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Agriculture, Roads, and Economic Development in Uganda

Douglas Gollin and Richard Rogerson

2.1 Introduction

In many developing countries, agriculture is the dominant economic activity, accounting for large shares of employment and output. This chapter considers the case of Uganda, a country in East Africa in which the

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We owe many intellectual debts, as well, particularly to Stephen Parente, with whom we have worked closely on previous papers that address related topics. We have also benefited from conversations with Cheryl Doss, Berthold Herrendorf, Jim Schmitz, and Anand Swamy. In Uganda, we received extraordinary help and intellectual contributions from Dr. Wilberforce Kisamba-Mugerwa, who took a great interest in our work in his official capacity as Chair of the National Planning Authority—but who also contributed his insights as a scholar, a policy practitioner, and a farmer. We gratefully acknowledge his help and support, without holding him accountable for any of the conclusions of our research.

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economy is heavily dependent on agriculture. Over 80 percent of Uganda's households (and 85 percent of the people) live in rural areas, and most of these depend on agriculture for their primary source of income.[1]

By any measure, rural and agricultural households are overwhelmingly and disproportionately poor. The poverty rate in rural areas was estimated at 34.2 percent in 2005/06, compared to an urban poverty rate of 13.7 percent. Other measures of living standards tend to support this estimate; rural households spend far larger fractions of their incomes on food and have significantly fewer clothes, shoes, and other possessions than do urban households.

This chapter asks a series of questions about the agricultural sector's role in economic development in Uganda. To begin with, why do so many people live and work in rural areas, when material living conditions are relatively much worse than in cities? In particular, why are so many people dependent for their livelihood on semisubsistence agriculture? The government estimates that in some regions of the country, 85–90 percent of households receive their main source of income from subsistence agriculture.

The literature notes several possible reasons why so many individuals are involved in subsistence agriculture, including such things as various barriers that impede the growth of the nonagricultural sector or a variety of factors that lead to low productivity in the agricultural sector. While our analysis will include an evaluation of these explanations, our primary focus is to assess the role that lack of transportation infrastructure plays in promoting such a large subsistence agriculture sector. While the idea that poor trans-

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Finally, we gratefully acknowledge the support of FEWS NET (the Famine Early Warning System Network) who provided us with a lengthy time series of data on agricultural prices in Uganda. The FEWS NET is a project of the US Agency for International Development. We particularly appreciate additional information and thoughtful comments provided by Mildred Magut and Patricia Bonnard of FEWS while absolving them of any responsibility for our interpretation of the data. For acknowledgments, sources of research support, and disclosure of the authors' material financial relationships, if any, please see http://www.nber.org/chapters/c13433.ack.

1. To be precise, nationally representative household surveys estimate that 78.8 percent of households in Uganda were rural in 2005/06, accounting for 84.6 percent of the population and 93.2 percent of those living below the poverty line.

portation infrastructure might play a key role in the development process does feature prominently in many policy discussions, there is relatively little systematic work to explore the economic mechanisms through which it operates. A key objective of this work is to take a first step toward articulating these economic mechanisms.

To pursue this, our chapter uses a static general equilibrium model that reflects key features of the Ugandan economy. We use a two-sector model in which there is an agricultural sector and a nonagricultural sector. This model is similar in spirit to earlier papers by Gollin, Parente, and Rogerson (2002, 2007) that focus on the structural transformation that accompanies development—in which economies move labor and other resources out of agriculture into other sectors and activities. We extend this basic model to reflect one of the realities of the Ugandan economy, namely, the fact that in much of the country, roads and other transportation infrastructure are very poor. This means that rural markets in Uganda are characterized by high transportation and transaction costs. Our model correspondingly includes an iceberg cost of moving goods from rural areas to urban areas (and vice versa). We examine the extent to which high transport costs can partly account for the large fraction of people living in rural areas in Uganda.

The underlying economics are intuitive. Individuals require food, implying that sufficient food must be produced in rural areas and transported to urban areas to support the nonagricultural 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 to economize on transportation costs. In a poor country where food accounts for a large share of overall expenditure, this force is potentially very large.

Next, our chapter asks how specific interventions would affect the allocation of labor and inputs across economic activities, and how these interventions would alter the welfare of people in the Ugandan economy. To assess the impact of these interventions, we first calibrate the model to replicate certain features of the Ugandan data. By altering parameters in the model, we can conduct some simple and straightforward simulations of various policies and interventions.

First, we ask how the economy would benefit from improvements in agricultural productivity. Would increased agricultural total factor productivity (TFP) push workers out of the agricultural sector, or would it draw more workers in? How much would TFP increases affect welfare in an economy where agricultural goods account for a large fraction of consumption? Second, we ask how the economy would respond to increases in nonagricultural productivity. How would these affect the fraction of the population living in urban areas and working in nonagriculture? How would nonagricultural TFP growth affect welfare? Third, we consider the impact of a reduction in transportation costs, such as might result from improvements in roads or other transportation infrastructure. How would the allocation of workers across sectors be affected by changes in the transportation cost structure? What would be the effects on welfare? What would be the joint effect of reducing transport costs simultaneous with an increase in agricultural TFP? Finally, we consider the effect of population growth on a fixed land base. Although this is not explicitly a policy question, we believe it offers useful insights on an economy that currently features one of the highest population growth rates in the world.

To briefly summarize the findings of the chapter, we find that agricultural productivity improvements have a relatively large impact on the economy. Because the nonagricultural sector is initially small, and because the economy faces a subsistence constraint that limits the expansion of the nonagricultural sector, improvements in nonagricultural TFP have relatively small positive impacts on the economy. Reductions in transportation costs generate sizable benefits for the economy and trigger substantial reallocations of labor across sectors. When agricultural TFP improves at the same time that transportation costs are reduced, the welfare gains exceed those achieved from the two interventions separately, suggesting a kind of interaction effect.

The remainder of the chapter is organized as follows. Section 2.2 presents some background information on Uganda's development, with a particular focus on agriculture and on transportation costs and infrastructure. In section 2.3, we review related literature. Section 2.4 presents a two-region model that will provide the backbone for our analysis. Section 2.5 discusses the calibration of this model and shows results. In section 2.6, we offer an expanded model with three regions, which allows us to focus in more detail on the quasi-subsistence agricultural sector. Section 2.7 draws out some conclusions and implications for policy.

2.2 Background

Uganda is among the poorest countries in the world, with real per capita income of just over $1,100 in 2003, according to the Penn World Tables (version 6.2; Heston, Summers, and Aten [2006]). This level of income places the country firmly in the bottom quintile of the cross-country income distribution. As noted above, Uganda also ranks among the countries most heavily dependent on agriculture. In many ways, Uganda is fairly typical of many sub-Saharan countries with large rural populations. However, in some respects, Uganda offers a distinct set of challenges and characteristics.

2.2.1 Agriculture in Uganda

Because it is landlocked, Uganda produces essentially all of its own food, and most of its agriculture is oriented toward production of food for domestic consumption. Clearly there is a significant amount of agricultural production for export—chiefly in coffee and a few other crops. Our model economy will be closed, so we will essentially ignore export agriculture. In the paragraphs that follow, we will explain why we think this is a reasonable depiction of agriculture in Uganda. We will also explain why we are specifically interested in the quasi-subsistence agriculture sector, which is a large fraction of the total in Uganda.

Almost all agricultural production in Uganda takes place on smallholder plots, with mixed cropping systems predominating. Two-thirds of agricultural households had between one and four plots in 2002, and about 40 percent of the plots were themselves mixed stands, where multiple crops are grown together (Uganda Bureau of Statistics 2004, 5–6). Most plots are close to the household (less than one kilometer), but 37 percent are more than one kilometer away from the homestead (Uganda Bureau of Statistics 2007b, 36). Few purchased inputs are used on smallholder plots, with only 1.0 percent of plots using chemical fertilizer and 6.3 percent reporting the use of improved seeds (Uganda Bureau of Statistics 2007b, 86). Fewer than 1.0 percent are irrigated (Uganda Bureau of Statistics 2007b, 86).

Ten crops account for over 90 percent of the plots under cultivation: matoke (a kind of cooking banana), beans, cassava, sweet potatoes, coffee, groundnuts, maize, millet, sorghum, and sesame. With the exception of coffee, all are food crops that are produced primarily for domestic consumption.[2] Although there is some disagreement in the data, one estimate from household survey data (Uganda Bureau of Statistics 2007b, 46) suggests that very large fractions of agricultural households in Uganda were growing bananas (73.1 percent), maize (85.8 percent), cassava (74.3 percent), and beans (80.8 percent). Presumably many households were growing several of these crops.[3]

Farms also typically include livestock. About 20 percent of farm households reported owning at least one cow, 30 percent reported keeping goats, and 46 percent of households reported keeping chickens, mostly on a very small scale (Uganda Bureau of Statistics 2004).

Most small farms market some fraction of their output, with the fraction varying by crop, by region, and by distance from markets. For example, households in 2005/06 reported selling 80 percent of the soybeans that they produced and about half the maize, but only 32 percent of matoke, 23 percent of cassava, and 16 percent of beans. There is significant variation across regions in the fraction of agricultural households that are primarily in subsistence, with government figures showing some regions—primarily those

2. The bananas produced in Uganda are largely—though not exclusively—cooking bananas that differ from the dessert bananas that represent a major global export commodity. Uganda is a nearly negligible exporter of bananas, ranking outside the top thirty countries of the world in net exports.

3. An earlier survey (Uganda Bureau of Statistics 2004, 7) suggested that 40 percent of households grew cassava and beans, with 30 percent growing maize, sweet potato, and banana. These data were drawn from an agricultural module added to the census. We prefer the data taken from the Uganda National Household Survey, which appears to have done a thorough job of documenting plot-level characteristics of agriculture.

near Kampala and with good market access to the city—having fewer than 70 percent of households in subsistence agriculture. In the more remote regions of the country, over 80 percent of households are reported as deriving their livelihoods from subsistence farming (Uganda Bureau of Statistics 2007a, 82).

There is size heterogeneity among smallholder farms. This is presumably linked to differences in the fraction of output marketed. In household survey data, about 20 percent of households farm more than five acres of land, with about 7 percent farming more than ten acres.

A small but active commercial agricultural sector also operates in Uganda. One portion of the commercial sector consists of large farms that are typically privately held. In 2006/07, the Uganda Bureau of Statistics reported nearly 400 officially registered commercial farms, employing 28,000 workers (Uganda Bureau of Statistics 2008, 142). Most of these businesses were quite small, with half employing five to nine workers, but about sixty were large farms employing fifty or more workers, and clearly a number were far larger, given a mean size of seventy workers. Most of the large farms specialized in animal agriculture, but of the very large farms, most were in crop agriculture, producing horticultural crops and grain, including tea, sugar, and cotton. One study in 1999 noted that the largest maize farm that could be identified by experts at the time was 150 acres (60 ha) (Robbins and Ferris 1999).

The principal food crops are not traded much on international markets: matoke, maize, cassava, yams, and other root crops. Of these, only maize is traded to any significant degree. The country does produce large amounts of coffee for export markets (along with smaller amounts of sugar and cotton), but the fraction of land devoted to export commodities is relatively modest, and some of these crops are produced on a scale comparable to that of basic food crops.

The major export crops—coffee, tea, cotton, and sugar—together account for under 8 percent of cropped area (FAOSTAT 2009). Of these, the most important is coffee, which is grown on over 3.5 million plots with an average plot size of 0.16 hectares. Even quasi-subsistence farmers often produce a little coffee for sale to the market. But across the country, the bulk of agricultural activity is devoted to producing food staples.

Another way of measuring the fraction of Ugandan agriculture that is devoted to domestic food production is to look at consumption. Imports of grain account for about 2.1 percent of Uganda's total food energy. Since Uganda is a net exporter of pulses, fish, and some other commodities that are domestically consumed, in a net sense, only 1.7 percent of total calorie consumption depends on imported foods.

Taking all these facts together, we will argue below that it is reasonable to model Uganda's food economy using a closed economy representation. Even though the country has a number of important agricultural exports, most of the resources devoted to agriculture in Uganda are applied to the production of food crops for domestic consumption, and by the same token, most of domestic consumption needs are met from domestic production.

2.2.2 Rural Income and Poverty

About three-quarters of Uganda's population live in rural areas, and most make their livings from subsistence agriculture (Uganda Bureau of Statistics 2007a, 16–17). By most estimates, rural households in Uganda are very poor. In 2005/06, 93.2 percent of Uganda's poor households (using a headcount measure) were rural, somewhat higher than the 84.6 percent of households in rural areas. The poverty rate for rural households, using a headcount measure, was 34.2 percent, which was almost triple the rate for urban households (Uganda Bureau of Statistics 2006, 60). Also, median nominal wages in rural areas are only one-third of the urban level (Uganda Bureau of Statistics 2007a, 19).[4]

Rural households allocated about 50 percent of their total expenditure to food, drink, and tobacco—although the pricing of these goods is complicated, since much of consumption is home produced (Uganda Bureau of Statistics 2006, 56–59). About 15 percent of rural households had fewer than two sets of clothes per household member, and only 43 percent reported that each member of the household had a pair of shoes in good condition. Most households outside Kampala owned their own homes and furnishings, including a radio or other electronic device. About 40 percent of rural households owned a bicycle, but very few owned any other mode of transportation (Uganda Bureau of Statistics 2006, 94–95).

Rural households primarily earn their livings from agriculture—but other activities are also important. Almost 40 percent of rural households reported operating informal noncrop enterprises in 2005/06, with most of these enterprises concentrated in trade (both wholesale and retail) and manufacturing (Uganda Bureau of Statistics 2007a, 26).

2.2.3 Transaction Costs and Access to Markets

Our chapter will focus in part on the high transaction costs faced by rural households in Uganda. In particular, we explore the hypothesis that high rural-to-urban transportation costs implicitly create incentives for poor people to live close to their food sources—effectively reducing the real price of food, which is their largest single expenditure category. This section of the chapter seeks to document and quantify the transportation costs involved in moving goods from Uganda's rural areas to its cities.

Like most countries in sub-Saharan Africa, Uganda has very low levels of physical infrastructure and public services. All forms of physical infrastructure are underdeveloped, and this is widely cited as one of the country's main

4. Of course, the median wages may reflect differences in skill levels, hours worked, costs of living, and other factors.

constraints to development. The lack of infrastructure is particularly acute in rural areas. Existing road networks leave many communities inaccessible by vehicles, and very few rural residents have access to electricity or piped water. (For example, less than 1 percent of rural households were estimated to have access to grid-supplied electricity in 2000. A large number—perhaps a majority—of towns and market centers also lacked electrical access.)

The government of Uganda has highlighted the need for infrastructure development in a series of planning documents, including a series of Poverty Eradication Action Plans and its most recent National Development Plan. In addition, a consortium of donors, including the World Bank, the African Development Bank, and several key national aid agencies, issued a Joint Assistance Strategy for Uganda in 2006. This document identified the most pressing needs for development investments in Uganda and agreed on a coordinated set of programs, with rural transportation infrastructure featuring high on the list of priorities.

Spatial data suggest that more than three-quarters of Uganda's population (78 percent) live two or more hours from a market center, and 25 percent live five or more hours from a market.[5] In the most remote regions of the country, transportation consists primarily of foot traffic. People walk long distances to markets and other services. For example, for the country as a whole (including urban areas), the average distance to a government health clinic was about 7 km, and 77 percent of people reported that they walked to these clinics. In less remote areas, people make effective use of bicycles and motorcycles. Cars, trucks, and buses traverse the limited network of major roads.

Measures of road length support the notion that Uganda's road network is far behind those of developed countries. In 2003, Uganda reported a network of paved roads consisting of 16,300 km in a land area of 200,000 km^2 (CIA Factbook 2009).[6] For a startling benchmark, we note that this was not much greater than the paved road density found in Britain in AD 350, when the retreating Roman Empire left a network of 12–15,000 km of paved roads in a land area of 242,000 km^2 (Lay 1992, 55). In this specific sense, then, Uganda lags Britain by almost two thousand years in the development of its road infrastructure.

Measures of roads and remoteness offer only an indirect view of trans-

5. Roads are not the only form of infrastructure lacking from rural areas; in 2005/06, only 9 percent of rural communities had any access to electricity.

6. It is only fair to note—as any traveler in Africa can attest—that paved roads are not necessarily better than unpaved roads; particularly when maintenance is poor, pavement may actually provide a worse surface than dirt or gravel. In this sense, we hesitate to use paved roads as a measure of transportation quality; nevertheless, we believe that this is a useful proxy for a more general measure of transportation infrastructure.

portation and transaction costs. To get a more detailed look, we turn to two types of data: price dispersion data and direct evidence on transportation costs and marketing margins.

Price Dispersion Data

The poor quality of Uganda's road network corresponds directly to an environment of high transaction costs that contributes to high dispersion of prices at a moment in time across geographic space. Although there are many possible reasons for the spatial dispersion of prices (including various forms of market power and collusion), these price wedges must, in some sense, reflect underlying transportation costs, or else the pressure would be great to arbitrage away the price differences.

Most of the available data on price dispersion are at the level of wholesale or retail markets. Table 2.1 shows price dispersion across wholesale markets for a number of crops at a single moment in time (the week of March 10–14, 2008). Each column of this table refers to a different wholesale market. Most are in agricultural regions. The one exception is the Kalerwe market, just north of Kampala, which is one of the major markets serving the capital city. Several features of the data are immediately striking. First, the spatial dispersion of prices is high. For matoke, the lowest wholesale price is in Mbarara, in the southwest of the country, at 180 USh/kg; the highest price is at Lira, in the north central part of the country, where the same commodity sold for 600 USh/kg. The straight line distance between the two markets is about 400 km; the estimated road distance is about 500 km. By contrast, the prices in nearby Kisenyi (about 35 km distance) is much closer to the Mbarara price, at 230 USh/kg.

Table 2.2 shows the full set of pairwise distances and price differentials for matoke between Mbarara and other markets. In general, distance from the center of cultivation is closely linked to price level. A similar picture comes from the market for potatoes—a crop for which there is a primary area of production in southwestern Uganda near Kabale and Kasese and a secondary area near Tororo in the east. As shown in table 2.3, this leads to a generally rising pattern of prices with distance from Kasese, although Tororo itself has prices that reflect the production in nearby Mbale and Kapchorwa districts.

The same general patterns hold in the price data for other moments in time. Figure 2.1 shows monthly prices of matoke and sweet potatoes at six major markets in Uganda from 1997 to 2006. It is apparent from the figure that prices of matoke move together across markets over time, and the same is true for sweet potatoes. (It also appears that the prices of the two starch foods are themselves correlated.) At any given moment in time, however, the price spreads across markets for a given commodity are substantial. For matoke, the major growing areas are in Mbarara, in the southwest, and

Table 2.1 Price dispersion in wholesale markets for agricultural crops, Uganda (March 10–14, 2008)

Crop	Kisenyi	Kalerwe	Arua	Kabale	Kasese	Kiboga	Lira	Masaka	Mbarara	Soroti	Tororo
Matoke	230	230	750	240	250	230	600	200	180	567	300
Fresh cassava	195	180	600		90			80			
Sweet potatoes			450		120			200			
Irish potatoes	265	275	1,000	220	180	400	900	300	400	700	400
Beans (K132)	1,000	1,050	1,300	900	930	1,500	1,050	900	1,050	1,100	1,200
Beans rosecoco	1,000	1,150		900	950	1,500	1,150	900	1,050		1,200
Cassava chips	200		300	370	320	200	350		280	250	200
Cassava flour	300	400	350	550	350	450	700	450	500	480	230
Groundnuts	1,400	1,600	1,500	1,800	1,400		1,400	1,600	1,600	1,400	1,600
Maize grain	338	375	310	380	250	240	320	170	380	300	350
Maize flour	550	620	750	700	400	550	700	600	700	600	550
Millet grain	580	600	530	580	750		500	400	700	750	800
Millet flour	650	750	550	700	950	850	900	600	900	1,150	1,000
Rice (super)	1,100	1,100	1,700	1,100	1,000	1,300	1,100	1,300	1,500	1,200	1,250
Sesame	1,650	1,700	1,500				1,500		2,200	1,800	1,800
Sorghum grain	270	400	350	500	750		350		300	300	350
Sorghum flour	450	500	650		900		600		700	700	400
Soybeans	930	1,000	550	1,000	480		750	800	900	1,000	1,100

Source: The ASPS/Danida/CIAT Market Information Service, Kawanda Agricultural Research Complex.

Note: All prices in Ugandan shillings per kg.

Table 2.2 **Distances from Mbarara and matoke price dispersion (March 10–14, 2008)**

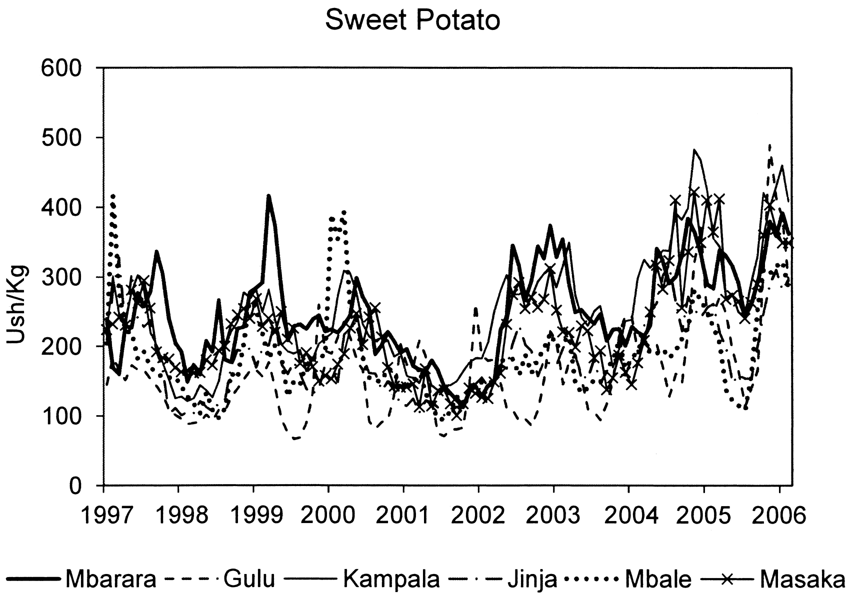
Market	Distance from Mbarara		Matoke price difference	Price difference as percent of Mbarara price
	Linear	Road		
Kisenyi	32	38	50	27.8
Kabale	105	126	60	33.3
Masaka	122	145	20	11.1
Kasese	125	150	70	38.9
Kiboga	213	255	50	27.8
Kalerwe	236	278	50	27.8
Masindi	284	343	120	66.7
Arua	410	492	570	316.7
Lira	400	500	420	66.7
Tororo	417	500	120	233.3
Soroti	418	501	387	215.0

Table 2.3 **Distance from Kasese and potato price dispersion (March 10–14, 2008)**

Market	Linear	Road	Potato price difference	Price difference as percent of Kasese price
Kisenyi	101	121	85	47.2
Mbarara	125	150	220	122.2
Kabale	173	207	40	22.2
Masaka	201	241	120	66.7
Kiboga	213	256	220	122.2
Masindi	250	300	220	122.2
Kalerwe	287	343	95	52.8
Arua	327	392	820	455.6
Lira	394	473	720	400.0
Soroti	435	522	520	288.9
Tororo	469	563	220	122.2

Mbale, in the southeast. These two markets typically have the lowest prices, and the remote northwestern market of Gulu invariably has the highest prices. The relative ordering of other markets is fairly stable and the price bands separating different markets appear to remain relatively constant over time. Even leaving aside the prices from Gulu, the width of the price band appears to be consistently about 50–100 USh/kg, meaning that the prices in Kampala, Jinja, and Mbale are often 60–70 percent higher than the prices in Mbarara. For sweet potato, price spreads are similarly large.

Table 2.4 provides information on the price bands across markets, based on monthly price observations across the six major wholesale markets during the year July 2005 to June 2006. The table shows the lowest of the six prices, the ratio of the highest price to the lowest price, the average (across



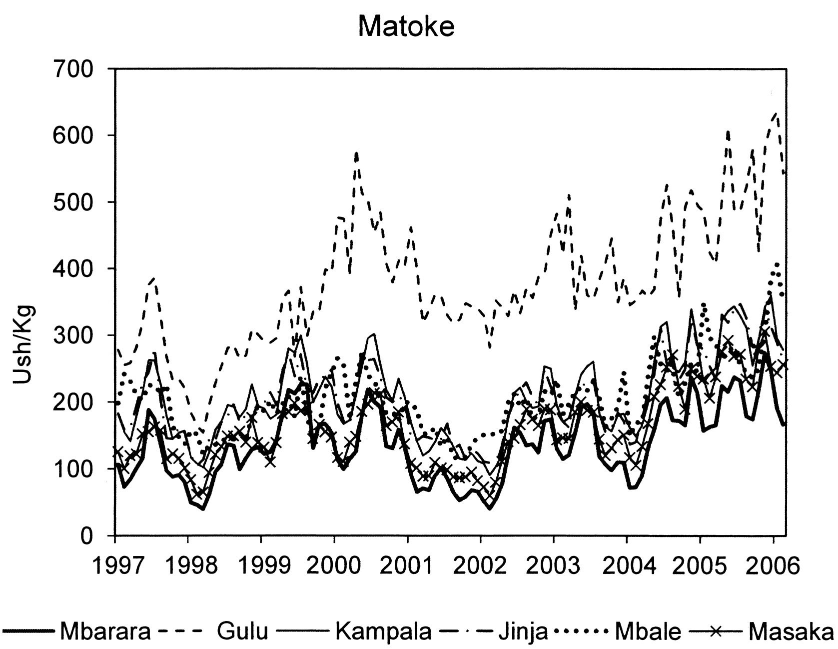


Fig. 2.1 Monthly wholesale prices for matoke and sweet potato, major Ugandan markets, June 1997 to July 2006

Table 2.4 **Price dispersion across six wholesale markets, average of monthly data for July 2005–June 2006**

	Min. price (USh/Kg)			
Commodity	Max./min.	Max.-Min. (USh/kg)	2nd highest price–2nd lowest(USh/kg)	
Cassava flour*	565	1.84	472	83
Dry beans, Kanyewba*	714	1.36	260	69
Dry beans, Nambale**	708	1.35	253	91
Fresh cassava**	144	2.44	205	121
Groundnuts, unpounded	1,509	1.25	390	202
Irish potato	321	2.15	346	95
Maize flour	593	1.37	206	110
Matoke	210	2.55	315	81
Millet flour	785	1.37	289	134
Rice	1,084	1.21	225	106
Sweet potato	193	2.00	169	107

Source: Uganda Bureau of Statistics, CPI data on food prices.

Note: Data are for six wholesale markets: Mbarara, Gulu, Kampala, Jinja, Mbale, and Masaka.

*Data available for four markets only.

**Data available for five markets only.

twelve monthly observations) of the absolute gap in prices between the highest and lowest, and the average of the absolute gap between the second highest and second lowest prices. These gaps are large, in general. Averaging across crops and across the whole year, nearly 300 USh/kg separated the most expensive price from the least expensive price, and on average over 100 USh/kg separated the second highest price from the second lowest.

The examples given here illustrate the point that prices of agricultural commodities are related to the distances over which the goods need to move—as well as to road quality and other factors that are not observed precisely. For the purposes of this chapter, we do not need to argue that all of the price differences across markets are due to actual transportation costs; we acknowledge that there are many other factors causing dispersion of prices across space. For instance, spatial dispersion of prices may reflect policy barriers, market power, and other factors. In Uganda's case, however, distance and road conditions are immediate and clear features of reality.

Transport Cost Data

As an alternative to looking at geographic dispersion of prices, we can try to measure transport costs directly. In principle, shipping costs should be observed directly without much difficulty. In practice, however, the costs of shipping agricultural goods are closely associated with the costs of grading, bagging, storing, and milling, among others. These costs can also contribute to the price wedges between different market locations. All of these constitute distribution costs associated with moving food from rural to urban areas. From our perspective, however, we will focus most closely on the transportation costs, since these will play an explicit role in our model.

The best source of data on shipping costs are agricultural marketing studies, which have been done by a number of agencies—often with a view to project interventions that aim to reduce marketing wedges between farmers and consumers. A major 2002 study undertaken as part of the government of Uganda's Plan for the Modernization of Agriculture documented transaction costs in the marketing process for six agricultural commodities: coffee, cotton, fish, maize, cassava, and dairy (Plan for Modernization of Agriculture 2002). We focus on the marketing costs of the three domestically consumed commodities.

For maize, the study considers four rural districts, where farm gate prices of maize ranged from 50 USh/kg (near Kapchorwa) to 65 USh/kg (near Mbale). As shown in table 2.5, transport from farm gate to primary market centers was estimated at 10 USh/kg. Further transport to secondary market centers (i.e., district markets) cost an additional 5–10 USh/kg; other handling costs—including labor charges for loading and unloading, bagging, storage, and losses—added up to around 10 USh/kg of additional transport-related cost. The price of maize at the secondary markets ranged from 90 USh/kg to 105 USh/kg, implying a 60–85 percent increase relative to farm gate prices. The study estimates that the total margins earned by traders and middlemen accounted for close to 10 USh/kg in all cases; essentially all of the remaining price wedges can be attributed to transportation and transaction costs. From the secondary markets, maize moved to major wholesale markets in cities like Mbale, Tororo, and Kampala. Wholesale prices in these markets were 115–20 USh/kg, with all of the price wedges between secondary and tertiary markets attributed to transportation costs (PMA 2002, 119–21). Eventual retail prices for milled maize flour were 210–400 USh/kg, depending on quality.

Summarizing, the farm gate prices of maize were 40–55 percent of urban wholesale prices for unmilled maize. By far the largest part of the price gap was attributed to explicit transport costs. Across the four rural districts, pure transport costs of moving maize to wholesale markets were approximately 55 USh/kg—meaning that the farm gate price and the transport cost were approximately the same.

For cassava, marketing takes place in several forms. Cassava is sold to market fresh, but it is also marketed as cassava chips (for subsequent milling into flour) and as flour. In all these forms, there are large price wedges between farmers and markets, with transportation costs accounting for a large fraction of the total. Table 2.6 reports data on the prices of cassava chips at various points in the distribution and marketing chain. Farm gate prices for cassava chips are 40–50 USh/kg, compared to wholesale prices

Table 2.5 **Maize marketing margins and transport costs: Farm gate to wholesale, 2002**

	Kapchorwa	Mbale	Iganga	Masindi
Farm gate price	**50**	**65**	**60**	**60**
Bagging materials	1	1	2	5
Labor costs (loading, sorting)				3
Weighing costs				
Transport (farm gate to primary market)	10	10	10	10
Market dues/local tax			2	2
Margins	4	9	6	5
Primary market price	**65**	**85**	**80**	**85**
Bagging materials	—	2	2	2
Labor costs (loading, sorting, unloading/weighing costs)	4	5	5	4
Transport (rural to urban market)	10	5	5	10
Storage	0.5	1	1	1
Losses	2	2	2	2
Market dues/local tax	1	1	1	1
Trading license & security	—	0.5	0.5	0.5
Margin	5	3.5	5	4.5
Total	22.5	20	21.5	25
Secondary market price	**90**	**105**	**101.5**	**110**
Labor costs (loading, sorting)				
Weighing costs				
Transport				
Mbale	20			
Kampala	45		20	25
Tororo			20	40
Kenya	25			
Market dues/local tax				
Total				
Tertiary market prices				
Mbale	**115**	**115**	**115**	**115**
Kampala	**120**	**120**	**120**	**120**
Kenya	**120**	**120**	**120**	**120**

Source: Plan for Modernization of Agriculture (2002, 119–21).

of 110–20 USh/kg, implying that farmers receive 33 to 45 percent of the wholesale price.

Similar figures can be found in the market for dried cassava, in which farmers receive something less than one-third of the wholesale price, and in which pure transport costs account for slightly more (4,500 USh/100 kg) than the farm gate price (4,000 USh/100 kg). Table 2.7 shows the other components of the price wedge between farm gate and wholesale. Although gross margins are large, net margins appear to be modest.

Table 2.6 **Cassava chip prices, January–February 2002**

Prices received by:	USh/kg	Source of information
Traveling traders, Kampala	120–40	Kampala wholesalers, who use custom mills and sell flour
Village dealers in Kumi district	50–55	Wholesalers in Jinja
Village dealers in Soroti district	60	Wholesalers in Jinja
Farmers in villages of Pallisa, Kumi, or Soroti districts	40–50	DAO Pallisa, farmers, wholesalers in Jinja, Kumi, and Soroti, AO Kumi
Farmers delivering chips at roadside markets in Kumi district	50–60	Farmers, trader
Farmers in Lira district	50–60	Wholesalers in Lira Town
Village dealers in Lira district	70–80	Wholesalers in Lira Town
Wholesale price in Lira Town	110–20	Wholesalers in Lira Town
Arua Mmarket	Approx. 200	Farmers in Bweyale

Source: Plan for Modernization of Agriculture (2002, 131).

Table 2.7 **Dried cassava marketing margins and transportation costs, 2002**

	Kampala-based traders Paidha, Kumi, Pallisa USh/100 kg
Farm gate price	**4,000**
Transport (farm gate to primary market)	1,000
Market dues/local tax	200
Estimated capital cost	36
Margins	764
Primary market price	**6,000**
Bagging materials	500
Labor costs (loading, sorting, unloading /weighing costs)	700
Transport (rural to urban market)	3,500
Estimated capital cost	162
Market dues/local tax	500
Trading license & security	200
Margin	1,438
Wholesale market price	**13,000**

Source: Plan for Modernization of Agriculture (2002, 140–41).

For fresh cassava, too, transport costs may easily exceed farm gate prices. By the time additional labor costs are added for loading, unloading, and bagging, along with market fees and similar charges, the gap between farm gate prices and wholesale prices may be large. In some cases, farmers may sell cassava standing in the field. The purchaser provides the labor to dig up the cassava and to market it. In these cases, the revenues received by farmers for cassava in the field are estimated to be just over 20 percent of the wholesale price.

Taken together, the evidence for maize and cassava suggests that transport costs and marketing margins are very high. Farm gate prices are often significantly less than half of wholesale prices, across many crops and regions. Although these data are only suggestive, a similar conclusion emerges from recent work by Svensson and Yanagizawa (2009) who calculate farm gate prices for maize from the nationally representative Uganda National Household Survey 2005. They find that for the period July 2004–June 2005, the average farm gate price of maize for households in a subset of maize-growing districts was 188 USh/kg, compared to a district market price of 291 USh/kg. The implied ratio of farm gate price to secondary market price is very similar to the data included in table 2.5.

A Benchmark for Costs: Grain Shipping in US Markets

To put the Ugandan data into perspective, it is useful to make a comparison to data from the United States. First, consider the data on US corn prices at major wholesale markets across the United States, presented in table 2.8. In this table, we consider several of the same measures used in table 2.4, including the ratio of the maximum price to the minimum. It is striking that other than the "gulf ports," all the other major markets have prices for each year that fall within a very narrow band. The average ratio of the highest price to the lowest price, across the seven years of data, was 1.25. By comparison, for maize in Uganda, the average ratio of the higest price to the lowest price across six wholesale markets was 1.61, even though the geographic distance between markets was much smaller in Uganda. The gap between the second highest price and the second lowest price averaged 10 percent of the minimum price in the United States, compared with 27 percent of the minimum price for Uganda.

Next, consider the unit costs of transporting 100 kg of maize a distance of

Table 2.8 **US corn prices, major wholesale markets: Annual average prices for yellow corn no. 2**

Market	2002	2003	2004	2005	2006	2007	2008
Central Illinois	2.34	2.52	1.93	2.00	3.33	4.79	3.68
Gulf ports	2.70	2.94	2.48	2.69	3.94	5.53	4.39
St. Louis	2.49	2.73	2.13	2.19	3.60	5.05	3.92
Omaha	2.29	2.50	1.82	1.88	3.33	4.84	3.80
Chicago	2.46	2.66	2.08	2.10	3.46	4.98	3.89
Kansas City	2.43	2.55	1.90	1.98	3.42	4.95	3.81
Toledo	2.47	2.58	1.97	2.00	3.41	4.92	3.86
Memphis	2.46	2.67	2.12	2.23	3.57	5.01	3.78
Minneapolis	2.26	2.50	1.88	1.85	3.16	4.70	3.62
Minimum Price	2.26	2.50	1.82	1.85	3.16	4.70	3.62
Max./min.	1.19	1.18	1.36	1.45	1.25	1.18	1.21
Max.–min.	0.44	0.44	0.66	0.84	0.78	0.83	0.77
2nd max.–2nd min.	0.20	0.23	0.25	0.35	0.27	0.26	0.23

100 km from farm to market. For the United States, as of 2009, a standard calculation used for farm-to-market transportation costs was $0.285/bushel per 100 miles. This is equivalent to $0.65 per 100 kg/100 km. For Uganda, by contrast, the cost associated with moving maize from the farm gate to a secondary market was about 20 USh/kg in 2002. At the prevailing exchange rate of 1,738 USh/$US, and assuming that on average farms were 50 km from the relevant market center, this corresponds to a unit transport cost of $2.30 per 100 kg/100 km. This is approximately four times the unit cost in the United States. If we assume instead that an average farm was only 25 km from the market center—which is perhaps a more reasonable estimate—the unit transport cost rises to $4.60 per 100 kg/100 km, which is about seven times the cost in the United States.

Similar results emerge from comparisons of shipping costs between wholesale markets (as opposed to farm-to-market transport). To ship maize from Minneapolis to St. Louis, a distance of 560 miles, cost an average of about $0.305/bushel in 2002–2008. This corresponds to a total cost of about $0.125 per 100 kg/100 km. To ship maize from Gulu to Jinja, by comparison, is a distance of 426 km by road. The implied cost per 100 kg/100 km is $15.74, about two orders of magnitude greater than the bulk transport rate in the United States.[7]

A conclusion from this analysis is that transport costs at all levels are high in Uganda. Transport costs, along with related storage and handling charges, appear to account for large fractions of the price wedges between farm and market, as well as the price wedges between markets. We make no judgment here as to the extent of market power in this sector. Some analyses suggest that traders behave noncompetitively, especially on long-distance routes, but the reported net margins in trading do not appear to be unreasonable, and there is robust (though not free) entry and exit from the markets.

2.3 Related Literature

This chapter has roots in several strands of economic literature. Our theoretical framework is most closely related to recent work on structural transformation and economic growth. We also draw on a large body of previous literature that deals with the issue of transportation and transaction costs.

2.3.1 Structural Transformation and the Movement out of Subsistence Agriculture

Modern economic growth is accompanied by a number of changes in the structural characteristics of production—including changes in the types of

7. The comparison is perhaps somewhat unfair; in the United States, barge transport helps to reduce the costs of moving grain along this route. But to some extent, the problem in Uganda is precisely the lack of alternatives to (low quality) roads.

goods produced, the size and organization of establishments, and the role of home production (Buera and Kaboski 2008). Changes in the sectoral composition of output are perhaps the most visible feature of the structural transformation. As economies grow, they move out of agriculture into industry and services. This empirical regularity was documented by Kuznets (1966), Chenery and Syrquin (1975), and others (e.g., Syrquin 1988). In fact, much early writing viewed development as essentially identical with the movement of people out of quasi-subsistence agriculture and into "modern" economic activities (e.g., Rosenstein-Rodan 1943; Rostow 1960; Lewis 1966; Fei and Ranis 1964).

What role does agricultural productivity play in this process? Some early development economist argued that growth depends on an economy's ability to generate an agricultural surplus—in other words, to reach a level of labor productivity such that farmers can produce substantial quantities in excess of their own food needs and can thereby support urban populations. T. W. Schultz (1953) characterized this challenge as the "food problem" facing poor countries. Schultz's view was later echoed in writings by many economists who argued that agricultural productivity increases drive the structural transformation (e.g., Johnston and Mellor 1961; Schultz 1964, 1968; Johnston 1970; Johnston and Kilby 1975; Timmer 1988; Johnson 1997). The same theme figures prominently in the later works of Mellor (1995, 1996) and the analyses of many other scholars (e.g., Eswaran and Kotwal 1993; Mundlak 2000).

In recent years, a number of papers have used two-sector growth models to examine this process in greater detail. A number of papers have sought to show how a growth model can generate changes in the sectoral composition of output (e.g., Echevarria 1995, 1997; Kogel and Prskawetz 2001; Irz and Roe 2005; Kongsamut, Rebelo, and Xie 2001). A related set of papers sought to model the structural transformation in a one-sector economy, focusing on the transition from a low-growth or no-growth traditional economy to a modern "Solow" economy. Among these papers are King and Rebelo (1993), Goodfriend and McDermott (1998), Laitner (2000), Hansen and Prescott (2002), Ngai (2004), and Ngai and Pissarides (2007).

Although these models can generate structural transformations, they have some difficulty in explaining the coexistence of a rich ("modern") sector and a poor ("traditional") agricultural sector. The "dualism" of developing economies is puzzling. Why do labor and capital not move more rapidly across sectors? As argued by Buera and Kaboski (2008), theories of dualistic economies may need to assume sector-specific distortions or more general market failures. For example, Temple (2004, 2005) and Vollrath (2009a, 2009b), among others, have explored multisector models in which unemployment or underemployment is possible. In these papers, there may be fixed urban wages or other rigidities that prevent the urban labor market from clearing. Caselli and Coleman (2001) use a framework in which transaction cost wedges prevent the labor market from equalizing marginal products across sectors. Dekle and Vandenbroucke (2006) similarly focus on distortions in labor markets. A slightly different approach is found in Restuccia, Yang, and Zhu (2008) and Herrendorf and Teixeira (2008), who consider the impact of distortions in the cost of farm inputs. These papers have the feature that the allocation of resources across sectors is inefficient; the social planner would allocate labor and capital differently.

Gollin, Parente, and Rogerson (2002, 2007) use models in which the allocation is efficient. They follow Schultz in assuming that many poor countries need to tie down large amounts of labor and other resources in food production. Countries that have low agricultural productivity—which could be due to poor technology, geography, or institutions—may sustain large differences in average productivity across sectors.

2.3.2 Transportation and Transaction Costs

Within the recent literature on structural transformation, few papers have addressed the role of transportation or the costs of moving goods between rural and urban areas. By contrast, transport cost has been a major topic in the international trade literature, as well as in the empirical literature on development economics. In the development policy literature, too, many donor organizations have directed attention and resources to the issue of rural transportation infrastructure. Transport costs also figure prominently in the agricultural economics literature, where there is a long tradition of studying marketing margins and farm-to-market value chains, in which transportation costs are prominent.

In the growth literature, our chapter is related to recent work by Herrendorf, Schmitz, and Teixeira (2006) and Herrendorf and Teixeira (2011). It is also somewhat related to Adamopoulos (2006), who uses a model with transportation costs to conduct a development accounting exercise.

In the development literature, many papers have looked at the impact of roads and infrastructure on development in Africa and other regions of the developing world. This includes theoretical papers, along with a number of recent policy and empirical papers, such as Platteau (1996), Limão and Venables (1999), Fan and Hazell (2001), Fan and Chan-Kang (2004), Torero and Chowdhury (2005), Renkow, Hallstrom, and Karahja (2004), Zhang and Fan (2004), Calderón (2009), Dorosh et al. (2008), and Minten and Stifel (2008). Many of these papers rely on cross-section regressions at the country or district level. There are obviously difficult identification problems with this approach.

Most analyses conclude that Africa suffers from a substantial deficit in transportation infrastructure, and studies along these lines have been used to advocate increases in spending on road construction and road maintenance. A consortium of donors have consequently established the African Infrastructure Country Diagnostic (AICD) to share knowledge and mobilize funding for further investments in infrastructure. One AICD document calls for an additional $31 billion annually on infrastructure spending in Africa, and another paper calls for $20 billion annually in spending on transportation infrastructure, including both capital improvements and maintenance of existing stocks.

Some observers have argued that transportation infrastructure is less of an issue in Africa than market imperfections and collusion in the transport sector. Raballand and Macchi (2008) have argued that trucking companies do not face particularly high costs of vehicle operation (and in fact, face very low labor costs), but that the prices they charge to customers reflect substantial markups that reflect cartelization in transport. Related work by Gachassin, Najman, and Raballand (2010) questions the likely impact of road investments on rural poverty, noting that in a study from Cameroon, rural infrastructure investments were not linked to increases in consumption expenditure. The authors argue that road improvements are most likely to have value in areas where they can support nonagricultural activities rather than in areas of smallholder farming.

Transportation and Agricultural Marketing in Uganda

Concerns over high transportation costs and marketing margins date back many decades in Uganda. Colonial governments viewed road construction as one of the priorities for the expansion of markets, and for an extended period, the colonial government required communities to provide forced labor for road construction and maintenance. Roads remain a concern of today's Ugandan government. As noted above, the existing road network is poor, but expansion is likely to be expensive. Road construction is expensive. Carruthers, Krishnamani, and Murray (2008) calculate that a program of road construction and maintenance that would expand Uganda's network of all-weather roads so that 75 percent of the population would be able to access such a road within a distance of 2 km would require spending of 3.6 percent of gross domestic product (GDP) annually for a period of ten years. Even a more modest goal (50 percent of the population, with lower-quality roads) would require 2.2 percent of GDP annually.

Our chapter relates to an issue raised by Raballand et al. (2009), who have argued that improvements in rural roads in Uganda would have little impact because productivity levels are too low to justify more frequent or heavier traffic. Their paper takes productivity levels as fixed; ours considers the connections between improvements in transportation, changes in input and output prices, and the resulting changes in yield and production.

2.4 Model

In this section we lay out a sequence of models that serve to highlight several forces that influence the allocation of workers to agriculture. We start with a simple version of the model in Gollin, Parente, and Rogerson. (2002) and then extend this model along several dimensions. We believe that developing these models sequentially serves to highlight the underlying economic forces in a more transparent and intuitive fashion. We note here that our analysis will exclusively focus on models of closed economies. The essence of this assumption is that an economy needs to be able to produce sufficient food to feed its population. As described previously in section 2.2.1, this assumption seems reasonable for an economy like Uganda, which is the focus of our analysis. Uganda imports relatively little of the basic food items that serves to sustain the vast majority of its population.

Looking ahead, some of the specifications that we analyze implicitly create an incentive for Uganda to import basic foodstuffs from abroad. Understanding why this does not occur is an important issue. Consistent with our general focus on transportation infrastructure, we believe that an important element of the explanation has to do with the difficult logistics of importing food into a landlocked country with very poor transportation infrastructure. Nonetheless, in our models we simply rule out trade and focus on allocations within a closed economy.

2.4.1 A Benchmark Model

We begin with a static version of the model in Gollin, Parente, and Rogerson. (2002). The basic setup is as follows: There is a measure one of identical agents. Each individual has preferences over two goods, which we label as agriculture (a) and manufacturing (m), given by:[8]

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

where u and v are both increasing, strictly concave functions and $\bar{a}$ and $\bar{m}$ are both strictly positive. The key feature of these preferences is the presence of the $\bar{a}$ and $\bar{m}$ terms, which serve to make the income elasticity of the agricultural good less than one and that of the manufactured good greater than one.[9] Gollin, Parente, and Rogerson (2002) consider the special case where the function u has the property that it is minus infinity if $a-\bar{a}$ is negative and equal to a constant for all nonnegative values of $a-\bar{a}$. The implication of this specification is that individuals will consume exactly $\bar{a}$ units of food. While not essential, this simplifies the analytics and increases the transparency of the key economic forces. In our quantitative work we will consider a more general specification in which individuals also value consumption of the agricultural good beyond $\bar{a}$.

The economy is endowed with one unit of land and each individual is

8. 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.

9. It is sufficient that at least one of $\bar{a}$ or $\bar{m}$ be greater than zero for this property to hold. Having both positive allows for the possibility of a corner solution in which $m = 0$

endowed with one unit of time. We assume that land ownership is equally distributed across the population. The technology for producing the manufactured good is given by:

$$(2) \qquad m = A_m n_m$$

where n_m is the number of workers that work in the manufacturing sector, and the technology for producing the agricultural good is given by:

$$(3) \qquad a = A_a L^{\theta} n_a^{1-\theta}$$

where n_a is the number of workers that work in the agricultural sector and l is land. We assume that the economy is able to produce sufficient amounts of a so as to provide all individuals with at least $\bar{a}$ units of the agricultural good. A sufficient condition for this is that $A_a > \bar{a}$.

We study the competitive equilibrium allocation for this economy, which can be obtained by solving the social planner's problem in which the utility of a representative household is maximized subject to the feasibility constraints. This turns out to be somewhat trivial given the extreme form of preferences that we have assumed. In particular, given that everyone needs to consume exactly $\bar{a}$ units of the agricultural good, but receives no benefit from consuming any additional amount, the optimal allocation is to allocate enough workers to the agricultural sector so as to produce $\bar{a}$ for each individual in the economy, and then to allocate all remaining workers to the manufacturing sector. It follows that the optimal value for n_a is given by:

$$(4) \qquad n_a = \left[\frac{\bar{a}}{A_a}\right]^{1/(1-\theta)}.$$

The key implication of this model is that in an economy in which food is a necessity, there is a powerful negative relationship between agricultural TFP and employment in agriculture. In particular, a 1 percent decrease in agricultural TFP A_a will lead to an even larger percentage increase in employment in agriculture, equal to $1/(1-\theta)$.

We next extend this simple model in order to illustrate two additional economic mechanisms that are potentially important determinants of the allocation of labor to agriculture.

2.4.2 Intermediate Goods In Agriculture

We modify the previous model by assuming that the output of the manufacturing sector can be used either for consumption or as an input in the production of the agricultural good. Let x denote the input of the manufactured good used in the agricultural sector. To simplify the exposition we again restrict attention to an agricultural production function that is Cobb-Douglas:

$$a = A_a l^{(1-\theta_x-\theta_n)} x^{\theta_x} n_a^{\theta_n}. \tag{5}$$

The social planner's problem for this economy is not as trivial as in the previous model, since there is now a decision about the input mix that is used to produce the required amount of agricultural output. Specifically, the social planner now seeks to solve:

$$\max_{n_a, x} v\left(A_m(1-n_a) - x + \bar{m}\right)$$

subject to:

$$\bar{a} = A_a x^{\theta_x} n_a^{\theta_n}.$$

This problem amounts to maximizing the consumption of the nonagricultural good subject to making sure that food requirements are met. Given our assumption of a Cobb-Douglas production function the solution for x will necessarily be interior. Letting λ_a be the Lagrange multiplier on the constraint, the first-order conditions for an interior solution are given by:

$$v'\left(A_m(1-n_a) - x + \bar{m}\right)A_m = \lambda_a \theta_n A_a x^{\theta_x} n_a^{\theta_n - 1} \tag{6}$$

$$v'\left(A_m(1-n_a) - x + \bar{m}\right) = \lambda_a \theta_x A_a x^{\theta_x - 1} n_a^{\theta_n}. \tag{7}$$

Dividing the two equations by each other yields:

$$A_m = \frac{\theta_n}{\theta_x}\frac{x}{n_a}, \tag{8}$$

which implies that the optimal choice of x for a given choice of n_a satisfies:

$$x = A_m \frac{\theta_x}{\theta_n} n_a. \tag{9}$$

It follows that we can rewrite the social planner's problem as:

$$\max_{n_a} v\left(A_m(1-n_a) - A_m\frac{\theta_x}{\theta_n}n_a + \bar{m}\right)$$

subject to:

$$\bar{a} = A_a A_m^{\theta_x} (\theta_x / \theta_n)^{\theta_x} n_a^{\theta_n + \theta_x}.$$

Because n_a is the only choice variable it follows that the constraint effectively determines the value of n_a, just as in the previous model, with the solution given by:

$$n_a = B\left[\frac{1}{A_a A_m^{\theta_x}}\right]^{1/(\theta_n+\theta_x)} \tag{10}$$

where $B = [\bar{a}\theta_n/\theta_x]^{1/(\theta_n+\theta_x)}$. The key result is that in this extended model, low productivity in either the agricultural or the manufacturing sector can give rise to increased employment in the agricultural sector. However, it is important to note that the elasticity of n_a with respect to A_m is smaller than the elasticity of n_a with respect to A_a by a factor of θ_x.

The above analysis has focused on optimal allocations taking as given the productivity of the economy in each of the two sectors. It is important to note that while the above argument stressed low productivity in the manufacturing sector as a factor leading to high employment in agriculture, the exact same logic shows that policies that increase the relative price of the intermediate good used in the agricultural sector would have the same effects.

2.4.3 Transportation Costs

In this subsection we abstract from intermediate inputs in agricultural production, but consider a different extension of the basic model described above. In particular, we consider a model in which production of agriculture and manufacturing goods takes place in different locations and it is costly to transport these goods between locations. Specifically, the two production technologies are as in the simple model that we described initially:

$$a = A_a l^\theta n_a^{1-\theta} \tag{11}$$

$$m = A_m n_m. \tag{12}$$

Workers reside in the location in which they work, and must consume goods delivered to that location. For simplicity, we assume that transportation costs take the form of iceberg costs and are symmetric, that is, the cost of transporting m from one region to the other is the same as transporting a from one region to the other. We denote this cost by q. We abstract from moving costs for individuals and hence do not need to specify the initial location of workers. We discuss this in more detail below. Letting a_m and a_a denote the consumption of agricultural goods of workers in region m and a respectively, and similarly for m_a and m_m, feasibility now requires the following:

$$n_a a_a + (1-n_a)\frac{a_m}{(1-q)} = A_a l^\theta n_a^{1-\theta} \tag{13}$$

$$(1-n_a)m_m + n_a\frac{m_a}{(1-q)} = A_m n_m. \tag{14}$$

We again consider the social planner's problem for this economy. The presence of the location decision gives rise to a nonconvexity in this economy, which means that optimal allocations will not necessarily equate utilities across individuals in different locations. We assume that the transfers across individuals that are implicitly part of supporting such an allocation as an equilibrium are taken care of within the family, so that we are viewing the economy as consisting of many families, each of which has many members.

In equilibrium, each family behaves the same way. This assumption serves to simplify the analysis by allowing us to better focus on the role of transportation costs for goods, and is not critical for our results. Our main result is that transportation costs also have the effect of inducing a larger allocation of workers to the agricultural sector. If we were to assume that all individuals begin in the agricultural location and it is costly for an individual to move to the other location, this would simply reinforce this result.

It remains true that the social planner needs to allocate workers so that each worker obtains $\bar{a}$ units of the agricultural good. From the feasibility condition for the agricultural good it follows that there is a unique value of n_a that is consistent with this outcome. Specifically, setting a_a and a_m equal to $\bar{a}$ in this expression yields:

(15)
$$n_a \bar{a} \frac{q}{1-q} = \frac{\bar{a}}{1-q} - A_a n_a^{1-\theta}.$$

It follows that decreases in A_a and increases in q both lead to increases in n_a. Considering the case in which $\theta = 0$ provides some additional insight. In this case we obtain:

(16)
$$n_a = \frac{\bar{a}}{\bar{a}q + (1-q)A_a}.$$

From this expression there are three results of interest. First, as in the initial model model, a decrease in A_a leads to an increase in n_a. Second, whereas in the case of no transportation costs (i.e., $q = 0$) this elasticity is equal to negative one, when $q > 0$ the elasticity is less than one in absolute value. Third, an increase in transportation costs leads to an increase in n_a, since our maintained assumption for an interior solution for n_a is that $A_a > \bar{a}$. The elasticity of n_a with respect to q is given by $(A_a - \bar{a}) / (\bar{a}n_a)$. The intuition for these results is straightforward. Transportation costs imply that it takes agricultural production in excess of $\bar{a}$ in order to support an individual who resides in the manufacturing sector. It follows that if transportation costs increase, then holding the labor allocation fixed will result in a shortage of agricultural production, thereby necessitating an increase in labor allocated to agricultural production. It follows that holding all else constant, an economy with greater transportation costs will have a greater fraction of its employment in the agricultural sector. The effect of changes in A_a are also muted by the presence of transportation costs. When $\theta = 0$ and there are no transportation costs, a 1 percent increase in A_a leads to a 1 percent decrease in n_a since the same amount of food can now be produced by 1 percent fewer workers. In an economy with transportation costs it remains true that the same amount of output can be produced by 1 percent fewer workers, but when more individuals move from the agricultural sector to the manufacturing sector, it is necessary to transport more food, and therefore the decrease in n_a is necessarily less.

2.4.4 The Interaction of Intermediate Inputs and Transportation Costs

To simplify exposition we have thus far considered intermediate inputs and transportation costs in isolation from each other. However, there is an interaction between the two that is important to point out. In our analysis of the intermediate input case we showed that low productivity in the production of intermediates acted in a similar fashion (though with a smaller magnitude) to low productivity in agriculture in terms of how it influences the allocation of labor. We commented at the end of that section that a policy distortion that serves to increase the relative price of the intermediate good would have the same effects. In this section we show that the introduction of transportation costs into a model with intermediate inputs in agriculture necessarily creates this same effect. The intuition is simple: if intermediate goods need to be transported to the agricultural region, then increases in transportation costs serve to decrease use of intermediates, thereby reducing labor productivity in that sector. In this section we quickly show this formally, in the simplest setting possible. Specifically, our starting point will be the intermediate good model studied in the previous subsection, extended to assume that there is a cost associated with transporting intermediate goods for use in agriculture. To facilitate exposition, we abstract from transportation costs associated with moving the final goods between locations. Given there is no cost associated with moving final goods between locations, the social planner will allocate the same final consumption allocation to all individuals.

The social planner now seeks to solve:

$$\max_{n_a, x} v\left(A_m(1-n_a) - \frac{x}{1-q} + \bar{m}\right)$$

subject to:

$$\bar{a} = A_a x^{\theta_x} n_a^{\theta_n}.$$

The presence of transportation costs for the intermediate input in agriculture implies that using one more unit of x in the agricultural sector implies a greater than one-unit sacrifice in terms of final consumption of the non-agricultural good. Proceeding just as before, and letting λ_a be the Lagrange multiplier on the constraint, the first-order conditions for an interior solution are given by:

$$v'\left(A_m(1-n_a) - \frac{x}{1-q} + \bar{m}\right)A_m = \lambda_a \theta_n A_a x^{\theta_x} n_a^{\theta_n - 1} \tag{17}$$

$$v'\left(A_m(1-n_a) - \frac{x}{1-q} + \bar{m}\right) = (1-q)\lambda_a \theta_x A_a x^{\theta_x - 1} n_a^{\theta_n}. \tag{18}$$

Dividing the two equations by each other yields:

$$A_m = \frac{1}{(1-q)} \frac{\theta_n}{\theta_x} \frac{x}{n_a},$$

which implies that the optimal choice of x for a given choice of n_a satisfies:

$$x = (1-q) A_m \frac{\theta_x}{\theta_n} n_a.$$

Relative to our earlier derivations, we see the intuitive result that a higher value of q reduces the ratio intermediate input use relative to labor. Proceeding just as before, it follows that we can rewrite the social planner's problem as:

$$\max_{n_a} v\left(A_m(1-n_a) - (1-q) A_m \frac{\theta_x}{\theta_n} n_a + \bar{m} \right)$$

subject to:

$$\bar{a} = A_a (1-q)^{\theta_x} A_m^{\theta_x} (\theta_x / \theta_n)^{\theta_x} n_a^{\theta_n + \theta_x}.$$

Because n_a is the only choice variable it follows that the constraint effectively determines the value of n_a, just as in the previous model, with the solution given by:

$$n_a = B\left[\frac{1}{A_a A_m^{\theta_x} (1-q)^{\theta_x}} \right]^{1/(\theta_n+\theta_x)} \tag{21}$$

where $B = [\bar{a}\theta_n/\theta_x]^{1/(\theta_n+\theta_x)}$. The key result is that in this extended model, a lower value for $(1 - q)$ operates just like a decrease in A_m.

2.4.5 Summary

The key message from the above analysis is to note three channels that can lead to greater allocation of labor to the agricultural sector. The first channel is low TFP in agriculture. The second channel is low TFP in the production of an intermediate good used in the agricultural sector (or equivalently, a policy that raises the relative price of this input). The third channel is higher transportation costs. Two results of interest emerge from the above analysis concerning the size of these effects. First, in a model without transportation costs, the magnitude of the second channel is likely to be much smaller than the first channel, since the second channel is reduced relative to the first by a factor equal to the factor share of the intermediate good. Second, the presence of transportation costs tends to decrease the magnitude of the first channel and increase the magnitude of the second channel.

2.5 Quantitative Analysis

The previous analysis has formally demonstrated three different channels that influence the allocation of labor to the agricultural sector in a setting in which some minimal amount of food is required. The goal of this section is to carry out a quantitative analysis to provide some information regarding the relative magnitudes of these effects, as well as to measure the welfare effects associated with these three channels. In this section we consider a two-sector model along the lines of the ones considered in the previous section, allowing for both intermediate goods as inputs into the agricultural sector, as well as symmetric transport costs q that apply to movement of both final and intermediate goods across locations. For our quantitative analysis we generalize preferences so that food consumption is not necessarily equal to $\bar{a}$:

$$\alpha \log(a - \bar{a}) + (1 - \alpha)\log(m + \bar{m}). \tag{22}$$

We continue to assume a Cobb-Douglas production function for agriculture, defined over land (l), intermediates (x) and labor (n_a):

$$a = A_a F(l, x, n_a) = A_a l^{1-\theta_x-\theta_n} x^{\theta_x} n^{\theta_n}. \tag{23}$$

Assuming that the land endowment is normalized to one, feasibility is determined by the two constraints:

$$n_a a_a + (1 - n_a)\frac{a_m}{(1-q)} = A_a F(1, x, n_a) \tag{24}$$

$$(1 - n_a) m_m + n_a \frac{m_a}{(1-q)} + \frac{x}{(1-q)} = A_m(1 - n_a). \tag{25}$$

We solve a social planner's problem for this economy, which as noted earlier, can be understood as the competitive equilibrium allocation that would emerge if we interpret our model as consisting of a large number of households, each with a large number of members, where households maximize the average utility of their members. As noted earlier, the presence of the nonconvexity associated with the discrete location choice coupled with transportation costs implies that not all household members will end up with the same utility. This implies that households are implicitly making transfers across family members.

Many of the results that we derived in the previous section continue to hold in this model that features a more general utility function. In particular, given an allocation of labor across the two locations and a choice of x that is feasible given the choice of n_a, we can derive closed form solutions for the consumption allocations. In particular, we have:

$$a_a = A_aF(1,x,n_a) - (1-n_a)\bar{a}\frac{q}{1-q} \tag{26}$$

$$a_m = (1-q)A_aF(1,x,n_a) + n_aq\bar{a}. \tag{27}$$

As noted earlier, when $\bar{m} > 0$, it is possible that the solution for m_a will be zero even when there is positive production of the manufacturing good net of inputs into the agricultural sector. This is easily incorporated into the analysis. Specifically, we have:

$$m_a = \max\left\{(1-q)\left[A_m(1-n_a) - \frac{x}{1-q}\right] - (1-n_a)\bar{m}q, 0\right\} \tag{28}$$

$$m_m = \max\left\{A_m(1-n_a) - \frac{x}{1-q} + n_a\bar{m}\frac{q}{1-q}, A_m - \frac{x}{(1-n_a)(1-q)}\right\}. \tag{29}$$

It follows that consumption in each location is biased toward consumption of the good produced in that location.

For a given value of n_a, and using the above allocation rules, increasing x shifts the overall consumption bundle, as well as production from the manufactured good, toward the agricultural good. The optimal choice of x will equate the marginal rate of substitution between consumption of agriculture and manufacturing to the marginal rate of transformation between the two, taking into account transportation costs and the rule for allocating consumption within the family. A simple calculation shows that if all solutions are interior, then the choice of x should be such that the following holds:

$$\frac{(1-\alpha)}{\alpha}\frac{(a_a - \bar{a})}{(m_a + \bar{m})} = A_aF_2 \tag{30}$$

where the solutions for a_a and m_a are those derived above.

We now turn to the quantitative analysis. We choose parameters so that the model captures some features of the Ugandan economy. The technology parameters A_a and A_m can be set to one without loss of generality, as this simply amounts to a choice of units. We also normalize the size of the population to equal one. For our benchmark results we set $\theta_x = .2$ and $\theta_n = .4$, implying a share for land that is also equal to .4. The preference parameter α is set to .20.

If $\bar{a}$ and $\bar{m}$ were zero, then expenditure shares would provide information on α. The parameters $\bar{a}$ and $\bar{m}$ become less relevant as a country becomes richer, so looking at expenditure shares for rich countries does provide information about α if we assume that preferences are the same across countries. If we were interpreting the agricultural sector output exclusively as food, then expenditure shares in a rich country such as the United States would suggest that our value of α is somewhat on the high side, but we think it is reasonable to have a broader notion of agricultural output that also includes clothing, for example, thereby motivating the somewhat higher value for α.

In terms of how they influence labor allocations, the parameters $\bar{a}$ and $\bar{m}$ have the same effect, which is to lead to a greater allocation of labor to agriculture holding all else constant. In view of this we set $\bar{m} = 0$ in our benchmark specification and rely on $\bar{a}$ to achieve the desired allocation of labor. In particular, we will choose $\bar{a}$ so that roughly 80 percent of the population works in the agricultural sector, consistent with the allocation of labor in Uganda. The final parameter to be set is the transportation cost parameter q. For our benchmark results we set $q = .5$. In the decentralized equilibrium, this would imply that prices of agricultural goods in the urban region are twice as high as in the rural area. This dispersion is consistent with the evidence for Uganda presented in section 2.2. Table 2.9 displays the equilibrium allocation that results from our calibrated economy.

We now consider the effects of changes in several of the model's parameters for the equilibrium allocations and welfare. Our measure of welfare is standard. Specifically, let the benchmark equilibrium have n_a^* workers in the agricultural sector and a consumption allocation to be $(a_a^*, m_a^*, a_m^*, m_m^*)$ and suppose that the new allocation that emerges from a particular change in the economy is given by $n'_a, a'_a, m'_a, a'_m, m'_m$. We then ask what proportional change in the consumption bundle $(a_a^*, m_a^*, a_m^*, m_m^*)$ holding the labor allocation n_a fixed, would yield the same average utility as generated by the new allocation.

In our qualitative analysis we considered three key driving forces for the allocation of labor to agriculture: TFP in agriculture, TFP in manufacturing, and transportation costs. We begin by exploring the impact of a 10 percent improvement in each of these variables in isolation. Table 2.10 presents the results.

Several points are worth noting. First, consistent with our theoretical analysis, all three changes result in a decline in the fraction of the population in the agricultural sector. Moreover, the ratio of θ_x to $\theta_x + \theta_n$ is one-third and the effect of a 10 percent increase in manufacturing TFP on labor allocated

Table 2.9 **Benchmark equilibrium allocation**

n_a/Pop	a_m	a_a	m_m	m_a	x
.800	.454	.458	.045	.023	.077

Table 2.10 **Comparison of the three channels**

	n_a/Pop	a_m	a_a	m_m	m_a	x	Δ
Benchmark	.800	.454	.458	.045	.023	.077	—
$A_a = 1.1$	.736	.460	.469	.103	.052	.081	.33
$A_m = 1.1$	.787	.455	.460	.063	.031	.086	.045
$q = .45$	.747	.457	.463	.080	.044	.095	.173
$A_a = 1.1, q = .45$	.681	.463	.474	.143	.079	.097	.769

to agriculture is roughly one-third the size of the effect from a 10 percent increase in A_a. The effect of a 10 percent improvement in transportation has an impact on labor allocated to agriculture that is roughly 80 percent as large as the 10 percent increase in agricultural TFP. At least in this parameterization, the effects of improvements in transportation technology seem to be of roughly similar importance to equivalent improvements in agricultural TFP, and are more important than improvements in the TFP for producing intermediate goods. This last result was predicted by our theoretical analysis, since we saw in the previous section that one of the effects of a 10 percent improvement in transportation is to mimic a 10 percent improvement in the TFP for producing intermediates, but that there are additional effects as well.

The welfare effects associated with these changes are very large—for example, a 10 percent increase in A_a leads to a welfare increase of more than 30 percent. From a mechanical perspective, note that the source of this large increase is mostly attributable to the fact that although the increase in the consumption levels is small, it represents a large percentage change in m. Specifically, for the case of the increase in A_a, the value of m more than doubles for workers in both locations. To understand why a 10 percent improvement in technology in only one sector can have such a large effect, it is important to note that the welfare effect is highly nonlinear due to the presence of the $\bar{a}$ term. For example, if we considered the welfare increase associated with changing A_a by 10 percent starting from a value of $A_a = 2$ instead of $A_a = 1$, and holding all other parameters fixed, then the welfare increase is only about half as large. Aside from noting the large welfare increases associated with small improvements in technology at low levels of development, it is also worth noting that the welfare effects associated with the increase in A_a are the largest in this economy, but that the welfare gain from a decrease in q is also very substantial. Given that the economy devotes 80 percent of its labor to the agricultural sector, it should not be surprising that the welfare effect of a change in A_m is substantially lower than that associated with a change in A_a.

There are two different channels through which changes in q influence welfare. One effect is that fewer resources are used in transportation. A second effect is that consumption allocations are smoother across locations. It is of interest to know what the relative importance of these two effects is. It turns out that the second effect is extremely small: if we compute the utility gain associated with smoothing consumption across locations, keeping total consumption constant, then the welfare gain is only .003.

It is also instructive to notice how the consumption allocation changes to better appreciate the different mechanisms at work. Table 2.10 shows that in each case the consumption allocation increases along all dimensions, with the increase in consumption being the greatest for the increase in A_a. However, the increase in intermediates used in agriculture is actually smallest for this case. As noted earlier, the cases of increases in A_m and decreases in q both

Table 2.11 **The effects of population growth**

	n_a/Pop	a_a	a_m	m_a	m_m	x	Δ
Benchmark	.800	.454	.458	.045	.023	.077	—
Pop = 1.1	.826	.452	.454	.023	.011	.084	–.009
Pop =1.1, A_a = 1.038	.800	.454	.458	.045	.023	.085	.000

serve to decrease the relative price of intermediates, and therefore lead to a larger increase in intermediate usage relative to the case of an increase in A_a.

The last row of table 2.10 reports the effects of having two of the changes occur simultaneously. The effect on the allocation of labor is roughly the sum of the two individual effects, but the improvement in welfare is much larger than the sum of the effects. This indicates a significant interaction effect between the two types of changes.

We next consider the effects of an increase in population size. It turns out that in a model with a fixed factor and food requirements, an increase in population pushes not only more people into agriculture but also a greater fraction of the population into this sector. This suggests that population increases (relative to available land) are also potentially an important factor in understanding the dynamics of labor allocation and productivity. Table 2.11 reports the results.

The first row of table 2.11 reports the results for a 10 percent increase in population. We note that not only does this lead to a lower fraction of people in the manufacturing sector, but also that the absolute size of the population in this sector also decreases. There is also a modest decrease in welfare associated with a 10 percent increase in population. Note that although fewer workers are working in the manufacturing sector, use of intermediate inputs in agriculture actually increases as a result of the population increase. The next row asks what increase in productivity in the agricultural sector would be required in order to offset the change in the fraction of the population in agriculture due to the 10 percent population increase. The answer turns out to be an increase of 3.8 percent. As this row shows, in this case the rest of the consumption allocation is also identical to that in the benchmark specification so that there is no net change in welfare, either. But this table illustrates an important finding, which is that in the presence of a fixed amount of land, population increases require fairly substantial improvements in agricultural productivity just to maintain a constant share of the workforce devoted to agriculture.

The next issue we examine is how improvements in transportation (or lack thereof) influence a develop path. Table 2.12 reports the results.

The second row shows the consequences of a doubling of TFP in both of the productive sectors. As the table shows, this had dramatic effects on the allocation of labor, the level of consumption, and on welfare. In par-

Table 2.12 Development paths

	n_a/Pop	a_a	a_m	m_a	m_m	x	Δ
Benchmark	.800	.454	.458	.045	.023	.077	—
$A_a = A_m = 2$	.344	.525	.599	1.01	.50	.15	10.45
$A_a = A_m = 2, q = .25$	.229	.614	.668	1.31	.980	.176	17.14

ticular, the share of labor devoted to agriculture is more than cut in half, and the welfare increase is roughly a factor of ten. As in standard models, large improvements in TFP lead to large improvements in welfare. The third row shows how the development path is altered if we assume that the large improvements in TFP in the two productive sectors are accompanied by an equivalent improvement in the transportation technology. The results are quite dramatic. In addition to producing an additional decline in the agricultural share of the workforce by roughly one-third, we see that the welfare gain is almost doubled. Comparing the second and third rows, one can conclude that the consequences for development of neglecting transportation are very substantial. A simple calculation that serves to quantify this is the following: Taking the third row of table 2.12 as a benchmark, we can ask how large would the improvements in the TFP parameters A_a and A_m need to be in order to achieve the same movement of labor out of agriculture if there were no associated improvements in transportation. The answer is that they would have to increase to 2.8 in order to achieve this same outcome.

2.6 Three-Region Analysis

A distinctive feature of agriculture in Uganda is its heterogeneity. As documented earlier, while a high percentage of individuals do subsistence agriculture using very low productivity methods, there is also a small segment of the agricultural sector that appears to be very modern. In this section we develop an extension of our model that can address this heterogeneity. There are three reasons why this extension is of interest. First, we think this heterogeneity is additional evidence for the importance of transportation costs relative to other factors, such as low productivity in producing intermediates. Second, it allows us to address the issue of subsistence agriculture. Third, while the basic messages from this extension are similar to those in the previous section, we think that it provides a richer structure for thinking about policy choices.

The extension that we consider is to assume that there are two rural regions instead of just one. Each rural region has a production function identical to that in the previous model, and each has a fraction of the total endowment of land. The distinguishing feature of the two regions is the cost associated with moving goods into and out of the region. We will refer to the region with lower transportation costs as region 1 and the region with higher transportation costs as region 2. We will refer to the urban area as region 0. We assume an iceberg cost of q_1 associated with moving goods between the urban area and the region 1, and an iceberg cost of q_2 associated with moving goods from region 1 to the region 2. The only way in which goods can be moved between the urban area and the region 2 is to pass through region 1. Note that if we set $q_2 = 0$ then this model reduces to that of the previous section.

We do not provide a detailed analysis of the analytics for the three-region case. It is straightforward to show that food is never transported from region 1 to region 2. This allows one to express feasibility in terms of the following two equations:

$$n_0 m_0 + n_1 \frac{m_1 + x_1}{1 - q_1} + n_2 \frac{m_2 + x_2}{(1 - q_1)(1 - q_2)} = A_m n_0$$

$$n_0 \frac{a_0}{(1 - q_1)} + n_1 a_1 + n_2 (1 - q_2) a_2 = A_a l_1^{1-\theta_x-\theta_n} x_1^{\theta_x} n_1^{\theta_n}$$

$$+ (1 - q_2) A_a l_2^{1-\theta_x-\theta_n} x_2^{\theta_x} n_2^{\theta_n}.$$

Assuming interior solutions, and similar to the two-region case, one can show that consumption allocations will satisfy:

$$m_0 + \bar{m} = \frac{m_1 + \bar{m}}{(1 - q_1)} = \frac{m_2 + \bar{m}}{(1 - q_1)(1 - q_2)}$$

$$\frac{a_0 - \bar{a}}{(1 - q_1)} = a_1 - \bar{a} = (1 - q_2)(a_2 - \bar{a}).$$

This implies that allocations become increasingly skewed toward agriculture and away from manufacturing as we move from region 0 to region 1 to region 2.

We now move to presentation of some illustrative quantitative results. We choose the same technology parameters as in the previous section: $\theta_x = .2$ and $\theta_n = .4$, and again set $\alpha = .2$. We allocate land between the two regions according to $l_1 = .1$ and $l_2 = .9$. Transportation costs are set according to $q_1 = .1$ and $q_2 = .6$. As in the previous section we set $\bar{m} = 0$ and choose the value of $\bar{a}$ so that in the equilibrium we have 80 percent of the population in agriculture. In the equilibrium it turns out that $n_1 = .096$ and $n_2 = .707$. Table 2.13 shows the consumption allocations.

Consistent with the above analysis, we see that individuals in region 2 have much lower consumption of manufacturing goods than do individuals in the other two regions. In terms of consumption allocations, individuals in region 2 very much capture the notion of subsistence agriculture. It is also of interest to examine the nature of agricultural production in the two regions. Table 2.14 provides some summary statistics.

Table 2.13 Consumption allocations: Three-region model

n_1	n_2	a_0	a_1	a_2	m_0	m_1	m_2
.096	.707	.409	.410	.425	.0516	.0464	.0186

Table 2.14 Agriculture production: Three-region model

l_1/n_1	l_2/n_2	x_1/n_1	x_2/n_2	y_{a1}/n_1	y_{a2}/n_2	y_{a1}/l_1	y_{a2}/l_2
1.04	1.27	.187	.066	.73	.64	.70	.50

The statistics reported are the land per worker (l/n), intermediates per worker (x/n), average labor productivity (y_a/n), and yield (y_a/l). Contrasting the two regions, we see that production in region 1 is relatively intensive in intermediate inputs, whereas production in region 2 is relatively intensive in land. The difference in relative use of intermediates is very large: region 1 has almost three times as much use of intermediate goods per worker. These factor intensities have opposing effects in terms of average labor productivity, but reinforcing effects in terms of yields. Nonetheless, we see that in the benchmark equilibrium, not only is yield higher in region 1, but that average labor productivity is also. However, perhaps somewhat surprisingly, despite the much more intensive use of intermediates in region 1, the yield in region 1 is only about 40 percent higher than in region 2.

We now carry out some counterfactual experiments similar to those conducted in the two-region model. Results for consumer allocations are presented in table 2.15, and results for agricultural production are in table 2.16. For completeness we include the results of the benchmark equilibrium in each table. The welfare measure is the same one that we used earlier.

We begin by discussing the results on allocations. The effects here are very similar to those from the two-region case. Of particular interest is that the welfare effects of TFP improvements are very similar in this model, while the effects of improvements in transportation are somewhat larger. Once again there are very large interaction effects between changes in agricultural TFP and changes in transportation costs. And as before, population increases have the effect of not only changing the share of the population in agriculture, but also reducing the absolute size of the population in the urban region. Moreover, the increase in the size of the population in subsistence is larger than the increase in the size of the overall population, so increases in population lead to an increase in the size of the subsistence farmer population.

The three-region model allows us to consider a new experiment relative to the two-region case. In particular, we can contrast the effect of improving overall transportation with that of expanding the size of region 1. Loosely

Table 2.15 **Experiments in the three-region model: Consumption allocations**

	n_1	n_2	a_0	a_1	a_2	m_0	m_1	m_2	Δ
Benchmark	.096	.707	.409	.410	.425	.052	.046	.019	—
$A_a = 1.1$	.115	.625	.415	.417	.442	.096	.087	.035	.32
$A_m = 1.1$	.105	.685	.411	.412	.429	.065	.059	.024	.06
$q = .9q$	.098	.643	.413	.414	.431	.085	.077	.036	.26
A_a, A_m, q	.124	.536	.420	.422	.448	.16	.15	.068	1.07
A_a and q	.114	.566	.420	.421	.447	.14	.13	.057	.82
$l_1 = 2$	.216	.504	.414	.415	.438	.095	.085	.034	.35
Pop = 1.1	.099	.812	.407	.407	.418	.036	.032	.013	–.02

Table 2.16 **Experiments in the three-region model: Agricultural production**

	l_1/n_1	l_2/n_2	x_1/n_1	x_2/n_2	y_{a1}/n_1	y_{a2}/n_2	y_{a1}/l_1	y_{a2}/l_2
Benchmark	1.04	1.27	.187	.066	.73	.64	.70	.50
$A_a = 1.1$	.87	1.44	.196	.080	.75	.77	.86	.53
$A_m = 1.1$	.95	1.31	.200	.075	.71	.66	.75	.51
$q = .9q$	1.02	1.40	.221	.097	.75	.72	.73	.51
A_a, A_m, q	.81	1.68	.254	.137	.77	.91	.95	.54
A_a and q	.88	1.59	.225	.115	.77	.86	.88	.54
$l_1 = 2$	.92	1.59	.226	.094	.72	.75	.78	.47
Pop = 1.1	1.02	1.11	.176	.058	.71	.59	.70	.53

speaking, if we think of region 1 as the well-connected region and region 2 as the remote region, we can contrast the effects of a general reduction in transport costs with the effects of increasing the size of the region that is well connected. This corresponds to the row in which l_1 is increased from .1 to .2. This corresponds to increasing the share of total land that is well connected by 10 percentage points. It is striking that this results in a substantially higher welfare effect than a uniform 10 percent reduction in transportation costs. It is important to keep in mind that we do not offer any metric in terms of the relative costs of these two types of changes, but we think it is definitely of interest that these policies have very quantitative effects in terms of welfare.

Next we consider the impact on the nature of agricultural production. Here there are some interesting patterns. Consider the case of a 10 percent increase in agricultural TFP. We know that this leads to fewer people in agriculture. But whereas the land per worker ratio does increase in region 2, somewhat surprisingly, this ratio actually decreases in region 1. This is because the flow of workers out of agriculture leads to greater production of manufacturing goods and hence greater use of intermediates in agriculture. This greater use of intermediates increases labor productivity and hence allows the economy to use even more workers in region 1, helping them to economize on transportation costs. A similar pattern is found for improvements in manufacturing TFP and reductions in transportation costs. The fact that these improvements lead to fewer workers per unit of land in region 2 but more workers per unit of land in region 1 lead to opposing effects on labor productivity, but amplify the differences in yields. In some cases, output per worker even becomes greater in region 2 than in region 1. The fact that we do not have capital as a factor of production may help explain this seemingly anomalous prediction. It may also be that the Cobb-Douglas production function also plays a role. For example, it could be that subsistence farming involves a constraint on how much land one individual can use productively. More generally, richer specifications of agricultural technology and technology choice are interesting extensions to explore.

An interesting finding is that crop yields (output per unit of land) in region 2 vary little across the experiments shown in table 2.16. In particular, these yields vary far less than the yields of the more intensively farmed region 1. Where some of the experiments lead to yield increases of 35 percent or more in region 1, relative to the benchmark, the largest increase in region 2 is 8 percent. A reason for this seems to be that rising agricultural TFP tends to lead to a movement of workers out of region 2 into the more productive region 1, with the reduction in labor offsetting the productivity benefits of increased TFP. A possible implication is that it may be somewhat difficult for policymakers to increase yields in the quasi-subsistence sector—even though it may be possible to increase welfare.

2.7 Conclusion

A key feature of the Ugandan economy is the large fraction of individuals engaged in farming at the same time that productivity of the agricultural sector is low relative to the nonagricultural sector. Earlier work has emphasized that this pattern obtains when low productivity in the agricultural sector is coupled with minimum food requirements and food is not easily imported. Our goal in this chapter has been to explore the possibility that high transportation costs associated with low infrastructure spending might also reinforce this pattern of labor allocation.

We first present evidence showing that regional price dispersion associated with transportation costs is very high in Uganda and then incorporate this feature into an otherwise standard two-sector model. We calibrate this model to resemble key features of the Ugandan economy and then perform several exercises aimed at uncovering the potential significance of transportation costs in accounting for the pattern of labor allocation in Uganda. We find that high transportation costs represent an important force in shaping the allocation of labor. Moreover, we find that improvements in transportation have an important interaction with improvements in agricultural productivity.

The underlying economics are intuitive: high transportation costs create an incentive for individuals to locate so as to minimize transportation costs for those goods that are most important to them. Since agricultural goods are relatively more important in poor economies, this leads to a greater fraction of the population in agriculture. Moreover, we argue that the predominance of subsistence agriculture can also be explained by this, since people who locate in remote areas in order to be close to their source of food will necessarily engage in little trade for other goods precisely because of the high transport costs. While our model has been simple and stylized, we believe it captures some important economic forces. Nonetheless, we want to emphasize three important directions for future research. The first is to gather more systematic data on the nature of transport costs. The second is to develop richer versions of our model that can provide better estimates of the quantitative effects of transportation infrastructure. Third, it is important to incorporate the costs associated with transportation infrastructure in order to provide better guidance regarding optimal policy.

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