{t-1}$, $\Delta \ln RF_{t-1}$, $\Delta \ln U_{t-2}^{NA}$, $\Delta \ln RF_{t-2}$, ΔP_t^{INS}, P_t^{INS}, RF_t, P_{t-1}^{MZ}, P_{t-1}^{CO}, R_{t-1}^{PP}, $S_{t-1}^{D} ect_{1,t-1} ect_{2,t-1} \Delta \ln A_{t-2}^{C}$. M_t^A denotes labor mobility out of the agricultural sector, A_t^C denotes area deforested, W_t^A denotes relative agricultural income, R_t^{PP} denotes rural population pressure, U_t^{NA} denotes non-agricultural unemployment rate, S_t^D denotes structural adjustment program dummy (equal to 1 for 1983–1999 and 0 otherwise), P_t^{CO}, P_t^{MZ}, P_t^{INS}, P_t^{FT} denote the respective real prices of cocoa, maize, cocoa insecticides and fertilizer; RF_t denotes the mean annual rainfall, and IR_t denotes access to irrigation infrastructure (proportion of arable land irrigated). The detailed short-run econometric results are presented in online appendix A5.
Source: Authors' computations.

is not significant even at the 10 per cent level in the short run in the deforestation model (table 2). The producer prices of maize and cocoa exhibit the expected positive signs and are statistically significant at the 5 per cent and 1 per cent levels respectively in the short run. The positive coefficient of 1.0495 relating to the producer price of cocoa indicates that, in the short run, a 1 per cent increase in the real producer price of cocoa results in a 1.05 per cent increase in agricultural deforestation, *ceteris paribus*. In the short run, increased profit margins received by farmers tend to encourage them to increase area cleared, *ceteris paribus*. The elasticity of the price of maize is 0.5709. The coefficient of the insecticide price is not significantly different from zero even at the 10 per cent level, although it bears the hypothesized negative sign. The coefficients of the rainfall variable and the price of fertilizer carry the hypothesized signs but are not statistically significant even at the 10 per cent level.

The negative coefficient of −4.3698 of access to irrigation infrastructure is approximately significant at the 10 per cent level and this implies that a 1 per cent increase in the proportion of arable land under irrigation leads to a 4.37 per cent decrease in the area deforested. The error correction terms have the expected negative signs and are statistically significant at the 1 per cent level in both the labor mobility and deforestation models, indicating that last periods equilibrium error of intersectoral labor mobility from agricultural to non-agricultural sectors has a significant impact on subsequent changes in the amount of area deforested through agricultural expansion. The short-run effect of the unemployment rate in the non-agricultural sector on deforestation is 1.2287 (that is, -3.1734×-0.3872). Thus, a 1 per cent increase (decrease) in the non-agricultural unemployment rate leads to a 1.23 per cent increase (decrease) in deforestation in the short run, *ceteris paribus*. These results, coupled with those corresponding to the long-run analysis, present important policy implications for the control of deforestation due to agricultural activities.

7. Concluding remarks

The long-run and short-run relationships between intersectoral labor mobility and area deforested in Ghana over the period 1970–2008 have been analyzed in this paper. Cointegration and error correction modeling procedures have been used to analyze the effects of the determinants of labor mobility and area deforested due to agriculture. The empirical results show that in the long run, intersectoral labor mobility from the agricultural to the non-agricultural sector increases with decreasing relative agricultural income, but decreases with increasing rate of unemployment in the non-agricultural sector. Labor flow out of agriculture also decreases with an increase in unemployment in the non-agricultural sector in the short run.

Labor mobility and irrigation are observed to exert negative effects on deforestation whereas the price of fertilizer, rural population and rainfall tend to exert positive effects on deforestation in the long run. Non-agricultural unemployment exerts a positive effect on deforestation in the long run. In the short run, decreasing non-agricultural unemployment stimulates increasing labor flow out of agriculture. Increasing labor flow out of agriculture decreases agricultural deforestation in the short run whereas the producer prices of cocoa and maize are observed to exert positive effects in the short run. Access to irrigation exerts a negative effect on agricultural deforestation in the short run.

Based on the empirical results of this study, the following policies for mitigating deforestation are suggested. Policies which precipitate lower relative urban incomes where the bulk of non-agricultural work is concentrated are likely to discourage labor from staying in that sector. Rather, labor is likely to flow into the agricultural sector and stimulate deforestation. To reverse this phenomenon, complementary policies including carefully targeted non-agricultural subsidies and fiscal incentives for manufacturing firms, as well as the removal of bottlenecks in the rural and urban labor markets, may be implemented. These are likely to curtail any potential adverse population pressure on land and mitigate deforestation.

Furthermore, the significant deforestation effect of intersectoral labor mobility from the agricultural sector to the non-agricultural sector coupled with the significant labor mobility effect of non-agricultural unemployment both in the short run and in the long run implies that the flow of labor to the agricultural sector due to a non-existence of off-farm job opportunities is likely to stimulate people to clear more land and generate adverse environmental consequences in Ghana. Hence, fiscal and other incentives for the establishment of cottage industries and other small- and medium-scale enterprises (SMEs) should be provided. Likewise, other rural development policies which encourage job creation in the rural sector should be implemented. In addition, subsidies on fertilizer and other soil fertility-enhancing technologies, as well as small-scale and affordable irrigation infrastructure, need to be provided to increase agricultural productivity. These are likely to discourage agricultural extensification and deforestation which tend to originate in adverse population pressure, inter alia. There is also the need to slow down increasing pressure on land by promoting other productivity-increasing technologies (coupled with producer price incentives) in the cocoa, maize and other major agricultural sub-sectors in the economy of Ghana.

Finally, it is important to note that rural-to-rural migration may be a significant determinant of deforestation. Future studies should therefore consider analyzing this possibility. Similarly, the issues of the roles of asymmetric information, missing markets, credit constraints and other 'second best' conditions could be considered in future research.

References

Ampadu-Agyei, O., G.A. Manful, J.E. Fleischer, M. Opam, and A.M. Ameyaw (1994), 'Climate and Africa', Conference on Policy Options and Responses to Climate Change, Nairobi, 5–8 December.

Angelsen, A. (1999), 'Agricultural expansion and deforestation: modelling the impact of population, market forces and property rights', *Journal of Development Economics* **58**(1): 185–218.

Armah, B. (1993), 'Trade structures and employment growth in Ghana: a historical comparative analysis: 1960–89', *African Economic History* **21**: 21–36.

Armah, F.A., J.O. Odoi, G.T. Yengoh, S. Obiri, D.O. Yawson, and E.K.A. Afrifa (2011), 'Food security and climate change in drought-sensitive savanna zones of Ghana', *Mitigation and Adaptation Strategies for Global Change* **16**(3): 291–306.

Asare, B. and A. Wong (2004), 'An economic development of two countries: Ghana and Malaysia', *West Africa Review* **5**(1).
Banerjee, B. and S.M.R. Kanbur (1981), 'On the specification and estimation of macro rural–urban migration functions: with an application to India data', *Oxford Bulletin of Economics and Statistics* **43**(1):7–29.
Barbier, E.B. (2000), 'Links between economic liberalization and rural resource degradation in the developing regions', *Agricultural Economics* **23**(3): 299–310.
Barbier, E.B. (2004), 'Explaining agricultural land expansion and deforestation in developing countries', *American Journal of Agricultural Economics* **86**(5): 1347–1353.
Barbier, E.B. and J.C. Burgess (1996), 'Economic analysis of deforestation in Mexico', *Environment and Development Economics* **1**(2): 203–239.
Barbier, E.B. and J.C. Burgess (2001), 'The economics of tropical deforestation', *Journal of Economic Surveys* **15**(3): 413–432.
Benhin, J.K. and E.B. Barbier (2004), 'Structural adjustment programme, deforestation and biodiversity loss in Ghana', *Environmental and Resource Economics* **27**(3): 337–366.
Binswanger, H.P. and M.R. Rosenzweig (1984), *Contractual Arrangements, Employment and Wages in Rural Labor Markets in Asia*, New Haven: Yale University Press.
Blackman, A., H. Albers, B. Avalos-Sartorio, and L.C. Murphy (2008), 'Land cover in a managed forest ecosystem: Mexican shade coffee', *American Journal of Agricultural Economics* **90**(1): 216–231.
Bluffstone, R.A. (1995), 'The effect of labor performance on deforestation in developing countries under open access: an example from rural Nepal', *Journal of Environmental Economics and Management* **29**(1): 42–63.
Boserup, E. (1965), *The Conditions of Agricultural Growth*, London: George Allen and Unwin.
Caldwell, J. (1969), *African Rural–Urban Migration: The Movement to Ghana's Towns*, New York: Columbia University Press.
Carr, D. (2009), 'Rural migration: the driving force behind tropical deforestation on the settlement frontier', *Progress in Human Geography* **33**(3): 355–378.
Cropper, M. and C. Griffiths (1994), 'The interaction of population growth and environmental quality', *American Economic Review* **84**(2): 250–254.
Engle, R.F. and C.W.J. Granger (1987), 'Cointegration and error correction: representations, estimations and testing', *Econometrica* **55**(2): 251–276.
EPA (2002), *National Programme to Combat Drought and Desertification*, Accra: Environmental Protection Agency.
Ewusi, K. (1987), *Structural Adjustment and Stabilization Policies in Developing Countries: A Case Study of Ghana's Experience in 1983–1986*, Tema: Ghana Publishing Corporation.
Ewusi, K., S.Y. Atsu, and L.O. Gyekye (1983), 'Land utilization and labor productivity in agriculture in Ghana: a report to the Jobs and Skills Programme for Africa (JASPA)', Technical Publication No. 46, Addis-Ababa: International Labor Organization.
FAO (2000), 'Tropical deforestation literature: geographical and historical patterns in the availability of information and the analysis of causes', Forest Resources Assessment Programme Working Paper No. 27, Rome: Food and Agriculture Organization of the United Nations.
FAO (2005), *Global Forest Resources Assessment 2005*, Rome: Food and Agriculture Organization of the United Nations.
Fosu, K.Y. (1989), 'Agriculture in Ghana's post-1970 development process', Paper presented to the 5th Biennial Conference of the West African Economic Association, Lome, Togo.

Fosu, K.Y. (1997), 'Research and policy interdependence for sustainable development in twenty-first century Ghana', in *Governance and Development in West Africa: Perspectives for the 21st Century*, Arlington: Winrock International.
Fosu, K.Y. (1998), 'Public policy and fertilizer demand in Ghana', in G.A.A. Wossink, G.C. van Kooten and G.H. Peters (eds), *Economics of Agrochemicals*, Aldershot: Ashgate.
Gibbs, H.K., A.S. Ruesch, F. Achard, M.K. Claytond, P. Holmgren, N. Ramankutty, and J.A. Foley (2010), 'Tropical forests were the primary sources of new agricultural land in the 1980s and 1990s', *PNAS* (Early Edition): 1–6.
Girdner, J., V. Olorunsola, M. Froning, and E. Hansen (1980), 'Ghana's agricultural food policy: Operation Feed Yourself', *Food Policy* **5**(1): 14–25.
GSS (2005), *Electronic Database: Digest of Statistics*, Accra: Ghana Statistical Service.
GSS (2007), *Pattern and Trends of Poverty in Ghana, 1991–2006*, Accra: Ghana Statistical Service.
GSS (2010), *Ghana Statistical Service Information and Database*, Accra: Ghana Statistical Service.
Harris, J.R. and M.P. Todaro (1970), 'Migration, unemployment and development: a two-sector analysis', *American Economic Review* **60**(1): 126–142.
ISSER (2010), *The State of the Ghanaian Economy Report, 2008*, Accra: Universities Press.
Johnston, B.F. and P. Kilby (1975), *Agriculture and Structural Transformation: Economic Strategies in Late-Developing Countries*, New York: Oxford University Press.
Kangalawe, R.Y.M. and J.G. Lyimo (2010), 'Population dynamics, rural livelihoods and environmental degradation: some experiences from Tanzania', *Environment, Development and Sustainability* **12**(6): 985–997.
Lee, E. (1966), 'A theory of migration', *Demography* **31**(1): 47–57.
Lopez, R. (1997), 'Environmental externalities in traditional agriculture and the impact of trade liberalization: the case of Ghana', *Journal of Development Economics* **53**(1): 17–39.
Mundlak, Y. and D. Larson (1997), 'On the intersectoral migration of agricultural labor', *Economic Development and Cultural Change* **45**(2): 295–319.
Nkamleu, G.L. and F. Louise (2006), 'Taking stock of research on regional migration in sub-Saharan Africa', MPRA Paper No. 15112, Munich University, Germany.
Quaye, A.K., C.A.S. Hall, and V.A. Luzadis (2010), 'Agricultural land use efficiency and food crop production in Ghana', *Environment, Development and Sustainability* **12**(6): 967–983.
Ruf, F. and H. Zadi (1998), 'Cocoa: from deforestation to reforestation', Paper presented at the International Workshop on Sustainable Cocoa Growing, 29th March–3rd April, Smithsonian Institute, Panama.
Scrieciu, S.S. (2007), 'Can economic causes of tropical deforestation be identified at a global level?' *Ecological Economics* **62**(3–4): 603–612.
Stock, J.H. and M.W. Watson (1993), 'A simple estimator of cointegrating vectors in higher order integrated systems', *Econometrica* **61**(4): 738–820.
Sunderlin, W.D. and I.A.P. Resosudarmo (1999), 'The effect of population and migration on forest cover in Indonesia', *Journal of Environment and Development* **8**(2): 152–169.
Todaro, M.P. (1969), 'A model of labor migration and urban unemployment in less developed countries', *American Economic Review* **59**(1): 138–148.
Tutu, K. and C. Akol (2009), 'Reversing Africa's deforestation for sustainable development', in E.K. Yanful (ed.), Appropriate Technologies for Environmental Protection in the Developing World, New York: Springer Science and Business Media.