Trends in Energy Use and Agriculture

Joelle Cook, Jessica Henson Cagley, and Professor Alison Cullen

Prepared for the Agricultural Policy and Statistics Team of the Bill and Melinda Gates Foundation

Evans School Policy Analysis and Research (EPAR)
Professor Leigh Anderson, PI and Lead Faculty
Associate Professor Mary Kay Gugerty, Lead Faculty

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Agricultural Transformation and Mechanization

1. Can we find evidence connecting trends in wage rates with agricultural mechanization?
2. Can we find evidence connecting agricultural transformation (rising GDP, falling share of agriculture in GDP and in employment) with higher wage rates?
3. Can we connect agricultural mechanization with higher energy use in the agriculture sector?

Research Finding

Overall, evidence connecting mechanization and wage rates is sparse. We think perhaps there is more literature connecting agricultural productivity and wage rates, though that may be specifically agricultural wages.

Articles

Guthiga, P. M., Karugia, J. T., & Nyikal, R. A. (2007). Does use of draft animal power increase economic efficiency of smallholder farms in Kenya? *Renewable Agriculture and Food Systems, 22*(04), 290-296.

> *Abstract*: Draft animal power (DAP) has been identified as an environmentally friendly technology that is based on renewable energy and encompasses integration of livestock and crop production systems. Draft animal technology provides farmers with a possibility to cheaply access and use manure from the draft animals and farm power needed to apply renewable practices for land intensification. Compared to motorized mechanization, DAP is viewed as an appropriate and affordable technology especially for small-scale farmers in developing countries who cannot afford the expensive fuel-powered tractor mechanization. However, it is apparent that there is no consensus among researchers on how it affects crop yields, profit and production efficiency when applied in farm operations. This study addressed the question of whether using DAP increases economic efficiency of smallholder maize producers in central Kenya. Results of the study are derived from a sample of 80 farmers, 57% of whom used draft animals while 43% used hand hoes in carrying farm

operations. In the study area, draft animals are almost exclusively used for land preparation and planting, with very few farmers applying them in the consecutive operations such as weeding. A profit function was estimated to test the hypothesis of equal economic efficiency between and farms. The results showed that farmers who used DAP obtained higher yields and operated at a higher economic efficiency compared to those who used hand hoes. The analysis underscores the viability of DAP in increasing profitability of small-scale farms; however, other aspects of the technology, such as affordability of the whole DAP package, availability of appropriate implements and skills of using the technology, must be taken into account when promoting adoption of DAP technology.

Gaiha, R., & Imai, K. (2006). *Agricultural growth, employment and wage rates in developing countries*. Manchester: University of Manchester School of Social Sciences Economic Discussion Paper EDP-0621.

Abstract: Drawing upon different specifications and methods of panel data estimation designed to make efficient use of cross-country samples, we have analyzed the relationships among agricultural productivity, employment, technology, openness of the economy, and inequality in land distribution. Agricultural productivity varies with technology and employment, but more so with employment. The effect of openness on agricultural productivity is ambiguous -it is positive, negative or not significant, depending on the definition of openness, specification and estimation procedure used. Agricultural employment and diversification of agriculture are inversely related. A somewhat surprising result is the positive effect of inequality in land distribution on agricultural productivity. Arguably, when credit markets are incomplete, greater inequality in land distribution may imply a more significant role for large landowners in agricultural investment through easier access to credit. In another specification, the determinants of growth rates of agricultural and non-agricultural employment, and their linkages are examined using both dynamic and static models. There is a strong (lagged) positive effect of growth rate of agricultural employment on that of non-agricultural employment. Even though the share of agriculture has declined in developing countries, its contribution to overall economic growth and generation of employment is substantial. While a case for acceleration of agricultural growth through modernisation of its technology, crop diversification and exploitation of high value export opportunities rests on more complete credit and insurance markets, and infrastructural support, some negative effects of crop-diversification on employment are likely.

Jayachandran, S. (2006). Selling labor low: Wage responses to productivity shocks in developing countries. *Journal of Political Economy, 114*(3), 538-575.

Abstract: Productivity risk is pervasive in underdeveloped countries. This paper highlights a way in which underdevelopment exacerbates productivity risk. Productivity shocks cause larger changes in the wage when workers are poorer, less able to migrate, and more credit constrained because of such workers' inelastic labor supply. This equilibrium wage effect hurts workers. In contrast, it acts as insurance for landowners. Agricultural wage data for 257

districts in India for 1956-87 are used to test the predictions, with rainfall as an instrument for agricultural productivity. In districts with fewer banks or higher migration costs, the wage is much more responsive to fluctuations in productivity.

Murgai, R., & Ravallion, M. (2005). *Is a guaranteed living wage a good anti-poverty policy?* Washington, DC: World Bank.

> *Abstract*: Minimum wages are generally thought to be unenforceable in developing rural economies. But there is one solution - a workfare scheme in which the government acts as the employer of last resort. Is this a cost-effective policy against poverty? Using a microeconometric model of the casual labor market in rural India, the authors find that a guaranteed wage rate sufficient for a typical poor family to reach the poverty line would bring the annual poverty rate down from 34 percent to 25 percent at a fiscal cost representing 3-4 percent of GDP when run for the whole year. Confining the scheme to the lean season (three months) would bring the annual poverty rate down to 31 percent at a cost of 1.3 percent of GDP. While the gains from a guaranteed wage rate would be better targeted than a uniform (untargeted) cash transfer, the extra costs of the wage policy imply that it would have less impact on poverty.

Savadogo, K., Reardon, T., & Pietola, K. (1995). Mechanization and agricultural supply response in the Sahel: A farm-level profit function analysis. *Journal of African Economies, 4*(3), 336.

> *Abstract*: This paper uses farm-level survey data from Burkina Faso to estimate, using a profit function approach, the supply responsiveness of farm households to changes in prices and non-price factors, for individual crops and aggregate output. The sample is stratified first by agroecological zone and then, with an endogenous partition, into animal traction and manual (hand-tool) households. Three main conclusions emerge. First, the results run counter to the common pessimism regarding Sahel agriculture's ability to respond to better incentives (such as those created by the recent devaluation of the CFA franc) — particularly for cash cropping. Second, aggregate output responds positively to increases in the price of currently commercialized crops (cotton and maize) among traction households in the zone with the most favorable agro-climate, the Guinean zone — thus averting the fear that price increases only lead to crop mix shifts. Third, absolute levels of response for cash crops and for aggregate output are much higher where non-price factors are propitious — specifically, in the favorable agro-climate and among animal traction households that use fertilizer. Supply response is more limited in less favorable agroclimates and among households limited to hand-tool technologies. The results underscore the greater flexibility of the animal traction farmers to respond to economic incentives for cotton and maize. Donor and government programs that promote animal traction and fertilizer adoption can — via agrarian capital formation — reduce structural constraints to farmer response to macro incentives.

Van den Berg, M. M., Hengsdijk, H., Wolf, J., Van Ittersum, M. K., Guanghuo, W., & Roetter, R. P. (2007). The impact of increasing farm size and mechanization on rural income and rice production in Zhejiang province, China. *Agricultural Systems, 94*(3), 841-850.

Abstract: Economic growth in China's agricultural sector lags behind growth in industry and services, creating an ever widening rural-urban income gap. Development of the non-agricultural sectors offers new opportunities for farmers in China's more advanced provinces such as Zhejiang. Increased income in the urban sector creates markets for new products, and migrating farmers rent their land to those staying. Until now, the prevailing rice-based systems have been managed mainly using manual labor and animal traction, but the larger farms resulting from migration may facilitate, or even require mechanization. In this study, we use a simulation model of the farm household to analyze the effects of increasing farm size and the transition from rice to vegetable production, while also studying the effects of mechanization. Our results show that at the present scale of farming, the dual government objectives of increasing rural incomes and increasing rice production are clearly conflicting. Farmers can generate incomes comparable to non-farm wages, but only when they switch completely to production of more remunerative crops, such as vegetables. At larger farm sizes, however, labor constraints inhibit farmers from specialization in non-rice crops, and rising per capita incomes and increasing rice production go hand in hand. Mechanization is necessary to allow substantial increases in farm size.

Point 3

Jekayinfa, S. O., & Olajide, J. O. (2007). Analysis of energy usage in the production of three selected cassava-based foods in Nigeria. *Journal of Food Engineering, 82*(2), 217-226.

Abstract: A study was conducted in 18 cassava processing mills situated in the southwestern part of Nigeria to investigate the energy utilization pattern in the production of three different cassava products, 'gari', cassava flour and cassava starch. Six mills specializing in the production of each of the products were randomly selected for investigation. The computation of energy use was done using the spreadsheet program on Microsoft Excel. Optimization models were developed to minimize the total energy input into each production line. The results of the study showed that the observed energy requirements per ton of fresh cassava tuber for production of gari, starch and flour were 327.17, 357.35 and 345 MJ, respectively. The study identified the most energy-intensive operations in each production line and concluded from optimization results that the total minimum energy inputs required for the production of gari, cassava starch and cassava flour per ton of fresh cassava tuber were 290.53, 305.20 and 315.60 MJ, respectively.

Dietary diversification and energy needs

1. Are there any life cycle assessments of energy use in modern food systems (e.g. supermarkets) as opposed to traditional food systems (e.g. wet markets, etc.)?
2. Any assessment of post harvest energy use trends (cold storage, transportation, processing, retail infrastructure) especially in big developing countries?

Research Finding

For point one, there were a few articles comparing energy use in traditional versus modern food production, but none that compared larger systems. For point two, we could not find quality, country-wide, longitudinal data exclusively investigating post-harvest energy use. Most of the data available traces postharvest energy use from the consumer backward and does not include changes over time.

Articles

Andersson, K., & Ohlsson, T. (1999). Life cycle assessment of bread produced on different scales. *The International Journal of Life Cycle Assessment, 4*(1), 25-40.

> *Abstract:* A case study of white bread has been carried out with the purpose of comparing different scales of production and their potential environmental effects. The scales compared are: home baking, a local bakery and two industrial bakeries with distribution areas of different sizes. Data from the three bakeries and their suppliers have been collected. The systems investigated include agricultural production, milling, baking, packaging, transportation, consumption and waste management. Energy use and emissions have been quantified and the potential contributions to global warming, acidification, eutrophication and photo-oxidant formation have been assessed. The large industrial bakery uses more primary energy and contributes more to global warming, acidification and eutrophication than the other three systems. The home baking system shows a relatively high energy requirement; otherwise, the differences between home baking, the local bakery and the small industrial bakery are too small to be significant.

Parikh, J. K., & Syed, S. (1988). Energy use in the post-harvest food (PHF) system of developing countries. *Energy in Agriculture, 6*(4), 325-351.

> *Abstract:* This paper reports on the methodology and results of the study on estimation of energy consumption in post-harvest-food systems in developing countries. The components of the PHF system are: food processing, transportation, storage and cooking. The study is rather ambitious in its coverage of 70 processed commodities in 90 countries of Africa, Latin America, the Far East and Near East. This was possible because of the considerable variety of computer data available at FAO for such an analysis. Of course, extensive checking was required for each country but much of the approximations remain, leading only to broad implications. Despite the difficulties with precise data, it seems reasonable to draw the

following conclusions from the available information: the post-harvest-food system requires 2 to 4 times more energy than at farm level: the share of commercial energy which is often used for food processing, such as milling, crushing, and food transport, and to some extent for cooking, ranges between 22% in Africa and 80% in the Near East; the levels of energy consumption in the PHF system depends on income levels and extent of urbanization, and whether a country has locally available fossil fuels or forests. In addition, different components of the PHF system are sensitive to different parameters. For example, energy in food processing depends on cropping, dietary patterns, and whether food is exported or imported, whereas food transport depends on the size of the countries and location of urban areas with respect to farms. These parameters are discussed here for the four world regions as well as for the 90 developing countries as a whole. Country-specific insights are given graphically due to impracticability of reporting all data in detail.

Conservation tillage

1. We're also interested in the extent of/potential for conservation tillage in improving soil carbon storage and mitigating greenhouse gas emissions. However, we are more familiar with the literature (what little there is) and are not aware of any solid review article. If you come across a stellar ref or two, this would be useful also.

Research Finding

There seem to be a number of good articles exploring potential for conservation tillage in mitigating climate change. The three articles below are all highly cited global reviews that were cited by the Intergovernmental Panel on Climate Change's 2007 Mitigation of Climate Change report. The paragraph discussing conservation tillage for mitigating climate change in the report is also included as the fourth citation.

Articles

West, T. O., & Post, W. M. (2002). Soil organic carbon sequestration rates by tillage and crop rotation: A global data analysis. *Soil Science Society of America Journal, 66*(6), 1930-1946.

Abstract: Changes in agricultural management can potentially increase the accumulation rate of soil organic C (SOC), thereby sequestering CO_2 from the atmosphere. This study was conducted to quantify potential soil C sequestration rates for different crops in response to decreasing tillage intensity or enhancing rotation complexity, and to estimate the duration of time over which sequestration may occur. Analyses of C sequestration rates were completed using a global database of 67 long-term agricultural experiments, consisting of 276 paired treatments. Results indicate, on average, that a change from conventional tillage (CT) to no-till (NT) can sequester 57 ± 14 g C m^{-2} yr^{-1}, excluding wheat (*Triticum aestivum* L.)-fallow systems which may not result in SOC accumulation with a change from CT to NT. Enhancing rotation complexity can sequester an average 20 ± 12 g C m^{-2} yr^{-1}, excluding a change from continuous corn (*Zea mays* L.) to corn-soybean (*Glycine max* L.) which may not result in a significant accumulation of SOC. Carbon sequestration rates, with a change from CT to NT, can be expected to peak in 5 to 10 yr with SOC reaching a new equilibrium in 15 to 20 yr. Following initiation of an enhancement in rotation complexity, SOC may reach a new equilibrium in approximately 40 to 60 yr. Carbon sequestration rates, estimated for a number of individual crops and crop rotations in this study can be used in spatial modeling analyses to more accurately predict regional, national, and global C sequestration potentials.

Smith, K. A., & Conen, F. (2004). Impacts of land management on fluxes of trace greenhouse gases. *Soil Use and Management, 20*(2), 255-263.

Abstract: Land use change and land management practices affect the net emissions of the trace gases methane (CH_4) and nitrous oxide (N_2O), as well as carbon sources and sinks. Changes in CH_4 and N_2O emissions can substantially alter the overall greenhouse gas balance of a system. Drainage of peatlands for agriculture or forestry generally increases N_2O emission as well as that of CO_2, but also decreases CH_4 emission. Intermittent drainage or late flooding of rice paddies can greatly diminish the seasonal emission of CH_4 compared with continuous flooding. Changes in N_2O emissions following land use change from forest or grassland to agriculture vary between climatic zones, and the net impact varies with time. In many soils, the increase in carbon sequestration by adopting no-till systems may be largely negated by associated increases in N_2O emission. The promotion of carbon credits for the no-till system before we have better quantification of its net greenhouse gas balance is naïve. Applying nitrogen fertilizers to forests could increase the forest carbon sink, but may be accompanied by a net increase in N_2O; conversely, adding lime to acid forest soils can decrease the N_2O emission.

Marland, G., West, T. O., Schlamadinger, B., & Canella, L. (2003). Managing soil organic carbon in agriculture: The net effect on greenhouse gas emissions. *Tellus, 55*, 613–621.

Abstract: A change in agricultural practice can increase carbon sequestration in agricultural soils. To know the net effect on greenhouse gas emissions to the atmosphere, however, we consider associated changes in CO_2 emissions resulting from the consumption of fossil fuels, emissions of other greenhouse gases and effects on land productivity and crop yield. We also consider how these factors will evolve over time. A change from conventional tillage to no-till agriculture, based on data for average practice in the U.S., will result in net carbon sequestration in the soil that averages 337 kg C ha^{-1} yr^{-1} for the initial 20 yr with a decline to near zero in the following 20 yr, and continuing savings in CO_2 emissions because of reduced use of fossil fuels. The long-term results, considering all factors, can generally be expected to show decreased net greenhouse gas emissions. The quantitative details, however, depend on the site-specific impact of the conversion from conventional to no-till agriculture on agricultural yield and N_2O emissions from nitrogen fertilizer.

Intergovernmental Panel on Climate Change (IPCC). (2007). Working group III report: Mitigation of climate change. Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Excerpt: Tillage/residue management: Advances in weed control methods and farm machinery now allow many crops to be grown with minimal tillage (reduced tillage) or without tillage (no-till). These practices are now increasingly used throughout the world (e.g., Cerri *et al.*, 2004). Since soil disturbance tends to stimulate soil carbon losses through enhanced decomposition and erosion (Madari *et al.*, 2005), reduced- or no-till agriculture often results in soil carbon gain, but not always (West and Post, 2002; Ogle *et al.*, 2005; Gregorich *et al.*, 2005; Alvarez 2005). Adopting reduced-or no-till may also affect N_2O, emissions but the net effects are inconsistent and not well-quantified globally (Smith and Conen, 2004; Helgason *et al.*, 2005; Li *et al.*, 2005; Cassman *et al.*, 2003). The effect of reduced tillage on N_2O emissions may depend on soil and climatic conditions. In some areas, reduced tillage promotes N_2O emissions, while elsewhere it may reduce emissions or have no measurable influence (Marland *et al.*, 2001). Further, no-tillage systems can reduce CO_2 emissions from energy use (Marland *et al.*, 2003b; Koga *et al.*, 2006). Systems that retain crop residues also tend to increase soil carbon because these residues are the precursors for soil organic matter, the main carbon store in soil. Avoiding the burning of residues (e.g., mechanizing sugarcane harvesting, eliminating the need for pre-harvest burning (Cerri *et al.*, 2004)) also avoids emissions of aerosols and GHGs generated from fire, although CO_2 emissions from fuel use may increase.