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ONSET RISKS AND DRAFT ANIMAL INVESTMENTS IN NIGERIA

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ABSTRACT

Farm productivity in Africa still depends on substantial labor inputs at the onset of the rainy season. High and increasing onset risks may affect farmers' demand for farm mechanization. I investigate the effect of onset risks on farmers' investment into draft animals in Nigeria. Based on the onset of the rainy season calculated from daily rainfall data, I identify locations in Nigeria that have experienced increasing, decreasing or constant onset risks in the past few decades. I then exploit the panel structure of our dataset and employ stratified propensity score matching (PSM) to estimate the average treatment effect on treated (ATT) differentiated by the onset risk and its change. I find that farmers in areas with higher, increasing or constant onset risks were more likely to invest into draft animals, and such effects are clearer among larger scale farmers. Linkages are also clearer with onset risks compared to annual rainfall risks.

Keywords: onset risk, rainfall risk, draft animal, external capital injection, stratified propensity score matching, Nigeria

JEL classifications: D81, O12, Q12

INTRODUCTION

Agricultural sector in developing countries is often characterized by high risk, risk-averse agents, high transaction costs, and failures of credit, insurance markets. Farmers in such environment employ a variety of informal risk-mitigation measures (Walker and Jodha 1986), ranging from consumption smoothing (Townsend 1994; Rosenzweig and Stark 1989), investments into land, income diversification, to conservation of biodiversity (Di Falco and Chavas 2009). Recent literature has focused on farmers' weather-related risk-mitigating motives in their investments into productive assets (Rosenzweig and Wolpin 1993; Takeshima and Yamauchi 2012). In many of these studies, uncertainty in annual rainfall

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(rainfall risk hereafter) is widely recognized as an important source of risk for farmers, together with other weather-related shocks such as drought and flood.

Yet another source of weather-related risk is the uncertainty in the onset timing of the rainy season (onset risk). Farming, input uses and productivity in sub-Sahara African (SSA) countries depend on the onset timing of the rainy season. Often in traditional rainfed agriculture, land preparation, plowing and planting need to be completed at the onset of the rainy season to maximize the crop yields (Fakorede 1985; Haggblade 2005). While many studies analyze the effect of rainfall risk (typically measured as variations in annual rainfall) on farmers' investment behaviors and welfare, fewer studies examine the effects of onset risk. While onset risks are sometimes correlated with rainfall risks, farmers may experience higher onset risks even when they perceive lower rainfall risks as is shown in this study. While rainfall risks affect the entire farm production period, onset risk affects the start of farming. Farmers may respond to onset risk differently from rainfall risk, as the onset of rainy season in SSA may involve switching from non-farming activities to farming activities, and some seasonal migration of laborers to the farm (Lapworth et al. 2010; van Westen and Klute 1986; van Dijk, Foeken and van Til 2001).

With insurance market failure, lack of reliable forecasting systems, greater onset risks may raise the cost of hiring sufficient farm labors at the beginning of the rainy season. Once the rainy season starts, labor mobility may decrease because some rural roads become impassable. Labor is also inelastic to wages particularly in remote areas (Jayachandran 2006),[1] so that offering higher wages may not lead to larger labor supply in the short-run. Migration can be still costly for many low-income farmers, and weather shocks can further reduce migration (Lewin, Fisher and Weber 2012). Farmers facing greater onset risks, when their liquidity constraint is relaxed, may therefore be more likely to invest into mechanization of farming activities at the beginning of production season, such as draft animals which give farmers more control over the timing of cultivation and enable higher yields (World Bank 2007).

I test this hypothesis by using an example of Second National Fadama Development Project (Fadama II project) in Nigeria, in which project participants were provided with financial assistance in obtaining productive assets. Takeshima and Yamauchi (2012) suggest farmers may invest into productive assets partly to mitigate the effect of rainfall risks. I build on their findings by investigating whether investments into draft animals respond to onset risk. In addition, investment into draft animals is motivated by many other factors, particularly farm size, soil workability and wages, and not only onset risks. I estimate the effects of onset risk across different farm sizes, soil workability and conduct robustness checks using wage indicators.

Onset risk has not been widely investigated in the literature as a factor driving farmers' investments than rainfall risk partly because the analysis of the former requires more temporally disaggregated rainfall data, typically at the daily level. The level of onset risk can be utilized for developing index-based insurance (World Bank 2007, p.149), and understanding farmers' response to onset risk is important in assessing potential benefits from such insurance. This study provides key insights into the effect of onset risk using the daily rainfall data from various meteorological stations in Nigeria, combined with the household

[1] While Jayachandran (2006)'s focus is on the inelastic labor supply at lower wage, it indicates potentially high labor mobility cost.

survey data collected for the evaluation of Fadama II project. I estimate the onset date based on the historical daily rainfall data. I find that external financial assistance leads to more investments into draft animals particularly by larger scale farmers in areas with low soil workability if they have experienced higher onset risk, or have not experienced a decrease in onset risk in the past few decades. In addition, while various methods have been suggested in the literature for determining onset date from daily rainfall data in Nigeria, many of them appear to lead to similar ranking of the cities regarding their onset risks, making our results robust to different formulas for onset date calculations.

This article has proceeds as follows. The section 2 discusses a conceptual framework. Section 3 discusses the estimation methodologies and data. Results are discussed in section 4 and section 5 concludes.

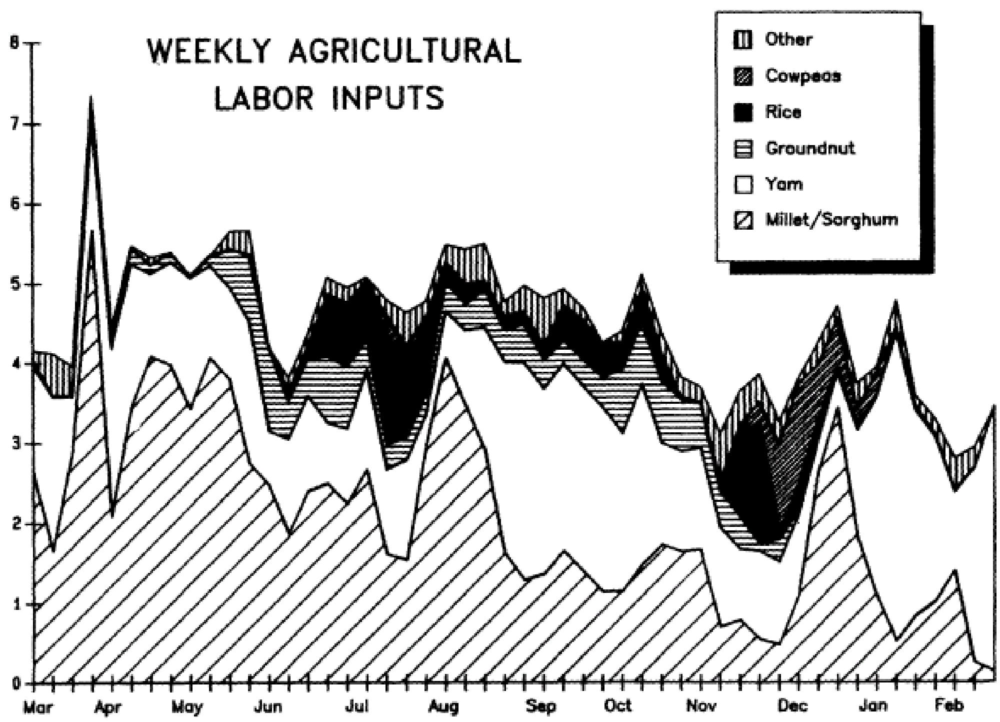
Farm Power Use in Central and Northern Nigeria at the Onset of Rainy Season

The northern and central Nigeria belongs to cereal-root crop mixed farming systems and agro-pastoral farming system environments (Dixon, Gulliver and Gibbon 2001). Rainfed agriculture is still dominant in the region with little use of irrigation. Most farmers in the regions are smallholders. Labor cost takes up a significant share of agricultural production costs in Nigeria (Phillip et al. 2009), partly because rural population particularly youths are increasingly leaving agriculture. Among farmers with relatively larger production scale, however, level of mechanization has been still low due not only to the high cost of tractors or power tillers, but also the lack of access to spare parts and reliable repairing services, and family as well as hired labors often provide important source of farm power (Takeshima, Nin Pratt and Diao 2013).

Intensive land preparation practices such as plowing become increasingly adopted as the population density reaches certain levels and fallow periods shorten as a result of the need to cultivate more area for food production (Pingali 2007). Because fallow periods are not long enough to replenish the soil fertility, more intensive plowing is needed to bring soil nutrients remaining underground. Countries like Ghana have reached this level, and the demand for land preparation and plowing has started rising (Diao et al. 2014). Nigeria shares similar agro-ecological and socio-economic conditions as Ghana and therefore the demands for land preparation and plowing are expected to be significant. Plowing is done after the onset of the rainy season as the soil is often too hard before the rain. Arrival of rain also means that the increasing farm power is required for weeding to remove weeds that germinate with rain. Delaying in planting after the rain starts often lead to significant yield loss in Nigeria (Stone, Netting and Stone 1990), typically 1 – 2 % per a day of delay for maize in Nigeria (Fakorede 1985) and Zambia (Haggblade 2005).

Onset of the rainy season is important even where rainy season is relatively long. Many farmers in rural Nigeria rely on farming for their income and want to make the most use of the rainy season during which they can grow crops. For smallholders, income from rainfed farming is often quite limited, particularly if improved varieties are scarce, and yields are low (Harris and Orr 2014). For example, farmers in Guinea Savannah zone grow cowpeas in relay-cropping after growing maize (Mortimore et al. 1997). Traditional varieties still grown by many farmers are typically slow-maturing and takes longer to grow. This is particularly so for subsistence staple crops like sorghum (Dugje, Kamara and Omoigui 2006). Many farmers in northern Nigeria therefore have great incentives to start plowing at the onset of the rainy season.

Consequently, farm power demand is typically the highest at the beginning of production season. For example, in Central Nigeria, labor inputs can almost double at the beginning week of production season than the prior week, and substantially higher than the rest of the production season (figure 1).



Source: Stone, Netting and Stone (1990).

[a]The figure shows the mean daily labor inputs per individual (scale in hours) for each week in the agricultural calendar, broken down by crop, observed in the village central Nigeria studied by Stone, Netting and Stone (1990).

Figure 1. Mean daily labor inputs per individual (scale in hours) by week (figure 2 in Stone, Netting and Stone (1990))[a].

Recent studies in the West Africa indicate that, in the case of maize for example, manual land preparation (including land clearing, plowing, harrowing) can require up to 50 man-days per hectare out of the total of 92 man-days for the whole production activities (Ngeleza et al. 2011; Takeshima, Nin Pratt and Diao 2013 Table 4.2). Even if all family labor is mobilized for these activities, with typically 5 (adult members and children) in Nigeria , the land preparation takes 10 days, which can lead to the maize yield loss of 10 ~ 20% (based on Fakorede 1985), as well as 10 days lost out of the rainy season. The demand may therefore be substantial for farm power beyond what is supplied by the family labor alone.

Use of animal traction could typically reduce the labor requirement for plowing by half in Nigeria (Jansen 1993). A farmer using five manual workers to complete these activities in one week can perform the same work with only two or three workers if a draft animal is used, significantly reducing the need to hire workers. Much of north and parts of central Nigeria are free from tsetse flies that harm livestock, compared to southern Nigeria. The price of draft animals can however constrain their adoption, as a pair of work bulls or oxen can cost as much as 30,000 Naira (approximately US$200) in Nigeria (Ja'afar-furo 2010).

Generally rising agricultural labor cost, farming intensification and higher demand for farm power at the onset of rainy season, and the relative benefit of draft animal compared to manual labor all suggest that demands for draft animals are potentially high in northern and central Nigeria, and financial assistance could significantly raise investment in draft animals. Existence of such conditions is important for this study because, although our focus is on farmers' insurance motive against onset risk behind draft animal investment, their investment motive may also be determined by the general profitability of draft animal. In other words, while farmers may choose insurance mechanisms against onset risk, they are unlikely to do so through draft animal investment if the productivity return from draft animal is not sufficiently high.

Conceptual Framework and Hypotheses

I now discuss a theoretical framework linking onset risk with demand for draft animal, and empirically testable hypotheses. The insurance role of draft animal is based on two premises discussed in the previous section; owning draft animal can reduce the need at the onset of rainy season to mobilize large labor resources, both own family members and hired labors; such mobilization potentially involves risks under uncertain onset timing[2] due to its irreversibility in short term around onset period.

Here I illustrate a model to conceptualize the effect of onset risk on farmer's utility linked to their labor resources allocation, insurance role of draft animal, and the effect of reduced liquidity constraints on their draft animal investments. I then derive hypotheses that are testable in empirical models. Onset risk is by no means the only type of risk farmers are exposed. In low income setting, farmers are exposed to various types of risks that are natural disaster related, health related, market related, policy related, or security related (World Bank 2007). I, however, focus here on the onset risk because, to my knowledge, onset risk has not been conceptualized in the literature that deals with risks and investment behaviors compared to more commonly studied types of risks. The model is based on the assumption that farmers' levels of exposures to as well as responses to other types of risks are implicitly embedded as functions of exogenous factors.

The model is a standard maximization of expected utility in the presence of risks. However, I start with an exposition of how the onset timing affects the utility, which is somewhat different from conventional utility maximization model where timing is often not part of the parameters of the utility function. I then introduce the risks associated with onset

[2] In Nigeria, several institutions like Nigerian Meteorological Agency (NIMET) and Institute of Agricultural Research (IAR) predict expected onset of rainy seasons and make it publicly available (NIMET 2011). The accurate forecasting, however, is still challenging and typically the onset date is predicted with margin of errors similar to the magnitude of uncertainty discussed in the later section. In addition, majority of Nigerian farmers may not have access to this information due to the shortage of extension agents who are primarily in charge of disseminating information to farmers in various locations.

timing in expected utility function. When the onset timing is known, a farmer maximizes utility U subject to,

$$\max_{\ell_t, L_t, M, X_t} U(X_T, \Pi_T)$$

s.t.

$$\Pi_T = \int_0^T f_t(\ell_t, M, t')dt$$

$$G_T = \int_0^T g_t(L_t)dt$$

$$X_T = \int_0^T X_t dt$$

$$A + G_\tau - M \cdot w(1 - F \cdot \psi) - [\int_0^\tau (\ell_t + L_t)dt + X_\tau] \geq 0, \ \forall \tau \in \{0, T\}. \quad (1)$$

U is a function of total consumption X_T and discounted future returns from farming activities Π_T realized between a particular period from $t = 0$ to T which consists of all months that onset of the rainy season can occur.

The farmer maximizes U by choosing optimal levels of labor use in farming (ℓ_t) and non-farm activity (L_t) at each t, and deciding whether to make new investment into draft animal ($M = 1$) or not ($M = 0$) at some point between $t = 0$ and T. The ℓ_t and L_t can be the opportunity costs of household labor force, or payment for hired labor, which are treated perfectly substitutable for simplicity.

The farming returns f_t is discounted value of the harvest which is realized after $t = T$ but depends on the resource uses for farming activities up to T such as plowing. While it may not bring in actual cash return before T, the farmer still balances current consumption X_T and discounted future return Π_T when maximizing the utility U.

The f_t depends on whether the new investments into draft animals is made ($M = 1$). Liquidity constraint for each period $t = \tau \in \{0, T\}$ states that investment into M at $t = \tau$ can be made only if the investment w does not exceed the total initial wealth available A at $t = 0$, plus any earning from non-farming activities up to τ (G_τ), minus the total labor resource uses and consumption up to τ ($\int_0^\tau (\ell_t + L_t)dt + X_\tau$). Investment into M is, however, subsidized by ψ if a farmer participates in the project ($F = 1$) that provides financial assistance.

Marginal value product of farm labor use $f_{t\ell}$ (= $\partial f_t / \partial \ell_t$) depends on the onset of rainy season t'. $f_{t\ell}$ is low before the onset ($t < t'$) as farm activity before it does not add much value to crop production. $f_{t\ell}$ rises after the onset ($t \geq t'$). $f_{t\ell}$ also depends on the availability of draft animal M. Marginal value product of labor in non-farm activity g_{tL} (= $\partial g_t / \partial L$) is assumed independent of t'.

The solution of the utility maximization problem (1) suggests that optimal ℓ_t* and L_t* satisfy an interior solution

$$f_{t\ell}^* = \partial f_t / \partial \ell_t \mid_{\ell t = \ell t^*} = g_{tL}^* = \partial g_t / \partial L_t \mid_{Lt = Lt^*} \quad (2)$$

or corner solutions

$$(\ell_t, L_t) = (0, L_t^*) \text{ if } f_{t\ell}^* < g_{tL}^*$$
$$(\ell_t, L_t) = (\ell_t^*, 0) \text{ if } f_{t\ell}^* > g_{tL}^*. \quad (3)$$

If a farmer expects that returns from farming activities are lower than the returns from non-farming activities before the onset t' but are higher after the onset t',

$$f_{t\ell} \lesseqgtr g_{tL} \text{ if } t \lesseqgtr t'. \quad (4)$$

The optimal ℓ_t^* and L_t^* is likely to change discontinuously at t'. The condition (3) is an example where a farmer switches completely from non-farming activities to farming activities at t'. With the uncertainty in onset t', solving the utility maximization involves choosing the timing of such switch $t = t^*$, which is the farmer's prediction of t'. Farmer's utility from choosing t^* can be expressed as

$$V(A, F, \psi, w, f, g, M, t', t^*) \quad (5)$$

in which the indirect utility function V specifies that farmer's utility depends on t' and t^*.[3] With (3),

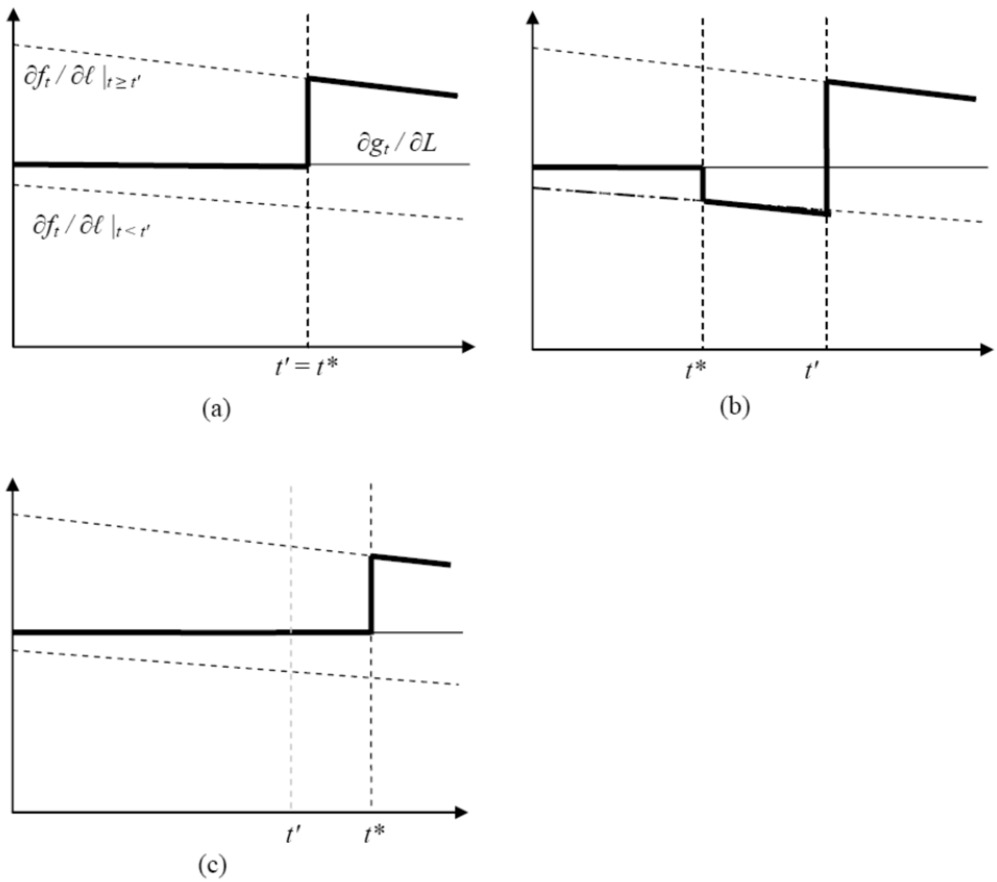
$$V(A, F, \psi, w, f, g, M, t', t^*) =$$
$$U\left\{\int_0^{t^*}\left[f_t(\cdot \mid \ell_t = 0) + g_t(\cdot \mid L_t = L_t^*)\right]dt,\quad \int_{t^*}^{T}\left[f_t(\cdot \mid \ell_t = \ell_t^*) + g_t(L_t \mid L_t = 0)\right]dt\right\}$$
$$= U\left[\int_0^{t^*} g_t(L_t^*)dt,\quad \int_{t^*}^{T} f_t(\ell_t^*, M, t')dt\right] \quad (6)$$

When there is uncertainty in t', choosing t^* can involve risk. For example, a farmer cannot easily reallocate the resource they have allocated for farming activities, either their own labor force or financial commitment for hired labor, back to non-farm activities due to various information failure, high migration and transaction costs which are common in SSA. Greater uncertainty in onset of the rainy season may raise the cost of securing labor force for farming activities at the onset of the rainy season. When the farmer owns insufficient number of draft animals ($M = 0$), the expected utility is

$$E[V \mid M = 0] = \int V(\cdot, t', \cdot \mid M = 0)h(t')dt' \quad (7)$$

[3] I assume that farmers can perceive t' correctly once it arrives. The case in which farmers cannot correctly perceive t' is beyond the scope of this study, as it requires more complicated modeling of farmers' perception process. I define onset date using a particular formula, and obtain empirical uncertainty based on historical realizations. I believe such empirical uncertainty can be good measure of farmers' perceptions of uncertainty as they often build their forecast based on their experience, as well as the experience of their ancestors passed down to them through oral tradition (Nnoli et al. 2006).

where expectation is taken over the possible range of t' which is randomly distributed based on density function $h(t')$. A greater distribution of t' indicates a greater uncertainty in onset timing. In this article, I use standard deviation of t', σ, as an indicator of risk.[4]



Source: Author.

Figure 2. Onset of rainy season (t') and returns from decision of timing t^*.

Figure 2 illustrates simple examples of the linkage between risks associated with the selection of t^* and realization of t'. For illustrational purposes, figure 2 shows the case in which $f_{t\ell}$ and g_{tL} are constant across all ℓ_t and L_t given t'. In (a), a farmer can select t^* exactly at $t^* = t'$, earns marginal return g_{tL} until $t = t'$ and $f_{t\ell}\,|_{t \geq t'}$ from $t = t'$. In (b), a farmer pre-selects t^* but the rain does not come on time. Marginal return drops to $f_{t\ell}\,|_{t < t'}$ from g_{tL} between t^* and t'. At the onset t', the marginal return jumps up to $f_{t\ell}\,|_{t \geq t'}$. Similarly in (c), the onset comes earlier than the farmer's prediction t^* and he loses the potential gains. In figure 2, marginal value product of farming labor is slightly declining over time due to the aforementioned effect

[4] In theory, higher moments such as skewness or different measurements of distributions, can be additional important indicators if some farmers' aversions to risks are asymmetric or against other specific nature of risks. Investigating their effects are beyond the scope of this article and left for future studies, as the samples of onset dates are relatively few due to the difficulty in obtaining longer time series, and characterizations of more sophisticated nature of risks is challenging.

of planting delay on yield as well as the insufficient use of the rainy season discussed above. Such declining return also suggests that choosing later t^* may be as risky as choosing early t^*. Due to the scarcity of information, I assume that farmers' perception of risk σ is constant for all t^*. Draft animal can make the uncertainty in t' irrelevant, as it allows the farmer to start farm activity whenever t' is observed. Therefore,

$$E[V \mid M=1] = V(\cdot, t', \cdot \mid M=1) . \tag{8}$$

The indirect utility function V is concave in rainfall onset date so that $\partial^2 V(\cdot)/\partial\sigma^2 < 0$ for a risk-averse farmer. Following Takeshima and Yamauchi (2012), if an external capital injection (F = 1) allows farmers to invest into draft animals that can shield them from onset risk, I have

$$\frac{\partial E[V \mid M=0, F=1]}{\partial \sigma} < \frac{\partial E[V \mid M=1, F=1]}{\partial \sigma} \leq 0 \tag{9}$$

in which $E[V \mid M = 0, F = 1)]$ is the expected utility of a farmer who is a project beneficiary but does not invest in draft animal. The equality holds if investments into draft animals make farmers completely free from onset risk. Condition (9) suggests,

$$\frac{\partial \{E[V \mid M=0, F=1] - E[V \mid M=1, F=1]\}}{\partial \sigma} < 0 . \tag{10}$$

On the other hand, in the absence of external capital injection (F = 0), farmers may not invest into draft animals even though their potential demand may vary based on the onset risks, so that

$$\frac{\partial \{E[V \mid M=0, F=0] - E[V \mid M=1, F=0]\}}{\partial \sigma} = 0 . \tag{11}$$

Conditions (10) and (11) indicate the following empirical conditions;

$$\frac{\partial \Pr(M=1 \mid F=1)}{\partial \sigma} - \frac{\partial \Pr(M=1 \mid F=0)}{\partial \sigma} = \frac{\partial \Pr(M=1 \mid F=1)}{\partial \sigma} > 0 . \tag{12}$$

In other words, when onset is less certain (greater σ), the external capital injection has a greater impact on the likelihood of draft animal investment.

Importantly, empirical condition (12) is more likely to hold for farmers whose demands for draft animals are sufficiently high so that they would actually make investments with a certain amount of external capital injection. Farmers cultivating larger areas may have such high initial demands because they are likely to rely on hired labor whose costs may be more susceptible to onset risk, and returns from draft animal investment may be sufficiently high given the economies of scale, compared to farmers cultivating smaller plot areas. In other words, larger scale farmers may be more likely sensitive to the onset risk. Similarly, some soils have greater workability constraints where plowing requires greater farm power. In such areas, the demand for draft animals may be greater as well.

Combining these two factors, I have an additional empirical condition,

$$\frac{\partial^2 \Pr(M = 1 \mid F = 1)}{\partial\sigma\partial\Omega} > 0 \tag{13}$$

in which Ω is either the farm size or the soil workability constraint.

Altogether, by testing whether (12) and (13) hold respectively, I test the following two hypotheses;

Hypothesis 1: In an environment with higher onset risks, the external capital injection has a greater impact on raising the likelihood of farmers' investment in draft animal (14)

Hypothesis 2: Effects in Hypothesis 1 are greater for farmers with large farm size. (15)

These hypotheses may not hold if, among other alternative conditions, (a) farmers are not averse to the onset risk because they have other means to insure themselves, (b) farmers are risk neutral, (c) external capital injection is insufficient to make draft animal investment profitable, or (d) farmers have already invested sufficiently into draft animals. Finding evidence supporting hypotheses 1 and 2 would suggest that investments into draft animals are partly led by insurance motive against onset risks, which has important implications on agricultural mechanization and climate change adaptation policies in SSA.

Empirical Methods and Data

I use the dataset collected for the evaluation of Second National Fadama Development Project in Nigeria (Fadama II dataset) for the investment behaviors into draft animals. I first briefly describe Fadama II project and its linkages with the empirical identification strategy. More detailed descriptions of the project and data collection are provided in Nkonya et al. (2010) and Takeshima and Yamauchi (2012). Fadama II project is the second phase of the National Fadama Development Projects which started in 1993 in Nigeria as one of the largest agricultural interventions by the government. Fadama II had been implemented from 2004 through 2009 with the objective of growing agricultural productivity through community-driven approach. One key component of the project was the financial support for investments in various productive assets including draft animals. Project participants were provided with 70% subsidies for such investments (with ceiling for total subsidy amount) in exchange for various activities such as joining local economic interest groups and developing a scheme where common resources such as public infrastructure are better managed for community development (Takeshima and Yamauchi 2010). The project was implemented in 10 local government areas (LGAs) in total of twelve states, which were purposively selected by both the Nigerian government and the World Bank, the donor of this project (Nkonya et al. 2010). All farmers in these Fadama II LGAs therefore became eligible for project participation upon government's designation in 2005. Farmers then determine whether to participate or not, depending on benefits of financial support and opportunity costs of engaging in required activities (Takeshima and Yamauchi 2012).

Source: Author. Kaduna is also the name of the corresponding state.

Figure 3. States and cities in the analysis (state is in *italic*).

I focus the analysis to five northern and central Nigerian states out of all twelve states surveyed in Fadama II data, due to the difference in farming system and use of draft animal in the Southern Nigeria, and also the lack of information of rainfall data in a few central states. In addition, I apply rainfall data from Bauchi and Sokoto cities for Gombe state and Kebbi state, respectively. Figure 3 illustrates the locations of states and cities for which data were analyzed. The data have a semi-panel structure and has information from 2005 (before the project implementation) and 2006 (after the project implementation). Exploiting the semi-panel structure of the data, I form my empirical specification in first difference expression in order to eliminate unobserved heterogeneity and obtain more consistent estimates.

I test Hypothesis 1 applying stratified propensity score matching (PSM) method used in Takeshima and Yamauchi (2012), in which sample is stratified by states based on the onset risk. Estimation of onset risk and stratification is discussed in the next section. I also further stratify samples based on the area cultivated by farmers in 2005 and soil workability, to test Hypothesis 2. I estimate the average treatment effects on treated (ATT) of the Fadama II project on the likelihood of farmer's investment into at least one of the draft animal and attachment, namely oxen, ox-plow or work bull, within each stratum. I then test Hypothesis 1 by testing whether the estimated ATTs in higher risk or non-decreasing risk groups are statistically significantly positive and greater compared to lower risk and decreasing risk groups, and Hypothesis 2 by testing whether the estimated ATTs are greater for farmers with larger farm size or lower soil workability. Estimation is conducted in STATA using command `psmatch2`, using the nearest neighbor matching method. Results are robust to different choices of matching methods.

Propensity is the probability that a farmer participates in the Fadama II project. In the first stage, I estimate a probit model,

$$p_i = \Pr[\Delta F_i = 1 \mid \Delta X_i] = \Phi(\Delta E_i \cdot (1, \sigma, \delta, \zeta, \eta, H_i), \beta) \qquad (16)$$

in which the probability of farmer i participating in the project depends on the change in eligibility (ΔE), and its interaction with onset risk (standard deviation σ), change in onset risk (δ = 1 if onset risk decreased, = 0 otherwise) and other household characteristics H. I also interact rainfall risk (ζ) and change in rainfall risk (η = 1 if rainfall risk decreased, = 0 otherwise) as they are conventionally used weather risk variables. The eligibility ΔE indicates whether the farmer resides in the local government areas (LGA) which are designated for project implementation. The change in eligibility ($\Delta E = 1$) arises for farmers in these LGAs upon government's designation of these LGAs. While $\Delta E = 0$ indicates that the respondent resides outside such LGAs and faces more difficulty in participating in the project, they may still participate if they are part of Economic Interest Groups in the eligible LGA, as application for project grant is made through the EIG. The key assumption for PSM that $0 < p < 1$ therefore holds for all observations, including those with $\Delta E = 0$. β is the vector of estimated parameters.

Household characteristics H is a set of all time-invariant variables measured in 2005, including age, gender, education status of respondent, household size, number of working age household member, area cultivated, distance to the nearest town, household expenditure level in 2005 as an indicator of household wealth, whether the farmer already owned irrigation pump in 2005 which may mitigate onset risk through better water access, or already owned draft animal in 2005 so no further investment is needed, and state dummy variables to capture any state level policy effects. LGA average price of maize in 2005 is included to control for farming profitability as maize is one of the most widely grown crops in Nigeria.[5] All these variables affect the farm productivity and incomes, and thus returns to animal plowing and draft animal investments. For example, areas cultivated in 2005 proxies the farm land available for plowing once draft animal is obtained, and the larger such area is, the greater the expected farm income effects. Age, education levels affect efficiency of other production management activities, while proximity to town affects access to outputs and inputs markets. Household wealth can also affect ability to overcome liquidity constraints that limit access to various production resources, including draft animals.

[5] The data only have maize seed prices. However, in rural SSA, grains are often used interchangeably as seeds. This is particularly so in Nigeria where most maize varieties are still open-pollinated, and not hybrid (Alene et al. 2009). Since seed costs generally account for only a small share of production costs and seed multiplication rates are generally high so that a large quantity of grains can be harvested from one seed (Takeshima et al. 2010), a high seed price in this study indicates greater farm incomes.

I also estimate the model including LGA average wages for agricultural processing as a proxy of wages for farming activities with fewer observations for which the information was available. Using the predicted value of probability p_i from (16) (P_i), each observation *i* in treated group is matched with the observation in the control group with similar P_j, and the differences in the outcome (whether *i* invested into draft animal in 2006) is obtained for each *i*. The average of the differences across all *i*'s is measured as ATT. I focus on how the estimated ATTs vary for populations facing different levels of onset risk and its change.

One of the critical assumptions underlying PSM is the ignorability assumption, i.e., the propensity to participation depends only on observable characteristics. This may not always hold. For example, while the model is controlled for average soil workability across states, due to the lack of information of district locations mentioned above, it does not capture the variations of soil workability within the state. In the empirical analysis, I test whether the results are robust against such "hidden bias". I use Mantel and Haenszel (1959)'s MH bounds, suggested by Aakvik (2001) and Becker and Caliendo (2007), which is a counterpart of Rosenbaum bounds to the case with binary outcome variables such as in this study.

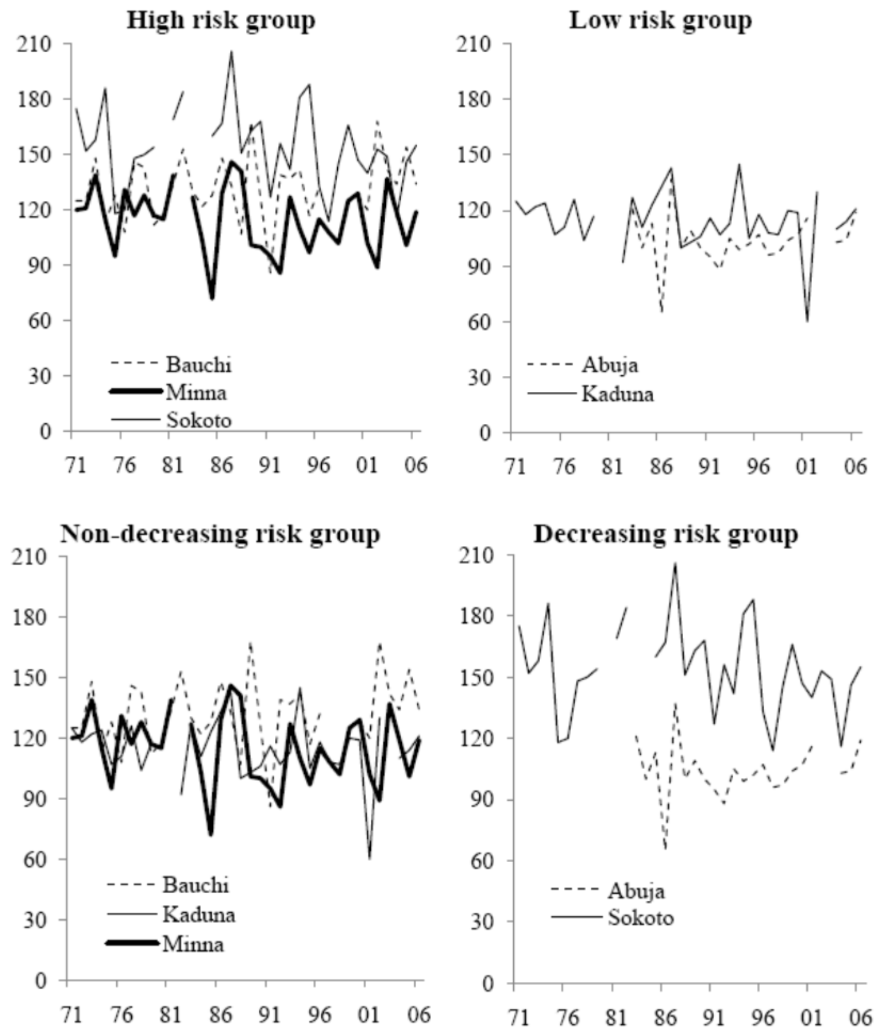
Onset Risk

I identify the onset dates in 5 locations across Nigeria using the historical daily rainfall data, and use its standard deviation as a proxy for the onset risks. I consider both long-term onset risk and its short-term fluctuations. The long-term risk is the standard deviations calculated from the entire data period, and the short-term fluctuation is determined by whether the standard deviations change significantly between and after any threshold years. While there may be potentially other ways to measure onset risks, measurements based on standard deviations are consistent with measurements used for other types of risks, particularly rainfall risks.

While the onset of rainy season in Nigeria is partly determined by the latitude of each location, it varies across locations and years due to variations in intensity of isolated showers, and duration of dry periods (Walter 1967). Many past studies use daily rainfall data to determine the onset dates, exploiting the cumulative percentages of daily rainfall (Walter 67; Ilesanmi, 1972; Odekunle 2004, 2005), as well as rainy days (Odekunle 2005), in which onset days depend on total annual rainfall by construction. Sivakumar (1988) provides different criteria which do not depend on total annual rainfall, but are applicable for Sudan Sahel which is the north of Nigeria. Alternatively, Nnoli et al. (2006) uses the following criteria; "The beginning of the first 10-day period with cumulative rainfall of greater than or equal to 30mm, one of which is at least 10mm and followed by another two ten-day periods each with at least 8-10 mm rain". I primarily draw on Nnoli et al. (2006) as it is independent of the total rainfall unlike Ilesammi (1972) or Odekunle (2004), and can be applied to more humid regions in Nigeria than Sudan Sahel as in Sivakumar (1988). I show below, however, that results from Nnoli et al. (2006) are robust across different methods.

Figure 4 plots the onset dates estimated using Nnoli et al. (2006), and how each city falls into each group based on high / low, and non-decreasing/decreasing risks defined below. Onset dates generally range between 75 ~ 175th days of the year (mid-March through late-June) for some Northern cities (Abuja, Bauchi, Kaduna, Minna) or 125 ~ 200th days of the year (early-May through late-July) for the other northern cities (Sokoto).

Table 1 summarizes the standard deviations of onset days at each location calculated using four different methodologies, Ilesanmi (1972), Odekunle (2005), Nnoli et al. (2006), and Nnoli et al. (2006) with threshold rainfall of 50mm instead of 30mm for the first 10 days.[6] Abuja and Kaduna cities have experienced relatively stable (more certain) onset dates, while other cities in the north and central zones (Bauchi, Sokoto, Minna) have experienced greater uncertainty. Standard deviations of 13.3 days would mean that, the onset dates can be 9 days earlier or later than the average with 50% of probability, and can differ by more than 17 days with 20% of probability, while the standard deviations of 21.7 days indicates 15 and 28 days, respectively.



Source: Author's calculation from NIMET (2009).
[a]The vertical axis measures the day of the year, and horizontal axis indicates the year of observations.

Figure 4. Onset days based on Nnoli et al. (2006)[a].

[6] I also found no evidence of serial correlations of onset dates, indicating that standard deviations may be fairly good proxy for onset risks (see detail in Appendix A).

Table 1. Standard Deviations of Onset Days at Each Location[ab]

City	State in Fadama II data	Methodology				Risk (H = high, L = low)
		Ilesanmi (1972)	Odekunle (2005)	Nnoli et al. (2006)[b]		
				Threshold = 30mm	Threshold = 50mm	
Bauchi	Gombe	14.8	10.4	17.2	18.6	*H*
Kaduna	Kaduna	9.5	8.0	15.2	17.4	*L*
Sokoto	Kebbi	14.8	13.7	21.7	20.9	*H*
Abuja	FCT	11.6	7.5	13.3	14.0	*L*
Minna	Niger	14.1	9.7	16.8	19.7	*H*
p-value for H_0: standard deviation is equal at all locations[a]		.173	.000	.015	.003	

Source: Author's calculation.

[a]Test based on Brown and Forsythe (1974).

[b]The beginning of the first 10-day period with cumulative rainfall of greater than or equal to either 30mm, or 50mm. Results are very similar.

Estimated standard deviations of onset dates are found jointly statistically significantly different across locations even given the small sample size, particularly under Odekunle (2005) and Nnoli et al. (2006), based on a robust test by Brown and Forsythe (1974) that does not require asymptotic normality assumption. Importantly, four methods give similar ranking of cities in terms of onset risk, as indicated by relatively high correlation coefficients between the methodologies (table 2). In most methods, cities can be ranked in the order of Abuja, Kaduna, Minna, Bauchi, and Sokoto with Abuja experiencing the lower risks.

Table 2. Similarity between Different Methods (Correlation Coefficients of Onset Date Uncertainty)

	Ilesanmi (1972)	Odekunle (2005)	Nnoli et al. (2006)
Odekunle (2005)	.934		
Nnoli et al. (2006) – 30mm	.849	.866	
50mm	.932	.944	.931

Source: Author's calculation.

I also identify the locations that have experienced significant short-term fluctuations in onset risk. Table 3 summarizes whether standard deviations in onset dates increased or decreased in each city after any threshold year.

Based on the aforementioned Brown and Forsythe (1974) test, I find several threshold years after which standard deviations of onset dates had changed statistically significantly than the prior period.

Importantly, direction of changes (whether increase or decrease) in onset risks is found consistent across all such threshold years, so that no city seems to have experienced both increase and decrease in onset risk. I therefore use these results as an indication that farmers in each city experienced short-term fluctuations (either increase, decrease or no change) in onset date risks in the past 10 – 30 years (last column of table 3). Sokoto and Abuja experienced decrease in onset risks, while Minna experienced increase in onset risks, and Bauchi and Kaduna experienced no change.

Table 3. Significance of Change in the Onset Risk and Threshold Years (Nnoli et al. 2006)[a]

City	Threshold year based on robust test (Brown and Forsythe 1974)	Change in risk (+: increasing –: decreasing)	
		Onset risk	Rainfall risk
Bauchi		0	0
Kaduna		0	0
Sokoto	97	–	–
Abuja	86–93	–	0
Minna	80–84	+	–

Source: Author's calculation.

[a]The table shows threshold years whereby standard deviations of onset dates have significantly increased (+) or decreased (–) from pre- to post- threshold years. For example, in Abuja, post-86 period experienced statistically significantly (p-value < 0.1) higher standard deviations than pre-86 period, and post-87 period compared higher standard deviations than to pre-87 period. For Abuja, each year between 1986 and 1993 can be considered such threshold years. Similar threshold years were found for Sokoto and Minna. No such threshold years were found for Bauchi or Kaduna.

Table 4. Correlation between Onset Risk and Rainfall Risk[a]

City	State	Correlation	Onset risk and rainfall risk	
			Rainfall risk = standard deviation	Rainfall risk = coefficient of variation
All			.722*	.295
North			.338	.872†
Bauchi	Gombe	–.100		
Kaduna	Kaduna	–.230		
Sokoto	Kebbi	–.385		
Abuja	FCT	–.263		
Minna	Niger	–.372		

Source: Author's calculation. *Significant at 5%; † Significant at 10%.

[a]Rainfall risk is obtained from Takeshima and Yamauchi (2012). The numbers are estimated correlation coefficients.

The late onset is often negatively correlated with the total rainfall of that year (table 4). Similarly, the onset risk is positively correlated with the rainfall risk. Significance of their correlation is, however, rather mixed. Patterns of changes in onset risks are different from changes in rainfall risks. While Sokoto experienced decrease in onset risks, no change in rainfall risks is observed. Similarly, while Minna experienced an increase in onset risk, it experienced a decrease in rainfall risk. These results also support the motivations of this study to examine specifically the effects of onset risks instead of rainfall risks which is more commonly studied in the literature.

Soil Workability Constraints

Soil workability constraints are measured using the soil workability scores developed by Fischer et al. (2008). It is a score assigned to soils in each of 30 arc-second grids across the globe based on how soil management is constrained by the soil texture, effective soil depth or volume and soil phases. It is scaled as the following; 1 = no or slight constraints; 2 = moderate constraints; 3 = severe constraints; 4 = very severe constraints. Using GIS, I calculated the average of these values for each of the five states studied, which are shown in table 5. Based on these, I classify states into high soil workability constraint states (Gombe, FCT and Niger) and low constraint states (Kaduna, Kebbi).

Table 5. State Average Soil Workability Constraint

State	Average soil workability constraint score	H = high, L = low
Gombe	1.76	*H*
Kaduna	1.48	*L*
Kebbi	1.61	*L*
FCT	1.77	*H*
Niger	1.67	*H*

Source: Author's calculation based on Fischer et al. (2008).

Table 6. Descriptive Statistics by Farm Size and Onset Risk (Median for All Variables except Percentage Variables)

	Farm size in 2005		Onset risk	
	≥ 2ha	< 2ha	High	Low
Invested into draft animal (Oxen, work bull or ox-plow) (%)	15	8	17	3
Age	40	40	42	38
Gender (%)	17	26	19	25
Household size	10	9	10	8
# of working age family member	4	3	4	4
Primary education (%)	52	45	43	58
Secondary education (%)	30	28	28	32
Owned draft animal in (2005) (%)	21	10	24	4
Owned irrigation pump (2005) (%)	10	9	8	11
Distance to nearest town (km)	4	5	5	6
Fadama II participation	58	47	53	54
Household expenditure (US$ / month)	212	113	144	180
LGA average wage (US$ / day)	1.4	1.5	1.3	4.0
LGA average seed maize price (US cents / kg)	61	66	65	60
Farm size (2005)	4.0	1.0	2.0	1.8
Number of observations[a]	366	289	402	253

Source: Author.

[a]The number of observations are smaller for some variables due to missing observations.

Stratification and Descriptive Statistics

Using the estimated onset risks, I stratify states in two separate ways. In the first stratification, based on the long-term onset risk (table 1) in which I stratify states into high onset risk group (Gombe, Niger, Kebbi) and low onset risk group (FCT and Kaduna). In the second stratification, based on the short term fluctuations in onset risk (table 3), I stratify states into non-decreasing risk group (Gombe, Niger, Minna) and decreasing risk group (FCT and Kebbi).

Table 6 summarizes the key descriptive statistics of farmers with different farm sizes and onset risks. Characteristics of respondents are similar across different farm sizes and onset risks, except the ownership of some draft animal prior to project implementation in 2005, household expenditure and LGA average wage. Respondents with larger farm sizes spend almost twice more (US$ 212 per month per household) than those with smaller farm size, indicating their greater wealth, and are more likely to have owned draft animals in 2005 (21% compared to 10%). Respondents in high onset risk groups are more likely to have owned draft animal in 2005 (24%) compared to those with low onset risk (4%), but also face lower wages (US$1.3 / day, compared to US$4 / day), and cultivating slightly more land (2ha compared to 1.8ha). Wages are not significantly different between respondents with different farm sizes. The descriptive statistics indicate that ownership of draft animals may be correlated with the onset risks as I hypothesize, while its association with wages is somewhat ambiguous.

RESULTS

Results are shown in tables 7 through 10. Balancing test based on t-test (Rosenbaum and Rubin 1985) indicate that matching quality is good for both entire group and stratified groups (results not shown).

Table 7. First Stage in Propensity Score Matching

	Onset risk				Change in onset risk			
Dependent variable (= 1 if invested in 2006, = 0 otherwise)	High		Low		Non-decreasing		Decreasing	
	Coef	*z*	Coef	*z*	Coef	*z*	Coef	*z*
ΔE × age	.002	.17	.011	1.06	.002	.20	-.023*	-2.21
ΔE × gender (female = 1)	.612*	2.06	-.164	-.54	.548†	1.92	.273	1.08
ΔE × household size	.050†	1.73	.024	.97	.051*	2.06	.036	1.01
ΔE × working age	-.038	-.71	-.000	-.00	.004	.09	-.143*	-2.31
ΔE × primary education (yes = 1)	-.407	-1.40	.074	.28	-.171	-.53	.289	.88
ΔE × secondary education (yes = 1)	.258	.79	.137	.50	-.186	-.50	-.005	-.02
ΔE × area in 2005 (ha)	-.003	-.15	-.032	-.36	.013	.44	.197**	3.08
ΔE × draft animal in 2005 (yes = 1)	.364	1.60	.725	1.37	.513*	2.08	.094	.32
ΔE × pump in 2005 (yes = 1)	-.772	-1.44	-.075	-.23	-.498	-1.00	-.788†	-1.78
ΔE × distance in 2005 (km)	.009	1.19	.014	.97	-.004	-.31	.008	.35
ΔE × expenditure in 2005 (USD / month)	3.078	.93	1.360	.54	.850	.33	14.643**	3.74

	Onset risk				Change in onset risk			
Dependent variable	High		Low		Non-decreasing		Decreasing	
(= 1 if invested in 2006, = 0 otherwise)	Coef	*z*	Coef	*z*	Coef	*z*	Coef	*z*
ΔE × maize price in 2005 (cents / kg)	-.002	-.25	.003	.34	-.006	-.83	-.001	-.12
ΔE × State	Included		Included		Included		Included	
ΔE × variables × onset risk	Included		Included		Included		Included	
ΔE × variables × onset risk change	Included		Included		Included		Included	
ΔE × variables × rainfall risk	Included		Included		Included		Included	
ΔE × variables × rainfall risk change	Included		Included		Included		Included	
Intercept	Included		Included		Included		Included	
Pseudo R-square	.276		.204		.250		.247	
p-value (H_0: No overall significance)	.000		.000		.000		.000	
Number of observations	402		253		331		324	
Number of matched observations	346		247		283		313	

Source: Author.

** Significant at 1%; * Significant at 5%; † Significant at 10%.

Table 8. Average Treatment on the Treated (ATT) and Onset Risks[a]

	All	All (with LGA average wage)	Farm size in 2005 (LGA average wage excluded)				*p*-value (by farm size)
			≥ 3 ha	≥ 2 ha	< 3 ha	< 2 ha	
High	.182** (.048)	.281** (.062)	.354** (.084)		.205** (.062)		.154
	346	*207*	*116*		*209*		
	[2.7]	[3.0]	[3.1]		[1.8]		
				.309** (.056)		.167** (.054)	.068
				163		*140*	
				[5.5]		[2.0]	
Low	.062** (.021)	.073** (.025)			.068* (033)		.039
	247	*203*			*147*		
	[1.2]	[1.1]			[1.0]		
				.029 (.029)		.102* (.044)	.166
				96		*109*	
				[1.0]		[1.0]	
p-value (by onset risk)	.022	.002	.000	.000	.051	.351	

Source: Author. ** Significant at 1%; * Significant at 5%; † Significant at 10%

[a]Numbers in parentheses are corresponding standard error, italic numbers are corresponding matched sample size, numbers in brackets are corresponding MH bounds threshold values, and *p*-values at the last column and row indicate the statistical significance in difference between ATTs from different onset risk, or farm size. For example, the first *p*-value at the last column shows the significance between ATTs for farmers with farm size greater than or equal to 3 ha and those with farm size less than 3 ha in high risk regions.

Table 9. Average Treatment on the Treated (ATT) and Changes in Onset Risks[a]

	All	All (with LGA average wage)	Farm size in previous year (LGA average wage excluded)				*p*-value (by farm size)
			≥ 3 ha	≥ 2 ha	< 3 ha	< 2 ha	
Increase or no change	.215** (.046)	.295** (.047)	.452** (.078)		.114* (.048)		.000
	283	*198*	*105*		*160*		
	[3.2]	[6.9]	[6.2]		[1.2]		
				.277** (.072)		.122** (.047)	.071
				150		*117*	
				[2.5]		[1.1]	
Decrease	.105** (.036)	.094† (.048)	.000 (.000)		.163** (.056)		.004
	313	*218*	*54*		*199*		
	[1.4]	[1.0]	[1.0]		[1.5]		
				.044 (.031)		.135* (.062)	.189
				112		*136*	
				[1.0]		[1.4]	
p-value (by change in onset risk)	.060	.002	.000	.003	.506	.867	

Source: Author. ** Significant at 1%; * Significant at 5%; † Significant at 10%.

[a]Numbers in parentheses are corresponding standard error, italic numbers are corresponding matched sample size, numbers in brackets are corresponding MH bounds threshold values, and *p*-values at the last column and row indicate the statistical significance in difference between ATTs from different onset risk, or farm size.

Table 7 shows the determinants of propensity of farmer's project participation. Risk variables σ, δ, ζ, η in this article are constant within each state, and the number of states within each risk group is small (three at the most). As a result, many of the variables interacted with these risk variables cause perfect collinearity with state dummy variables and automatically dropped. When they are not dropped, they tend to capture not only the effects of risks but also state specific effects. I therefore only indicate that these variables are "included" in table 7. Their inclusions guarantee that coefficients shown in table 7 of other variables that are interacted only with ΔE are consistent. Besides, I de-mean all risk variables, so that these coefficients shown in table 7 can be interpreted as effects at the average risk levels.

Propensities are affected by factors differently based on the onset risk and its changes. In the high or non-decreasing onset risk groups, eligible female respondents with larger households were more likely to participate, possibly because female is generally more liquidity-constrained and per capita income is lower due to large household size. In non-decreasing onset risk group, eligible farmers who already had draft animals in 2005 were also more likely to participate. Various potential reasons explain this, as the projects provide financial support for a range of assets not only draft animals but also complementary assets to them such as plough, or milling machines. In decreasing onset risk group, eligible younger farmers with a smaller number of working age household members, greater farm size, no prior ownership of irrigation pump, and higher expenditure level were more likely to participate.

Table 10. Average Treatment on the Treated (ATT) and Changes in Rainfall Risks[a]

	All	All (with LGA average wage)	Farm size in previous year (LGA average wage excluded)				*p*-value (by farm size)
			≥ 3 ha	≥ 2 ha	< 3 ha	< 2 ha	
Increase or no change	.146** (.042)	.188** (.031)	.255* (.118)		.133** (.040)		.327
	364	*320*	*121*		*184*		
	[2.0]	[5.5]	[1.1]		[2.0]		
				.207** (.059)		.122** (.047)	.260
				190		*120*	
				[2.0]		[1.1]	
Decrease	.154** (.036)	.122 (.088)	.500* (.224)		.169** (.056)		.152
	229	*90*	*30*		*171*		
	[3.1]	[1.0]	[1.0]		[1.7]		
				.172* (.071)		.130* (.064)	.660
				73		*127*	
				[1.0]		[1.0]	
p-value (by change in onset risk)	.885	.479	.333	.705	.601	.920	

Source: Author. ** Significant at 1%; * Significant at 5%; † Significant at 10%.

[a]Numbers in parentheses are corresponding standard error, italic numbers are corresponding matched sample size, numbers in brackets are corresponding MH bounds threshold values, and *p*-values at the last column and row indicate the statistical significance in difference between ATTs from different onset risk, or farm size.

This is possibly because younger farmers may be more willing to adopt the use of improved productive assets, or are more liquidity-constrained due to smaller wealth accumulation than older farmers. Households with fewer working age members and larger farm size may have incentives to invest into some labor-saving productive assets such as milling machines, or irrigation pumps to irrigate larger areas. The positive effects of household expenditure in this group is somewhat puzzling. It is probably because the returns to various productive assets subsidized under the project sometimes depend on the access to other complementary inputs or services, payments for which cannot entirely be financed through the project.

In low onset risk group, impacts of these characteristics on participation were generally weak. I also ran the specifications including the wage variables and found similar results (not shown). Overall, propensity scores are affected by different factors across groups with different onset risk level and its changes, indicating potential heterogeneity in project impacts based on the onset risks.

Table 11. Impact of Project by Onset Risk and Soil Workability[a]

	Soil workability constraint		*p*-value (by soil workability)		Soil workability constraint		*p*-value (by soil workability)
	High	Low			High	Low	
High	.314** (.077)	.138** (.051)	.057	Increase or no change	.314** (.077)	.088* (.038)	.008
	158	*186*			*158*	*122*	
	[2.8]	[1.2]			[2.8]	[1.0]	
Low	.044† (.025)	.088* (.038)	.328	Decreasing	.044† (.025)	.138* (.051)	.098
	120	*122*			*120*	*186*	
	[1.0]	[1.0]			[1.0]	[1.2]	
p-value (by onset risk)	.001	.432			.001	.432	

Source: Author. ** Significant at 1%; * Significant at 5%; † Significant at 10%.

[a]Numbers in parentheses are corresponding standard error, italic numbers are corresponding matched sample size, numbers in brackets are corresponding MH bounds threshold values, and *p*-values at the last column and row indicate the statistical significance in difference between ATTs from different onset risk, or farm size. For example, the first *p*-value at the last column shows the significance between ATTs for farmers with farm size greater than or equal to 3 ha and those with farm size less than 3 ha in high risk regions.

Tables 8 and 9 show the estimated ATTs for groups with different onset risk and farm size. The second and the third columns show the estimated ATTs for all samples regardless of farm size, in which the third column shows the results when LGA average wage and its interaction terms are added as explanatory variables. In states with higher onset risk, the project raised the likelihood of farmers investing in draft animals by 18.2 percentage point, which was statistically significantly higher (p-value = .002) than 6.2 percentage points in states with lower onset risk. The findings are also similar when the LGA average wage is included in the set of explanatory variables.

The remaining columns in table 8 show the ATTs estimated for sub-groups of farmers differentiated based on the farm size in 2005 (pre-project year). I use 2ha and 3ha as thresholds as they are 50th and 75th percentile of farm size in the data, respectively. The estimations for these sub-groups are conducted excluding LGA average wage, as the sample size becomes too small. The effect of the onset risk becomes more substantial for farmers with larger farm size. Among farmers who cultivated 2ha or more in 2005, the effect of the project is 30.9 percentage points in higher onset risk group, which was statistically significant while the ATT is statistically insignificant in lower onset risk group. Among farmers who cultivated less than 2ha in 2005, the ATTs are 16.7 percentage points in higher onset risk group and 10.2 percentage points in low risk group, with their difference statistically insignificant (p = .351). Similar results are observed if 3ha is used as the farm size threshold instead of 2ha, where the differences in impacts diminishes from 35.4 percentage points to 13.7 percentage points (20.5 – 6.8). The results in table 8 therefore support both Hypotheses 1 and 2 suggesting that higher long-term onset risk raises the demand for draft animal, particularly among farmers with larger farm size.

Results of MH bounds test are shown in brackets in each table under corresponding result. The test assesses how the statistical significance of impacts change when the odds-ratio of project participation changes. I show the threshold values of such changes in odds-ratio where the statistical significance of impacts drops below 10%. For example, in table 8, the impact of 0.182 in high onset risk group remains statistically significant at 10% level even if the odds-ratios of the person's project participation change by 2.7 times due to hidden bias. The value for low onset risk group is 1.2. In Social Science, the rule of thumb is that if this threshold greater than 2 indicates that results are robust against hidden bias (Hu and Hibel 2014).

I also estimated similar impacts stratifying based on rainfall risk instead of onset risk. Results are qualitatively similar to table 8, suggesting that draft animal investments may also respond in a similar manner to rainfall risks. However, as is discussed below, the change in rainfall risk has much weaker effects.

Results in table 9 provide further evidence of the effects of onset risk. Among non-decreasing onset risk group, the project raised the likelihood of participants investing into draft animals by 21.5 percentage points, while it is 10.5 percentage points in states where onset risk decreased. These differences become statistically significant when LGA wage and interaction terms are also included as explanatory variables. The difference is even sharper among larger size farmers. The ATT is 45.2 percentage points compared to 0.0 percentage points (which are statistically insignificant) among farmers who cultivated 3 ha or more in 2005, and 27.7 percentage points for those who cultivated 2ha or more compared to 4.4 percentage points, which are both statistically significantly different across groups. The differences are statistically insignificant among smaller size farmers. The results in table 9 add stronger support to Hypotheses 1 and 2, by suggesting that not only long-term onset risk but its short term fluctuations also affects farmers' investment behaviors into draft animals.

Results in table 10 show similar analyses of effects of the change in rainfall risk, which are contrasting to table 9. No significant differences in effects are observed across groups experiencing different rainfall risk changes, even within the sub-groups differentiated by the farm size, although the effects of projects are statistically significantly positive in both groups. The gap between tables 9 and 10 suggests that draft animal investment is more responsive to a change in onset risk than the change in annual rainfall risk.

Results in table 11 further show that differences in impacts across states with different soil workability constraints are consistent with the hypotheses. Note that, because I stratify five states in four groups, most group has only one state. As a result, only the estimated impacts in low soil workability constraint group switch when I focus on onset risk change instead of onset risk level. Within states with high onset risks or non-decreasing onset risks, project impacts on draft animal investments are greater in states with high soil workability constraint (31.4 percentage points). In states with low onset risks or decreasing onset risks, differences based on soil workability constraints are less clear.

Results of MH bound tests in all tables generally suggest that stronger results observed in high / non-decreasing onset risk groups, larger farm size groups, and low soil workability groups discussed above are also more robust than the other groups. I use these sets of evidence to conclude that the main findings are robust against hidden biases.

Overall, results indicate that, not only longer-term onset risk, but also its short-term fluctuations have significant effects on the investment into draft animals. Moreover, the investment into draft animals responds more to the change in onset risk, than to a change in rainfall risk. This may be possibly because farmers can more easily recognize the change in onset days compared to the total rainfall of the year, when few of them presumably have access to rainfall data. Moreover, these effects are stronger for farmers with larger farm size, and in areas with lower soil workability which requires more farm power.

CONCLUSION

Farmers' investment into productive assets is often driven by their risk-mitigating motives. Agriculture in developing countries, in particular, is subject to not only the uncertainty in total rainfall, but also its timing. Analyzing the patterns of such timing uncertainty and its effect on farmers' investment behaviors can deepen our understandings of how different aspects of risks matter. Onset risk, the uncertainty at the beginning of the rainy season, is particularly important in that regard.

Long-term onset risk appears to vary significantly across locations. It is also associated with significant short-term fluctuations in northern and central Nigeria. Various methodologies lead to similar ranking of the locations by risks. For several locations, their short-term increase or decrease in onset risk within the periods can be identified and they are robust to the choice of threshold years.

I tested the hypotheses that the investment into draft animals is in part driven by farmers' motive for mitigating onset risks which could otherwise raise the cost of critical farm activities at the beginning of the rainy season. I find that farmers experiencing high or non-decreasing onset risks are more likely to use external capital injections to invest into draft animals. These effects are stronger for those with larger farm size and lower soil workability, both of which are associated with greater farm power needs.

Farmers' perceptions of onset risk may be affected both by the longer- and shorter- term trends. High and increasing onset risks may raise the importance of public support in appropriate productive assets investment such as draft animals. Although such public support may not be entirely pro-poor since larger-scale farmers may benefit more than small-scale farmers, improved insurance against onset risk can lead to generally more productive uses of resources on both farming and non-farming activities in rural areas and can benefit the poor as well in the long run. Close monitoring of onset risk may be valuable and can detect further source of risks for farmers even when rainfall risks are small. Therefore, in addition to providing effective risk mitigation support in high risk areas, informing farmers of the recent trends in onset dates variations and their potential effect on productivity may be beneficial.

APPENDIX A. SERIAL CORRELATION IN ONSET DATES

One way to test the auto-correlation in unbalanced, unequally-spaced data, as our onset date, is to use locally best invariant (LBI) test proposed by Baltagi and Wu (1999). Table 12 shows the Baltagi-Wu LBI statistics for all samples as well as samples from each region. Though the critical values for Baltagi-WU LBI test vary, generally other studies suggest that the Baltagi-WU LBI statistics exceeding 2 indicates the absence of autocorrelation. As in table 12, therefore, onset dates are not significantly autocorrelated.

Table 12. Test for Serial Correlation (Baltagi-Wu Statistics)[ab]

	No of obs	Baltagi-Wu LBI Statistics
All	224	2.215
North	97	2.019
Central	48	2.314
North and Central	145	2.096

Source: Author's calculation.
[a]North = Bauchi, Kaduna, Sokoto; Central = Abuja, Minna;
[b]Baltagi-Wu test is appropriate for testing serial correlation in unbalanced, unequally-spaced panel data. The Baltagi-Wu LBI statistics exceeding 2 generally indicates the absence of autocorrelation.

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THE IMPACT OF THE AFRICAN GROWTH AND OPPORTUNITY ACT (AGOA): AN EMPIRICAL ANALYSIS OF SUB-SAHARAN AFRICAN AGRICULTURAL EXPORTS TO THE UNITED STATES

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ABSTRACT

This study evaluates the impact of the 2000 African Growth and Opportunities Act (AGOA) on agricultural exports from Sub-Saharan African (SSA) countries to the United States.

A gravity model is estimated with panel data that include observations from 1990 to 2013 to capture trade flows both before and after the implementation of AGOA. The model is first estimated with fixed effects to account for differences among the 35 AGOA-eligible countries and then re-estimated using the Heckman sample selection model and the Poisson family of models to control for potential sample selection biases resulting from the presence of zero trade flows in the dependent variable.

The empirical results suggest that AGOA has no discernable effect on the value of agricultural exports nor does it appears to have led to an increase in the probability that there will be positive agricultural trade flows from SSA to the United Sates.

Keywords: AGOA, agriculture, SSA, United States, gravity model

JEL Codes: Q17, F13, F14, F15

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INTRODUCTION

Moyo (2010) has pointed out that about $1 trillion in foreign aid has been transferred to Sub-Saharan Africa (SSA) over the past fifty years to little avail. Economic growth has been slow across the continent with average annual per capita income in 2005 international dollars for the period 2008 to 2012 only about 9 percent higher than the average for 1981 to 1985 (authors' calculations based on data from World Bank, 2014). Moyo and others (see, for example, Okonjo-Iweala, 2007) have argued that promoting international trade represents a better strategy for growth and development than relying on foreign aid. While foreign aid is unlikely to disappear altogether, – members of the Organization for Economic Cooperation and Development (OECD) provided $126 billion in official development assistance in 2012 (OECD, 2013), about 25 percent of the aggregate GDPs of all low-income countries based on World Bank (2014) data – there does appear to be increased interest among both donors and recipients in increasing the role of trade in economic development. Since the 1970s, high-income countries have taken advantage of GATT/WTO waivers allowing them to violate the Most Favored Nation (MFN) requirement by granting preferential access to their markets to developing countries under the Generalized System of Preferences (GSP; VanGrasstek, 2013). In 2000, the United States adopted the African Growth and Opportunity Act (AGOA) extending trade preferences to eligible countries in SSA and in 2001, the European Union launched an initiative named "Everything but Arms" granting duty-free access for exports of all goods other than arms from 49 least-developed countries including 33 in SSA (ITA, 2013; European Commission, 2013). In addition, OECD countries have recently undertaken a program referred to as "Aid for Trade" which aims to encourage trade by supporting the development of infrastructure and institutional frameworks in developing countries (OECD, 2011).

The intent of such initiatives is to encourage export growth which, in turn, is expected to lead to broader economic growth and development. The actual impacts of trade preferences have not always lived up to these expectations, however. Jones and Williams (2013) note that trade preferences may benefit traditional export industries in developing countries discouraging economic diversification. They also point to potential negative impacts in other developing countries not included in the preferential arrangements. Brenton and Ikezuki (2005) examine agricultural trade preferences finding that because of limitations in product coverage, issues surrounding rules of origin and ambiguities about the length of time the preferences will remain in effect, such preferential arrangements have had limited economic impacts in developing countries. On the other hand, there is empirical evidence that trade preferences can be of benefit to particular industries or countries. Condon and Stern (2011) review 21 studies of the effects of AGOA on SSA exports noting that four of the studies find significant impacts for apparel. Most studies of AGOA focus on the overall impact of this program with limited attention to its specific effects on agricultural trade. The purpose of this study is to evaluate the impact of AGOA on SSA agricultural exports to the United States using a gravity equation estimated with panel data for 35 AGOA-eligible SSA countries from 1990 to 2013. Most previous studies of AGOA have been based on shorter time periods and may not have captured the full effects of the program because it often takes time for exporters to adjust to new terms of trade.

Gravity models are widely used in empirical studies of international trade. The use of this analytical framework raises some important technical issues that may affect the reliability of the parameter estimates. In particular, the panel data used in this and many other studies include a large number of zero values for the dependent variable which cause special problems when the gravity equation is estimated in logarithms as is usually the case. Standard statistical software often eliminates the zero values so that the estimated parameters are actually based on a truncated sample. The test for the influence of AGOA on SSA agricultural exports is based on a dummy variable for the years AGOA has been in effect and the statistical significance of the coefficient for this variable could differ between models based on the truncated sample and those that include the zero-value observations. For this study, the problem of zero values is addressed using the Heckman sample selection model and the Poisson family of models (see Martin and Pham, 2013 and Philippidis et al., 2013). The models estimated for this study include corrections for heteroscedasticity with fixed effects to account for country characteristics. The time series data are tested and found to be stationary on the basis of conventional unit-root tests. The econometric analyses are designed to insure that the results are as reliable as possible given the available data.

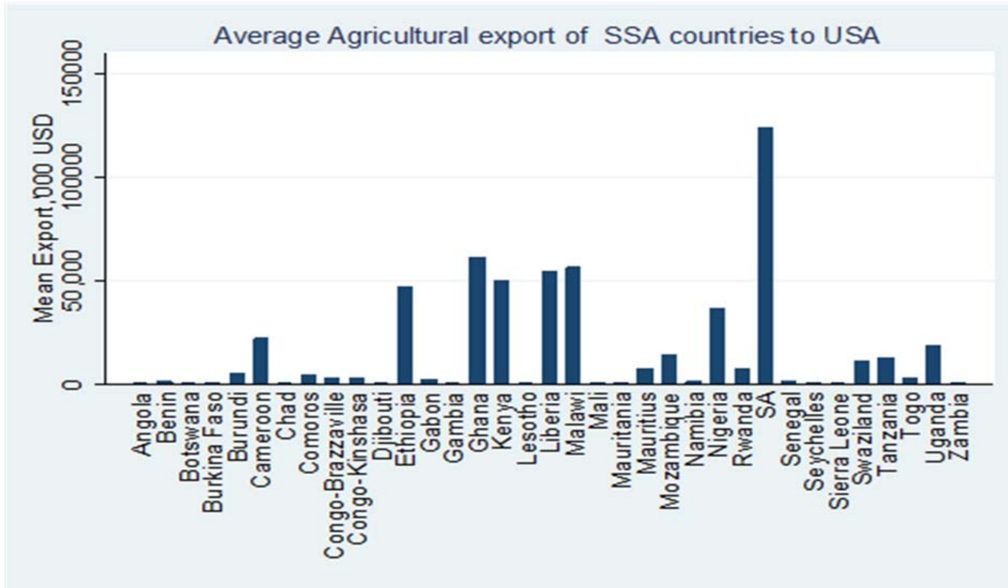
International trade is an important part of SSA economies with the value of exports in 2013 equal to about 34% of the region’s aggregate GDP (World Bank, 2014). Primary commodities make up the bulk of these exports and recent favorable commodity prices have contributed to significant economic growth across the region (World Bank, 2013). Although petroleum and other minerals account for the majority of SSA exports (about 58 percent of total exports in 2012), agricultural commodities such as cocoa, coffee, tree nuts, rubber, fruits, vegetables, and cotton are of great importance particularly in countries without significant oil or mineral resources (United Nations, 2013). In many SSA countries, agriculture is still the most important economic sector in terms of employment and agricultural growth and development is frequently the most effective way to raise living standards. These factors suggest that efforts to promote agricultural exports could contribute significantly to broad-based development in the region. In addition to developing quantitative measures of the effects of AGOA on SSA agricultural exports, this study also identifies potential modifications that might improve the effectiveness of the program. In the next section, background on trade between the United States and SSA, a detailed description of AGOA provisions and a short review of the relevant literature are presented. The analytical approach, data and econometric issues are discussed in the third section which is followed by presentation and discussion of the results. The final section sets out the overall conclusions and a discussion of the policy implications of the analysis.

The African Growth and Opportunity Act

Most countries in SSA were colonies of various European powers at some point in their histories. One motivation for the colonization of Africa was to secure supplies of raw materials for European industry. Current trade patterns reflect this colonial legacy in that SSA exports are dominated by primary commodities sold historically to the highly industrialized economies of Western Europe and North America and more recently to rising industrial powers in Asia. Over half of all exports consist of mineral fuels (coal, petroleum, natural gas and related commodities) with agricultural commodities the next largest group. On the import side, machinery and transport equipment constitute the largest category amounting to $120 billion in 2012, about 31 percent of total merchandise imports in SSA (United Nations, 2013). In recent years, trade with China and other Asian countries has increased dramatically. In 1990, almost 88 percent of SSA exports were destined for the European Union (EU) and the United States (IMF, 2007) but by 2012 the share of these countries was down to about 40 percent (United Nations, 2013). China's share of SSA exports increased from about 5 percent in 2000 to over 16 percent in 2012 and East Asian countries now account for about 20 percent of SSA imports up from 11 percent in 2000 (United Nations, 2013).

SSA agricultural exports are made up primarily of classic export crops such as cocoa, coffee, rubber, and a wide range of tropical products. The ten leading agricultural export commodities made up 78 percent of total agricultural exports in 2011 (United Nations, 2013). Export concentrations are even more dramatic in individual countries. In 2011, the proportions of total agricultural exports accounted for by a single commodity reached 97 percent in Guinea-Bissau (cashew nuts), 87 percent in Liberia (rubber), 80 percent in Ghana (cocoa) and 76 percent in Burundi (coffee; FAOSTAT, 2014). Export concentrations for general merchandise trade are also quite high, particularly in countries with large endowments of petroleum and other mineral resources. The World Bank (2013) notes that petroleum exports made up 97 and 85 percent of total merchandise exports in 2011 for Angola and Nigeria respectively. In countries with limited mineral resources, a small number of agricultural commodities may account for a large share of the country's export revenues. In Côte d'Ivoire, for example, exports of coffee, cocoa, rubber, fruits and vegetables represented almost 40 percent of total merchandise exports in 2011 (FAOSTAT, 2014). While the United States is generally an important trading partner for SSA, purchasing about 14 percent of total SSA merchandise exports (United Nations, 2013), U.S. imports of agricultural goods from the region have remained small representing less than 2 percent of total U.S. agricultural imports in 2013 (FAS/GATS, 2014). From the point of view of the SSA countries, the volume of agricultural exports to the United States represents about 5 percent of total SSA agricultural exports, most of which are destined for Europe (35 percent) or Asia (33 percent; United Nations, 2013).

According to Figure 1, the main agricultural exporters to the United States are South Africa, Ghana, Malawi, Liberia, Kenya, Ethiopia, and Nigeria. In addition, based on data from FAS/GATS (2014), the share of agricultural exports in total exports from SSA countries to the United States between 2000 and 2011 varies widely from zero percent for large oil exporting countries such as Angola, Nigeria and Gabon, to more than 95 percent in Liberia, 82 percent in Kenya, and 96 percent in Comoros. On average, agricultural exports form a very small fraction of SSA's total exports to the United States, about 2% between 1996 to 1999 and a half percentage point lower over the period 2000-2011. Agricultural exports in high performing economies such as South Africa, Ghana and Mauritius, account for less than 5% of total exports to the United States although South Africa and Ghana are the first and second largest exporters of agricultural products from the AGOA countries to the United States. Some countries show significant increases in the agricultural share of exports to the United States from about 63% during the period 1996-1999 to 96% in 2000-2011 in Liberia, 1% to 23% in Malawi, 54% to 82% in Kenya, 7% to 38% in Uganda, and 28% to 63% in Togo. The value of AGOA agricultural exports to the United States since enactment of AGOA has grown by about 178 percent from $719 million in 2000 to $1,999 million in 2013 (FAS/GATS, 2014).



Source: Own calculation based on USITC agricultural import data.

Figure 1. Average Annual Agricultural exports of SSA countries to the United States (2000-2011).

AGOA was adopted and signed into law as Title 1 of The Trade and Development Act of the United States in May 2000 (USTR, 2014). The main objective of this act is to promote economic growth in Africa by encouraging African exports to the United States through reducing or eliminating tariffs on African goods. AGOA also includes provisions designed to facilitate investment flows between the United States and eligible SSA countries and to foster the integration of African economies with the world economy (USTR, 2014). Unlike regional trade agreements that include reciprocal reductions in trade barriers, AGOA and other preferential arrangements do not require that the beneficiaries reduce their trade barriers on goods imported from the country granting the preferences. As noted previously, an early preferential agreement is the GSP which dates from the 1970s. Preferential treatment under the GSP is usually accorded to all developing countries. In recent years, numerous non-reciprocal programs that target specific countries or regions have been put in place (Hoekman, 2005).

Initially, 34 SSA countries were included in the list of AGOA beneficiaries and currently 41 of the 48 SSA countries are eligible for the trade preferences. Each year the U.S. government decides which SSA countries are eligible for AGOA preferences. The eligibility criteria include determination that beneficiary countries are working to develop market economies, to assure respect for human rights, and to promote the rule of law and good governance (AGOA, 2014). Eligibility can be withdrawn if there are adverse changes in the local political environment. AGOA adds about 1,800 tariff lines to the 5,000 lines already covered under GSP. (AGOA, 2014b). Schneidman and Lewis (2012) note that most of the tariff reduction under AGOA is for nonagricultural products, mostly textiles and apparel, petroleum, minerals and precious stones. 81 percent of U.S. imports from Africa consist of petroleum and minerals compared with just under 7 percent for agricultural commodities

(United Nations, 2013). AGOA was first set to expire in 2008, but in 2004 it was extended to 2015 (USTR, 2014) and further extension of this agreement was a prominent topic at the 2014 summit meeting between African leaders and the U.S. administration (Mauldin, 2014). Many African leaders have argued that there is a need to extend AGOA beyond 2015 and this sentiment has been echoed by both African and U.S. companies (AGOA, 2014c).

Many studies of the impacts of AGOA on African exports have focused on aggregate merchandise trade and most empirical evaluations have been based on data prior to 2006 (Mattoo, Roy and Subramanian, 2002). Nouve (2005) estimated a dynamic gravity model using panel data for 46 countries from 1996 to 2004 finding that AGOA has had a statistically significant impact on SSA exports to the United States. The specific economic sector that has received the most attention from analysts is textiles and apparel (Olarreaga and Özden, 2005; Lall, 2005; Collier and Venables, 2007; Tadesse and Fisseya, 2007; Mueller 2008; Condon and Stern, 2011). Collier and Venables (2007) and Tadesse and Fisseya (2007) investigate the impact of AGOA on apparel exports using gravity models finding significant positive effects. Other authors have examined both aggregate merchandise exports and exports from the textile and apparel sector. Olarreaga and Özden (2005), Frazer and Van Biesebroeck (2007) and Condon and Stern (2011) all find that AGOA has had positive impacts on SSA merchandise exports but these effects have been particularly pronounced for apparel. Brenton and Hoppe (2006) and USTR (2010 and 2011) found evidence of significant increases in total exports under AGOA but noted that petroleum and apparel products made up the bulk of SSA exports to the United States. They argued that the impact of AGOA has been reduced by the remaining barriers to agricultural and textile exports.

In contrast to these studies, Mueller (2008), Seyoum (2007) and Zappile (2011) find that AGOA has had no significant impact on general merchandise trade between SSA and the United States. Mueller (2008) estimated two versions of a gravity model, the first focusing on all U.S. imports under AGOA except petroleum while the second evaluated the impact of AGOA on apparel exports. The models were estimated using panel data for the period 2000 to 2004 and including countries eligible for AGOA preferences during that period. The results of the first model included a negative but statistically insignificant impact on non-oil trade for the eligible countries. Likewise, the impact of AGOA on apparel exports was found to be statistically insignificant in the second model. Seyoum (2007) used an ARIMA model for a similar time period finding that AGOA has had a small positive but statistically insignificant impact on total SSA exports to the United States. Zappile (2011) used a gravity model to assess the effects of AGOA finding that it has had no statistically significant effect on either aggregate merchandise or textile exports from SSA to the United States.

A few authors have focused on specific regions or countries within SSA. Remy and Applegate (2008) use a computable general equilibrium (CGE) model to simulate the effects of AGOA on the West African Economic and Monetary Union (WAEMU). The CGE model allows the authors to estimate macroeconomic impacts in addition to the effects on particular economic sectors. They find that AGOA has had strong positive effects not only on trade but also on such macroeconomic variables as economic growth, investments, savings and government revenues. Lall (2005) analyzed the impact of AGOA on apparel exports from Lesotho noting that AGOA has helped Lesotho become the largest SSA apparel exporter to the United States on the basis of substantial foreign direct investment from Asia. Other studies focusing on particular countries include those of Rolfe and Woodward (2005) on Kenya and Akanji (2007) on Nigeria.

Only a few empirical studies have examined the effects of AGOA on agricultural trade (Nouve, 2005). Asmah and Taiwo (2010) document the small role of agricultural commodities in U.S. trade with SSA finding that annual agricultural imports under AGOA amount to only $1.2 to $1.4 billion and about 85 percent of these imports come from South Africa. Nouve and Staatz (2003) examined U.S. agricultural imports from 46 SSA countries over the period 2000 to 2003 using three gravity equations, the first for the full sample of 46 countries, the second for 27 countries that registered significant agricultural exports and the third for the eight largest agricultural exporters. All of these models were estimated both with and without South Africa on the grounds that this country might distort the overall effects of AGOA because of its economic weight. Coefficients for all of the AGOA dummy variables across the estimated equations were positive but none was significantly different from zero. The authors concluded that AGOA has had no observable impact on agricultural trade in part because the program was still relatively new when their study was conducted. Frazer and Van Biesebroeck (2007) included agriculture in their broader study of AGOA over the period 2000 to 2006. They found that AGOA has had a positive and significant impact on AGOA-eligible agricultural exports as well as on general merchandise and apparel exports.

The results of the studies of the impact of AGOA on agricultural exports from SSA to the United States are mixed making it difficult to draw reliable conclusions about the effectiveness of this program. Some of the studies relied on data from relatively short time periods and one of the purposes of the present research is to determine whether basing the analysis on a longer period will change the results reported by these authors. In addition, the studies based on gravity models generally did not explicitly address the problem of missing values for the dependent variables. The specific methods employed to address this and other statistical problems are described in the following section.

Analytical Approach

The traditional gravity model draws on an analogy with Newton's Law of Gravitation which explains the gravitational attraction between objects as a function of their mass and the distance between them**.** An historical review of how the gravity equation is used in international trade can be found in Anderson (1979, 2011) and Brakman and van Bergeijk (2010). Initially, the gravity equation was an ad hoc specification with little link to a particular theoretical model. Anderson (1979, 2011), Anderson and van Wincoop (2003) and others have developed theoretical models from which the gravity equation can be derived (see Feenstra, 2004). In its simplest form, a measure of bilateral trade is regressed on income in the two countries with the expectation that the larger the two countries' incomes, the greater the attraction between them and the greater will be the volume of bilateral trade (Feenstra 2004, p. 145-6). In addition to the income variables, gravity equations often include variables such as geographic distance or linguistic similarities that may discourage or encourage trade. In many cases, analysts assume that prices are equalized between countries in each trading pair. Feenstra (2004) describes several studies based on models of this nature. Anderson and Van Wincoop (2003), among others, develop a more realistic gravity model in which prices in the two countries differ as a result of border effects, including transportation costs, trade barriers and other costs of doing business. With different prices, the simple gravity equation is no longer appropriate.

Anderson and Van Wincoop (2003) derive a theoretically consistent gravity model that includes price indices which they refer to as “multilateral resistance variables” (p. 176). These variables depend on the level of the trade barriers between a given country and all of its trading partners. Their incorporation into the gravity equation raises some problems in the statistical estimation of the relationships. Feenstra suggests that such problems can be overcome by using panel data to estimate the equation with fixed effects. Country-specific fixed effects can be thought to capture the impact of the unobserved multilateral resistance variables. Feenstra (2004) shows that the gravity equation is consistent with various assumptions about market structure as long as countries are not all producing identical goods (p. 167). He points to various analysts who have derived gravity equations from Ricardian, Heckscher-Ohlin and monopolistic competition models formulated so as to insure that countries are specialized in different goods. Although the original gravity model was used to explain bilateral trade among sets of countries, the review of the literature on AGOA in the preceding section of this paper shows that this approach has been used extensively to analyze unilateral trade flows such as those from SSA to the United States.

The basic empirical model for trade between two countries (i and j) takes the form of equation 1. Goods supplied at origin i are attracted to destination j according to the economic weights of the two countries as measured by GDP (Y_i and Y_j), but the potential flow is reduced by the distance between them D_{ij}. A simple form of the gravity equation is:

$$T_{ij} = G\frac{Y_i^{\beta_1} Y_j^{\beta_2} Z_{ij}^{\beta_3}}{D_{ij}^{\beta_4}} \tag{1}$$

where T_{ij} is the trade flow from i to j and Y is the economic mass of the importing and exporting countries as measured by GDP or GDP per capita. D_{ij} is the physical distance between country i and j and Z_{ij} represents other characteristics affecting bilateral trade such as a common language, common border, colonial ties, regional trade agreements, or trade barriers. G is a constant intercept.

The traditional gravity equation is usually rewritten in a log-linear form to estimate the vector of β:

$$\ln T_{ij} = \beta_0 + \beta_1 \ln Y_i + \beta_2 \ln Y_j + \beta_3 Z_{ij} - \beta_4 D_{ij} + \varepsilon_{ij} \tag{2}$$

β_0 is a constant intercept common to all trading countries and ε_{ij} is an error term. Including fixed country and year effects, the model can be presented in a log-linear specification:

$$\ln T_{ijt} = \beta_0 + \omega_t + \omega_{ij} + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 Z_{ij} - \beta_4 D_{ij} + \varepsilon_{ijt} \tag{3}$$

where ω_{ij} represents a fixed effect for country pairs that is common to all years and which captures country heterogeneity, and ω_t is a time fixed effect common to all countries, but specific to each year t.

The analytical model for this study is represented in a log-linear specification:

$$\ln T_{ijt} = \beta_0 + \omega_t + \omega_{ij} + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 Z_{it} + \beta_4 AGOA + \ln \varepsilon_{ijt} \quad (4)$$

where T_{ijt} is the export values of eligible agricultural commodities under the AGOA agreement from SSA i to the United States in a year t, i represents exporting SSA countries, $j = 1$ representing the importing country, the United States, and t is the year .The export values included in the data are only for eligible commodities under the AGOA agreement so any SSA agricultural exports to the United States that are outside the list of eligible goods under AGOA are excluded. Y_{it} and Y_{jt} are GDP for SSA countries and the United States at time t respectively. We also included the GDP per capita of the SSA countries to capture the impact of income growth on the value of agricultural exports. $AGOA$ is a dummy variable with a value of 0 for years prior to the implementation of the AGOA provisions for a given country (1990-1999) and 1 for years following its implementation (2000-2013). ε_{ijt} is assumed to be normally distributed with zero mean and constant variance for all observations. It is also assumed that the disturbances are pairwise uncorrelated. ω_{ij} represents a fixed effect for country pairs that is common to all years and which captures country heterogeneity, We assume the time fixed effect common to all countries but specific to each year t, ω_t, is zero since this effect is captured in the AGOA dummy variable. The distance variable is omitted since the distance between the exporting SSA country and the United States is fixed over time and is captured by the country fixed effects. Equation (4) can be estimated by nonlinear or linear ordinary least squares (OLS) with fixed effects as suggested by Anderson and van Wincoop (2003) and Feenstra (2004). Note that Equation (4) is essentially an export supply equation.

Zero or missing observations are quite common in bilateral/unilateral trade flows particularly for agricultural commodities. In the data set used for this study, 13 % of the dependent variable observations are zero. Common approaches for dealing with zero trade flows include truncating the sample by dropping the zero values, systematically adding a small positive number to all trade observations so that the log linear transformation is defined, and estimating the model in levels (i.e., in linear or non-log form). Since zero trade flows are usually not randomly distributed, truncating the observations may lead to biased and inefficient estimates (Burger et.al, 2009; Heckman, 1979; Xiong and Beghin, 2011). Systematically adding a small positive number by itself is problematic since there is no theoretical or empirical justification for such a procedure, and it can distort the estimates (Linders and de Groot, 2006; Flowerdew and Aitkin, 1982; Xiong and Beghin, 2011). This study will address the problem of zero trade flows by estimating two alternative gravity model approaches using the Heckman sample selection model (Heckman 1979; Hoffmann and Kassouf, 2005) and the Poisson Family specification of the gravity model (Santos Silva and Tenreyro, 2006; Burger et.al, 2009; Xiong and Beghin,2011). The problem of zero trade flows has also been addressed in their analysis of trade among 158 countries by Helpman, Melitz and Rubinstein (2008).

The Heckman Selection Model

The Heckman gravity econometric model retains the log linear transformation and treats zero trade values as censored observations. This approach involves estimating a Probit model in which the dependent variable is a [1, 0] indicator of whether or not a given observation is non-zero. The Heckman sample gravity selection model is based on both censored variables (selection equation 5) and uncensored variables (outcome equation 6):

$$\ell^*_{ij} = \theta' X_i + u_{ij} \tag{5}$$

where ℓ^*_{ij} is a latent variable that shows if bilateral, in this case unilateral, trade between SSA countries i and j, occurred. ℓ_{ij} is not observed but we do observe if countries trade or not, such that $\ell_{ij} = 1$ if $\ell^*{}_{ij} > 0$; $\ell_{ij} = 0$ if $\ell^*{}_{ij} \leq 0$ and $\ln T_{ij} = \ln T^*{}_{ij}$ if $\ln T^*_{ij} > 0$ and $\ln T_{ij}$ is not observed if $\ell^*{}_{ij} \leq 0$. θ' is a vector of parameters to be estimated for the explanatory variables in the selection equation. For ease of exposition, the time subscript has been dropped from these and later equations. The outcome equation based on uncensored observations is written:

$$\ln T^*_{ij} = \beta' X_i + \varepsilon_{ij} \tag{6}$$

$\ln T^*_{ij}$ is the logarithm of the volume of unilateral trade as defined in equations 1 to 4. $\ln T_{ij} = \ln T^*_{ij}$ if $\ell^*{}_{ij} > 0$. u_{ij} is the error term associated with the selection process. ε_{ij} is the error term of the outcome equation. X_i is a vector of variables that affect $\ln T^*_{ij}$. The errors u_{ij} and ε_{ij} have a bivariate normal distribution with zero means and standard errors of σ_u and σ_ε . The most popular way to correct for selection bias is the two stage Heckman selection estimation that introduces in the specification the inverse of the "Mills ratio" (Heckman 1979). The Mills ratio is the ratio of the probability density function to the cumulative distribution function. The two-step procedure first estimates the bivariate selection equation using a Probit model and generates the inverse of the Mills ratio $\lambda(\pi_j)$ [1]. Then the main model, which is the outcome equation, is estimated with OLS, including a measure of the probability of being in the sample, derived from the Probit estimates. Greene (2003) and Hoffmann and Kassouf (2005) show that:

$$E[T_{ij}^* \mid \ell_{ij} = 1] = \beta' X_i + \rho \sigma_\varepsilon \lambda_i(\pi_j) \tag{6a}$$

Due to the correlation between X_i and $\lambda(\pi_j)$, OLS regression on $\ln T_{ij}^*$ without the term $\lambda(\pi_j)$ would produce an inconsistent estimator of β (Hoffmann and Kassouf 2005). The empirical version of equation (5) becomes:

$$\ell^*_{ij} = \theta_0 + \gamma_{ij} + \theta_1 \ln Y_{it} + \theta_2 \ln Y_{jt} + \theta_3 Z_{it} + \theta_4 AGOA_{it} + u_{ij} \tag{5a}$$

And the outcome-equation 6:

$$\ln T_{ij}^* = \beta_0 + \alpha_{ij} + \beta_1 \ln Y_{it} + \beta_2 \ln Y_{jt} + \beta_3 Z_{it} + \beta_4 AGOA_{it} + \varepsilon_{ij} \tag{6b}$$

The variable $\lambda(\alpha_j)$ is then included as an additional regressor, allowing the parameters of the outcome equation (6b) to be consistently estimated by OLS (Greene 2003; Hoffmann and Kassouf 2005). ρ shows the correlation between the error terms of the selection and the outcome equation $Corr(u_{iu}, \varepsilon_{iu})$ in equations 5a and 6a.

Poisson Family Regressions

Since the Heckman gravity model adopts the same log-linear specification as the conventional model, it is still subject to heteroscedasticity. This implies that $E(\ln Y) \neq \ln E(Y)$ (Santos Silva and Tenreyro, 2006). A recent study by Martin and Pham (2013) noted that: "The Heckman sample-selection estimators-whether in two-step or maximum likelihood-gave very poor results when estimated for a single equation with the same variables in the selection and estimation equations" (p. 41).

Santos-Silva and Tenreyro (2006) recommend using a Poisson Pseudo Maximum-Likelihood (PPML) estimator with the dependent variable in levels and the independent variables in logs. They show that the PPML consistently estimates the gravity equation and is robust to

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[1] $\lambda(\pi_j) = \dfrac{\phi(\ell_{ij} = \theta' X_i + u_i / \sigma_j)}{\Phi(\ell_{ij} = \theta' X_i + u_i / \sigma_j)}$. Where ϕ is the standard normal density function and Φ is the cumulative standard normal distribution function.

different patterns of heteroskedasticity and measurement error. Westerlund and Wilhelmsson (2009) also suggested that the Poisson fixed effects estimation can overcome the problem of zero trade. The Poisson family of models originally derives from the analysis of count data. In the presence of zero bilateral trade flows and heteroskedastic error terms resulting from Jensen's inequality, the gravity model is estimated consistently with PPML (Santos Silva and Tenreyro, 2006). We follow the specification of Burger et al. (2009) with the dependent variable in levels and the independent in logs.

The observed volume of trade, T_{ij} between countries i and j in period t has a Poisson distribution with a conditional mean (μ) that is a function of the independent variables (equation 1). T_{ij} is assumed to have a non-negative integer value so that it ensures that T_{ij} is zero or positive and has the probability mass function of:

$$\Pr[T_{ij}] = \frac{Exp(-\mu_{ij})\mu_{ij}^{T_{ij}}}{T_{ij}}, \text{ where } T_{ij} = 0,1 \tag{7}$$

The conditional mean μ_{ij} becomes:

$$\mu_{ij} = Exp(\alpha_0 + \beta' X_{ij} + \eta_i + \tau_i) \tag{8}$$

X_{ij} is a vector of explanatory variables defined previously and β is the corresponding parameter vector for X . η_i and τ_i are effects specific to the exporting and importing countries respectively.

The Poisson model requires the equidispersion property, that is, the conditional variance must be equal to the conditional mean (Cameron & Trivedi, 2010). This equidispersion property is commonly violated because the dependent variable of bilateral trade flows is often overdispersed, implying that the conditional variance exceeds the conditional mean. The presence of overdispersion might result in inefficient estimation. A negative binomial (NB) model is frequently employed to correct for overdispersion (Burger et al., 2009).

The probability mass function of the negative binomial distribution (NB) is defined as

$$\Pr[T_{ij}] = \frac{\Gamma(T_{ij} + \alpha^{-1})}{T_{ij}!\Gamma(\alpha^{-1})} \left(\frac{\alpha^{-1}}{\alpha^{-1} + \mu_{ij}} \right)^{\alpha^{-1}} \left(\frac{\mu_{ij}}{\alpha^{-1} + \mu_{ij}} \right)^{T_{ij}} \tag{9}$$

Γ is the gamma function, and α is a parameter that determines the degree of dispersion in predictions. According to Burger et al. (2009), the larger α is, the larger the degree of over dispersion in the data. A likelihood ratio test of α can be used to test whether the negative binomial distribution is preferred over the Poisson distribution (Cameron and Trivedi, 2010). If α is approximately zero, the NB regression model reduces to the Poisson regression model.

Zero Inflated Poisson (ZIP) and Zero Inflated Negative Binomial (ZINB) models are used if the number of observed zero values exceeds the number of zeros predicted by the PPML or NB distributions (Burger et al., 2009). The zero inflated Poisson regression consists of two parts, equations 10 and 11. The first part of the zero-inflated model is a logit (or probit) regression of the probability that there is no bilateral trade at all. The second part is a Poisson regression (eqn. 11) of the probability of each count for the group that has a non-zero probability or interaction intensity other than zero. The probability mass functions of the first part and second part of the zero inflated Poisson (ZIP) model are described in Eqns. (10) and (11), respectively.

$$\Pr[T_{ij}] = \psi_{ij} + (1-\psi_{ij})\exp(-\mu_{ij}) \text{ , if } T_{ij} = 0 \tag{10}$$

$$\Pr[T_{ij}] = (1-\psi_{ij})\frac{\exp(-\mu_{ij})\mu_{ij}^{T_{ij}}}{T_{ij}!} \text{ , if } T_{ij} \succ 0 \tag{11}$$

ψ_{ij} is the proportion of zero trade observations in the study sample, $0 \le \psi_{ij} \le 1$. If $\psi_{ij} = 0$, the ZIP model reduces to the Poisson model.

In the presence of both overdispersion and zero inflated problems in the study sample, a ZINB model can be defined in a similar fashion as the ZIP model:

$$\Pr[T_{ij}] = \psi_{ij} + (1-\psi_{ij})\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_{ij}}\right)^{\alpha^{-1}} \text{ , if } T_{ij} = 0 \tag{12}$$

$$\Pr[T_{ij}] = (1-\psi_{ij})\frac{\Gamma(T_{ij}+\alpha^{-1})}{T_{ij}!\Gamma(\alpha^{-1})}\left(\frac{\alpha^{-1}}{\alpha^{-1}+\mu_{ij}}\right)^{\alpha^{-1}}\left(\frac{\mu_{ij}}{\alpha^{-1}+\mu_{ij}}\right)^{T_{ij}} \text{ , if } T_{ij} \succ 0 \tag{13}$$

For both ZIP and ZINB regression models, the Vuong statistic (Vuong, 1989) was employed to test if the zero-inflated model is favored against its non-zero inflated counterpart by evaluating if significant evidence for excessive zero counts exists. The likelihood ratio (LR) test of over dispersion is also used to test whether the negative binomial specification or the Poisson specification is preferred (Burger et.al 2009). The Vuong statistic follows a standard normal distribution with large positive values favoring the ZIP/ZINB model and large negative values favoring the PPML/NB model (Cameron & Trivedi, 2010).

RESULTS

The gravity equation was estimated using panel data on U.S. agricultural imports from 35 SSA countries that have been AGOA-eligible throughout the period[2]. The panel includes years prior to the adoption of AGOA (1990-1999) as well as years following its implementation (2000-2013). U.S. agricultural import statistics from the individual SSA countries were obtained from FAS/GATS (2014) and USDC (2013). Unilateral exports from SSA country i to the United States j are measured as the aggregate of all agricultural exports to the United States from that country under the AGOA product category. U.S. import price indices (United States Bureau of Labor Statistics, 2014) are used to deflate agricultural import values. GDP and GDP per capita data are from the World Bank's world development indicators (WDI, 2014) and are in constant 2005 U.S. dollars.

Table 1. OLS Regression Results

	Coefficient
GDP- SSA	0.938^{***} (0.061)
GDP- US	1.301 (1.004)
GDPK- SSA	-0.826^{***} (0.072)
AGOA	-0.604 (0.377)
_cons	-15.61 (16.10)

Standard errors in parentheses $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; R^2=0.25; N=727

Table 2. Individual Country Fixed Effect using Least Squares Dummy Variable model

	Coefficient	Country	Coefficient
GDP- SSA	4.434^{***} (0.781)	Lesotho	12.51^{***}(1.599)
GDP- US	-3.266^{**}(1.000)	Liberia	18.39^{***}(1.299)
GDPK- SSA	-3.401^{***}(0.899)	Malawi	12.65^{***}(0.665)
AGOA	-0.299(0.203)	Mali	7.057^{***}(0.525)
_cons	34.92^{*}(14.45)	Mauritania	10.26^{***}(1.364)
Benin	7.477^{***}(0.799)	Mauritius	17.41^{***}(2.035)
Botswana	10.98^{***}(1.812)	Mozambique	8.831^{***}(0.707)
Burkina Faso	6.812^{***}(0.599)	Namibia	12.50^{***}(1.711)
Burundi	12.38^{***}(0.876)	Nigeria	0.341 (1.785)
Cameroon	8.731^{***}(0.293)	Rwanda	11.58^{***}(0.702)
Chad	6.651^{***}(0.811)	South Africa (SA)	6.986^{***}(0.465)
Comoros	22.17^{***}(2.523)	Senegal	22.82^{***}(4.213)

[2] The list of 35 eligible SSA countries are displayed in Table 2 along their fixed effect estimates.

Congo (Brazzaville)	12.88***(1.204)	Seychelles	11.28***(0.980)
Congo (Kinshasa)	3.117*(1.219)	Sierra Leone	4.201***(0.902)
Djibouti	18.18***(2.491)	Swaziland	19.02***(2.058)
Ethiopia	4.952**(1.550)	Tanzania	5.853***(0.927)
Gabon	15.14***(2.060)	Togo	11.94***(0.921)
Gambia	13.84*** (1.855)	Uganda	7.880***(0.798)
Ghana	9.527***(0.531)	Zambia	7.543***(0.412)
Kenya	7.232***(0.794)		

Standard errors in parentheses $^{+}$ $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; R^2=0.822; N=727.

Table 3. Heckman Model Results

	Outcome	Selection
GDP- SSA	0.954*** (0.071)	0.247*** (0.046)
GDP- US	1.230 (1.024)	-0.843 (0.704)
GDPK- SSA	-0.845*** (0.087)	-0.240*** (0.052)
AGOA	-0.579 (0.385)	0.229 (0.258)
Exchange rate	-	0.057** (0.018)
_cons	-14.52 (16.39)	14.03 (11.24)
rho, ρ	0.107 (0.170)	
Lambda, λ	0.246 (0.390)	
N	726	112

Standard errors in parentheses; * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$; LR test (rho= 0): chi2(1) = 20.81 Prob > chi2 = 0.0000

The stationarity test proposed by Fisher for unbalanced panel data was used to determine whether the time series data have unit roots (Choi, 2001). The result shows that the null hypothesis that the panel data contain unit roots is rejected. Second, because the initial gravity equation is estimated using ordinary least squares (OLS), we also checked for the presence of heteroscedasticity using White's Test (1980). The result suggests that there is heteroscedasticity, hence the robust regression estimation as described by Andersen (2008) is used to correct for this problem.

The statistical results of the OLS model presented in Table 1 show that the dummy variable reflecting the introduction of AGOA is not significantly different from zero at any normal significance level. The estimated parameters of GDP variables in a gravity equation are in logarithms and represent the elasticity of agricultural exports to the United States in response to a change in GDP. The results from Table 1 suggest that a one-percent increase in GDP of the SSA countries results in about 0.94 % increase in agricultural exports to the

United States but the same percentage increase in per capita income of SSA countries leads to a decrease in agricultural exports of about 0.83 %.

Results for the fixed effects models with a country dummy are presented in Table 2. Most of the coefficient estimates for the fixed country effects are significantly different from zero and positive. Angola which has virtually no agricultural exports to the United States was chosen as the omitted country in the fixed effects estimation so that the other country dummies as measured relative to the intercept (the coefficient for Angola) would be positive. Holding the other variables constant and assuming there is no AGOA policy, virtually all SSA countries export more agricultural products to the United States compared to Angola. This is consistent with the earlier observation that almost all of Angola's exports consist of petroleum products. The different values of the intercept parameters suggest the presence of wide variation among the countries studied due to country-specific unobserved heterogeneity which may reflect variation in trade policies, exchange rates, historical ties, distance and other country-specific factors.

The Heckman two stage gravity model first estimates the selection equation, i.e., a Probit model to capture the probability of trade participation between SSA and the United States. In the second stage (outcome equation), an OLS regression is employed with nonzero trade values using the same regressors as the Probit selection equation plus the inverse Mills ratio from the first stage. In order to correct for model identification issues and obtain consistent estimates in the presence of non-random sample selection, the selection equation is estimated with an additional variable that is not in the outcome equation. The selection equation relates the latent variable to a set of observed explanatory variables. The official exchange rate of SSA (local currency units per U.S. dollar, period average) is the additional variable used to control for the model identification issues.

The Heckman results in Table 3 show that the estimated coefficients for SSA GDP and GDP per capita have the same sign both in the outcome and selection models, implying that GDP and GDP per capita affect the value of agricultural exports to the United States and the probability of trade engagement between SSA and United States in the same direction in both equations. The coefficient of interest in this study is that for the AGOA dummy variable, which is not statistically significant in either the selection or outcome equations. The statistical estimate of rho displayed in the final row of Table 3 provides information on whether the error terms of the outcome and selection equations are correlated. The estimate of rho is large in absolute value suggesting that sample selection is a major problem in this dataset. The likelihood ratio test of the null hypothesis that rho is equal to zero is rejected suggesting that the two error terms are correlated. These results are consistent with arguments by Silva and Tenrevro (2006) that the Heckman estimation methods do not address heteroscedasticity and the normality assumptions of the error terms. The Poisson family of regressions offers an alternative way to account for zero trade values that may be more appropriate than the Heckman model.

Results for the Poisson family models (PPML, NB, ZIP, and ZINB) are displayed in Table 4. Choosing the preferred model among the four Poisson models is done using the Vuong statistic, Likelihood Ratio (LR) test and the Akaki Information Criterion (AIC). The Vuong statistic (Vuong, 1989) is used to test whether the inflated versions are preferred to the noninflated versions (i.e., NB vs. ZINB; and PPML vs. ZIP). The LR statistic is used to test for the significance of the over dispersion parameter (α). The LR tests of the possible over-dispersion indicate that trade flows are significantly over-dispersed (Table 4). The AIC test indicates that PPML is the least preferred model against the ZIP and Negative binomial models (NB and ZINB). Based on the AIC test and Vuong statistic, the ZIP model is inferior to the Negative binomial (NB and ZINB). Further head-to-head comparison between NB and ZINB indicated that ZINB is the preferred model. The various test statistics are displayed in the lower panel of Table 4 and show that the PPML and NB models perform poorly compared to their zero-inflated variants of ZIP and ZINB. The test result implies that a binary choice process is necessary to account for SSA countries' self-selection to trade or not to trade with the United States.

The zero-inflated models generate two sets of parameter estimates, the logit and the Poisson (ZIP) or binomial (ZINB) labeled "export" in Table 4.

Table 4. Poisson family regressions

	PPML	NB	ZIP		ZINB	
	Export	Export	Export	Logit	export	Logit
GDP- SSA	0.668*** (0.047)	0.654*** (0.050)	0.616*** (0.0002)	-0.417*** (0.083)	0.596*** (0.044)	-0.461*** (0.108)
GDP- US	2.057** (0.683)	0.618 (0.897)	2.215*** (0.00343)	0.901 (1.244)	0.924 (0.786)	1.052 (1.525)
GDPK- SSA	-0.400*** (0.049)	-0.726*** (0.0725)	-0.323*** (0.0003)	0.462*** (0.086)	-0.636*** (0.0648)	0.483*** (0.099)
AGOA	-0.320 (0.227)	0.101 (0.354)	-0.366*** (0.001)	-0.368 (0.465)	0.0162 (0.311)	-0.382 (0.568)
_cons	-26.96* (10.92)	-1.580 (14.36)	-29.43*** (0.055)	-15.97 (19.92)	-6.483 (12.58)	-18.48 (24.45)
Over-dispersion, α	n.a	4.37(0.181)	n.a	n.a	2.96(0.16)	
LR-test	n.a	2.3e+07	n.a		2.1e+07	
AIC	23,283,745	15,242	20,799,849		15,176	
Vuong test			220		0.31	
N	840	840	840		840	

Likelihood-ratio test of alpha=0: chibar2(01) = 2.3e+07 Prob>=chibar2 = 0.000.
Likelihood-ratio test of alpha=0: chibar2(01) = 2.1e+07 Pr>=chibar2 = 0.0000.

The logit equation in the ZIP and ZINB models shows factors affecting the probability of having zero trade values, and this zero-inflated logit model identifies groups of countries in SSA that always have zero export values. The direction of the effect of both GDP and per capita income on the value of agricultural exports is consistently in the same direction and statistically significant but appeared to have limited impacts on SSA exports to the United States with a magnitude that is remarkably similar in all of the models analyzed. It appears that an increase in per capita income in SSA countries implies a fall in agricultural exports to the United States as well as a lower probability that SSA countries engage in trade with US.

The results in Table 4 indicate that AGOA has had no significant impact either on the value of agricultural exports or the propensity to trade for all models with one exception. In the ZIP model, the coefficient for the AGOA variable is significantly negative in the export equation although not significantly different from zero in the logit equation. This is the only case where the estimated AGOA coefficient is significantly different from zero and the negative sign is inconsistent with prior expectations. The statistical tests indicate that the best of the Poisson family of models is the ZINB in which the coefficient for the AGOA variable is insignificant in both the export and logit equations. Given the results for the ZINB model as well as those reported for the PPML and NB models, it seems safe to conclude that the significant coefficient for the AGOA dummy in the ZIP model is an anomaly. Overall, the estimates for the Poisson family of models suggest that AGOA has no discernable effect on the value of agricultural exports nor does it increase the probability of trade engagement between SSA and the United Sates. With the exception of the ZIP estimates, the models incorporating zero trade values yield similar results in terms of the significance of the AGOA coefficient to those obtained from the truncated samples used for the the robust OLS and the country fixed effects models. It is probably safe to conclude on the basis of the results from all models that AGOA has no statistically significant impact on SSA agricultural exports to the United States. The weight of the evidence from these alternative models, thus, suggests that while AGOA may have had a positive impact for some SSA exports, its effect on agricultural exports is imperceptible.

CONCLUSION AND IMPLICATIONS OF THE STUDY

This study developed a gravity trade model framework to explore the impact of AGOA on SSA countries' agricultural exports using a longer time frame to determine whether AGOA has had greater effects than found in previous studies. The issue of zero trade flows between the AGOA countries and the United States was also addressed. The results in all of the estimated models are consistent with studies finding that the AGOA trade preferences do not have a statistically significant impact on U.S. agricultural imports from SSA. It is worth noting, however, that this and most other analyses have been conducted for commodity aggregates rather than specific food and agricultural products. A more disaggregated analysis might reveal that AGOA has had significant effects at the level of certain specific products. A more disaggregated analysis may be a fruitful avenue for further research. While the focus of this study is on the effects of AGOA, the statistical results for other explanatory variables are also of interest. The coefficients for both GDP and per capita income are significant with GDP positively related to agricultural exports while the coefficient for per capita GDP is negative. The statistically significant negative coefficient for per capita income might reflect increases in domestic demand that would lead to a fall in exports as incomes grow. An alternative explanation might be that broader economic growth reflects increasing urbanization and a decline in the agricultural sector's share of the national economy, a common pattern as countries grow and develop that might be reflected in a fall in agricultural exports.

The results of this study may not be too surprising. In general, AGOA preferences are only applied to agricultural products that do not compete with goods produced in the United States. Many important agricultural exports from SSA compete with domestic production in the United States and, as a result, are subject to U.S. quotas and other barriers that predate AGOA and by the specific exclusion of certain agricultural commodities in the AGOA legslation. In addition, there is a general lack of processing capacity for agricultural products and a high dependency on primary agricultural commodity exports in many SSA countries. Product standards and quality measures can also limit agricultural market access for AGOA-eligible agricultural products. In this regard the United States provides capacity-building support to African countries and this support is a critical part of strategies to enable SSA countries to negotiate and implement market-opening trade agreements and to improve their capacity to benefit from increased trade. More support is needed to improve the implementation of these programs and to establish credible monitoring mechanisms to help countries to take advantage of the trade assistance and support and meet the required quality standards for the export of processed agricultural products to the U.S. market.

Even though AGOA has had no discernable impact on agricultural trade, its effects in such sectors as energy, textiles and apparel have been shown to be more significant by other analysts (Condon and Stern, 2011). As wages in China and other emerging economies increase, these countries may lose their competitive advantage in textiles and apparel products and this may lead to increased development of these industries in the lower-wage countries in SSA. AGOA may contribute to this transition and, by extension, to increased economic growth and development in SSA. With respect to agriculture, however, the impact of AGOA is likely to remain limited as long as markets for commodities such as sugar, cotton, tobacco, peanut oil, and other agricultural commodities are not fully opened to African exports.

It remains to be seen whether AGOA will be extended beyond its expiration date in 2015. If it is extended, its effectiveness could be increased by expanding U.S. trade preferences for agricultural goods that are important in SSA economies. Policy changes of this nature may be politically difficult to accomplish as such commodities as cotton, peanuts, and sugar, for example, are particularly sensitive in the United States. Further, greater access to the U.S. market may not be enough if the internal problems in SSA countries noted above reduce their ability to compete on world markets.

Consequently, the governments of SSA countries should take advantage of the trade development programs offered by the United States and other OECD countries in an effort to increase their ability to meet international standards and to offer agricultural goods at internationally competitive prices. Investments in infrastructure, institutional arrangements, information services, agricultural productivity and agricultural processing that meets high quality standards are needed to improve Sub-Saharan Africa's competitiveness in regional and global agricultural markets.

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INSTITUTIONAL DIFFERENCES AND AGRICULTURAL PERFORMANCE IN SUB-SAHARAN AFRICA

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ABSTRACT

The long term debate on the development failure of Africa considers a greater share for the role of institutions and their contribution to the agriculture sector. Governance indicators, especially in Sub-Saharan Africa (SSA), are gaining more attention, compared to the 1970s and 1980s. The main purpose of this study is to analyze the impact of political and economic institutional differences on the overall agricultural performance of SSA countries. Corruption control, higher government expenditures, and enhanced investment freedom as well as higher share of health expenditures in GDP imply better governance and health situation in the countries and have a significant positive impact on the value added by agriculture to the GDP of those countries.

Keywords: agricultural performance, institutions, Sub-Saharan Africa, growth

JEL codes: O130, O170, I130, H750

INTRODUCTION

African countries have failed to sustain their rapid growth of the first half of the twentieth century. Most of these countries experienced both market-led and state-led development policies in the post-independence decades where, according to statistics and empirical studies, generally neither of the policies were successful (Ndulu and O'Connell 1999; Tiffen 2003; Dorward, Kydd, and Poulton 2005). Traditional development economists believe that agricultural development provides excess food, raw materials, labor, capital, and foreign exchange income which are essentials for development in other sectors and ultimately for the whole economy (Johnston and Mellor 1961; Thorbecke and Morrisson 1989; Tiffin and Irz 2006). Some recent empirical works suggest the reverse causality direction. Hence, growth in the whole economy drives agricultural growth and increases value added per worker in this

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sector which would cause labor transfers to other sectors (Gardner 2000, Tiffen 2003). Regardless of the causality direction, which is beyond the scope of this article, the importance of the agricultural sector in the development process, specifically at the early stages, is not negligible. Despite the promising start during the 1950s and 1960s, and all the national efforts and international policy recommendations in the following decades, the remaining question for African countries is why the agricultural sector, either as the main driver of growth or as the complementary sector, did not contribute to economic growth as expected. While the classical approach to address this issue would be to raise productivity through technological change and thus encourage physical capital accumulation, new institutional economics extends the neo-classical theory by emphasizing the important role of institutions in economic performance (North 1995).

In many developing countries, lack of certain technical, educational and institutional inputs, known as complementary inputs, causes low productivity of conventional inputs like labor, land and fertilizer in the agricultural sector. Identifying these complementary inputs and determining the required combination of them would greatly help to prioritize development programs designed to increase their availability (Johnston and Mellor 1961). The main purpose of this study is to analyze the impact of institutional differences in governance, markets and health on the overall agricultural performance of developing countries. To do so, we use internationally reported indices of governance, economic and health status in Sub-Saharan Africa (SSA) for the time period of 1995-2011. This region consists of 48 countries and one territory (figure A-1 in the appendix) which is distinct from North Africa (Algeria, Egypt, Libya, Morocco, Tunisia, and Western Sahara). Institutional and political problems such as ethnic conflicts, political corruption, military governments and secessionist movements caused the large lag in the development process of the region (Tyler and Gopal 2010). In contrast to Asia and Latin America, decision makers in SSA continue to struggle to find solutions to obtain rapid growth and to define the role of agriculture. This continuous debate is not only about the general role of agriculture in economic development but also about policy priorities in these countries such as export crops versus food crops, large versus small farms, mechanical versus biological technology, and so forth (Delgado, Mellor and Blackie 1987).

According to Johnston and Mellor (1961), agricultural development occurs in three phases. The first phase is the development of agricultural preconditions in which farmers perceive some personal gains. Improvement in land property rights, an important institutional factor, is the most critical requirement for this phase. The second phase is an increase in agricultural output using labor-intensive, capital-saving techniques. The third phase is expansion of agricultural output based on capital-intensive, labor-saving technology. Institutions help translate the potential for capital accumulation and savings from increased agricultural productivity into actual increase in investment. It seems that the majority of the SSA countries are still at the first or optimistically the second phase.

Statistics show that development indices in SSA are still poor. In West Africa, the education level for the population aged 25 years and above is 2.2 years of schooling while it is 4.3 years for East and South Africa. Average years of education in most of the developing countries for rural adult males are 4 years, and for rural adult female are 1.5 to 4 years. Only half of the rural population in SSA has access to improved water and sanitation. Low education levels and poor health status could reduce productivity of agricultural labor in these countries (IMF 2012, World Bank 2007).

Government plays an important role in economics and politics in developing countries. Agriculture-based countries tend to suffer more from governance problems because they are more likely to be in the early stages of development and, thus, their industrial sectors and critical institutions like liberalized markets and private investments are not yet well developed. There is a tradeoff between costs and benefits of government interventions. It should be noted that the widespread government intervention in the economy, from production decisions to market regulations, provides prone areas to failure of development efforts in case of poor performance. Meanwhile, governance infrastructure is crucial to create and maintain institutions required for functioning of the market system and to improve incentives for production and investment. Good governance lowers transaction costs, creates and supports a competitive environment, and encourages agricultural innovation (Lio and Liu 2008).

For a long time, most of the international assistance programs have focused on providing irrigation facilities and chemical fertilizers, introducing modern agricultural technologies, and building schools to stimulate agricultural performance in developing countries. Studies on least developed countries, however, show that agricultural productivity declines even in countries that adopted Green Revolution varieties of rice and wheat especially if they are suffering from poor governance. The absence of good governance strictly limits the achievements of development (Lio and Liu 2008; Fulginiti and Perrin 1998). African countries had failed to implement policy recommendations on agriculture made by the World Bank in its 1982 world development report mainly due to government problems. Today there is a higher probability of overcoming governance problems due to institutional improvements and ongoing processes of corruption control, public sector management reform, decentralization efforts, rising weight of agribusiness, civil society participation, and democratization during past two decades. All these developments would, optimistically, provide a great potential of improving agricultural performance (World Bank 2007).

The new approach of explaining development failures in SSA countries focuses on how politics and economics are interrelated. There are at least three features that must be included in a model of politics and growth. First, it should reveal a political conflict in the society to capture some heterogeneity among agents. Second, it should specify political institutions which help to form actual policies. Finally, it should explain the underlying economic structure (Verdier 1994).

Including political and economic indicators into the model may address all three of the mentioned features but to cover the other important aspect of the development process health status needs to be considered as well. Institutions in this study are categorized into the broad areas of political, economic and health institutions with an emphasis on political institutions and the role of government. To the best of our knowledge, the empirical literature on the political economy of growth mostly examines the impact of institutional variables on the overall economic growth (Guseh 1997; Fosu 2001) and a few studies focus on the agricultural sector, especially in SSA countries (Beghin and Kherallah 1994; Fulginiti, Perrin and Yu 2004; Tyler and Gopal 2010).

Farmers need to make economically sound decisions to develop agriculture. Political systems can affect these decisions. Empirical studies show that countries with dominant party systems are highly protectionist and, compared to more democratized ones, provide the highest level of agricultural assistance. Since such policies reinforce rent-seeking behavior, one expects that rents would be dissipated in the most democratic systems (Beghin and Kherallah 1994).

Political instability, measured differently in various studies, has a negative impact on overall and sectorial economic growth. For instance, SSA countries engaged in political conflicts and wars experience a significant reduction in agricultural productivity while higher levels of political rights and civil liberties lead to higher productivity levels (Guseh 1997; Fulginiti, Perrin and Yu 2004; Tyler and Gopal 2010). Political systems may amplify the effect of policies in different countries. According to Fosu (2001) the negative effects of government size in non-democratic socialist systems are three times as great as in countries with democratic market systems.

Political systems, political rights, and political stability are three main indicators of governance status considered in the literature studying impacts of political institutions on agricultural productivity and growth. Although analyzing the impact of political and economic regime type of SSA countries on their economic growth is beyond the scope of this article, we include a measure of political and economic institutions quality. The economic freedom index, provided by the Heritage Foundation, measures the freedom of individuals to work, produce, consume, and invest with that freedom both protected by the state and unconstrained by the state (Miller et al. 2013). Subjective indexes such as institutional quality indexes are always associated with measurement error and aggregation bias.

To reduce these biases, we use components of the economic freedom index which consist of ten indicators representing various political and economic institutions. Unlike previous studies that include different institution measures from different sources, all ten indicators included in this article are calculated by the same source (Miller et al. 2013). Disaggregating the governance measures is expected to reduce the bias to some extent; however, we cannot claim this index is the perfect measurement for political and economic institutions in SSA. The economic freedom index for each country shows how wide is the gap between its current economic and political status and a fully liberalized country. State-controlled markets are generally considered inefficient in allocating resources and, therefore, the alternative prescription is to move toward economic freedom. Nevertheless, private markets may experience inefficiencies too.

Given the historical underdevelopment and slow market liberalization of SSA countries, the main focus of this article is to find aspects of economic freedom that have significant impact on agricultural growth in these countries. Since agriculture is the dominant, yet primitive sector in the development process of SSA, our focus is on the relation between political and economic institutions, and agricultural productivity. The main contribution of our article is to consider all components of the economic freedom index as the indicators of governance in SSA countries in one model.

Each of these ten indicators would measure the level of a specific social, economic and political institution for the relevant country and consequently, including all of them improves the comprehensiveness of the model and provides a better understanding of the role of institutions on development for SSA.

METHODS AND DATA

The development of the agricultural sector and factors impacting capital accumulation process are highly critical in early stages of the economic development. Institutions can provide the basic infrastructure expected for capital accumulation and investment in developing countries. The hypothesis in this article is that higher quality of institutions, which reflect better status in governance, health and economic situation of each country, would have positive effect on the performance of the agricultural sector in SSA countries.

Various types of variables representing institutions have been used in the literature. Beghin and Kherallah (1994) analyze the impact of political systems and rights on agricultural protection for selected commodities in 25 developing and industrialized countries. They include political system of the countries, index of civil liberties, and a measure of social equity to address political institution influence on agricultural protection. They suggest that the agricultural assistance level (protection, subsidies, direct payments, etc.) would be affected by political systems in each country and as a result, confirm the importance of the institutional setting in which the agricultural policy is going to be implemented.

Fulginiti, Perrin and Yu (2004) use colonial heritage, number of years since independence, armed conflicts, and political rights/civil liberty as institutional variables to investigate agricultural productivity in SSA countries. Their results indicate that institutional factors significantly contribute to agricultural productivity growth. Tyler and Gopal (2010) examine regional patterns of development in SSA using principal component analysis and Kohonen's self-organizing map technique. They consider governance indicators (political stability and absence of violence, voice and accountability, government effectiveness, regulatory quality, rule of law, and control of corruption), human development index, health indicators (HIV prevalence, mortality rate, access to improved water and sanitation), and technology indicators as well as food and trade indicators to identify similarities and differences among countries. Their analysis shows the significance of governance variables in some clusters.

Fosu (2001) examines the relation between political instability and economic growth in SSA countries. In this study, events of coups d'état, as the measure of political instability, is incorporated into a simple Cobb-Douglas production function. The focus of this study is on the specification empirics associated with the relation between political instability and economic growth. However, estimation results show that political instability has a positive effect on growth but a negative effect on the impact of capital on growth; suggesting the adverse impacts of coup d'état events on marginal product of capital. Guseh (1997) also considers a neoclassical production function to describe the aggregate production of the economy. He includes government size, measured as the share of government consumption expenditure in GDP, and political and economic systems as the institutional variables to assess the impact of government on economic growth in developing countries. Based on the empirical results, he suggests that reduction in government size and the improvements in political and economic liberties should be considered in policy recommendations for economic growth and development in emerging economies.

Theoretical and empirical works that improved neo-classical growth theory start with the Solow model (Mankiw, Romer and Weil 1992; Easterly and Levin 1997) and then redefine the term, *A*, not just as technology but also a reflection of resource endowments, climate, and institutions that is determined internally in an economic system and may differ across countries (Romer 1990; Mankiw, Romer and Weil 1992; Easterly and Levin 1997; Aghion and Howitt 2009). Consequently, unlike the neo-classical economists, the government is treated as an endogenous actor in development policy by institutional economists. In this context, the government can achieve desired price settings only if proper institutions, according to the country's development stage, are already in place that would produce competitive market conditions (North 1995).

In this study, we start with an aggregate neo-classical production function for the agricultural sector, with three main inputs, for country *i* at time *t* as equation 1:

$$Q_{it} = f(K_{it}, L_{it}, N_{it}) \quad (1)$$

where Q is agricultural outcome measured as gross value added by agriculture to GDP; K is the stock of capital; L is the labor force in the agricultural sector; and N is agricultural land. Because the focus of this study is on the agricultural sector outcome, we control for conventional factors (capital, labor and land) that directly affect agricultural production. Dividing both sides of equation 1 by population, the production function in equation 2 turns to per capita terms. Subscripts are omitted for ease of notation.

$$Q' = f(K', L', N') \quad (2)$$

where Q' is per capita gross value added by agriculture to GDP; K' is the capital labor ratio; L' is the labor force participation rate in agriculture; and N' denotes agricultural land per capita. Because the data on capital stock for developing countries is hard to obtain, gross domestic investment is used in the literature (Guseh 1997). Since the agricultural sector is the primary sector in the economy of developing countries and it represents the majority of economic activities, it is assumed that the priority of investment in the early stages of development would be the agricultural sector. However, domestic investment in the agricultural sector of SSA countries is difficult to obtain. Therefore, the domestic investment in each country is used as a proxy for agricultural sector investment (K'). Guseh (1997) assumes total population as a proxy for total labor force in the economy. Thus, dividing the agricultural labor by total population represents the share of the agricultural sector of the total labor force of each country (L'). SSA countries are mostly agriculture based countries with a high ratio of rural to urban population and consequently, a large agricultural labor force.

Moussa (2002) suggests that, among land expansion, irrigation, mechanization, high yielding varieties, and fertilizers, the most effective factors of increasing food production and poverty reduction is the use of high yielding varieties. Minten and Barrett (2008) show that communities with higher rates of adoption of improved agricultural technologies would, consequently, have higher crop yields. Since cereals are the main staple in SSA countries, we control the agricultural production technology differences between countries over time by including cereal yield, denoted by T, in the equation 3. Adapting the function in equation 2 to include technology and institutions yields:

$$Q' = f(K', L', N', T, I) \quad (3)$$

Where I is the matrix of institutional variables. Note that here T and I together can be considered as the innovation term, A, as in conventional growth literature. Aghion and Howitt (2009) suggest that to identify appropriate institutions at each stage of development, the matrix should be decomposed into more specific components. The main focus of this article is on the components of the economic freedom index, as the institutional variables, that have been published annually by the Wall Street Journal and The Heritage Foundation since 1995. Ten specific components of this index can be grouped into four key pillars: a) rule of law, b) limited government, c) regulatory efficiency, and d) open markets. There are two components in the first group: property rights, and freedom from corruption. The second group contains fiscal freedom and government spending indices. The third group contains business freedom, labor freedom, and monetary freedom. The last group contains trade freedom, investment freedom, and financial freedom components (Miller et al. 2013).

There has been a debate on the slow growth of Africa and its causes for a long time. Early discussions criticize external policies, especially exchange rate and trade policies, mainly recommended by the International Monetary Fund and the World Bank. More recent explanations focus on domestic problems. Domestic policy-induced issues that SSA countries suffer the most are undemocratic governments, poor public service delivery, government interventions, regulated financial markets, and governments' focus on urban areas rather than the agricultural sector (Collier and Gunning 1999). In this article, we hypothesize that good governance can contribute positively to economic growth of SSA countries. Political and economic institutions are represented by nine components of the economic freedom index. Labor freedom index is not used in this study due to the lack of information on this index in SSA countries. The computation of the economic freedom index is based on Adam Smith's theory of free markets and it measures how governments refrain from coercion or constraint of liberty and allow labor, capital, and goods to move freely within and between the markets. According to Miller et al. (2013) the economic freedom index can demonstrate the relation between economic freedom and economic growth.

To control for income heterogeneity, we use the World Bank classification of the SSA countries. The World Bank classifies SSA into middle income, fragile low income, and low income countries based on their per capita income and institutional quality. The average gross national income for middle income counties is U.S. $4000 per capita. For fragile low income countries the average is U.S. $500 per capita and for low income countries is U.S. $ 400 per capita (IMF 2012). Two dummy variables are included in the model to control for the income level of the countries (middle income and fragile low income). The World Bank classification excludes oil selling countries; therefore, a dummy variable is considered to differentiate Cameroon, Gabon, and Republic of Congo from other countries since oil revenues are a significant share of their income. Although Djibouti's share of oil revenues in its economy may not be as significant as the previous three countries, we grouped it with other oil selling countries since it has started to produce and export oil recently.

To consider the health status of each country, total health expenditure as a percentage of GDP is included in the model. Health expenditure covers the provision of health services (preventive and curative), family planning activities, nutrition activities, and emergency aid designated for health but does not include provision of water and sanitation (World Data Bank 2013).

Ethnical heterogeneity is an important issue in this region and has caused serious conflicts during past decades within the countries. Alesina et al. (2003) suggest three measures of ethnic, language, and religion fractionalization for about 190 countries. Ethnic and language fractionalization variables are more likely to influence economic success. The impact of these two variables is found negative on long-run growth while religion does not show significant effect. Since ethnic and language variables are highly correlated, we only include ethnic fractionalization using the data provided by Alesina et al. (2003) for SSA countries. However, ethnic fractionalization does not always lead to armed conflicts and not all the armed conflicts have an internal origin. Many armed conflicts have been reported in this region during past decades in which governments were involved (Themner and Wallensteen 2014). To account for the impact of such incidents, we control for the years that at least one party of the armed conflict is a government of a state.

Using a logarithmic form for equation 3, the empirical model is specified and estimated as equation 4:

$$Inagvaluepc_{it} = \beta_0 + \beta_1 Incapitalpc_{it-1} + \beta_2 Inaglabor_{it} + \beta_3 Inarablepc_{it} +$$

$$\beta_4 Incereal_{it} + \beta_5 Inpropright_{it} + \beta_6 Infreecorrupt_{it} +$$

$$\beta_7 Infiscalfree_{it} + \beta_8 Ingovspend_{it} + \beta_9 Inbusnfree_{it} +$$

$$\beta_{10} Inmoneyfree_{it} + \beta_{11} Intradefree_{it} + \beta_{12} Ininvestfree_{it} +$$

$$\beta_{13} Infinancefree_{it} + \beta_{14} oilexp_i + \beta_{15} midinc_i + \beta_{16} fragile_i +$$

$$\beta_{17} Inpubhealth_{it} + \beta_{18} Inethnic_{it} + \beta_{19} conflicts_{it} + \varepsilon_{it} \quad (4)$$

where i denotes countries included in the empirical model and t denotes time. All variables are in logarithmic form except four dummy variables for oil selling countries, middle income countries, fragile low income countries, and armed conflicts.

The dependent variable, $lnagvaluepc_{it}$, is the logarithm of per capita gross value added by agriculture to the GDP for each country during the study period. The first three explanatory variables are conventional inputs to agricultural production representing capital, labor and land, respectively. The variable lncapitalpc is the logarithm of the per capita gross domestic investment in constant 2005 US dollars. It is included in the model with one year lag, $lncapitalpc_{it-1}$, because it is assumed that the outcome of investment in agriculture would be realized at least with one year interval. Higher lags of this variable are tested but not reported since they are not significant. However, higher lag orders of the variable for capital were not significant and not included in the model. The important advantage of including lagged capital variable is to avoid potential endogeneity in the structure of the model, by relating the value of agriculture to previous years' investment. The logarithm of the percentage of the agricultural labor is included, denoted by $lnaglabor_{it}$, which implies the ratio of agricultural labor to the total labor in each country. Land input is calculated as logarithm of the ratio of total arable land in square kilometers to the total population for each country and represented by $lnarablepc_{it}$ in the model. The logarithm of cereal yield ($lncereal_{it}$) is included to control for the different technology of production in countries. It is measured as kilograms per hectare of harvested land for dry grain only and includes wheat, rice, maize, barley, oats, rye, millet, sorghum, buckwheat, and mixed grains (World Data Bank 2013).

Nine components of the economic freedom index are used as the measure for political and economic institutions in the countries studied. The components are graded on a scale of 0 to 100. Some of these components are composites of additional measures and the raw data for calculation is gathered from various national and international sources (Miller et al. 2013). The first two components, property rights index and freedom from corruption index, measure the rule of law in each country and are represented by $lnpropright_{it}$ and $lnfreecorrupt_{it}$ in the model. The property rights index measures the ability of individuals to accumulate private property, protected by clear laws that are enforced by the state. A higher score means it is more certain that the property is legally secured. Corruption brings insecurity and uncertainty into economic relationships. The score of zero indicates very corrupt government while 100 indicates very little corruption. The next two variables, $lnfiscalfree_{it}$ and $lngovspend_{it}$, are indicators of fiscal freedom and government spending, respectively. Together, they measure the extent and quality of government intervention in the economy. Fiscal freedom is a measure of the tax burden imposed by governments and government spending is the level of government expenditures as a percentage of GDP. A higher score of fiscal freedom means lower tax burden in an economy. Although its optimum level varies from country to country and depends on various factors, researches have shown that excessive government spending would lead to budget deficits and unmitigated debt (Miller et al. 2013). Regulatory efficiency of each country is measured by business freedom and monetary freedom variables denoted by $lnbusnfree_{it}$ and $lnmoneyfree_{it}$, respectively. Business freedom varies from zero to 100 for each country, with 100 as an indicator of freest business environment. Business freedom, generally, indicates how efficient a government is in regulating business. Monetary freedom is a combination of price stability measures and an assessment of price controls. It is assumed that price stability without microeconomic interventions is the ideal state. Lower inflation and lower extend of price controls would lead to a higher score for each country. The last three components measure the level of market openness in each country. Trade freedom, denoted by $lntradefree_{it}$, is a measure of the absence of tariff and non-tariff barriers. Higher extent of non-tariff barriers in a country significantly reduces its score. Ideally, there should be no constrains on the flow of capital, both internally and across the borders, in an economically free country. Investment freedom index, represented by $lninvestfree_{it}$ in the model, evaluates typical restrictions imposed on investments. Higher scores show a less restricted economy. Banking efficiency and the measure of independence from government interference in the financial sector is measured by financial freedom index and denoted by $lnfinancefree_{it}$ in the model. Lowest score is zero and it shows the prohibition of private financial institutions in a country while 100 means negligible government interference.

Three dummy variables, $oilexp_i$, $midinc_i$, and $fragile_i$, are included to control for the oil selling, middle income, and fragile low income countries. The omitted group is low income countries. Health situation of the countries is represented by the variable $lnpubhealth_{it}$, which is the logarithm of the sum of public expenditures as a percentage of GDP for each country. To control for the ethnic differences between and within countries, the logarithm of the index of ethnic fractionalization, $lnethnic_{it}$, is used with the range of zero for complete ethnic homogeneity to one for complete heterogeneity. The variable $conflicts_{it}$ is a dummy variable for each country and gets the value of one for the years that central government was involved in an armed conflict with either domestic forces or a foreign government, and zero otherwise.

We used panel data for 28 Sub-Saharan Africa countries for 1995-2011. The information for the excluded countries is not available for a significant number of variables in the study period.[1] It is important to note that countries with better governance status, politically stable, and not involved with conflicts are expected to produce and report more comprehensive databases and therefore, enter the study sample which in turn may bias the results. Although our sample is not a complete set of countries, there are significant variations in the stability related variables. However, lack of data for the rest of the countries and other possible institutional variables, especially education, is a caveat in our study and because of this exclusion, one should be cautious about generalizing the results to all SSA countries. It is not possible to extend the dataset back in time since the economic freedom index reports start in 1995. Data on the components of the economic freedom index are obtained from the various annual reports published by The Heritage Foundation (2013). Ethnical fractionalization data are obtained from Alesina et al. (2003). The information on the years of armed conflicts is obtained from Themner and Wallensteen (2014). The rest of the data are obtained from the World Bank data base (World Data Bank 2013). Descriptive statistics of the data are presented in table 1.

Table 1. Descriptive Statistics

Variable	Definition	Unit	Mean	Std. Dev.	Min	Max
agvaluepc	Gross Value Added-Agriculture	$ per capita	144.17	76.4	26.13	388.27
capitalpc	Gross domestic investment	$ per capita	349.52	466.57	-8.01	2339.74
aglabor	Agricultural labor force	% of total	24.12	11.14	2.24	44.68
arablepc	Arable land	km^2 per capita	22.42	11.36	0.12	52.96
cereal	Cereal production yield	kg/hectare	1448.61	1203.25	110.07	9453.7
propright	Property rights	0 - 100	41.81	15.56	10	75
freecorrupt	Freedom from corruption	0 - 100	29.43	12.84	10	70
fiscalfree	Fiscal freedom	0 - 100	68.52	10.4	41	92.5
govspend	Government spending	% of GDP	76.78	14.65	5.9	97.6
busnfree	Business freedom	0 - 100	58.41	11.2	32.9	85
moneyfree	Monetary freedom	0 - 100	73.75	8.67	12.2	90.4
tradefree	Trade freedom	0 - 100	58.08	15.37	0	89
investfree	Investment freedom	0 - 100	49.91	13.87	10	90
financefree	Financial freedom	0 - 100	46.67	14.91	10	70
oilexp	Oil selling countries	0 or 1	0.14	0.35	0	1

[1] See appendix for the list of the countries (table A-1) and map of the region (figure A-1).

Variable	Definition	unit	Mean	Std. Dev.	Min	Max
midinc	Middle income countries	0 or 1	0.32	0.47	0	1
fragile	Fragile low income countries	0 or 1	0.07	0.26	0	1
lowinc	Low income countries	0 or 1	0.46	0.5	0	1
healthexp	Health expenditure	% of GDP	5.79	2.72	2.09	22.19
ethnic	Ethnical fractionalization	0 - 100	67.42	20.74	5.82	93.02
conflicts	Armed conflicts	0 or 1	0.16	0.36	0	1

Note: Detailed descriptive statistics are presented in the appendix table A-2.

RESULTS AND DISCUSSION

We estimate random effects and fixed effects models for equation 4. The random effects model is more appropriate for this study because it accounts for country specific characteristics that may have been unchanged during the time frame of our study but can explain differences between countries. The random effects model was tested for serial correlation and the fixed effects model for heteroskedasticity. Results show that the null hypothesis of no autocorrelation is rejected for the random effects model and the null hypothesis of homoskedasticity is rejected for the fixed effects model. Therefore, a generalized least squares (GLS) estimator is used for the random effects model to overcome serial correlation and robust standard errors are used for fixed effects model to address heteroskedasticity.

The Pesaran cross-sectional dependence (CD) test is used to test whether residuals are correlated across countries. Based on the test results, there is no evidence of cross-sectional dependence in the fixed effects model. Using the Breusch-Pagan Lagrange Multiplier (LM) test, the random effects model is preferred to Ordinary Least Square (OLS) estimator. Fixed effects and random effects models are tested for the preferred model using the Hausman test.

In the fixed effects model, dummy variables representing income levels and oil selling countries are automatically omitted from the regression since they are time invariant. Table 2 presents estimation results for equation 4. The Hausman test result (last row of the table) implies that the random effects model fits the data better than the fixed effects model. More variables are statistically significant in the random effects model.[2]

In the random effects model, the sign for the lag of capital is positive. We use total domestic investment as a proxy for investment in the agricultural sector. Therefore, the positive sign of the coefficients suggest that, as far as the share of agriculture in total investment remains unchanged, increasing domestic investment by 10 percent would increase the share of agriculture from GDP by 1.5 percent for the next year.

[2] We empirically test for endogeneity using the augmented Durbin-Wu-Hausman test. In this two stage procedure, each explanatory variable is assumed to be endogenous and therefore regressed on other independent variables. The residual from the first regression is included in the model and tested if the coefficient is significant. None of the explanatory variables showed evidence of being endogenous.

Table 2. Estimation Results for Equation 4

Variables	Random effects	Fixed effects
Gross domestic investment (t-1)	0.15***	-0.01
	(0.03)	(0.02)
Agricultural labor force	-0.25***	-0.25
	(0.05)	(0.16)
Arable land	0.21***	0.26**
	(0.02)	(0.10)
Cereal production yield	-0.07**	0.10***
	(0.03)	(0.04)
Property rights	-0.07	0.00
	(0.06)	(0.03)
Freedom from corruption	0.13***	0.05
	(0.05)	(0.04)
Fiscal freedom	-0.30*	0.07
	(0.16)	(0.07)
Government spending	0.59***	0.13
	(0.08)	(0.09)
Business freedom	-0.17	0.00
	(0.12)	(0.05)
Monetary freedom	-0.20*	-0.02
	(0.12)	(0.07)
Trade freedom	-0.09	0.03
	(0.06)	(0.02)
Investment freedom	0.35***	0.02
	(0.07)	(0.03)
Financial freedom	-0.05	0.04
	(0.05)	(0.02)
Oil selling countries	-0.09	-
	(0.08)	
Middle income countries	-0.25***	-
	(0.07)	
Fragile low income countries	0.15*	-
	(0.09)	
Health expenditure	0.11**	0.03
	(0.05)	(0.04)

Variables	Random effects	Fixed effects
Ethnical fractionalization	-0.10***	-
	(0.04)	
Armed conflicts	-0.15***	-0.01
	(0.05)	(0.02)
Constant	4.15***	2.84***
	(0.87)	(0.61)
sigma_u		0.40
sigma_e		0.09
rho		0.95
Test: Ho: difference in coefficients not systematic		
$chi^2(16)$= (b-B)'[(V_b-V_B)^(-1)](b-B) = 3.18		
Prob>chi^2 = 0.9994		
Standard errors in parentheses		

*significant at 10%, **significant at 5%, and ***significant at 1%.

Agricultural labor force and agricultural land are two important production factors that are significant in the model. However, the negative sign of agricultural labor would suggest that, *ceteris paribus*, agricultural output would decrease by an increase in the share of agricultural labor in total labor force. In other words, agricultural labor is currently oversupplied in SSA rural areas which, without utilizing more efficient technology and increasing cultivated land, create a negative marginal product. The estimated coefficient for arable land is positive. Larger agricultural land areas for each country lead to higher production of agricultural commodities and increase the value added by this sector to GDP. Cereal yield is included to control for the effect of technology improvements in different countries. This variable is negative, which is not as expected, and significant in the random effects model. In the fixed effects model, however, the estimated coefficient for cereal yield is positive and significant. The random effects model captures technology differences between countries thus when we do not control for country specific characteristics in the fixed effects model, technology variations among countries, through our cereal yield variable, has a significant positive impact on agricultural output.

Five out of nine components of economic freedom index are statistically significant in the random effects model. Freedom from corruption, government spending, and investment freedom have a positive sign as expected while fiscal freedom and monetary freedom have an unexpected negative sign. These results should be interpreted cautiously. It is an extremely hard task to improve all aspects of economic freedom at the same time with the same speed. Governments need to focus on domestic priorities. The traditional approach of interpreting the coefficients, *ceteris paribus* condition, would not prioritize different aspects of political and economic development that each of these components represent. Testing for complementary or substitutability relation between these components is beyond the scope of this article but could be a good starting point for further investigation. A systematic approach of choosing the right indicators in future research would enhance the results and make interpretations more reliable.

The lowest score for property rights is zero which shows that all property belongs to the state. As countries implement more privatization the score increases, with 100 being the maximum. The negative sign of the coefficient could be related to the need of national industries at the early stages of development in SSA countries to produce and provide service based on equity measures instead of just profitability. However, the estimated coefficient for property rights is not significant. A positive significant estimated coefficient for any of the economic freedom components highlights the important role of government in improving the agricultural sector in SSA countries and also shows the impact of good governance on agricultural development. Indeed, less corrupt countries have been more successful in increasing the value added by the agricultural sector to their GDP. According to our results, improving the freedom from corruption index by 10 percent, leads to an additional 1.3 percent of value added by agriculture to GDP. Similar to the property rights index, the negative sign for the fiscal freedom component could suggest the need for government regulations and interference in tax systems at the early stages of development in these countries.

A higher score for fiscal freedom represents less tax burden in the economy which implies lower tax income for the government. Higher tax income would enable governments to increase their support to agricultural sector in the form of government expenditure especially to provide infrastructures. According to the estimation results, 10 percent additional government spending in the SSA countries would raise the value added by agriculture to GDP by 5.9 percent, all other variables constant. One explanation for this positive impact is that government expenditures, presumably through public services like telecommunications and transportation, reduce the transaction costs and relate markets to rural areas which ultimately facilitate and accelerate agricultural growth (Tiffen 2003).

The monetary freedom index measures a combination of price stability and price control interventions by governments. The negative sign of its estimated coefficient may suggest the need for regulation and government policy making at this level of development.

Lowering the restrictions on investment flow in SSA countries would positively impact the agricultural sector outcome. Policies and practices that improve the investment freedom score of each country by 10 percent would lead to 3.5 percent increase in agricultural value added to GDP for that country.

The estimated coefficient for the dummy variable representing oil selling countries is negative but not significant. Middle income SSA countries have a significant lower share of agriculture in GDP, because of a higher level of industrialization relative to low income SSA countries. The magnitude of this difference is 25 percentage points. Fragile low income countries have significantly higher agricultural value added to GDP, 15 percentage points more than low income SSA countries. The coefficient on health expenditure is positive and significant which implies that countries with higher total health expenditure as a percentage of GDP would have higher agricultural value added. The magnitude of the estimated coefficient suggests that a 10 percent increase in health expenditure leads to a 1.1 percent increase in the value added by agriculture to GDP in the SSA countries. A higher rate of ethnical fractionalization has a negative impact on agricultural output in SSA countries. This result is consistent with previous findings that suggest a negative correlation between ethno-linguistic fractionalization variables and economic growth, whether as a direct effect or amplified by the undemocratic political systems (Easterly and Levin 1997; Collier and Gunning 1999; Alesina et al. 2003).

Armed conflicts have a significant and negative, as expected, impact on the share of agriculture in GDP. According to the estimated coefficient, if the central government of a Sub-Saharan Africa country is involved in a domestic conflict or is in war with other foreign governments, agricultural output would decrease on average 15 percentage points compared to countries in peace.

CONCLUSION

Agriculture is a key factor to spur growth and reduce poverty in most African societies. It is more than just an economic activity. Because of its large share in the economy and its close linkages with other sectors, growth in agriculture can be the main driver of general economic growth, particularly in SSA countries (Zimmermann et al. 2009). Lack of technical, educational and institutional resources lowers the productivity of conventional inputs in the agricultural sector of developing countries. Institutions foster the process of transforming the potential for capital accumulation and savings from increased agricultural productivity into actual increase in investment. Since the 1990s market-led growth became the prominent recommended policy by international organizations to recover from lagged growth in SSA countries (Dorward, Kydd, and Poulton 2005). However, in early stages of development, liberalization would not necessarily lead to expected results and specific aspects of policy, to constitute governance, should be selected according to the level of development (Aghion and Howitt 2009). In this study we focus on the impact of political and economic institutions on the outcome of the agricultural sector in SSA countries. Previous studies show that many SSA countries suffer from governance problems like political instability, corruption, military governments, and ethnic conflicts, while good governance can foster the development process in these countries.

Based on our results, freedom from corruption, government spending and investment freedom have positive impacts on agricultural outcome. While national and international efforts should not be limited to these factors, political and economic reforms can be focused on these three factors more carefully. However, making progress on each of these factors could not be achieved solely and without considering the potential interrelation among factors.

One of the most important measures of good governance is the freedom from corruption index. In the context of SSA countries with high level of fractionalization, prioritizing interests of special groups over national interests, and the unjust distribution of benefits, may cause severe conflicts. Less corrupt governments would allocate resources in a more effective and efficient way with less discrimination. Results show that improvements in controlling and lowering corruption increase agricultural outcome. Most of the SSA countries suffer from corrupt or unstable governments. Improvements in the governance status would positively affect the agricultural sector as the first step of the development process. Government size, measured as the share of government spending from GDP, has a positive effect on the value added by the agriculture to GDP. This result suggests that expenditure by central and local governments which usually tends to provide public and essential services is enhancing the outcome of the agricultural sector in SSA countries. Along with less corrupt governments and more government expenditure on infrastructure, lowering the constraints on investment flow would enable the agricultural sector to attract funds and capital needed to foster growth. The positive sign of government spending along with the negative sign of monetary and fiscal freedom indexes imply the critical role of government policies at this stage of development in SSA countries.

Providing health services, specifically in rural areas, enhances the general health level and the quality of life in the SSA countries and subsequently would positively impact the level of productivity in the agricultural sector. Health expenses are generally high and most rural households have difficulty to access improved sanitation, especially to clean water (Tyler and Gopal 2010).

Participation and financial support by SSA governments in health improvement programs is critical at this stage of development. Finally, following a policy of *détente* at the regional, national and international levels, i.e. avoiding political, social, and economic policies that turn domestic and regional issues to a conflict, can reduce the probability of ethnical conflicts and wars between neighboring countries and improve the economic growth path in Sub-Saharan Africa.

APPENDIX

Table A-1. List of Sub-Saharan Africa Countries

Angola	Gabon*	Rwanda*
Benin*	Gambia, The*	Sao Tome and Principe
Botswana*	Ghana	Senegal*
Burkina Faso*	Guinea	Seychelles
Burundi	Guinea-Bissau	Sierra Leone*
Cameroon*	Kenya*	Somalia
Cape Verde*	Lesotho*	South Africa*
Central African Republic	Liberia	South Sudan
Chad	Madagascar*	Sudan
Comoros	Malawi	Swaziland*
Congo, Dem. Rep.	Mali*	Tanzania*
Congo, Rep. *	Mauritania*	Togo*
Cote d'Ivoire*	Mauritius*	Uganda*
Djibouti*	Mozambique*	Zambia*
Equatorial Guinea	Namibia*	Zimbabwe
Eritrea	Niger	
Ethiopia*	Nigeria	

*Included in the sample.

Table A-2. Detailed Descriptive Statistics

Variable		Mean	Std. Dev.	Min	Max	Obs.
Gross Value Added-Agriculture	overall	144.17	76.40	26.13	388.27	N =476
	between		75.44	27.74	335.70	n =28
	within		18.37	83.26	301.99	T =17
Gross domestic investment	overall	349.52	466.57	-8.01	2339.74	N =461
	between		450.58	31.62	1639.27	n =28
	within		130.23	-335.01	1062.08	T̅ =16.46
Agricultural labor force	overall	0.24	0.11	0.02	0.45	N =476
	between		0.11	0.03	0.43	n =28
	within		0.01	0.20	0.28	T =17
Arable land	overall	22.42	11.36	0.12	52.96	N =476
	between		11.23	0.16	45.78	n =28
	within		2.69	13.78	32.92	T =17
Cereal production yield	overall	1448.61	1203.25	110.07	9453.70	N =476
	between		1150.63	343.23	6576.75	n =28
	within		410.43	-1274.80	4325.57	T =17
Property rights	overall	41.81	15.56	10.00	75.00	N = 451
	between		13.12	20.67	70.29	n =28
	within		8.94	20.47	71.14	T̅= 16.11
Freedom from corruption	overall	29.43	12.84	10.00	70.00	N = 451
	between		11.09	14.94	55.06	n =28
	within		6.97	4.37	53.19	T̅= 16.11
Fiscal freedom	overall	68.52	10.40	41.00	92.50	N = 451
	between		8.30	55.45	84.48	n =28
	within		6.56	44.39	91.57	T̅= 16.11
Government spending	overall	76.78	14.65	5.90	97.60	N = 451
	between		13.34	33.30	91.24	n =28
	within		6.58	41.76	95.76	T̅= 16.11
Business freedom	overall	58.41	11.20	32.90	85.00	N = 451
	between		8.86	38.57	76.09	n =28
	within		7.30	31.26	85.05	T̅= 16.11
Monetary freedom	overall	73.75	8.67	12.20	90.40	N = 451
	between		4.94	56.43	80.81	n =28
	within		7.15	29.52	94.62	T̅= 16.11

Table A-2. (Continued)

Variable		Mean	Std. Dev.	Min	Max	Obs.
Trade freedom	overall	58.08	15.37	0.00	89.00	N = 451
	between		8.15	42.11	71.07	n =28
	within		13.11	1.69	86.68	$\overline{T}$= 16.11
Investment freedom	overall	49.91	13.87	10.00	90.00	N = 451
	between		10.07	27.19	62.69	n =28
	within		9.90	22.26	77.22	$\overline{T}$= 16.11
Financial freedom	overall	46.67	14.91	10.00	70.00	N = 451
	between		11.30	26.92	68.82	n =28
	within		10.16	18.55	78.55	$\overline{T}$= 16.11
Oil selling countries	overall	0.14	0.35	0.00	1.00	N =476
	between		0.36	0.00	1.00	n =28
	within		0.00	0.14	0.14	T =17
Middle income countries	overall	0.32	0.47	0.00	1.00	N =476
	between		0.48	0.00	1.00	n =28
	within		0.00	0.32	0.32	T =17
Low income countries	overall	0.46	0.50	0.00	1.00	N =476
	between		0.51	0.00	1.00	n =28
	within		0.00	0.46	0.46	T =17
Fragile low income countries	overall	0.07	0.26	0.00	1.00	N =476
	between		0.26	0.00	1.00	n =28
	within		0.00	0.07	0.07	T =17
Health expenditure	overall	5.79	2.72	2.09	22.19	N =476
	between		2.52	2.62	16.39	n =28
	within		1.12	-1.29	11.59	T =17
Ethnical fractionalization	overall	67.42	20.74	5.82	93.02	N =476
	between		21.10	5.82	93.02	n =28
	within		0.00	67.42	67.42	T =17
Armed conflicts	overall	0.16	0.36	0.00	1	N =476
	between		0.27	0.00	1	n =28
	within		0.24	-0.79	1.1	T =17

N is the number of total observations for each variable, n is the number of cross-sections (countries), T is the number of longitudinal observations for each country (years), and $\overline{T}$ is the average number of longitudinal observations for the variables with missing data.

Source: Australian Government Website (http://australia.gov.au/).

Figure A-1. Map of Sub-Saharan Africa countries.

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EXCHANGE RATE VOLATILITY AND AGRICULTURAL TRADE FLOWS: THE CASE OF THE UNITED STATES AND OECD COUNTRIES*

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ABSTRACT

This study documents the effect of exchange rate volatility and the real exchange rate on bilateral agricultural trade flows between the United States and OECD countries. In addition, implementation of Free Trade Agreements (FTAs) and use of the Euro as a national currency are investigated to determine their impacts. The Gravity Model was applied to bilateral trade flow panel data from 1970 to 2010. Results show that exchange rate volatility and the real exchange rate have a statistically significant and negative effect on both agricultural and non-agricultural trade flows. Exchange rate volatility is found to have a greater impact on the agricultural sector, while the real exchange rate has a greater impact on the non-agricultural sector. Effects of FTAs and the Euro are always found to be positive, with FTAs having a greater impact on the agricultural sector and the Euro on the non-agricultural sector.

Keywords: bilateral agricultural trade, exchange rate volatility, United States, OECD, gravity equation

1. INTRODUCTION

Economists have been interested in exchange rate volatility and its effect on trade flows since the system of fixed exchange rates (Bretton Woods System) was abandoned in the 1970s. Empirical evidence suggests that international markets have become more vulnerable to volatile exchange rates which are usually believed to have a negative effect on the level of

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exports (Cushman 1998, Thursby and Thursby 1987). However, some researchers documented a positive trade flow effect stemming from a volatile exchange rate (Klein 1990; Jozsef 2011). Exchange rate volatility can have a negative effect on international trade flows, either directly through uncertainty and adjustment costs or indirectly through its effect on the allocation of resources and government policies. The volatile nature of exchange rates might lead risk-averse traders to reduce their trading activities which would reduce the scale and scope of international trade flows.

Many believe that international trade liberalization over the past four decades, along with an increase in cross-border financial transactions, has increased exchange rate volatility (Chit et al. 2010; Clark, Tamirisa, and Wei 2004). In contrast, the use of credit and hedging instruments in financial markets, proliferation of multinational firms, continued agricultural support policies, and currency stabilization efforts of central banks and monetary authorities may have contributed to the positive effect of exchange rate volatility on trade flows (Clark, Tamirisa, and Wei 2004). In this light, many empirical studies have tried to determine the net effect of exchange rate volatility on trade flows. However, results from the previous studies are ambiguous.

For example, Dell'Ariccia (1999) found a negative effect of exchange rate volatility on international trade flows. The results hold even after controlling for simultaneity bias from the endogenous behavior of monetary authorities. Similarly, Kandilov (2008) documented a negative impact of exchange rate volatility on bilateral trade flows. What is fascinating is that the impact was larger in the agricultural sector and even worse in the case of developing countries.

In addition, Pick (1990), Cho, Sheldon and McCorriston (2002), Wang and Barrett (2007) and Chit et al. (2010) showed that exchange rate volatility has had a negative impact on trade flows. On the other hand, Klein (1990), Pick (1990), Broll and Eckwert (1999), and Jozsef (2011) are some of the previous studies that reported a positive impact of exchange rate volatility on both agricultural and non-agricultural trade flows.

Schuh (1974) originally raised the issue of the exchange rate and its effects on agricultural trade flows. His effort was followed by several other studies where the effect of the nominal exchange rate and the real exchange rate were quantified. Carter and Pick (1989) found that market factors other than changes in the exchange rate have had the primary impact on U.S. agricultural trade flows. On the other hand, Doroodian et al. (1999) found a significant effect of exchange rate fluctuations on U.S. agricultural trade flows. Later in the 1990s, Pick looked at the effect of exchange rate volatility on agricultural trade flows. Since then, most studies in agricultural trade have concentrated on exchange rate fluctuations and the impact on agricultural exports and/or agricultural commodity prices (Kristinek and Anderson 2002).

Over the past several years, economists have recognized the influence and importance of the exchange rate on international agricultural trade flows. Agricultural producers have been both more sensitive to and interested in the role of exchange rates in determining commodity prices. However, for many years, the role of exchange rates as a primary determinant of trade flows was overlooked.

Many researchers have examined the influence of exchange rate movement on agricultural trade but disagreement persists as to the magnitude of the effect. In this study, we look at the effect of the real exchange rate and exchange rate volatility on bilateral agricultural trade flows between the United States and Organization for Economic Cooperation and Development (OECD) countries.

In addition to exchange rate volatility, this study incorporates the real exchange rate level in the model because traders' decision on where and when to trade depends on the exchange rate level as well. Most of the previous studies used export flows and total trade flows (exports + imports) interchangeably. However, we expect some difference on the impact of exchange rate volatility on export and import flows. The difference may arise from a simple distinction, such as importing sector concerns with domestic demand whereas the exporting sector takes account of foreign demand and domestic supply conditions. Therefore, in addition to the effect on combined trade flows, the effect of exchange rate volatility and the real exchange rate on both export and import flows are estimated separately.

In this study, we estimate the effect of long run exchange rate volatility on international trade flows. In the short run, exchange rate risk can be mitigated with risk management instruments, such as hedging and credit opportunities provided by central banks. In the long run, however, the exchange rate market can go through "sustained misalignment" which is costly to hedge against (Peree and Steinherr 1989). In that sense, short run exchange rate volatility may not affect trade flows, unlike long run volatility.

The rest of the article is organized as follows. First, an overview of U.S. – OECD agricultural trade as well as trade in other sectors is presented. Next, a section containing theoretical and econometric specifications of the gravity model is presented followed by an overview of the dataset and the first difference method of measuring exchange rate volatility. Empirical results are then reported and discussed, followed by conclusions.

2. U.S.–OECD AGRICULTURE TRADE

The United States is viewed as a large market in that it is the largest importer of goods and services, as well as one of the largest exporters in the world. The largest U.S. trade partners are also members of OECD.

There is a long-standing history of trade between the United States and OECD countries. In 2010, 64.6 % of total U.S. exports were exported to OECD[1] countries, with Canada being the largest U.S. export destination, followed by Mexico, Japan, the United Kingdom, and Germany (table 1). In the same year, 56.25% of total imports into the United States came from OECD countries (table 2). Canada was the largest importer followed by Mexico, Japan, Germany, the United Kingdom and South Korea. Distribution of import share is similar to that of export share.

The United States is also a large agricultural exporter, with U.S. farm product exports going primarily to OECD countries. The top 15 US agricultural export markets are also OECD members. For example, in 2010, Canada, which imported 15.25% of U.S. agricultural exports, was the largest agricultural export destination followed by China (13.87%), Mexico (12.82%), Japan (10.33%) and the EU (7.83%) (USDA, 2001). Figure 1 illustrates the pattern of U.S.–OECD agricultural trade flows over the past four decades. In general, agricultural trade flows between the United States and OECD countries have increased (figure 1).

[1] In this particular case, OECD includes only 28 out of 34 countries. The Czech Republic, Estonia, Slovakia, Slovenia, and Luxemburg are not included given lack of data availability. Belgium incorporates Luxemburg as well.

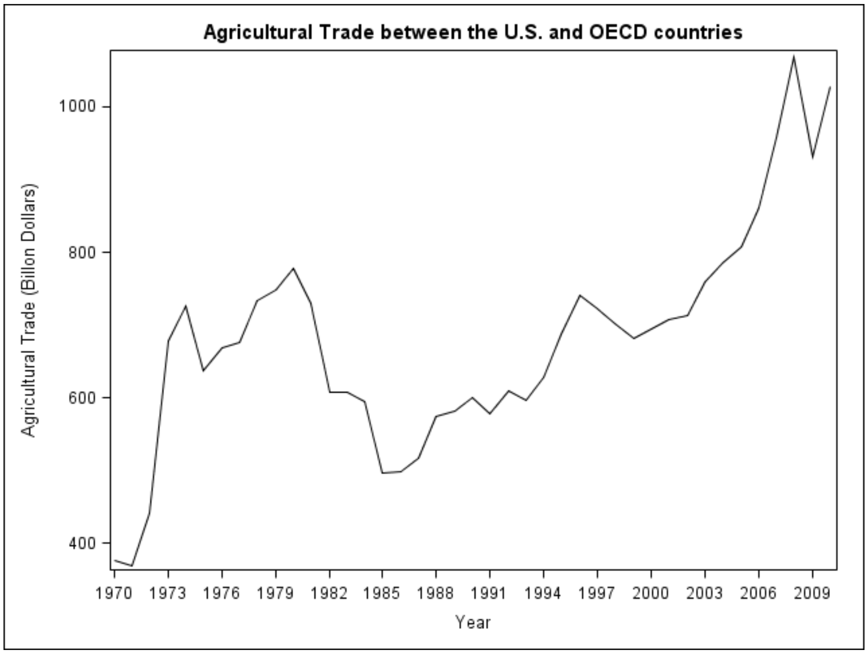

Figure 1. Agricultural trade flows between the United States and OECD countries (1970-2010).

Table 1. U.S. export destinations and share of total export by OECD countries in 2010

S.N.	Partner	% of Total Exports	S.N.	Partner	% of Total Exports
1	Canada	19.416	15	Turkey	0.822
2	Mexico	12.777	16	Spain	0.794
3	Japan	4.736	17	Ireland	0.569
4	United Kingdom	3.788	18	Sweden	0.367
5	Germany	3.758	19	Norway	0.243
6	Korea	3.039	20	Poland	0.233
7	Netherlands	2.738	21	New Zealand	0.221
8	France	2.173	22	Austria	0.181
9	Belgium	1.999	23	Finland	0.171
10	Australia	1.661	24	Denmark	0.166
11	Switzerland	1.619	25	Hungary	0.101
12	Italy	1.110	26	Greece	0.087
13	Israel	0.882	27	Portugal	0.083
14	Chile	0.851	28	Iceland	0.049
OECD		64.632			

Table 2. U.S. import sources and share of total imports by OECD countries in 2010

S.N.	Partner	% of Total Imports	S.N.	Partner	% of Total Imports
1	Canada	14.598	15	Spain	0.464
2	Mexico	12.122	16	Australia	0.458
3	Japan	6.458	17	Chile	0.390
4	Germany	4.410	18	Norway	0.376
5	United Kingdom	2.646	19	Austria	0.361
6	Korea	2.645	20	Denmark	0.321
7	France	2.048	21	Turkey	0.231
8	Ireland	1.779	22	Finland	0.211
9	Italy	1.538	23	Poland	0.162
10	Israel	1.109	24	New Zealand	0.154
11	Netherlands	1.023	25	Hungary	0.133
12	Switzerland	1.019	26	Portugal	0.116
13	Belgium	0.830	27	Greece	0.044
14	Sweden	0.568	28	Iceland	0.040
	OECD	56.253			

Although minor fluctuations are observed, there was a consistent increase in agricultural trade flows from 1984 to 2010. The constant growth in agricultural trade between the United States and OECD countries could be attributed to various factors, for example, technological growth, income growth, increased availability of hedging opportunity, and implementation of Free Trade Agreements[2] (FTAs). This paper attempts to determine the effects of exchange rate volatility on agricultural trade flows by incorporating the aforementioned factors in the model. We expect that the GDP growth over time captures both technological change and income growth.

3. Methodology and Data

The gravity model is based on Newton's law of universal gravitation which describes the gravitational force between two masses as a result of the product of the masses divided by the squared distance between the two objects, multiplied by a gravitational constant. This relationship was first used in the early 1960s by both Pöyhönen and Tinbergen to describe bilateral trade flows between nations while Linneman later employed the Gravity Model in his exhaustive study on world trade flows (Deardorff 1998). In Linneman's model, variables that tended toward a more theoretical justification of the Gravity Model as opposed to the more intuitive arguments of Pöyhönen and Tinbergen were added (Deardorff 1998). In 1974, Leamer employed both the Gravity Model and the Heckscher-Ohlin model to lend credence

[2] The United States has four Free Trade Agreements (FTAs) with five member countries of OECD; they are a) the North American Free Trade Agreement (NAFTA), b) the U.S.–Australia FTA, c) the U.S.–Israel FTA, and d) the U.S.–Chile FTA.

as to the motivation for the explanatory variables in his regression analysis of trade flows. However, Leamer refrained from combining the Gravity Model and the Heckscher-Ohlin model together theoretically (Leamer 1974). Bergstrand posited that by assuming CES preferences and accepting the Armington assumption for traded goods, a reduced form equation for the estimation of the flow of goods between nations could be obtained (Bergstrand 1985).

The fundamental economic principle of the gravity model resides on properties of expenditure systems with the maintained hypothesis of identical homothetic preferences across regions (Anderson 1979). Anderson rearranged the Cobb-Douglas expenditure system assuming complete specialization, no tariff and transportation costs, and identical Cobb-Douglas preferences in each country i and j. The complete specialization guarantees that country i produces good i only and country j produces good j only. If trade occurs, country i imports good j and vice versa. Therefore, the value of consumption of good i in country j is $M_{ij} = b_i Y_j$, where Y_j is income in country j, and b_i is fraction of income spent on product i. Consequently, country i's total income equals country j's total expenditure on good i, i.e. $Y_i = b_i(\sum_j Y_j)$. Thus, the value of the consumption of good i in country j is $M_{ij} = \frac{Y_i Y_j}{\sum_j Y_j}$, which gives the fundamental form of the gravity equation as outlined in Anderson (1979). In other words, if countries i and j are producing differentiated products with economies of scale, which leads to specialization in production, then the share of country i and j in world's spending and their GDP provide a theoretical explanation of the gravity model (Helpman 1987).

Anderson's gravity equation has been modified by several researchers to obtain a relaxed gravity equation (Deardorff 1998; Anderson and van Wincoop 2003). Anderson and van Wincoop's (2003) exposition is more flexible and provides an operational form of the gravity equation. Assuming compete product specialization and homothetic preferences, they extended Anderson's (1979) basic model by incorporating transaction cost of trade (t_{ij}) between countries i and j and respective price indices (P_i and P_j). Thus, the value of exports from country i to j now depends on income, transaction cost, and price indices, $M_{ij} = \frac{Y_i Y_j}{\sum_j Y_j} . (\frac{t_{ij}}{P_i P_j})^{\frac{1}{1-\sigma}}$ where σ is elasticity of substitution between goods i and j. This equation provides the fundamental theoretical explanation of the gravity model.

The basic gravity model has been used extensively in the international trade literature (Chit et al. 2010; Wang et al. 2010; Kandilov 2008; Clark, Tamirisa and Wei 2004; Cho, Sheldon, and McCorriston 2002; Dell'Ariccia 1999). The gravity model and its use in empirical studies of international trade flows is substantiated because of its ability to include a wide range of variables such as border effects, language, infrastructure availability, custom union effects, exchange rate volatility, historical and colonial ties and so on (Dell'Ariccia 1999).

Use of the gravity model in estimating bilateral trade flows is validated through the theoretical literature that has developed the microeconomic foundations for the gravity model (Helpman 1987). Furthermore, this model is characterized by its widespread use under the auspices of imperfect competition and intra-industry trade (Doroodian, Jung, and Boyd 1999). The basic economic logic behind this model is that bilateral trade volume between two countries is directly proportional to the product of their respective GDPs but inversely proportional to transaction costs as proxied by geographical distance. Since longer distance between trade partners and fluctuating exchange rates both can increase the transaction cost of trade, exchange rate volatility between two countries may augment the effect of the distance between them. Thus, distance and exchange rate volatility are assumed to be inversely proportional to bilateral trade flows (Dell'Ariccia 1999).

Mathematically,

$$TRADE_{ijt} \sim \frac{1}{(DIST_{ij}).(EXV_{ijt})}, \text{ and } TRADE_{ijt} \sim GDP_{ijt}.POP_{ijt}.$$

Therefore,

$$TRADE_{ijt} = \beta_0.\frac{(GDP_{ijt})^{\beta_2}.(POP_{ijt})^{\beta_3}}{(EXV_{ijt})^{\beta_1}.(DIST_{ij})^{\beta_4}} \tag{1}$$

where $TRADE_{ijt}$ is bilateral trade flows between countries *i* and *j* at time *t*, GDP_{ijt} is the product of the GDPs of countries i and j at time t, and POP_{ijt} is the product of the populations of countries *i* and *j* at time *t*. Similarly, $DIST_{ij}$ is a geographical distance between trading countries *i* and *j* and EXV_{ijt} is a measure of exchange rate volatility between countries *i* and *j* at time *t*. Among additional variables, $LANG_{ij}$ equals 1 if the US and its trade partner use the same language and 0 otherwise, $BORDER_{ij}$ equals 1 if the countries share a common border and 0 otherwise. Similarly, EURO_{ijt} equals 1 if the country is a member of European Union and 0 otherwise. Finally, FTA_{ijt} equals 1 if the country is a member of a Free Trade Agreement (FTA) with the United States and 0 otherwise.

The aforementioned specification of the gravity model is slightly modified in this study. Particularly, instead of using the product of the respective GDPs and the product of trade partners' populations separately, the product of GDP and population – defined as the *economic mass* of the country – is used. In the gravity model, economic mass of a country is directly proportional to trade flows from and to the country. That is,

$$TRADE_{ijt} \sim EM_{it}.EM_{jt}.$$

Therefore,

$$TRADE_{ijt} = \exp(\beta_0).\frac{(EM_{it})^{\beta_2}.(EM_{jt})^{\beta_3}}{\exp(\beta_1\, EXV_{ijt}).(DIST_{ij})^{\beta_4}} \tag{2}$$

where EM_{it} and EM_{jt} are the economic mass for countries *i* and *j* at time *t*, respectively. Equation (2) is simply a redefined version of equation (1), where GDP and population are replaced by economic mass and exchange rate volatility is exponentiated for ease of econometric specification as described later. As far as the constant β_0 is concerned, using an exponentiated β_0 in place of β_0 is equivalent in the sense that both of them are arbitrary constants.

3.1. Econometric Specifications

Following the previous literature, the gravity equation is used to model the determinants of bilateral agricultural export flows between the U.S. and OECD countries. Equation (3) provides the detailed specifications.

$$AGEXP_{ijt} = \exp(\beta_0).\frac{(EM_{it})^{\beta_2}.(EM_{jt})^{\beta_3}}{\exp(\beta_1 EXV_{ijt}).(DIST_{ij})^{\beta_4}} \quad (3)$$

where $AGEXP_{ijt}$ is the agricultural export flows between countries *i* and *j* at time *t*, respectively. Country *i* is always the home country (i.e. the United States) and country *j* is the foreign country. A preliminary estimating equation is obtained when (3) is log-linearized and the dummy variables are added to the transformed equation:

$$\ln(AGEXP_{ijt}) = \beta_0 + \beta_1 EXV_{ijt} + \beta_2 \ln EM_{it} + \beta_3 \ln EM_{jt} + \beta_4 \ln DIST_{ij} + \beta_5 Euro_{jt} + \beta_6 FTA_{ijt} + \beta_7 LANG_{ij} + \beta_8 BORDER_{ij} + \varepsilon_{ijt} \quad (4)$$

where ε_{ijt} is an error term varying with time and assumed to have conditional mean of '0' and be independent from other explanatory variables. Although estimating economic mass as a single variable restricts GDP and Population to have the same coefficient, mathematically there is nothing wrong in doing so[3]. As equation (4) is to be estimated by a fixed-effect model, the time invariant variables, $DIST_{ij,}$ $LANG_{ij}$, and $BORDER_{ij}$ are dropped out of the equation. In addition, a variable for the real exchange rate level is also added to obtain equation (5) as follows:

$$\ln(AGEXP_{ijt}) = \gamma_0 + \gamma_1 EXV_{ijt} + \gamma_2 RER_{ijt} + \gamma_3 \ln EM_{it} + \gamma_4 \ln EM_{jt} + \gamma_5 FTA_{ijt} + \gamma_6 EURO_{jt} + v_{ijt}, \quad (5)$$

where γ_0 is an intercept term which is different from β_0 in equation (4). Now the effect of time invariant variables and any other simultaneous variables is captured by the intercept term. In fact, the intercept term γ_0 is defined as $\gamma_0 = \beta_0 + \alpha_{ij}$, where α_{ij} accounts for the country pair specific effect and effect of any other time invariant variables and is known as the fixed effect.

A policy measure can be taken as a time invariant variable and therefore the fixed effect model is an easy solution to the problem of possible simultaneity bias that arises from policy measures, for example the currency stabilization efforts of central banks and monetary authorities. Moreover, the error term in equation (5), v_{ijt} is different from the error in equation (4), ε_{ijt}. However, both of the error terms have conditional mean of zero and are assumed to have identical variances.

$E(\varepsilon_{ijt}) = E(v_{ijt}) = 0$, and
$Var(\varepsilon_{ijt}) = \sigma_E{}^2$, and $Var(v_{ijt}) = \sigma_V{}^2$

[3] As defined above, $EM_{it} = GDP_{it} \times POP_{it}$, if we log linearize both sides we obtain, $\ln(EM_{it}) = \ln(GDP_{it} \times POP_{it}) = \ln(GDP_{it}) + \ln(POP_{it})$. Therefore, mathematically, natural log of an economics mass of a country at time t is equivalent to summation of natural log of GDP and population of the same country at time t.

Equation (5) is estimated nine times by replacing the explained variable $AGEXP_{ijt}$ with eight other variables. Not only is the explained variable replaced, but the same equation is estimated three times with different sets of right hand side variables. The first equation includes both exchange rate volatility (EXV_{ijt}) and the real exchange rate (RER_{ijt}). For each OECD member country, RER_{ijt} is defined as US Dollar (USD) per respective country's national currency. The second equation includes exchange rate volatility and the third equation includes real exchange rate. Therefore, in addition to (5), two other equations (6) and (7) are also estimated:

$$ln\ (AGEXP_{ijt}) = \alpha_0 + \alpha_1 EXV_{ijt} + \alpha_2 ln\ EM_{it} + \alpha_3\ ln\ EM_{jt} + \alpha_4 FTA_{ijt} + \alpha_5\ EURO_{jt} + u_{ijt} \quad (8)$$

$$ln\ (AGEXP_{ijt}) = \mu_0 + \mu_1 RER_{ijt} + \mu_2 ln\ EM_{it} + \mu_3\ ln\ EM_{jt} + \mu_4 FTA_{ijt} + \mu_5\ EURO_{jt} + z_{ijt} \quad (7)$$

As in the case of v_{ijt} in equation (5), the error terms u_{ijt}, and z_{ijt} in equations (6) and (7) also satisfy the properties of conditional mean and homogenous variance. Similarly, the intercept terms μ_0 and α_0 include the respective fixed effects. In total, there are nine different dependent variables for three different estimating equations which yield a total number of twenty seven equations to be estimated. All of the dependent variables represent trade flows as measured in monetary values. The nine dependent variables include three categories of trade flows (exports, imports, and exports plus imports) for three sectors (agricultural trade, non-agricultural trade, and the entire economy's trade).

3.2. Measurement of Exchange Rate Volatility

It is a widely accepted notion in the literature that there is a significant risk on export and import activities since exchange rates are highly variable and persistently deviated from Purchasing Power Parity (PPP). Thus, any increase in exchange rate volatility forces traders to make costly adjustments regarding production inputs and can even force them to leave the business (Dell'Ariccia 1999; Kandilov 2008; Cho, Sheldon, and McCorriston 2002; Wang and Barrett 2007). However, finding an appropriate measure of exchange rate volatility has been a key to understand the potential effect of exchange rate volatility on trade flows. Although various measures have been employed in the literature, there is no general consensus on choosing an appropriate variable to represent the variability of the exchange rate.

Among the previous literature, most studies have used some variant of the standard deviation of the real exchange rate in level (Cho, Sheldon, and McCorriston 2002). Some of the measures that have been frequently used in the literature are the moving standard deviation of the first difference of the logarithmic real exchange rate, the standard deviation of the percentage change in the real exchange rate, and the standard deviation of the real exchange rate obtained from a first-order autoregressive equation. In recent years, use of various forms of Autoregressive Conditional Heteroskedasticity (ARCH) approaches, for example GARCH (1, 1), has become very common (Kandilov 2008; Cho, Sheldon, and McCorriston 2002). This approach is capable of estimating exchange rate variability by conditioning the variance and allowing it to change over time based on past errors (Bollerslev 1986).

In this study, we use the first difference method to construct a measure of exchange rate volatility. This is consistent with similar studies in the past, such as Cho, Sheldon, and McCorriston (2002) and Kandilov (2008). However, unlike previous studies, our exchange rate volatility is based on the real exchange rate rather than the nominal exchange rate. The choice of the real exchange rate to construct an exchange rate volatility measure is guided by fundamental economic reasoning. Theoretically, it is assumed that profits are affected by the nominal exchange rate as well as commodity prices. In other words, a trader's decision whether to take part in trading activity largely depends upon commodity prices even if there is fixed exchange rate system. Therefore, the real exchange rate is used so as to account for inflationary pressures and other price information in model specification.

Time varying volatility in the bilateral real exchange rate between countries *i* and *j* is estimated using the equation below:

$$EXV_{ijt} = \sqrt{\frac{\sum_{k=1}^{n}(X_{ij,(t-k)} - \mu_{ijt})^2}{9}}$$

where $X_{ijt} = \ln e_{ijt} - \ln e_{ijt-1}$ is the first difference of logarithmic exchange rate, e_{ijt} is real exchange rate between countries *i* and *j* at time *t* and $\mu_{ijt} = \frac{\sum_{k=1}^{10} X_{ij,t-k}}{10}$ is the mean of X_{ijt} over 10 years. This formula assures that exchange rate volatility at time *t,* say 1970, depends on real exchange rates in the previous 10 years, in this case 1959 to 1969.

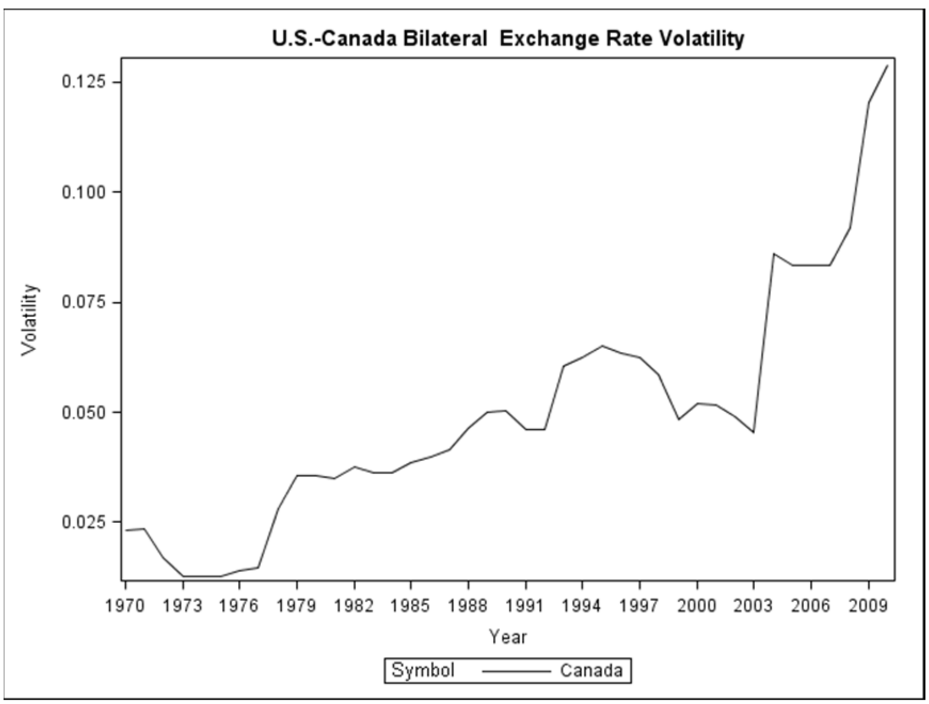

Figure 2. U.S.- Canada bilateral exchange rate volatility.

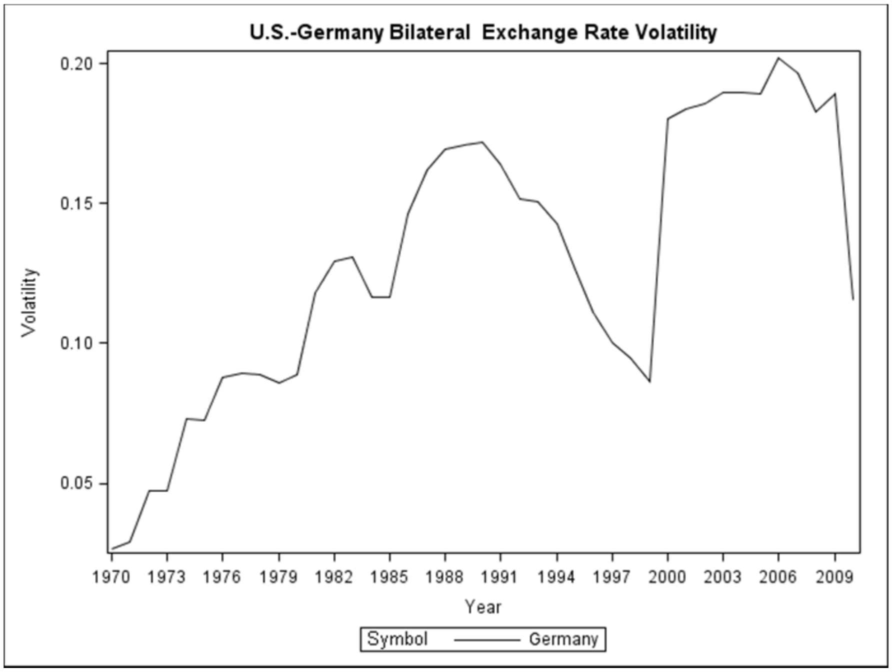

Figure 3. U.S.- Germany bilateral exchange rate volatility.

A calculated measure of exchange rate volatility between the U.S. and Canada is presented in figure 2. As the figure shows, U.S.-Canada exchange rate volatility has generally risen over time with a very high degree of volatility for the periods of 2003-04 and 2008-09.

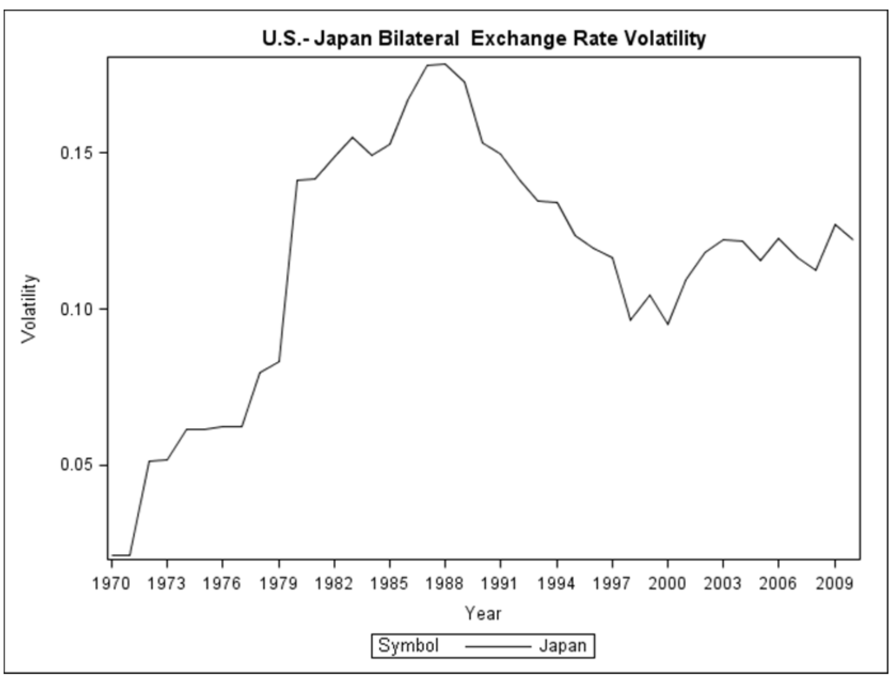

Figure 4. U.S.- Japan bilateral exchange rate volatility.

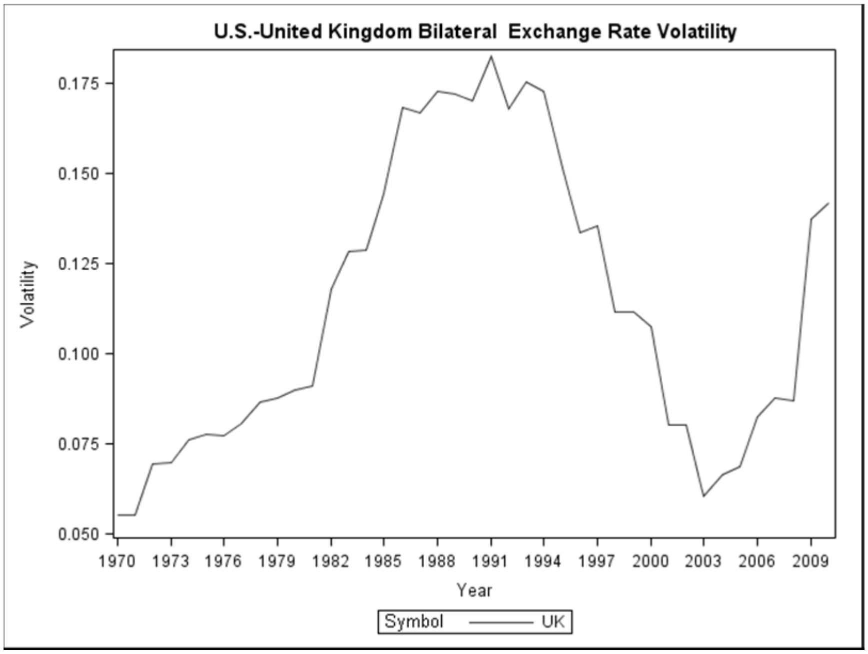

Figure 5. U.S.- U.K. bilateral exchange rate volatility.

The increasing trend of volatility makes forecasting the exchange rate difficult and significantly impacts trading activities between the United States and Canada. The unpredictability of the exchange rate decreases traders' ability to make forward contracts for future trade activities reducing overall trade flows. This anomaly is more prominent in the agricultural sector as agricultural products tend to be perishable and cannot be stored for a long period of time.

Similarly, figures 3, 4, and 5 portray exchange rate volatility between the United States and Germany, Japan, and the United Kingdom, respectively. It is clear that none of the countries have exhibited a stable exchange rate relationship with the United States over the past four decades. Exchange rates between the U.S. dollar (USD) and Canadian dollar appear to be the most volatile with increasing volatility throughout. The USD – British Pound Sterling (BPS) exchange market shows a trend of decreasing volatility from 1991 to 2003. However, there is a continuous increase in USD – BPS volatility after 2003 (figure 5). Exchange rate volatility between the U.S. and other European countries is represented by U.S.-German volatility. Similarly, Japan provides an example of exchange rate volatility for non-European countries.

3.3. Data

Annual data for the past 41 years (1970-2010) were used so that the long run volatility of the exchange rate and its effect on trade flows could be captured. The data consists of 41 time periods and 28 cross sections (countries) giving us an appropriate sample size for reasonable econometric estimation. The bilateral total exports and imports data came from the United Nation's Commodity Trade (COMTRADE) database and are disaggregated as per SITC Rev.

1 for the period 1970-1977 and as per SITC Rev. 2 for the period of 1978-2010. Similarly, data on agricultural exports and imports values came from the Global Agricultural Trade System (GATS) of the United States Department of Agriculture (USDA). Moreover, data on GDP and population were obtained from the World Bank's World Development Indicators (WDI) and Global Development Finance.

It is important to note that both the bilateral exports, imports and GDP data values are in current U.S. dollars and therefore are converted to constant 2005 U.S. dollars using the U.S. Consumer Price Index (CPI, 2005=100). Moreover, CPI and bilateral nominal exchange rate date comes from the International Monetary Fund's International Financial Statistics (IFS). Nominal exchange rates are in USD per National Currency (NC) and are deflated using both the United States and respective partner country's CPI (2005=100) to obtain the real exchange rate (USD/NC). The exchange rate volatility variable is constructed using real exchange rate data as described in section 3.3. Dummy variables are used for Euro and FTA. They represent the use of the Euro as a national currency and membership in a free trade agreement with the United States, respectively.

3.4. Heteroskedasticity and Simultaneity

Despite multiple advantages of using panel data, there are some econometric issues that need to be addressed before estimating the model. A problem with heteroskedasticity in panel data analysis arises when a large country trades with a smaller country or two smaller countries trade between themselves (Frankel 1997). The problem can be addressed by using heteroskedasticity corrected standard errors. However, no heteroskedasticity consistent standard errors are used in this study. In fact, even if it is present, "heteroskedasticity does not affect the consistency of the estimators, and it is only a minor nuisance for inference" (Wooldridge 2002).

Another problem frequently faced by researchers in similar studies is the problem of simultaneity bias. Dell'Ariccia (1999) and Cho, Sheldon, and McCorriston (2002) identified the currency stabilization effort by the central bank or monetary authority as a potential source of simultaneity bias. In their words, "when exchange rate uncertainty affects trade between two countries, a national government or central bank may have attempted to stabilize the exchange rate between major trading partners". The stabilization effort that usually comes to improve the notoriously volatile exchange rate should be included in the estimating model to obtain an unbiased estimate.

Dell'Ariccia (1999) proposed the following solution to the potential source of simultaneity bias:

$U_{ijt} = \alpha_{ijt} - \beta \frac{T_{ijt}}{T_{it}} - \gamma \frac{T_{jit}}{T_{jt}} + \varphi_{ijt}$, where U_{ijt} is exchange rate uncertainty between country *i* and *j* at time *t* and $\frac{T_{ijt}}{T_{it}}$, and $\frac{T_{jit}}{T_{jt}}$ are exports from country *i* to *j* and *j* to *i* relative to *i*'s and *j*'s total exports, respectively. The coefficients β and γ represent the stabilization effort functions of central banks of country *i* and *j*, respectively. If bilateral trade shares are more or less constant over time, then the equation reduces to the following form:

$$U_{ijt} = \alpha_{ijt} + \theta_{ij} + \varphi_{ijt}.$$

In this case, the central bank's effort is assumed to be constant over time and taken as a fixed effect. Therefore, estimating the equation as a fixed effect model corrects for simultaneity bias and yields an unbiased estimate.

4. RESULTS AND DISCUSSION

Table 3 presents the effect of exchange rate volatility on bilateral trade flows between the United States and OECD countries. Exchange rate volatility has a significant negative impact in all three kinds of trade flows, agricultural, non-agricultural, and total. The magnitude of impact is larger in the agricultural sector as compared to the non-agricultural sector in all three categories: exports, imports, and total trade flows. For example, a one unit increment in exchange rate volatility decreases agricultural exports from the United States to OECD countries by approximately[4] 16.8% and non-agricultural exports by 9.5%. At the same time, total exports decrease by 20.8% (table 3).

Table 3. Effect of exchange rate volatility (EXV) on U.S.– OECD trade flows

Sector	Type of Flows		
	Export	Import	Total (export + import)
Agricultural	-0.168*** (0.049)	-0.234*** (0.041)	-0.209*** (0.036)
Non-Agricultural	-0.095*** (0.028)	-0.146*** (0.039)	-0.124*** (0.028)
Total	-0.208*** (0.027)	-0.184*** (0.033)	-0.198*** (0.026)

Note: Standard errors are in parentheses. The asterisks ***, **, and * indicate level of significance at 1%, 5% and 10% level, respectively.

This result is consistent with Kandilov (2008), and Cho, Sheldon, and McCorriston (2002) where they found a significant negative effect of exchange rate volatility on bilateral export flows. They further reported a larger impact on the agricultural sector as compared to other sectors.

The effects of exchange rate volatility on U.S. imports are also presented in table 3. As expected, exchange rate volatility has a highly significant and negative effect on all types of import flows. The magnitude of impact is larger on agricultural imports than on that of non-

[4] As the dependent variable is log linearized and independent variables are not, interpretation of coefficients is critical. In general, a one unit change in the independent variable results in β_i x100% change in the dependent variable holding all else constant. However, the exact % change can be calculated using back transformation. Consider equation (5): $\ln(TRADE_{ijt}) = \gamma_0 + \gamma_1 EXV_{ijt} + \gamma_2 RER_{ijt} + \gamma_3 \ln EM_{it} + \gamma_4 \ln EM_{jt} + \gamma_5 FTA_{ijt} + \gamma_6 EURO_{jt}$. Back transforming equation (5) yields:

$TRADE_{ijt} = e^{\gamma 0} + e^{\gamma 1 EXVijt} + e^{\gamma 2 RERijt} + e^{\gamma 3} EM_{it} + e^{\gamma 4} EM_{jt} + e^{\gamma 5\ FTAijt} + e^{\gamma 6\ EUROjt}$.

Replacing coefficients and variables with given values, we obtain the value of trade, say for 1970, and then can easily find the percent change in value of trade with 1 unit change in the independent variable. For simplicity, this analysis uses the approximate percent change, i.e. β_i x100%.

agricultural and total imports. Particularly, a one unit increase in exchange rate volatility reduces U.S. agricultural, non-agricultural, and total imports from OECD countries by 23.4%, 14.6%, and 18.4%, respectively.

When exchange rate volatility increases, risk-averse traders either leave the business and greatly reduce their production activities, or require a risk premium to maintain their previous level of economic activity. Those who stay in business are often forced to adjust their production costs by reducing the size of their production facilities and the volume of production (Dell'Ariccia 1999; Kandilov 2008; Cho, Sheldon, and McCorriston 2002). Other traders, who are risk takers, increase their export prices to offset the potential losses from the associated risk. This makes markets vulnerable and reduces export flows. Moreover, the volatile exchange rate indirectly reduces trade flows by distorting the allocation of resources and government policies (Orden 2002).

Table 4. Effect of the real exchange rate (RER) on U.S.– OECD trade flows

Sector	Type of Flows		
	Export	Import	Total (export + import)
Agricultural	-0.465*** (0.097)	-0.253*** (0.082)	-0.334*** (0.072)
Non-Agricultural	-0.247*** (0.055)	-0.766*** (0.075)	-0.509*** (0.054)
Total	-0.313*** (0.053)	-0.672*** (0.064)	-0.526*** (0.051)

Note: Standard errors are in parentheses. The asterisks ***, **, and * indicate level of significance at 1%, 5% and 10% level, respectively.

The effect of the real exchange rate on exports, imports, and total trade between the United States and OECD countries is presented in table 4. The real exchange rate has a significant negative impact on all types of export flows, with the largest impact on agricultural exports (-0.465). On average, an increase in the real exchange rate by one USD per foreign currency decreases U.S. agricultural exports to OECD countries by 46.5%. The same change in the real exchange rate reduces non-agricultural and total exports by 24.7% and 31.3%, respectively. The exchange rate is measured as USD per foreign currency and therefore any decrease in the real exchange rate depreciates the U.S. dollar. When the dollar weakens, U.S. export prices are reduced and foreign importers will increase their imports of U.S. product. Hence, U.S. export increases with any decrease in the real exchange rate.

In practice, traders' decisions on doing business are based not only on their past experiences with exchange rate fluctuations, but also on their experiences with market rates. The combined effect of exchange rate volatility and the real exchange rate level needs to be estimated to determine how the exchange rate affects trade flows. These combined effects are presented in table 5. While taking exchange rate volatility into consideration, the real exchange rate always has a larger impact on all kinds of trade flows and its impacts are in the same direction as those of exchange rate volatility. Putting this all together, a one unit increase in the real exchange rate reduces total exports by 18.3%. The same effect in the case of agricultural and non-agricultural exports is 39.4%, and 20.5%, respectively. Likewise, a one unit increase in exchange rate volatility reduces total exports by 17.3% with a corresponding effect in the case of agricultural and non-agricultural exports of 9.3%, and 5.7%, respectively.

Table 5. Effect of EXV and RER on U.S.– OECD trade flows

Sector	Type of Flows					
	Export		Import		Total (export + import)	
	EXV	RER	EXV	RER	EXV	RER
Agricultural	-0.093* (0.052)	-0.394*** (0.105)	-0.217*** (0.044)	-0.091 (0.088)	-0.169*** (0.039)	-0.207*** (0.077)
Non-Agricultural	-0.057* (0.029)	-0.205*** (0.059)	-0.001 (0.041)	-0.765*** (0.081)	-0.032 (0.029)	-0.485*** (0.059)
Total	-0.173*** (0.028)	-0.183*** (0.057)	-0.066* (0.035)	-0.623*** (0.069)	-0.115*** (0.027)	-0.439*** (0.054)

Note: Standard errors are in parentheses. The asterisks ***, **, and * indicate level of significance at 1%, 5% and 10% level, respectively.

The effect of volatility on non-agricultural imports is negative but not significant as is the case with the effect of the real exchange rate on agricultural imports. Non-agricultural products consist of those products which can be stored until the market price is more advantageous.

Conversely, agricultural products often have to be sold irrespective of price fluctuations. In the other words, non-agricultural traders can make exports and imports an option that can be exercised when profitable. In either case, exchange rate volatility does not necessarily have a significant impact on non-agricultural trade flows.

Based on these results, it can be argued that the U.S. non-agricultural importers care more about spot exchange rate while agricultural importers pay more attention to exchange rate fluctuations.

4.1. Effects of FTAs on Exports, Imports, and Total Trade Flows

It is expected that the promotion of free trade agreements (FTAs) encourages bilateral and multi-lateral trade flows not only among the members but also with non-members. This can occur for several reasons, such as reducing the risk premium of the traders (Grant and Lambert 2008). Although there are few trade agreements between the United States and the other members of the OECD it is still expected that overall U.S.–OECD bilateral trade increases when FTAs are in force. The effect of promotion of FTAs on exports, imports and total flows between the United States and the OECD is presented in table 6.

The first row of table 4 reports the effect of FTAs on agricultural exports, imports, and total trade flows between the United States and OECD countries over the past 41 years. Similarly, the corresponding effects on the non-agricultural sector and the total economy are presented in the second and third rows of table 6, respectively. Participation in free trade agreements always has the largest impact on the agricultural sector, giving greater, but comparable, benefits to U.S. agricultural importers (63.3%) relative to U.S. agricultural product exporters (54.6%). More importantly, the effect of FTAs on the non-agricultural sector is never significant, although it is always positive. This suggests that none of the non-agricultural exporters, either in the United States or in foreign countries have gained from FTAs. This result is consistent with the findings of Grant and Lambert (2008), Sun and Reed (2010) and Rose and Wincoop (2001). They found a positive impact of regional trade agreements (RTAs) on international trade flows and that the gains are always bigger in the agricultural sector.

Table 6. Effect of FTAs on U.S.– OECD bilateral trade flows

Sector	Type of flows		
	Export	Import	Trade
Agricultural	0.546*** (0.089)	0.633*** (0.075)	0.589*** (0.066)
Non-Agricultural	0.037 (0.051)	0.046 (0.079)	0.071 (0.049)
Total	0.154*** (0.048)	0.168*** (0.046)	0.168*** (0.046)

Note: Standard errors are in parentheses. The asterisks ***, ** and * denote the level of significance at 1%, 5% and 10% level respectively.

4.2. Effects of the Euro on Exports, Imports, and Trade Flows

One of the purposes of constructing a monetary union (e.g. Eurozone) within the European Union was to promote intra-member and international trade flows (EU 1990). Given this, it is important to empirically examine the validity of this assertion. Unfortunately, none of the studies reviewed have estimated the effect of the Eurozone on international trade flows. In order to examine this assertion, a dummy variable was created, $EURO_{jt}$, which equals 1 if county *j* uses the Euro as its national currency and 0 otherwise. The effects of the Euro on exports, imports and trade flows between the United States and OECD countries are summarized in table 7.

The establishment of the Eurozone appears to have had a positive effect on international trade flows. However, unlike FTAs, the size of the impact of the Euro is larger in the non-agricultural sector than in the agricultural sector. For example, U.S. – OECD bilateral trade in non-agricultural goods increased by a coefficient of 0.465 as compared to a 0.409 increment for agricultural trade (table 7, column 4). Moreover, U.S. agricultural exports to OECD countries (or agricultural imports of the Eurozone countries) are independent of the establishment of the Eurozone (table 7, column 1, row 1).

Table 7. Effect of the Euro on U.S.–OECD bilateral trade flows

Sector	Type of flows		
	Export	Import	Trade
Agricultural	0.074 (0.107)	0.566*** (0.09)	0.409*** (0.079)
Non-Agricultural	0.131* (0.061)	0.694*** (0.083)	0.465*** (0.06)
Total	0.213*** (0.058)	0.751*** (0.071)	0.529*** (0.055)

Note: Standard errors are in parentheses. The asterisks ***, ** and * denote the level of significance at 1%, 5% and 10% level respectively.

This result makes sense both economically and practically. First, Eurozone countries account for a very small proportion of U.S. agricultural exports to OECD countries and are not a major export destination of U.S. agricultural products. Second, the relatively strong market power of the United States gives its traders increased options. They may switch exports to an alternative destination if a partner's currency exchange rate is unfavorable.

CONCLUSION

The results of this analysis indicate that both exchange rate volatility and the real exchange rate have a significant and negative effect on all types of trade flows. This outcome regarding exchange rate volatility is not surprising given expectations of how producers and consumers behave under uncertainty. Interestingly, no positive effect of the real exchange rate is observed as claimed by a number of previous studies. Economic theory suggests that a currency appreciation will result in increased imports and decreased exports. However, the expected effect of exchange rate movements on overall trade is not clearly defined.

The established notion that the agricultural sector is more responsive to exchange rate volatility is confirmed. This is consistent with theory, from the perspective that the agricultural sector has a greater degree of commodity trade than do other sectors of the economy. As commodity trade tends to be more sensitive to price fluctuations than are goods with a greater degree of processing, so too we would expect commodities to be more sensitive to exchange rate volatility.

Although exchange rate volatility always has the biggest impact on agricultural trade flows, the real exchange rate level has a bigger impact on non-agricultural imports. Similarly, the same pattern holds for agricultural and non-agricultural trade flows where the latter is more responsive to the real exchange rate. Interestingly, the results show that the impact of the real exchange rate on either kind of trade flows (exports, imports, or exports plus imports) is always bigger relative to the impact of exchange rate volatility. This result leads to the conclusion that the effect the real exchange rate has on international trade flows has been overlooked.

The positive effect of FTAs and the Euro on all three types of trade flows suggests that the adoption of free trade agreements and construction of monetary unions enhance international trade flows. Although FTAs have a greater positive impact on the agricultural sector, agricultural importers have benefitted more than have agricultural exporters. However, the effects of FTAs on the non-agricultural sector are not significant. When it comes to the effect of a monetary union on trade flows, positive effects are reported in all cases. Nevertheless, construction of the Eurozone is shown to be of most benefit to non-agricultural traders. In general, importers experience a greater positive effect than do exporters.

Future analysis should disaggregate total trade flows in order to determine the specific impact of the real exchange rate on imports and exports. At the same time, such analysis would provide more detailed information with respect to the impact of exchange rate volatility and free trade agreements on exports and imports rather than aggregate trade volumes. This information would provide greater detail for policymakers and allow for a greater degree of precision in examining the specific welfare effects of various factors on trade.

Policymakers in the United States and OECD countries have entered into numerous bilateral, regional, and multilateral free trade agreements in order to increase agricultural trade volumes among the participating countries. The overall objective of this strategy is to provide increased gains from trade. The results from this analysis show that participation in trade agreements has in fact increased agricultural trade volumes. However, our results also show that exchange rate volatility can negate these gains. While it is important that governments actively seek free trade through the removal of impediments to trade through fair and equitable trade agreements, a balanced approach must be taken to achieve a healthy trading environment. This includes developing and maintaining a stable trading environment with minimal impediments to trade and stable currency exchange rates. In seeking to establish a healthy trade environment, neither of these factors should be promoted at the expense of the other.

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AGRICULTURAL PRODUCTION IMPACTS OF HIGHER PHOSPHATE FERTILIZER PRICES

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ABSTRACT

We use the Food and Agricultural Policy Research Institute – Center for Agricultural and Rural Development model to estimate the impacts of higher phosphate fertilizer prices on global agricultural commodity production. We consider two scenarios: a tripling of prices globally and a tripling of prices only in the United States. In the global scenario, we find that fertilizer application rates decline and U.S. wheat acreage shifts to corn and soybeans. Crop production in the rest of the world declines. In the U.S. scenario, U.S. crop production decreases while international crop production increases. Impacts on livestock and biofuels production are modest in both scenarios.

Keywords: agricultural production, fertilizer price, phosphorus

INTRODUCTION

Phosphorus is a necessary element for crop production that has no substitute. The global demand for phosphate fertilizer[1] is projected to increase in the next several decades to accommodate a larger population and greater levels of per capita meat consumption (Metson, Bennett, and Elser 2012, FAPRI-ISU 2012). This factor, when combined with market characteristics of the supply of phosphate fertilizer, has raised concerns that phosphate fertilizer prices could be significantly higher in the future. Higher phosphate fertilizer prices would make crop production more expensive which, in turn, could have cascading effects throughout the agricultural supply chain and raise prices for many food products. We use the Food and Agricultural Policy Research Institute – Center for Agricultural and Rural

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[1] Phosphorus in fertilizer is conventionally measured in units of P_2O_5, which contains 44% phosphorus. We use the phrase "phosphate fertilizer" when referring to fertilizer to indicate that the units are being measured in P_2O_5.

Development (FAPRI-CARD) model to estimate the market impacts that increased phosphate fertilizer prices would have on global agricultural commodity production. FAPRI-CARD is a partial equilibrium, multi-market, multi-region econometric model that projects the supply, demand, and prices of agricultural commodities into the future.

Processes used to create fertilizer for the three major nutrients used in crop production vary. Nitrogen fertilizer can be created synthetically from a gaseous state and is biologically fixed in leguminous plants, while potassium can be both mined and extracted from seawater. In contrast, phosphate fertilizer is predominately derived from mined phosphate rock[2], which is a non-renewable resource (Cordell, Drangert, and White 2009). Phosphate fertilizer input costs are anticipated to increase in the future as phosphate rock reserves[3] are depleted and phosphate rock of a lower phosphorus concentration and quality is mined, although the timing and magnitude of extraction cost increases are uncertain due to challenges with estimating global phosphate rock reserves (Cordell, Drangert, and White 2009, Van Kauwenbergh 2010, Van Vuuren, Bouwman, and Beusen 2010, Cordell and White 2011). Adopting efficiency improvements that reduce processing and on-farm losses from runoff, developing more phosphorus-efficient crops, and utilizing other sources of phosphorus can mitigate the impact of increased phosphate rock extraction costs on phosphate fertilizer prices. Some of these farming practices, such as planting cover crops or using animal manure as a fertilizer, could have other agroecological benefits in addition to conserving phosphorus. However, the ability of farmers to adapt their practices may require greater information than currently available due to regional variation in the feasibility and effectiveness of incorporating sustainable farming practices or substituting alternate phosphorus sources. For example, applying animal manure as a fertilizer may require measurement to determine how much to apply since manure nutrient composition can vary depending upon the type of livestock, and the transportation costs associated with acquiring manure depend on the proximity of crop and livestock production due to its weight (Ribaudo et al. 2003, MacDonald et al. 2009).

The geographic concentration of reserves and high degree of market concentration could further contribute to phosphate fertilizer price increases by reducing the competitiveness of market conditions. These price increases could occur either globally or regionally if market barriers, such as export restrictions, constrained international trade. Seventy-five percent of global reserves are located in Morocco and the Western Sahara where production is controlled by a state-sanctioned monopoly, OCP (Bloomberg Businessweek 2010, Taylor and Moss 2013, USGS 2013). China is the world's largest phosphate rock producer and has 6% of global reserves, although it has historically not been active in the global market since it has imposed export tariffs to ensure that it has sufficient domestic supply (Bloomberg Businessweek 2010, Taylor and Moss 2013, USGS 2013). There is also a high degree of market concentration in the United States (U.S.), which is the world's second-largest phosphate rock producer and largest exporter of phosphate fertilizer (Huang 2009, Taylor and Moss 2013, USGS 2013). The Phosphate Chemical Export Association ("PhosChem"), a government-sanctioned export cartel consisting of two companies (Mosaic and PotashCorp),

[2] "Phosphate rock" refers to the naturally-occurring rock that can contain between 11% and 15% phosphorus after beneficiation (Smil 2000).

[3] Phosphate rock "reserves" refer to rock that could be "economically extracted or produced", which is currently 22% of global phosphate rock resources (USGS 2013). It currently does not include, for example, phosphate rock buried in the ocean.

was responsible for 52% of global phosphorus trade (Taylor and Moss 2013). Although PhosChem was disbanded in October 2013, the market remains nonetheless concentrated.

Another way price increases could occur is if a region taxes phosphate fertilizer so that farmers internalize the pollution costs that its use creates. Phosphorus in surface waters, along with other nutrients, contributes to hypoxia that can devastate aquatic life, reduce property values, increase municipal water treatment costs, and impede recreational use. Both nitrogen and phosphorus contribute to eutrophication, and the relative contribution of phosphorus depends on nutrient levels and the type of water system (Conley et al. 2009). Runoff from arable soil erosion is estimated to be responsible for 84% of phosphorus entering coastal and inland waters (Cordell, Drangert, and White 2009). An input tax on phosphate fertilizer is a second best mechanism to regulating agricultural phosphorus runoff, although, due to challenges with measuring and predicting farm-specific nutrient discharges, its implementation could be motivated as a regulation to reduce fertilizer use with low transaction costs (Sheriff 2005, Shortle and Horan 2013).

A U.S. phosphate fertilizer price increase could have global ramifications on agricultural commodity markets since the U.S. is one of the largest agricultural producing nations. There are several factors that could contribute to such a scenario. Although 14% of global phosphate rock production occurred in the U.S. in 2012, U.S. phosphate rock reserves will be exhausted in 48 years if existing extraction rates are maintained annually and new reserves are not discovered (USGS 2013). This implies that export restrictions from regions that contain reserves could result in relatively higher future phosphate fertilizer prices in the U.S. Further, farmers in the U.S. often apply fertilizer in excess of agronomic requirements (Sheriff 2005). The resulting nutrient runoff contributes to ecological “dead zones” in the Gulf of Mexico and Chesapeake Bay and poor water quality throughout the U.S. in rivers, lakes, and estuaries. U.S. freshwater damages from eutrophication are conservatively estimated to equal $2.2 billion annually (Dodds et al. 2009). Environmental regulation to reduce these damages, such as an input tax on phosphate fertilizer, would result in relatively higher phosphate fertilizer prices in the U.S.

Despite the various ways by which phosphate fertilizer prices could increase globally or in the U.S., the impacts that such price increases would have on agricultural commodity production have been insufficiently researched. Variables that can influence how farmers change fertilizer application rates in response to changes in fertilizer prices include the substitutability of farmland and fertilizer, the crops and nutrients under consideration, the time period, fertilizer price levels, and the ratio of crop prices to fertilizer prices. Many studies have found that in developed countries that fertilizer demand is price inelastic, although this finding is not universal. See Sheriff (2005), Heisey and Norton (2007), and Williamson (2011) for further discussion.

Regional or localized studies have estimated the changes in crop production in response to changes in fertilizer prices. Many of these studies have combined crop production cost data with biophysical data to evaluate the cost-effectiveness of nutrient control policies within a watershed (e.g., Westra, Easter, and Olson 2002, Rodriguez et al. 2011, Burkhart and Jha 2012, Merel et al. 2014). The impacts of these policies on agricultural markets outside of the watershed are typically not considered. However, we identified factors that could contribute to increases in phosphate fertilizer prices at the national or global level. The ramifications of such a price shock on agricultural commodity production would be global and, in addition to affecting crop production, it would impact agricultural production in sectors further downstream, such as livestock and biofuels.

Estimating these downstream impacts requires a more expansive model of agricultural commodity markets. Shakhramanyan et al. (2012) estimates the impacts of phosphate fertilizer price shocks and taxes in the United States (U.S.) using the Agricultural Sector and Mitigation Greenhouse Gas Model. They found that higher phosphate fertilizer prices would not lead to significant decreases in U.S. agricultural production. However, they do not report detailed results of the impacts that higher phosphate fertilizer prices would have on the application of specific fertilizer nutrients, the production of specific crops and livestock, agricultural production outside of the U.S. for specific regions, and the extent to which farmers would substitute between farmland and fertilizer use in crop production. This detail is essential to understanding these impacts since the relative use of phosphate fertilizer varies regionally by crop.

Elobeid et al. (2013) use FAPRI-CARD to analyze the impact of a 10% increase in U.S. nitrogen fertilizer prices on global agricultural commodity markets. They find that U.S. soybeans production increases at the expense of U.S. corn and wheat production. This is because soybeans production becomes relatively more profitable under higher nitrogen fertilizer prices since it uses relatively less nitrogen. Since farmers in the rest of the world do not experience the increased price of nitrogen fertilizer, international corn and wheat production increases to compensate for the decline in U.S. exports while international soybeans production declines. Elobeid et al. (2013) also find geographic shifts in livestock production. Specifically, U.S. beef and broilers production increases while U.S. pork production decreases, and vice versa in the rest of the world.

DESCRIPTION OF THE FAPRI-CARD MODEL

FAPRI-CARD Overview

The FAPRI-CARD model, which is maintained at Iowa State University, produces an annual outlook of agricultural commodity markets that has been widely used to evaluate and inform policy issues. FAPRI-CARD's 2012 World Agricultural Outlook projects market conditions through 2021. FAPRI-CARD projections are developed by combining historical data of production, consumption, trade flows, and prices of major agricultural commodities with forecasts of socioeconomic variables. The equations in the FAPRI-CARD model were developed using economic, agronomic, and biological relationships based on historical data, academic research, and expert judgment. There are 58 regions in FAPRI-CARD, many of which are at the country-level, although agricultural production in the United States and Brazil is regionally disaggregated. The model has undergone significant enhancements since its initial development in 1984, and has been validated in academic journals and by external reviewers (Meyers et al. 2010).

FAPRI-CARD consists of several interconnected partial equilibrium models of global agricultural commodity markets (figure 1). These include models of the markets for grain, oilseed, and sugar crops; biofuels (ethanol and biodiesel); dairy products; and meat products derived from livestock production, including beef, pork, and poultry. All commodities are treated as homogeneous. FAPRI-CARD also projects fertilizer use and application rates by nutrient type (nitrogen, phosphate, and potash). Macroeconomic variables in FAPRI-CARD that are used to project future commodity demands and trade patterns, such as gross domestic product, exchange rates, and population growth, are exogenous.

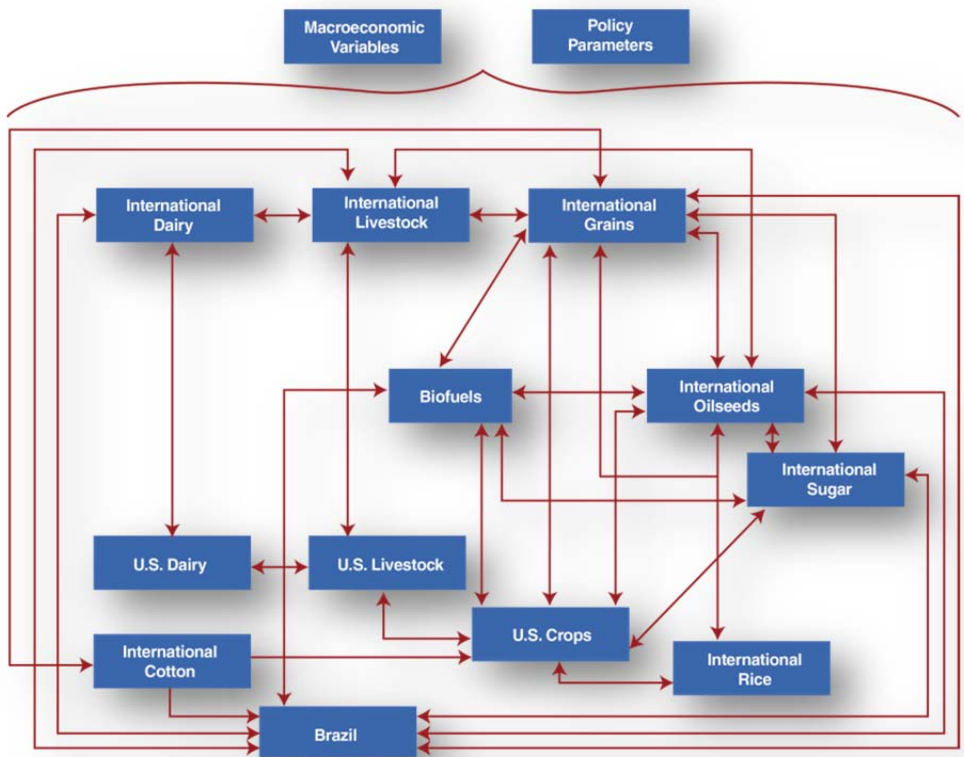

Figure 1. FAPRI-CARD model schematic overview.

Crops are consumed as food or used as an input for livestock or biofuels production. For crops, each model has equations that determine area, yield, and production on the supply side; and retail demand (direct consumption for food), derived demand (feed and industrial demand), and ending stock equations on the demand side. There are also separate market equations for by-products from crops, such as dry distiller grains from corn. Changes in crop production occur in response to changes in the relative profitability of other crops. The same holds with livestock. For example, the livestock model informs the grains model of the feed demand for grains, while the oilseeds model provides the grains model with information on the relative profitability of oilseed crops. FAPRI-CARD imposes "long-run equilibrium" conditions in the biofuel, dairy, and livestock sectors. This implies that after any shocks are implemented to baseline conditions, net profits in the last model year provide no incentive for either exit or entry into these sectors.

The world price for each commodity is obtained by finding the price level for which its global excess demand is equal to zero. This process is repeated iteratively until all commodity markets attain equilibrium. For some commodities, a major exporting country will be the residual supplier for excess demand from the rest of the world, and its price will be the world reference price[4]. In such instances, other countries are price-takers, and their domestic commodity price is derived from the world commodity price after making adjustments for exchange rates, transportation costs if the country is importing the commodity, and any policy interventions that may exist, such as a tariff, between the world and domestic markets. For these countries, either exports or imports are set as a residual so that the supply of the commodity is equal to its demand.

In FAPRI-CARD, the product of the yield and harvested area for each crop is equal to that crop's production. Yield equations in FAPRI-CARD, in country i for crop j at time t, are specified according to equation (1).

$$y_{ijt} = \alpha_{ij} + \beta_{ij}t + \delta_{ij}\frac{Rev_{ijt}}{Cost_{ijt}} + \gamma_{ij}\frac{Rev_{ij10avet}}{Cost_{ij10avet}} + \theta_{ij}a_{ijt} + \varphi_{ij}\sum a_{it} + \varepsilon_{ijt} \quad (1)$$

where:

$$Cost_{ijt} = NFCost_{ijt} + p_{Nit}N_{ijt} + p_{Pit}P_{ijt} + p_{Kit}K_{ijt} \quad (2)$$

The independent variables in (1) are, respectively, a constant, a time trend, the ratio of total revenue to variable costs in the current period, a ten-year moving average of the ratio of total revenue to variable costs, area harvested for that crop, and total area harvested for all crops. The coefficients associated with the third and fourth variables, δ and γ, represent the "intensification" effect of prices. These coefficients are positive since input use will increase when the increase in revenue is greater than the increase in cost. The coefficients on the fifth and sixth variables, θ and φ, represent the "extensification" effects of expanding acreage. These coefficients are negative as yields generally decline when land devoted to crop production expands into less productive areas. Equation (2) shows that the variable cost terms in (1) equal the sum of non-fertilizer costs ($NFCost_{ijt}$) and fertilizer costs. Fertilizer costs equal the sum of the per-unit prices of nitrogen (p_{Nit}), phosphate (p_{Pit}), and potash (p_{Kit}) multiplied by their respective application rate (N_{ijt}, P_{ijt}, and K_{ijt}).

We provide the equation that determines the area harvested, denoted AH, for crop j in country i at time t in equation (3) premised on the equation for corn. The arguments of the area harvested equations for a particular crop or pasture in a given year depend on variables that can include the lagged area harvested of that crop, lagged real gross returns of that crop and other competing crops (denoted GR), lagged real variable costs for that crop (denoted VC), and livestock revenue (denoted LR). Thus, changes in input costs impact both harvested area and yields for crops, since both are a function of variable costs. The number of competing crops for a given crop varies by country, and in this example we assume there is just one competing crop for simplicity, which is denoted with subscript c. We use accents on the coefficients and error term to distinguish them from the coefficients and error term in (1).

$$AH_{ijt} = \dot{\alpha}_{ij} + \dot{\beta}_{ij}AH_{ijt-1} + \dot{\delta}_{ij}GR_{ijt-1} + \dot{\gamma}_{ij}GR_{ict-1} + \dot{\theta}_{ij}VC_{ijt-1} + \dot{\varphi}_{ij}LR_{it} + \dot{\varepsilon}_{ijt} \quad (3)$$

[4]This country is the United States for most commodities. Exceptions to this include Canada for barley, Thailand for rice, Brazil for ethanol, Australia for dairy, and the European Union for biodiesel.

The U.S. Department of Agriculture Foreign Agricultural Service and the Food and Agriculture Organization of the United Nations are the primary data sources for agricultural commodity data, the International Monetary Fund's International Financial Statistics is the source of historical macroeconomic data, and IHS Global Insight is the primary data source for future projections of macroeconomic variables. The baseline assumes average weather conditions and that agricultural and trade policies, such as tariffs, subsidies, and quotas, remain in place throughout the baseline projection period.

These policies include provisions of the Food, Conservation, and Energy Act of 2008 in the U.S.; provisions of the Common Agricultural Policy in the European Union; obligations of contracting countries in the Uruguay Round Agreements Act of 1995; and provisions of the Renewable Fuel Standard and Energy Independence and Security Act of 2007 in the U.S., with the exception of the cellulosic ethanol mandates. Biofuel production tax credits and import tariffs end in 2012.

Fertilizer Application in FAPRI-CARD

Fertilizer application rates are endogenous in FAPRI-CARD and are specific for each crop, nutrient, region, and year. In each successive year, crop demands change as a result of changes to exogenous and endogenous variables. As a consequence, farmers adjust their input use. Equation (4) represents the change in "intensification", ΔI_{ijt}, as previously defined in equation (1).

$$\Delta I_{ijt} = \left(\frac{Rev_{ijt}}{Cost_{ijt}} - \frac{Rev_{ijt-1}}{Cost_{ijt-1}}\right) + \left(\frac{Rev_{ij10avet}}{Cost_{ij10avet}} - \frac{Rev_{ij10avet-1}}{Cost_{ij10avet-1}}\right) \tag{4}$$

The percentage change in yield is then estimated according to (5), where $\%Y_I$ is a time-invariant parameter representing the percentage change in yield that is due to intensification.

$$\%\Delta Y_{ijt} = \frac{\%Y_I * \Delta I_{ijt}}{Y_{ijt-1}} \tag{5}$$

For a given crop and nutrient, the annual percentage change in application rate ($\%\Delta F_{ijt}$) for the three fertilizer nutrients in the model is calculated in each year in every region as the ratio of the percentage change in yield and the elasticity of crop yield with respect to fertilizer nutrient application ($\epsilon_{YF(j)}$). This is specified in equation (6).

$$\%\Delta F_{ijt} = \frac{\%\Delta Y_{ijt}}{\epsilon_{YF(j)}} \tag{6}$$

The yield elasticity coefficients are crop and nutrient specific, and were estimated at the global level using 2007 and 2008 nutrient application rates and yield data in FAPRI-CARD countries (Rosas 2011). Yields increase at a decreasing rate as additional nutrients are applied. Calculating a new fertilizer nutrient application rate is straightforward according to (7).

$$F_{ijt} = max(0, F_{ijt-1} * (1 + \%\Delta F_{ijt})) \tag{7}$$

The specific impacts of higher phosphate fertilizer prices in FAPRI-CARD for specific crops depends both on the size of the shock and the opportunity costs of the land. This is because farmland and fertilizer are both substitutes, as farmers can expand farmland to maintain production while reducing fertilizer use, and complements, since farmland is required for fertilizer application. The three types of fertilizer nutrients are also complementary with each other. Holding other factors constant, greater opportunities for substitution in FAPRI-CARD occur when input costs increase in only select regions or when there is greater variability in the relative use of inputs between crops.

Fertilizer prices in FAPRI-CARD are exogenous, and historical prices are derived from the U.S. Department of Agriculture National Agricultural Statistics Service (Rosas 2011). Country-specific fertilizer prices are derived for each nutrient from the U.S. price by making adjustments for exchange rates and import tariffs (Rosas 2011). Projections for variable costs, including nutrient costs, in the FAPRI-CARD baseline are obtained from IHS Global Insight producer price index projections of cost of production components, such as fertilizer, seed, and fuel.

Phosphate Fertilizer Price Shock Scenarios

We estimate the impacts that higher phosphate fertilizer prices would have on agricultural markets under two price shock scenarios. In the global price shock scenario, we implement a price shock on phosphate fertilizer equal to three times greater than the FAPRI-CARD baseline phosphate fertilizer prices since this corresponds to a projection of the increase in phosphate rock extraction costs under scarcer reserve levels (Van Vuuren, Bouwman, and Beusen 2010).

For reference, a price shock of this magnitude results in a phosphate fertilizer price in 2012 that is 59% greater than the peak 2008 price, a year in which phosphate fertilizer prices rose sharply from preexisting levels (World Bank 2013).

We implement this shock in every year in the FAPRI-CARD model, which is consistent with how an oil shock was implemented in FAPRI-CARD in previous research (Tokgoz et al. 2010). In the U.S. price shock scenario, the 200% phosphate fertilizer price shock occurs only in the U.S. We choose 200% in the U.S. price shock scenario so that we can directly compare the results of the two scenarios.

RESULTS

Baseline Scenario Projections

We first report the market projections under the FAPRI-CARD "baseline" conditions to provide a basis for comparison for our phosphate fertilizer price shock scenarios. Table 1 shows that global phosphate fertilizer consumption is projected to increase by 4% from 33.5 million metric tons P_2O_5 (MMT) in 2011 to 34.8 MMT by 2021[5]. Asia is projected to have

[5] The fertilizer projection estimates include fertilizer consumption for cotton and rice production in the United States, but does not include fertilizer consumption for these two crops in the rest of the world.

the largest absolute increase in phosphate consumption of 0.5 MMT (3%). The largest percentage increases are projected to occur in Other Africa (11%), Latin America (9%), and Europe (8%), which correspond to increases of 0.04 MMT, 0.4 MMT, and 0.3 MMT, respectively. Phosphate fertilizer consumption is projected to increase by 0.1 MMT in North America (2%). Phosphate fertilizer prices are projected to increase by 18% over the FAPRI-CARD baseline period from 2011 to 2021. Phosphate use is projected to increase by the slowest percentage amount of the three fertilizer nutrients. Global nitrogen use is projected to increase from 84 MMT to 88 MMT (5%) and potash (K_2O) use is projected to increase from 24 MMT to 26 MMT (8%).

Table 1. Projected Global Phosphate Fertilizer Consumption

	2011	2021 Baseline	2021 "Global" Scenario	2021 "US" Scenario	% Change* Global	% Change** US
	Thousand MT P_2O_5					
Asia	17,654	18,150	17,664	18,163	-3%	0%
Africa	444	454	447	460	-2%	1%
North America	5,089	5,184	5,084	4,979	-2%	-4%
Europe	3,632	3,913	3,808	3,936	-3%	1%
Oceania	729	738	700	740	-5%	0%
Latin America & Caribbean	4,091	4,447	4,117	4,484	-7%	1%
Other Asia	797	746	738	752	-1%	1%
Other Africa	376	417	414	424	-1%	2%
Other Americas	440	462	453	467	-2%	1%
Other Europe	208	211	209	212	-1%	1%
Other Oceania	44	44	47	44	7%	0%
Total	33,503	34,764	33,680	34,662	-3%	0%

Note: Asterisk (*) is the percentage change between 2021 Baseline and 2021 "Global" Scenario and double asterisk (**) is the percentage change between 2021 Baseline and 2021 "US" Scenario.

Global corn production is projected to be 1,024 MMT in 2021, a 20% increase relative to 2011. Corn consumed as animal feed is projected to increase from 503 MMT to 612 MMT, and corn consumed as food and other uses is projected to increase from 357 MMT to 410 MMT. U.S. corn prices are projected to decline from $295/MT in 2011 to $244/MT (-17%) in 2021, with corn yields increasing at an annual average rate of 1.5%. Global wheat production is projected to increase to 758 MMT by 2021, which is an 11% increase in production relative to 2011. Whereas the largest use of global corn production is for animal feed, 80% of wheat is projected to be consumed as food or other use.

Global soybean production is projected to reach 307 MMT by 2021. Table 2 shows that soybean prices are projected to decrease from $506/MT in 2011 to $465/MT (-8%) in 2021. Soybean meal production is projected to increase from 182 MMT in 2011 to 215 MMT in 2021 and soybean oil production is projected to increase from 43 MMT to 52 MMT.

Vegetable oil prices are projected to increase over this period while vegetable meal prices are projected to decline.

Table 2. Projected Prices for Major Commodities

	2011	2021 Baseline	2021 "Global" Scenario	2021 "US" Scenario	% Change* Global	% Change** US
	USD / MT					
Wheat FOB Gulf	318	286	323	296	13%	4%
Corn FOB Gulf	295	244	278	255	14%	5%
Soybean CIF Rotterdam	506	465	523	470	13%	1%
Steer Nebraska Direct	2,513	2,927	2,978	2,940	2%	0%
Barrow and Gilt, National	1,459	1,596	1,678	1,614	5%	1%
Broiler U.S. 12-City	1,733	2,021	2,134	2,046	6%	1%
	USD / gal.					
Anhydrous Ethanol, Brazil	3.33	2.99	3.21	3.00	7%	0%
Ethanol FOB Omaha	2.71	2.37	2.55	2.43	8%	3%
Biodiesel Central Europe FOB	5.75	6.14	6.32	6.14	3%	0%
U.S. Biodiesel Plant	5.17	5.19	5.34	5.19	3%	0%

Note: Asterisk (*) is the percentage change between 2021 Baseline and 2021 "Global" Scenario and double asterisk (**) is the percentage change between 2021 Baseline and 2021 "US" Scenario.

The U.S. is the only region in which per capita meat consumption declines during the projection period. By 2021, global beef, broiler, and pork production is projected to reach 72 MMT, 101 MMT, and 129 MMT, respectively. Table 2 shows that their corresponding producer prices are projected to increase throughout the projection period to $2,927/MT (16%), $2,021/MT (17%), and $1,596/MT (9%), respectively. Global ethanol production is projected to reach 38 billion gallons (BG) and global biodiesel production is projected to reach 7 BG by 2021. Table 2 shows that ethanol prices (FOB Omaha) are projected to decline to $2.37/gallon (-13%) by 2021, whereas biodiesel prices (Central Europe FOB) are projected to increase to $6.14/gallon (7%).

Global Phosphate Fertilizer Price Shock Projections

Table 1 shows that in the global price shock scenario, global phosphate fertilizer consumption is inelastic and declines by 1.1 MMT (-3%) in 2021 relative to the baseline. Phosphate fertilizer consumption declines by the greatest amount in Asia by 0.5 MMT (-3%). Latin America phosphate fertilizer consumption declines by 0.3 MMT (-7%) and consumption declines in both Europe and North America by 0.1 MMT (-3% and -2%, respectively).

Table 2 shows that, in 2021, the phosphate fertilizer price spike would result in a 14% increase in corn prices relative to the baseline, a 13% increase in wheat prices, and a 13% increase in soybean prices. Barley and sorghum prices would also increase by 14%. The increase in input costs causes production to decline for many crops. By 2021, sugarcane experiences the largest global production decline of among crop sectors of 52 MMT (-2%) relative to the baseline. Global wheat production declines by 13 MMT (-2%), corn production declines by 10 MMT (-1%), and soybeans production declines by 4 MMT (-1%) relative to baseline projections. In addition, global potash use declines by 2% and nitrogen use declines by 1%. Crop inventory changes are projected to be modest, and global corn and wheat consumption decline by 21 and 11 MMT, respectively, relative to baseline projections.

Table 3 presents changes in variable costs for corn production subsequent to a tripling of phosphate fertilizer prices for eight countries that are projected to account for 82% of 2021 global corn production under baseline conditions. There is variability in phosphate fertilizer use among these countries. Before the price shock, phosphate fertilizer as a percentage of corn fertilizer costs range from as low as 8% in Mexico to as high as 47% in Brazil. Thus, phosphate fertilizer ranges from 3% of variable costs in Mexico to 20% in Brazil.

The price shock causes phosphate fertilizer application rates to increase by 1% in Mexico, and remain unchanged or decline in the rest of the countries. For corn, changes in phosphate application rates result in a larger percentage change in potash application rates and smaller percentage changes in nitrogen application rates. These changes in fertilizer application rates result in variable cost increases that range between 6% in Mexico to 29% in Brazil. Table 3 also shows that reductions in area harvested mitigate the impact of reduced fertilizer application on yield, since corn production ceases on farmland on which it is less productive. Harvested area decreases by 11% in Argentina, 9% in India, 6% in Brazil, and 2% in the European Union, whereas yield declines in those countries are 2%, 6%, 1%, and 0%, respectively. In contrast, harvested area increases in the U.S. and Mexico.

Table 3 shows that the three countries in the table for which phosphate fertilizer comprises the greatest percentage of corn variable costs – Argentina, Brazil, and India – are the three countries that experience the greatest percentage reduction in phosphate use and corn production as a consequence of the price shock. However, production impacts in the two largest corn producing countries are not as significant -- there is a 1% increase in production the U.S. and no change in China.

In Mexico, the country in the table for which phosphate fertilizer comprises the smallest percentage of corn variable costs, total phosphate use increases by 2% since it becomes a region that is relatively cheaper to grow corn, and production increases by 1%. Thus, the total decline in corn production of the countries in the table is 1%. Changes in crop production in a given region, however, are attributable to both the relative profitability of that crop in other regions as well as the relative profitability of other crops. While table 3 demonstrates how production adjusts for a given crop between regions, table 4 shows changes in production between crops within the U.S. and rest of the world. Table 4 shows that the application rate for phosphate fertilizer declines by the largest percentage amount for U.S. wheat (-7%) relative to U.S. corn (-3%) and soybeans (0%). U.S. corn and soybean acreage expands by 2% with application rates for nitrogen and potash that remain constant or decline, as less fertilizer is needed for production since acreage has expanded.

Table 3. Impact of Global 200% Phosphate Fertilizer Price Increase on Corn Production

	Argentina	Brazil	Canada	China	European Union	India	Mexico	United States
	Before Price Shock							
Corn production (TMT)	36,128	74,544	11,920	237,097	65,594	26,162	21,784	362,333
% of global production	4%	7%	1%	23%	6%	3%	2%	35%
Phos. % in fertilizer costs	39%	47%	19%	13%	21%	42%	8%	24%
Phos. % in variable costs	14%	20%	7%	5%	7%	15%	3%	11%
	After Price Shock (% changes)							
Phosphate App. Rate	-4%	-5%	0%	0%	-1%	-11%	1%	-3%
Nitrogen App. Rate	-1%	-1%	0%	0%	0%	-4%	1%	-1%
Potash App. Rate	-9%	-14%	-1%	1%	-2%	-26%	4%	-7%
Variable Costs	26%	29%	14%	9%	15%	23%	6%	21%
Area Harvested	-11%	-6%	0%	0%	-2%	-9%	1%	2%
Yield	-2%	-1%	0%	0%	0%	-6%	1%	-1%
Phosphate Use	-14%	-6%	0%	0%	-2%	-19%	2%	0%
Production	-12%	-7%	0%	0%	-2%	-14%	1%	1%

Table 4. Impact of Phosphate Fertilizer Price Increase on Crop Production

	Phosphate App. Rate (kg/ha)	Nitrogen App. Rate (kg/ha)	Potash App. Rate (kg/ha)	Area Harvested (hectares 000)	Yield (MT / ha)	Production (TMT)
	Baseline					
U.S. Corn	63	183	79	32,627	11.1	362,333
U.S. Soybeans	20	5	31	31,055	3.2	97,735
U.S. Wheat	35	88	15	18,229	3.2	58,195
ROW Corn	22	90	11	140,243	4.7	662,070
ROW Soybeans	35	10	22	80,259	2.6	209,401
ROW Wheat	30	84	7	212,358	3.3	699,906
	Global Phosphate Price Shock					
U.S. Corn	61	182	73	33,341	11.0	366,217
U.S. Soybeans	20	5	31	31,737	3.1	99,628
U.S. Wheat	33	87	14	17,178	3.2	54,642
ROW Corn	21	90	10	138,762	4.7	647,998
ROW Soybeans	33	10	20	79,277	2.6	203,986
ROW Wheat	30	84	7	210,151	3.3	690,242
	U.S. Phosphate Price Shock					
U.S. Corn	61	181	72	31,819	11.0	348,438
U.S. Soybeans	20	5	31	31,288	3.1	97,675
U.S. Wheat	32	87	13	17,270	3.2	54,764
ROW Corn	22	90	11	141,742	4.7	671,723
ROW Soybeans	35	10	23	80,029	2.6	209,238
ROW Wheat	30	84	7	212,790	3.3	701,853

Table 4. (Continued)

	Phosphate App. Rate (% change)	Nitrogen App. Rate (% change)	Potash App. Rate (% change)	Area Harvested (% change)	Yield (% change)	Production (% change)
	Global Phosphate Price Shock					
U.S. Corn	-3%	-1%	-7%	2%	-1%	1%
U.S. Soybeans	0%	-1%	0%	2%	0%	2%
U.S. Wheat	-7%	-1%	-10%	-6%	0%	-6%
ROW Corn	-2%	0%	-6%	-1%	-1%	-2%
ROW Soybeans	-6%	0%	-8%	-1%	-1%	-3%
ROW Wheat	-1%	0%	-1%	-1%	0%	-1%
	U.S. Phosphate Price Shock					
U.S. Corn	-3%	-1%	-9%	-2%	-1%	-4%
U.S. Soybeans	-1%	-3%	0%	1%	-1%	0%
U.S. Wheat	-8%	-1%	-11%	-5%	-1%	-6%
ROW Corn	1%	0%	3%	1%	0%	1%
ROW Soybeans	0%	0%	1%	0%	0%	0%
ROW Wheat	0%	0%	1%	0%	0%	0%

Corn yields decline by 1% and soybean yields are unchanged. In contrast, U.S. wheat acreage declines by 6%, and application rates for all three fertilizer nutrients decrease. U.S. wheat yields remain unchanged despite the reduction in fertilizer application rates as wheat production ceases in less productive land. Thus, U.S. wheat production declines by 6% while U.S. corn and soybeans production increase by 1% and 2%, respectively. The shift of U.S. crop acreage from wheat into corn and soybeans occurs, in part, because U.S. wheat production uses a greater amount of phosphate fertilizer for a given level of output relative to U.S. corn and soybeans production.

In the rest of the world, however, soybeans utilize the greatest amount of phosphate per unit of output among the three crops and the phosphate application rate for soybeans declines by the largest percentage amount (-6%). Phosphate and potash application rates decline for all three crops in the rest of the world while there is no change in the nitrogen application rate. The area harvested for three crops declines in the rest of the world by 1% each. Yields decline by 1% each for corn and soybeans and do not change for wheat. Thus, while the production of all three crops decline in the rest of the world, soybeans production declines by the greatest percentage amount (-3%) relative to corn (-2%) and wheat (-1%) production.

Higher crop prices increase livestock production costs. By 2021, producer prices for broilers, hogs, and cattle are 6%, 5%, and 2% higher than baseline projections, respectively (table 2). Global broiler production declines by 0.8 MMT (-1%) relative to baseline conditions, which is larger than the global pork production decline of 0.4 MMT (0%) and beef production decline of 0.1 MMT (0%). Figure 2 decomposes the changes in livestock production between the U.S. and rest of the world. Although global beef and pork production declines, U.S. beef and pork production increases by 0.03 MMT (0%) and 0.1 MMT (1%), respectively. U.S. broiler production declines by 0.03 MMT (0%), which accounts for a modest amount of the total global decline in broiler production.

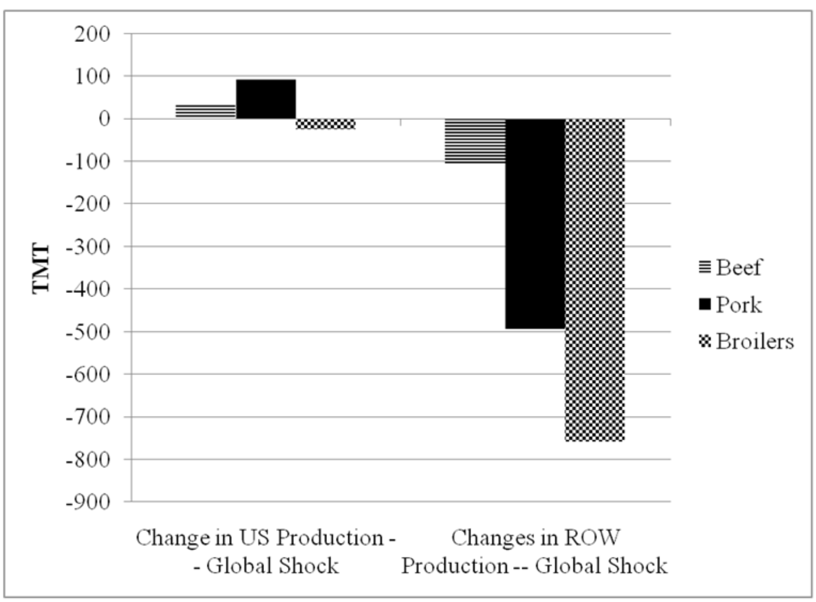

Figure 2. Projected changes in 2021 livestock production relative to baseline – global phosphate price shock.

The percentage declines in biofuels production are similar to percentage reductions in livestock production. Global ethanol and biodiesel production in 2021 are projected to decline by 0.4 BG (-1%) and 0.03 BG (0%), respectively, under the global price shock scenario. Brazil accounts for 24% of the decline in global pork production, 68% of the decline in global broiler production, and 99% of the decline in global ethanol production. This occurs since, as shown in table 3, phosphate use in corn production in Brazil is high relative to other major agricultural countries. As a result, less corn is produced for both animal feed and food uses. This has indirect impacts on the production of other crops, including a diversion of sugarcane production from ethanol use to sugar use.

United States Phosphate Fertilizer Price Shock Projections

Table 4 shows that, in the U.S. price shock scenario, U.S. phosphate application rates decline by 8% for wheat, 3% for corn, and 1% for soybeans relative to the baseline. U.S. application rates for nitrogen and potash either decline or remain the same, and yields decline by 1% for all three crops. The percentage reductions in phosphate fertilizer use in the U.S. are 13% for wheat and 6% for corn. Phosphate fertilizer use declines by a greater percentage than the reduction in application rates since the harvested area for wheat and corn decline by 5% and 2%, respectively. In contrast, U.S. soybeans acreage expands by 1%. These changes correspond to a 14 MMT reduction in U.S. corn production (-4%), 3 MMT reduction in U.S. wheat production (-6%), and 0.1 MMT (0%) reduction in U.S. soybeans production relative to baseline projections. U.S. wheat experiences the largest percentage reduction in production and phosphate application rate of the three crops just as in the global price shock scenario. This decline in U.S. crop production is mitigated by corn and wheat production increasing by 10 MMT (1%) and 2 MMT (0%), respectively, in the rest of the world. International crop production increases since these farmers do not experience an increase in production costs while market prices increase as U.S output is reduced.

Since the reductions in global crop production are smaller in this scenario relative to the global price shock scenario, the crop price increases are also more modest. Table 2 shows that corn prices increase by 5%, wheat prices by 4% and soybean prices by 1%. This implies the changes in downstream livestock prices are also smaller. By 2021, table 2 shows that this results in U.S. broiler and hog producer prices increasing by 1% each relative to the baseline while U.S. cattle producer prices increase by 0.5%. At the retail level, this translates into a 1% increase in U.S. broiler prices, 0.5% increase in U.S. pork prices, and 0.3% increase in U.S. beef prices. As a consequence, U.S. consumption of pork and poultry declines by 0.02 MMT (0%) and 0.06 MMT (0%) respectively, while U.S. beef consumption increases by 0.01 MMT (0%) as consumers switch to beef in response to the relatively higher price increases of pork and poultry. Changes in global livestock and biofuels production relative to baseline conditions are also smaller in the U.S. price shock scenario than they are in the global price shock scenario, and correspond to 0% each for beef, pork, broilers, ethanol, and biodiesel.

Nutrient Fertilizer Comparison

We use the results of Elobeid et al. (2013) to compare the elasticity of production in U.S. agricultural sectors with respect to the U.S. prices of nitrogen and phosphate fertilizer. The fertilizer price shocks implemented in our study and Elobeid et al. (2013) are for different magnitudes and the elasticities can vary depending on the size of the shock. While this makes elasticity comparisons of specific crops between scenarios challenging, we can compare which of the three major U.S. crop sectors experienced the greatest relative impacts within the two scenarios. Figure 3 shows that U.S. corn, soybeans, and wheat production is slightly more elastic for a 200% U.S. phosphate price shock than a 10% U.S. nitrogen price shock, even though nitrogen fertilizer comprises a greater percentage of variable costs for corn and wheat than phosphate fertilizer. For example, in the U.S., nitrogen fertilizer accounts for 20% of total variable costs for corn, whereas phosphate fertilizer comprises 11% of variable costs.

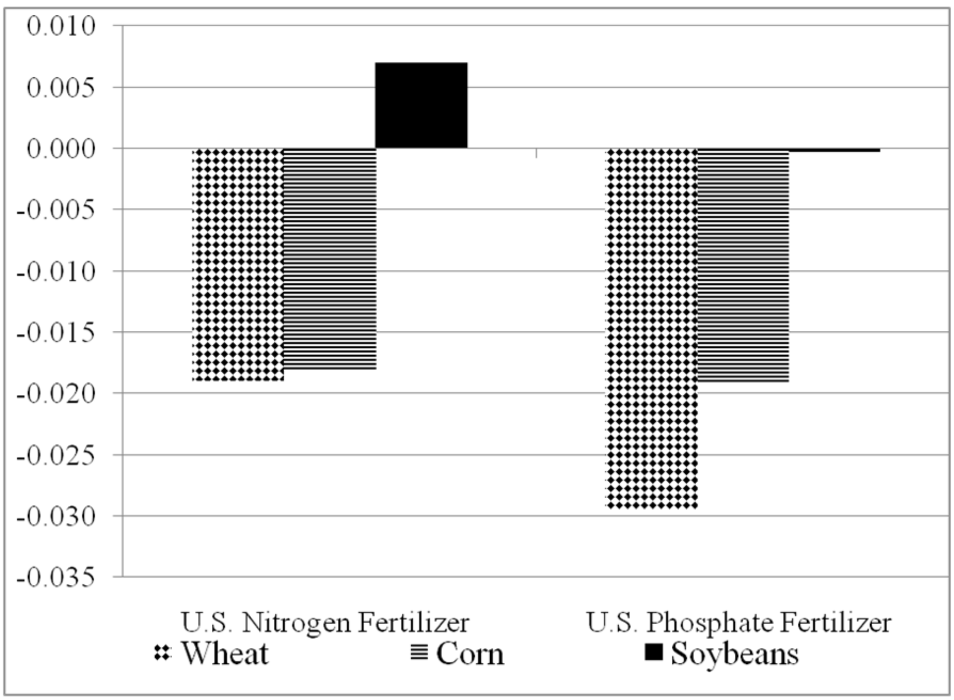

Figure 3. Elasticity of U.S. crop production with respect to U.S. fertilizer prices.

We see that the U.S. crop production elasticities have the same ordinal ranking among the three crops with regard to U.S. nitrogen and U.S. phosphate fertilizer prices. The elasticity of U.S. wheat production is -0.02 with respect to U.S. nitrogen prices and -0.03 for U.S. phosphate prices. U.S. wheat production is more elastic with respect to changes in U.S. nitrogen and phosphate prices in part because it uses a greater amount of nitrogen and phosphate per unit of output relative to U.S. corn and soybeans production. Also, U.S. wheat production requires more phosphate and the same amount of nitrogen per unit of output relative to wheat production in the rest of the world, whereas U.S. corn and soybean production utilizes less phosphate and nitrogen per unit of output relative to international corn and soybean production. The elasticity of U.S. corn production is -0.02 with respect to U.S.

nitrogen and phosphate prices and the elasticity of U.S. soybeans production is 0.01 for U.S. nitrogen prices and 0 for U.S. phosphate prices. The elasticities of U.S. livestock and biofuels production with respect to U.S. nitrogen and phosphate fertilizer prices are all less than 0.01 in absolute value. The livestock and biofuels elasticities are smaller than the elasticities for crop production since this production is further downstream on the supply chain.

CONCLUSION

Greater demands on upstream inputs necessary for crop production are anticipated to increase in the upcoming decades as global populations and per capita incomes increase. For phosphate fertilizer, there are also a variety of factors that could reduce the future availability of phosphate fertilizer at current market prices. While higher phosphate fertilizer prices could propagate through the agricultural supply chain and increase food prices, these potential market impacts have not been extensively researched. Changes in the regions and types of crops that are produced has environmental and productivity implications. This is because agricultural exports exacerbate water pollution in countries with phosphorus surpluses in the soil and reduce soil fertility in countries with phosphorus deficiencies (Schipanski and Bennett 2012). Further, the dynamic interaction of residual soil phosphorus and the substitution among different types of crops could be explored in future efforts since residual soil phosphorus influences future phosphorus requirements (Sattari et al. 2012).

We use the FAPRI-CARD agricultural commodity model to provide the first global estimates of changes in specific types of crop and livestock production by region under higher phosphate fertilizer prices. In our global price shock scenario, we find that higher phosphate fertilizer prices result in a shift of U.S. crop acreage from wheat into corn and soybeans. As a consequence, U.S. corn and soybeans production increases even though fertilizer application rates decline, while U.S. wheat production declines. This change in crop production occurs because U.S. wheat production requires more phosphate per unit of output than U.S. corn or soybeans production. Soybeans production utilizes the most amount of phosphate for a given level of output in the rest of the world, and we also find that international soybeans production decreases by a larger percentage amount relative to international corn and wheat production. The relative changes in global livestock and biofuels production are modest. Production declines in several of these sectors are most pronounced in Brazil, where corn production uses relatively more phosphate fertilizer than elsewhere.

We further estimate changes in agricultural production under higher U.S. phosphate fertilizer prices. As in Shakhramanyan et al. (2012), we find that increases in phosphate fertilizer prices result in relatively modest decreases in agricultural production. Unlike Elobeid et al. (2013), which found that U.S. soybeans production increased under higher U.S. nitrogen prices, we did not find that production increases for any of the three major U.S. crops. However, as Elobeid et al. (2013) found with nitrogen, we found that U.S. wheat production experiences the largest percentage decline and U.S. corn production experiences the second largest percentage decline of the three major crops. We find smaller impacts on livestock and biofuels production in the U.S. price shock scenario than in the global scenario since crop production costs only increase in one region.

While phosphate fertilizer prices are exogenous in our application, research that assessed the capability of farmers to adapt to higher phosphate fertilizer prices in different regions is a priority. Some adaptation methods that may be available to farmers, such as planting cover crops or a greater integration of crop and livestock systems, would provide additional agroecological benefits. However, since the means of adaptation could vary locally and may require greater information than currently available, public investment in research and outreach may be necessary for adaptation methods to be widely adopted.

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GLOBALIZATION AND OBESITY: A DYNAMIC MODEL USING GOLDEN SECTION SEARCH METHOD

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ABSTRACT

The World Health Organization announced the global obesity epidemic almost a decade ago. It has been recently demonstrated that economic and social globalization factors generate health externalities and contribute to global obesity growth. Dynamic model developed in this study measures the proportion of overweight people becoming obese and the timeframe in which this will happen, both globally and by region. A golden section search method is used to find a function of several parameters. The United States have the biggest increase in proportion in the shortest period of time, whereas the World and the European Union have a tendency to experience this increase during a longer-term period. The results confirm less than complete transmission of a globalization externality from one of its origins (i.e., the United States) to the rest of the world.

Key Words: dynamic model, optimization, quadratic function, golden section search method, globalization and obesity

JEL: F69, C61

1. INTRODUCTION

The externalities arising as a consequence of trade liberalization have rarely been a topic of much public debate with the exception of the relationship between the international trade and resulting environmental degradation (e.g., Markusen, 1975; Conrad, 1993; Ludema and Wooten, 1994**)**. Miljkovic et al. (2015) have recently established both theoretically and

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empirically the connection between economic and social/cultural globalization and global increase in obesity. According to the World Health Organization (WHO) (2008), approximately 1.8 billion adults were overweight and at least 500 million were obese all around the world. Obesity has not only increased in developed countries but more surprisingly in developing countries as well (FAO, 2008). Due to this rapid and continuous global increase of obesity, the WHO describes obesity as a global epidemic.

Globalization is a process by which national/regional economies, societies, and cultures have become integrated through a global network of economic, technological, socio-cultural, political, and biological factors (Croucher, 2004). The implications of globalization are different for different countries and regions. Rich, more developed countries are leading the charge and promote the idea of globalization which enables them to enlarge the markets for their products and increase the socio-political influence on the rest of the world (Croucher, 2004). Many positive aspects of globalization are likely to lead to an increase in standard of living in most countries of the world. Yet there are some unwanted side-effects of globalization such as the increase in obesity which is now considered a global epidemic (Miljkovic et al., 2014) or adverse impact on national and regional cultural values (UNESCO, 2001; Cowen, 2002). High social cost of obesity is surely to lower the benefits of globalization, especially in less developed countries which are most susceptible to these external influences (Cowen, 2002).

Following the premises and implications from Miljkovic et al. (2014) who developed a theoretical economic model of the impact of economic and social globalization on obesity rates globally, and then tested it using a sample of 79 countries over 20-year period, we develop a dynamic model in order to measure the proportion of overweight people becoming obese and the timeframe in which this will happen both globally and by region. This information provides a useful outlook about the potential scope of this problem in future with possibly serious economic implications for all impacted countries.

2. MODEL AND DATA

Suppose that $I=I(t)$ represents the number of overweight people at year t and $y_{actual}=y_{actual}(t)$ the number of obese people at year t. The model incorporates three parameters, α, β and μ. Parameters β and μ represent respectively the proportion of overweight people that will go obese and the rate of convergence, *i.e.*, how fast the response between overweight and obesity will be. Parameter α is a general parameter given by $\alpha\beta = \mu$.

This can be modeled as a differential equation given in equation (1):

$$y' = \alpha(I(t) - \beta y) \tag{1}$$

or

$$y' = \beta(\mu I(t) - y).$$

For more simplicity, we set $\mu I(t) = w$

The function *w* is a piecewise function, *i.e.,* a function whose definition changes depending on the value of the independent variable. The function takes known values at time points t_j where j=1,2,..,n.

Equation (1) becomes:

$$y' = \beta(w - y) \tag{2}$$

Following the general solution of differential equations (Mikosch, 1998), the solution of the equation is given by:

$$y(t_{j+1}) = e^{-\alpha(t_{j+1}-t_j)}y(t_j) + \int_{t_j}^{t_{j+1}} e^{-\alpha(t_{j+1}-s)}I(s)ds \tag{3}$$

where t_j and t_{j+1} represent time points where the measurements w_j are available and

j = 1,…, n is a year.

The function I(s), representing by actual data on overweight population, is given by equation (4):

$$I(s)_{t_j \leq s \leq t_{j+1}} = I(t_j) + \frac{s-t_j}{t_{j+1}-t_j}\left(I(t_{j+1}) - I(t_j)\right) \tag{4}$$

or

$$I(s)_{t_j \leq s \leq t_{j+1}} = I(t_j)\frac{t_{j+1}-s}{t_{j+1}-t_j} + I(t_{j+1})\frac{s-t_j}{t_{j+1}-t_j}\,. \tag{5}$$

Knowing the function *I(s)* being on the interval $[t_j;t_{j+1}]$, an integration by parts is used to solve the integral in equation (3). The overall solution is obtained for equation (3):

$$y(t_{j+1}) = e^{-\alpha(t_{j+1}-t_j)}y(t_j) + \frac{1}{\alpha}\left[w(t_{j+1}) - e^{-\alpha(t_{j+1}-t_j)}w(t_j)\right] + \frac{1}{\alpha^2}\frac{w(t_j)-w(t_{j+1})}{t_{j+1}-t_j}(1 - e^{-\alpha(t_{j+1}-t_j)}) \tag{6}$$

j = 1, 2, 3,…, n where n represents the length of w and y.

Setting t_{j+1} - t_j = dt, which represent the time interval between years, equation (6) can be re-written as:

$$y(t_{j+1}) = e^{-\alpha dt}y(t_j) + \frac{1}{\alpha}\left[w(t_{j+1}) - e^{-\alpha dt}w(t_j)\right] + \frac{1}{\alpha^2}\frac{w(t_j)-w(t_{j+1})}{dt}(1 - e^{-\alpha dt}) \tag{7}$$

A cost function is introduced in the model in order to find the best available parameters. In other words, the cost function, a quadratic function, is used to optimize results obtain for the set of parameters. The overall goal is to minimize the cost function in order to find the more suitable α, β and μ. Thus, we need to find the minimum of the function:

$$f(y) = min \sum_{j=1}^{n-1} \left(y(t_{j+1}) - y_{actual}(t_{j+1}) \right)^2 \quad (8)$$

A Golden Section Method (Kiefer, 1953; Press, Teukolsky, Vetterling, and Flannery, 2007) is used in order to find a function of several parameters. Let [a,b] be a broad interval, where a is the minimum value and b the maximum value of the interval. Let x_1 and x_2 be two values of the interval and $x_1<x_2$

- If $f(x_1) < f(x_2)$ then the interval [a,b] is reduced to $[a,x_2]$

where $x_2 = a + \frac{\sqrt{5}-1}{2}(d-a)$

- If $f(x_1) > f(x_2)$ then the interval [a,b] is reduced to $[x_1,b]$

where $x_1 = a + \frac{3-\sqrt{5}}{2}(d-a)$

This method uses an algorithm that implements the statement above until finding a suitable interval, *i.e.,* the suitable parameters.

Data are collected for the period from 1986 to 2008 for 79 countries listed in Appendix 1, including both developing and developed countries. The data on obesity have been collected mainly from the WHO database; some missing data have been filled with data from the Organization for Economic Cooperation and Development (OECD) database. Notice that data on obesity are not collected and reported annually in most countries hence leading the entire data set to be in the form of the unbalanced panel data.

3. Results and Implications

A weighted average method is used in order to generate a single value for the different regions studied for each year. Equations (9) and (10) present the method used:

$$Obesity_{region} = \frac{\sum_{i=1}^{4} w_i y_i}{\sum_{i=1}^{4} w_i} \quad (9)$$

where w_i is the weight of the variable, *i.e*, the population of the country i and y_i is the percentage of obese people in the country *i*.

$$Overweight_{region} = \frac{\sum_{i=1}^{4} w_i v_i}{\sum_{i=1}^{4} w_i} \quad (10)$$

where w_i is the population of the country *i* and v_i is the percentage of overweight people in the country *i*. Matlab estimates the parameters given the set of data for the United States, the World and the European Union. Given all the set of parameters, we compare between all the categories the different proportion of overweight people that will go obese and how fast that will happen. The comparison is made in Table 1.

Table 1. Results of the Dynamic Model

	Parameter estimates		
Parameter	United States	World	European Union
α	2.473	Infinity	Infinity
β	0.344	0.344	0.274
μ	0.851	Infinity	Infinity

Parameters μ and β represent respectively the time correlation between the increase in overweight and the increase in obesity and the proportion of overweight people that go obese on the average years that have been used. It is important to notice the difference between the United States and the European Union for the parameter β: where 34.4% of overweight Americans become obese, only 27.4% of overweight Europeans take this path. A possible explanation for these results would be different diet patterns, different life-style habits or a different perception of obesity.

Overweight people in the European Union might be more aware and more concerned of the consequences of obesity on their body image. A study by McElhone et al. (1999) showed that European females are highly concerned with their body image; most women are unhappy with their weight and suffer from the societal pressure to be thin. People, concerned about their image, will be more willing to improve their body shape with weight-loss diet, more physical activity or healthier eating habits in order to return to a normal BMI and avoiding obesity.

On the contrary, a study by Rucker III and Cash (1992) suggested that Black-American women were less concerned about their weight. Thus, less effort will be made to change appearance and being obese will not necessarily be considered as being unconventional.

The second point to notice is the values of the parameter μ for the United States, the World and the European Union. Parameter μ tends to infinity for the World and the European Union.

This results means that if there is an increase in the amount of overweight people, the response for obesity will be infinitely deferred, *i.e.*, an increase of obese people will occur a long time later. On the contrary, the value of μ for the United States of 0.857 indicates that the response will happen in a shorter period of time (2.47 years). This result confirms the fact that overweight people in the United States have more chance to become obese faster than Europeans or people of the World.

This emphasizes the idea of "obesity consciousness" being less important for people in the United States, leading to a non-surveillance of weight and a weight transition from overweight to obese.

Diet habits and lifestyle are as well two potential explanations of these value differences. Finally, these results confirm less than complete transmission of a globalization externality from one of its origins (i.e., the United States) to the rest of the world.

APPENDIX 1: LIST OF COUNTRIES INCLUDED IN THE STUDY

Cuba	1	Pakistan	25	Poland	49	Finland	73
Czechoslovakia	2	Serbia and Montenegro	26	Austria	50	Israel	74
Egypt	3	Iceland	27	Czech Republic	51	Germany	75
India	4	South Africa	28	Malaysia	52	Canada	76
Lao Peoples Democratic Republic	5	Bosnia and Herzegovina	29	United Arab Emirates	53	United States of America	77
Gambia	6	Chile	30	Portugal	54	United Kingdom of Great Britain and Northern Ireland	78
Indonesia	7	Brazil	31	Nauru	55	Saudi Arabia	79
China	8	Malta	32	Mexico	56		
South Korea	9	Macedonia, FYR	33	Latvia	57		
Eritrea	10	Seychelles	34	Croatia	58		
Philippines	11	Lebanon	35	Slovakia	59		
Romania	12	Colombia	36	Estonia	60		
Kyrgyzstan	13	Greece	37	Sweden	61		
Korea (North)	14	Tunisia	38	Italy	62		
Ghana	15	Morocco	39	France	63		
Singapore	16	French Polynesia	40	Australia	64		
Cyprus	17	Norway	41	Spain	65		
Fiji	18	Denmark	42	Lithuania	66		
Mauritius	19	Iran (Islamic Republic of)	43	New Zealand	67		
Slovenia	20	Switzerland	44	Luxembourg	68		
Mongolia	21	Turkey	45	Netherlands	69		
Vanuatu	22	Japan	46	Hungary	70		
Peru	23	Bahrain	47	Tonga	71		
Dominican Republic	24	Ireland	48	Kuwait	72		

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