Transport Investments and Agricultural Development in Sub-Saharan Africa

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Agriculture, Transportation, and Structural Transformation

- Agriculture is a large sector in most poor countries, both in terms of employment and output.
- Economic growth is strongly associated with declining shares of agriculture in output and employment.
  - Growth typically involves big changes in the structure of the economy.
  - Large changes in the agriculture sector are likely to have large general equilibrium effects.
- This paper focuses on understanding and measuring these general equilibrium effects.

Public Investments in Agriculture

- Agricultural sector linkages to other sectors:
  - As a source of supply for key consumption goods
  - As a source of demand for non-agricultural products
  - As a potential source of labor and other productive resources (land, capital)
  - As an input into processing and other industries.
- Public investments that affect the agricultural sector may thus have large general equilibrium effects.
  - Agricultural research
  - Roads and rural infrastructure
  - Irrigation systems, rural electrification, etc.

Central Questions

Accounting for General Equilibrium Effects

- This paper explores the impact of public investments that affect the agricultural sector.
  - Focuses on rural transportation infrastructure.
- How do these investments affect the overall economy?
  - Allocations of labor and other inputs across locations and sectors.
- How should we evaluate programs of public investment when they have substantial effects on the structural transformation of the economy?
  - Many standard approaches will tend to miss benefits.

Rural Transportation in Africa

- Broad consensus that rural transportation in Africa is slow, expensive, and erratic.
- Roads are poor and rural connectivity is very low.
- Possibly also issues of competition and institutional quality.

Connectivity and the Rural Access Index

- Many ways to measure the effectiveness of a transportation network.
  - Road density (km of road length per km^2).
  - Proportion of roads in different conditions.
- Recent advances in mapping and GIS have made possible another measure that focuses on rural areas:
  - Rural Access Index (RAI): measures proportion of rural population living within 2 km of an all-season road (i.e., a road, generally unpaved, that is passable most of the year).
- Evidence suggests that in many countries of sub-Saharan Africa, RAI is currently 20-40%.
- Of existing rural roads, perhaps 60% are in poor condition; only 3% paved.

Roads on the African Development Agenda

- Recent donor interest in the topic: Africa Infrastructure Country Diagnostic (AICD) project seeks to increase knowledge about infrastructure in Africa.
  - Data about current status and condition of infrastructure
  - Models: cost, priority setting
- Across 44 countries in sub-Saharan Africa, a recent AICD report (Carruthers et al., 2010) estimates that:
  - Reaching a set of relatively modest "pragmatic" targets for improved connectivity would cost about 2% of African GDP annually for 10 years.
  - 80% of spending would go towards roads.
- Ambitious targets, but some countries have sustained much higher levels of investment in transport sector over comparable periods of time (e.g., China) .

Impact Evaluation for Public Investments

Are we looking in the right place?

- How should we assess the *ex ante* or *ex post* impact of investments of this magnitude?
  - By design and intention, these investments are meant to be transformative.
  - But current approaches offer limited options for evaluation of this type.
  - Tend to focus on benefits received in partial equilibrium by some set of target beneficiaries, or else on crude econometric evidence from cross-sectional comparisons.
- Micro evaluations that do not consider general equilibrium effects may give misleading results.

Evaluating Rural Transportation Infrastructure Investments in Uganda

- Based on Gollin and Rogerson (2010).
- Use a static general equilibrium model to consider general equilibrium effects of programs and policies that generate agricultural development.
- These interventions cause the share of agriculture in GDP and employment to fall.
- Naive evaluation techniques might fail to recognize agriculture's role.

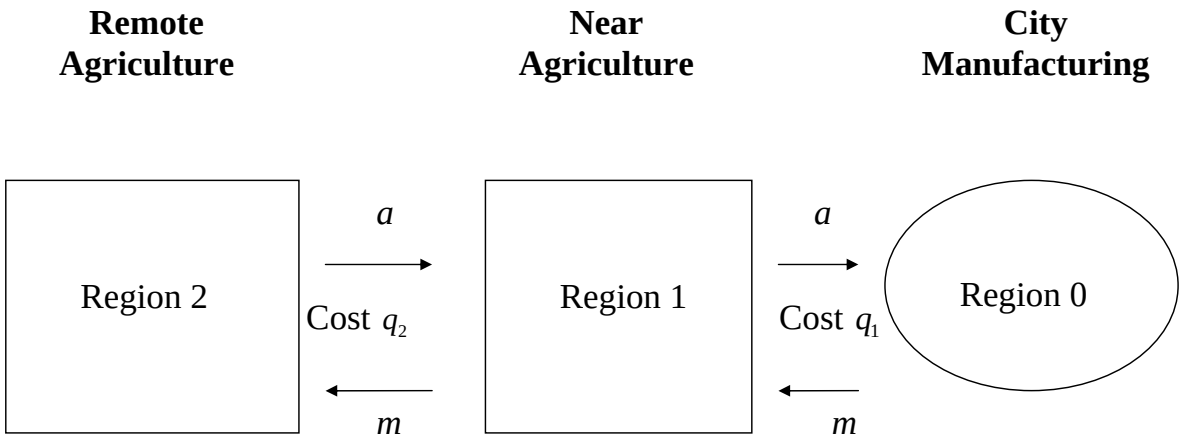
Related literature

- Close in spirit to Eswaran and Kotwal (1993).
- Some similarities to Caselli and Coleman (2001), Vollrath (2004, 2008).
- Also related to work on transportation and growth in Herrendorf, Schmitz, and Teixeira (2006, 2008); Adamopoulos (2005).
- Most similar to models of structural transformation in Gollin, Parente, and Rogerson (2004, 2007).

Model environment

- Consider a closed developing economy with two sectors: an agricultural sector that produces food and an urban sector that produces non-agricultural goods.
- Non-agricultural goods can be consumed or used as inputs into the production process in either sector.
- Non-agricultural goods are produced in the city.
- Food can be produced in either of two rural regions: an area "close" to the city or an area that is more "remote".
- There are (high) transportation and transaction costs that make it expensive to move manufactured goods from the city to rural areas and (symmetrically) make it costly to move food from rural areas to the city.

Schematic Representation



Model environment, cont.

- In equilibrium, people will inhabit all three regions.
- Those in the remote rural area will produce less for the market than those in the close rural area.
- The urban population is limited by the ability of the agricultural sector to produce "marketable surplus;" low agricultural productivity implies small urban populations.
- High transportation costs will make it costly to move goods across regions.

Three-Region Model

Preferences

Log linear preferences with non-homotheticities:

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

Three-Region Model

Technologies

- Agricultural technology: $a_j = A_a F(l_j, x_j, n_{aj}) = A_{aj} l_j^{1-\theta_x-\theta_n} x_j^{\theta_x} n_j^{\theta_n}$
- Manufacturing technology: $m = A_m n_m$.

Three-Region Model

Endowments

- One unit of land, divided into "close" and "remote" agricultural regions.
- Labor is allocated endogenously.

Feasibility Conditions

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

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

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

Equilibrium Allocations

- For interior solution:

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

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

- Corner solutions are plausible under some specifications. We solve for them and check for them computationally.

Quantitative Experiment

Parameter Values

- Choose parameter values to match a few stylized observations from Uganda.
  - $A_a = A_m = 1$
  - $l_1 = 0.1,\ l_2 = 0.9$
  - $\theta_x = .2,\ \theta_n = .4$
  - $\alpha = .20$
  - $\bar{m} = 0$
  - $\bar{a} \Rightarrow n_1 + n_2 = 0.80$
  - $q_1 = 0.1,\ q_2 = 0.6$

Benchmark Allocations

Consumption Allocations: Three Region Model

n_0	n_1	n_2	a_0	a_1	a_2	m_0	m_1	m_2
.214	.110	.676	.406	.407	.417	.073	.066	.026

- Individuals in the "near" agricultural region consume bundles quite similar to urban residents.
- Individuals in the "remote" agricultural region seem to be in quasi-subsistence.
  - Consume very few non-agricultural goods, but food consumption is relatively high.

Agriculture, Near and Far

Inputs and Intensity across Regions

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
0.91	1.33	.399	.049	.801	.613	.882	.461

- Labor intensity is greater in near region.
- Far greater use of intermediates in near region.
- Output per unit of land (yield) is 90% higher in the near region.
- Differences in output per worker are smaller.

Comparative Statics

- Consider four alternative investment programs:
  1. Increase RAI from 0.27 to 0.50 (AICD "pragmatic" case).
  2. Increase RAI from 0.27 to 0.75 (AICD "base" case).
  3. Improve connectivity only on national roads.
  4. Scenarios (2) and (3) together.
- Our welfare comparison: Ask how by what fraction the benchmark consumption bundle would need to be increased in order to yield the same utility as each scenario.
- Alternative measures of impact.

Matching Scenarios to the Model

Table: Four Scenarios: Model Representations

Scenario	Description	Parameters				Cost (Share of GDP)
		q_1	q_2	l_1	l_2	
1	RAI "pragmatic"	-15%	-15%	–	–	0.42%
2	RAI "base"	-30%	-30%	–	–	0.76%
3	National roads only	-20%	–	.15	.85	1.34%
4	(2) and (3) together	-30%	-30%	.15	.85	2.00%

Costs represent annual spending requirement over a 10-year horizon, as a share of GDP.

Equilibrium Scenarios

Experiments in the Three Region Model: Consumption Allocations

	n_0	n_1	n_2	a_0	a_1	a_2	Δ
Benchmark	.214	.110	.676	.406	.407	.417	–
1. RAI "pragmatic"	.296	.110	.594	.410	.411	.423	.28
2. RAI "base"	.378	.102	.520	.416	.417	.429	.86
3. National roads only	.270	.170	.560	.409	.410	.424	.14
4. (2) and (3) together	.402	.146	.452	.418	.419	.433	1.06

Manufacturing Consumption in Equilibrium

Experiments in the Three Region Model: Manufacturing Consumption

	m_0	m_1	m_2	Δ
Benchmark	.073	.066	.026	–
1. RAI "pragmatic"	.127	.116	.0578	.28
2. RAI "base"	.190	.177	.102	.86
3. National roads only	.108	.099	.040	.14
4. (2) and (3) together	.209	.194	.113	1.06

Agriculture in Equilibrium

Intensification and Input Use

Experiments in the Three Region Model: Agricultural Production

	y_{a1}/n_1	y_{a2}/n_2	y_{a1}/l_1	y_{a2}/l_2
Benchmark	.801	.613	.882	.461
1. RAI "pragmatic"	.807	.729	.888	.481
2. RAI "base"	.837	.8486	.855	.490
3. National roads only	.799	.663	.906	.437
4. (2) and (3) together	.854	.880	.832	.468

Agriculture in Equilibrium

Intensification and Input Use

Experiments in the Three Region Model: Agricultural Production

	l_1/n_1	l_2/n_2	x_1/n_1	x_2/n_2
Benchmark	908	1.332	.399	.049
1. RAI "pragmatic"	.908	1.515	.414	.090
2. RAI "base"	.980	1.731	.429	.146
3. National roads only	.882	1.518	.420	.056
4. (2) and (3) together	1.027	1.881	.431	.150

Impact assessment

The perils of overlooking GE effects

- In most of these scenarios, large fractions of welfare gains come from relocation of people across regions.
- Impact assessment techniquest that focus on "within" measures of welfare gains will give misleading (low) estimates of impact.
- Similar in spirit to Lewis model, in which growth consists of moving people from a low productivity sector to a higher productivity sector.

Welfare Gains with and without Reallocation

The perils of holding sampling frames static

Scenario	Welfare Gains	Gains without Reallocation
Benchmark	–	–
1. RAI "pragmatic"	0.284	0.200
2. RAI "base"	0.860	0.482
3. National roads only	0.140	0.092
4. (2) and (3) together	1.064	0.548

Yield and Agricultural Productivity Measures

- Many rural development programs are evaluated by looking at incremental production or yield.
- In our model, there are big effects of the scenarios on agricultural production incentives (through price channels), but yields increase a maximum of 5% in the most favorable case (Scenario 3).
- Why? Because increases in input intensity are offset by movements of population out of agriculture.
- Standard evaluation techniques may miss this.
- At a national level, yield increases by 7.7% (for a population-weighted sample) or 8.3% (for an area-weighted sample). Both are smaller in percentage terms than the TFP increases.

Rural transportation infrastructure improvements

The perils of overlooking GE effects

- Rural transportation projects have little impact on yields or overall production, since income elasticity of demand for food is relatively modest in our economy.
- Evaluation approaches that calculate the quantity of agricultural output will tend to understate the benefits.
- The big effect is that 20% of the total population is able to move out of subsistence agriculture.

Implications

- Need a general equilibrium model to think properly about these impacts.
- In evaluating economy-wide changes (e.g., Green Revolution, any kind of national-level interventions), but *especially* transportation investments, ignoring the GE effects may lead to serious errors.
- Surveys that track migration and sectoral movements will do a better job than studies that focus only on rural or agricultural households.
- Need to be careful with attribution of benefits:
  - Big gains occur through rural-to-urban migration.
  - But this movement may be driven powerfully by investments in rural areas.
  - Empirical finding that rural-to-urban migrants achieve the biggest welfare gains will tell us nothing about the causal mechanisms; possibly this reallocation is best achieved through investments in agriculture.

A Cost-Benefit Estimate??

- Ideally, this kind of analysis could help us think about the true returns to public investments.
- Parameterization is problematic; this study should be taken as proof-of-concept rather than an empirical exercise.
- Nevertheless, we do calculate GDP for our model economy, and we can compare the costs of the different scenarios with the GDP benefits.

Returns to Investment

Scenario	Annual Cost	GDP Increase
Benchmark	–	–
1. RAI "pragmatic"	0.42%	26.7%
2. RAI "base"	0.76%	47.2%
3. National roads only	1.34%	18.2%
4. (2) and (3) together	2.00%	51.4%

5. Conclusions and Questions

- We need to remember that in many developing countries, agricultural interventions have impacts that spill out from the sector. Will a macro perspective change our assessments of which interventions are successful?
- What government investments and policies can help to reduce the costs of change?