

## Summary Ch 8 Non-Tradable Goods and the Real Exchange Rate

The MX model overestimates the role of the TOT as a driver of fluctuations. Here we break the assumption that all goods are perfectly traded by introducing Non Tradable goods.

A first consequence is that we start accounting for the Real Exchange Rate. In too simplified models this variable is constant. Here it will fluctuate.

$$\text{Real Exchange Rate: } RER_t = \frac{E_t P_t^*}{P_t} \quad (1) \quad (\text{Relative price of consumption goods basket})$$

$E_t$ : Nominal ER. Price of foreign currency in terms of local currency units.

When RER increases the local goods basket becomes relatively expensive. This is denoted as an **depreciation**. Similarly, if the RER decreases, we observe an **appreciation**.

Three approaches: **1. TNT** model: endowment framework, **2. SVAR**: Empirical framework, **3. MXN**: SOE-RBC framework with exportable, importable and non-tradable goods.

### TNT Model

Endowment Open Economy model, with one fully imported good (not domestically produced), one fully exported good (not domestically consumed), and one non-tradable good.

Households:

$$\begin{aligned} & \max_{C_t^m, C_t^n, d_{t+1}} \sum_{t=0}^{\infty} p_t^t U(c_t) \\ \text{s.t.} \quad & c_t = A(c_t^m, c_t^n), \\ & c_t^m + p_t^n c_t^n + d_t = \frac{d_{t+1}}{1+r} + \underline{tot}_t y^x + p_t^n y^n \\ & \lim_{j \rightarrow \infty} (1+r)^{-j} d_{t+j} \leq 0, \end{aligned}$$

Units: importables ( $P_t^m = 1$ )  
 $y^x, y^n$ : Constant endowments (n: Non tradable)  
 $A(\cdot, \cdot)$ : Increasing, concave, HD1  
 $d_t$ : External debt maturing in  $t$   
 $r > 0$  interest rate (constant)

FOCs:

$$[C_t^m]: U'(c_t) A_1(c_t^m, c_t^n) = \lambda_t, \quad (2)$$

$$[d_{t+1}]: \lambda_t = \beta(1+r)\lambda_{t+1}, \quad (3)$$

$$[C_t^n]: p_t^n = \frac{A_2(c_t^m, c_t^n)}{A_1(c_t^m, c_t^n)}, \quad (4)$$

$$[TVC]: \lim_{j \rightarrow \infty} (1+r)^{-j} d_{t+j} = 0. \quad (5)$$

This condition involves  $A_1(c_t^m, c_t^n)$  because  $\lambda_t / U'(c_t)$  is replaced from (2) in the original FOC wrt  $C_t^n$

Given  $A(\cdot, \cdot)$  is HD1, (4) can be rewritten as:

$$[C_t^n]': p_t^n = P\left(\frac{c_t^m}{c_t^n}\right); \quad \text{with } P'(\cdot) > 0. \quad (6) \quad \text{Intuition: Consumption of NT (importables) decreases (increases) w/ price of NT goods}$$

**Link between RER and relative price of Non-Tradables:** there is a one-to-one inverse relationship between the RER and the relative price of non-tradable goods.

**This is why paper talk about RER and prices of Non-Tradables as analogous quantities**

$$RER = \frac{E_t P_t^*}{P_t} = \frac{E_t P_t^*/P_t^m}{P_t/P_t^m} = \frac{P_t^*/P_t^m}{P_t/P_t^m} = \frac{P_t^*}{P_t} \quad \begin{matrix} 1: \text{Assumed} \\ \text{Exogenous, constant} \\ \text{(and normalized)} \end{matrix}$$

Where the second to last equality uses the LOP assumption ( $P_t^m = E_t P_t^*$ )

This result implies the RER can be directly associated to the relative price of consumption goods ( $P_t^*$ ). Now we check how  $P_t^*$  is linked to  $P_t^n$  (and then how RER is linked to  $P_t^n$ )

Firms bundling (or producing)  $C_t$  by aggregating the sub-baskets  $C_t^m, C_t^n$  solve:

$$\max_{C_t^m, C_t^n} p_t^t A(C_t^m, C_t^n) - C_t^m - p_t^n C_t^n$$

FOCs:

$$[C_t^m]: p_t^t A_1(C_t^m, C_t^n) = 1$$

$$\Rightarrow A_1(C_t^m, C_t^n) = RER_t$$

$$\text{given } A(\cdot, \cdot) \text{ is HD0: } A_1(C_t^m, C_t^n) = A_1\left(\frac{c_t^m}{c_t^n}, 1\right)$$

$$\text{and by (6): } = A_1(p_t^{-1}(P_t^n), 1) = RER_t$$

$$\text{then: } RER_t = e(p_t^n), \quad \text{with } e'(\cdot) < 0 \quad (\text{or } RER_t \propto \frac{1}{P_t^n})$$

Therefore, **if the prices of non-tradable increase, the RER appreciates (decreases)**

### Market clearing

$$\text{Non-tradable goods: } C_t^n = y_t^n \quad (8) \quad \text{can only be consumed/produced domestically}$$

Subst. (8) in the HH budget constraint to obtain dynamics of debt (current account):

Resource constraint of tradable sector:

$$c_t^m + d_t = \frac{d_{t+1}}{1+r} + \underline{tot}_t y^x. \quad (9)$$

### Intertemporal Budget Constraint analysis:

Now assume  $\beta = \frac{1}{1+r}$

Then given (3) we have:  $\lambda_t = \lambda \forall t \Rightarrow C_t^m = C^m$  (this follows bc  $r$  is constant here so it cancels out w/  $r$  in  $\beta$ )

Iterate BC forward (to infinity) & use TVC (5):  $c^m = -\frac{r}{1+r} d_0 + \frac{r}{1+r} \sum_{t=0}^{\infty} \frac{\underline{tot}_t y^x}{(1+r)^t}$ .  $(10)$

The assumption  $(\beta(1+r)=1)$  and the FOC wrt  $C_t^n$ . Also imply:  $C_t^n = C^n$

The by (6) we get an expression for the equilibrium RER:  $p^n = P\left(\frac{c^m}{y^n}\right) \quad (11) \quad \uparrow P^n \equiv \downarrow RER$  (RER appreciates)

**RER appreciates when:**

- Supply of non-tradable falls
- Current TOT or supply of tradables increase
- Future TOT or  $y^x$  are expected to grow  $(c^m \uparrow, \underline{tot}_t \uparrow, y^x \uparrow)$

### Effects of TOT shocks

Temporary shock:  $\underline{tot}_0$  increases, other  $\underline{tot}_t$  remain unchanged

$$\text{Effect on RER: } \left. \frac{\partial p^n}{\partial \underline{tot}} \right|_{\text{temporary}} = \frac{r}{1+r} \frac{y^x}{y^n} P'\left(\frac{c^m}{y^n}\right) > 0. \quad \text{RER decreases (appreciates)}$$

Increase in relative price of exportables creates an income effect, driving up the demand for all goods. Given the supply of NT is fixed, its price increases to eliminate excess demand.

With higher price NT goods the RER will go down (appreciates).

**Permanent shock:** TOTt increases for all t (starting at t=0)

### Effect on RER:

$$\text{From (10) and (11) we have: } \frac{\partial p^n}{\partial tot} \Big|_{\text{permanent}} = \frac{y^x}{y^n} P' \left( \frac{c^m}{y^n} \right) > 0$$

$$\text{Moreover, } \frac{\partial p^n}{\partial tot} \Big|_{\text{permanent}} > \frac{\partial p^n}{\partial tot} \Big|_{\text{temporary}} > 0$$

the more permanent the increase in TOT, the larger the income effect it generates, the larger will be the increase in NT demand, prices, RER appreciation

### Effect on output:

Unexpected and permanent increase in TOT at t=0

$$\text{with non-tradable the output } Y_t \text{ is: } Y_t = \frac{P_t^x y^x + P_t^n y^n}{P_t}$$

Multiply/divide by  $P_t^n$ :

$$Y_t = \frac{tot_t y^x + P_t^n y^n}{P_t^n}$$

$$\text{Given } P_t^e = \frac{1}{A_1(c^m, y^n)}, P_t^n = \frac{A_2(c^m, y^n)}{A_1(c^m, y^n)} : Y_t = A_1(c^m, y^n) tot_t y^x + A_2(c^m, y^n) y^n \quad (12)$$

Assume  $A(\cdot, \cdot)$  is a Cobb-Douglas aggregator:  $A(c^m, y^n) = (c^m)^\alpha (y^n)^{1-\alpha}$

$$\text{Then (12) becomes: } Y_t = C_t \left[ \alpha \frac{tot_t y^x}{c^m} + (1-\alpha) \right]$$

$$\text{Implied: } \frac{\partial y_0}{\partial tot} \Big|_{1-\alpha=0} = y^x > 0 \text{ and } \frac{\partial y_0}{\partial tot} \Big|_{1-\alpha=1} = 0$$

the larger the share of non-tradables in consumption the lower the effect of TOT shocks on output

We can see how the inclusion of NT goods dampens the effect of the TOT on the output. Then, adding NT goods can be good for reconciling the results in the model with the data. We do this in the MX-N model.

### Interest Rate shocks:

One time increase in interest rate at t=0: FOCs evaluated at imply that:  $c^m > c^n$ .

In addition it follows that  $c^m$  falls wrt previous levels. Then:  $\frac{\partial c_0}{\partial r_0} < 0$

This result, together with (6), (8) implies:

$$\frac{\partial p_0}{\partial r_0} = P' \left( \frac{c^m}{y^n} \right) \frac{1}{y^n} \frac{\partial c_0}{\partial r_0} < 0$$

RER depreciates (increases)

Intuition: Households want to save by consuming less of all goods. Given the supply of NT is fixed the price of non-tradables falls to clear the market

### SVAR Empirical Evidence

Here the SVAR from the previous chapter is extended to include the RER.

$$\text{Let: } x_t = [\widehat{tot}_t, \widehat{tb}_t, \widehat{y}_t, \widehat{c}_t, \widehat{i}_t, \widehat{RER}_t]'$$

$$\text{SVAR: } x_t = h_x x_{t-1} + u_t \quad \text{Identification of TOT shocks: } u_t = \Pi \epsilon_t$$

$$\epsilon_t \sim (0, I)$$

$$\Pi_{1,j} = 0 \text{ for } j = 2, \dots, 6$$

It is assumed the TOT is an exogenous univariate AR(1) process:  $h_{x,1,i} = 0 \text{ for } j = 2, \dots, 6$

All variables except the TB are log-deviations from a quadratic trend.

For TB: trade balance divided by trend component of output and then removing a quadratic time trend

$$\text{RER set relative to the US: } \widehat{RER}_t = \frac{E_t P_t^{US}}{P_t}$$

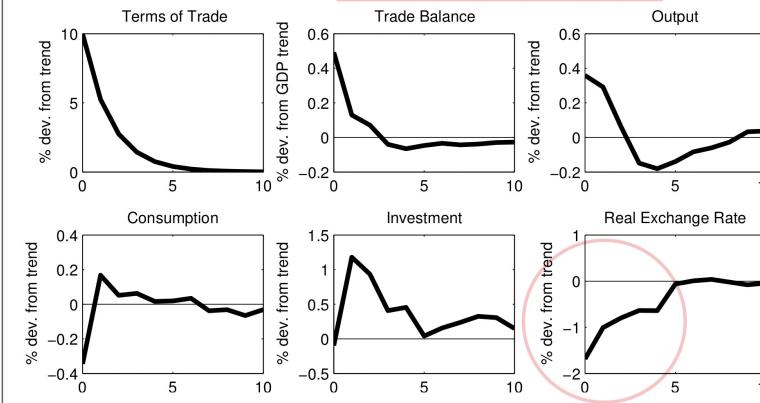
Data source: WDI (38 countries -w/ at least 30 consecutive data points in all variables-, poor and EMEs, period: 1980-2011, country-wise estimation)

$$\widehat{tot}_t = \rho \widehat{tot}_{t-1} + \sigma_{tot} \epsilon_t^{tot}; \quad \epsilon_t^{tot} \sim (0, 1)$$

Estimate  $\rho$  and  $\sigma_{tot}$  country by country

$\rho$	$\frac{\sigma_{tot}}{\sqrt{1-\rho^2}}$
Median	0.52
Interquartile Range	[0.41, 0.61] [0.09, 0.13]

Impulse Response to A 10% Increase in the Terms of Trade  
SVAR Evidence, Median across 38 countries



- TOT shocks are short-lived
- TB improves after the shock (HLM effect)
- TOT improvements are expansionary
- TOT increase leads to appreciation of RER (J-RER)

TOT shocks explain on avg 10% of output.

Then this SVAR is also at odds w/ conventional wisdom (and MX model) indicating TOT is a key driver of fluctuations

### Variance decomposition:

	tot	tb	y	c	i	RER
Median	100	12	10	9	10	14
Median Absolute Deviation	0	7	7	6	7	11

### MXN model

RBC-SOE extended to include exportable, importable and **non-tradable** goods.

-TOT are taken as given.

-All goods are produced and consumed (unlike TNT model) and production uses labor and K as input.

-Factors are specific to each sector.

**The Household Problem:** Maximize

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

subject to the period budget constraint

$$c_t + i_t^m + i_t^x + i_t^n + p_t^r d_t + \Phi_m(k_{t+1}^m - k_t^m) + \Phi_x(k_{t+1}^x - k_t^x) + \Phi_n(k_{t+1}^n - k_t^n) = \frac{p_t^r d_{t+1}}{1+r_t} + w_t^m h_t^m + w_t^x h_t^x + w_t^n h_t^n + u_t^m k_t^m + u_t^x k_t^x + u_t^n k_t^n,$$

and to the laws of motion for physical capital

$$k_{t+1}^m = (1-\delta)k_t^m + i_t^m; \quad k_{t+1}^x = (1-\delta)k_t^x + i_t^x; \quad k_{t+1}^n = (1-\delta)k_t^n + i_t^n.$$

Final goods Firms:

$$\text{Max } a_t - p_t^r a_t^x - p_t^n a_t^n$$

$$\text{s.t. } a_t = \left[ \chi_t(a_t^x)^{1-\frac{1}{\mu_{Tn}}} + (1-\chi_t)(a_t^n)^{1-\frac{1}{\mu_{Tn}}} \right]^{\frac{1}{1-\frac{1}{\mu_{Tn}}}}$$

$a_t$  = domestic absorption of final goods a.

$a_t^x$  = domestic absorption of a composite of traded goods.

$a_t^n$  = (domestic) absorption of nontradable goods.

$\mu_{Tn}$  = elasticity of substitution between T and N goods.

$\chi_t$  = expenditure share on tradables if  $\mu_{Tn}$ .

Units: Final Goods

$p_t^r$ : Relative price of tradables

$d_t$ : Debt due in t

Tradable good is a composite of imported and exported goods

Tradable composite good firms:  $\max\{p_t^x a_t^x - p_t^m a_t^m - p_t^r a_t^r\}$

$$a_t^r = \left[ \chi_m (a_t^m)^{1-\frac{1}{\mu_{mx}}} + (1-\chi_m) (a_t^x)^{1-\frac{1}{\mu_{mx}}} \right]^{\frac{1}{1-\frac{1}{\mu_{mx}}}}$$

$a_t^r$  = domestic absorption of tradable goods.

$a_t^m$  = domestic absorption of importable goods.

$a_t^x$  = domestic absorption exportable goods.

$\mu_{mx}$  = elasticity of substitution between importables and exportables.

$\chi_m$  = expenditure share if  $\mu_{mx} = 1$ .

Importable good firms:

$$\begin{aligned} & \underset{h_t^r, K_t^m}{\text{Max}} \quad p_t^m y_t^m - w_t^m h_t^m - u_t^m k_t^m \\ \text{s.t. } & y_t^m = A_t^m (k_t^m)^{\alpha_m} (h_t^m)^{1-\alpha_m} \end{aligned}$$

Exportable good firms:

$$\begin{aligned} & \underset{h_t^x, K_t^x}{\text{Max}} \quad p_t^x y_t^x - w_t^x h_t^x - u_t^x k_t^x \\ \text{s.t. } & y_t^x = A_t^x (k_t^x)^{\alpha_x} (h_t^x)^{1-\alpha_x} \end{aligned}$$

Non-tradable goods firms:

$$\begin{aligned} & \underset{h_t^r, K_t^r}{\text{Max}} \quad p_t^r y_t^r - w_t^r h_t^r - u_t^r k_t^r \\ \text{s.t. } & y_t^r = A_t^r (k_t^r)^{\alpha_r} (h_t^r)^{1-\alpha_r} \end{aligned}$$

Interest rate (IDEIR):

$$\begin{aligned} r_t &= r^* + p(dw) \\ p(w) &= \psi(e^{d-\delta} - 1) \end{aligned}$$

TOT process:

$$\ln\left(\frac{tot_t}{tot}\right) = \rho \ln\left(\frac{tot_{t-1}}{tot}\right) + \sigma_{tot} \epsilon_t^{tot}; \quad \epsilon_t^{tot} \sim (0, 1)$$

Calibrated parameters:

<u>Calibrated Structural Parameters</u>	$\rho$	$\sigma_{tot}$	$\alpha_m, \alpha_x$	$\alpha_n$	$\omega_m, \omega_x, \omega_n$	$\mu_{mx}$	$\mu_{rn}$	$\overline{tot}$	$A^m, A^n$	$\beta$	$\sigma$	$\delta$	$r^*$	
*	*	0.35	0.25		1.455	1	0.5	1	$\frac{1}{1}$	$\frac{1}{1}$	$\frac{1}{1/(1+r^*)}$	2	0.1	0.11
<u>Moment Restrictions</u>														
*	$\sigma_y$	$\sigma_{tb}$	$\sigma_{tot+yx}$	$s_n$	$s_x$	$s_{tb}$	$\frac{p^m y^m}{p^x y^x}$							
*	1.5	1.5	$\sigma_{tot+yx}$	0.5	0.2	0.01	1							
<u>Implied Structural Parameter Values</u>														
*	$\phi_m$	$\phi_x$	$\phi_n$	$\psi$	$\chi_m$	$\chi_x$	$\bar{d}$	$A^x$	$\frac{1}{1}$	$\frac{\beta}{0.9009}$				
*				*	0.8980	0.4360	0.0078							

\* country specific estimates

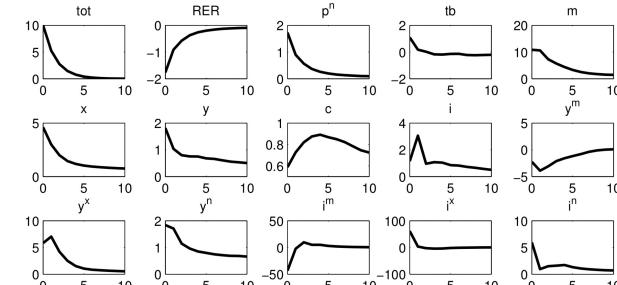
$$\frac{\sigma_t}{\sigma_y}, \frac{\sigma_{tb}}{\sigma_y}: \text{Conditional on TOT shocks}$$

$$S_n: p^m y^m / y, S_x: x / y, S_{tb}: (x-m) / y \\ \text{with: } y = p^m y^m + p^x y^x + p^n y^n$$

Relevant parameters for checking the effect of the TOT shocks:

- $\rho$  and  $\sigma_{tot}$ : persistence and volatility of TOT shocks.
- Size of non-traded sector:  $p^m y^m / y = 0.5$ . The larger the smaller the effect of TOT on output.
- Steady State trade share:  $(x+m)/y = 0.39$ . The larger, the larger the effect of TOT on output.

#### Median of country specific IRF to a ten percent TOT shock (MXN model)



- **Supply side:** Production of Exportables increases, of Importables decreases, of non-tradable goods increases.

- **Demand side:** Demand for importable goods and non-traded goods increases given lower relative price. Domestic demand for exportable goods falls. The improvement in TOT generates a wealth effect that increases total demand.

- Price of non-tradable rises (**RER appreciates**)

- Exports and imports increase. The **trade balance improves. Then the HLM effect holds.**

#### Comparison of data and theoretical counterparts

For comparison purposes we should measure the empirical and theoretical variables of the model in the same units. Then, a theoretical counterpart to the observable variables is constructed.

Unit: constant LCU (local currency units).

For the construction: deflate nominal variables by a Paasche GDP deflator

#### Share of Variance Explained by Terms of Trade Shocks:

##### SVAR Versus MXN Predictions

	$tb$	$y$	$c$	$i$	$RER$
MXN Model	21	13	18	11	1
SVAR Model	12	10	9	10	14

Note. Cross-country medians.

Note: to compute the share of variance the procedure consists on:

1. with  $\text{tot}_t$  as the whole driving process, compute the variance of output predicted by the MXN model.
2. Divide this value by the observed unconditional variance of output predicted by the SVAR model (variance of output when all shocks are active)

The same is done for the other variables.

- Median share of output explained by TOT shocks is similar to that of the SVAR.

- Then both models concur that TOT are not a major driver of the business cycles.

#### Importance of Consistent Measuring of Variables between Empirical and Theoretical model

Suppose that instead of computing the predictions of the model in constant prices we would obtain them in units of current consumption (as can be a common practice).

In that case, variance of all variables is higher than in constant prices (over-predicting the variability). That may favor the conventional wisdom view where TOT shocks are important drivers of fluctuations.

#### TOT Disconnect

Median and average results showed suggest MXN model and the SVAR have similar implications with regards to the importance of the TOT shocks for aggregate movement in output.

However, when checking predictions at country level the conclusion is the opposite: when plotting the % of explained variance by country there are important differences between SVAR and MXN model. The match is good on average but is also poor at the individual level.

#### Conclusion

Conventional wisdom: TOT represent a major source of fluctuations for EMEs.

**SVAR results:** the explanatory role for TOT is modest.

**MXN model results:** with non-tradable goods the role is modest too.

This does not mean that world prices are not important shocks. TOT are a highly aggregated summary variable that may capture poorly the transmission mechanism of certain individual prices.

Typically a country trades a large number of goods and services.

To test this further: Fernandez, Schmitt-Grohe, and Uribe (JIE,2017) estimate a variation of the SVAR in which the TOT is replaced by 3 world commodity prices. Then, jointly, these prices explain about 30% of the aggregate fluctuations.