An Estimated DSGE Model of the Indian Economy

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NIPFP Research Agenda

- Build a Model of the Indian Economy that is 'fit for purpose'
  - Micro-founded and more immune from the Lucas Critique
  - Incorporates important features of Emerging Economies and the Indian Economy in particular
  - From closed to open
  - Empirically based to enable quantitative analysis.
  - Hence **DSGE Model estimated by Bayesian-Maximum-Likelihood Methods** with calibrated values or estimates from microeconometric studies as priors
- Compare the welfare outcome of Taylor-type simple rules rules with existing policy

The Work So Far

- This paper: estimates a closed economy model with financial and labour market frictions and formal/informal sectors
- Model fitted to data on GDP, CPI inflation, Investment and a Nominal Interest Rate
- Papers on the **Informal Economy**: a survey – [Batini *et al.*(2010b)]– and a study of monetary policy and the informal economy – [Batini *et al.*(2010c)]
- A paper on the **Open Economy**: [Batini *et al.*(2010a)], drawing on [Batini *et al.*(2007)] and [Batini *et al.*(2009)]
- Related paper: [Anand *et al.*(2010)]

Modelling Methodology

- Build up the model in stages
- Model 1: A standard NK model fitted to both Indian and US Data
- Model 2: Add financial frictions
- Model 3: Add informal sector with labour market frictions
- Questions:
  - What is different about the Indian (compared with the US) Economy ?
  - Do the new features improve the fit of the model?
  - Does Bayesian ML Estimation in Model 3 provide information about the size of the informal sector?

The Models: From RBC to NK

- An RBC Core
  - Household make an intertemporal utility-maximizing choice of consumption and labour supply over time subject to a budget constraint
  - Firms produce output according to a production technology and choose labour and capital inputs to minimize cost
  - Labour, output and financial markets clear
  - Add investment adjustment costs
- Add monopolistic competition in retail market and price stickiness
- Add an interest rate Taylor rule with persistence
- Arrive at the standard NK Model

A Calvo-Type Interest Rate Taylor Rule

- Following [Levine *et al.*(2007)] and [Gabriel *et al.*(2009)], we model monetary policy in a very general way by formulating a Calvo-type forward-backward interest rate rule:

$$
\begin{aligned}
\log\left(\frac{1+R_{n,t}}{1+R_n}\right) &= \rho\log\left(\frac{1+R_{n,t-1}}{1+R_n}\right)+\theta\log\frac{\Theta_t}{\Theta}+\phi\log\frac{\Phi_t}{\Phi}\\
&+ \epsilon_{MPS,t}
\end{aligned}
$$

  where $\epsilon_{MPS,t}$ is a monetary policy shock and

$$
\begin{aligned}
\varphi E_t[\log\Theta_{t+1}] &= \log\Theta_t-(1-\varphi)\log(\Pi_t)\\
\log\Phi_t &= \log\Pi_t+\tau\log\Phi_{t-1}
\end{aligned}
$$

- Interpret as a feedback from expected inflation with mean forecast horizon $(1-\varphi)\sum_{h=1}^{\infty}h\varphi^h=\varphi/(1-\varphi)$
- Similarly, τ can be interpreted as the degree of backward-lookingness of the monetary authority

Results for NK Model: US

	Standard Deviation			
Model	Output	Inflation	Interest rate	Investment
Data	2.06	0.48	0.92	8.47
NK Model	2.87	0.38	0.64	8.51
	Cross-correlation with Output			
Data	1.00	-0.02	0.14	0.56
NK Model	1.00	0.38	0.40	0.73
	Autocorrelations (Order=1)			
Data	0.91	0.85	0.94	0.95
NK Model	0.96	0.70	0.91	0.96

Table: Selected Second Moments - US Economy (80:1-06:4)

Results for NK Model: India

Model	Output	Inflation	Interest rate	Investment
Standard Deviation				
Data	1.22	0.97	1.93	5.30
NK Model	2.02	1.04	1.41	7.59
Cross-correlation with Output				
Data	1.00	0.11	0.32	0.42
NK Model 1	1.00	0.27	0.05	0.50
Autocorrelations (Order=1)				
Data	0.44	0.13	0.83	0.88
NK Model	0.74	0.05	0.71	0.93

Table: Selected Second Moments - Indian Economy (96:1-08:4)

Financial Frictions: The Financial Accelerator

- Financial Accelerator facing firms: risk premium $\uparrow$ with leverage

$$\begin{aligned}
\text{Balance Sheet} : \underbrace{Q_{t-1}K_t}_{\text{Capital}} &= \underbrace{N_t}_{\text{Equity}} + \underbrace{B_t}_{\text{External Finance}} \\
\text{Leverage} : \frac{B_t}{N_t} &= \frac{Q_{t-1}K_t - N_t}{N_t} \\
\text{Risk Premium} &= \Theta_t = k\left(\frac{Q_{t-1}K_t}{N_t}\right)^{\chi} \underbrace{RPS_t}_{\text{Exog Shock}}
\end{aligned}$$

- Suppose Θ is observed (see [Haugen(2005)].) Let $n_k \equiv \frac{N}{QK} = \frac{1}{1+\ell}$ where ℓ is leverage. Then we can set the scaling parameter k as $k = \Theta n_k^{\chi}$

Financial Frictions: Rule of Thumb Consumers

- A proportion λ of households are credit-constrained

$$C_t = \underbrace{\lambda C_{1,t}}_{\text{Non-Ricardian}} + \underbrace{(1-\lambda) C_{2,t}}_{\text{Ricardian}}$$

$$C_{1,t} = \frac{W_t h_t}{P_t} = \text{Wage Income}$$

- $C_{2,t}$ given by the standard Euler-consumption equation

The Informal Sector

According to [Sen and Kolli(2009)] and [Rada(2009)] the broad characteristics of the informal sector are

- Individual or household enterprises
- No complete accounts
- Produces some marketable goods and services
- Not registered
- 90% workers are in the I-sector producing 50% of GDP

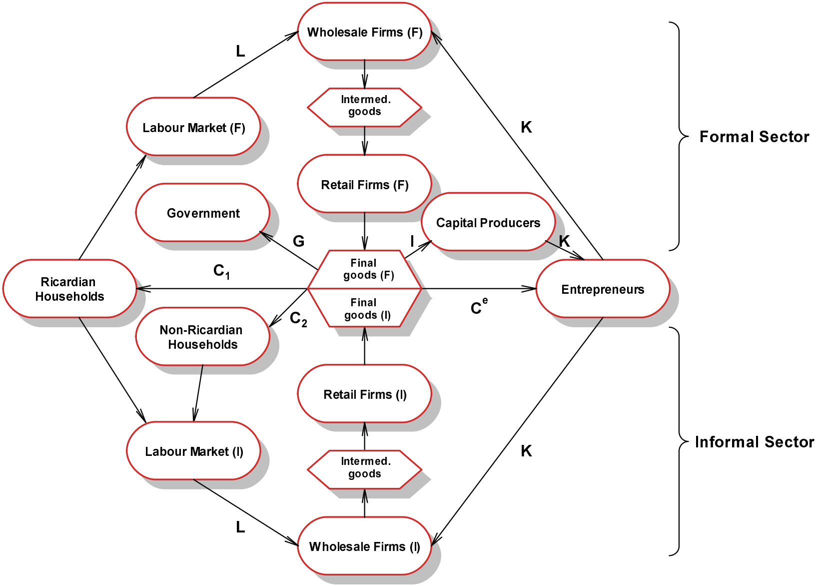
Table: **Characterizing Informality in the Model**

	Lab. Market	Credit Market	Taxation	Lab. Share
F Sector	frictions	lower frictions	taxed	lower
I Sector	no frictions	higher frictions	untaxed	higher

The Model: Overview

- We consider a two-sector "Formal" (F) and "Informal" (I) economy, producing different range of differentiated goods with different technologies which sell at different aggregate retail prices, $P_{F,t}$ and $P_{I,t}$
- Distortionary (employment) taxes in the F-sector
- Real wage norm in the F-sector
- Capital and government services part of the F-sector
- Different FAs in the two sectors; higher steady-state risk premium in the I-sector
- A proportion $n_{F,t}$ of Ricardian households work in the F-sector. All non-Ricardian households work in the I-sector

The Model: Structure



The Model: Some Details

- The real wage in the F-sector given by a real wage norm RW_t that is a mark-up rw on the real wage in the informal sector:
$$\frac{W_{F,t}}{P_t} = RW_t = (1 + rw)\frac{W_{I,t}}{P_t}\,;\;\; rw > 0$$
- On the demand side of the model we construct Dixit-Stiglitz consumption and price aggregates
$$\begin{aligned} C_t &= \left[\mathrm{w}^{\frac{1}{\mu}} C_{F,t}^{\frac{\mu-1}{\mu}} + (1-\mathrm{w})^{\frac{1}{\mu}} C_{I,t}^{\frac{\mu-1}{\mu}}\right]^{\frac{\mu}{\mu-1}} \\ P_t &= \left[\mathrm{w}(P_{F,t})^{1-\mu} + (1-\mathrm{w})(P_{I,t})^{1-\mu}\right]^{\frac{1}{1-\mu}} \end{aligned}$$
where μ is the elasticity of substitution between I and F goods, and w is a preference "parameter". Then standard results are:
$$C_{F,t} = \mathrm{w}\left(\frac{P_{F,t}}{P_t}\right)^{-\mu} C_t\,;\;\; C_{I,t} = (1-\mathrm{w})\left(\frac{P_{I,t}}{P_t}\right)^{-\mu} C_t$$

Calibration and Priors

- We calibrate the model to fit two variables for which we have information: relative nos of workers (rel_n) and relative GDP contributions ($rel_Y \equiv \frac{P_F Y_F}{P_I Y_I}$). Let n_F be the proportion of Ricardian households in the F-sector. From the model we have:

$$rel_n = \frac{(1-\lambda)n_F}{(1-\lambda)(1-n_F)+\lambda} \tag{1}$$

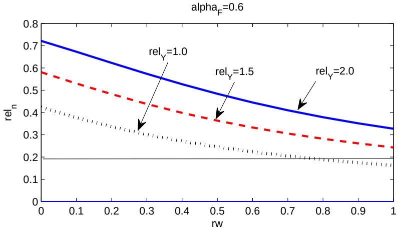
$$rel_Y = \frac{P_F Y_F}{P_I Y_I} = \frac{\mathrm{w}\left(\frac{P_F}{P}\right)^{1-\mu}\bar{C}_t + \left(\frac{P_F}{P}\right)(\bar{I}_t + \bar{G}_t)}{(1-\mathrm{w})\left(\frac{P_I}{P}\right)^{1-\mu}\bar{C}_t} \tag{2}$$

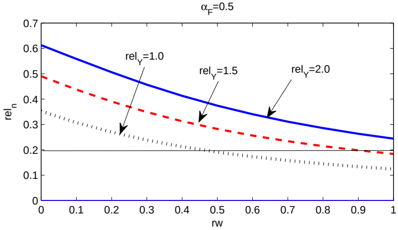
- From (2) we can solve for w to obtain

$$\mathrm{w} = \frac{rel_Y\left(\frac{P_I}{P}\right)^{1-\mu}\bar{C}_t - \left(\frac{P_F}{P}\right)(\bar{I}_t + \bar{G}_t)}{\left(\frac{P_F}{P}\right)^{1-\mu}\bar{C}_t + rel_Y\left(\frac{P_I}{P}\right)^{1-\mu}\bar{C}_t}$$

Calibration of rw and α_I to fit rel_n and rel_Y.

Labour shares $\alpha_I = 0.8 > \alpha_F$.





Bayesian Estimation

Parameter	Notation	Prior distribution			Posterior distribution♢
		Density	Mean	S.D/df	
Calvo prices (F)	ξ_F	Beta	0.75	0.15	0.75 [0.57:0.95]
Calvo prices (I)	ξ_I	Beta	0.75	0.15	0.30 [0.15:0.43]
Labour share (F)	α_F	Beta	0.60	0.10	0.68 [0.60:0.76]
Labour share (I)	α_I	Beta	0.80	0.10	0.74 [0.61:0.87]
Preference parameter	ϱ	Beta	0.50	0.20	0.22 [0.10:0.31]
Degree of Labour market frictions	r_W	Beta	0.75	0.10	0.78 [0.64:0.92]
GDP Contribution	$rel_Y \equiv \frac{P_F Y_F}{P_I Y_I}$	Normal	1.00	0.50	1.15 [0.67:1.64]
Employment Ratio	$reln$	n.a.	0.20	n.a.	0.28 [0.22:0.35]
External finance premium elasticity (F)	χ_F	Inv. gamma	0.05	4.00	0.05 [0.01:0.10]
External finance premium elasticity (I)	χ_I	Inv. gamma	0.05	4.00	0.03 [0.01:0.05]
Inverse of Leverage (F)	n_F	Beta	0.5	0.15	0.53 [0.29:0.75]
Inverse of Leverage (I)	n_I	Beta	0.5	0.15	0.61 [0.39:0.81]
Proportion of RT consumers	λ	Beta	0.40	0.10	0.30 [0.19:0.43]
Interest rate rule					
Interest rate smoothing	ρ	Beta	0.75	0.10	0.80 [0.68:0.93]
Feedback from expected inflation	θ	Normal	2.00	1.00	2.40 [1.09:3.53]
Feedback from past inflation	ϕ	Normal	2.00	1.00	1.00 [0.15:1.76]
Degree of forward-lookingness	φ	Beta	0.50	0.20	0.50 [0.21:0.78]
Degree of backward-lookingness	τ	Beta	0.50	0.20	0.50 [0.15:0.88]

♢ We report posterior means and 95% probability intervals (in parentheses) except for *reln* which has an unknown distribution

Bayesian Estimation: Summary

- Model Comparison: Decisive Support for FF and an I-Sector

Model	LL	Probability
NK	-358.95	0.0005
NK+FF	-356.28	0.0067
NK+FF+I-Sector	-350.73	0.9928

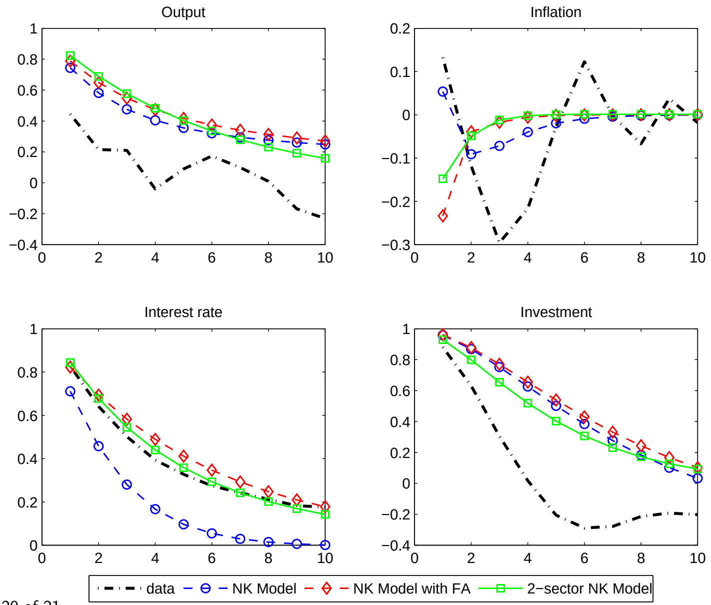
- Average Price Contract lengths : 4.02 quarters (F-sector) and 1.43 (I-sector). Suggests I-sector prices are more flexible
- I-sector less leveraged, but with a weaker FA
- Stronger forward-looking response to inflation in the Calvo interest rate rule; but data is not informative on average lags
- Data is informative about the size of the informal sector.

Model Validation I: Selected Second Moments

	Standard Deviation			
Model	Output	Inflation	Interest rate	Investment
Data	1.22	0.97	1.93	5.30
NK Model	2.02	1.04	1.41	7.59
NK Model with FA	2.42	1.02	1.76	8.37
2-sector NK Model	**1.59**	**0.97**	**1.84**	**7.80**
	Cross-correlation with Output			
Data	1.00	0.11	0.32	0.42
NK Model 1	1.00	0.27	0.05	0.50
NK Model with FA	1.00	0.14	0.44	0.46
2-sector NK Model	**1.00**	**0.18**	**0.31**	**0.29**
	Autocorrelations (Order=1)			
Data	0.44	0.13	0.83	0.88
NK Model	0.74	0.05	0.71	0.96
NK Model with FA	0.79	-0.23	0.82	0.96
2-sector NK Model	**0.70**	**-0.11**	**0.88**	**0.93**

Table: Selected Second Moments - Indian Economy (96:1-08:4)

Model Validation II: Autocorrelations



Work-in-progress

- **Which Steady-State?** We have assumed a non-growth zero-inflation steady state. We should be assuming a balanced-growth non-zero-inflation steady state with a stochastic trend as in [Schmitt-Grohe and Uribe(2008)]
- Trending issues? Trend agnostic one-step estimation (Ferroni, 2010)
- Endogenous Calvo Price Contracts that decrease in duration as steady-state inflation increases
- Add openness and do the policy analysis to complete the project
    - Model_SOE 1: A standard open-economy NK model
    - Model_SOE 2: An open-economy NK model with financial frictions
    - Model_SOE 3: An open-economy NK model with financial frictions and incomplete exchange rate pass-through.

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