GLOBAL SOURCING AND DOMESTIC VALUE-ADDED IN EXPORTS

Edwin L.-C. Lai	Han (Steffan) Qi	Heiwai Tang
HKUST	HK Baptist University	Johns Hopkins University

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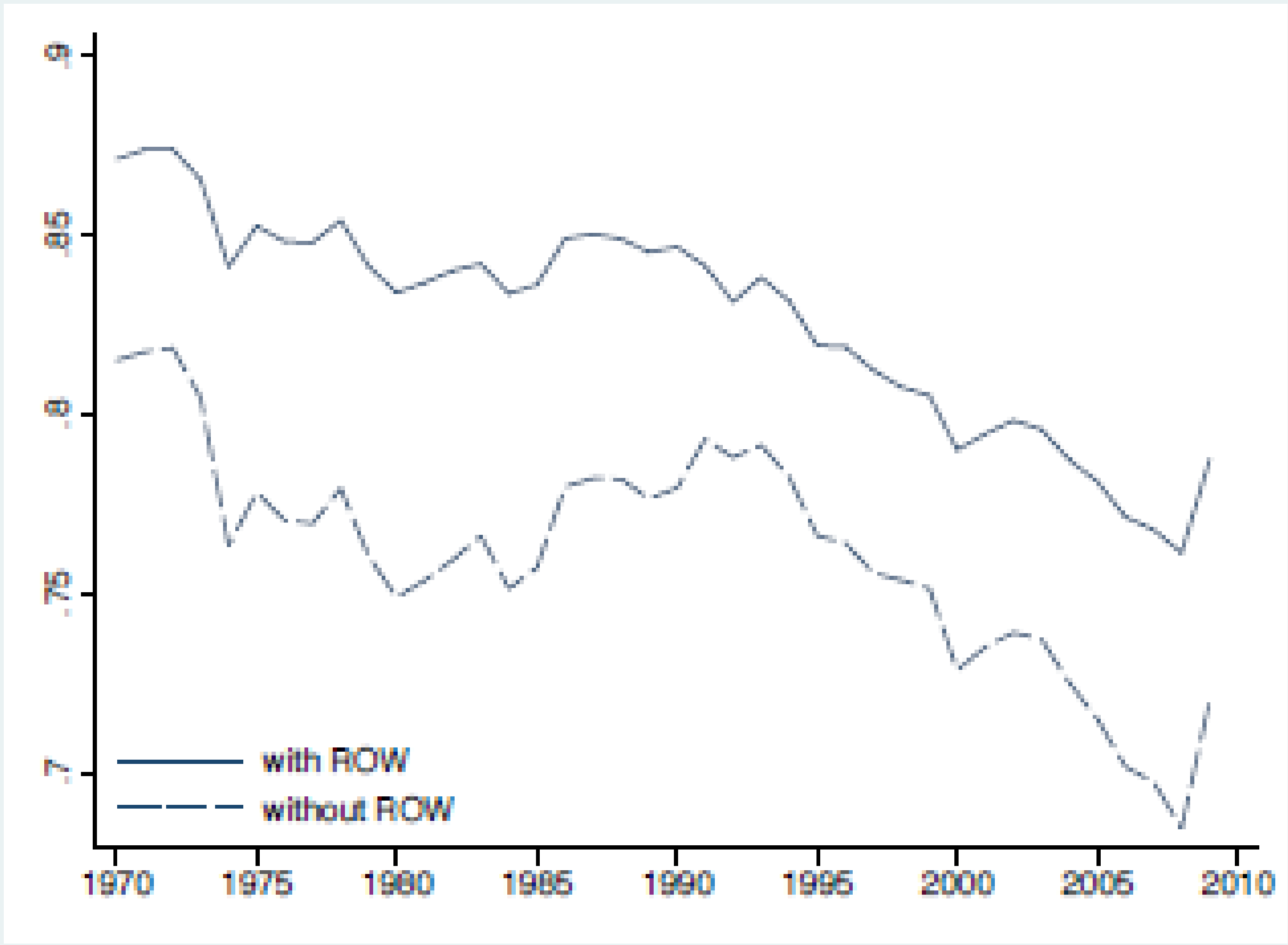
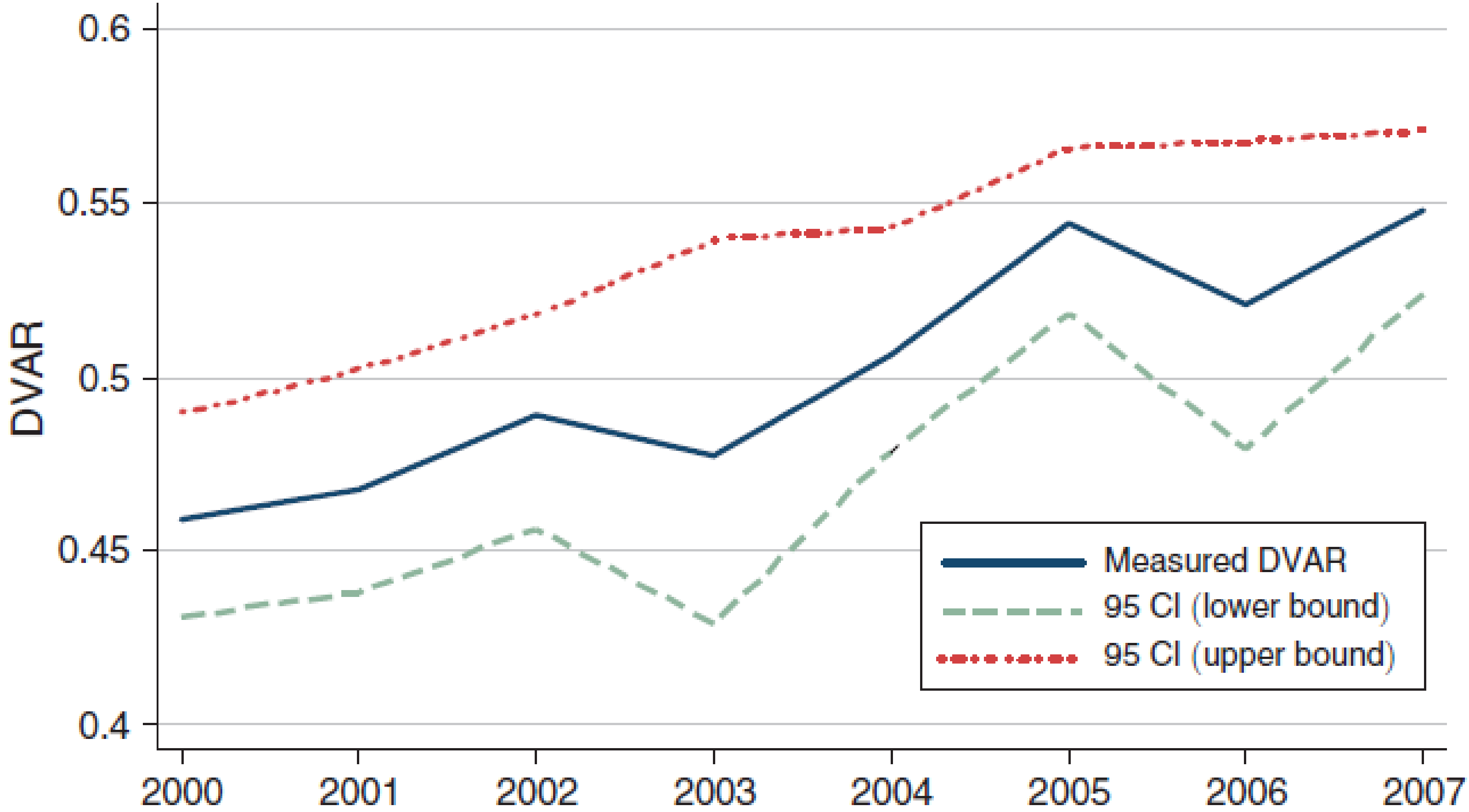
Preliminary Only.

Downward Trend in Domestic Value Added in Exports across the World



Source: Johnson and Noguera (2014)

China has recently defied the global trend



Kee and Tang (2016); also documented by Koopman, Wang and Wei (2012) for 2002 and 2007.

Misguided Policies?

- “The main drive is for countries to move up the value chain and become more specialised in knowledge-intensive, high value-added activities." (OECD, 2007)
- “Moving toward a more upstream position in production and raising economic complexity are associated with a growing share of GVC value added captured by countries." (IMF 2015)

What we do

- What contributes to a country's domestic content in exports, or its domestic value added ratio in exports (DVAR)?

- Build a multiple-sector Eaton-Kortum model with domestic and global input-output linkages (a la Caliendo-Parro) to quantify the determinants of individual countries' DVAR.

- Use the calibrated version of our model and the World Input-Output Database (WIOD) over 1995-2008 to fully decompose the changes in a country's and global DVAR due to (exogenous) changes in

  – Technology (T);

  – Trade costs (τ);

  – Other exogenous factors (factor endowments, trade imbalance)

  – (Endogenous) primary factor costs (w and r).

Related Literature

- Models of fragmentation
  - Baldwin (2006), Baldwin and Venables (2013); EK (2002); Alvarez and Lucas (2007); Yi (2003; 2010); Antras and Chor (2017)
- The measurement of global value chains.
  - Koopman, Wang and Wei (JDE 2008; AER 2014), Johnson and Noguera (2012), Johnson (2014); Timmer et al. (2014).
  - KWW (2012), Ma, Wang and Zhu (2015), Kee and Tang (2016)
- Bridging the two literatures
  - Antras and Chor (2017); Antras and de Gortari (2017); Johnson and Noguera (2017); Fally and Hillberry (2018); de Gortari (2018)

Model

- N countries; each country has potentially time-varying labor and capital endowments.
- J sectors. Output used as both final goods and intermediate inputs (with input-output linkages) anywhere.
- All countries have the capability to produce all intermediates and final goods.
- International trade is costly, and is country-pair-sector-pair specific
- Markets are perfectly competitive.
- Basically Caliendo-Parro (2015) with more flexible trade frictions.

Aggregates of Varieties

- In each country, the representative household aims to maximize the following utility function

$$U = \prod_{i=1}^{J} \left\{ \left[\int_0^1 \left(q^i(\omega) \right)^{\frac{\sigma^i - 1}{\sigma^i}} d\omega \right]^{\frac{\sigma^i}{\sigma^i - 1}} \right\}^{\alpha^i}, \text{ with } \sum_{i=1}^{J} \alpha^i = 1.$$

  – $q^i(\omega)$ stands for consumption of final good i of variety ω.

- The production function of variety ω of sector i in country n is given by

$$y_n^i(\omega) = z_n^i(\omega) \left[M_n^i(\omega) \right]^{1-\beta^i} \left\{ \left[l_n^i(\omega) \right]^{\mu^i} \left[k_n^i(\omega) \right]^{(1-\mu^i)} \right\}^{\beta_n^i}$$

  where $z_n^i(\omega)$ the efficiency of country n in producing variety ω of sector i.

- Production funciton of intermediate composite M_n^i (sector i and country n):

$$M_n^i = \prod_{k=1}^{J} \left\{ \left[\int_0^1 \left(q^k(\omega) \right)^{\frac{\sigma^k - 1}{\sigma^k}} d\omega \right]^{\frac{\sigma^k}{\sigma^k - 1}} \right\}^{\gamma_n^{ik}}, \text{ with } \sum_{k=1}^{J} \gamma_n^{ik} = 1.$$

– $q^k(\omega)$ is the quantity of sector-k intermediate input variety ω

Prices of Varieties

- Iceberg trade costs: $\tau_{mn}^{ji} > 1$; $j = F$ stands for final good trade costs; $\tau_{nn}^{ji} = 1$ for all i, j.

- Competitive price of a variety:

$$p_{nl}^{ji}(\omega) = \frac{\tau_{nl}^{ji} c_l^i}{z_l^i(\omega)} \qquad \text{for all } \omega \in [0,1],$$

where

$$c_l^i = \left(\frac{P_l^i}{1-\beta_l^i}\right)^{1-\beta_l^i} \left(\frac{w_l}{\beta_l^i \mu_l^i}\right)^{\beta_l^i \mu_l^i} \left(\frac{r_l}{\beta_l^i (1-\mu_l^i)}\right)^{\beta_l^i \left(1-\mu_l^i\right)}$$

- P_l^i = the price index of M_l^i, while w_l and r_l are the wage and rental cost of capital.

- A firm in sector-i and country l draws efficiency z_l^i, distributed Fréchet:

$$F\left(z_l^i < z\right) = e^{-T_l^i z^{-\theta}},$$

where T_l^i stands for country l's technology stock for sector i.

Aggregate Prices and Trade Shares

- Perfect competition: firms in country n will purchase the intermediates from the firm that offers the lowest cost across all possible source countries.

- Thanks to Fréchet distribution of z, the price index of intermediates in country n and sector j

$$P_n^j = \Upsilon_n^j \prod_{i=1}^{J} \left(p_n^{ji}\right)^{\gamma_n^{ji}} = \Upsilon_n^j \prod_{i=1}^{J} \left(\Phi_n^{ji}\right)^{-\frac{\gamma_n^{ji}}{\theta}},$$

where $\Upsilon_n^j = \prod_{i=1}^{J} \left(\gamma_n^{ii}\right)^{-\gamma_n^{ii}}$ is a constant and

$$\Phi_n^{ji} = \sum_l T_l^i \left(c_l^i \tau_{nl}^{ji}\right)^{-\theta}.$$

- For sector-j in country n, the cost share of intermediates i from country l in total costs spent on intermediates i:

$$\pi_{nl}^{ji} = \frac{T_l^i \left(c_l^i \tau_{nl}^{ji}\right)^{-\theta}}{\Phi_n^{ji}}$$

Expressions of DVAR

- Domestic value added (DVA) in sales (domestic or exports) includes

1. DVA from foreign countries embodied in imported intermediates;
2. DVA embodied in domestically-produced intermediates;
3. Primary factors directly employed (direct DVA) — capital and labor.

- Let r^i_{mn} = VAR (value-added ratio) of country n embodied in country m's production of sector-i goods:

$$\begin{aligned} r^i_{nn} &= \beta^i_n + (1-\beta^i_n)\sum_{h=1}^{N}\sum_{k=1}^{J}\pi^{ik}_{nh}\gamma^{ik}_n r^k_{hn} \\ \text{and } r^i_{mn} &= (1-\beta^i_m)\sum_{h=1}^{N}\sum_{k=1}^{J}\pi^{ik}_{mh}\gamma^{ik}_m r^k_{hn} \text{ for } m \neq n \end{aligned}$$

Expressions of DVAR in Matrix Form

- In matrix form:

$$\mathbf{r} = \left[r^i_{mn}\right] = \beta + (\mathbf{I} - \mathbf{B})\,\mathbf{G}\mathbf{r}$$
$$\Rightarrow \mathbf{r} = \left[\mathbf{I} - (\mathbf{I} - \mathbf{B})\,\mathbf{G}\right]^{-1}\beta$$

  where $\mathbf{r}$ is a $NJ \times N$ matrix of VAR of country n

- $\mathbf{B}$ is the $NJ \times NJ$ value-added share matrix with the diagonal element being β^i_n $(n = 1, ..., N;\ i = 1, ..., J)$, and other elements being zero.

- $\mathbf{G} = \left[\pi^{ik}_{nm}\gamma^{ik}_n\right]$ is the $NJ \times NJ$ global intermediate goods cost share matrix.

- $\beta = \left[\beta^i_n I_{mn}\right]$ is a $NJ \times N$ matrix (stacking up J number $N \times N$ matrixes each with element β^i_n when $m = n$ and 0 otherwise). (I_{mn} is an indicator function equal 1 when $m = n$ and 0 otherwise).

Decomposition of DVAR

- Recall that the DVAR matrix $\mathbf{r}$ satisfies

$$\mathbf{r} = \beta + (\mathbf{I} - \mathbf{B})\,\mathbf{G}\mathbf{r}$$

- Taking total derivative yields a decomposition of the yearly changes in the DVAR:

$$\begin{aligned} d\mathbf{r} &= d\beta - (d\mathbf{B})\,\mathbf{G}\mathbf{r} + (\mathbf{I} - \mathbf{B})\,(d\mathbf{G})\,\mathbf{r} + (\mathbf{I} - \mathbf{B})\,\mathbf{G}\,(\mathbf{dr}) \\ \Rightarrow d\mathbf{r} &= [\mathbf{I} - (\mathbf{I} - \mathbf{B})\,\mathbf{G}]^{-1}\,[d\beta - (d\mathbf{B})\,\mathbf{G}\mathbf{r}] \\ &\quad + [\mathbf{I} - (\mathbf{I} - \mathbf{B})\,\mathbf{G}]^{-1}\,(\mathbf{I} - \mathbf{B})\,(d\mathbf{G})\,\mathbf{r} \end{aligned}$$

- The first term of the RHS captures the pure effect of changing β_n^i
- The second term captures the effect of the changes in intermediate goods shares π_{nm}^{ik} and input-output coefficients γ_n^{ik}.

A 2 x 1 x 1 Toy Model

- 2 countries, with technology level T_i and wage w_i for country i, and $t = T_1/T_2$; $c = c_1/c_2$. Define $\tau_1 \equiv \tau_{12}$ and $\tau_2 \equiv \tau_{21}$.

- 1 primary factor of production (labor), one sector, and IO linkages.

- Trade Shares

$$\begin{aligned}
\pi_{11} &= \frac{tc^{-\theta}}{tc^{-\theta} + \tau_1^{-\theta}}, \pi_{12} = \frac{\tau_1^{-\theta}}{tc^{-\theta} + \tau_1^{-\theta}}, \\
\pi_{22} &= \frac{1}{1 + tc^{-\theta}\tau_2^{-\theta}}, \pi_{21} = \frac{tc^{-\theta}\tau_2^{-\theta}}{1 + tc^{-\theta}\tau_2^{-\theta}}.
\end{aligned}$$

- DVAR follows

$$\begin{aligned}
r_{11} &= \beta + (1 - \beta)(\pi_{11} r_{11} + \pi_{12} r_{21}) \\
r_{21} &= (1 - \beta)(\pi_{21} r_{11} + \pi_{22} r_{21})
\end{aligned}$$

Partial Effect on DVAR

- Totally differentiating gives

$$\begin{aligned} dr_{11} &= (1-\beta)(\pi_{11}dr_{11}+\pi_{12}dr_{21})+(1-\beta)(r_{11}-r_{21})\,d\pi_{11} \\ dr_{21} &= (1-\beta)(\pi_{21}dr_{11}+\pi_{22}dr_{21})-(1-\beta)(r_{11}-r_{21})\,d\pi_{22} \end{aligned}$$

  which leads to

$$dr_{11} = Ad\pi_{11} - Bd\pi_{22}$$

  where $A > B > 0$.

- Taylor series expansion of $d\pi_{11}$ and $d\pi_{22}$ up to the second order derivative gives the decomposition of effects on DVAR, r_{11} , due to different forces

Pure and Interactive Effects

Rearranging the terms and ignoring the second order effects on c, the effect on r_{11} can be decomposed into

- Pure effect of technology

$$(C + D)\frac{dt}{t} - [C\pi_{11} + D\pi_{21}]\left(\frac{dt}{t}\right)^2$$

where C, $D > 0$.

- Pure effect of trade frictions

$$-C\left[\frac{d\left(\tau_1^{-\theta}\right)}{\tau_1^{-\theta}} - \pi_{12}\left(\frac{d\left(\tau_1^{-\theta}\right)}{\tau_1^{-\theta}}\right)^2\right] + D\left[\frac{d\left(\tau_2^{-\theta}\right)}{\tau_2^{-\theta}} - \pi_{21}\left(\frac{d\left(\tau_2^{-\theta}\right)}{\tau_2^{-\theta}}\right)^2\right]$$

- Interactive effect of technology and trade frictions

$$C\left(\pi_{11} - \pi_{12}\right)\left(\frac{dt}{t}\right)\left(\frac{d\left(\tau_1^{-\theta}\right)}{\tau_1^{-\theta}}\right) + D\left(\pi_{22} - \pi_{21}\right)\left(\frac{dt}{t}\right)\left(\frac{d\left(\tau_2^{-\theta}\right)}{\tau_2^{-\theta}}\right)$$

where $C = A\pi_{11}\left(1 - \pi_{11}\right)$ and $D = B\pi_{22}\left(1 - \pi_{22}\right)$

Major Source of Data

Use 2013 edition of the World Input-Output (WIOD) Database

- $J = 40$ countries + ROW
- $S = 35$ industries/sectors
- $T = 14$ years: 1995-2008
- A model to map the yearly changes in the $NJ \times NJ$ (2,059,225) global intermediate goods cost share matrix $\mathbf{G}$ due to changes in intermediate goods shares π_{nm}^{ik}

Taking the Model to Data

- We estimate the change in competitiveness (relative to the US) using the following gravity equation, which is derived from the model:

$$\ln\left(\frac{\pi_{nlt}^{ji}}{\pi_{nnt}^{ji}}\right) = \ln\left(T_{lt}^{i}\left(c_{lt}^{i}\right)^{-\theta}\right) - \theta e x_{lt}^{i} - \ln\left(T_{nt}^{i}\left(c_{nt}^{i}\right)^{-\theta}\right) - \theta v_{nlt}^{ji}$$

- The estimated asymmetric bilateral trade costs $\{\tau_{nl}^{ji}\}$ is obtained from the gravity estimation based on

$$\ln \tau_{nlt}^{ji} = e x_{lt}^{i} + v_{nlt}^{ji}$$

- The data are directly obtained from the WIOD table or PWT9.0 (Penn World Table).

Solving for the Equilibrium

- Following Dekle, Eaton, and Kortum (2008), we use hat algebra to characterize the equilibrium changes. $\widehat{x} = x'/x$

- For each year, use the estimated $\{\widehat{T}_l^i \left(\widehat{c}_l^i\right)^{-\theta}\}$ and $\{\widehat{\tau}_{nl}^{ji}\}$ as initial values. Start with a guess of $\{\widehat{w}_l\}$ and $\{\widehat{r}_l\}$, solve for $\{\widehat{c}_l^i\}$ and $\left\{\widehat{P}_l^i\right\}$ as follows:

$$\widehat{c}_l^i = \left(\widehat{P}_l^i\right)^{1-\beta_l^i} \left(\widehat{w}_l\right)^{\beta_l^i \mu_l^i} \left(\widehat{r}_l\right)^{\beta_l^i \left(1-\mu_l^i\right)}$$

$$\widehat{P}_n^j = \prod_{i=1}^{J} \left(\widehat{p}_n^{ji}\right)^{\gamma_n^{ji}}$$

$$\widehat{p}_n^{ji} = \left[\sum_{l=1}^{N} \pi_{nl}^{ji} \widehat{T}_l^i \left(\widehat{c}_l^i \widehat{\tau}_{nl}^{ji}\right)^{-\theta}\right]^{-\frac{1}{\theta}}$$

- We can thus get the changes in trade shares $\{\widehat{\pi}_{nl}^{ji}\}$, and thus the new trade shares $\pi_{nl}^{ji\prime} = \pi_{nl}^{ji} * \widehat{\pi}_{nl}^{ji}$ from

$$\widehat{\pi}_{nl}^{ji} = \widehat{T}_l^i \left(\frac{\widehat{c}_l^i \widehat{\tau}_{nl}^{ji}}{\widehat{p}_n^{ji}} \right)^{-\theta}$$

Constraints

- The total expenditure on final goods is equal to total output plus trade deficit:

$$E'_n = w'_n L'_n + r'_n K'_n + D'_n$$

where D_n is trade deficit.

- Total production of each sector in each country $\{(X^i_n)'\}$

$$(X^i_n)' = \sum_{k=1}^{J} \sum_{m=1}^{N} \left(1-\beta^k_m\right) \gamma^{ki}_m \left(\pi^{ki}_{mn}\right)' \left(X^k_m\right)' + \sum_{m=1}^{N} \left(\pi^{Fi}_{mn}\right)' \alpha^i_m E'_m$$

- Capital and labor market clearing conditions

$$\begin{aligned} r'_n K'_n &= \sum_{i=1}^{J} \beta^i_n \left(1-\mu^i_n\right) \left(X^i_n\right)' \\ w'_n L'_n &= \sum_{i=1}^{J} \beta^i_n \mu^i_n \left(X^i_n\right)' \end{aligned}$$

- We solve for $\{\widehat{w}_l\}$ and $\{\widehat{r}_l\}$.

- Repeat the entire process until $\{\widehat{w}_l\}$ and $\{\widehat{r}_l\}$ converge.

- K_n', L_n' and μ_n^i are directly obtained from the WIOD table of each year and PWT9.0.
- $\{\widehat{c}_l^i\}, \left\{\widehat{P}_l^i\right\}, \{\widehat{w}_l\}$, $\{\widehat{r}_l\}$ and thus $\{\widehat{T}_l^i\}$ are solved from the general equilibrium described previously

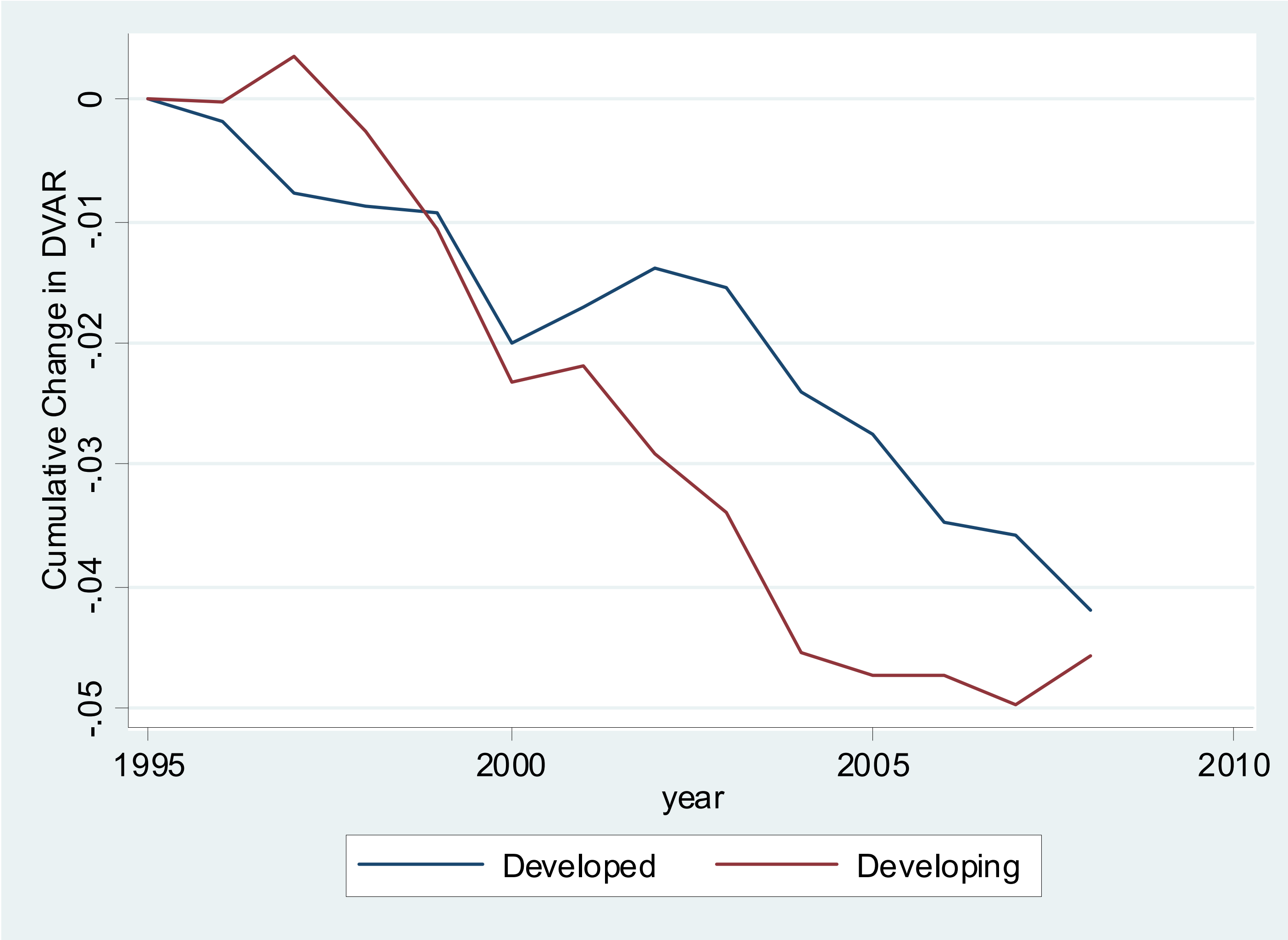


Figure 1: Developed and Developing Countries' DVAR

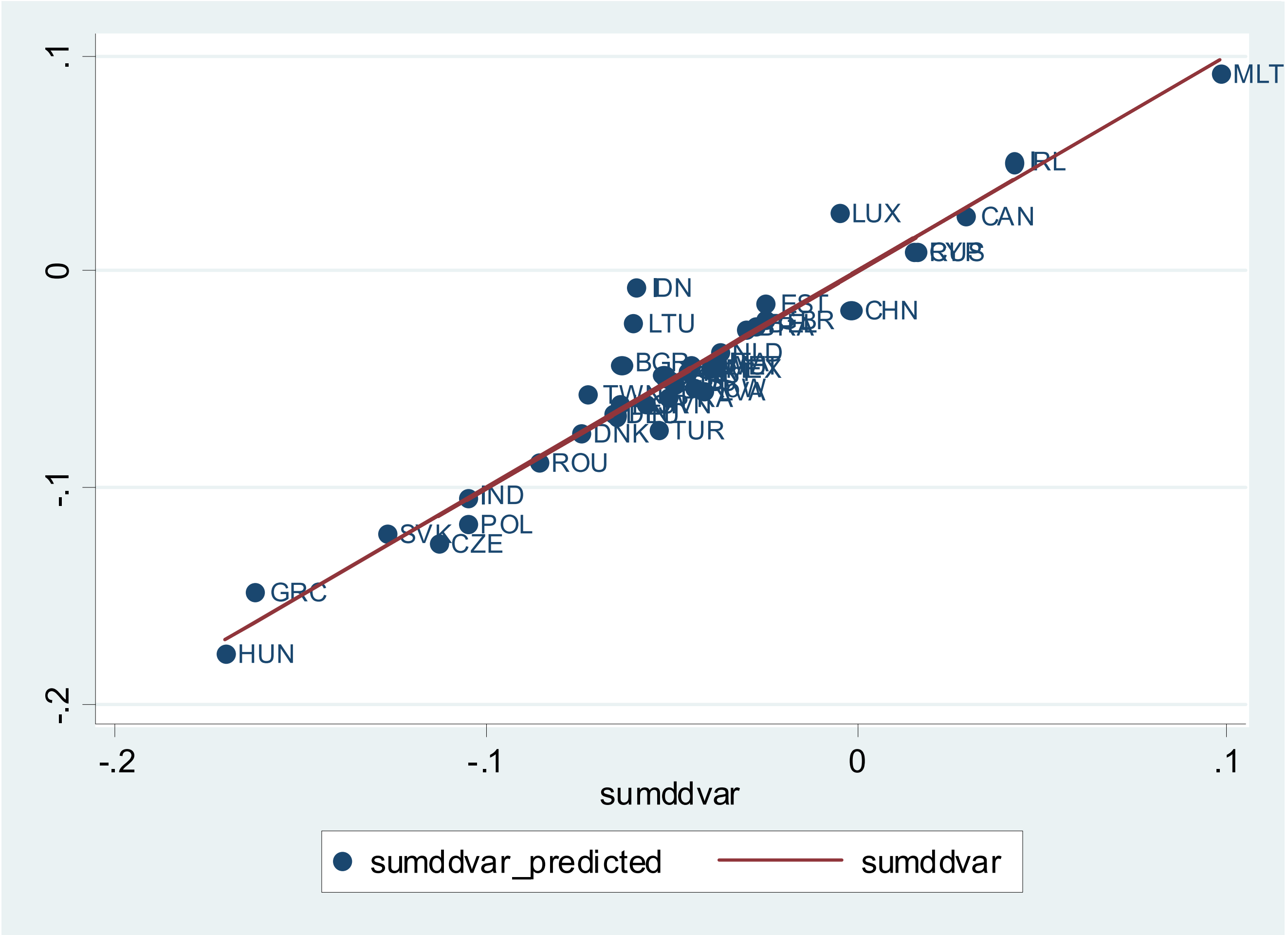


Figure 2: Fit of the Calibration.

The vertical axis is our prediction and the horizontal axis is the data. The fit is very good.

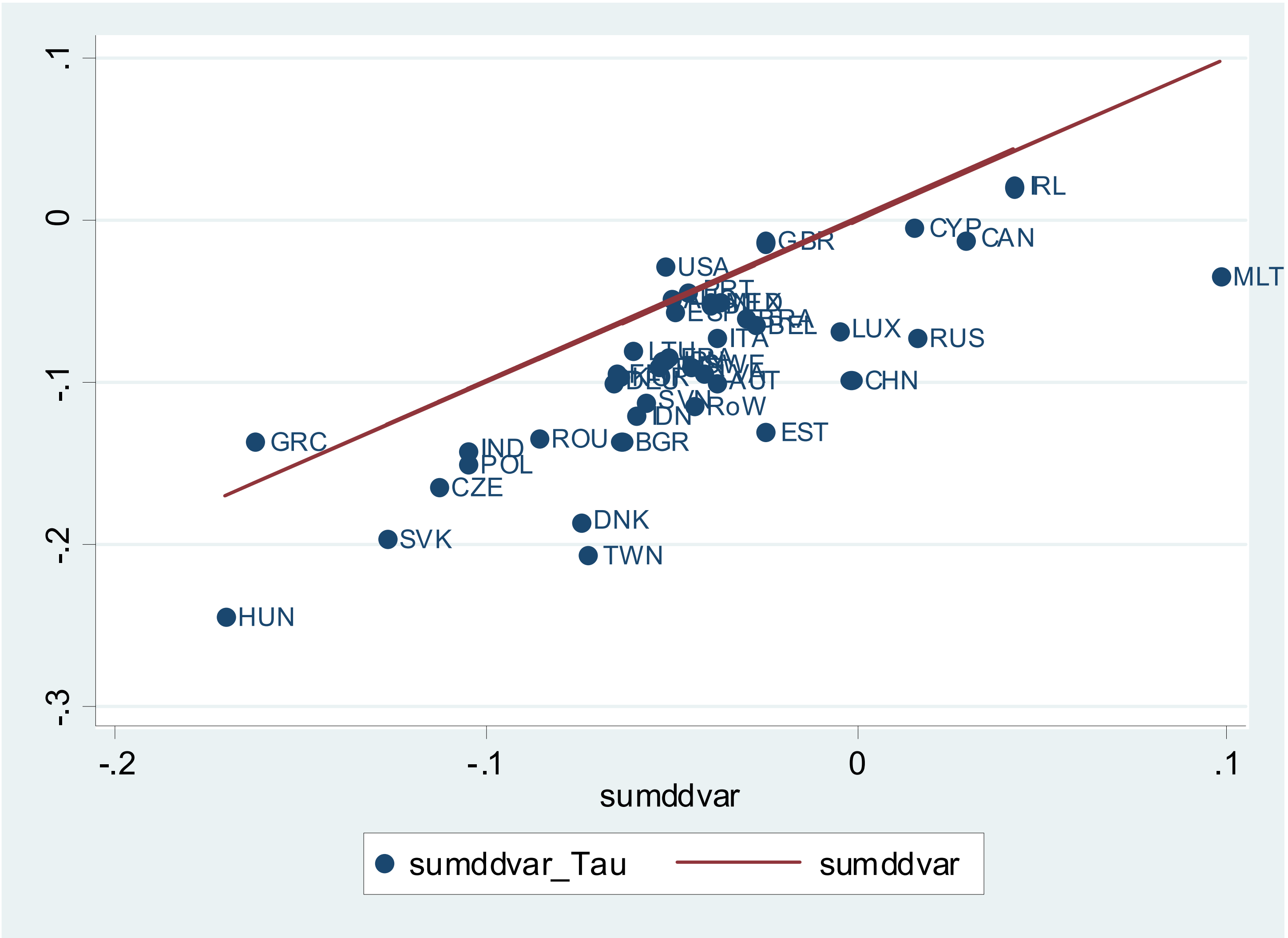


Figure 3: The Pure (Stand-alone) Effect of Changes in τ.
The pure (stand-alone) effect of changes in trade costs does not fit the data very well.

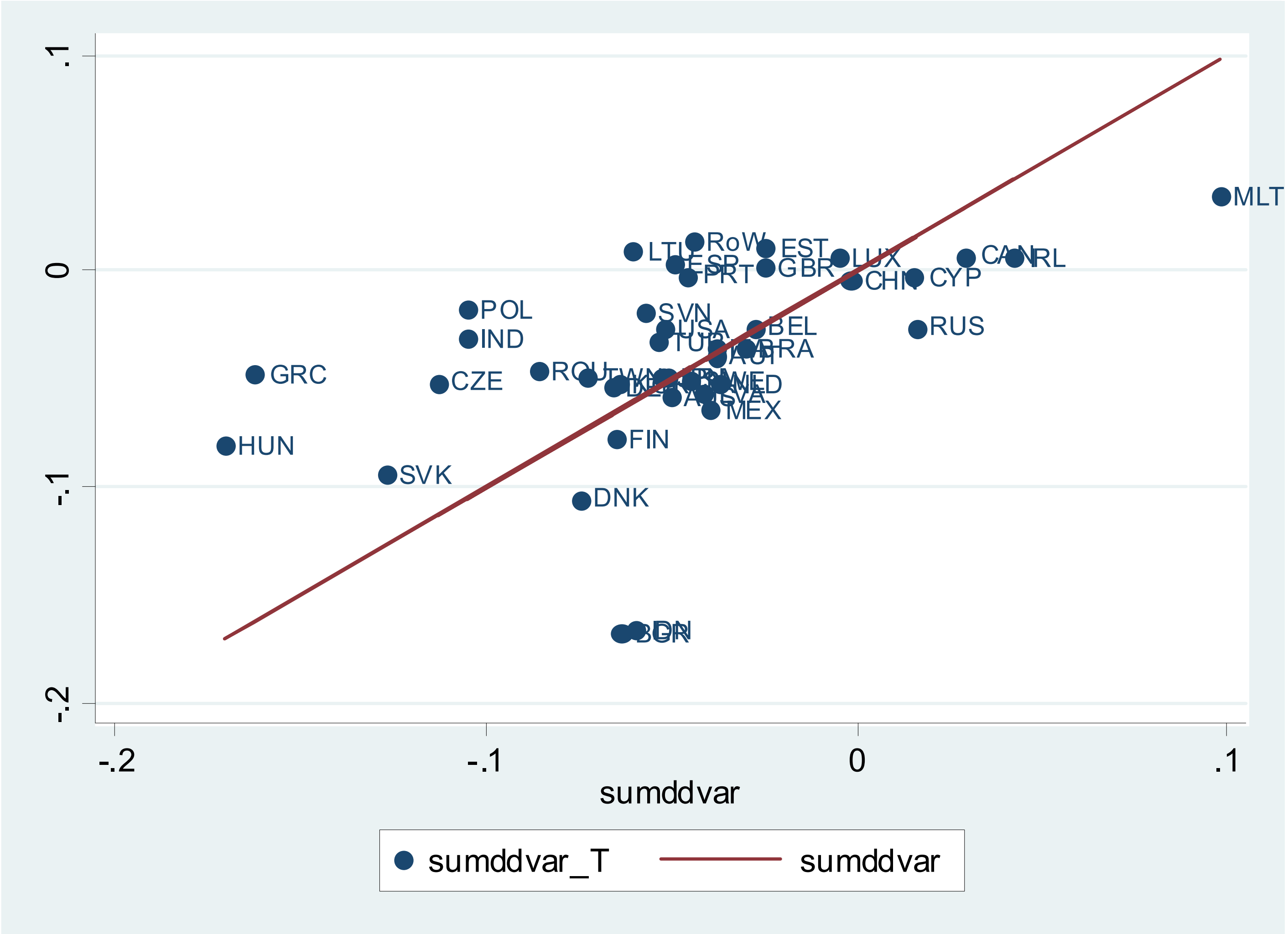


Figure 4: Pure Effect of Changes in T.

The pure effect of changes in technology stocks also does not fit the data well.

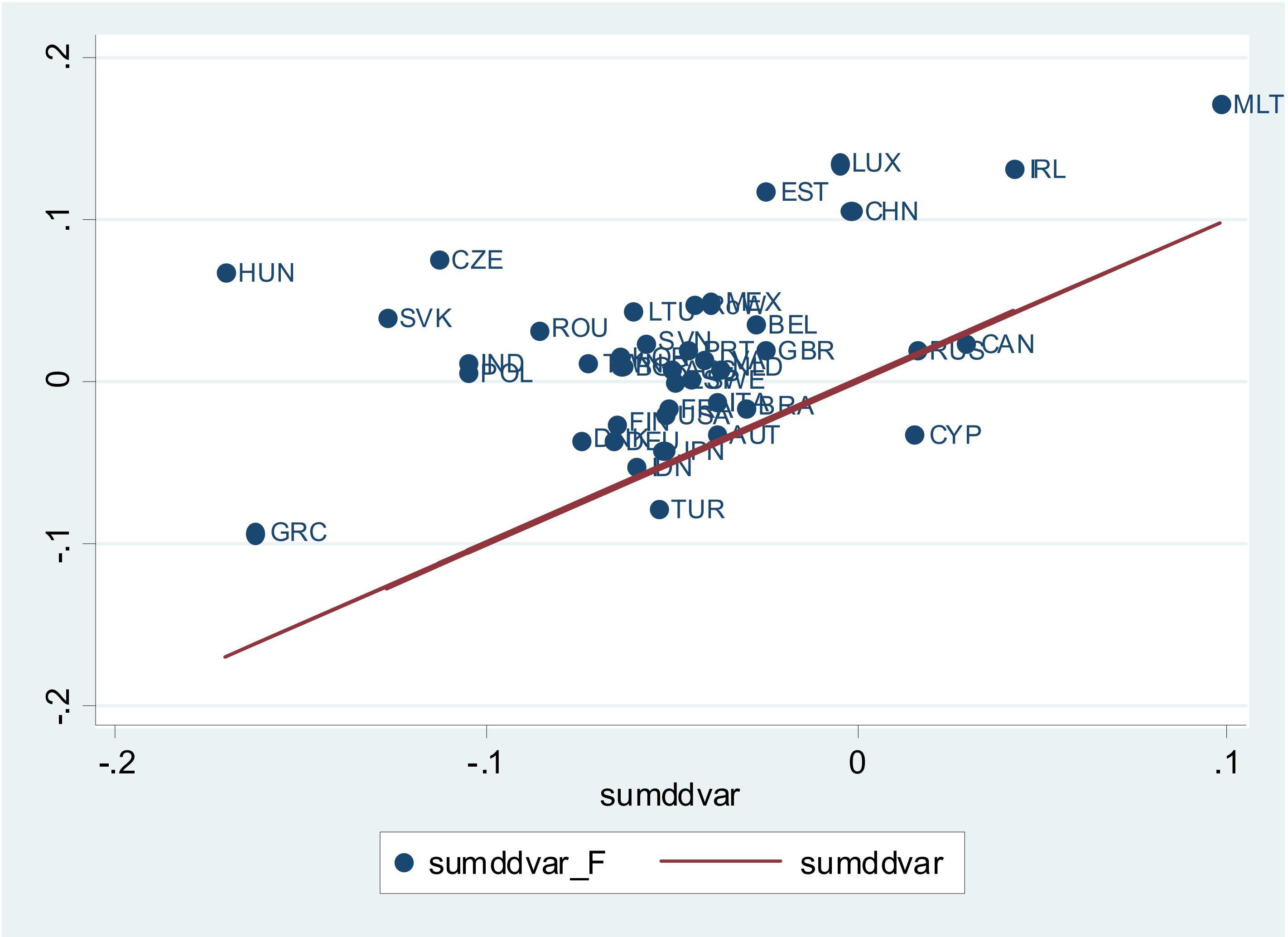


Figure 5: Pure Effects of Changes in Other Factors (i.e. K, L and trade balance). The pure effect of "other factors" provides the poorest fit among the three sets of factors.

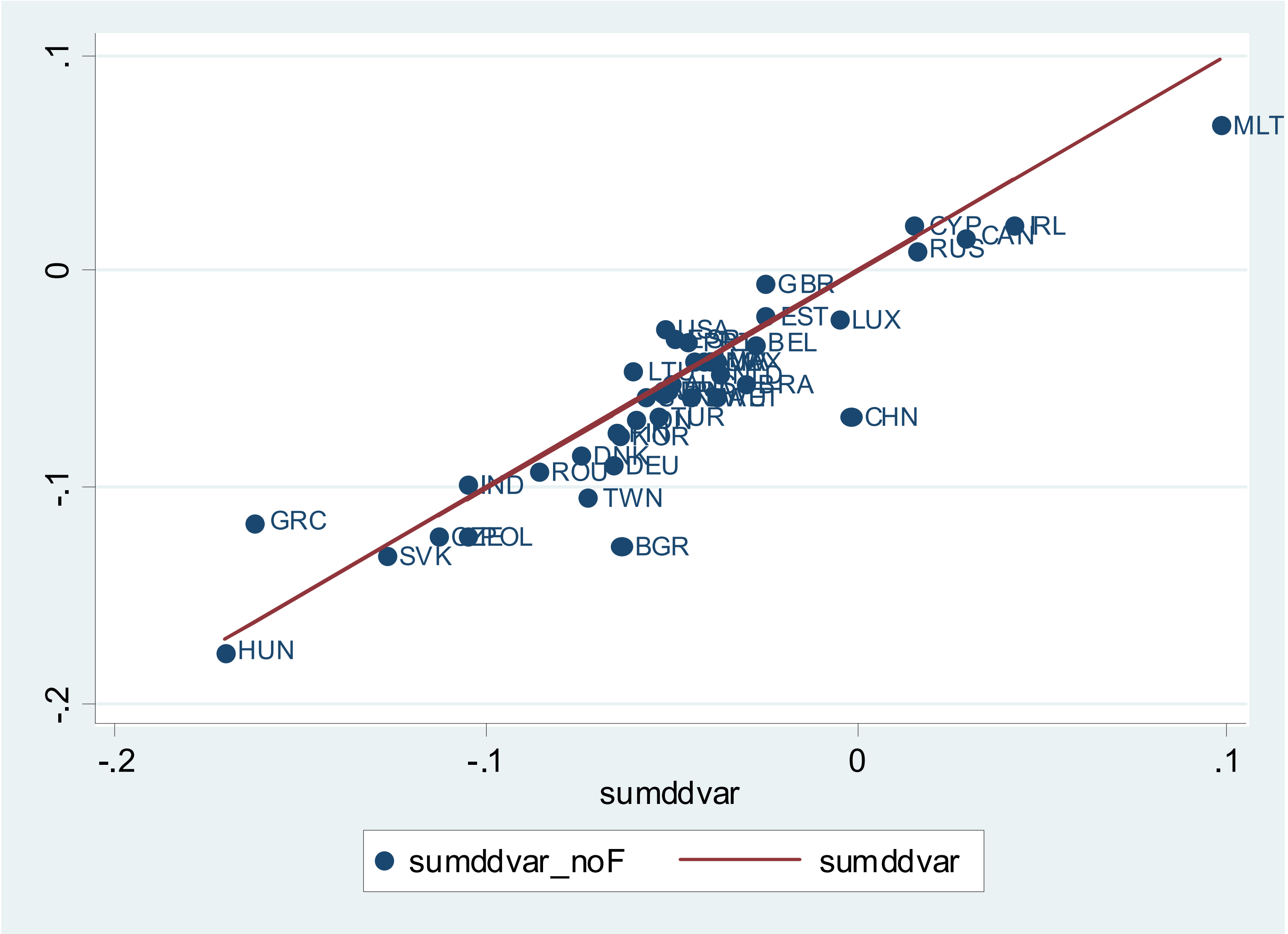


Figure 6: Counterfactuals of Shutting Down Other Factors

Decomposition Results

- Percentage-point Changes in DVAR (1995-2008)

	Global	Developed	Developing
Total	-4.36	-4.20	-4.58
due to changes in			
Technology (stand-alone)	-2.78	-3.25	-2.28
Trade Costs (stand-alone)	-8.03	-5.84	-10.62
Other Factors (stand-alone)	0.94	-0.69	2.75
Tech * Trade Costs	5.79	4.82	6.99
Tech * Other Factors	-0.72	0.42	-1.98
Trade Costs * Other Factors	-0.86	0.41	-2.27
All Three Forces	1.05	-0.14	2.38
Residual	0.25	0.07	0.45

Total Effects

- Percentage-point Changes in DVAR (1995-2008)

	Global	Developed	Developing
Total	-4.36	-4.20	-4.58
total effect of			
Technology	3.34	1.84	5.11
Trade Costs	-2.05	-0.74	-3.52
Other Factors	0.40	0.01	0.88

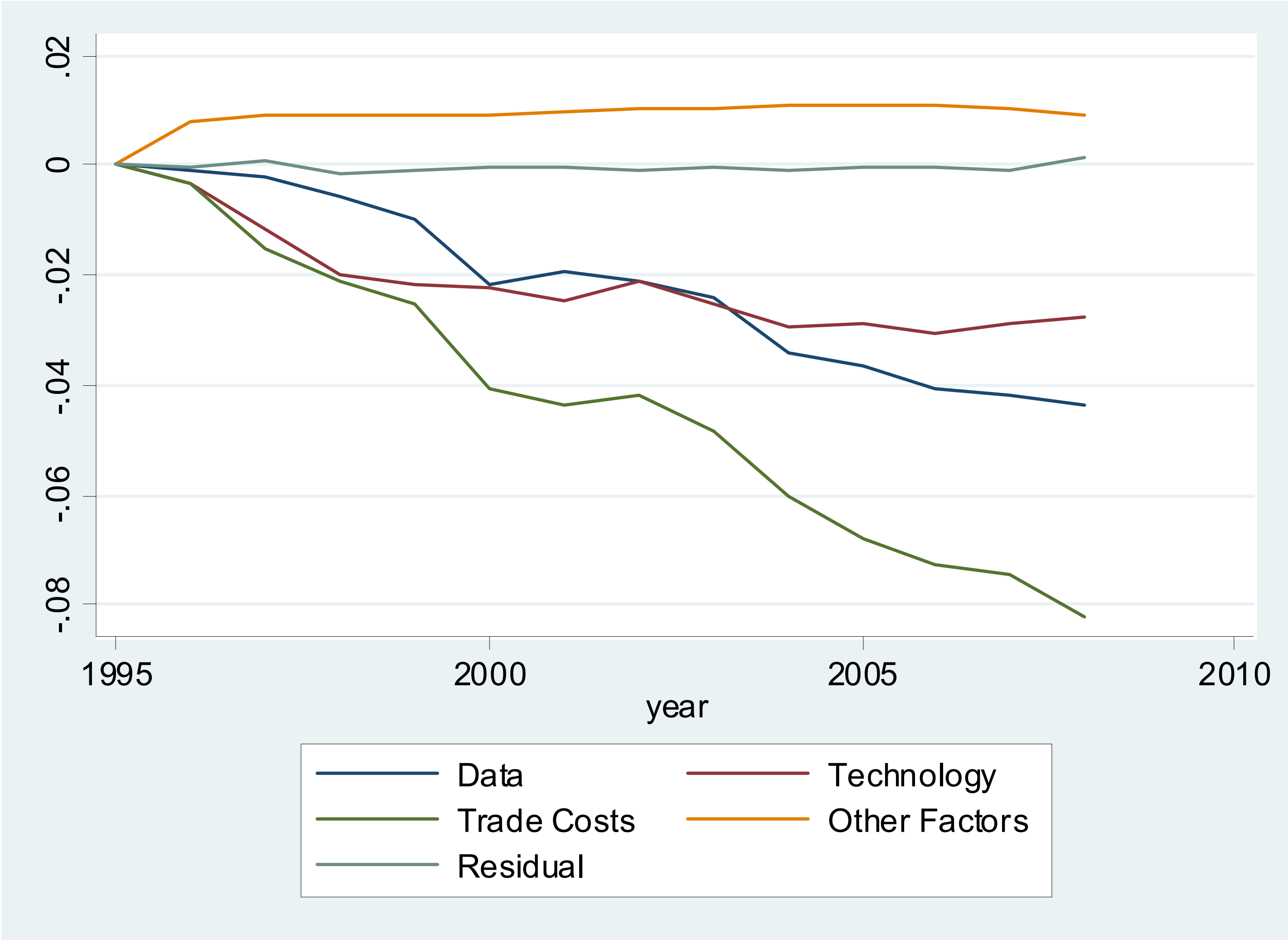


Figure 7: Different Pure Effects on Global DVAR

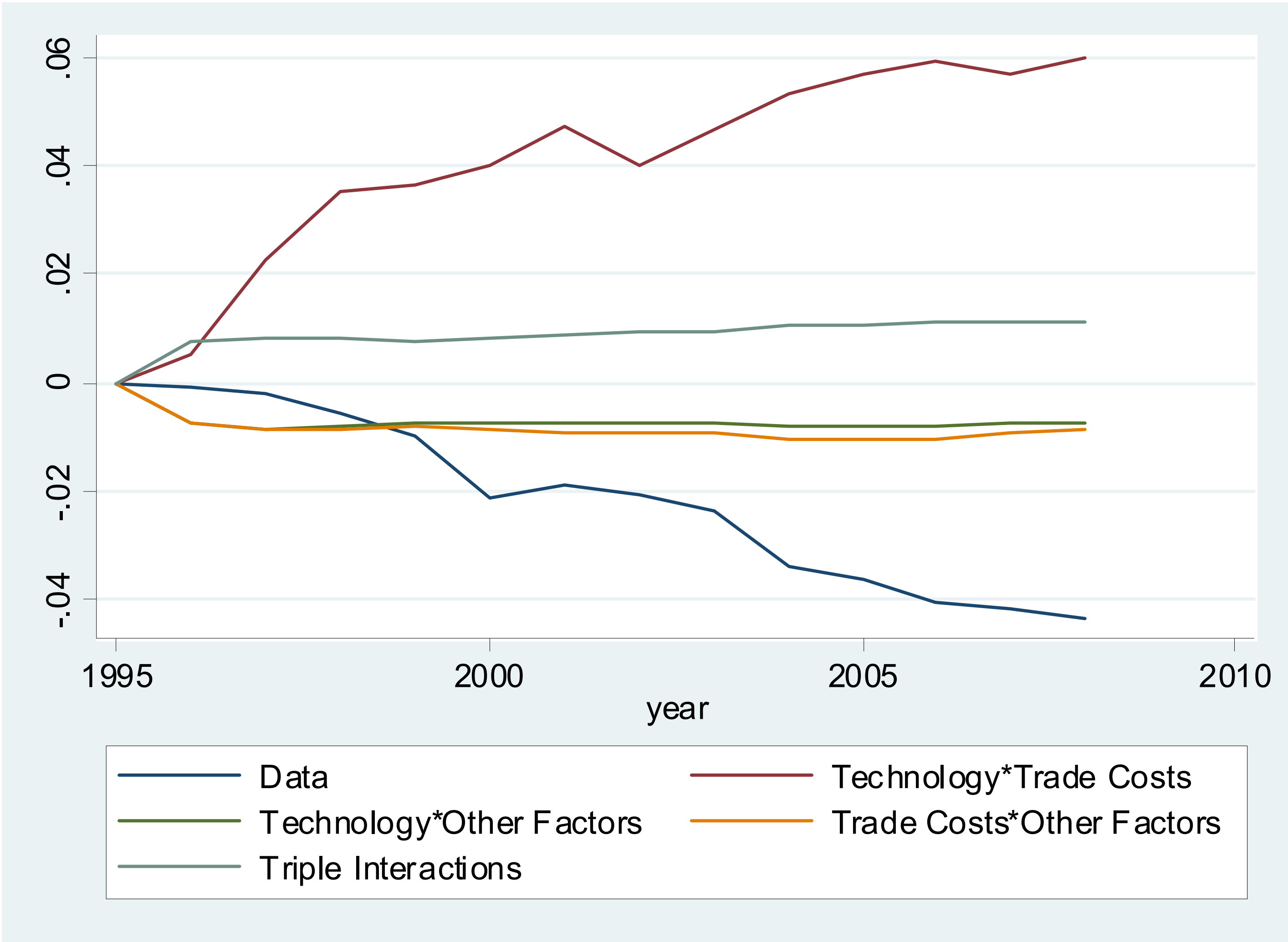


Figure 8: Effects of Interaction Terms on Global DVAR

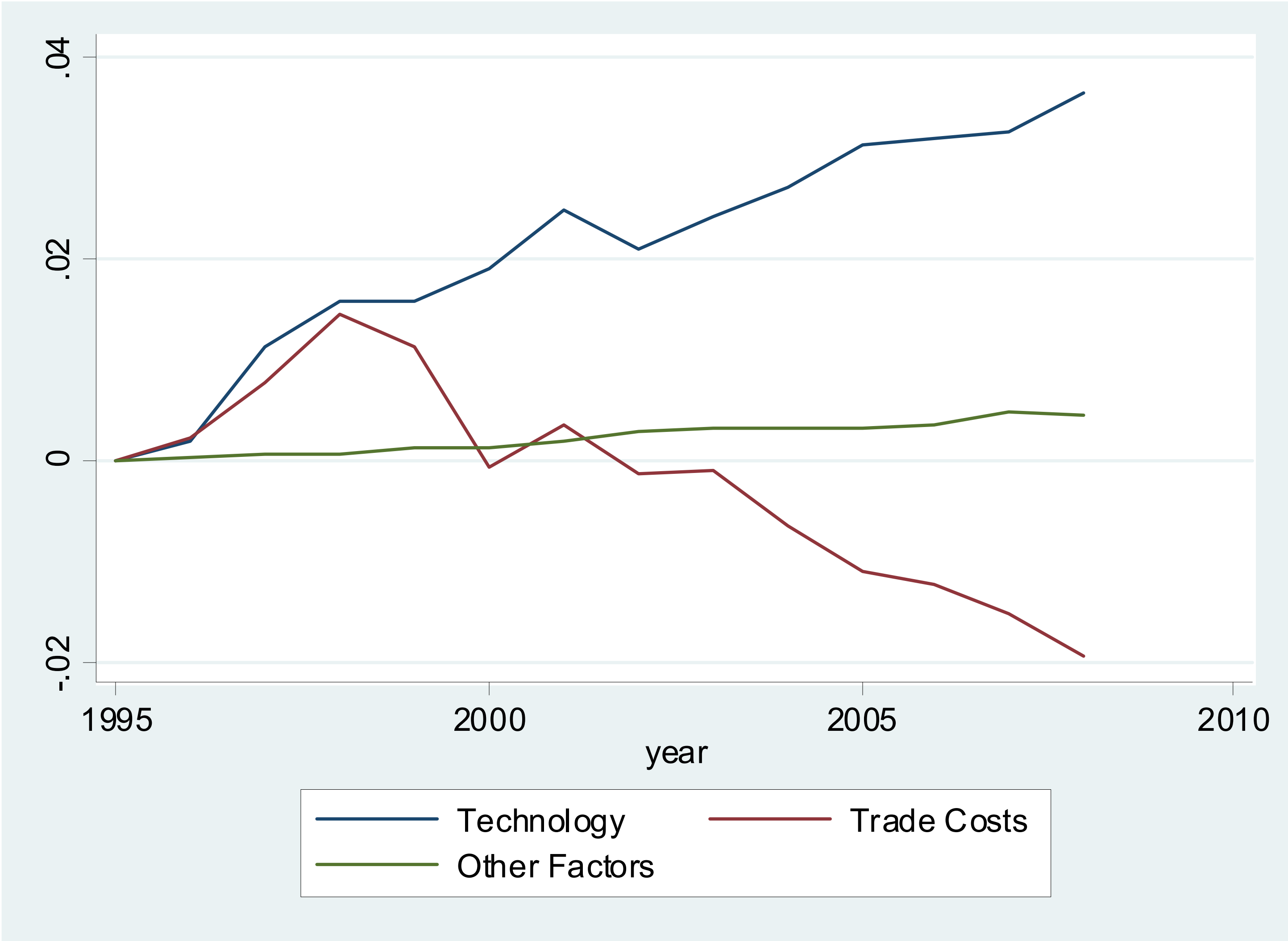


Figure 9: Total Effects of T, τ, and Other Factors on Global DVAR

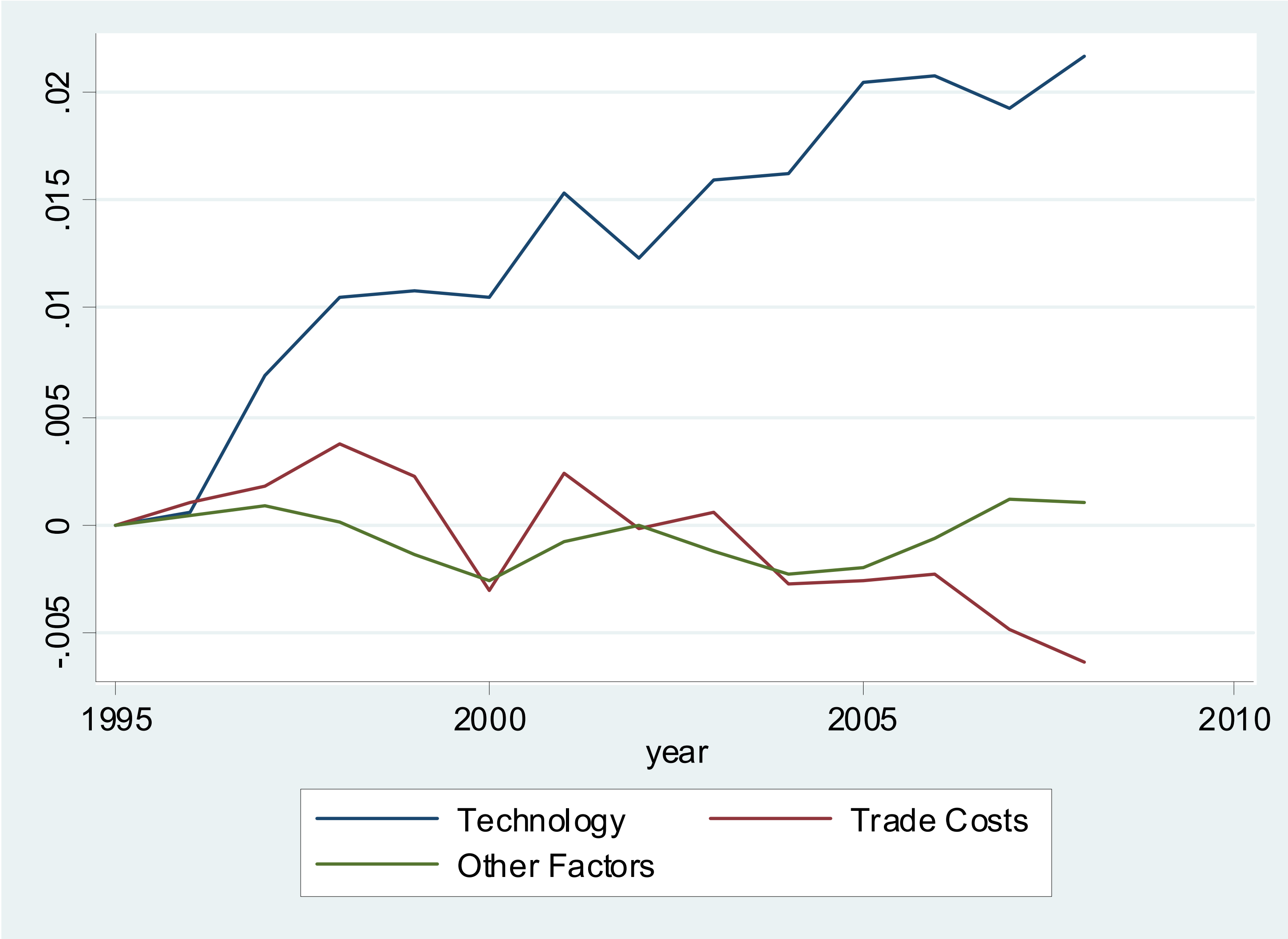


Figure 10: Total effects of T, τ and other factors for Developed Countries

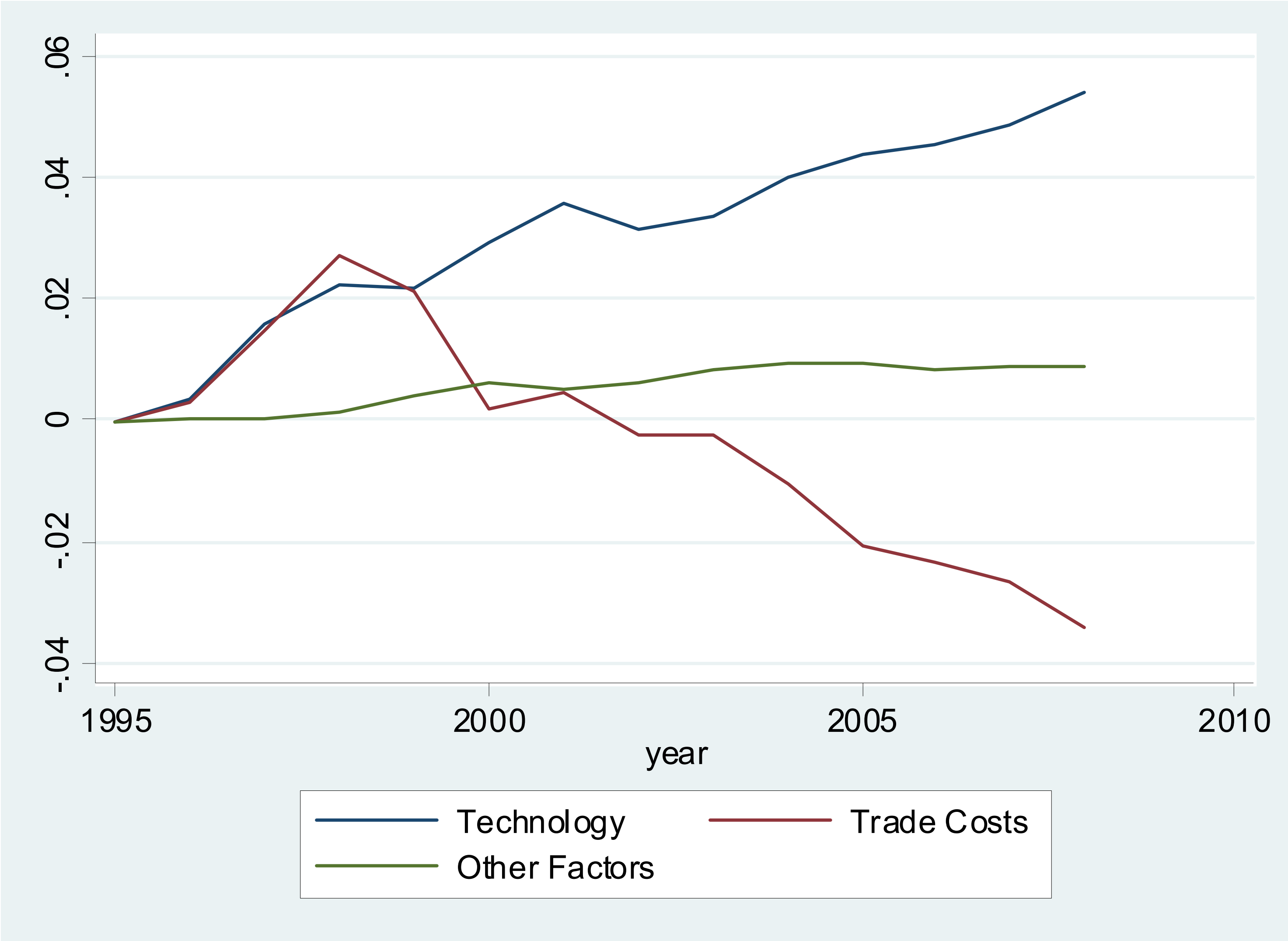


Figure 11: Total effects of T, τ and other factors on Developing Countries

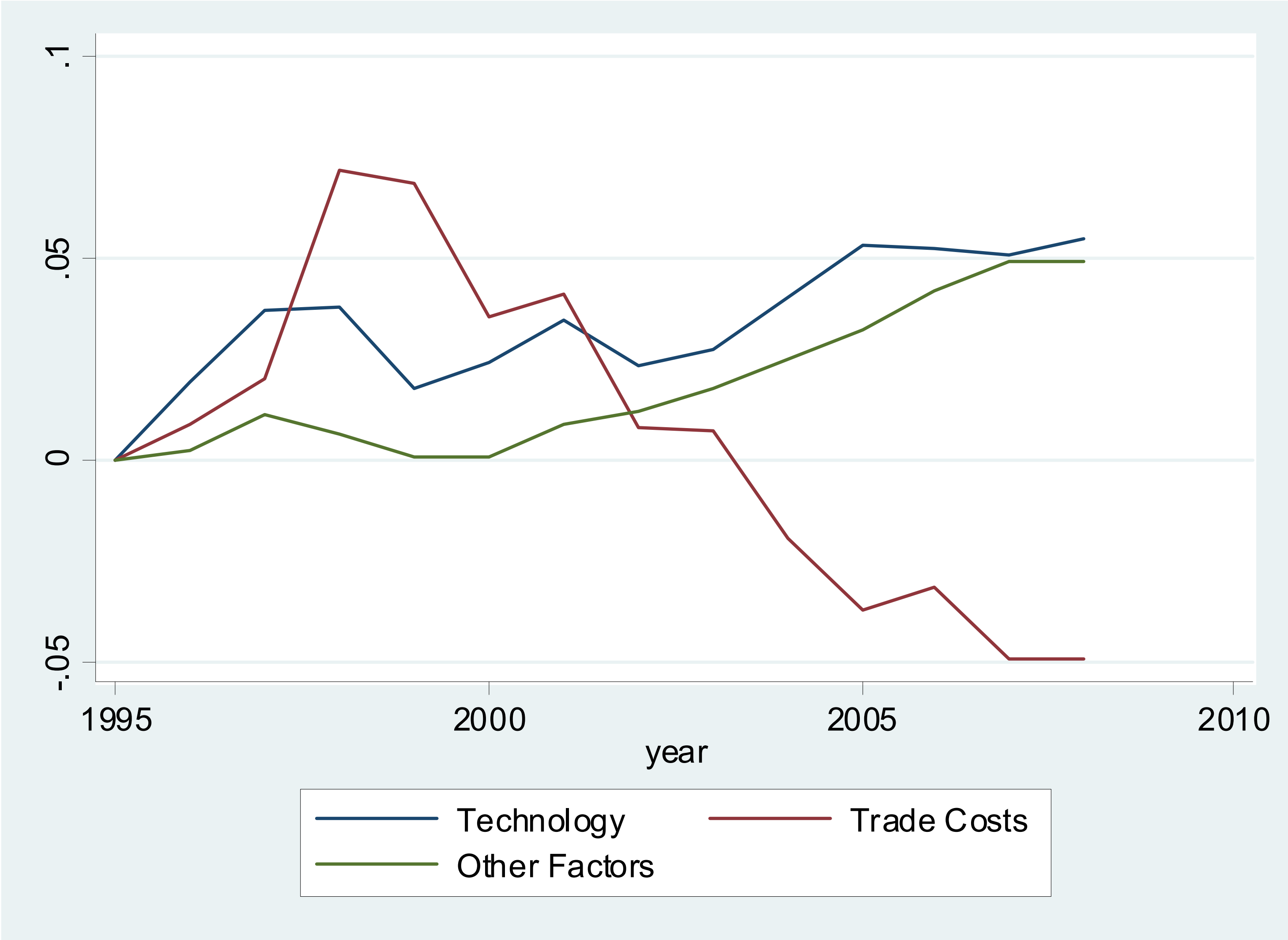


Figure 12: Total effects of T, τ and other factors on China

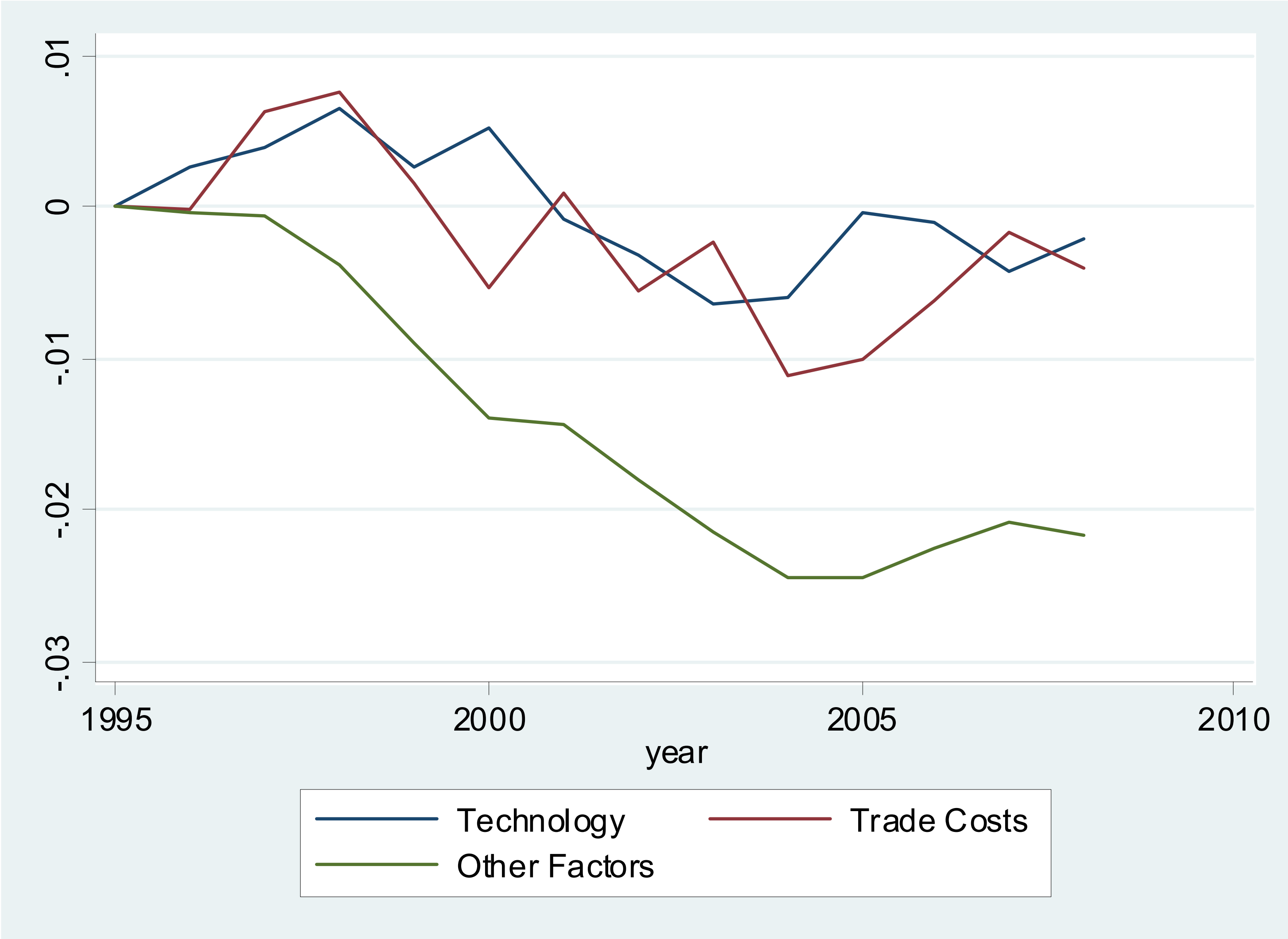


Figure 13: Total effects of T, τ and other factors on the US

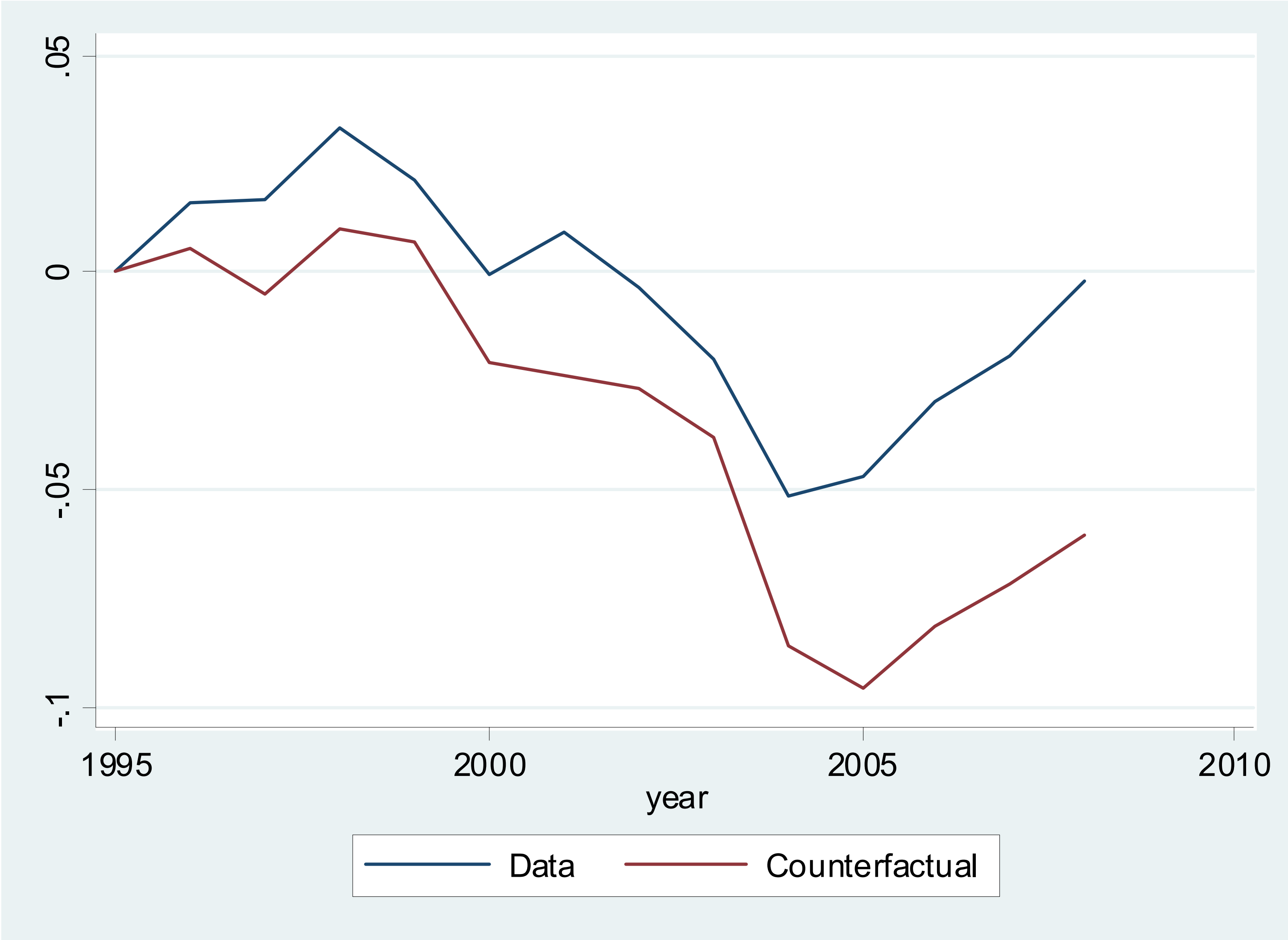


Figure 14: Effects of Shutting Down Changes in China's T on China's DVAR

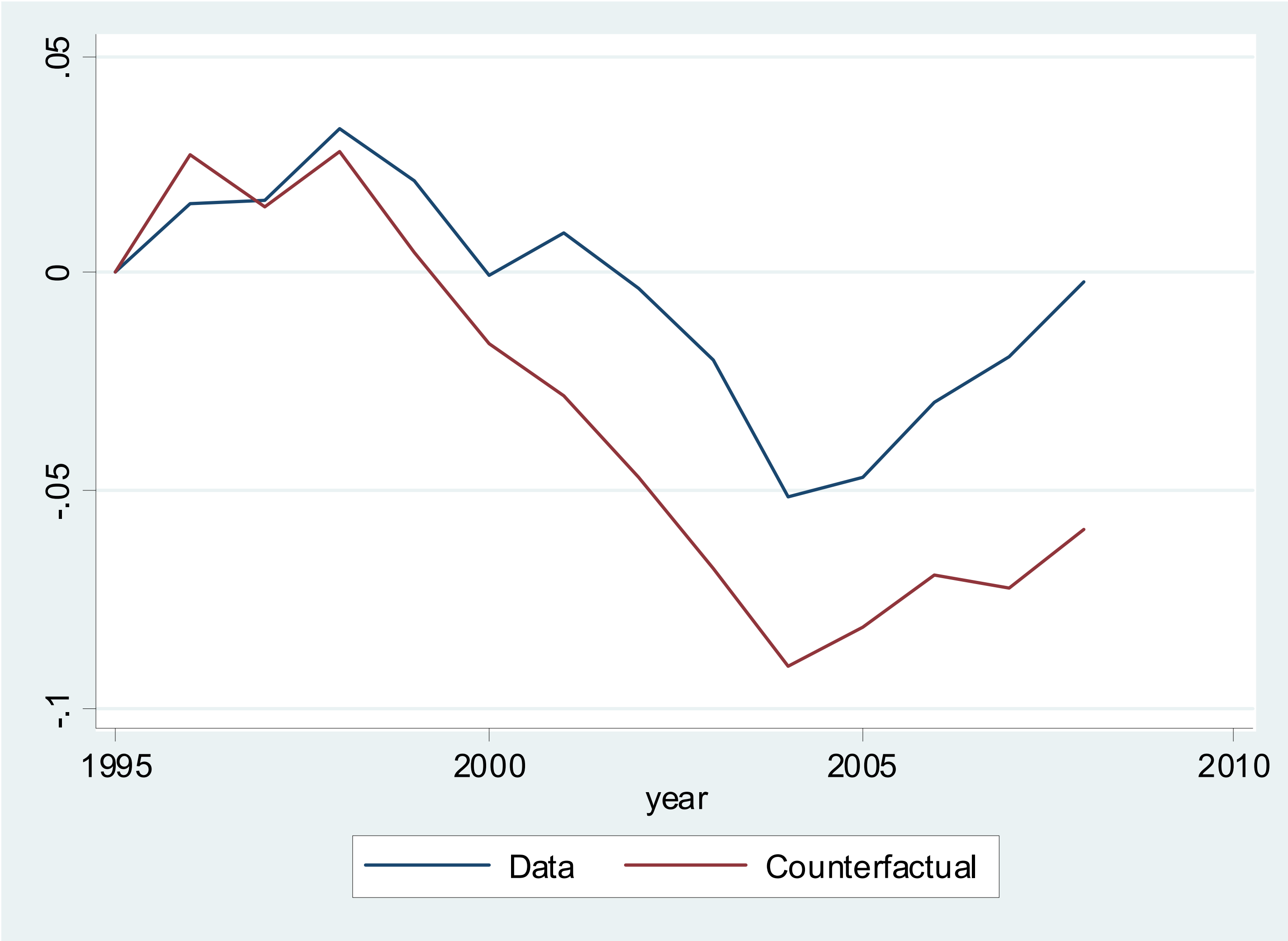


Figure 15: Effects of Shutting Down Changes in China's τ on China's DVAR

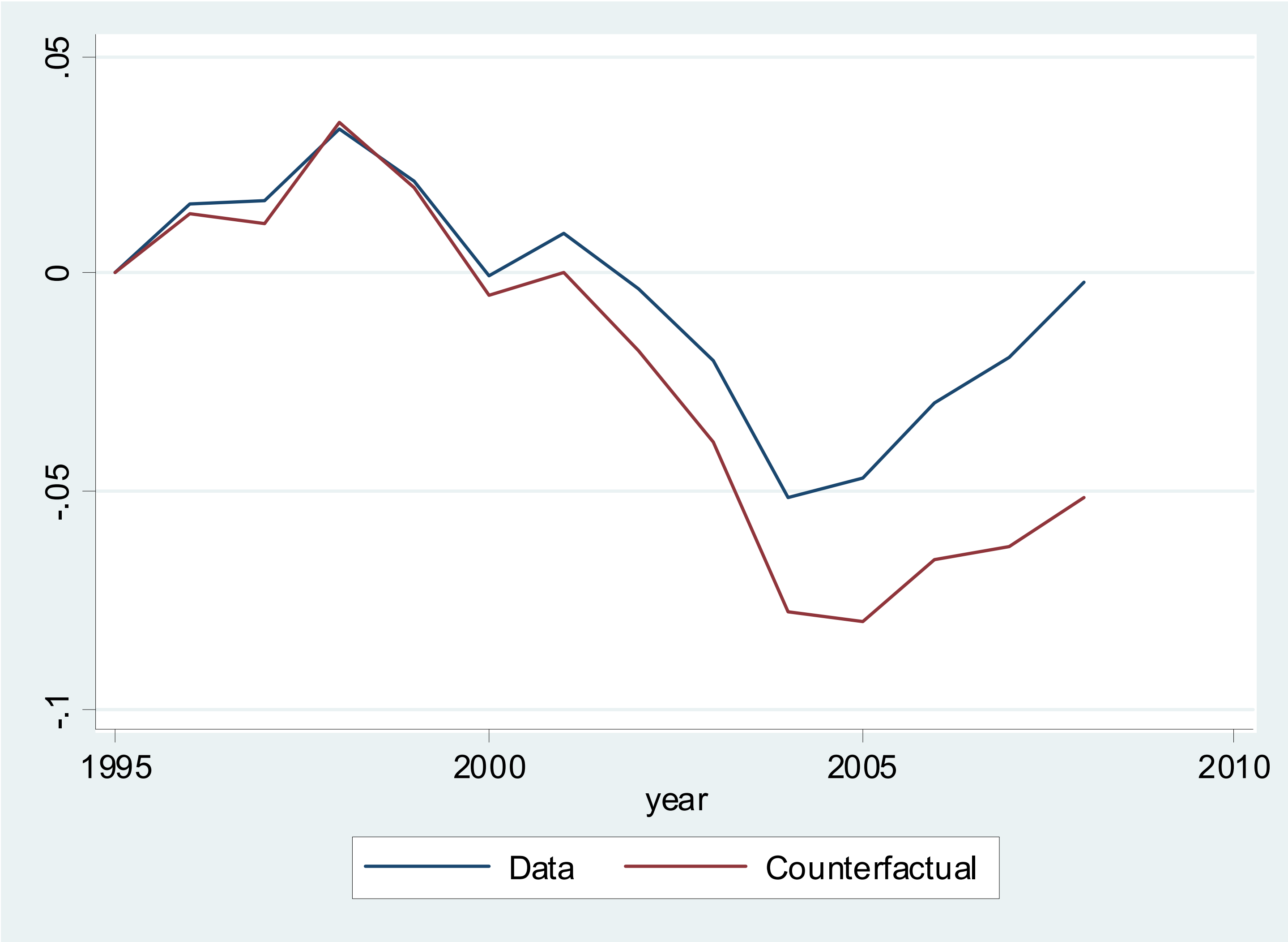


Figure 16: Effects of Shutting Down Changes in China's Capital on China's DVAR

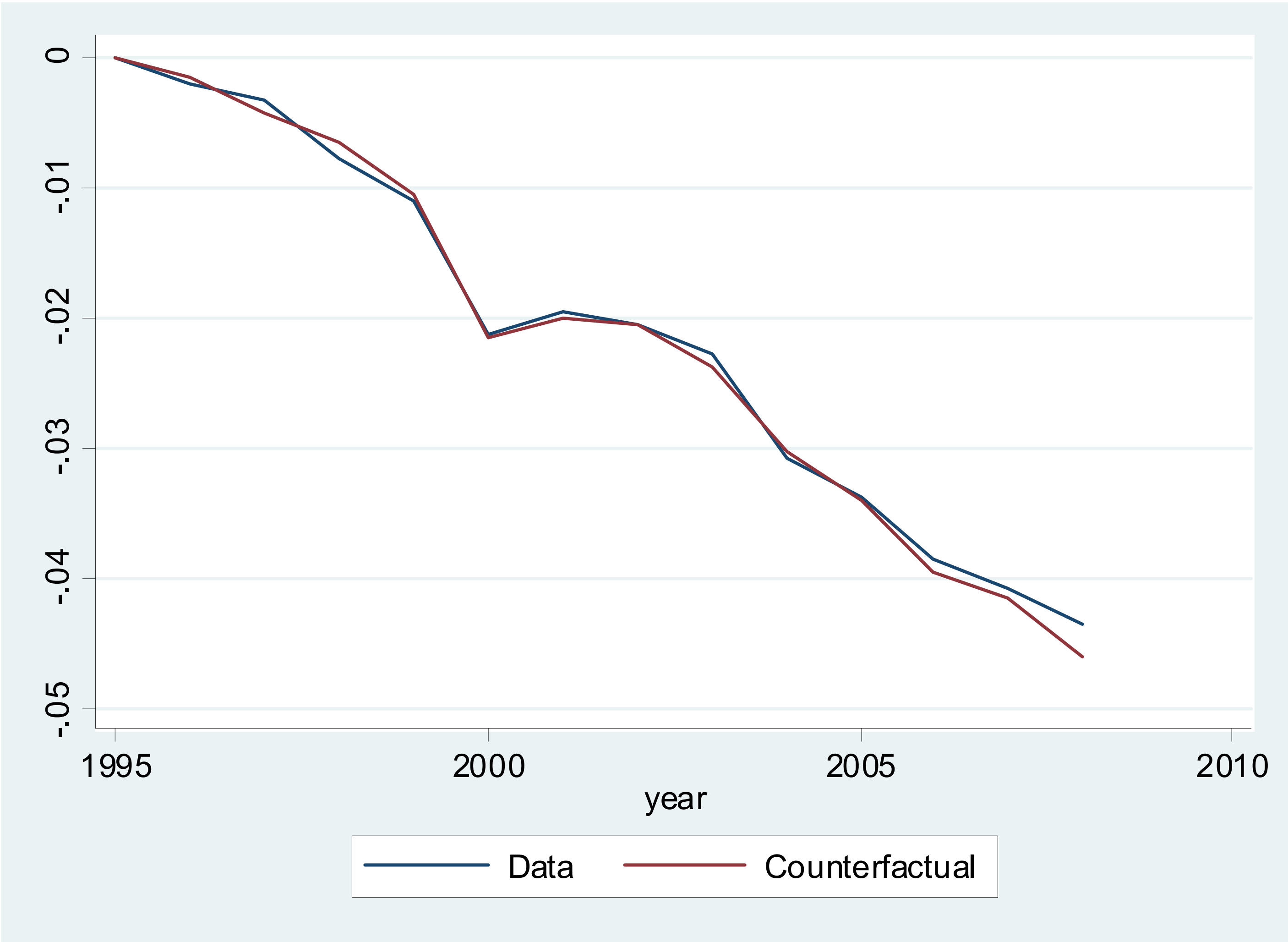


Figure 17: Effects of Shutting Down Changes in China's Technology on ROW's DVAR

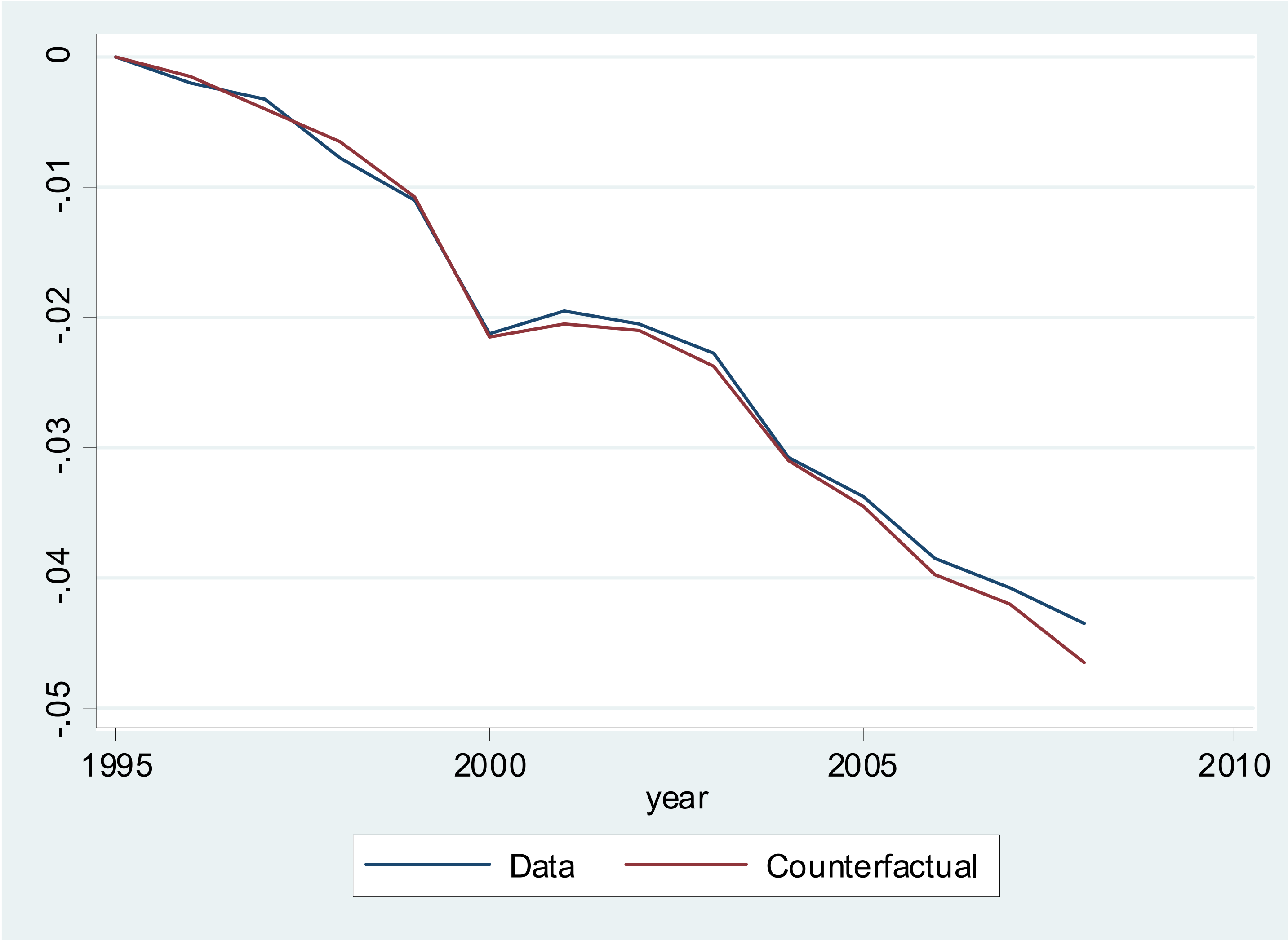


Figure 18: Effects of Shutting Down Changes in China's τ on ROW's DVAR

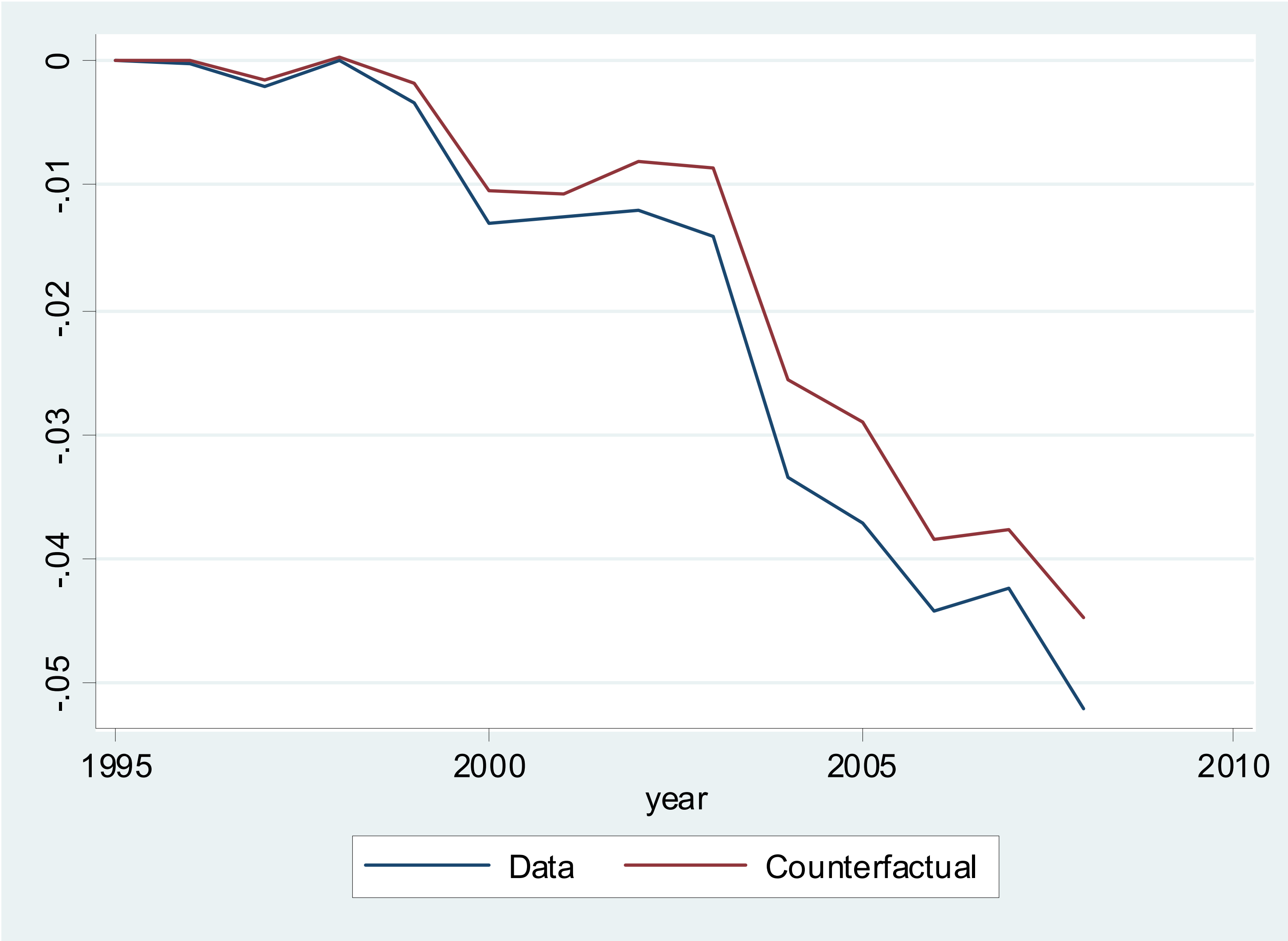


Figure 19: Effects of Shutting Down Changes in China's T on US's DVAR

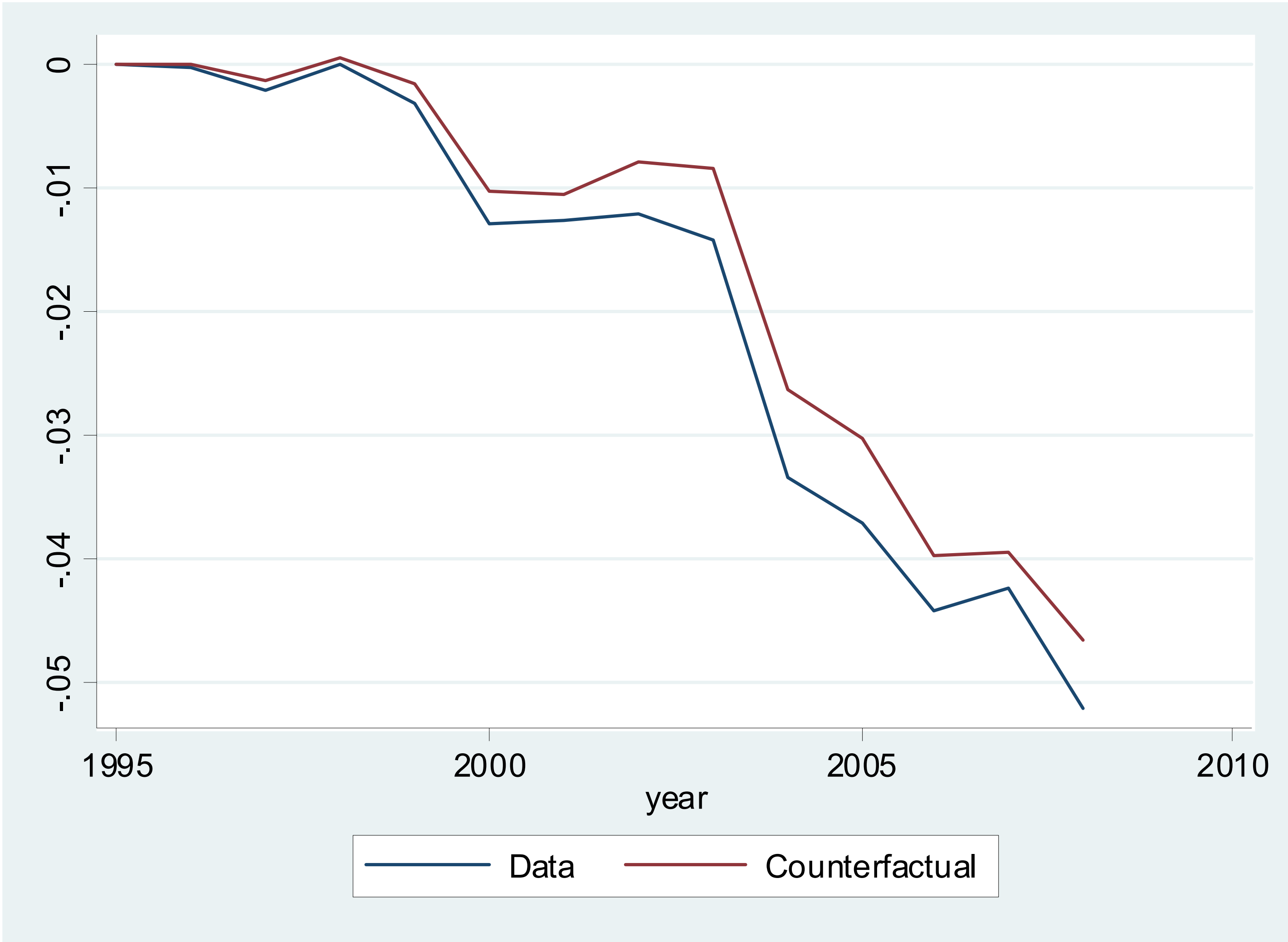
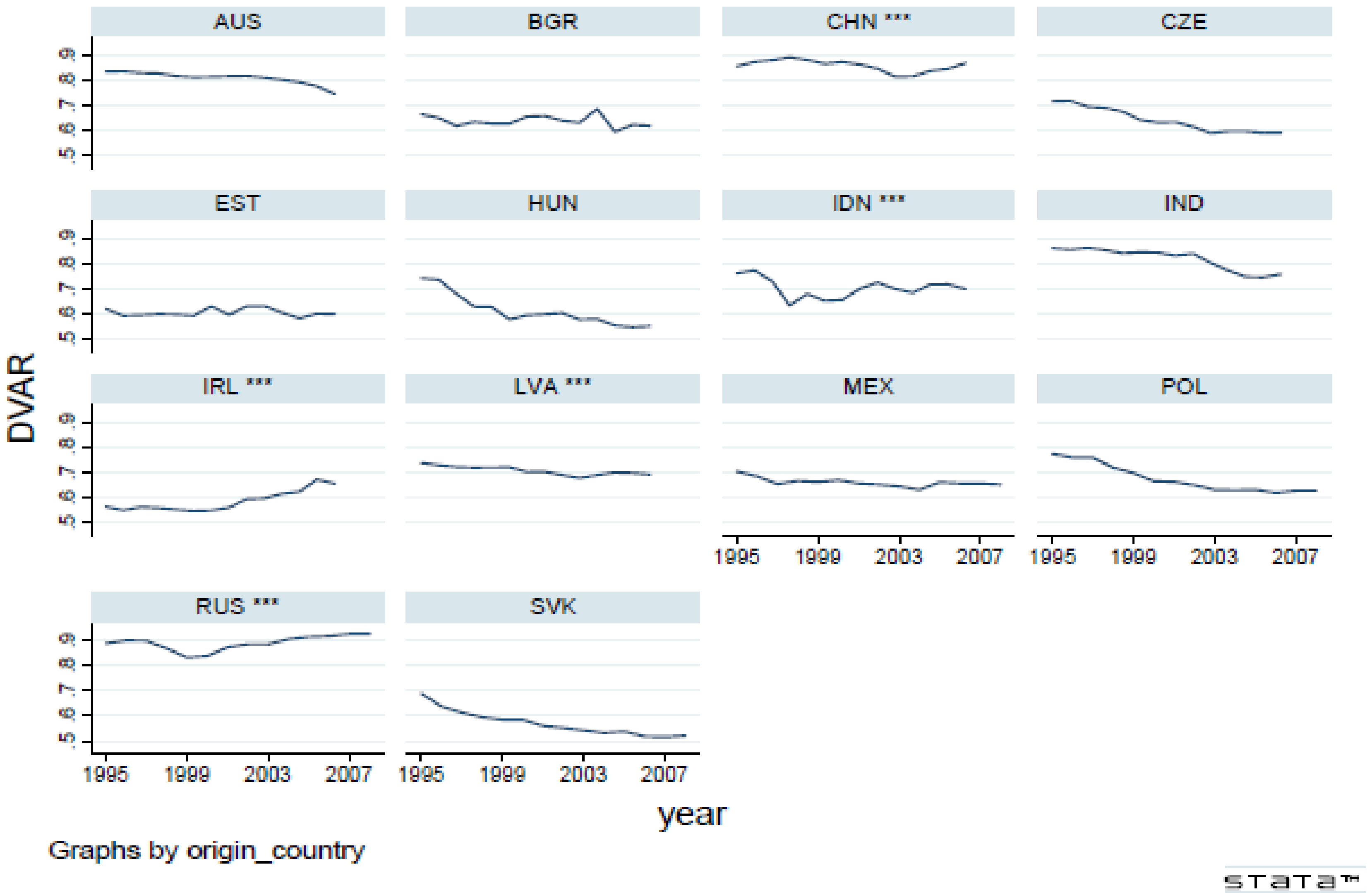


Figure 20: Effects of Shutting Down Changes in China's τ on US's DVAR

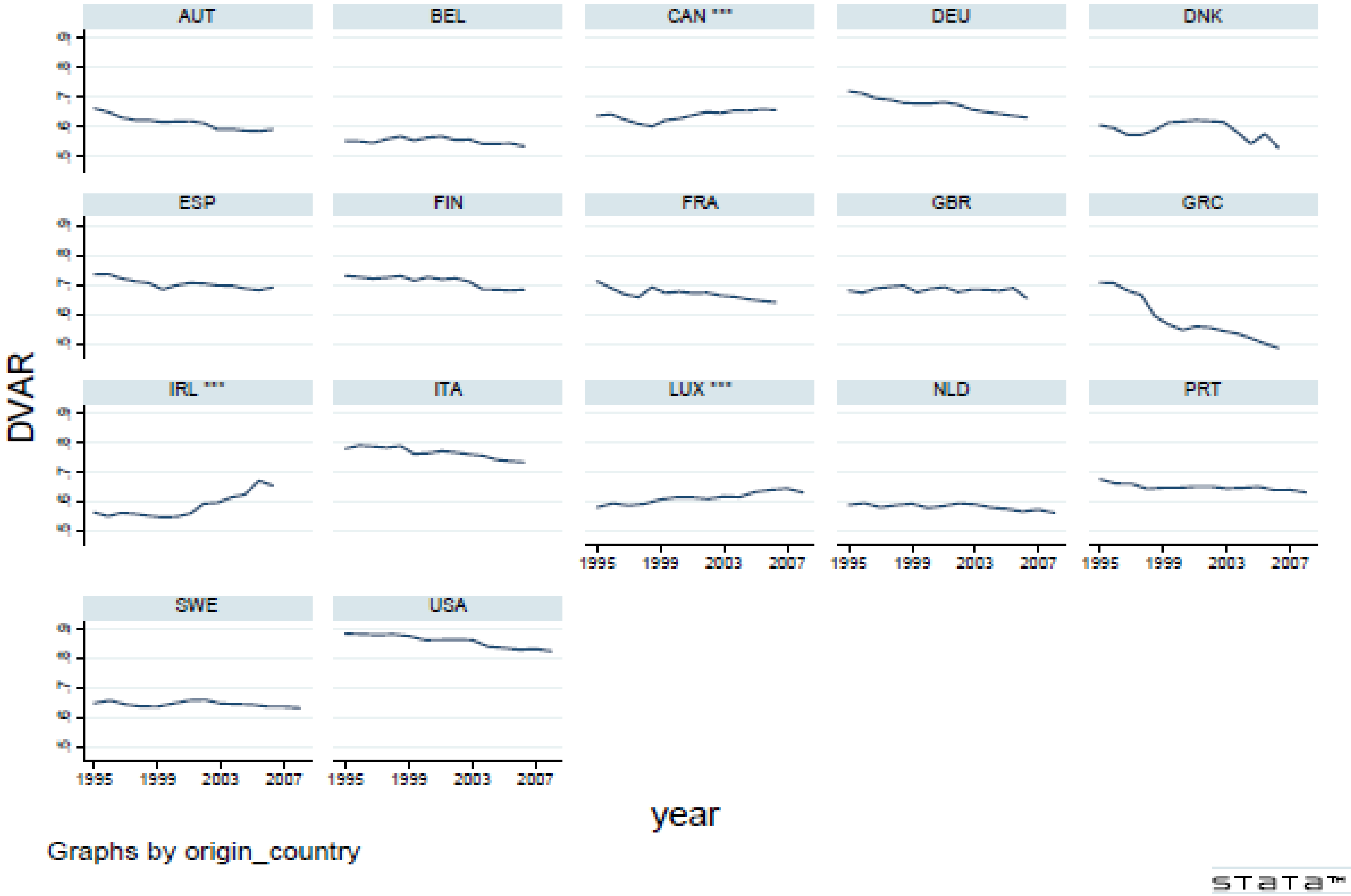
Conclusion

- Based on a multi-sector EK model with domestic and global input-output linkages, we quantify the contributions of different factors to the changes in individual countries' and global DVAR (1995-2008)
- In addition to trade frictions, emphasize the importance of the positive effect of technology on countries' and global DVAR.
- The contribution of other exogenous factors (factor endowment, trade imbalance) are small.
- Fast-growing countries, like China, which experienced a substantial improvement in technology, despite falling trade frictions, could have DVAR increasing over time.

Fast Growing Countries' DVAR



Developed Countries' (OECD) DVAR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ITA
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SWE
USA
DVAR
1995
1999
2003
2007
year
Graphs by origin_country
stata™