International Finance
Lecture IV: Business Cycle in EMs
Productivity Shocks versus Financial Frictions

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Outline

- Readings: USG Chapter 5. Sections 5.1-5.6 (no 5.7)
- From Advanced Economies (AE) to EMDEs
  - We saw that a calibrated version of the SOE-RBC model captures well key empirical regularities of a developed SOE like Canada (chapter 4).
  - **Question:** Can the OE-RBC model also explain business cycles in EMDEs?
  - Two important differences between business cycles in AE and EMDEs:
    1. EMDEs are twice as volatile as AE (fact 8).
    2. In AEs consumption is less volatile than output, whereas in EMDEs consumption is at least as volatile as output (fact 9).
  - We will look at each of these two differences more closely.

A Quick Reminder Of The OE-RBC Model

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, h_t),$$

subject to

$$d_t + A_t F(k_t, h_t) = (1 + r_{t-1}) d_{t-1} + c_t + k_{t+1} - (1 - \delta) k_t + \Phi(k_{t+1} - k_t).$$

and a no-Ponzi-game constraint.

The driving force is the productivity shocks

$$\ln A_{t+1} = \rho \ln A_t + \tilde{\eta} \epsilon_{t+1},$$

A debt-elastic country interest rate to induce stationarity

$$r_t = r^* + p(\tilde{d}_t).$$

EMDEs are twice as volatile as AE (fact 8)

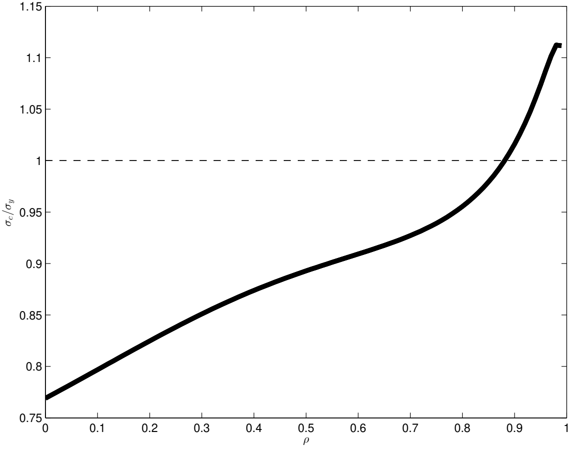
- In principle, the SOE-RBC model can easily handle this difference.
- Simply jack up (by a factor of around 2) the standard deviation of the productivity shock. After all, in the SOE-RBC model, σ_a was calibrated to match the standard deviation of Canadian GDP.
- Since not only output but also all of the components of aggregate demand (consumption, investment, net exports) are more volatile in EMDEs than in AEs, increasing σ_a would help along more than one dimension.
- But in models with just one exogenous shocks, up to first order, the ratio of two standard deviations is independent of the standard deviation of the exogenous shocks

Relative volatility of consumption and output (fact 9)

- **Problem:** Not all volatilities increase in the same proportion as we move from AE to EMDE.
- In AEs consumption is less volatile than output, whereas in EMDEs consumption is at least as volatile as output
- In principle, the OE-RBC model can also handle this fact.
- Consider varying the persistence of the productivity shock, governed by the parameter ρ.

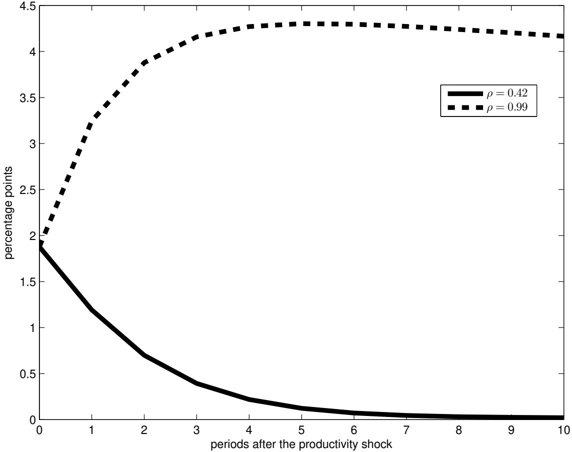
The Open-Economy RBC Model

The Relative Volatility of Consumption as a Function of the Persistence of the Stationary Technology Shock



The SOE-RBC Model:

Impulse Response of Output to a One-Percent Increase in Productivity for High and Low Persistence Of the Stationary Productivity Shock



Intuition:

- With highly persistent productivity shocks, the impulse response of y_t is increasing over time for a number of periods.
- This makes it possible that at $t = 0$, permanent income is higher than current income.
- Since consumption depends on permanent income, consumption increases by more than current income.
- With less persistent productivity shocks, the impulse response of y_t is decreasing over time. This means that future output is expected to be lower
- Since consumption depends on permanent income, consumption increases by less than current income.
- With high persistence the impact response of consumption exceeds that of income generating excess volatility of consumption

Intuition:

- What drives the different shapes of income?
- The behavior of investment is key
- If the serial correlation of the technology shock is small, investment does not react much to increases in productivity. Thus the behavior of income follow that of productivity
- If shocks to productivity are persistent, firms will increase the stock of physical capital to take advantage of the fact that productivity will be high for many periods.
- But with adjustment costs, increasing capital takes time.
- The gradual build-up of the capital stock dominates the gradual decline of productivity to its steady state, which translates into an increasing path for output (see Chapter 3).
- So, the key is the reaction of investment. Capital accumulation is crucial for the RBC model to capture the excess volatility of consumption that we observe in EMDEs

Intuition:

- Recap:
  - When ρ is low, investment does not react much to a technology shock (because the shock is expected to die out quickly) and output moves closely with technology
  - Consumption increases less than output
  - If ρ is high, investment goes up more and output continues to increase for a while even when technology goes back to SS.
  - Consumption increases more than output
- **Problem:** Recall that in the calibration strategy of chaper 4, ρ was picked to match the observed serial correlation of output with the one predicted by the OE-RBC model.
- Thus, there is a tradeoff between using ρ to match the excess volatility of consumption and using it to match the serial correlation of output.

The SOE-RBC Model with Nonstationary Technology Shocks

- Aguiar and Gopinath (2007) propose solving this problem by adding a second productivity shock.
- The second productivity shock is nonstationary as in the closed-economy RBC model of King, Plosser, and Rebelo (1988).
- So, they have one stationary shock and one non-stationary shock
- The analysis of Chapter 2 suggests that even in the context of an endowment economy, nonstationary endowment shocks have the potential to induce excess volatility of consumption.

The SOE-RBC Model With Nonstationary Technology Shocks: Consumption

The HH problem:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t^{\gamma}(1-h_t)^{1-\gamma}]^{1-\sigma} - 1}{1-\sigma}$$

subject to the standard NPG $\lim_{j\to\infty} E_t \frac{D_{t+j+1}}{\Pi_{s=0}^{j}(1+r_{t+s})} \leq 0$ and

$$\frac{D_{t+1}}{1+r_t} + Y_t = D_t + C_t + K_{t+1} - (1-\delta)K_t + \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - g\right)^2 K_t,$$

- Most variables and parameters as before.
- We now have a Cobb-Douglas period utility index instead of GHH
- Debt takes the form of one-period discount bonds. The HH receives $\frac{D_{t+1}}{(1+r_t)}$ units of good in period t and needs to repay D_{t+1} in period $t+1$. (for the HH, there is no difference between this formulation and the one introduced before, to see this set $D'_t = D_t/(1+r_{t-1})$.
- Also: β, and δ are between 0 and 1 and γ, σ, ϕ, and g (g is the gross growth rate of X in a non-stochastic equilibrium path; X will be defined next page) are positive.

The SOE-RBC Model With Nonstationary Technology Shocks: Production and interest rate

Production

$$Y_t = a_t K_t^{\alpha} (X_t h_t)^{1-\alpha}$$

With $\alpha \in (0, 1)$. There are **two** exogenous stochastic productivity shocks: a_t and X_t

The country interest rate

$$r_t = r^* + \psi \left[e^{\tilde{D}_{t+1}/X_t - \overline{d}} - 1 \right],$$

Where r^*, ψ, and $\bar{d}$ are parameters and $\tilde{D}_t$ is the cross-sectional level of external debt per capita. As all HHs are identical, in equilibrium: $\tilde{D}_{t+1} = D_t$.

Laws of Motion of Productivity Shocks

- Main difference with respect to what we did so far are the two productivity shocks. One stationary and one non-stationary.
- We assume that a_t and X_t are mutually independent random variables

$$\ln a_t = \rho_a \ln a_{t-1} + \sigma_a \epsilon_t^a$$

and

$$\ln(g_t/g) = \rho_g \ln(g_{t-1}/g) + \sigma_g \epsilon_t^g,$$

- Where $g_t \equiv \frac{X_t}{X_{t-1}}$ is the gross growth rate of X_t.
- The parameter $g > 0$ denotes the gross growth rate of productivity in a non-stochastic equilibrium path
- We also assume that $\rho_a \in (-1, 1)$, $\rho_g \in (-1, 1)$, $\sigma_a > 0$, and $\sigma_g > 0$; ϵ_t^g and ϵ_t^a are exogenous independent white noise i.i.d process distributed $N(0, 1)$

Putting things together

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \frac{[C_t^{\gamma}(1-h_t)^{1-\gamma}]^{1-\sigma}-1}{1-\sigma}$$

subject to

$$\frac{D_{t+1}}{1+r_t} + Y_t = D_t + C_t + K_{t+1} - (1-\delta)K_t + \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - g\right)^2 K_t,$$

$$Y_t = a_t K_t^{\alpha}(X_t h_t)^{1-\alpha}$$

$$\lim_{j\to\infty} E_t \frac{D_{t+j+1}}{\Pi_{s=0}^{j}(1+r_{t+s})} \leq 0,$$

The country interest rate

$$r_t = r^* + \psi\left[e^{\tilde{D}_{t+1}/X_t - \overline{d}} - 1\right],$$

In equilibrium, $\tilde{D}_{t+1} = D_t$.

FOC for the HHs problem

Set up the Lagrangean and get:

$$\frac{1-\gamma}{\gamma}\frac{C_t}{1-h_t} = (1-\alpha)a_t X_t \left(\frac{K_t}{X_t h_t}\right)^{\alpha}$$

$$\gamma C_t^{\gamma(1-\sigma)-1}(1-h_t)^{(1-\gamma)(1-\sigma)} = \Lambda_t$$

$$\gamma C_t^{\gamma(1-\sigma)-1}(1-h_t)^{(1-\gamma)(1-\sigma)} = \Lambda_t$$

$$\Lambda_t = \beta(1+r_t)E_t\Lambda_{t+1}$$

$$\Lambda_t\left(1+\phi\left(\frac{K_{t+1}}{K_t}-g\right)\right) = \beta E_t\Lambda_{t+1}\left[1-\delta+\alpha a_{t+1}\left(\frac{K_{t+1}}{X_{t+1}h_{t+1}}\right)^{\alpha-1}+\phi\frac{K_{t+2}}{K_{t+1}}\left(\frac{K_{t+2}}{K_{t+1}-g}\right)-\frac{\phi}{2}\left(\frac{K_{t+2}}{K_{t+1}-g}\right)^2\right]$$

Λ_t is the Lagrange multiplier associated with the sequential budget constraint of the household

Laws of Motion of Productivity Shocks

- The productivity factor X_t is non-stationary because it has long-run growth at an average g and a random walk component.
- Hence, innovations in g_t have a permanent effect on the level of X
- If $Y_t = A_t F(K_t, h_t)$, then A_t is total factor productivity.
- Then, we can define total factor productivity as $TFP_t \equiv \frac{Y_t}{K_t^{\alpha} h_t^{1-\alpha}}$ and get

$$TFP_t = a_t X_t^{1-\alpha}$$

- As a_t is a stationary r.v. independent of X_t, TFP is as non-stationary as X_t and, in eqm, this is tramsitted to all all other variables in the model (Cons. Inv., Capital, Debt, the marginal utility of wealth)
- As none of these endogenous variables has a deterministic Steady State, it is impossible to linearize the model around such deterministic SS.
- However, all these variable exhibit the same trend (they all share the same stochastic trend X, they are cointegrated) and we can transform them in a way that makes the transformed variables stationary

Laws of Motion of Productivity Shocks

- Stationary transformation.
- Just divide by X_{t-1} and get $c_t = C_t/X_{t-1}$, $k_t = K_t/X_{t-1}$, $d_t = D_t/X_{t-1}$
- We can use these transformed variables to transform the problem and the FOC in a system of six stochastic difference equations in the endogenous variables c_t, d_{t+1}, h_t, λ_t, and r_t. (see page 145 of the book for the full system)
- This system, together with the law of motions of g_t and a_t can be used to approximate the equilibrium dynamics as it has the following properties:
  1. It has a deterministic SS which is independent of initial condition
  2. The rational expectations dynamics of all variables is mean reverting. This implies stationarity
- Recall that $C_t = c_t X_{t-1}$. Given that c_t is stationary, C_t has the same RW component of X_t (the same applies to other transformed variables)
- The presence of a common stochastic trend, implies that the share of consumption, investment, and capital in GDP are all stationary (the levels are **cointegrated** with each other and with GDP).
- This property is known as the **balanced-growth property**

Calibration

- AG econometrically estimate the parameters defining the law of motion σ_g, σ_a,ρ_g, and ρ_a, steady state growth g, and the parameter that governs adjustment costs ϕ using quarterly data from Mexico (1980:Q1 to 2003:Q1).
- They use 11 moments (one first moment, the average growth rate of GDP, and 10 second moments): $\sigma(y)$, $\sigma(\Delta y)$, $\sigma(c)/\sigma(y)$, $\sigma(i)/\sigma(y)$, $\sigma(nx)/\sigma(y)$, $\rho(y)$, $\rho(\Delta y)$, $\rho(y, nx)$, $\rho(y, c)$, $\rho(y, i)$, and g
- The estimation consists of picking values for the six parameters to be estimated to match the 11 moments listed above (see also Table next page).
- They use GMM because the number of parameters to be estimated (six) is smaller than the number of moments matched.

Calibrated Parameters

β	γ	ψ	α	σ	δ	$\overline{d}$
0.98	0.36	$\boxed{0.001}$	0.32	2	0.05	0.1

Estimated Parameters (GMM)

σ_g	σ_a	ρ_g	ρ_a	g	ϕ
0.0213	0.0053	0.00	0.95	1.0066	1.37

Model Fit

Statistic	Data	Model
$\sigma(y)$	2.40	2.13
$\sigma(\Delta y)$	1.52	1.42
$\sigma(c)/\sigma(y)$	1.26	1.10
$\sigma(i)/\sigma(y)$	4.15	3.83
$\sigma(nx)/\sigma(y)$	0.80	0.95
$\rho(y)$	0.83	0.82
$\rho(\Delta y)$	0.27	0.18
$\rho(y, nx)$	-0.75	-0.50
$\rho(y, c)$	0.82	0.91
$\rho(y, i)$	0.91	0.80

Note. y denotes HP-filtered log output and Δy denotes growth rate of output. Same for c and i; nx denotes the HP-filtered trade balance.

The model matches the fact that $\sigma(c)/\sigma(y) > 1$. The presence of the non-stationary productivity shock plays a key role in this. Note that in the Canadian data $\rho = 0.6$

The Implied Importance of Nonstationary Productivity Shocks

Let $TFP_t \equiv a_t X_t^{1-\alpha}$ be total factor productivity, and $X_t^{1-\alpha}$ its nonstationary component, which is orthogonal to a_t.

$$\Delta \ln TFP_t = \Delta \ln(a_t) + (1-\alpha)\Delta \ln(X_t)$$

recalling that $g_t = \frac{X_t}{X_{t-1}} = \Delta \ln(X_t)$

$$\Delta \ln TFP_t = \Delta \ln a_t + (1-\alpha) g_t$$

- Note that the variance of $\Delta \ln a_t$ is $2\sigma_a^2/(1+\rho_a)$ and the variance of g_t is $\sigma_g^2/(1-\rho_g^2)$
- Given that the two shocks are orthogonal:

$$var(TFP) = var(\Delta \ln a_t) + (1-\alpha)^2 var(g_t) \tag{1}$$

- We can thus decompose the $var(TFP)$ and see what share of this variance is explained by g_t

In case you forgot

- Why is the variance of $\Delta \ln a_t$ is $2\sigma_a^2/(1+\rho_a)$ and the variance of g_t is $\sigma_g^2/(1-\rho_g^2)$?
- Recall that if $y_t = \rho y_{t-1} + e$ and $\rho < 1$, we have that $V(y) = \frac{\sigma_e^2}{1-\rho^2}$
- So, $V(g_t) = \sigma_g^2/(1-\rho_g^2)$
- Also, $V(\Delta \ln a_t) = V(\ln a_t) + V(\ln a_{t-1}) - 2cov(\ln a_t, \ln a_{t-1})$
- Because of stationarity the variance is constant: $V(\ln a_t) = V(\ln a_{t-1}) =$ $= V(\ln a) = \sigma_a^2/(1-\rho_a^2)$
- And the covariance is the first auto correlation $cov(\ln a_t, \ln a_{t-1}) = \rho V(\ln a)$
- Putting things together: $V(\Delta \ln a_t) = 2\sigma_a^2/(1-\rho_a^2) - 2\rho\sigma_a^2/(1-\rho_a^2) =$ $= 2\sigma_a^2/(1+\rho_a)$

The Implied Importance of Nonstationary Productivity Shocks

Share of TFP variance explained by the non-stationary productivity shock g:
$\frac{\text{var}\left(\Delta \ln X_t^{1-\alpha}\right)}{\text{var}(\Delta \ln TFP_t)}$

$$
\begin{aligned}
\frac{\text{var}\left(\Delta \ln X_t^{1-\alpha}\right)}{\text{var}\left(\Delta \ln TFP_t\right)} &= \frac{\text{var}((1-\alpha)g_t)}{\text{var}(\Delta \ln TFP_t)} \\
&= \frac{(1-\alpha)^2\sigma_g^2/(1-\rho_g^2)}{2\sigma_a^2/(1+\rho_a)+(1-\alpha)^2\sigma_g^2/(1-\rho_g^2)} \\
&= \frac{(1-0.32)^2 \times 0.021^2/(1-0.00^2)}{2\times 0.005^2/(1+0.95)+(1-0.32)^2\times 0.021^2} \\
&= 0.8793.
\end{aligned}
$$

$\Rightarrow$ The estimated model predicts that TFP growth is driven primarily by nonstationary productivity shocks.
$\Rightarrow$ AG also estimate the model using Canadian data and find that the non-stationary technology shock only explains 40% of the variance of TFP.

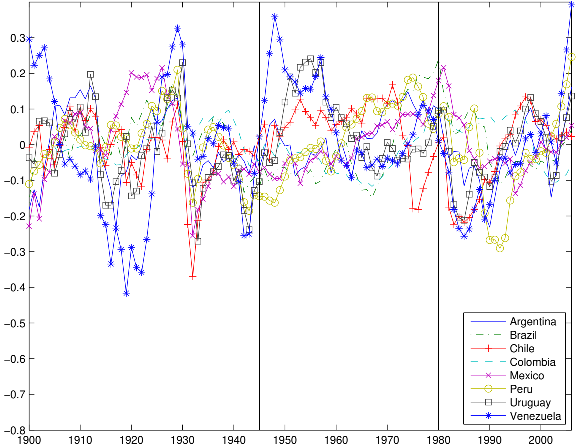
The Implied Importance of Nonstationary Productivity Shocks

- The nonstationary component of productivity explains 88% of the variance of the growth rate of TFP
- The model fit the mexican data well when nonstationary technology shocks play a significant role in moving TFP at the business cycle frequency
- In EMs, The Cycle is the Trend,
- Things are different in AE where nonstationary shocks are less important.

How Should We Interpret This Result?

- Three observations:
  1. Short sample (1980-2003): problematic if the main goal is to distinguish persistent but transitory productivity shocks from nonstationary productivity shocks.
  2. Only productivity shocks are allowed in the horse race.
     * How about other important shocks for emerging countries, such as country-interest-rate shocks?
     * There are many studies that show that world interest rate shocks and country-specific spreads play an important role in driving the business cycle in EMs
  3. The environment is constrained to be the frictionless neoclassical model.
     * What if distortions were allowed?
     * Financial frictions, including default risk and balance-sheet effects are important propagation mechanism in EMs.
     * What about nominal rigidities?

Business Cycles in Latin America: 1900-2005



⇒ The sample 1980-2003 contains at most one and a half cycles.

⇒ Any econometric estimation applied to such a small number of cycles will have problems separating stationary from non-stationary productivity shocks.

⇒ What about HP? (Hamilton)

Addressing these Issues

- Short sample (1980-2003)
    * Use annual data on output, consumption, investment, and the trade balance from 1900 to 2005.
- Only productivity shocks are allowed in the horse race
    * Add more shocks: country-interest-rate shocks, preference shocks, and government spending shocks.
- The environment is constrained to be the frictionless neoclassical model
    * Add financial frictions, namely, by allowing the data to pick the debt elasticity of the country interest rate and by including a working capital constraint.
    * Let stationary and non-stationary productivity shocks compete with interest rate shocks, preferences shocks (shifts in the marginal rate of intertemporal substitutions), and public spending shocks

A Model With Multiple Shocks and Financial Frictions. (Garcia-Cicco, Pancrazi & Uribe (GPU) AER, 2010)

Households

$$\max E_0 \sum_{t=0}^{\infty} \nu_t \beta^t \frac{\left[C_t - \omega^{-1} X_{t-1} h_t^{\omega}\right]^{1-\gamma} - 1}{1-\gamma},$$

subject to

$$\frac{D_{t+1}}{1+r_t} = D_t - W_t h_t - u_t K_t + C_t + S_t + I_t + \frac{\phi}{2}\left(\frac{K_{t+1}}{K_t} - g\right)^2 K_t,$$

Law of motion for capital

$$K_{t+1} = (1-\delta)K_t + I_t,$$

Period Utility Function

$$\max E_0 \sum_{t=0}^{\infty} \nu_t \beta^t \frac{\left[C_t - \omega^{-1} X_{t-1} h_t^{\omega}\right]^{1-\gamma} - 1}{1-\gamma},$$

ν_t is a preference shock and X_t is a stochastic trend.
X_t is in the period utility function for two reasons:

1. Technical reasons: It makes it possible for a model with GHH preferences to have balanced growth (output, investment, consumption, and the capital stock grow at the same rate **and** hours do no grow in the long run).
2. Econ interpretation: technological progress in HH production

USG use uppercase letters for non-stationary variables and lower case letters for re-scaled stationary variables

A Model With Multiple Shocks and Financial Frictions

Firms:

$$\max_{\{h_t, K_t\}} \left\{ a_t K_t^{\alpha} (X_t h_t)^{1-\alpha} - u_t K_t - W_t h_t \left[1 + \frac{\eta r_t}{1 + r_t} \right] \right\},$$

The production function is Cobb-Douglas with stationary (a) and non-stationary shocks (X). u_t is the rental rate of capital and W_t is the real wage. Note that the non-stationary shock is also in the utility function but at $t-1$

Country Interest Rate:

$$r_t = r^* + \psi \left(e^{\frac{\widetilde{D}_{t+1}/X_t - \overline{d}}{\overline{y}}} - 1 \right) + e^{\mu_t - 1} - 1,$$

The interest rate r_t is for debt issued at t and due at $t+1$.
There is a **random shock** μ to domestic interest rate

Five Shocks

ν_t and X_t evolve with the following laws of motion

$$\ln \nu_{t+1} = \rho_\nu \ln \nu_t + \epsilon^\nu_{t+1},$$

$$\ln(g_{t+1}/g) = \rho_g \ln(g_t/g) + \epsilon^g_{t+1}, \qquad g_t \equiv \frac{X_t}{X_{t-1}}$$

The other three exogenous stochastic shocks are as follows:

The stationary productivity shock

$$\ln a_{t+1} = \rho_a \ln a_t + \epsilon^a_{t+1}.$$

The random variation in the world interest rate and/or country spread

$$\ln \mu_{t+1} = \rho_\mu \ln \mu_t + \epsilon^\mu_{t+1}.$$

The aggregate shift to domestic absorption (maybe unproductive govt expenditure).

$$\ln(s_{t+1}/\overline{s}) = \rho_s \ln(s_t/\overline{s}) + \epsilon^s_{t+1}, \qquad s_t \equiv \frac{S_t}{X_{t-1}},$$

Five Shocks

- Shocks ϵ_t^i are i.i.d and independent with mean zero and variances σ_i
- Parameters $\rho_i \in (-1, 1)$ govern the persistence of the shocks

Careful

- The model discussed in the book (pp 149-154) is a bit more complicated
- It is a decentralized equilibrium in which there are three types of agents (HHs, Firms, and Banks) and three types of debt: HHS borrow from banks (D_t^h), firms borrow from banks (D_t^f) and banks borrow abroad (D_t).
- Firms also need to hold money (M_t): firms have a working capital constraint $\eta W_t h_t \leq M_t$
- The fact that firms need to hold working capital leads to a situation in which an increase of the interest rate acts like an increase in the real wage and leads to a reduction of employment
- Banks balance-sheet is

$$\frac{D_{t+1}^h + D_{t+1}^f}{(1+r_t)} = \frac{D_{t+1}}{(1+r_t)} + M_t \tag{2}$$

The LHS are bank assets and the RHS bank liabilities

Competitive Equilibrium

- The maximization process yield a stationary competitive equilibrium given by a set of processes for 8 variables (pp 154-155): c_t, h_t, λ_t, k_{t+1}, d_{t+1}, i_t, r_t, y_t
- Given the exogenous processes a_t, g_t, ν_t, μ_t, s_t
- GPU use Argentinean data on output growth, consumption growth, investment growth and the trade balance/GDP over 1900-2005
- GPU assume that these variables are measured with error
- Eight calibrated parameters are set to match long-run data from Argentina or calibrated using knowledge outside the model

Calibrated Parameters

Parameter	Value
g	1.0107
$\overline{d}/\overline{y}$	0.037
δ	0.1255
r^*	0.10
α	0.32
γ	2
ω	1.6
$\overline{s}/\overline{y}$	0.10

1. g is set to match average growth per capita in Argentina ove the 1900-2005
2. Steady-State trade balance to output ratio of 0.3% (this is the average in Arg.) which leads to SS debt to output ratio of 0.037 (MUCH smaller than the observed 27% post 1970). Note that $\bar{y}$ is equal to the SS value of detreneded output
3. The value of δ imply an investment to output ratio of 19% which is in-line with what observed in Argentina post 1970
4. r^* is at 10% and given that $(1 + r^*) = \beta^{-1}g^{\gamma}$ the subjective discount factor β is 0.9286
5. α is set to 0.32 which is standard in the literature
6. γ is the parameter that defines the curvature of the utility function is set at 2 which is also standard
7. ω is calibrated at 1.6, which implies a labor supply elasticity $(1/(\omega - 1))$ of 1.7
8. The share of exogenous spending over GDP is set at 10%

Bayesian Estimation

- GPU estimate the remaining parameters applying likelihood based Bayesian estimation on 4 time series for Argentina: output growth, consumption growth, investment growth, and the trade balance-to-output ratio.
- Estimate 13 structural parameters and the standard deviations of the measurement errors of the four nonstructural parameters.
- The structural parameters include
  - 10 defining the processes of the 5 structural shocks, σ_g, ρ_g, σ_a, ρ_a, σ_ν, ρ_ν, σ_s, σ_μ, ρ_μ
  - The parameters governing capital adjustment costs, ϕ, the debt elasticity of the country interest rate, ψ, and the magnitude of the working-capital constraint, η.
- The nonstructural parameters are the standard deviations of measurement errors on output growth, $\sigma^{me}_{g^Y}$, consumption growth, $\sigma^{me}_{g^C}$, investment growth, $\sigma^{me}_{g^I}$, and the trade-balance-to-output ratio, $\sigma^{me}_{TB/Y}$.

Bayesian Estimation Results

Parameter	Uniform Prior Distributions			Posterior Distributions			
	Min	Max	Mean	Mean	Median	5%	95%
$\boxed{\sigma_g}$	0	0.2	0.1	0.0082	$\boxed{0.0067}$	$\boxed{0.00058}$	$\boxed{0.021}$
$\boxed{\rho_g}$	-0.99	0.99	0	0.15	$\boxed{0.21}$	$\boxed{-0.69}$	$\boxed{0.81}$
σ_a	0	0.2	0.1	0.032	0.032	0.027	0.036
ρ_a	-0.99	0.99	0	0.84	0.84	0.75	0.91
σ_ν	0	1	0.5	0.53	0.51	0.39	0.77
ρ_ν	-0.99	0.99	0	0.85	0.85	0.76	0.93
σ_s	0	0.2	0.1	0.062	0.064	0.0059	0.12
ρ_s	-0.99	0.99	0	0.46	0.56	-0.42	0.92
σ_μ	0	0.2	0.1	0.12	0.11	0.067	0.18
ρ_μ	-0.99	0.99	0	0.91	0.92	0.83	0.98
ϕ	0	8	4	5.6	5.6	3.9	7.5
ψ	0	10	5	1.4	$\boxed{1.3}$	0.55	2.4
η	0	5	2.5	0.42	0.4	0.18	0.7
$\sigma^{me}_{g^Y}$	0.0001	0.013	0.0067	0.0045	0.0042	0.00051	0.0096
$\sigma^{me}_{g^C}$	0.0001	0.019	0.0095	0.0075	0.0076	0.00097	0.014
$\sigma^{me}_{g^I}$	0.0001	0.051	0.025	0.041	0.044	0.022	0.05
$\sigma^{me}_{TB/Y}$	0.0001	0.013	0.0065	0.0033	0.0031	0.00041	0.0068

Note. Based on an MCMC chain of length 1 million produced using the Metropolis-Hastings algorithm. Estimates of the standard deviations of measurement errors are presented in chapter 5.

Observations on Estimation and Estimation Results

- All prior distribution are assumed to be uniform.
  - For the structural parameters, the support is very wide.
  - For the standard deviations, GPU set an upper bound to the possible error (measurement error cannot account for more than 6.25% of the variance of the corresponding observable).
- The parameters defining the process of the nonstationary technology shock are estimated with substantial uncertainty. (point estimate .21 CI -0.69-0.81)
- The parameters defining the process of the stationary technology shock are more tightly estimated (point estimate .032, CI .027-.036.)
- The data assigns a value significantly higher than 0 to the debt-elasticity of the country interest rate, ψ.

Observations on Model Fit

- The estimated model does a good job at matching some key business cycle parameters:
  - Excess volatility of consumption with respect to output
  - High volatility of investment and trade balance/GDP
  - Procyclicality of consumption and investment
  - Countercyclicality of TB/GDP (but much more than in the data)
- Less so for other:
  - Low serial correlation of output and consumption
  - Serial correlation of investment is negative

Empirical and Theoretical Second Moments

Statistic	g^Y	g^C	g^I	TB/Y
Standard Deviation				
Model	$\boxed{6.2}$	$\boxed{8.9}$	18.6	$\boxed{4.9}$
Data	$\boxed{5.3}$	$\boxed{7.5}$	20.4	$\boxed{5.2}$
	(0.43)	(0.6)	(1.8)	(0.57)
Correlation with g^Y				
Model		0.80	0.53	$\boxed{-0.18}$
Data		0.72	0.67	$\boxed{-0.04}$
		(0.07)	(0.09)	(0.09)
Correlation with TB/Y				
Model		-0.37	-0.31	
Data		-0.27	-0.19	
		(0.07)	(0.08)	
Serial Correlation				
Model	0.04	-0.06	-0.098	0.51
Data	0.11	-0.0047	0.32	0.58
	(0.09)	(0.08)	(0.10)	(0.07)

Variance Decomposition

- We saw that the estimates for the parameters guiding the non-stationary productivity shock are very imprecise
- It is interesting to compute the share of variance of the growth rate of TFP explained by the nonstationary productivity shock
- We saw that in the AG model when only two types of shocks are allowed, the non-stationary productivity shock explains 88% of the movements in TFP.
- This means that trend shocks are the major drivers of business cycle in EMs
- How does this share change when productivity shocks compete with other shocks and frictions?
- Let us now evaluate $\frac{\text{var}\left(\Delta \ln X_t^{1-\alpha}\right)}{\text{var}(\Delta \ln TFP_t)}$ using the variance of MCMC chain of posterior draws to do the following

$$\text{posterior median}\left(\frac{\text{var}((1-\alpha)g_t)}{\text{var}(\Delta \ln TFP_t)}\right) =$$

$$= \text{posterior median}\left(\frac{(1-\alpha)^2\sigma_g^2(1-\rho_g^2)}{2\sigma_a^2/(1+\rho_a)+(1-\alpha)^2\sigma_g^2/(1-\rho_g^2)}\right) = 0.024$$

- The non-stationary shock explains only 2.4% of movements in TFP
- The long data used in the estimation procedure plus the inclusion of additional shocks and financial frictions lead to a situation in which the data favor stationary shocks as drivers of TFP

Variance Decomposition

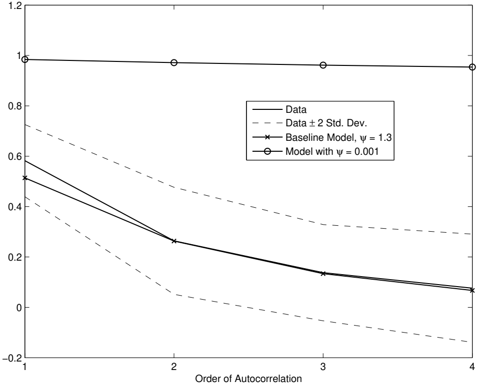
- The table shows the predicted contribution of each shock to explaining the variance of output growth
  1. Negligible contribution of nonstationary shock in explaining aggergate fluctuations (less than 3% of variances).
  2. Output is primarily driven by stationary productivity shocks (82%)
  3. Variation in investment growth and trade balance are mostly driven by interest rate shocks (52% and 92%, respectively)
  4. Consumption volatility is driven by stationary tecnology shock and preference and interest rate shocks
- The data favor an explanation based on stationary technology and other shocks rather than permanent productivity shocks
- We get this effect because this method creates huge persistence for the stationary shock: $\rho_a = 0.84$ which is twice as large than what we got for Canada.
- Interest rate and preferences are also important because they change the relative price of present consumption in terms of future consumption

Shock	g^Y	g^C	g^I	TB/Y
Nonstationary Tech.	$\boxed{2.6}$	1.1	0.2	0.1
Stationary Tech.	81.8	42.4	12.7	0.5
Preference	6.8	27.7	29.1	6.2
Country Premium	6.1	25.8	52.0	92.1
Spending	0.0	0.3	0.3	0.1
Measurement Error	0.4	0.7	5.2	0.4

The Importance of Financial Frictions

- The model introduces financial frictions in two ways:
  (i) interest rate respond to debt levels (the relevant parameter is ψ)
  (ii) the working capital constraint (the relevant parameter is η)
- The debt elasticity can be driven by enforcement problems in the spirit of Eaton and Gerosvitz or by collateral constraints
- The posterior estimate of ψ is 1.3 (see Table above)
  * This implies that an increase in debt of 1% causes an increase in the interest rate by 1.3 percentage points (see pages 160-161)
  * This is value is much higher than the small value required to induce stationarity.
  * This is an indication of the importance of this financial friction.
- This high elasticity plays an important role in explaining the cyclical behavior of the trade balance
- To quantify this importance, let's look at the observed autocorrelation function of the trade-balance-to-output ratio along with those predicted by the model for two values of ψ: its posterior median of 1.3 and a small value of 0.001.

The Autocorrelation Function of the Trade-Balance-To-Output Ratio



Note. The point estimate and error band of the empirical autocorrelation function was estimated by GMM. After setting ψ to 0.001, the theoretical model was reestimated.

The Importance of Financial Frictions

- Why look at the trade balance to output ratio?
- Because ψ affects the country's ability to borrow internationally, and, as a result, the cyclicality of the current account, of which the trade balance is a main component.
- Intuition: In the absence of financial frictions, debt becomes highly persistent and after a while the trade balance is fully driven by the need of servicing the debt.
- This generate persistence in the trade balance
- If ψ is large enough, debt is less persistent and less persistent debt leads to a less persistent trade balance
- Note that the other financial friction (η) does not matter much for the cyclicality of the trade balance.