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The Effect of Agricultural Technology on the Speed of Development

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Summary. — We examine heterogeneity in the elasticity of agricultural output with respect to labor. Employing panel data from 128 countries over a forty-year period we find distinct heterogeneity in the elasticity of agricultural output with respect to labor. This elasticity is lowest in countries with temperate and/or cold climate regions, and higher in countries including tropical or highland regions. This agricultural parameter determines the speed of structural change following changes in agricultural productivity or population. Calibration shows shifts in labor allocations and welfare will be 2–3 times larger in temperate regions than in tropical or highland regions.

Key words — agricultural development, technology heterogeneity, agro-climatic environment, structural change

1. INTRODUCTION

The agricultural sector is a significant portion of GDP and employment in most developing countries today, and historically made up a large fraction of both in currently developed countries. As such, agricultural production has been of interest to economists studying the process of development and growth. A prominent view of the importance of agriculture for development comes from Schultz's (1953) characterization of the "food problem"; until countries can produce a sufficient amount of food, labor is trapped in agriculture and they cannot begin the process of modern growth. This idea has been carried forward by others, such as Johnston and Mellor (1961), Johnston and Kilby (1975), and Mellor (1995). Gollin (2010) provides an overview of this line of thinking, which implies that increased agricultural productivity is a key to structural transformation and subsequent economic development in response to productivity shocks. McMillan, Rodrik, and Verduzco-Gallo (2014) argue that this structural transformation remains an important source of potential economic growth in sub-Saharan Africa.

In this paper we emphasize that the positive effects of agricultural *productivity* improvements—i.e., higher total factor productivity (TFP) or the increased use of non-labor inputs—depend crucially on agricultural *technology*. Specifically, we define agricultural technology as the elasticity of agricultural output with respect to labor. We first show that in a standard model of structural change this technology affects the pace of development. In particular, an economy with a low labor elasticity will experience larger shifts of labor between sectors, greater increases in agricultural labor productivity, and greater increases in GDP per capita than an economy with a high elasticity after any kind of productivity increase in agriculture. The logic of this result rests on the importance of labor in the agricultural technology, which is captured by the elasticity. If the elasticity is low, then agricultural output is insensitive to the number of workers in that sector. A productivity increase makes it possible to release a large number of workers and still meet the demand for food. These freed-up workers are available to produce non-agricultural goods, raising GDP per capita. In contrast, a large elasticity implies that agricultural output is very sensitive to the number of workers. Even with a productivity increase, few workers can leave agriculture without decreasing production below what is demanded. Hence high-elasticity economies do not shift as many workers out of agriculture and are able to produce fewer additional non-agricultural goods in response. Real GDP per capita rises, but not by as much as seen in economies with a low elasticity.

Given this theoretical distinction, we then undertake two tasks, one empirical and one quantitative. The empirical task is to estimate agricultural production functions for a panel of 128 countries using annual data over a long time horizon. We adopt an empirical framework that allows for heterogeneity in technology as well as for common shocks to production and/or technology spillovers between countries ("cross-sectional dependence"). The common factor model framework employed is particularly suited to this type of analysis, where a primary concern is an unobserved TFP term (Bai, 2009; Chudik, Pesaran, & Tosetti, 2011). This empirical setup speaks directly to Matsuyama's (2009) criticism of empirical studies of structural change as being analyzed "under the false assumption that each country offers an independent observation" (484).

The heterogeneous technology setup we allow in our empirical analysis takes into account Hayami and Ruttan's (1970) claim that technology differences between countries are likely to be substantial. Subsequent research—including Hayami and Ruttan's (1985) own work—has tended to ignore this claim and work with homogenous technology parameters. [1] The closest studies to our work here are Mundlak, Butzer, and Larson (2012) and Eberhardt and Teal (2013a, 2013b). These papers show that common technology across countries is rejected by the data, although technology parameters appear to be constant over time within countries. While those papers focus primarily on *establishing* the presence of technology heterogeneity, in this study we explore the agro-climatic patterns of technology heterogeneity and their implications for development.

Our results indicate that while on average the labor elasticity of agriculture (our measure of technology) is about 0.3, there is wide variation in this value based on climate type. Countries with primarily temperate climate have elasticities

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of approximately 0.15, while tropical and highland countries have an elasticity that ranges from 0.35 to 0.55. The relationship of the elasticity and climate zone is not an artifact of development levels, as the patterns of our country-specific estimates of the labor elasticities do not align systematically with income per capita.

The second, quantitative, task we pursue is to assess the role that agricultural technology plays in structural change and development. We calibrate our standard two-sector model of labor allocations between agriculture and non-agriculture. This type of model has been used by Duarte and Restuccia (2010), Restuccia, Yang, and Zhu (2008), and Gollin, Parente, and Rogerson (2007) among others to quantitatively study structural change and development.[2] We calibrate the model using data from South Korea during 1963–2005. In this period South Korea experienced a significant shift of labor out of agriculture, as well as major increases in labor productivity in both agriculture and non-agriculture. It therefore serves as a useful benchmark for evaluating the effects of productivity increases on sectoral shifts in developing countries.

Using the calibrated model we examine the effect of an increase in agricultural total factor productivity (TFP) on sectoral labor shares, consumption levels, and real GDP per capita for developing economies that begin with 80% of their workforce in agriculture. The model economies we examine are identical in their initial labor shares and consumption levels. With a labor elasticity in agriculture of 0.15, such as in temperate regions, a 20% increase in agricultural TFP reduces the agricultural labor share to under 40%, more than doubles real labor productivity in agriculture, and increases real GDP by about 50%. In contrast, an economy with a labor elasticity in agriculture of 0.55, such as in equatorial or highland regions, the same 20% increase in agricultural TFP only reduces agricultural labor to 60%, increases labor productivity in agriculture by only 37%, and increases real GDP per capita by only 22%. This is a 2–3-fold advantage for the low-elasticity economy, even though the improvement to agricultural productivity was identical.

The situation is not universally favorable to countries with low labor elasticities in agriculture, though. Just as they are able to move large amounts of labor *out* of agriculture when productivity rises, they are also forced to move large amounts of labor *in* to agriculture when population rises, which acts like a decline in productivity. A 5% increase in population will take the agricultural labor share from 80% to 94% in an economy with a labor elasticity of 0.15, while the same increase in population will only raise the labor share from 80% to 82% when the elasticity is 0.55. The population increase drops real GDP per capita by 15% when the elasticity is 0.15, but only by 2.5% if the elasticity is 0.55.

Agricultural technology therefore does not provide a unique indicator of development possibilities. What is crucial is the gain in agricultural productivity relative to population growth. So long as the productivity increases out-run population growth, a low-elasticity economy will develop faster than a high-elasticity one. To understand just what a dramatic difference this can make over the long run, we feed the observed changes in agricultural productivity, non-agricultural productivity, and population growth from South Korea 1963–2005 through the model using different values of the labor elasticity. For an economy with an elasticity of 0.15, this reduces the agricultural labor share from 80% to less than 5%, while raising GDP per capita by a factor of 4.6. In an economy with an elasticity of 0.55, the labor share drops from 80% to 13%, while GDP per capita only rises by a factor of 3.9. Differing solely in their agricultural technology, the economies end up with a significant difference in living standards despite having access to the same productivity improvements and experiencing the same population growth rate.

These results suggest that a "one-size-fits-all" approach to thinking about agricultural productivity and structural change is not warranted. There are significant differences in agricultural technology across countries, and these differences determine the degree to which an economy can take advantage of productivity improvements or suffer from population increases. Slow migration rates from rural to urban areas (de Brauw, Mueller, & Lee, 2014) and the subsequent inability to exploit urban agglomeration effects (Dorosh & Thurlow, 2014; Tiffen & Mary, 2003) within Africa may be the result of tropical agriculture's relatively high labor elasticity. While agricultural productivity improvements may be necessary to drive economic growth (Collier & Dercon, 2014; Diao, Hazell, & Thurlow, 2010), our results show that tropical agriculture will require a greater scale of improvements compared to temperate countries. We cannot expect that all developing countries will respond similarly to productivity-enhancing policies in agriculture, and the past experience of temperate countries may not be a useful benchmark for tropical countries today.

The paper proceeds as follows. In the next section we introduce our simple dual economy model and derive our theoretical results. Section 3 discusses the data, empirical setup, and regression results. Having established the variation in the labor elasticity from these estimation, we then present our calibration and counterfactual exercises in Section 4. The final section concludes.

2. AGRICULTURAL TECHNOLOGY AND STRUCTURAL CHANGE

To understand the impact of agricultural technology in contrast to agricultural productivity we use a simple model of the process of structural change and development. There are two sectors: agriculture and non-agriculture. Individuals face a subsistence constraint for agricultural goods that makes the income elasticity less than one, and they are endowed with some units of non-agricultural goods that ensure the income elasticity of these goods is greater than one. The model shares its structure with that found in recent work by Alvarez-Cuadrado and Poschke (2011), Duarte and Restuccia (2010), Herrendorf, Rogerson, and Valentinyi (2014). Within the model, agriculture is produced using land and labor, and the agricultural technology is captured by the elasticity of agricultural output with respect to labor. The model will show that the response of the agricultural labor share to a shock in productivity depends on agricultural technology. In particular, economies with low labor elasticities will experience more rapid structural change than economies with high elasticities.

(a) *Production*

The production function for agriculture is

$$Y_a = AL_a^{\beta_L}, \tag{1}$$

where L_a is labor employed in agriculture, and β_L is the elasticity of output with respect to that labor. This parameter will be the focus of our analysis, and we will show below in the empirical section that this parameter varies widely across different types of crop systems.[3]