Cointegrated TFP Processes and International Business Cycles

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October 15, 2008

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  3. The cointegrating vector is (1, -1): important for balanced growth.

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The Great Moderation and the Real Exchange Rate

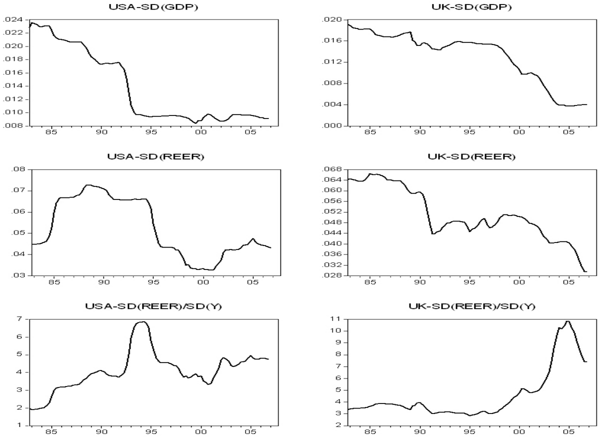

Figure: Standard Deviation of HP-Filtered Data. USA and UK.

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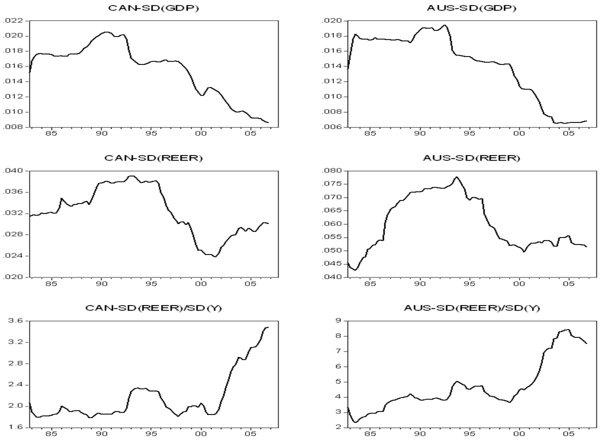

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- We show that the volatility increase can be related to changes in the parameter estimates of the VECM.

Related Literature

- Role of stochastic trends: King, Plosser, Stock, and Watson (1991), Lastrapes (1992), Alvarez and Jermann (2005), Engel and West (2005), Aguiar and Gopinath (2007), Nason and Rogers (2008).

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  - Nontradable goods: Corsetti, Dedola and Leduc (2007, 2008), Benigno, G. and Thoenissen (2007), Dotsey and Duarte (2006).

The Model

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- Incomplete markets.
- Firms in the intermediate and final goods sectors operate under perfect competition.
- Departure from the literature: TFP processes are C(1,1) and can be characterized with a VECM.

The Model: Households

$$\max E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left\{ C\left(s^t\right)^{\tau} \left[1 - L\left(s^t\right)\right]^{1-\tau} \right\}^{1-\sigma}}{1-\sigma}$$

s.t.

$$P\left(s^t\right)\left[C\left(s^t\right) + X\left(s^t\right)\right] + P_H\left(s^t\right)\overline{Q}\left(s^t\right)D\left(s^t\right) \leqslant P_H\left(s^t\right)D\left(s^{t-1}\right) +$$
$$P\left(s^t\right)\left[W\left(s^t\right)L\left(s^t\right) + R\left(s^t\right)K\left(s^{t-1}\right)\right] - P_H\left(s^t\right)\Phi\left(D\left(s^t\right)\right),$$

and

$$K\left(s^t\right) = (1-\delta)K\left(s^{t-1}\right) + X\left(s^t\right),$$

The Model: Final Goods Producers

$$\max P\left(s^t\right) Y\left(s^t\right) - P_H\left(s^t\right) Y_H\left(s^t\right) - P_F\left(s^t\right) Y_F\left(s^t\right)$$

s.t.

$$Y\left(s^t\right) = \left[\omega^{\frac{1}{\theta}} Y_H\left(s^t\right)^{\frac{\theta-1}{\theta}} + (1-\omega)^{\frac{1}{\theta}} Y_F\left(s^t\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}$$

The Model: Intermediate Goods Producers

$$Max \left\{ \begin{array}{c} P_H\left(s^t\right)\left[Y_H\left(s^t\right)+Y_H^*\left(s^t\right)\right]- \\ P\left(s^t\right)\left[W\left(s^t\right)L\left(s^t\right)+R\left(s^t\right)K\left(s^{t-1}\right)\right] \end{array} \right\}$$

s.t.

$$Y_H\left(s^t\right)+Y_H^*\left(s^t\right)=A\left(s^t\right)^{1-\alpha}K\left(s^{t-1}\right)^{\alpha}L\left(s^t\right)^{1-\alpha}$$

The Model: TFP

$$\begin{pmatrix} \Delta \log A\left(s^{t}\right) \\ \Delta \log A^{*}\left(s^{t}\right) \end{pmatrix} = \begin{pmatrix} c \\ c^{*} \end{pmatrix} + \rho(L) \begin{pmatrix} \Delta \log A\left(s^{t-1}\right) \\ \Delta \log A^{*}\left(s^{t-1}\right) \end{pmatrix}$$
$$+ \begin{pmatrix} \kappa \\ \kappa^{*} \end{pmatrix} \left[\log A\left(s^{t-1}\right) - \gamma \log A^{*}\left(s^{t-1}\right) - \log \xi\right] + \begin{pmatrix} \varepsilon^{a}\left(s^{t}\right) \\ \varepsilon^{a,*}\left(s^{t}\right) \end{pmatrix}$$

- Implies that:
  - $\Delta \log A\left(s^{t}\right)$
  - $\Delta \log A^{*}\left(s^{t}\right)$, and
  - $\log A\left(s^{t-1}\right) - \gamma \log A^{*}\left(s^{t-1}\right)$ are stationary processes.

The Model: Equilibrium Conditions

$$U_C\left(s^t\right) = \lambda\left(s^t\right),$$

$$\frac{U_L\left(s^t\right)}{U_C\left(s^t\right)} = W\left(s^t\right),$$

$$\lambda\left(s^t\right) = \beta E_t\left\{\lambda\left(s^{t+1}\right)\left[R\left(s^{t+1}\right) + (1-\delta)\right]\right\},$$

$$K\left(s^t\right) = (1-\delta)\,K\left(s^{t-1}\right) + X\left(s^t\right),$$

The Model: Equilibrium Conditions

$$\overline{Q}\left(s^{t}\right)=\beta E_{t}\left[\frac{\lambda\left(s^{t+1}\right)}{\lambda\left(s^{t}\right)}\frac{\widetilde{P}_{H}\left(s^{t+1}\right)}{\widetilde{P}_{H}\left(s^{t}\right)}\right]-\frac{\Phi'\left[D\left(s^{t}\right)\right]}{\beta}.$$

$$\begin{aligned}\widetilde{P}_{H}\left(s^{t}\right)\overline{Q}\left(s^{t}\right)D\left(s^{t}\right) &= \widetilde{P}_{H}\left(s^{t}\right)Y_{H}^{*}\left(s^{t}\right)-\widetilde{P}_{F}^{*}\left(s^{t}\right)RER\left(s^{t}\right)Y_{F}\left(s^{t}\right)\\ &\quad+\widetilde{P}_{H}\left(s^{t}\right)D\left(s^{t-1}\right)-\widetilde{P}_{H}\left(s^{t}\right)\Phi\left[D\left(s^{t}\right)\right]\end{aligned}$$

$$E_{t}\left[\frac{\lambda^{*}\left(s^{t+1}\right)}{\lambda^{*}\left(s^{t}\right)}\frac{\widetilde{P}_{H}\left(s^{t+1}\right)}{\widetilde{P}_{H}\left(s^{t}\right)}\frac{RER\left(s^{t}\right)}{RER\left(s^{t+1}\right)}-\frac{\lambda\left(s^{t+1}\right)}{\lambda\left(s^{t}\right)}\frac{\widetilde{P}_{H}\left(s^{t+1}\right)}{\widetilde{P}_{H}\left(s^{t}\right)}\right]=-\frac{\Phi'\left[D\left(s^{t}\right)\right]}{\beta}$$

The Model: Equilibrium Conditions

$$W\left(s^t\right) = (1-\alpha)\widetilde{P}_H\left(s^t\right) A\left(s^t\right)^{1-\alpha} K\left(s^{t-1}\right)^{\alpha} L\left(s^t\right)^{-\alpha},$$

$$R\left(s^t\right) = \alpha\widetilde{P}_H\left(s^t\right) A\left(s^t\right)^{1-\alpha} K\left(s^{t-1}\right)^{\alpha-1} L\left(s^t\right)^{1-\alpha},$$

$$Y_H\left(s^t\right) = \omega\widetilde{P}_H\left(s^t\right)^{-\theta} Y\left(s^t\right),$$

$$Y_F\left(s^t\right) = (1-\omega)\left(\widetilde{P}_F^*\left(s^t\right) RER\left(s^t\right)\right)^{-\theta} Y\left(s^t\right),$$

The Model: Equilibrium Conditions

$$C\left(s^t\right) + X\left(s^t\right) = Y\left(s^t\right),$$

$$Y\left(s^t\right) = \left[\omega^{\frac{1}{\theta}} Y_H\left(s^t\right)^{\frac{\theta-1}{\theta}} + (1-\omega)^{\frac{1}{\theta}} Y_F\left(s^t\right)^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}},$$

$$Y_H\left(s^t\right) + Y_H^*\left(s^t\right) = A\left(s^t\right)^{1-\alpha} K\left(s^{t-1}\right)^{\alpha} L\left(s^t\right)^{1-\alpha},$$

$$Y_F\left(s^t\right) + Y_F^*\left(s^t\right) = A^*\left(s^t\right)^{1-\alpha} K^*\left(s^{t-1}\right)^{\alpha} L^*\left(s^t\right)^{1-\alpha},$$

and

$$D\left(s^t\right) + D^*\left(s^t\right) = 0.$$

The Model: Balanced Growth

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- But in the open economy we need an additional restriction

$$\widehat{Y}_F\left(s^t\right) = (1-\omega)\left[\widetilde{P}_F^*\left(s^t\right) RER\left(s^t\right)\right]^{-\theta} \widehat{Y}\left(s^t\right) \frac{A\left(s^{t-1}\right)}{A^*\left(s^{t-1}\right)}$$

where $\widehat{Y}_F\left(s^t\right) = Y_F\left(s^t\right)/A^*\left(s^{t-1}\right)$, $\widehat{Y}\left(s^t\right) = Y\left(s^t\right)/A\left(s^{t-1}\right)$.

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- $\frac{A\left(s^{t-1}\right)}{A^*\left(s^{t-1}\right)}$ is stationary if $\gamma = 1$.

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- Rest of the world: Euro Area, Canada, Japan, Australia, and the UK. Also Mexico and South Korea.
- Aggregate GDPs using PPP-adjusted exchange rates. We aggregate number of employees.
- Follow Heathcote and Perri (2002)

$$\log A\left(s^t\right) = \left[\log Y\left(s^t\right) - (1-\alpha)\log L\left(s^t\right)\right] / (1-\alpha)$$

$$\log A^*\left(s^t\right) = \left[\log Y^*\left(s^t\right) - (1-\alpha)\log L^*\left(s^t\right)\right] / (1-\alpha)$$

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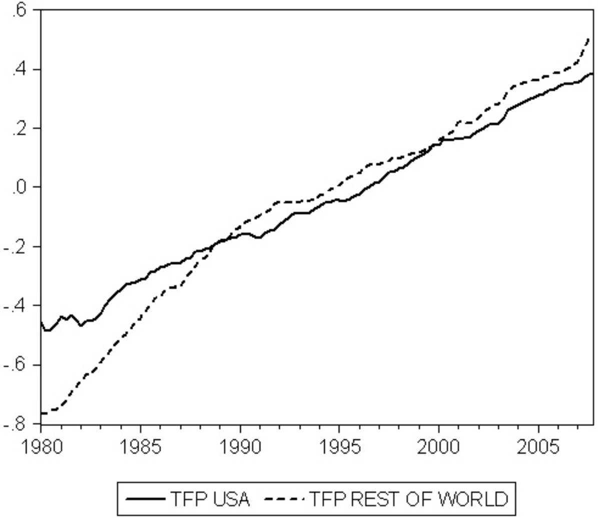

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- We estimate the VECM with 2 lags and cannot reject that $\gamma = 1$.
- We run several likelihood ratio tests to test for symmetry.

Estimation of the VECM for TFP

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$$

$$
+\rho^{2} \begin{pmatrix} \Delta \log A\left(s^{t-2}\right) \\ \Delta \log A^{*}\left(s^{t-2}\right) \end{pmatrix}
$$

$$
+ \begin{pmatrix} \kappa \\ \kappa^{*} \end{pmatrix} \left[\log A\left(s^{t-1}\right) - \gamma \log A^{*}\left(s^{t-1}\right) - \log \xi\right] + \begin{pmatrix} \varepsilon^{a}\left(s^{t}\right) \\ \varepsilon^{a,*}\left(s^{t}\right) \end{pmatrix}
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Estimation of the VECM for TFP

Table 4: Likelihood ratio tests.

Restriction	Likelihood value	Degrees of freedom	p-value
None	744.18	-	-
$\gamma = 1$	743.33	1	0.19
$\kappa = -\kappa^*$	741.71	2	0.09
$c = c^*$	740.43	3	0.06
Symmetry across VAR coefficients	736.51	7	0.032

Estimation of the VECM for TFP

Table 5: Parameter Estimates, VECM model

	1980 – 2007
c	0.0071^{*} (5.83)
κ	-0.0045^{*} (-2.65)
ρ_{11}^{1}	0.2041^{*} (2.97)
ρ_{11}^{2}	0.1026 (1.54)
ρ_{12}^{1}	0.1035 (1.55)
ρ_{12}^{2}	-0.1497^{*} (-2.40)

t-statistics in parenthesis.

* means significance at the 5 percent level

Table 6: Calibration

Preferences	$\beta = 0.99$
	$\mu = 0.34$
	$\sigma = 2$
	$\phi = 0.01$
Technology	$\alpha = 0.36$
	$\delta = 0.025$
	$\omega = 0.9$
	$\theta = [0.85, 0.62]$

Table 7a: Results

Full Sample	σ_Y	σ_C^+	σ_X^+	σ_N^+	σ_{RER}^+	$\rho(RER)$
Data	1.25	0.80	3.40	0.91	4.28	0.84
Coint. TFP, $\theta = 0.85$	0.81	0.63	2.32	0.28	1.75	0.72
Coint. TFP, $\theta = 0.62$	0.70	0.62	2.31	0.28	4.26	0.70
Stat. TFP, $\theta = 0.85$	1.19	0.52	2.53	0.32	0.75	0.77
Stat. TFP, $\theta = 0.62$	1.12	0.54	2.51	0.31	1.41	0.75

$^+$ denotes relative to output.

Table 7b: Results

Full Sample	CORR(Y,N)	CORR(Y,C)	CORR(Y,X)
Data	0.79	0.81	0.91
Coint. TFP, $\theta = 0.85$	0.94	0.95	0.97
Coint. TFP, $\theta = 0.62$	0.92	0.93	0.95
Stat. TFP, $\theta = 0.85$	0.97	0.93	0.97
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Explaining the Mechanism

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- Estimated non-stationary TFP shocks find high persistence (by definition there is one unit root) and slow spillovers.
- First, we discuss the role of persistence in a stationary model. Then we discuss the role of spillovers in a non-stationary model.

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  - Labor supply decreases, and output at home increases less on impact.
  - Consumption increases, leading to more demand of the foreign intermediate good.
  - Lower production of home intermediate good and higher production of foreign intermediate good lead to larger RER and TOT depreciation.
- Hence **higher persistence leads to higher RER volatility**.

Explaining the Mechanism

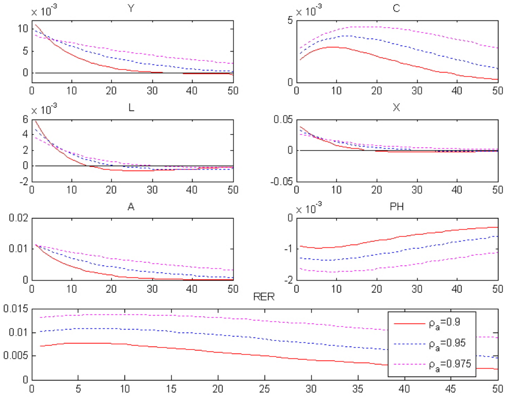

Figure: Impulse Response to a Home-Country TFP shock. Model with stationary TFP shocks.

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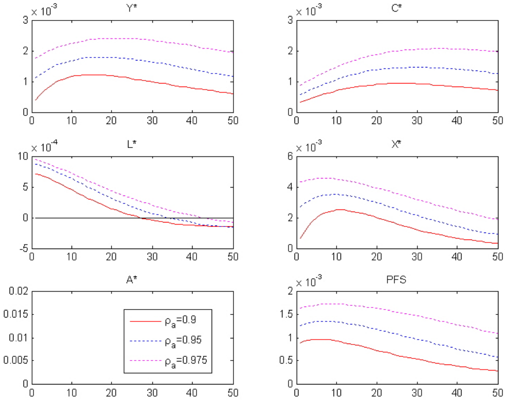

Figure: Impulse Response to a Home-Country TFP shock. Model with stationary TFP shocks.

Explaining the Mechanism

- Now we switch to the model with VECM shocks:

$$
\begin{aligned}
\Delta a_t &= -\kappa\left(a_{t-1} - a^*_{t-1}\right) + \varepsilon^a_t \\
\Delta a^*_t &= \kappa\left(a_{t-1} - a^*_{t-1}\right) + \varepsilon^{a,*}_t
\end{aligned}
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- Increased κ implies a stronger "news channel" in the foreign country:

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- Increased κ implies a stronger "news channel" in the foreign country:
  - Labor supply and investment decreases, and output in the foreign country decreases on impact.

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- Now we switch to the model with VECM shocks:

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\Delta a_t &= -\kappa(a_{t-1} - a_{t-1}^*) + \varepsilon_t^a \\
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- Hence **higher speed of convergence leads to lower RER volatility**.

Explaining the Mechanism

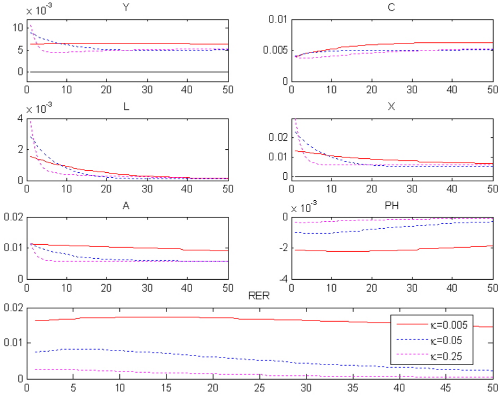
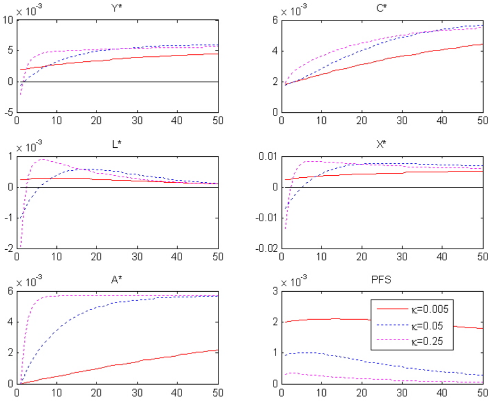


Figure: Impulse Response to a Home-Country TFP shock. Model with cointegrated TFP shocks.

Explaining the Mechanism



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Explaining the Mechanism

Table 8: Changing ρ_a and κ

	$SD(RER)$	$SD(Y)$	$SD(RER)^+$
ρ_a			
0.9	1.43	1.33	1.07
0.95	1.96	1.2	1.64
0.975	2.47	1.06	2.33
κ			
0.005	1.98	0.64	3.1
0.05	1.02	0.82	1.25
0.25	0.71	0.86	0.82

Explaining the Mechanism

- Therefore, one unit root in the joint process of TFP across countries is not enough. We need the second root to be very close to one.

$$\begin{pmatrix} a_t \\ a_t^* \end{pmatrix} = \begin{pmatrix} 1-\kappa & \kappa \\ \kappa & 1-\kappa \end{pmatrix} \begin{pmatrix} a_{t-1} \\ a_{t-1}^* \end{pmatrix} + \begin{pmatrix} \varepsilon_t^a \\ \varepsilon_t^{a,*} \end{pmatrix}.$$

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A VAR in levels or a VECM?

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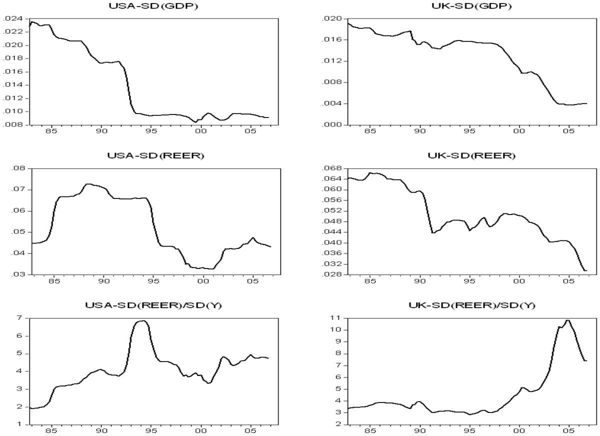

Figure: Standard Deviation of HP-Filtered Data. USA and UK.

The Great Moderation and the Real Exchange Rate

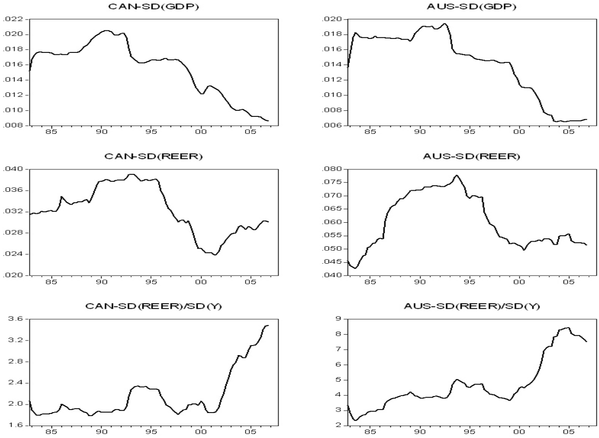

Figure: Standard Deviation of HP-Filtered Data. Canada and Australia.

Estimation of the VECM for TFP

Table: Subsample analysis

	1980 – 1993	1994 – 2007
c	0.007^{*}	0.008^{*}
κ	-0.008^{*}	-0.003
ρ_{11}^{1}	0.22^{*}	0.13
ρ_{11}^{2}	0.07	0.12
ρ_{12}^{1}	0.07	0.13
ρ_{12}^{2}	0.01	-0.36^{*}

* means significance at the 5 percent level

Table 7a: Results

	σ_Y	σ_C^+	σ_X^+	σ_N^+	σ_{RER}^+	$\rho(RER)$
1980-1993						
Data	1.57	0.80	3.08	0.89	3.97	0.85
Coint. TFP, $\theta = 0.85$	1.12	0.63	2.17	0.25	1.33	0.72
Coint. TFP, $\theta = 0.62$	0.95	0.65	2.15	0.25	3.17	0.71
1994-2007						
Data	0.83	0.76	4.20	0.96	5.17	0.81
Coint. TFP, $\theta = 0.85$	0.64	0.55	2.74	0.38	2.04	0.71
Coint. TFP, $\theta = 0.62$	0.62	0.43	3.01	0.42	5.06	0.69

$^+$ denotes relative to output.

Table 7b: Results

	CORR(Y,N)	CORR(Y,C)	CORR(Y,X)
1980-1993			
Data	0.82	0.82	0.93
Coint. TFP, $\theta = 0.85$	0.93	0.96	0.97
Coint. TFP, $\theta = 0.62$	0.91	0.96	0.96
1994-2007			
Data	0.71	0.76	0.90
Coint. TFP, $\theta = 0.85$	0.89	0.82	0.94
Coint. TFP, $\theta = 0.62$	0.94	0.78	0.97

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- If we allow the speed of convergence to the cointegrating vector to change as it does in the data, the model can also explain the observed increase in the relative volatility of the real exchange rate.
- Cointegration of TFP processes should be introduced in larger-scale models (Adolfson et al., 2007)