Revisiting output convergence and economic growth determinants in OECD and some emerging countries

French-Japanese Webinar in Economics

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Table of Contents

1. Motivation
2. Concept of Output Convergence
3. Model and Statistical Methodology
4. Empirical Analysis 1 (Time series)
5. Empirical Analysis 2 (Panel, ordered logit)
6. Remaining issues

1. Motivation

- Mixed evidence of long-run convergence of per capita output

  E.g., Bernard and Durlauf (1995), Oxley and Greasley (1995), Evans and Karras (1996), Li and Papell (1999), Flessig and Strauss (2001), Lim and McAleer (2004) and others.

- Jones (2016) "the Great Divergence"
- Issue: Convergence vs. divergence (no convergence)
- Two key things we should consider

  1. Lack of test power to find weak signs of output convergence
  2. Few considerations on the information of economic growth determinants in the convergence analysis

1. Motivation – Recent discussion

Figure. Great divergence

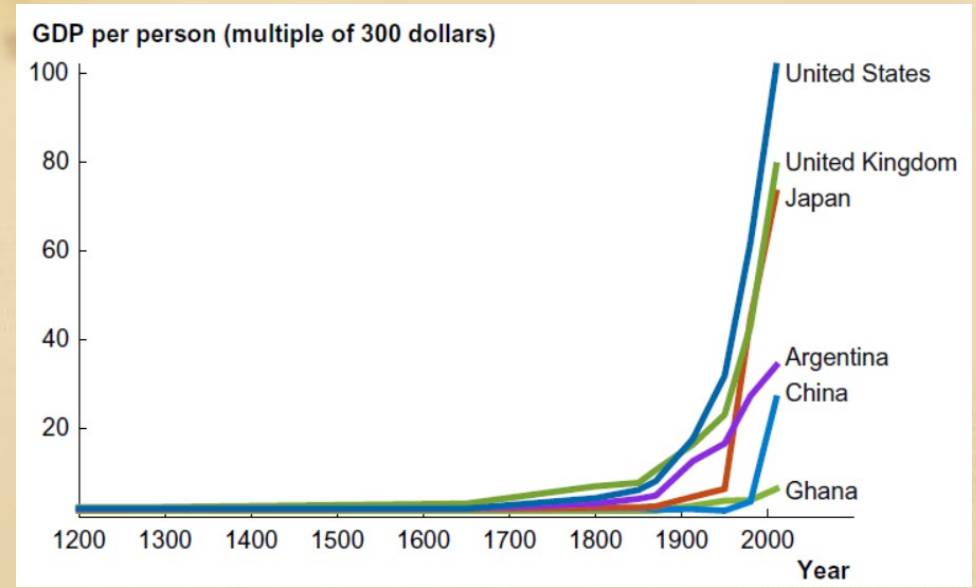
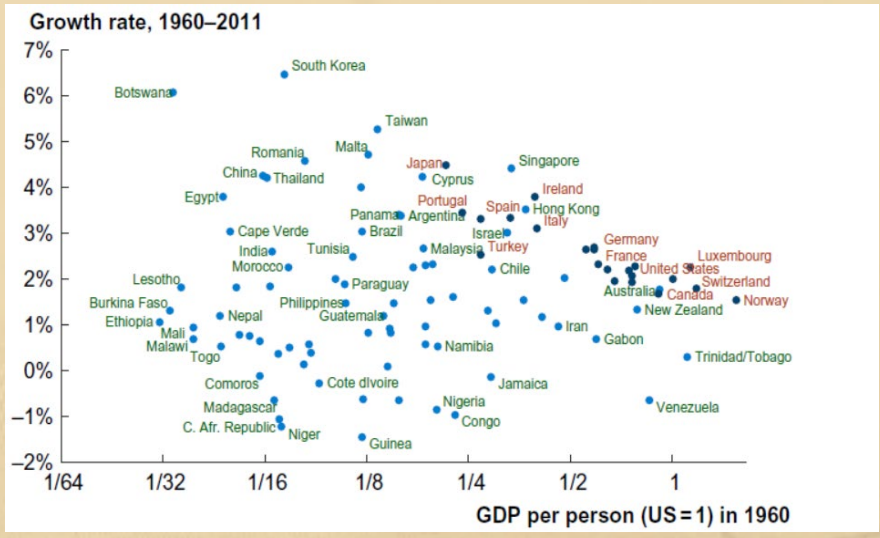


Figure. Lack of convergence worldwide



(Source) Jones (2016)

In the sense of absolute convergence or unconditional convergence, aggregate per capita output convergence does not seem to be observable. On the contrary, they may diverge.

Aims of this paper

- Obtain more evidence of converging series (pairs of countries) by employing more powerful unit root tests
- Simultaneously examine how influential possible long-run economic growth determinants are to output convergence
- Also investigate whether / which political and institutional determinants significantly affect output convergence

Summary of the empirical results

- 31 countries out of 41 are still on the path of either absolute convergence (unconditional convergence) or relative convergence toward the US.
- Some economic growth determinants (Trade/GDP, inflation rate, etc.) seem to promote output convergence.
- Some institutional factors are significant
  - Civil liberty, trade freedom, economic freedom, government integrity, robots per employees, and ICT

2. Concept of Output Convergence

- Definition in time series data (Bernard and Durlauf (1995), Hobijn and Franses (2000))

$$\lim_{h\to\infty} E(y_{i,t+h} - y_{j,t+h}|I_t) = 0 \; or \; constant \quad (1)$$

where y_i and y_j are per capita outputs of countries i and j, h is the forecasting horizon, I_t is an information set at time t.

∗ US is a reference country.

- $y_{US} - y_j$ = a zero-mean stationary process

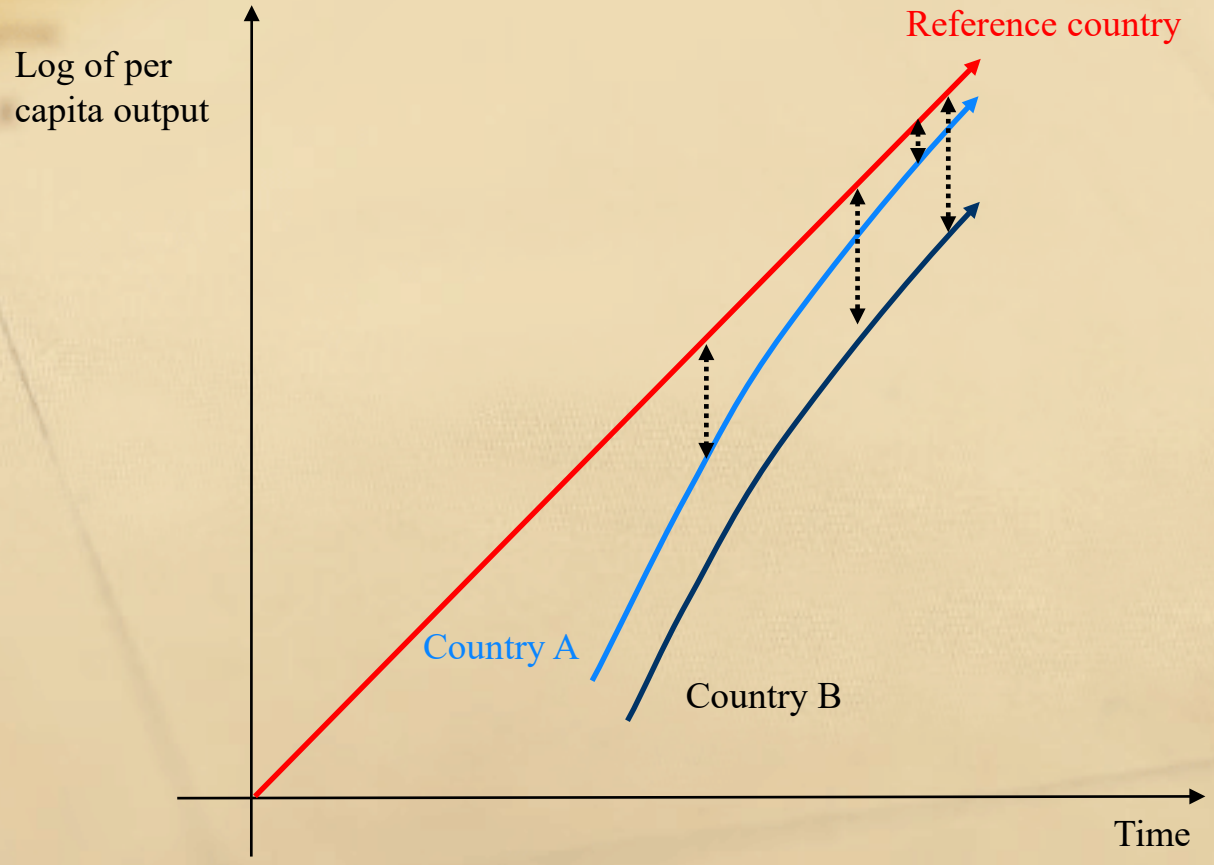
  ➡ (Asymptotically) **Absolute convergence**

- $y_{US} - y_j$ = a nonzero-mean stationary process

  ➡ (Asymptotically) **Relative convergence**

2. Concept of Output Convergence

Figure. Concept of output convergence in time series analysis



Absolute convergence (Country A) and Relative convergence (Country B)

2. Concept of Output Convergence

- $y_i - y_j$ + additional information

  $\Rightarrow$ Confirm convergence (Eq. (1) holds)

  $\Rightarrow$More effective approach (adopted here)

- Possible economic growth determinants to achieve and maintain long-run output convergence, e.g., export-oriented strategy, macroeconomic stability, and accumulation of human capital, can be valid additional information.

3. Models and Statistical Methodology

- **The covariate augmented Dickey-Fuller (CADF) test (Hansen (1995))**
  - **Model**

$$y_t = d_t + S_t \tag{2}$$

$$a(L)\Delta S_t = \delta S_{t-1} + v_t \tag{3}$$

$$v_t = b(L)'(\Delta x_t - \mu_x) + e_t \tag{4}$$

where d_t is a deterministic term, wherein $d_t = \{\emptyset\}$ and $\{1\}$. $a(L) = 1 - a_1 L - a_2 L^2 - \cdots - a_p L^p$ is a p-th order polynomial in the lag operator. v_t is a white noise process, which covariates with Δx_t. Δx_t is an m-vector, $\mu_x = E(\Delta x_t)$, and $b(L) = b_{q2} L^{-q2} + \cdots + b_{q1} L^{q1}$ is a lag polynomial allowing for both q2 leads and q1 lags of Δx_t.

3. Models and Statistical Methodology

- **The CADF test**
  - **Regression equation**

$$\Delta y_t = \hat{\alpha} d_t + \hat{\delta} y_{t-1} + \hat{b}(L)'(\Delta x_t - \mu_x) + \sum_{p=1}^{\bar{p}} \hat{a}_p \Delta y_{t-p} + error \quad (7)$$

  - **Limiting distribution of t-type test** $t(\hat{\delta}) = \hat{\delta}/s(\hat{\delta})$

$$t(\hat{\delta}) \Rightarrow \rho \frac{\int_0^1 W(r)dW}{\left(\int_0^1 W^2(r)dr\right)^{1/2}} + (1-\rho^2)^{\frac{1}{2}} N(0,1) \quad (8)$$

where $\Rightarrow$ denotes weak convergence in distribution, and $W(r)$ denotes a standard Wiener process, and $N(0,1)$ denotes a standard normal variable, which is independent of $W(r)$. $t(\hat{\delta})$ has a (kind of) weighted sum of the augmented Dickey-Fuller distribution and the normal distribution.

3. Models and Statistical Methodology

- **The CADF test with structural breaks (Matsuki (2019))**
  - **Regression equation**

$$\Delta y_t = \hat{\alpha} d_t + \hat{\delta} y_{t-1} + \hat{b}(L)'(\Delta x_t - \mu_x) + \hat{\gamma} DU(\tau_1)_t + \hat{\zeta} DU(\tau_2)_t + \sum_{p=1}^{\bar{p}} \hat{a}_p \Delta y_{t-p} + error \quad (10)$$

  - **Limiting distribution of min *t* test** $\min_{\tau} t(\hat{\delta}) = \min_{\tau} \hat{\delta}/s(\hat{\delta})$ in the case of $d_t = \{\emptyset\}$, as $T \to \infty$,

$$\min_{(\tau_1,\tau_2)} t(\hat{\delta}) \Rightarrow \inf_{(\tau_1,\tau_2)} \left[\frac{\rho \int_0^1 W_1(r) dW_1 + (1-\rho^2)^{1/2} \int_0^1 W_1(r) dW_2}{\left[\int_0^1 W_1(r)^2 dr - A \right]^{1/2}} \right] \quad (12)$$

when $d_t = \{1\}$, $W(r)$ is replaced by a demeaned standard Wiener process defined as $W^{\mu}(r) \equiv W(r) - \int_0^1 W(r)\, dr$.

A is given by

$$A = \frac{1}{(1-\tau_2)(\tau_2-\tau_1)}\Big\{(1-\tau_2)\left(\int_{\tau_1}^{1} W_1(r)dr\right)\left(\int_{\tau_1}^{1} W_1(r)dr - \int_{\tau_2}^{1} W_1(r)dr\right) - \left(\int_{\tau_2}^{1} W_1(r)dr\right)\left((1-\tau_2)\int_{\tau_1}^{1} W_1(r)dr - (1-\tau_1)\int_{\tau_2}^{1} W_1(r)dr\right)\Big\}.$$

4. Empirical Analysis 1

Data

- Sample period and countries: 1953-2019, 41 countries
- Main data sources are ***Penn World Table 10.0*** and ***World Development Indicators (World Bank)***.
- Logarithm of real per capita GDP (output-side real GDP (in mil. 2005US$) by population)
- 5 long-run stationary covariates:

  ・Trade/GDP ratio ・・・Effectiveness of export-oriented strategy

  ・Gov. expenditure/GDP・・・Contribution of gov. fiscal policies

  ・Inflation rate・・・Macroeconomic stability

  ・TFP index ・・・Possible improvement of production

  ・Human capital index・・・Quality of potential labor force

Table A1. Sample countries

Sample countries			
41 world countries			
Asia & Pacific (13)	China	Europe (18)	Austria
	Hong Kong		Belgium
	India		Denmark
	Indonesia		Finland
	Japan		France
	Korea		Germany
	Malaysia		Greece
	Philippines		Iceland
	Singapore		Ireland
	Taiwan		Italy
	Thailand		Luxembourg
	Australia		Netherlands
	New Zealand		Norway
America (6)	Brazil		Portugal
	Canada		Spain
	Chile		Sweden
	Colombia		Switzerland
	Costa Rica		UK
	Mexico	Eastern Europe (2)	Hungary
Middle east (2)	Israel		Poland
	Turkey		

Results of conventional tests

- Augmented Dickey-Fuller (ADF) test

  Regression w/ constant: 4/41 (rejections/all hypotheses)

  w/o constant: 11/41

- Zivot and Andrews test (one endogenous break)

  Regression w/ constant: 2/41

  w/o constant: 0/41

- Lumsdaine and Papell type test (two endogenous breaks)

  Regression w/ constant: 2/41

  w/o constant: 1/41

Table 4. Results of the CADF test (Reference country: US)

Countries	Covariate: Trade/GDP ratio				Covariate: Government expenditure/GDP ratio				Covariate: Inflation rate			
	Raw data		Demeaned data		Raw data		Demeaned data		Raw data		Demeaned data	
	t	ρ^2	t	ρ^2	t	ρ^2	t	ρ^2	t	ρ^2	t	ρ^2
Australia	-0.789	0.93	-2.264	0.80	-0.621	1.00	-1.367	1.00	-0.906	1.00	-1.390	0.99
Austria	-2.017 **	0.97	0.141	1.00	-1.776 *	1.00	0.230	0.96	-2.218 **	0.98	-0.604	0.98
Belgium	-0.992	0.99	-1.335	0.98	-0.805	0.90	-0.219	0.91	-1.222	1.00	-1.590	1.00
Canada	-0.029	0.99	-1.633	0.97	0.242	0.84	-0.420	0.93	-0.177	0.43	-3.225 ***	0.23
Chile	-0.710	0.85	-1.733	0.79	-0.671	0.66	-1.053	0.68	-0.978	0.84	-1.547	0.81
Colombia	-0.385	0.89	-1.923	0.93	-0.386	1.00	-2.228	0.99	-0.754	0.99	-2.327	1.00
Costa Rica	-0.812	0.99	-0.808	0.98	-0.839	0.95	-0.995	0.92	-0.798	0.84	-0.914	0.83
Denmark	-1.125	0.94	-1.759	0.76	-0.887	0.99	-0.422	0.99	-1.077	0.95	-0.817	0.94
Finland	-1.552	0.98	-2.657 *	0.74	-1.102	0.84	-0.454	0.89	-1.323	0.99	-1.814	0.99
France	-0.806	0.97	-1.169	0.99	-0.788	0.84	-0.769	0.86	-0.990	1.00	-2.033	0.95
Germany	-1.571	0.99	-0.063	1.00	-1.475	0.95	0.094	0.92	-1.559	0.96	0.289	0.89
Greece	-1.027	0.87	-1.306	0.93	-0.975	0.69	-0.043	0.66	-0.819	0.99	-1.778	0.98
Iceland	-1.233	1.00	-1.964	1.00	-1.135	0.99	-1.221	1.00	-1.189	0.96	-1.791	0.82
Ireland	-3.616 ***	0.36	-0.040	0.85	-2.357 **	0.62	0.007	0.84	-1.531	0.97	0.668	0.99
Israel	-1.282	0.94	-1.156	0.99	-1.226	0.97	-1.432	0.99	-1.246	0.96	-2.558 *	0.94
Italy	-1.868 *	0.92	-0.777	0.96	-1.727 *	0.59	0.421	0.54	-2.459 **	0.88	-1.713	0.93
Japan	-2.358 **	0.80	-1.235	0.87	-2.075 **	0.66	0.034	0.67	-2.258 **	0.96	-1.406	0.99
Korea	-2.355 **	0.98	-0.021	0.92	-3.187 ***	0.97	0.016	0.92	-3.876 ***	0.97	-1.122	0.94
Luxembourg	-1.804 *	0.62	-1.999	0.57	-0.357	0.99	-0.429	0.99	-0.358	0.99	-0.449	0.99
Mexico	0.334	1.00	-2.300	0.87	0.351	1.00	-1.815	0.99	0.394	0.72	-0.449	0.76
Netherlands	-1.377	1.00	-0.902	0.99	-1.005	0.94	0.200	0.90	-1.449	0.93	-0.710	0.93
New Zealand	0.198	0.95	-1.884	1.00	0.183	0.95	-1.890	1.00	0.085	0.85	-0.373	0.34
Norway	-0.510	0.88	-0.050	0.86	-0.838	0.99	-0.321	0.98	0.014	0.66	0.509	0.64
Portugal	-1.969 **	0.98	-0.521	0.99	-1.974 **	0.99	-0.824	0.98	-2.281 **	0.87	-1.857	0.77
Spain	-1.445	1.00	-1.033	0.95	-1.371	0.99	-0.476	1.00	-1.644 *	0.95	-1.420	0.89
Sweden	-1.225	0.84	-2.539 *	0.55	-0.860	0.99	-0.564	1.00	-1.131	0.95	-1.219	0.90
Switzerland	-0.825	0.61	-1.392	0.60	-1.154	0.97	-2.218	0.90	-1.138	1.00	-1.624	1.00
Turkey	-1.326	0.94	-0.987	0.90	-1.293	0.98	-0.838	0.94	-1.648 *	0.70	-1.657	0.66
UK	-0.485	0.97	-2.373	0.83	-0.391	0.91	-1.293	0.94	-0.535	0.97	-1.156	1.00
Brazil	-1.014	0.99	-1.846	0.97	-1.046	1.00	-2.244	0.87	-1.055	1.00	-1.898	0.99
China	-3.482 ***	0.52	-0.952	0.65	-1.221	1.00	0.370	1.00	-1.573	0.87	-0.113	0.90
India	-1.435	0.59	-2.155	0.41	-0.679	0.92	-0.200	0.96	-1.042	0.98	-0.826	0.96
Taiwan	-2.398 **	0.99	-0.461	0.98	-2.643 ***	1.00	-1.146	0.99	-2.606 ***	0.97	-0.739	1.00
Philippines	-0.701	0.98	-1.514	0.98	-0.681	0.99	-1.608	0.98	-0.740	0.90	-1.869	0.86
Thailand	-2.296 **	1.00	-0.602	0.97	-2.242 **	0.98	-0.023	0.97	-2.543 **	0.85	-0.908	0.87
Malaysia	-1.961 **	0.99	-0.943	0.97	-1.939 *	1.00	-0.958	0.96	-1.993 **	0.94	-0.745	0.95
Hong Kong	-2.054 **	1.00	-0.276	0.91	-2.020 **	1.00	0.047	0.81	-2.306 **	1.00	-0.648	0.96
Indonesia	-1.615 *	0.84	-0.858	0.86	-1.540	0.94	-0.932	0.96	-1.660 *	0.90	-1.812	0.84
Singapore	-3.683 ***	0.78	-0.762	0.95	-1.782 *	0.98	-0.187	1.00	-2.041 **	0.94	0.617	0.86
Hungary	-1.193	0.80	-0.707	0.73	-1.025	1.00	0.454	1.00	-1.183	0.81	-0.626	0.76
Porland	-2.243 **	0.98	-0.293	0.79	-2.068 **	1.00	0.084	0.97	-3.991 ***	0.48	-1.934	0.49

***, **, and * denote statistical significance at the 1, 5, and 10% levels, respectively. The percentage points of the tests are displayed in Table 1 in Hansen's (1995) paper.

Table 4 (continued)

Countries	Covariate: TFP growth				Covariate: Human capital index growth			
	Raw data		Demeaned data		Raw data		Demeaned data	
	t	ρ^2	t	ρ^2	t	ρ^2	t	ρ^2
Australia	-0.929	0.97	-0.878	0.96	-1.013	0.68	-1.559	0.66
Austria	-1.977 **	0.89	-0.032	0.86	-2.088 **	1.00	-0.269	1.00
Belgium	-1.192	0.90	-0.821	0.93	-1.204	1.00	-1.568	1.00
Canada	-0.016	0.97	-1.287	0.99	-0.040	0.87	-1.704	0.84
Chile	-0.726	0.41	0.143	0.42	-0.994	0.89	-1.126	0.66
Colombia	-0.706	0.81	-2.359	0.77	-0.797	0.95	-2.966 **	0.78
Costa Rica	-0.910	0.81	-0.233	0.82	-0.724	0.93	-0.232	0.93
Denmark	-1.197	0.99	-0.554	0.99	-1.130	0.95	-1.068	0.91
Finland	-1.011	0.45	0.581	0.43	-1.298	0.99	-0.823	0.99
France	-0.890	0.83	-1.735	0.88	-1.006	0.98	-1.956	0.94
Germany	-1.734 *	0.62	0.319	0.63	-1.535	1.00	0.002	0.98
Greece	-0.798	0.49	-0.375	0.48	-0.814	0.98	-1.706	0.98
Iceland	-0.728	0.62	-0.987	0.64	-1.308	0.69	-1.292	0.66
Ireland	-0.418	0.58	1.411	0.56	-1.539	0.95	0.448	0.99
Israel	-0.763	0.52	-0.867	0.57	-1.205	1.00	-2.467	0.99
Italy	-1.709 *	0.54	0.516	0.48	-2.408 **	0.97	-1.828	0.99
Japan	-1.693 *	0.71	-0.112	0.68	-2.166 **	0.65	0.018	0.60
Korea	-2.449 **	0.69	-0.166	0.67	-3.510 ***	1.00	-0.120	0.94
Luxembourg	0.853	0.63	0.729	0.64	-0.635	0.97	-0.724	0.97
Mexico	0.338	0.48	-0.672	0.47	0.268	0.90	-1.074	0.97
Netherlands	-1.460	0.86	-0.391	0.89	-1.472	1.00	-0.992	1.00
New Zealand	0.151	0.73	-1.272	0.81	0.155	0.98	-2.244	0.94
Norway	-0.480	0.96	0.039	0.93	-0.722	0.97	-0.250	0.95
Portugal	-1.999 **	0.72	0.042	0.67	-1.973 **	1.00	-1.029	0.99
Spain	-1.378	1.00	-0.831	1.00	-1.702 *	0.91	-1.443	0.87
Sweden	-1.057	0.63	-0.493	0.65	-1.030	1.00	-0.785	0.99
Switzerland	-1.141	0.76	-1.723	0.75	-1.279	0.98	-1.820	0.97
Turkey	-1.086	0.74	-0.516	0.75	-1.371	0.98	-0.283	0.98
UK	-0.806	0.97	-1.397	0.98	-0.496	0.97	-1.170	0.98
Brazil	-1.253	0.73	-0.685	0.75	-1.032	0.98	-1.789	0.98
China	-3.750 ***	0.33	-0.845	0.39	-2.962 ***	0.68	-0.214	0.85
India	-1.625 *	0.54	-1.206	0.67	-0.979	1.00	-0.885	0.96
Taiwan	-3.156 ***	0.73	-0.249	0.74	-5.551 ***	0.77	-1.014	0.97
Philippines	-0.895	0.73	-1.414	0.76	-0.727	0.87	-1.915	0.86
Thailand	-2.816 ***	0.46	0.136	0.52	-2.264 **	1.00	-0.701	1.00
Malaysia	-1.331	0.38	-1.470	0.32	-1.977 **	1.00	-0.913	0.98
Hong Kong	-2.233 **	0.89	-0.992	0.88	-2.087 **	0.85	-0.580	0.78
Indonesia	-2.020 **	0.57	-0.823	0.58	-1.465	0.99	-1.512	0.85
Singapore	-1.876 *	0.91	0.116	0.90	-1.628 *	0.87	1.340	0.62
Hungary	-1.140	0.57	-0.922	0.51	-1.078	0.71	0.530	0.71
Porland	-3.127 ***	0.49	-0.219	0.63	-2.450 **	0.97	0.316	0.85

- Covariate augmented Dickey-Fuller (CADF) test

・Covariate: Trade/GDP ratio

Regression w/ constant: 2/41

w/o constant: 15/41

・Covariate: Government expenditure/GDP ratio

Regression w/ constant: 0/41

w/o constant: 12/41

・Covariate: Inflation rate

Regression w/ constant: 2/41

w/o constant: 14/41

・Covariate: TFP growth

Regression w/ constant: 0/41

w/o constant: 14/41

・Covariate: Human capital index growth

Regression w/ constant: 1/41

w/o constant: 13/41

Table 5. Results of the CADF test with one structural break (Ref. C. : US)

Countries	Covariate: Trade/GDP ratio						Covariate: Government expenditure/GDP ratio						Covariate: Inflation rate					
	Raw data			Demeaned data			Raw data			Demeaned data			Raw data			Demeaned data		
	t	ρ^2	Break	t	ρ^2	Break	t	ρ^2	Break	t	ρ^2	Break	t	ρ^2	Break	t	ρ^2	Break
Australia	-2.200	0.50	1972	-2.997	0.93	2008	-0.938	0.99	2012	-3.457	0.92	2005	-1.456	0.99	1971	-2.791	1.00	2005
Austria	-2.579	0.71	2009	-3.931 *	0.13	1990	-1.880	1.00	2012	-1.799	0.65	1990	-2.436	0.99	2008	-2.817	0.44	1988
Belgium	-2.696	0.57	1981	-2.685	0.41	1981	-1.156	0.95	2011	-1.516	0.97	2000	-2.592	0.88	1981	-2.877	0.97	2000
Canada	-2.389	0.61	1990	-2.383	0.65	1991	-1.035	0.85	1990	-0.898	0.97	1990	-1.658	0.36	1972	-6.318 ***	0.05	1983
Chile	-2.725	0.37	1972	-2.430	0.97	2004	-0.908	0.63	1996	-0.422	0.41	2008	-1.462	0.74	1972	-2.186	0.78	2002
Colombia	-3.307 *	0.19	1994	-1.540	1.00	2006	-1.589	0.88	1981	-3.568	0.50	2006	-2.111	0.95	1981	-2.421	0.79	2006
Costa Rica	-0.890	1.00	1980	-2.462	0.86	2007	-2.335	0.68	1978	-2.855	0.48	1981	-0.952	0.84	1978	-1.299	0.86	2014
Denmark	-2.332	0.56	1972	-3.852	0.90	2005	-1.077	0.99	2012	-3.766	0.95	2005	-1.549	0.91	1971	-3.936	0.90	2005
Finland	-3.568 *	0.49	1975	-4.945 ***	0.18	1992	-1.225	0.90	2009	-0.381	0.51	1977	-1.925	1.00	1975	-3.228	0.91	1997
France	-3.042	0.67	1981	-3.701	0.43	1983	-1.584	0.95	1981	-2.036	0.86	1983	-3.310	0.72	1983	-4.311 **	0.39	1997
Germany	-2.475	0.69	2012	-3.180	0.55	1990	-1.664	0.97	2012	-2.113	0.42	1974	-1.766	0.98	2012	-2.497	0.47	1986
Greece	-2.420	0.99	1973	-3.377	0.85	2010	-1.956	0.85	2010	-2.061	0.99	2010	-3.996 **	0.50	2010	-3.057	0.81	2012
Iceland	-2.424	0.56	2009	-3.994	0.99	1973	-2.795	0.50	1989	-4.310 *	0.78	1973	-2.027	1.00	1983	-4.734 **	0.76	1973
Ireland	-5.126 ***	0.09	2008	-2.883	0.17	1986	-2.683	0.63	2001	-1.743	0.32	1972	-1.843	1.00	2012	-0.532	0.95	1995
Israel	-1.789	1.00	1976	-2.240	0.98	1990	-1.855	1.00	1976	-3.764	0.45	1990	-2.900	0.96	1976	-2.846	0.80	2004
Italy	-2.762	1.00	1981	-2.537	0.79	2012	-1.927	0.65	2012	-1.548	0.45	1979	-3.565 *	0.97	1981	-4.566 **	0.31	1985
Japan	-3.125	0.91	1997	-3.501	0.76	1985	-1.989	0.76	1971	-2.693	0.44	1985	-3.859 **	0.92	1997	-4.107	0.99	1986
Korea	-2.626	0.98	1991	-1.894	0.99	1986	-2.876	0.98	1997	-1.582	0.93	1982	-4.426 ***	0.64	1997	-3.163	0.98	1985
Luxembourg	-3.351 +	0.40	1989	-4.082 *	0.35	1990	-1.488	0.96	2005	-2.542	0.85	1989	-1.673	0.99	2005	-2.862	0.94	1989
Mexico	-2.568	0.70	1983	-3.003	0.92	1986	-2.679	0.71	1982	-3.878	0.65	1986	-1.665	0.72	1983	-1.213	0.69	1986
Netherlands	-2.382	0.64	2009	-2.358	0.97	1999	-1.211	0.98	2009	-1.704	0.97	1999	-1.602	0.95	2014	-3.165	0.79	1999
New Zealand	-0.974	0.79	1975	-3.115	0.91	2008	-1.146	0.68	1975	-4.725 **	0.38	2007	-0.484	0.75	1988	-1.325	0.24	2009
Norway	-1.392	0.83	1999	-2.156	0.83	1999	-1.441	0.98	1999	-2.076	0.99	1999	-0.986	0.64	1999	-2.453	0.51	1990
Portugal	-2.372	0.97	1974	-2.965	1.00	1990	-2.858	0.75	1974	-3.215	0.91	1988	-3.761 **	0.38	1995	-4.609 **	0.57	1986
Spain	-2.607	0.71	1975	-1.948	0.92	1997	-2.177	0.72	1975	-1.901	0.90	1995	-2.857	0.63	1981	-2.583	0.97	1987
Sweden	-3.606 *	0.21	1976	-3.913	0.55	2007	-1.059	1.00	2012	-3.313	0.98	2004	-1.490	0.88	2012	-3.223	0.98	2004
Switzerland	-1.933	0.94	2005	-3.868	0.24	1975	-4.367 ***	0.45	2007	-5.492 ***	0.42	2007	-4.310 ***	0.48	2007	-4.590 **	0.45	2007
Turkey	-2.692	0.61	1977	-3.303	0.97	2007	-1.612	0.94	1977	-3.483	0.78	2007	-1.929	0.64	2012	-3.285	0.73	2010
UK	-1.313	0.81	2006	-4.799 **	0.94	1995	-0.526	0.91	1983	-4.624 **	0.94	1995	-0.705	0.98	2014	-3.847	0.68	1995
Brazil	-1.887	0.90	1997	-2.535	0.96	2006	-2.434	0.69	1997	-2.910	0.98	2006	-1.854	1.00	1975	-3.091	1.00	2006
China	-3.702 **	0.45	2012	-3.454	0.08	2009	-1.822	0.99	2003	-1.880	0.93	2001	-2.077	0.86	2005	-2.238	0.67	2001
India	-2.398	0.30	2011	-4.212 **	0.03	1976	-1.207	0.89	2011	-2.149	0.98	2005	-1.544	0.93	2011	-2.805	0.92	2005
Taiwan	-3.675 *	0.58	2006	-3.729	0.76	1986	-3.381	0.98	2006	-3.896	0.99	1986	-4.275 **	0.86	1986	-4.261 *	0.82	1986
Philippines	-0.422	0.98	1981	-2.408	0.91	2009	-0.787	0.99	1981	-2.027	1.00	2009	-1.556	0.81	1997	-1.962	0.96	2008
Thailand	-4.296 ***	0.16	1997	-1.865	0.05	1997	-2.342	1.00	2013	-1.809	0.96	1987	-3.008	0.82	1997	-2.043	0.82	1973
Malaysia	-2.317	0.80	1983	-2.934	0.67	2007	-2.315	0.75	1983	-2.418	0.84	2007	-2.026	0.94	2013	-2.386	0.94	2007
Hong Kong	-3.855 **	0.07	2006	-3.204	0.10	2006	-3.288	0.66	2014	-2.021	0.96	1986	-2.780	0.98	2014	-3.072	1.00	1986
Indonesia	-1.994	0.79	2012	-1.256	0.69	2008	-1.874	0.90	2012	-1.394	0.92	2008	-2.409	0.82	1981	-3.725	0.93	2004
Singapore	-4.043 **	0.74	2010	-4.363 **	0.74	2000	-3.157	1.00	2004	-4.203 *	0.85	2000	-2.496	0.90	2004	-3.047	0.89	2000
Hungary	-1.829	0.50	2011	-2.702	0.90	2005	-0.932	1.00	2012	-2.774	0.97	2005	-1.422	0.72	2012	-3.088	0.74	2005
Porland	-2.439	0.74	2012	-0.240	0.59	2013	-1.989	1.00	2012	-0.443	0.99	2007	-4.386 ***	0.39	2012	-4.370 **	0.32	2007

Note: Preliminary results.

Table 5 (continued)

Countries	Covariate: TFP growth						Covariate: Human capital index growth					
	Raw data			Demeaned data			Raw data			Demeaned data		
	t	ρ^2	Break	t	ρ^2	Break	t	ρ^2	Break	t	ρ^2	Break
Australia	-1.156	0.97	2014	-3.090	0.95	2005	-1.973	0.47	1972	-1.360	0.57	2008
Austria	-1.967	0.89	2012	-2.009	0.90	1989	-2.561	0.83	2012	-2.185	1.00	1990
Belgium	-1.531	0.92	2011	-2.434	0.91	2000	-2.229	0.99	1981	-3.061	0.73	2005
Canada	-1.708	0.98	1976	-2.234	0.99	1991	-1.459	0.94	1976	-2.357	0.99	1990
Chile	-0.942	0.41	2014	-1.684	0.55	2004	-1.757	0.39	1972	-0.942	0.45	2005
Colombia	-1.405	0.82	1972	-1.809	0.95	2007	-1.152	0.96	2012	-2.878	0.76	2007
Costa Rica	-1.020	0.82	1978	-0.840	0.82	2014	-1.053	0.93	1978	-1.082	0.96	2011
Denmark	-1.540	1.00	1972	-3.696	0.98	2005	-2.203	0.73	1971	-3.738	0.98	2005
Finland	-0.842	0.44	2013	-0.836	0.26	1997	-1.769	1.00	2009	-2.366	0.98	1999
France	-2.134	0.95	1981	-2.893	1.00	1983	-3.310	0.74	1981	-3.225	0.57	1990
Germany	-1.848	0.65	2012	-1.818	0.67	1986	-2.073	0.92	2012	-1.281	0.46	2007
Greece	-2.603	0.47	2010	-0.977	0.46	2014	-2.783	0.78	2010	-2.805	0.96	2014
Iceland	-1.459	0.58	1983	-1.874	0.73	1973	-1.830	0.95	1983	-2.706	0.67	1973
Ireland	-1.363	0.59	2014	-0.277	0.54	2012	-2.644	0.92	2014	-0.824	0.97	1995
Israel	-1.025	0.52	2001	-1.414	0.73	1990	-2.997	0.97	1976	-3.010	0.92	2009
Italy	-2.107	0.57	2010	-2.060	0.53	1974	-3.742 *	1.00	1981	-3.149	1.00	2013
Japan	-2.404	0.73	2011	-2.409	0.79	1985	-2.450	0.85	1971	-3.495	0.23	1986
Korea	-2.474	0.70	1997	-3.028	0.68	1985	-4.142 **	0.32	1997	-2.692	0.77	1981
Luxembourg	-1.228	0.61	2005	-1.282	0.61	2005	-2.041	0.95	2005	-2.816	0.96	1989
Mexico	-1.311	0.51	1983	-1.650	0.80	1985	-2.181	0.80	1983	-2.239	0.89	1985
Netherlands	-1.613	0.88	2014	-2.668	0.88	1999	-2.284	0.72	1981	-3.163	0.77	1999
New Zealand	-0.225	0.77	1976	-1.940	0.82	1976	-0.528	0.92	1975	-3.783	0.69	2006
Norway	-1.219	0.93	1999	-1.892	0.93	1999	-1.461	0.95	1999	-2.123	0.86	1995
Portugal	-2.271	0.73	2011	-3.038	0.74	1986	-2.521	1.00	1974	-4.063	1.00	1986
Spain	-2.253	0.96	1975	-2.517	1.00	1995	-2.079	0.93	1975	-4.621 **	0.46	1986
Sweden	-1.247	0.64	2012	-2.520	0.86	2006	-1.314	0.97	2012	-3.277	0.98	2004
Switzerland	-2.510	0.78	2005	-2.227	0.76	2008	-4.127 **	0.47	2007	-4.448 **	0.57	2007
Turkey	-1.154	0.74	1976	-3.332	0.69	2006	-1.427	1.00	1977	-3.071	0.99	2010
UK	-1.229	0.97	1981	-3.824	0.97	1995	-0.622	0.99	2014	-3.629	0.94	1995
Brazil	-1.573	0.75	2012	-2.099	0.83	2006	-1.704	0.99	1975	-2.530	0.94	2006
China	-5.092 ***	0.28	2001	-0.764	0.32	2001	-3.107	0.63	2014	-1.942	0.59	1991
India	-1.895	0.66	2012	-1.373	0.62	2005	-1.339	0.99	2011	-2.746	0.97	2005
Taiwan	-3.152	0.73	1994	-3.917	0.72	1986	-5.689 ***	0.81	2012	-5.364 ***	0.47	1986
Philippines	-1.828	0.65	1997	-0.551	0.77	2005	-2.831	0.35	1997	-1.789	0.99	2008
Thailand	-3.259	0.45	2013	-1.570	0.69	1974	-2.529	1.00	1971	-1.851	1.00	2007
Malaysia	-2.870	0.28	1983	-2.098	0.68	2007	-2.177	0.97	2013	-2.372	0.86	1999
Hong Kong	-2.627	0.87	2014	-2.975	0.95	1986	-2.664	0.90	2014	-3.392	0.69	1986
Indonesia	-2.638	0.52	2012	-2.312	0.78	2004	-2.589	0.56	2012	-2.535	0.98	2004
Singapore	-2.473	0.88	2005	-3.359	0.94	2000	-1.878	0.64	2004	-2.169	0.98	2000
Hungary	-1.339	0.48	2012	-2.082	0.76	2008	-0.577	0.58	2015	-2.197	0.87	2005
Porland	-3.126	0.51	2009	-5.261 **	0.34	2007	-2.348	0.97	2012	-0.313	0.95	2007

- Covariate augmented Dickey-Fuller (CADF) test (1 break)

・Covariate: Trade/GDP ratio

Regression w/ constant: 6/41

w/o constant: 9/41

・Covariate: Government expenditure/GDP ratio

Regression w/ constant: 5/41

w/o constant: 1/41

・Covariate: Inflation rate

Regression w/ constant: 8/41

w/o constant: 8/41

・Covariate: TFP growth

Regression w/ constant: 1/40

w/o constant: 1/40

・Covariate: Human capital index growth

Regression w/ constant: 3/41

w/o constant: 4/41

Table 6. Results of the CADF test with two structural breaks (Ref. C. : US)

Countries	Covariate: Trade/GDP ratio									Covariate: Government expenditure/GDP ratio								
	Raw data					Demeaned data				Raw data					Demeaned data			
	t		ρ^2	Break 1	Break 2	t		ρ^2	Break 1	Break 2	t		ρ^2	Break 1	Break 2	t		ρ^2	Break 1	Break 2
Australia	-2.589		0.44	1972	1976	-4.033		0.57	1995	2008	-1.677		0.88	1971	2001	-4.675		0.76	1995	2008
Austria	-3.089		0.22	1975	2006	-4.321		0.13	1971	1990	-2.054		0.32	1976	2002	-3.093		0.76	1990	2004
Belgium	-4.285	+	0.15	1981	2011	-3.157		0.41	1983	1988	-1.937		0.95	1981	1986	-3.020		0.39	1981	1988
Canada	-3.042		0.48	1977	1990	-2.748		0.49	1992	2003	-1.205		0.87	1977	2013	-2.351		0.93	1973	1991
Chile	-2.946		0.35	1972	2009	-3.670		0.45	1988	2004	-1.157		0.20	1981	2009	-3.269		0.43	1982	2004
Colombia	-5.334	***	0.07	1987	1996	-3.261		0.40	1996	2006	-1.801		0.75	1981	2012	-4.776		0.26	1971	2006
Costa Rica	-1.859		0.85	1981	2008	-3.976		0.97	1982	2007	-2.981		0.51	1978	2013	-4.053		0.88	1982	2009
Denmark	-2.854		0.18	1973	2013	-4.489		0.64	1981	2005	-1.921		0.91	1971	2004	-4.182		1.00	1981	2005
Finland	-4.579	*	0.18	1971	1996	-6.366	***	0.11	1986	1992	-1.220		0.28	2000	2013	-0.887		0.34	1986	2002
France	-4.052		0.24	1981	2012	-4.851	*	0.09	1983	2013	-1.933		0.68	1975	1981	-2.707		0.93	1971	1983
Germany	-2.497		0.39	1981	2012	-3.987		0.39	1971	1990	-1.974		1.00	1981	1986	-3.580		0.71	1990	2005
Greece	-4.936	**	0.37	1973	2010	-4.357		1.00	1997	2010	-3.068		0.96	1973	2010	-2.510		0.66	1997	2009
Iceland	-2.599		0.46	1983	2009	-4.785		0.98	1973	1992	-3.163		0.36	1989	2009	-4.899		0.49	1971	1977
Ireland	-5.100	**	0.10	2008	2013	-3.289		0.09	1983	1986	-2.658		0.63	2002	2008	-2.774		0.26	1974	1992
Israel	-2.129		0.97	1976	1990	-2.976		1.00	1990	2003	-1.981		0.95	1976	2001	-4.220		0.47	1990	2003
Italy	-3.277		0.75	1981	2012	-3.059		0.85	1973	2012	-1.697		0.63	2010	2013	-2.212		0.27	1979	1987
Japan	-3.553		0.78	1983	1986	-3.726		0.97	1986	1997	-2.128		0.51	1971	1986	-3.327		0.77	1986	1997
Korea	-3.245		0.94	1990	1997	-2.582		0.64	1973	1986	-3.243		1.00	1986	1997	-2.330		0.95	1971	1981
Luxembourg	-4.593	**	0.11	1991	2003	-4.837	*	0.19	1981	1989	-2.598		0.99	1975	1989	-4.086		0.77	1989	2013
Mexico	-3.918		0.26	1983	2013	-3.905		0.96	1974	1985	-3.422		0.44	1982	2013	-4.795		0.34	1986	1995
Netherlands	-3.920		0.08	1981	2012	-3.109		0.07	1981	2012	-1.489		0.98	1977	1990	-2.606		0.74	1981	1997
New Zealand	-1.289		0.70	1975	2010	-5.758	**	1.00	1977	2007	-1.170		0.69	1975	2013	-6.298	***	0.61	1977	2007
Norway	-1.405		0.83	1977	1999	-3.460		0.83	1975	1999	-2.341		0.89	2005	2013	-3.294		0.72	1977	1999
Portugal	-2.766		0.70	1975	2011	-3.990		0.64	1986	2005	-3.280		0.37	1975	2001	-3.780		0.56	1983	1986
Spain	-2.953		0.48	1975	2010	-3.472		0.50	1981	1987	-2.368		0.55	1975	2008	-2.768		0.55	1991	2005
Sweden	-4.720	**	0.10	1976	1992	-4.928	*	0.19	1977	2007	-0.937		0.65	2002	2013	-4.166		0.95	1999	2007
Switzerland	-2.372		0.99	1991	2005	-5.996	***	0.15	1975	1997	-5.720	***	0.29	1979	2007	-5.685	**	0.38	1996	2007
Turkey	-3.172		0.26	1977	1994	-4.379		0.77	2006	2010	-1.705		0.94	1977	1980	-4.480		0.56	2006	2010
UK	-1.350		0.79	2006	2011	-5.925	***	0.89	1991	1995	-0.825		0.94	1983	1995	-5.840	**	0.85	1991	1995
Brazil	-2.043		0.85	1975	1997	-3.622		0.85	1971	2006	-2.740		0.64	1997	2004	-3.677		0.96	1971	2007
China	-3.647		0.46	2009	2012	-3.797		0.08	2001	2009	-2.866		0.73	2007	2012	-2.418		1.00	1991	2001
India	-2.880		0.11	1976	2011	-4.590		0.03	1976	2009	-1.925		0.39	1976	2003	-3.588		0.56	1976	2005
Taiwan	-7.400	***	0.61	1990	1998	-5.698	**	0.77	1971	1986	-8.152	***	0.93	1987	1998	-6.052	***	0.96	1971	1986
Philippines	-1.835		0.49	1997	2008	-4.073		0.14	1997	2008	-1.396		0.80	1997	2002	-4.123		0.51	1997	2007
Thailand	-5.243	***	0.05	1971	1997	-3.310		0.05	1997	2002	-2.400		1.00	1971	1988	-2.022		0.79	1987	1998
Malaysia	-2.850		0.59	1983	2007	-3.254		0.33	1998	2007	-2.513		0.71	1983	2007	-2.720		0.94	1973	2004
Hong Kong	-4.716	**	0.00	2006	2014	-4.211		0.00	2006	2014	-3.239		0.75	2011	2014	-3.004		1.00	1979	1986
Indonesia	-1.938		0.76	2009	2012	-5.381	**	0.68	1989	2008	-2.110		0.95	1997	2004	-2.654		0.58	1989	2008
Singapore	-4.553	+	0.69	1981	1996	-5.306	**	0.47	1996	2010	-4.626	*	0.61	1991	2000	-4.392		0.89	2000	2004
Hungary	-1.823		0.50	2011	2015	-4.067		0.36	2001	2008	-0.926		1.00	2012	2015	-3.798		0.86	2002	2008
Porland	-2.311		0.80	2012	2015	-1.570		0.92	1993	2009	-1.980		1.00	2012	2015	-2.567		0.71	1992	2007

Note: Preliminary results.

Table 6 (continued)

Countries	Covariate: Inflation rate								Covariate: TFP growth							
	Raw data				Demeaned data				Raw data				Demeaned data			
	t		ρ^2	Break 1	Break 2	t		ρ^2	Break 1	Break 2	t		ρ^2	Break 1	Break 2	t		ρ^2	Break 1	Break 2
Australia	-2.281		0.99	1971	2005	-3.414		0.98	1972	2001	-2.031		0.97	1972	2001	-3.594		0.96	1972	2005
Austria	-2.501		1.00	2007	2013	-3.901		0.61	1987	2004	-2.533		0.85	1976	1986	-3.460		0.96	1989	2005
Belgium	-2.711		0.91	1981	2000	-3.195		0.78	1987	2000	-1.971		0.94	1981	1986	-2.642		0.85	1974	2000
Canada	-1.768		0.39	1972	2014	-6.446	***	0.04	1983	2005	-1.991		0.97	1976	2014	-3.284		0.97	1973	1992
Chile	-1.980		0.78	1972	2005	-3.831		0.63	1975	2004	-1.658		0.55	1972	2002	-2.602		0.56	1974	2005
Colombia	-2.320		0.30	1973	2001	-5.229	**	0.25	1983	2006	-1.588		0.83	1976	1987	-3.760		0.96	1996	2006
Costa Rica	-1.288		0.93	1978	2004	-3.763		0.99	1981	2009	-1.453		0.83	1978	2007	-3.628		0.93	1981	2008
Denmark	-2.419		0.99	1971	2004	-4.350		0.70	1997	2005	-3.037		1.00	1972	2004	-4.597		1.00	1977	2005
Finland	-1.962		0.96	1975	1998	-4.143		0.65	1979	1995	-0.911		0.42	1975	1995	-1.318		0.68	1994	2005
France	-3.333		0.69	1983	2013	-5.169	**	0.15	1987	2005	-2.296		0.98	1975	1981	-3.442		0.97	1983	2005
Germany	-1.730		0.90	2008	2011	-3.316		0.33	1987	2005	-1.980		0.50	1983	1986	-2.842		0.67	1986	2005
Greece	-4.438	*	0.32	1992	2010	-3.346		0.70	1988	2011	-2.650		0.45	2010	2013	-2.913		0.47	2005	2010
Iceland	-2.040		1.00	1983	2009	-5.387	**	0.60	1971	1977	-1.469		0.56	1983	2010	-3.786		0.76	1973	1992
Ireland	-2.209		1.00	2000	2014	-2.945		0.99	1995	2014	-1.509		0.61	1995	2014	-1.421		0.70	1995	2014
Israel	-3.114		0.98	1976	1990	-3.439		0.91	1990	2003	-1.389		0.47	2003	2009	-2.352		0.70	1991	2003
Italy	-5.336	***	0.15	1971	1986	-5.725	***	0.10	1986	1994	-2.073		0.55	2010	2014	-2.740		0.52	1974	1986
Japan	-4.075		0.86	1971	1997	-4.973		0.96	1986	2011	-2.641		0.75	1996	2011	-3.339		0.81	1986	2011
Korea	-4.666	*	0.62	1997	2001	-4.705		0.81	1973	1986	-4.092		0.68	1990	1997	-3.478		0.70	1986	2001
Luxembourg	-2.501		0.97	1975	1990	-4.957		0.86	1989	2014	-1.654		0.74	1975	1989	-2.756		0.78	1991	2014
Mexico	-1.976		0.99	1983	1989	-2.208		0.61	1974	1986	-1.505		0.53	1983	1989	-2.686		0.52	1979	1983
Netherlands	-2.158		0.96	1976	1997	-3.809		0.67	1995	2005	-2.110		0.90	1976	1997	-3.048		0.96	1981	1999
New Zealand	-0.482		0.75	1988	2010	-6.730	***	0.74	1977	2007	-0.442		0.74	1976	2006	-5.112		0.87	1977	2007
Norway	-1.295		0.52	1971	1990	-2.897		0.49	1974	1990	-1.419		0.92	2000	2014	-3.192		0.92	1974	1999
Portugal	-4.002		0.33	1992	2011	-4.933		0.74	1983	1986	-2.907		0.80	1975	1986	-4.044		0.81	1983	1986
Spain	-3.099		0.48	1981	2009	-3.325		0.84	1981	1989	-2.650		0.99	1975	1987	-3.323		1.00	1981	1989
Sweden	-1.703		0.83	1971	1994	-3.956		0.90	1995	2006	-1.510		0.51	1992	2007	-2.974		0.92	1999	2007
Switzerland	-4.389		0.45	1977	2007	-6.355	***	0.53	1975	2007	-2.637		0.78	1996	2005	-3.654		0.93	1983	2007
Turkey	-2.395		0.98	1977	2004	-3.887		0.84	2006	2010	-2.119		0.70	1977	2005	-4.377		0.68	2002	2006
UK	-0.640		0.98	2009	2012	-5.029		0.79	1991	1995	-1.441		0.95	1981	1992	-4.793		0.97	1991	1995
Brazil	-2.069		0.96	1975	2004	-3.661		0.97	1971	2007	-1.648		0.74	1997	2006	-2.508		0.83	1973	2007
China	-2.310		0.57	1986	1999	-3.059		0.63	1995	2001	-5.745	***	0.20	2001	2013	-1.968		0.38	1991	2008
India	-1.499		0.95	2011	2014	-4.442		0.83	1976	2005	-1.983		0.53	2011	2014	-4.012		0.94	1976	2005
Taiwan	-6.740	***	0.94	1988	1994	-5.566	**	0.92	1971	1986	-8.775	***	0.70	1987	1994	-4.482		0.72	1978	1986
Philippines	-1.629		0.79	1997	2000	-3.135		0.85	1998	2008	-2.134		0.60	1997	2007	-1.242		0.71	1998	2011
Thailand	-4.122		0.74	1997	2001	-3.151		0.78	1973	2002	-3.740		0.40	1997	2001	-2.645		0.65	1974	2002
Malaysia	-2.397		0.91	1975	1999	-2.798		0.93	1980	2007	-3.209		0.31	1985	1989	-2.295		0.33	1989	2007
Hong Kong	-3.140		1.00	2011	2014	-3.367		1.00	1977	1986	-3.200		0.87	2011	2014	-3.249		0.86	1980	1989
Indonesia	-2.740		0.83	1981	2004	-5.250	*	0.91	1989	2008	-2.665		0.47	2008	2012	-3.911		0.74	1980	2007
Singapore	-2.770		0.91	1985	2000	-3.679		0.85	1978	2000	-3.556		0.72	1985	1996	-4.835		0.92	2000	2005
Hungary	-1.424		0.70	2012	2015	-3.734		0.69	2005	2008	-1.339		0.49	2012	2015	-3.005		0.76	2002	2008
Porland	-4.888	**	0.29	1999	2007	-4.949	*	0.27	1987	2007	-4.159		0.34	2008	2012	-5.983	***	0.12	1994	2007

Table 6 (continued)

Countries	Covariate: Human capital index growth							
	Raw data				Demeaned data			
	t	ρ^2	Break 1	Break 2	t	ρ^2	Break 1	Break 2
Australia	-2.873	0.39	1972	2009	-4.359	0.46	1974	2008
Austria	-3.193	0.44	1976	2011	-3.847	0.64	1990	2004
Belgium	-2.489	0.74	1975	2000	-3.519	0.56	1999	2005
Canada	-2.428	0.71	1981	2014	-3.678	1.00	1973	1991
Chile	-2.613	0.75	1972	2005	-5.264 **	0.29	1982	2005
Colombia	-1.557	0.92	1983	2006	-4.070	0.85	1998	2006
Costa Rica	-1.467	0.99	1978	2005	-4.385	0.91	1982	2008
Denmark	-2.734	0.81	1971	2005	-4.483	0.85	1981	2005
Finland	-1.750	1.00	2009	2012	-4.175	0.50	1978	1997
France	-3.565	0.67	1981	2005	-3.336	0.99	1984	2005
Germany	-2.130	0.41	1981	2012	-2.640	0.28	1974	2007
Greece	-3.287	0.88	1973	2010	-3.718	0.93	2001	2010
Iceland	-1.822	0.95	1983	2008	-4.816	0.97	1973	1992
Ireland	-2.688	0.91	2000	2014	-3.297	0.94	1995	2014
Israel	-3.261	0.86	1976	2009	-3.753	0.90	1990	2003
Italy	-3.988	0.94	1981	2012	-3.547	0.62	1974	1990
Japan	-2.582	0.98	1971	1997	-3.975	0.28	1986	1997
Korea	-4.213	0.34	1997	2000	-3.519	0.38	1973	1987
Luxembourg	-3.041	0.98	1975	1989	-4.649	0.90	1989	2014
Mexico	-2.269	0.69	1983	2013	-3.158	0.97	1983	2005
Netherlands	-3.271	0.10	1971	1981	-3.910	0.32	1990	1999
New Zealand	-2.191	0.48	1975	2011	-6.348 ***	0.85	1977	2007
Norway	-2.256	0.90	2003	2013	-3.433	0.93	1974	1999
Portugal	-4.905 **	0.58	1975	1986	-4.607	0.99	1983	1986
Spain	-3.057	0.97	1975	1986	-4.918	0.52	1986	2014
Sweden	-1.624	0.98	1971	2002	-3.909	0.93	1995	2006
Switzerland	-4.745	0.47	1990	2007	-5.770 **	0.74	1975	2007
Turkey	-2.611	0.71	1977	1986	-3.986	1.00	2006	2010
UK	-0.591	1.00	1981	2014	-4.436	0.89	1989	1995
Brazil	-1.891	0.91	1975	1997	-3.118	0.70	1991	2007
China	-3.101	0.60	2011	2014	-3.048	0.89	1982	2001
India	-2.623	0.57	1976	2001	-3.498	0.98	1976	2005
Taiwan	-9.319 ***	0.53	1983	1986	-6.064 ***	0.62	1971	1986
Philippines	-4.355 *	0.14	1983	1997	-2.562	0.43	1998	2008
Thailand	-3.547	0.97	1997	2000	-3.161	0.99	1987	2002
Malaysia	-2.169	0.91	1984	1988	-3.459	0.82	1989	2004
Hong Kong	-2.831	0.92	2001	2014	-3.453	0.63	1986	1990
Indonesia	-2.388	0.46	1992	2012	-3.841	0.98	1980	2008
Singapore	-2.283	0.89	1985	2000	-3.384	0.46	1979	2005
Hungary	-1.039	0.04	2001	2011	-3.255	0.68	2005	2008
Porland	-2.379	0.97	2012	2015	-2.390	0.91	1993	2007

- Covariate augmented Dickey-Fuller (CADF) test (2 breaks)

・Covariate: Trade/GDP ratio

Regression w/ constant: 10/41

w/o constant: 11/41

・Covariate: Government expenditure/GDP ratio

Regression w/ constant: 4/41

w/o constant: 3/41

・Covariate: Inflation rate

Regression w/ constant: 10/41

w/o constant: 5/41

・Covariate: TFP growth

Regression w/ constant: 1/40

w/o constant: 2/40

・Covariate: Human capital index growth

Regression w/ constant: 4/41

w/o constant: 3/41

Summary of Tables 4-6

- In the case of no break, some countries (Austria, Italy, Japan, Korea, Portugal, Taiwan, Thailand, Hong Kong, Singapore, and Poland) show consistent trends of absolute convergence to the US in all covariates.
- In the case of one break, when the trade/GDP ratio or inflation rate is a covariate, absolute/relative convergence tendencies become more evident in Finland, France, Greece, Ireland, Iceland, Luxembourg, Sweden, Switzerland, the UK, India, and China.
- In the case of two breaks, some other countries (Canada, Columbia, NZ) are observed as converged in one or two covariate cases.
- In general, the trade/GDP ratio and inflation rate are more effective determinants, but other covariates still have positive impacts.

Table 7. Summary of test results

Test	# of countries	
	Absolute convergence	Relative convergence
ADF	11	4
Zivot and Andrews	0	2
Lumsdaine and Papell	1	2
CADF w/o break	18	5
CADF w/ one break	16	16
CADF w/ two breaks	15	14

31 countries have the tendency of absolute convergence and/or relative convergence (a zero- and/or a nonzero-mean stationarity).

5. Empirical Analysis 2

Data 1 (panel estimation)

- 31 zero-mean or nonzero-mean stationary series ($y_{US} - y_i$) are used in panel estimation. The existing structural breaks are removed for each series before estimation.
- Sample period: 1995-2018
- Possible political and institutional variables are included.
  - Political rights, civil liberty (Freedom House)
  - Overall economic freedom, property rights, government integrity, business freedom, tax burden, trade freedom, investment freedom, financial freedom (Heritage Freedom)
  - Variable related to recent technologies: Robots per employees (IFR), ICT (Internet users (%))

Table A2. Data descriptions

Variable	Description	Data source
Political insitutions		
Polity 2 score	Graded on a scale of 1 to 10	Polity IV project
Political rights	Poritical rights rating obtained from Freedom in the World (FIW) research	Freedom House
Civil liberty	Civil liberties rating obtained from Freedom in the World (FIW) research	Freedom House
Governance quality		
Overall economic freedom index	Measured based on 12 quantitative and qualitative factors, grouped into four broad categories, or pillars, of economic freedom.	Heritage Freedom
Property rights	Graded on a scale of 0 to 100	Heritage Freedom
Government integrity	Graded on a scale of 0 to 100	Heritage Freedom
Business freedom	Graded on a scale of 0 to 100	Heritage Freedom
Trade freedom	Graded on a scale of 0 to 100	Heritage Freedom
Fiscal policies		
Tax burden	Graded on a scale of 0 to 100	Heritage Freedom
Financial institutions		
Investment freedom	Graded on a scale of 0 to 100	Heritage Freedom
Financial freedom	Graded on a scale of 0 to 100	Heritage Freedom
Recent technologies		
Robots per employees	Operating stock of robots per 1,000 employees	International Federation of Robotics, ILO database
ICT	Internet users (%)	World Telecommunication/ICT indicators database

Table 8. Panel estimation results

Variables	(1)	(2)	(3)	(4)	(5)
Polity2	-0.002	-0.002	0.016		
	(0.008)	(0.008)	(0.009)		
Political rights	0.021	0.022	0.195		
	(0.030)	(0.030)	(0.035)		
Civil liberty	-0.098 ***	-0.100 ***	-0.066 **	-0.072 ***	-0.045
	(0.024)	(0.024)	(0.030)	(0.022)	(0.030)
Overall economic freedom	-0.012 *	-0.012 **	-0.012 *	-0.009 **	-0.010 *
	(0.007)	(0.005)	(0.006)	(0.004)	(0.005)
Property rights	0.001	0.001	0.002		
	(0.002)	(0.002)	(0.002)		
Government integrity	-0.003 *	-0.002	-0.002	-0.003 *	-0.002 *
	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
Business freedom	0.003	0.002	0.002		
	(0.002)	(0.002)	(0.002)		
Tax burden	0.000	0.000	-0.002		
	(0.002)	(0.002)	(0.003)		
Trade freedom	-0.010 ***	-0.011 ***	-0.013 ***	-0.011 ***	-0.014 ***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Investment freedom	0.006 ***	0.006 ***	0.004 **	0.005 ***	0.004 **
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Financial freedom	0.000	0.000	0.000		
	(0.002)	(0.002)	(0.002)		
Robots per employees	-0.007		-0.019 **		-0.019 ***
	(0.010)		(0.008)		(0.007)
ICT	-0.002 **	-0.002 **		-0.002 **	
	(0.001)	(0.001)		(0.001)	
R-squared	0.549	0.527	0.510	0.509	0.491
Constant	Yes	Yes	Yes	Yes	Yes
Model	Fixed	Fixed	Fixed	Fixed	Fixed
Observations	644	691	644	713	666
Years	1995-2018	1995-2018	1995-2018	1995-2018	1995-2018
Countries	27	29	27	30	28

5. Empirical Analysis 2

Data 2 (Ordered logit model)

- Qualitative data:

  Absolute convergence => $y_i = 3$

  Relative convergence => $y_i = 2$

  Non convergence => $y_i = 1$ 40 available ordered data

- Estimate an ordered logit model with selected explanatory variables: Civil liberty, government integrity, trade freedom, robots per employees, ICT

Model: $y_i = X_i\beta + \varepsilon_i \qquad i = 1, \dots, 40$

Where $y_i = j \Leftrightarrow k_{j-1} < y_i^* < k_j \ (j = 1, 2, 3)$
y_i^* is an unobservable latent variable, k_j is a threshold.

Table 9. Results of ordered logit

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Civil liberty	0.976 *	1.514 **	1.201 **	1.140 ***	0.641 *	1.154 **	0.881 **	0.725 **
	(0.525)	(0.640)	(0.598)	(0.428)	(0.347)	(0.555)	(0.376)	(0.311)
Government integrity	0.055	0.100	0.018	0.020	0.012	0.045	-0.010	0.009
	(0.065)	(0.065)	(0.038)	(0.040)	(0.052)	(0.050)	(0.042)	(0.038)
Trade freedom	0.073	0.058	0.016	0.028	0.219 *	0.296 **	0.092	0.061
	(0.054)	(0.044)	(0.045)	(0.046)	(0.119)	(0.145)	(0.118)	(0.108)
Robots per employees	1.966 ***	1.665 ***	1.552 ***		1.427 ***	1.345 ***	1.099 ***	
	(0.656)	(0.512)	(0.529)		(0.488)	(0.363)	(0.315)	
ICT	-0.082	-0.122 *		0.002	-0.057 *	-0.099 ***		-0.005
	(0.081)	(0.070)		(0.052)	(0.032)	(0.037)		(0.033)
D Europe		1.740 *	1.316	1.612 **		1.943 *	1.223	1.357 *
		(1.044)	(1.008)	(0.824)		(1.018)	(0.841)	(0.793)
Pseudo R-squared	0.213	0.255	0.224	0.106	0.208	0.261	0.207	0.073
Observations	37	37	37	40	37	37	37	40

Note: Explanatory variables are the sample averages (1995-2018) in Eqs.(1)-(4) and the recent 10-year averages in Eqs. (5)-(8).

Summary of Tables 8-9

- In the panel estimation, civil liberty, trade freedom, robots per employees and ICT are strongly significant with negative coefficients. In addition, overall economic freedom index and government integrity are weak but significant. These variables significantly narrow the output gaps between the US and follower countries.
- In the ordered logit model, in all cases, civil liberty and robots per employees are significant. Trade freedom is also significant in two cases. Their positive coefficients mean that these variables are more supportive for the countries to get on a better state of convergence (non convergence to relative convergence / relative convergence to absolute convergence).
- Digital divide caused by ICT may lower the probability that a country shifts to relative/absolute convergence.

6. Remaining issues

- Over-rejection of the null:

  Some output (difference) series may be over-rejected due to overfitting structural breaks to the data or mis-specifying their nonlinearities.

  ⇒Need different model specifications

- Covariate selection issue:

  No standard/measure for covariate selection. One alternative: Extract a common component from several stationary covariates in a PCM or a DFM, and use it as one stationary covariate for each series.

Thank you for your attention

Figure 1a. 29 OECD countries (against US)

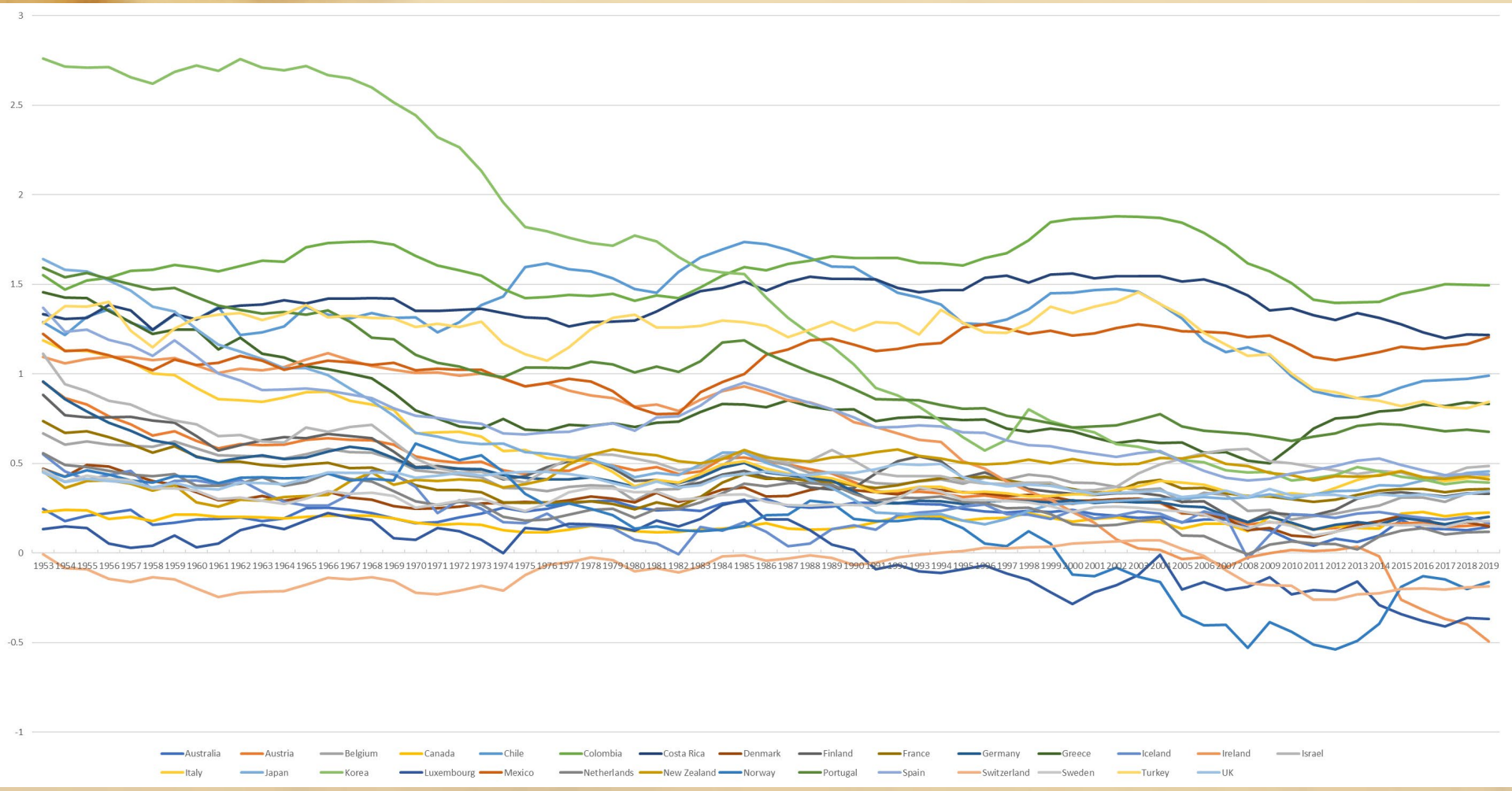


Figure 1b. 12 Asian and EEU countries (against US)