Journal of Development Economics 107 (2014) 38–48

Contents lists available at ScienceDirect

Journal of Development Economics

journal homepage: www.elsevier.com/locate/devec

Productivity, transport costs and subsistence agriculture ☆

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ARTICLE INFO

Article history:
Received 20 February 2012
Received in revised form 24 June 2013
Accepted 7 October 2013

Keywords:
Economic development
Structural transformation
Transport costs
Subsistence agriculture
Agricultural development
Two-sector model

ABSTRACT

A defining feature of many poor economies is the large fraction of workers engaged in subsistence agriculture. We develop a multi-sector multi-region model of a poor economy in which it is costly to transport goods across regions in order to study this outcome. A key finding is that higher transport costs drive up the size of the agricultural workforce and the fraction in subsistence. In a calibrated version of our model we show that the effect of transport productivity is quantitatively important in terms of both allocations and welfare.

1. Introduction

In many developing countries, agriculture is the dominant economic activity, accounting for large shares of employment and output. For example, in sub-Saharan Africa the employment share of agriculture is almost 60% and many countries in the region derive 25% or more of GDP from the agricultural sector.[1] Moreover, many individuals in the agricultural sector in these countries are best characterized as engaging in subsistence or quasi-subsistence agriculture, meaning that they consume most of what they produce. While there is no systematic evidence on the prevalence of subsistence agriculture, we note that in Uganda, for example, 58% of rural households are defined as being in subsistence, with some remote districts reporting totals as high as 80% (Uganda Bureau of Statistics, 2006, p. 74). To the extent that the lack of development in these economies is synonymous with a large fraction of the population engaged in subsistence agriculture, understanding what factors lead to such heavy reliance on subsistence agriculture is an issue of importance to policy makers. (See, for example, World Bank, 2007).

The literature on structural transformation emphasizes productivity in agriculture and non-agriculture as determinants of the sectoral allocation of labor.[2] A distinct literature has argued that high transport costs pose a major impediment to development in Africa and other regions of the developing world.[3] In this paper we develop a simple general equilibrium model of subsistence agriculture in which the extent of subsistence agriculture reflects the interplay among sectoral productivities and transportation productivity. We use this model to understand how changes in each of these factors influence the extent of subsistence agriculture and welfare.

Our model features two goods: an agricultural good and a manufacturing good. The manufacturing good uses only labor as an input, whereas the agricultural good uses labor, land and the manufacturing good as an intermediate input. On the preference side, the key feature of our model is a non-homotheticity that generates an income elasticity for the agricultural good that is less then unity. On the production side our model emphasizes the spatial structure of production: we assume that all manufacturing activity takes place in the urban region while all agricultural activity takes place in the rural region. The rural region is

☆ Research for this paper was funded by the NBER Program on African Successes. We appreciate the support of the Program's organizers, Sebastian Edwards, Simon Johnson, and David Weil; we also benefited from the comments of the participants in the Program workshops in February 2009 and December 2009. We gratefully acknowledge the comments and intellectual inputs of Diego Comin, Cheryl Doss, Berthold Herrendorf, Stephen Parente, Jim Schmitz, and Anand Swamy, as well as two anonymous referees whose suggestions greatly improved the paper. We are especially grateful to Dr. Wilberforce Kisamba-Mugerwa, Chair of the Uganda National Planning Authority, who contributed many valuable insights.

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[1] The employment share is from FAOSTAT (Food and Agriculture Organization of the United Nations, 2012), and the GDP share is from World Development Indicators (World Bank, 2012) for 2005, the most recent year with relatively complete data.

[2] See, for example, the analysis of by Ngai and Pissarides (2007), which generalized the earlier work of Baumol (1967). Herrendorf et al. (2013) survey the related literature. Restuccia et al. (2008) make the point that sectoral productivity differences are an important proximate reason for cross-country income disparities.

[3] This includes theoretical papers along with a number of recent policy and empirical papers, such as Platteau (1996), Fan and Hazell (2001), Fan and Kang-Chan (2004), Torero and Chowdhury (2005), Renkow et al. (2004), Zhang and Fan (2004), and Minten and Stifel (2008). A recurring view in this literature is that African transport costs are so high that they alter incentives for agricultural investment and impede development.

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http://dx.doi.org/10.1016/j.jdeveco.2013.10.007

further subdivided into two distinct areas that differ in their extent of remoteness, and we will accordingly refer to them as the "near" and the "remote" region. Specifically, we assume that there are iceberg transportations costs associated with moving goods across the three regions, and that these costs are greatest for moving goods into and out of the remote region. People are assumed to be mobile across regions. In our calibrated equilibrium, individuals who live in the remote region will be very close to autarky, and we will identify them with the subsistence agriculture sector.

Our simple model embodies several intuitive forces that shape the allocation of labor to agriculture. In a model without transportation costs, but with non-homotheticities in preferences, lower productivity in either agriculture or non-agriculture can lead to a greater share of labor in agriculture. Low productivity in the agricultural sector leads to greater allocation of labor to agriculture because food is a necessity. And low productivity in the manufacturing sector implicitly hampers the use of intermediate inputs in agricultural production, thereby indirectly lowering labor productivity in that sector and again leading to a greater share of labor allocated. Lower productivity in transport (i.e., higher iceberg transportation costs) has a similar effect: because individuals require food, sufficient food must be produced in rural areas and transported to urban areas to support the non-agricultural workforce. If transport costs are very high, food becomes very expensive in urban areas relative to rural areas, creating an incentive for individuals to locate in rural areas. Similarly, high transport costs limit the use of intermediate inputs in agriculture, inducing the same effects as lower productivity in the manufacturing sector. We establish these effects analytically in a two-region version of our model.

We then calibrate our model to match the features of a typical sub-Saharan African country and we use our calibrated model to assess the quantitative magnitudes of these effects. The first issue we address is the relative importance of marginal changes in agricultural productivity, transportation costs, and the price of intermediate goods on the share of labor devoted to agriculture, and in particular the share of the population in subsistence agriculture. Improvements in agricultural productivity and lower costs of intermediate inputs both serve to increase the output of the agricultural sector for a given level of labor input; hence, both serve to free up labor from the agricultural sector. Consistent with earlier papers (see, for example, Gollin et al., 2002, 2007), improvements in agricultural productivity have a large impact on the share of labor devoted to agriculture. Interestingly, all of the decrease occurs in subsistence agriculture; in fact, the share of the population that resides in the near region actually increases. We also find that improvements in transportation have significant effects on the fraction of the population living in agriculture. Here the effect is essentially to move individuals from subsistence agriculture into manufacturing, leaving the share of workers living in the near region virtually unchanged. While improvements in manufacturing productivity also lower the share of the population in subsistence agriculture – with an almost identical increase in the share of the population in manufacturing – the magnitude of this effect is dramatically lower than the other two. We conclude that at low levels of development, structural transformation is largely dictated by improvements in agricultural productivity and transportation productivity.

We are also interested in the interaction effects between various changes that one might generally associate with development. In particular, we contrast the experiences of two economies that have identical initial situations but then experience changes. In one economy, total factor productivity (TFP) increases uniformly across all sectors, whereas in the other economy this increase in TFP is matched with an equivalent improvement in transportation productivity. We find that there are large interaction effects, so that an economy that fails to experience improvements in transportation productivity will experience substantially less structural transformation in response to given increases in productivity.

Having established that improvements in transportation are important, we can also study the relative importance of the different margins through which aggregate transportation productivity may increase. Specifically, we contrast the case of a uniform improvement, applying to both the near and the remote region, with an alternative case in which we simply expand the size of the near region, holding transport costs to the remote region unchanged. This effectively approximates an experiment in which transport connections are improved between the urban area and a surrounding hinterland. We find the effects of the second alternative to be much larger, suggesting that there is an incentive to concentrate improvements in transportation, although we do not take into account possible cost differences of the two experiments.

Lastly, we also consider the effect of population increases in our model. Given the high rates of population growth in sub-Saharan Africa, we think it is important to understand the effects of this background process for the allocation of labor across activities. An important finding is that increases in population, holding productivity levels constant, lead to an increase in the fraction of the population living in subsistence. The qualitative mechanism is as follows: holding land endowments constant, a higher population implies (given a diminishing marginal product of labor) that output per person is lower. This decreases the amount of food that is available for shipment into urban areas, leading to a reallocation of some workers back into the rural area. We find that this mechanism is quite substantial quantitatively.

Our paper is most closely related to Adamopoulos (2011) and Herrendorf et al. (2012). Like us, these authors consider how differences in transport costs affect sectoral labor allocations. While there are several details that differ between their specifications and ours, the key difference is that we consider heterogeneity in transport costs across rural areas, allowing us to generate heterogeneity within the agricultural sector and thereby distinguish between "modern" agriculture and "subsistence" agriculture. This feature also allows us to consider some additional policy questions related to transportation, since we can distinguish between intensive and extensive margins in terms of connectedness. Relative to Adamopoulos, we consider some additional exercises and focus on a somewhat different setting. Specifically, we address the issue of how population growth affects labor allocations and we also distinguish between the effects of agricultural and manufacturing productivity. Lastly, we carry out explicit welfare calculations.

In addition to these two papers, we also note briefly several other recent papers that estimate intranational transportation costs in developing countries, including Allen (2012), Atkin and Donaldson (2012), Donaldson (2010), and Storeygard (2012). Although our paper takes a different methodological approach, there are important areas of thematic overlap between our work and this line of research.

2. Model

We assume that the model economy consists of a large number of identical families, each of which is composed of many identical individuals. For convenience we normalize the number of families to equal one and also assume that each family has a mass one of individuals. All individuals have preferences over two goods, which we label as agriculture (a) and manufacturing (m), given by[4]:

$$u(a-\overline{a}) + v(m+\overline{m}) \tag{1}$$

where u and v are both increasing, strictly concave functions and $\overline{a}$ and $\overline{m}$ are both strictly positive. The key feature of these preferences is the presence of the $\overline{a}$ and $\overline{m}$ terms, which serve to make the income elasticity of the agricultural good less than one and that of the manufactured good greater than one.[5] Each family seeks to maximize an equal weighted average of its members' utilities.

[4] While we follow the tradition of referring to the nonagricultural good as the manufacturing good, it should be interpreted as representing both the manufacturing and the service sectors.

[5] It is sufficient that at least one of $\overline{a}$ or $\overline{m}$ be greater than zero for this property to hold. Having both positive allows for the possibility of a corner solution in which $m = 0$, even if v has infinite marginal derivative at zero.