THE WORLD BANK

ICRIER

UKaid from the Department for International Development

WORKSHOP

Growth and Inclusion: Theoretical and Applied Perspectives

Session IV

Presentation

Sectoral Infrastructure Investment in an Unbalanced Growing Economy: The Case of India

Chetan Ghate
Indian Statistical Institute

January 13, 2012

The Claridges Hotel
12 Aurangzeb Road
New Delhi, India

Sectoral Infrastructure Investment in An Unbalanced Growing Economy: The Case of India.

Chetan Ghate (joint work with Gerhard Glomm and Jialu Liu)

Indian Statistical Institute, Delhi Centre

Conference on Growth and Inclusion
January 2012

Literature

- Large literature on how structural change and growth inter-relate in the development process.
  - Very little work on India
  - No role for sector specific policies (taxes, public capital, labor laws)
- India stands out for three main reasons

- Employment in agriculture is persistent
- Entire decline in agricultural GDP in the last two decades has been picked up by the service sector.
  - Manufacturing share virtually constant
  - Large service sector (puzzling because many components of service are income related)
- Sectoral $\frac{K}{Y}$ exhibit large changes.

- Challenge is to build a model with sectoral policies that explains all three: sectoral GDP shares, sectoral $\frac{K}{Y}$ ratios, sectoral employment shares.

Literature

- Large literature on how structural change and growth inter-relate in the development process.
    - Very little work on India
    - No role for sector specific policies (taxes, public capital, labor laws)
- India stands out for three main reasons
- Employment in agriculture is persistent
- Entire decline in agricultural GDP in the last two decades has been picked up by the service sector.
    - Manufacturing share virtually constant
    - Large service sector (puzzling because many components [illegible] income related)
- Sectoral $\frac{K}{Y}$ exhibit large changes.
- Challenge is to build a model with sectoral policies that explains all three: sectoral GDP shares, sectoral $\frac{K}{Y}$ ratios, sectoral employment shares.

Literature

- Large literature on how structural change and growth inter-relate in the development process.
  - Very little work on India
  - No role for sector specific policies (taxes, public capital, labor laws)
- India stands out for three main reasons
- Employment in agriculture is persistent
- Entire decline in agricultural GDP in the last two decades has been picked up by the service sector.
  - Manufacturing share virtually constant
  - Large service sector (puzzling because many components of service are income related)
- Sectoral $\frac{K}{Y}$ exhibit large changes.
- Challenge is to build a model with sectoral policies that explains all three: sectoral GDP shares, sectoral $\frac{K}{Y}$ ratios, sectoral employment shares.

Literature

- Large literature on how structural change and growth inter-relate in the development process.
  - Very little work on India
  - No role for sector specific policies (taxes, public capital, labor laws)
- India stands out for three main reasons

- Employment in agriculture is persistent
- Entire decline in agricultural GDP in the last two decades has been picked up by the service sector.
  - Manufacturing share virtually constant
  - Large service sector (puzzling because many components of service are income related)

- Sectoral $\frac{K}{Y}$ exhibit large changes.

- Challenge is to build a model with sectoral policies that explains all three: sectoral GDP shares, sectoral $\frac{K}{Y}$ ratios, sectoral employment shares.

Literature

- Large literature on how structural change and growth inter-relate in the development process.
  - Very little work on India
  - No role for sector specific policies (taxes, public capital, labor laws)
- India stands out for three main reasons
- Employment in agriculture is persistent
- Entire decline in agricultural GDP in the last two decades has been picked up by the service sector.
  - Manufacturing share virtually constant
  - Large service sector (puzzling because many components of service are income related)
- Sectoral $\frac{K}{Y}$ exhibit large changes.
- Challenge is to build a model with sectoral policies that explains all three: sectoral GDP shares, sectoral $\frac{K}{Y}$ ratios, sectoral employment shares.

Literature

- Large literature on how structural change and growth inter-relate in the development process.
  - Very little work on India
  - No role for sector specific policies (taxes, public capital, labor laws)
- India stands out for three main reasons
- Employment in agriculture is persistent
- Entire decline in agricultural GDP in the last two decades has been picked up by the service sector.
  - Manufacturing share virtually constant
  - Large service sector (puzzling because many components of service are income related)
- Sectoral $\frac{K}{Y}$ exhibit large changes.
- Challenge is to build a model with sectoral policies that explains all three: sectoral GDP shares, sectoral $\frac{K}{Y}$ ratios, sectoral employment shares.

Literature

- Large literature on how structural change and growth inter-relate in the development process.
  - Very little work on India
  - No role for sector specific policies (taxes, public capital, labor laws)
- India stands out for three main reasons
- Employment in agriculture is persistent
- Entire decline in agricultural GDP in the last two decades has been picked up by the service sector.
  - Manufacturing share virtually constant
  - Large service sector (puzzling because many components of service are income related)
- Sectoral $\frac{K}{Y}$ exhibit large changes.
- Challenge is to build a model with sectoral policies that explains all three: sectoral GDP shares, sectoral $\frac{K}{Y}$ ratios, sectoral employment shares.

Table

Table 1: Data

	Agriculture		Manufacturing		Services	
	1970	2000	1970	2000	1970	2000
Employment Shares$^{(a)}$	77%	62%	12%	19%	12%	20%
GDP Shares	48%	25%	23%	27%	29%	48%
K/Y Ratios	3.3	0.85	0.6	4.33	11	1.82
Gross Capital Formation	18%	9%	33%	30%	49%	61%

Source: Verma(2008)

(a): the employment share data are for 1970 and 1997.

Main policy question addressed

- We build upon the literature on the impact of infrastructure investments on growth
- We confine our analysis to an agricultural sector and a "modern" sector.
- We ask: what are the effects of infrastructure investments in economies undergoing structural changes?
- More specifically: What is the effect of the allocation of infrastructure investment on economic growth in a dynamic general equilibrium model where one sector, say agriculture, shrinks over time, and another, manufacturing, rises over time ?
- Many analyses are carried out in a one-sector growth model with an aggregate production function of the Cobb-Douglas variety.
  - This would predict constant $\frac{K}{Y}$ ratios along a balanced growth path in the aggregate economy.

Motivating the model

- We construct a two sector OLG model to explain India's unique pattern of structural transformation.
- Features

1. Agricultural sector and a "modern" sector.
    - This identification is not really necessary
2. In each sector, the stock of infrastructure is a productive input.
3. Assume perfect mobility of both private factors of production (K, L), between the two sectors.
4. We deviate from the standard Cobb-Douglas assumption in both sectors: we allow for a CES production function in manufacturing. This allows changing $\frac{K}{Y}$ ratios to be matched at least qualitatively.
5. Robustness exercise uses Stone-Geary utility.

Motivating the model

- We construct a two sector OLG model to explain India's unique pattern of structural transformation.
- Features

1. Agricultural sector and a "modern" sector.
    - This identification is not really necessary
2. In each sector, the stock of infrastructure is a productive input.
3. Assume perfect mobility of both private factors of production (K, L), between the two sectors.
4. We deviate from the standard Cobb-Douglas assumption in both sectors: we allow for a CES production function in manufacturing. This allows changing $\frac{K}{Y}$ ratios to be matched at least qualitatively.
5. Robustness exercise uses Stone-Geary utility.

Motivating the model

- We construct a two sector OLG model to explain India's unique pattern of structural transformation.
- Features

1. Agricultural sector and a "modern" sector.
   - This identification is not really necessary
2. In each sector, the stock of infrastructure is a productive input.
3. Assume perfect mobility of both private factors of production (K, L), between the two sectors.
4. We deviate from the standard Cobb-Douglas assumption in both sectors: we allow for a CES production function in manufacturing. This allows changing $\frac{K}{Y}$ ratios to be matched at least qualitatively.
5. Robustness exercise uses Stone-Geary utility.

Motivating the model

- We construct a two sector OLG model to explain India's unique pattern of structural transformation.
- Features

1. Agricultural sector and a "modern" sector.
    - This identification is not really necessary
2. In each sector, the stock of infrastructure is a productive input.
3. Assume perfect mobility of both private factors of production (K, L), between the two sectors.
4. We deviate from the standard Cobb-Douglas assumption in both sectors: we allow for a CES production function in manufacturing. This allows changing $\frac{K}{Y}$ ratios to be matched at least qualitatively.
5. Robustness exercise uses Stone-Geary utility.

Motivating the model

- We construct a two sector OLG model to explain India's unique pattern of structural transformation.

- Features

1. Agricultural sector and a "modern" sector.
    - This identification is not really necessary
2. In each sector, the stock of infrastructure is a productive input.
3. Assume perfect mobility of both private factors of production (K, L), between the two sectors.
4. We deviate from the standard Cobb-Douglas assumption in both sectors: we allow for a CES production function in manufacturing. This allows changing $\frac{K}{Y}$ ratios to be matched at least qualitatively.
5. Robustness exercise uses Stone-Geary utility.

Motivating the model

- We construct a two sector OLG model to explain India's unique pattern of structural transformation.

- Features

1. Agricultural sector and a "modern" sector.
   - This identification is not really necessary
2. In each sector, the stock of infrastructure is a productive input.
3. Assume perfect mobility of both private factors of production (K, L), between the two sectors.
4. We deviate from the standard Cobb-Douglas assumption in both sectors: we allow for a CES production function in manufacturing. This allows changing $\frac{K}{Y}$ ratios to be matched at least qualitatively.
5. Robustness exercise uses Stone-Geary utility.

Motivating the model

- We construct a two sector OLG model to explain India's unique pattern of structural transformation.

- Features

1. Agricultural sector and a "modern" sector.
    - This identification is not really necessary
2. In each sector, the stock of infrastructure is a productive input.
3. Assume perfect mobility of both private factors of production (K, L), between the two sectors.
4. We deviate from the standard Cobb-Douglas assumption in both sectors: we allow for a CES production function in manufacturing. This allows changing $\frac{K}{Y}$ ratios to be matched at least qualitatively.
5. Robustness exercise uses Stone-Geary utility.

Our contribution

- Provide a tractable framework to think about structural transformation in the Indian context
- We construct several policy experiments varying the fraction of GDP allocated to public investments.
- Model is not able to match changing $\frac{K}{Y}$ ratios unless productive infrastructure capital is introduced.

Benchmark Model without Public Infrastructure

- Economy populated by a large number of individuals in an OLG set up.
- Each individual lives for two periods (works when young, and retires when old)
- Consumption only takes places in the second period (all first period income is saved)
- We assume no population growth: within each generation individuals are identical ex-ante

Benchmark Model without Public Infrastructure

- Two production sectors: "agriculture" and "manufacturing"
  - Differ in their elasticity of substitution between labor and capital.
- Agriculture production function

$$Y_{at} = A_a K_{a,t}^{\alpha} L_{a,t}^{1-\alpha}$$

- Manufacturing production function

$$Y_{mt} = A_m \left[(1-\theta) K_{m,t}^{\rho} + \theta L_{m,t}^{\rho} \right]^{\frac{1}{\rho}}, \qquad \rho \leq 1$$

- $\rho \leq 1$ allows for non-balanced growth feature of the Indian economy
- Allow for competitive factor markets (marginal products across sectors equated)

- Following Glomm (1992), Lucas (2004), utility function captures zero income elasticity of demand for food (the ag. good)

$$u(c_{m,t}, c_{a,t}) = c_{m,t+1} + \phi \ln c_{a,t+1}, \qquad \phi > 0$$

- Agricultural household's problem

$$\max_{c_m, c_a} \; c_{m,t+1} + \phi \ln c_{a,t+1}$$

subject to

$$c_{m,t+1} + p_{t+1} c_{a,t+1} = p_t w_{at}(1 + r_{t+1})$$

where w_{at} = real agricultural wage, p_t = price of the agricultural good relative to the manufacturing good.

- Ag household's demand for
  - Manuf good: $c^a_{m,t+1} = p_t w_{a,t}(1 + r_{t+1}) - \phi$
  - Ag good: $c^a_{a,t+1} = \frac{\phi}{p_{t+1}}$

- Following Glomm (1992), Lucas (2004), utility function captures zero income elasticity of demand for food (the ag. good)

$$u(c_{m,t}, c_{a,t}) = c_{m,t+1} + \phi \ln c_{a,t+1}, \qquad \phi > 0$$

- Agricultural household's problem

$$\max_{c_m, c_a} \; c_{m,t+1} + \phi \ln c_{a,t+1}$$

subject to

$$c_{m,t+1} + p_{t+1} c_{a,t+1} = p_t w_{at} (1 + r_{t+1})$$

where w_{at} = real agricultural wage, p_t = price of the agricultural good relative to the manufacturing good.

- Ag household's demand for
  - Manuf good: $c^a_{m,t+1} = p_t w_{a,t} (1 + r_{t+1}) - \phi$
  - Ag good: $c^a_{a,t+1} = \frac{\phi}{p_{t+1}}$

- Manuf household's problem is analogous
  - Manuf good: $c^m_{m,t+1} = w_{m,t}(1 + r_{t+1}) - \phi$
  - Ag good: $c^m_{a,t+1} = \frac{\phi}{p_{t+1}}$
- Equating the MP_L to the wage in agriculture gives

$$w_{a,t} = (1-\alpha) A_a K^{\alpha}_{a,t} L^{-\alpha}_{a,t}$$

In manufacturing,

$$w_{m,t} = \theta \frac{Y_{m,t}}{L_{m,t}} \left[(1-\theta) \left(\frac{K_{m,t}}{L_{m,t}} \right)^{\rho} + \theta \right]^{-1}$$

- Equivalent compensation conditions for capital become

$$q_{a,t} = \alpha A_a K^{\alpha-1}_{a,t} L^{1-\alpha}_{a,t},$$

$$q_{m,t} = (1-\theta) \frac{Y_{m,t}}{K_{m,t}} \left[(1-\theta) + \theta \left(\frac{L_{m,t}}{K_{m,t}} \right)^{\rho} \right]^{-1}$$

- Manuf household's problem is analogous
  - Manuf good: $c^m_{m,t+1} = w_{m,t}(1 + r_{t+1}) - \phi$
  - Ag good: $c^m_{a,t+1} = \frac{\phi}{p_{t+1}}$
- Equating the MP_L to the wage in agriculture gives

$$w_{a,t} = (1-\alpha)A_a K^{\alpha}_{a,t} L^{-\alpha}_{a,t}$$

In manufacturing,

$$w_{m,t} = \theta \frac{Y_{m,t}}{L_{m,t}} [(1-\theta)(\frac{K_{m,t}}{L_{m,t}})^{\rho} + \theta]^{-1}$$

- Equivalent compensation conditions for capital become

$$q_{a,t} = \alpha A_a K^{\alpha-1}_{a,t} L^{1-\alpha}_{a,t},$$

$$q_{m,t} = (1-\theta)\frac{Y_{m,t}}{K_{m,t}} [(1-\theta) + \theta(\frac{L_{m,t}}{K_{m,t}})^{\rho}]^{-1}$$

- Allocation of factor inputs determined by

$$p_t(1-\alpha)A_a K_{a,t}^{\alpha} L_{a,t}^{-\alpha} = \theta \frac{Y_{m,t}}{L_{m,t}}[(1-\theta)(\frac{K_{m,t}}{L_{m,t}})^{\rho} + \theta]^{-1}$$

$$p_t \alpha A_a K_{a,t}^{\alpha-1} L_{a,t}^{1-\alpha} = (1-\theta)\frac{Y_{m,t}}{K_{m,t}}[(1-\theta) + \theta(\frac{L_{m,t}}{K_{m,t}})^{\rho}]^{-1}$$

- This allocation determine sectoral output, which implies

$$\frac{K_{a,t}}{L_{a,t}} = \frac{\alpha\theta}{(1-\alpha)(1-\theta)}\left(\frac{K_{m,t}}{L_{m,t}}\right)^{1-\rho}$$

- $\frac{\alpha\theta}{(1-\alpha)(1-\theta)} < 1$ iff $\alpha + \theta < 1$ (reasonable)

- Aggregate market clearing is given by

$$\begin{aligned} K_{t+1} &= L_{a,t}s_{a,t} + L_{m,t}s_{m,t} \\ &= L_{a,t}p_t w_{a,t} + L_{m,t}w_{m,t} \end{aligned}$$

    - This yields

$$K_{t+1} = \phi(1-\alpha) + \theta A_m\left[(1-\theta)K_{m,t}^{\rho} + \theta L_{m,t}^{\rho}\right]^{\frac{1}{\rho}-1} L_{m,t}^{\rho}$$

    - Increase in labor income, $w_{at}L_{at}$ in agriculture is exactly offset by a decrease in the relative price, p_t. Investment in capital originating in agriculture is independent of income (stage of development in the economy)

- We now simulate the model for reasonable parameter values.

Table: Calibration Values

Table 2: Calibration Values

	Definition	model 1	model 2	model 3
	Utility function	Semilinear	Semilinear	Stone-Gary
	TFP growth	no	yes	yes
	taxation	no	tax manuf	tax both
A_a	initial TFP in agriculture	2	2	2
A_m	initial TFP in manufacturing	1	1	1
g_a	raw growth rate of agri TFP (20 years)	-	1.2	1.2
g_m	raw growth rate of manuf TFP (20 years)	-	1.05	1.05
α	income share of K in agri	0.33	0.33	0.33
θ	income share of L in manuf	0.75	0.75	0.75
ρ	power parameter in CES in manuf	0.6	0.6	0.6
ϕ	parameter in consumption func	5.0	5.0	0.5
ψ_a	power param of G in agri prod.	-	0.1	0.1
ψ_m	power param of G in manuf prod.	-	0.1	0.1
δ_a	gov funding share for agri	-	0.2	0.2
τ_a	tax rate of agricultural income	-	-	0.3
τ_m	tax rate of manufacturing income	-	0.3	0.3
μ_a	subsistent consumption of agri goods	-	0.3	0.3
μ_m	subsistent consumption of manu goods	-	0.3	0.3

Experiment

- Vary ρ between -0.5 *to* $.7$
- (K and L) Capital and agriculture and manufacturing is accumulated. $L_m \uparrow$ over time, $L_a \downarrow$ over time.
- (Employment Shares) As $\rho \uparrow$, employment in agriculture declines, and increases in manufacturing. However, steady state shares are different for different values of ρ (manufacturing employment higher in steady state with higher value of ρ because capital and labor are now more substitutable).
- (Sectoral GDP Shares) Over time, agriculture accounts for a smaller share of GDP, and manufacturing accounts for a larger.
- ($\frac{K}{Y}$ ratios) The model can't replicate the $\frac{K}{Y}$ ratios as these are rising in both sectors.

Model Simulation

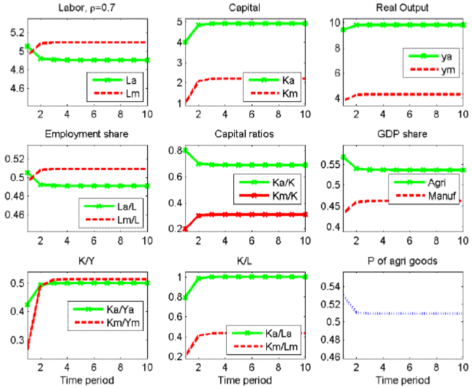

Figure 5: (Model 1): a benchmark with no infrastructure policy, varying ρ

Benchmark Model with Sectoral Infrastructure Policies

- Consider the effects of a policy that

1. invests in infrastructure projects in both sectors
2. raises taxes from labor income in the manufacturing sector only

- Following Barro (1990),

$$\begin{aligned} Y_{a,t} &= A_a G_{a,t}^{\psi_a} K_{a,t}^{\alpha} L_{a,t}^{1-\alpha} \\ Y_{m,t} &= A_m G_{m,t}^{\psi_m} [(1-\theta) K_{m,t}^{\rho} + \theta L_{m,t}^{\rho}]^{\frac{1}{\rho}} \end{aligned}$$

where $G_{a,t}^{\psi_a}$ and $G_{m,t}^{\psi_m}$ are the stock of infrastructure in the two sectors.

- Assume 100% depreciation.

Benchmark Model with Sectoral Infrastructure Policies

- Consider the effects of a policy that

1. invests in infrastructure projects in both sectors
2. raises taxes from labor income in the manufacturing sector only

- Following Barro (1990),

$$
\begin{aligned}
Y_{a,t} &= A_a G_{a,t}^{\psi_a} K_{a,t}^{\alpha} L_{a,t}^{1-\alpha} \\
Y_{m,t} &= A_m G_{m,t}^{\psi_m} \left[(1-\theta) K_{m,t}^{\rho} + \theta L_{m,t}^{\rho}\right]^{\frac{1}{\rho}}
\end{aligned}
$$

where $G_{a,t}^{\psi_a}$ and $G_{m,t}^{\psi_m}$ are the stock of infrastructure in the two sectors.

- Assume 100% depreciation.

- Investment in infrastructure is financed by a tax on labor income in the manufacturing sector only

$$G_{a,t}^{\psi_a} + G_{m,t}^{\psi_m} = \tau w_{m,t} L_{m,t}$$

- Sectoral GBC's given by

$$\begin{aligned} G_{a,t} &= \delta_a \tau w_{m,t} L_{m,t} \\ G_{m,t} &= (1-\delta_a) \tau w_{m,t} L_{m,t} \end{aligned}$$

- Factor price equalization implies

$$\begin{aligned} p_t (1-\alpha) A_a G_{a,t}^{\psi_a} K_{a,t}^{\alpha} L_{a,t}^{-\alpha} &= \theta \frac{Y_{m,t}}{L_{m,t}} [(1-\theta)(\frac{K_{m,t}}{L_{m,t}})^{\rho} + \theta]^{-1} \\ p_t \alpha A_a G_{a,t}^{\psi_a} K_{a,t}^{\alpha-1} L_{a,t}^{1-\alpha} &= (1-\theta) \frac{Y_{m,t}}{K_{m,t}} [(1-\theta) + \theta(\frac{L_{m,t}}{K_{m,t}})^{\rho}]^{-1} \end{aligned}$$

- As before, equilibrium law of motion for K is determined by aggregate savings,

$$K_{t+1} = \phi(1-\alpha) + (1-\tau)\theta A_m G_{m,t}^{\psi_m}\left[(1-\theta)K_{m,t}^{\rho} + \theta L_{m,t}^{\rho}\right]^{\frac{1}{\rho}-1} L_{m,t}^{\rho}$$

- In the simulations, we now assume productivity growth of 2% in both sectors.

Model Simulation

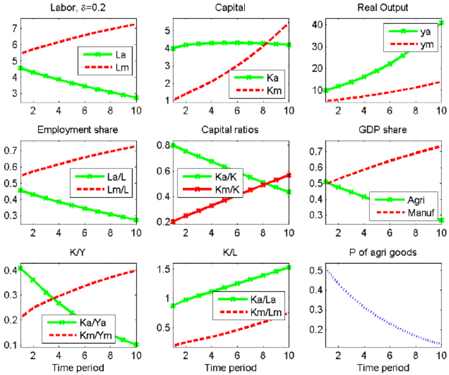

Figure 13: (Model 2): a benchmark with infrastructure policy, varying δ

Model Simulation (Contd)

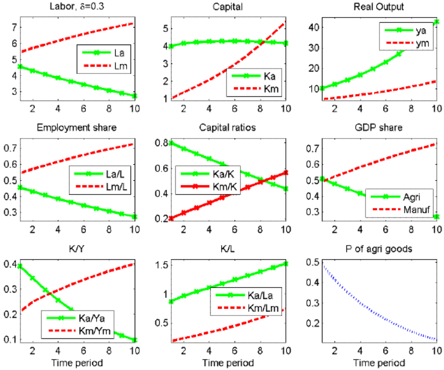

Figure 15: (Model 2): a benchmark with infrastructure policy, varying δ

Model Simulation (Contd)

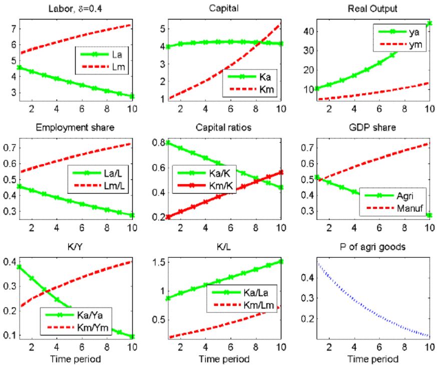

Figure 17: (Model 2): a benchmark with infrastructure policy, varying δ

Intuition

- We would expect that ag. employment and GDP rise as $\delta \uparrow$
- Expectation not borne out by the experiments
- As $\delta \uparrow \Rightarrow G_a \uparrow \Rightarrow Y_a \uparrow$. (agricultural supply shifts outwards)
- But since preferences are semi-linear, there is zero income elasticity of demand for the ag good$\Rightarrow Y_a \uparrow$ implies that $c_m^a \uparrow$.
- L_a,K_a move to the manufacturing sector.
- $L_a \downarrow, K_a \downarrow$ and $L_m \uparrow, K_m \uparrow \Longrightarrow Y_m \uparrow \Rightarrow c_m^m \uparrow$. Note that Y_a still increases because G_a has increased.
- $\frac{K}{Y}$ ratio in ag. falls, $\frac{L_a}{L} \downarrow$,$\frac{Lm}{L} \uparrow, \frac{K_a}{K} \downarrow, \frac{K_m}{K} \uparrow$.
- Zero income elasticity of demand key to results.

Stone Geary Utility with Public Infrastructure

- Utility function now given by

$$u_t = \ln(c_{m,t+1} + \mu) + \phi \ln(c_{a,t+1} - \gamma), \qquad \phi > 0$$

- Income elasticity of demand < 1 for ag. good, > 1 for manufacturing good.
- We tax both the manufacturing and agricultural sector
- Agricultural household's problem

$$\max_{c_m, c_a} \; \ln(c_{m,t+1} + \mu) + \phi \ln(c_{a,t+1} - \gamma)$$

subject to

$$c_{m,t+1} + p_{t+1} c_{a,t+1} = (1 - \tau_a) p_t w_{a,t}$$

- Ag household's demand for
  - Ag good: $c^a_{a,t+1} = \frac{\phi}{(1+\phi)p_{t+1}}[(1 - \tau_a p_{a,t} w_{a,t} + \mu) + \frac{1}{1+\phi}\gamma]$
  - Manuf good: $c^m_{m,t+1} = \frac{1}{(1+\phi)}(1 - \tau_a) p_{a,t} w_{a,t} - \frac{\phi}{1+\phi}\mu - \frac{p_{t+1}}{1+\phi}\gamma$

Stone Geary Utility with Public Infrastructure

- Utility function now given by

$$u_t = \ln(c_{m,t+1} + \mu) + \phi \ln(c_{a,t+1} - \gamma), \qquad \phi > 0$$

- Income elasticity of demand < 1 for ag. good, > 1 for manufacturing good.
- We tax both the manufacturing and agricultural sector
- Agricultural household's problem

$$\max_{c_m, c_a} \ \ln(c_{m,t+1} + \mu) + \phi \ln(c_{a,t+1} - \gamma)$$

subject to

$$c_{m,t+1} + p_{t+1} c_{a,t+1} = (1 - \tau_a) p_t w_{a,t}$$

- Ag household's demand for
  - Ag good: $c^a_{a,t+1} = \frac{\phi}{(1+\phi)p_{t+1}}[(1 - \tau_a p_{a,t} w_{a,t} + \mu) + \frac{1}{1+\phi}\gamma]$
  - Manuf good: $c^m_{m,t+1} = \frac{1}{(1+\phi)}(1 - \tau_a) p_{a,t} w_{a,t} - \frac{\phi}{1+\phi}\mu - \frac{p_{t+1}}{1+\phi}\gamma$

- Similar problem for household's in the manufacturing sector
- Manuf household's optimal consumption:
  - Ag good: $c^m_{a,t+1} = \frac{\phi}{(1+\phi)p_{t+1}}[(1 - \tau_m p_{a,t} w_{m,t} + \mu) + \frac{1}{1+\phi}\gamma]$
  - Manuf good: $c^m_{m,t+1} = \frac{1}{(1+\phi)}(1 - \tau_m)p_{a,t} w_{m,t} - \frac{\phi}{1+\phi}\mu - \frac{p_{t+1}}{1+\phi}\gamma$
- Production function, factor prices, and GBCs remain the same
- Applying the market clearing condition for the agricultural and manufacturing goods, the law of motion of K is given by

$$\begin{aligned} K_{t+1} &= L_{a,t}(1-\tau_a)p_t w_{a,t} + L_{m,t}(1-\tau_m)w_{m,t} \\ &= L(1-\tau_m)w_{m,t} \end{aligned}$$

- Similar problem for household's in the manufacturing sector
- Manuf household's optimal consumption:
  - Ag good: $c_{a,t+1}^{m} = \frac{\phi}{(1+\phi)p_{t+1}}[(1 - \tau_m p_{a,t} w_{m,t} + \mu) + \frac{1}{1+\phi}\gamma]$
  - Manuf good: $c_{m,t+1}^{m} = \frac{1}{(1+\phi)}(1 - \tau_m) p_{a,t} w_{m,t} - \frac{\phi}{1+\phi}\mu - \frac{p_{t+1}}{1+\phi}\gamma$
- Production function, factor prices, and GBCs remain the same
- Applying the market clearing condition for the agricultural and manufacturing goods, the law of motion of K is given by

$$\begin{aligned} K_{t+1} &= L_{a,t}(1 - \tau_a) p_t w_{a,t} + L_{m,t}(1 - \tau_m) w_{m,t} \\ &= L(1 - \tau_m) w_{m,t} \end{aligned}$$

Model Simulation

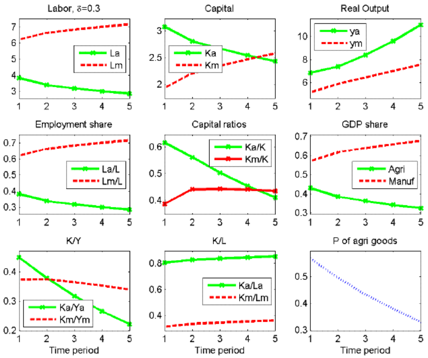

Figure 27: (Model 3): stone-geary with infrastructure policy, varying δ

Intuition

- As $\delta \uparrow \Rightarrow G_a \uparrow \Rightarrow Y_a \uparrow$. (agricultural supply shifts outwards)
- $c_a \uparrow$ less than the increase in Y_a
- L_a, K_a move to the manufacturing sector.
- $L_a \downarrow, K_a \downarrow$ and $L_m \uparrow, K_m \uparrow \Longrightarrow Y_m \uparrow$. Note that Y_a still increases because G_a has increased.
- $\frac{K}{Y}$ ratio in ag. falls, $\frac{L_a}{L} \downarrow$,$\frac{Lm}{L} \uparrow$, $\frac{K_a}{K} \downarrow$, $\frac{K_m}{K} \uparrow$.
- Positive (but < 1) income elasticity of demand of the agricultural good implies gradient of structural transformation less steep than semi-linear case.

Conclusion and Future Work

- Provide a tractable framework to think about structural transformation in the Indian context
- Model is not able to match changing $\frac{K}{Y}$ ratios unless productive infrastructure capital is introduced.
- Other policies and distortions can be studied in this framework (subsidies to agriculture, labor market distortions)