Panel Co-integration Analysis of the Short-Run and Long-Run Relationships for a Multi-Country Mortality Index

Presenter: Sharon S. Yang
National Central University, Taiwan
Co-author: Jr-Wei Huang

Longevity 7th Conderence, Sep. 8-9, 2011

Introduction

Introduction

- There is a need to deal with longevity/mortality risk across countries because the pooling policies may expose the risk internationally.

- In addition, many mortality-linked securities are based on a multi-country mortality index.

- For example, Swiss Re Mortality Bond.
  - A Combined mortality index in five selected countries (France, England, USA, Italy and Switzerland.)

- Yang and Wang(2011) price a longevity bond based on a multi-country structure.

Introduction

- Time series analysis is one of the main technique to forecast future mortality rates.

  - The ARIMA (p,d,q) process was common used to model the period effect in Lee Carter model (Koissi et al.2006; Denuit et al., 2007).
  - Gao and Hu (2009) investigate the conditional heteroskedasticity of the period effect in the Lee Carter model.
  - Chen et al.(2010) introduce the jump effect with the Kt in the Lee Carter model.

→ These researches don't investigate the effect across countries.

Introduction

Co-integration Analysis

a popular method for economists to study the long-term relationships between various economic variables

- Lazar (2004) use co-integration analysis to study the long-run equilibrium relationship between variables in Lee carter model.

$$\Delta y_{xt} = \mu + \chi t + \alpha \hat{\varepsilon}_{x;t-1} + \sum_{i=0}^{m} \beta_i \Delta k_{t-i} + \sum_{i=1}^{n} \delta_i \Delta y_{x;t-i} + \eta_{xt}$$

- Darkiewicz and Hoedemakers (2004)
  - Based on log-mortality rates
  - Test whether log-mortality rates for different ages are co-integrated.

Introduction

- Njenga and Sherris (2009) and Gaille and Sherris (2010)
  - a long-run equilibrium relationship between variables in Heligman and Pollard (1980) 's mortality model
  - They show that mortality improvement across these countries, for both females and males, has common trend.

$$q_{x,t} = A_t^{(x+B_t)^{C_t}} + D_t e^{-E_t(\ln(x)-\ln(F_t))^2} + \frac{G_t H_t^x}{1+K_t G_t H_t^x},$$

Introduction

- This paper extends the co-integration analysis to deal with the multi-country mortality investigation.

- However, Campbell and Perron (1991) have pointed out that the short time spans or limited number of individual data will weaken the power of the unit root test, and of the co-integration and causality test.

- The available mortality data is usually on annual basis.
  - HMD database

Introduction

- Al-Iriani (2006) suggested that the adoption of recently developed panel techniques could eliminate the problems associated with the low power of the traditional unit root and co-integration test.

- To overcome the problem of the limited mortality data, we adopt the panel co-integration analysis to investigate the short-run and long-run equilibrium relationship for a multi-country mortality index.
  - **Focus on the co-movement and the causality relationship for the multi-country mortality rates.**
  - **Implement the panel unit root, panel co-integration and panel causality test**
  - **Compare the results with traditional co-integration analsyis**

Methodology

Panel Co-integration Analysis

Three steps:

- Panel Unit Root Test

  →to ensure the mortality data in different countries is stationary.

- Panel co-integration Test

  →to examine the long-run relationship of mortality rate across countries.

- Panel causality Test

  →to assess the short-run and long-run causality relationship of mortality rate across countries.

Panel Unit Root Test

- We apply three popular methods for panel unit root test, which are based on Levin et al. (2002), Im et al. (2003) and Hadri (2000) separately.

  - Levin et al. (2002) assumes an ADF test with a panel setting and restricts γ_i to keep it identical across cross sectional regions. The test model is set up as follows:

$$\Delta q_{it} = \alpha_i + \gamma_i q_{it-1} + \sum_{j=1}^{k} \alpha_j \Delta q_{it-j} + \varepsilon_{it}$$

  - Under the null hypothesis of a unit root, q_{it} is nonstationary
  - One drawback is the γ is restricted by being kept identical across regions.

Panel Unit Root Test

- Im et al. (2003) relaxes this assumption of Levin et al. (2002) by allowing γ to vary across regions under the alternative hypothesis.

$$\Delta q_{it} = \alpha_i + \gamma_i q_{it-1} + \varepsilon_{it}$$

- Under the null hypothesis of a unit root, q_{it} is nonstationary

Panel Unit Root Test

- Hadri (2000) Lagrange multiplier (LM) test uses panel data to test the null hypothesis that the data stationary versus the alterative that at least on panel contain a unit root

$$q_{it} = \gamma_{it} + \beta_i t + \varepsilon_{it}$$

$$\gamma_{it} = \gamma_{i,t-1} + \mu_{it}$$

where γ_{it} is a random walk

Panel Co-integration Test

- **The Group Mean Statistics**
  - The first step is to estimate equation by least squares for each individual *i*, which yields

$$\Delta q_{it} = \hat{\delta}_i^{'} d_t + \hat{\alpha}_i q_{it-1} + \hat{\lambda}_i^{'} x_{it-1} + \sum_{j=1}^{pi} \hat{\alpha}_{ij} \Delta q_{it-j} + \sum_{j=0}^{pi} \hat{\gamma}_{ij} \Delta x_{it-j} + \hat{e}_{it}$$

  - To compute the test statistics as follows

$$G_\tau = \frac{1}{N} \sum_{i=1}^{N} \frac{\hat{\alpha}_i}{SE(\hat{\alpha}_i)}, \qquad G_\alpha = \frac{1}{N} \sum_{i=1}^{N} \frac{T\hat{\alpha}_i}{\hat{\alpha}_i(1)}$$

  - where $SE(\hat{\alpha}_i)$ is the standard error of $\hat{\alpha}_i$ and $\alpha_i(1) = 1 - \sum_{j=1}^{p_i} \alpha_{ij}$.

Panel Co-integration Test

- **The Panel Statistics**
  - The panel statistic are complicated by the fact that the both the parameters and dimension of equation (*) are allows to differ between the cross-section units, , and we implement three-step procedure carry out the panel statistics. The first step, we regress Δq_{it} and q_{it-1} onto d_t , the lags of Δq_{it} as well as the contemporaneous and lagged values of Δx_{it} . This yields the projection errors

$$\Delta\tilde{q}_{it} = \Delta q_{it} - \hat{\delta}_i^{'} d_t - \hat{\lambda}_i^{'} x_{it-1} - \sum_{j=1}^{pi} \hat{\alpha}_{ij} \Delta q_{it-j} - \sum_{j=0}^{pi} \hat{\gamma}_{ij} \Delta x_{it-j},$$

$$\tilde{q}_{it-1} = q_{it-1} - \tilde{\delta}_i^{'} d_t - \tilde{\lambda}_i^{'} x_{it-1} - \sum_{j=1}^{pi} \tilde{\alpha}_{ij} \Delta q_{it-j} - \sum_{j=0}^{pi} \tilde{\gamma}_{ij} \Delta x_{it-j}.$$

Panel Co-integration Test

- **The Panel Statistics**
  - The second step involves using $\Delta\tilde{q}_{it}$ and $\tilde{q}_{it-1}$ to estimate the common error correction parameter α and its standard error. Further, we compute

$$\hat{\alpha} = \left(\sum_{i=1}^{N} \sum_{t=2}^{T} \tilde{q}_{it-1}^{2} \right)^{-1} \sum_{i=1}^{N} \sum_{t=2}^{T} \frac{1}{\hat{\alpha}_i(1)} \tilde{q}_{it-1} \Delta\tilde{q}_{it}.$$

The standard error of $\hat{\alpha}$ is given by $SE(\hat{\alpha}) = \left((\hat{S}_N^2)^{-1} \sum_{i=1}^{N} \sum_{t=2}^{T} \tilde{q}_{it-1}^{2} \right)^{-1/2}$

  - The final step is to compute the panel statistics as

$$P_\tau = \frac{\hat{\alpha}}{SE(\hat{\alpha})}, \qquad P_\alpha = T\hat{\alpha}.$$

Panel error correction model (ECM)

- To identify the direction of causality, we estimate a panel ECM and use it to conduct Granger causality tests on the five countries mortality rate relationship.

- We use a panel ECM to account for the short-run and long-run relationship using the two-step procedure adopted by Engle and Granger (1987) after the variables are co-integrated.

Panel error correction model (ECM)

- The empirical model is represented by the following five-equation ECM.

$$
\begin{aligned}
\Delta q(France)_{it} &= \theta_{1j} + \Sigma_{k=1}^{m}\theta_{11ik}\Delta q(France)_{it-k} + \Sigma_{k=1}^{m}\theta_{12ik}\Delta q(England)_{it-k} + \Sigma_{k=1}^{m}\theta_{13ik}\Delta q(USA)_{it-k} \\
&+ \Sigma_{k=1}^{m}\theta_{14ik}\Delta q(Italy)_{it-k} + \Sigma_{k=1}^{m}\theta_{15ik}\Delta q(Switzerland)_{it-k} + \lambda_{1i}\varepsilon_{it-1} + \mu_{1it} \\
\Delta q(England)_{it} &= \theta_{2j} + \Sigma_{k=1}^{m}\theta_{21ik}\Delta q(France)_{it-k} + \Sigma_{k=1}^{m}\theta_{22ik}\Delta q(England)_{it-k} + \Sigma_{k=1}^{m}\theta_{23ik}\Delta q(USA)_{it-k} \\
&+ \Sigma_{k=1}^{m}\theta_{24ik}\Delta q(Italy)_{it-k} + \Sigma_{k=1}^{m}\theta_{25ik}\Delta q(Switzerland)_{it-k} + \lambda_{2i}\varepsilon_{it-1} + \mu_{2it} \\
\Delta q(USA)_{it} &= \theta_{3j} + \Sigma_{k=1}^{m}\theta_{31ik}\Delta q(France)_{it-k} + \Sigma_{k=1}^{m}\theta_{32ik}\Delta q(England)_{it-k} + \Sigma_{k=1}^{m}\theta_{33ik}\Delta q(USA)_{it-k} \qquad (**) \\
&+ \Sigma_{k=1}^{m}\theta_{34ik}\Delta q(Italy)_{it-k} + \Sigma_{k=1}^{m}\theta_{35ik}\Delta q(Switzerland)_{it-k} + \lambda_{3i}\varepsilon_{it-1} + \mu_{3it} \\
\Delta q(Italy)_{it} &= \theta_{4j} + \Sigma_{k=1}^{m}\theta_{41ik}\Delta q(France)_{it-k} + \Sigma_{k=1}^{m}\theta_{42ik}\Delta q(England)_{it-k} + \Sigma_{k=1}^{m}\theta_{43ik}\Delta q(USA)_{it-k} \\
&+ \Sigma_{k=1}^{m}\theta_{44ik}\Delta q(Italy)_{it-k} + \Sigma_{k=1}^{m}\theta_{45ik}\Delta q(Switzerland)_{it-k} + \lambda_{4i}\varepsilon_{it-1} + \mu_{4it} \\
\Delta q(Switzerland)_{it} &= \theta_{5j} + \Sigma_{k=1}^{m}\theta_{51ik}\Delta q(France)_{it-k} + \Sigma_{k=1}^{m}\theta_{52ik}\Delta q(England)_{it-k} + \Sigma_{k=1}^{m}\theta_{53ik}\Delta q(USA)_{it-k} \\
&+ \Sigma_{k=1}^{m}\theta_{54ik}\Delta q(Italy)_{it-k} + \Sigma_{k=1}^{m}\theta_{55ik}\Delta q(Switzerland)_{it-k} + \lambda_{5i}\varepsilon_{it-1} + \mu_{5it}
\end{aligned}
$$

Panel error correction model (ECM)

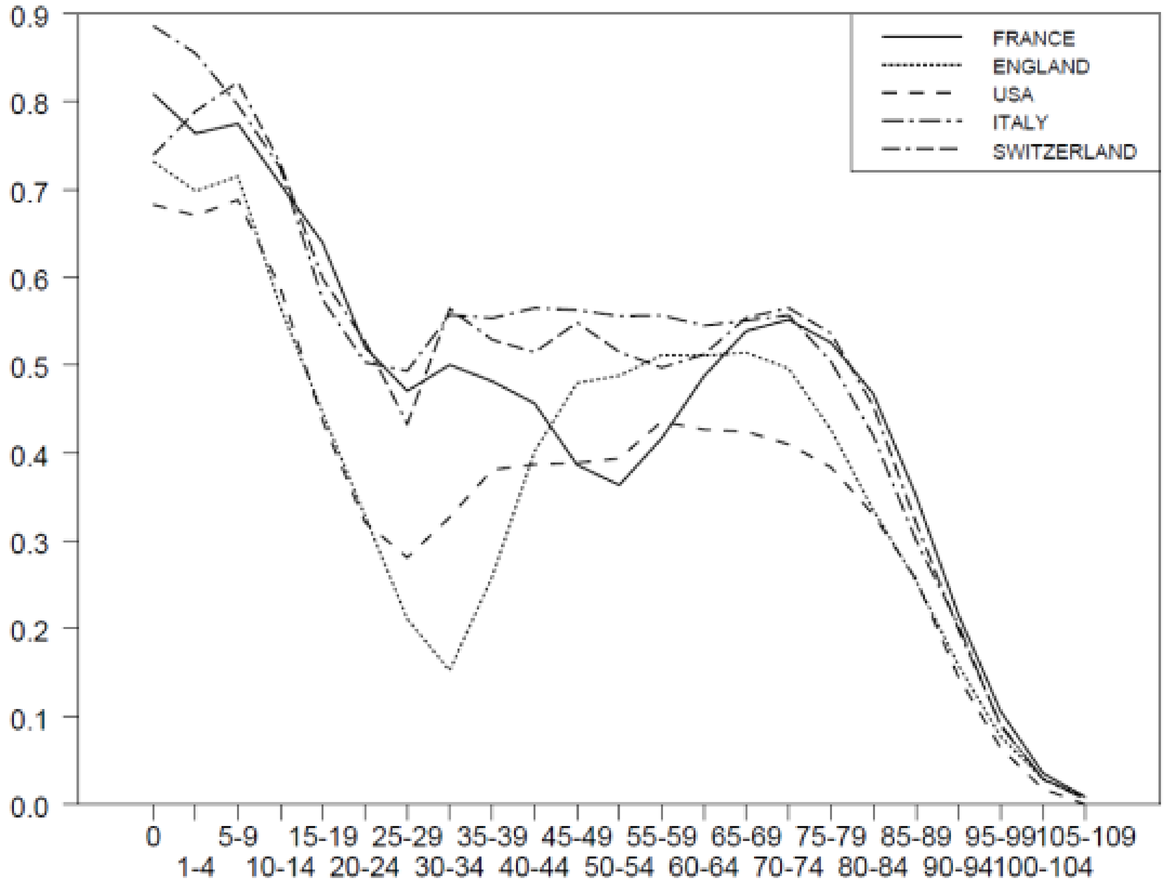
- Using the specification in above equation allows us to test for both short-run causality and long-run equilibrium.
  - For example, in the short-run England morality rate does not Granger-cause France mortality rate if and only if all the coefficient of θ_{12ik} are equal to zero in above equation.
- The presence (or absence) of long-run equilibrium can be established by examining the significance using a *t*-test on the speed of adjustment coefficient λ , of the error correction term in above equation.

Empirical Study

Mortality experience

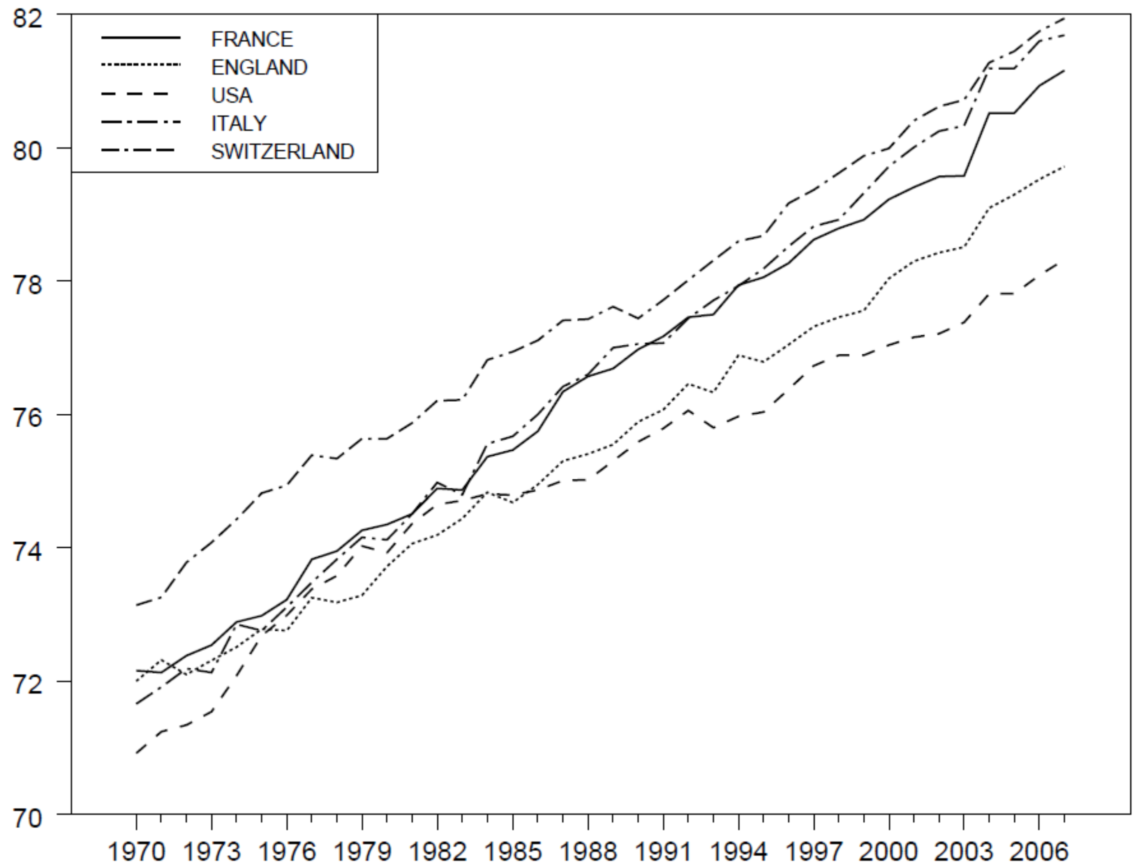
- Human mortality database
- Data Period: 1970 to 2007
- Countries: France, England, USA, Italy and Switzerland.
- Mortality data: Five-age Group

The Pattern of Mortality Experience



- Lee (2000) attributes the improvements in life expectancies to greater reduction in mortality rates at lower age rather than at higher ages.

The Pattern of Life Expectancy



- The fi … oward with the technological progress from these five countries.

Results: Panel Unit Root Tests

Variable	LLC		IPS		Hadri	
	Constant	Constant & Trend	Constant	Constant & Trend	Constant	Constant & Trend
$q(France)$	-1.005	0.699	4.924	2.217	110.936^{***}	19.286^{***}
$\Delta q(France)$	-11.281^{***}	-9.832^{***}	-18.865^{***}	-19.311^{***}	-3.509	-5.385
$q(England)$	0.317	-0.269	2.546	-0.303	108.604^{***}	12.568^{***}
$\Delta q(England)$	-13.289^{***}	-11.899^{***}	-20.061^{***}	-20.724^{***}	-3.627	-5.410
$q(USA)$	-0.701	2.110	0.377	-0.311	93.459^{***}	37.164^{***}
$\Delta q(USA)$	-7.455^{***}	-6.985^{***}	-15.167^{***}	-16.066^{***}	-1.721	-4.203
$q(Italy)$	-1.090	-0.851	3.060	-0.960	111.979^{***}	15.816^{***}
$\Delta q(Italy)$	-12.127^{***}	-10.908^{***}	-19.206^{***}	-19.824^{***}	-4.089	-5.230
$q(Switzerland)$	-0.714	-0.618	1.030	1.018	107.845^{***}	14.504^{***}
$\Delta q(Switzerland)$	-15.877^{***}	-13.378^{***}	-21.167^{***}	-21.465^{***}	-4.158	-5.111

- We therefore conclude that the variables five countries morality rate appear to be non-stationary and integrated of order one, i.e., I(1).

Results: Panel Co-integration Tests

Panel Variance	Test	Statistic Value	*P*-Value
Group Mean Statistics	G_τ	-2.801	0.000
	G_α	-12.118	0.066
Panel Statistics	P_τ	-15.134	0.000
	P_α	-13.706	0.000

- Most statistics significantly reject the null hypothesis of no co-integration at the 1% level of significance,.
- →It appears the co-movement of mortality rates across countries.

Results: Panel Causality Tests

Countries	Null Hypothesis	Short-Run Causality Test	Long-Run Relationship
France	$\Delta q(England) \rightarrow \Delta q(France)$	47.73^{***}	
	$\Delta q(USA) \rightarrow \Delta q(France)$	6.42^{**}	
	$\Delta q(Italy) \rightarrow \Delta q(France)$	97.90^{**}	
	$\Delta q(Switzerland) \rightarrow \Delta q(France)$	7.33^{**}	
	$\lambda_{1i} = 0$		73.67^{***}
England	$\Delta q(France) \rightarrow \Delta q(England)$	38.54^{***}	
	$\Delta q(USA) \rightarrow \Delta q(England)$	106.30^{***}	
	$\Delta q(Italy) \rightarrow \Delta q(England)$	78.03^{***}	
	$\Delta q(Switzerland) \rightarrow \Delta q(England)$	294.97^{***}	
	$\lambda_{2i} = 0$		1743.06^{***}
USA	$\Delta q(France) \rightarrow \Delta q(USA)$	5.13^{*}	
	$\Delta q(England) \rightarrow \Delta q(USA)$	23.20^{***}	
	$\Delta q(Italy) \rightarrow \Delta q(USA)$	229.87^{***}	
	$\Delta q(Switzerland) \rightarrow \Delta q(USA)$	6.97^{**}	
	$\lambda_{3i} = 0$		3.35^{*}
Italy	$\Delta q(France) \rightarrow \Delta q(Italy)$	457.73^{***}	
	$\Delta q(England) \rightarrow \Delta q(Italy)$	72.30^{***}	
	$\Delta q(USA) \rightarrow \Delta q(Italy)$	100.67^{***}	
	$\Delta q(Switzerland) \rightarrow \Delta q(Italy)$	53.21^{***}	
	$\lambda_{4i} = 0$		7.99^{***}
Switzerland	$\Delta q(France) \rightarrow \Delta q(Switzerland)$	8.59^{**}	
	$\Delta q(England) \rightarrow \Delta q(Switzerland)$	65.97^{***}	
	$\Delta q(USA) \rightarrow \Delta q(Switzerland)$	122.98^{***}	
	$\Delta q(Italy) \rightarrow \Delta q(Switzerland)$	229.75^{***}	
	$\lambda_{5i} = 0$		5.14^{**}

Results: Panel Causality Tests

- Our study results support of bi-directional short-run causality for these five countries,
  - which imply that the five countries may have similar life-style, environment, and the consumption of both goods and health service.

- In addition, we find the long-run relationship of mortality rates for these five countries.
  - Thus, the mortality for these five countries share the common trend for mortality improvement.

Results: A Comparison of Panel and Tradition Co-integration Approach

- The co-integration test results in table 5 indicate

- However, the table 6 reveals rejection of the null of no co-integration for most test. Therefore, one may conclude that our variables are in fact co-integrated.
  - In other words, the empirical results consistent with Campbell and Perron (1991) show that the short time spans of individual data sets will weaken the power of the co-integration test, thereby giving rise to distorted and mixed results.

Result: a Comparison of Panel and Tradition Co-integration Approach

Variable	Time Series Approach			
	Engle and Granger (1987)	0.05 Critical Values	Johansen (1988)	0.05 Critical Values
Mortality Index	-2.393	-4.840	60.769	69.610
Female : Mortality Index	-2.164	-4.840	63.537	69.610
Male : Mortality Index	-3.108	-4.840	126.450**	69.610
France	-2.924	-3.510	15.657**	15.410
England	-1.110	-3.510	6.669	15.410
USA	-0.063	-3.510	8.435	15.410
Italy	-1.552	-3.510	12.616	15.410
Switzerland	-4.113**	-3.510	19.537**	15.410

- **Most statistics value cannot reject the null hypothesis of no co-integration**

Result: a Comparison of Panel and Tradition Co-integration Approach

Variable	Panel Approach	
	Test	Statistics Value
Mortality Index	G_τ	-2.801***
	G_α	-12.118*
	P_τ	-15.134***
	P_α	-13.706***
Female : Mortality Index	G_τ	-3.274***
	G_α	-15.333*
	P_τ	-16.387***
	P_α	-15.058***
Male : Mortality Index	G_τ	-2.971***
	G_α	-12.744**
	P_τ	-13.985***
	P_α	-12.060***
Frannce	G_τ	-2.105***
	G_α	-9.569***
	P_τ	-7.703***
	P_α	-2.133**
England	G_τ	-1.711***
	G_α	-6.285***
	P_τ	-5.837***
	P_α	-2.284**
USA	G_τ	-1.709***
	G_α	-5.137*
	P_τ	-9.874***
	P_α	-4.531***
Italy	G_τ	-1.871***
	G_α	-6.060***
	P_τ	-5.966***
	P_α	-1.433
Switzerland	G	-3.203***

It reveals rejection of the null of no co-integration.

The empirical results consistent with Campbell and Perron (1991) show that the short time spans of individual data sets will weaken the power of the co-integration test, thereby giving rise to distorted and mixed results.

Robustness Checks

- Furthermore, we also control gender and also investing short-run and long-run relationship in female and male mortality, separately for five countries.

Gender	Panel Variance	Test	Statistics Value	*P*-Value
Female	Group Mean Statistics	G_τ	-3.274	0.000
		G_α	-15.333	0.066
	Panel Statistics	P_τ	-16.387	0.000
		P_α	-15.058	0.000
Male	Group Mean Statistics	G_τ	-2.971	0.000
		G_α	-12.744	0.027
	Panel Statistics	P_τ	-13.985	0.000
		P_α	-12.060	0.000

- Note: The Null hypothesis is no co-integration relationship.

Robustness Checks

- In Female

Gender	Countries	Null Hypothesis	Short-Run Causality Test	Long-Run Relationship
Female	France	$\Delta q(England) \rightarrow \Delta q(France)$	29.98^{***}	
		$\Delta q(USA) \rightarrow \Delta q(France)$	88.04^{**}	
		$\Delta q(Italy) \rightarrow \Delta q(France)$	178.20^{**}	
		$\Delta q(Switzerland) \rightarrow \Delta q(France)$	55.3^{**}	
		$\lambda_{1i} = 0$		67.84^{***}
	England	$\Delta q(France) \rightarrow \Delta q(England)$	91.37^{***}	
		$\Delta q(USA) \rightarrow \Delta q(England)$	454.40^{***}	
		$\Delta q(Italy) \rightarrow \Delta q(England)$	338.78^{***}	
		$\Delta q(Switzerland) \rightarrow \Delta q(England)$	185.80^{***}	
		$\lambda_{2i} = 0$		976.44^{***}
	USA	$\Delta q(France) \rightarrow \Delta q(USA)$	1.23	
		$\Delta q(England) \rightarrow \Delta q(USA)$	97.17^{***}	
		$\Delta q(Italy) \rightarrow \Delta q(USA)$	352.48^{***}	
		$\Delta q(Switzerland) \rightarrow \Delta q(USA)$	81.26^{**}	
		$\lambda_{3i} = 0$		4.78^{**}
	Italy	$\Delta q(France) \rightarrow \Delta q(Italy)$	209.99^{***}	
		$\Delta q(England) \rightarrow \Delta q(Italy)$	49.97^{***}	
		$\Delta q(USA) \rightarrow \Delta q(Italy)$	55.62^{***}	
		$\Delta q(Switzerland) \rightarrow \Delta q(Italy)$	31.5^{***}	
		$\lambda_{4i} = 0$		13.28^{***}
	Switzerland	$\Delta q(France) \rightarrow \Delta q(Switzerland)$	3.66	
		$\Delta q(England) \rightarrow \Delta q(Switzerland)$	35.15^{***}	
		$\Delta q(USA) \rightarrow \Delta q(Switzerland)$	139.31^{***}	
		$\Delta q(Italy) \rightarrow \Delta q(Switzerland)$	122.68^{***}	
		$\lambda_{5i} = 0$		2.41

Robustness Checks

- In Male

Gender	Countries	Null Hypothesis	Short-Run Causality Test	Long-Run Relationship
Male	France	$\Delta q(England) \rightarrow \Delta q(France)$	21.16***	
		$\Delta q(USA) \rightarrow \Delta q(France)$	60.30**	
		$\Delta q(Italy) \rightarrow \Delta q(France)$	14.17**	
		$\Delta q(Switzerland) \rightarrow \Delta q(France)$	84.32**	
		$\lambda_{1i} = 0$		30.02***
	England	$\Delta q(France) \rightarrow \Delta q(England)$	9.04**	
		$\Delta q(USA) \rightarrow \Delta q(England)$	68.54***	
		$\Delta q(Italy) \rightarrow \Delta q(England)$	13.24***	
		$\Delta q(Switzerland) \rightarrow \Delta q(England)$	3.42	
		$\lambda_{2i} = 0$		32.37***
	USA	$\Delta q(France) \rightarrow \Delta q(USA)$	2.55	
		$\Delta q(England) \rightarrow \Delta q(USA)$	3.52	
		$\Delta q(Italy) \rightarrow \Delta q(USA)$	82.00***	
		$\Delta q(Switzerland) \rightarrow \Delta q(USA)$	180.97**	
		$\lambda_{3i} = 0$		3.56*
	Italy	$\Delta q(France) \rightarrow \Delta q(Italy)$	169.06***	
		$\Delta q(England) \rightarrow \Delta q(Italy)$	228.35***	
		$\Delta q(USA) \rightarrow \Delta q(Italy)$	312.81***	
		$\Delta q(Switzerland) \rightarrow \Delta q(Italy)$	3.03	
		$\lambda_{4i} = 0$		4.47**
	Switzerland	$\Delta q(France) \rightarrow \Delta q(Switzerland)$	93.74***	
		$\Delta q(England) \rightarrow \Delta q(Switzerland)$	94.35***	
		$\Delta q(USA) \rightarrow \Delta q(Switzerland)$	84.63***	
		$\Delta q(Italy) \rightarrow \Delta q(Switzerland)$	95.62***	
		$\lambda_{5i} = 0$		7.48**

Robustness Checks

- Finally, we also control countries and also investing short-run and long-run relationship in female and male mortality.

Countries	Panel Variance	Test	Statistics Value	*P*-Value
France	Group Mean Statistics	G_τ	-2.105	0.000
		G_α	-9.569	0.000
	Panel Statistics	P_τ	-7.703	0.000
		P_α	-2.133	0.033
England	Group Mean Statistics	G_τ	-1.711	0.000
		G_α	-6.285	0.004
	Panel Statistics	P_τ	-5.837	0.002
		P_α	-2.284	0.019
USA	Group Mean Statistics	G_τ	-1.709	0.000
		G_α	-5.137	0.080
	Panel Statistics	P_τ	-9.874	0.000
		P_α	-4.531	0.000
Italy	Group Mean Statistics	G_τ	-1.871	0.000
		G_α	-6.060	0.009
	Panel Statistics	P_τ	-5.966	0.001
		P_α	-1.433	0.250
Switzerland	Group Mean Statistics	G_τ	-3.203	0.000
		G_α	-20.433	0.000
	Panel Statistics	P_τ	-13.492	0.000
		P_α	-12.300	0.000

Robustness Checks

Countries	Null Hypothesis	Short-Run Causality Test	Long-Run Relationship
France	$\Delta q(Male) \rightarrow \Delta q(Female)$	3.12	
	$\Delta q(Female) \rightarrow \Delta q(Male)$	42.6^{***}	
	$\lambda_{Fi} = 0$		46.72^{***}
	$\lambda_{Mi} = 0$		15.90^{***}
England	$\Delta q(Male) \rightarrow \Delta q(Female)$	1.80	
	$\Delta q(Female) \rightarrow \Delta q(Male)$	42.30^{***}	
	$\lambda_{Fi} = 0$		1.76
	$\lambda_{Mi} = 0$		33.55^{***}
USA	$\Delta q(Male) \rightarrow \Delta q(Female)$	69.32^{***}	
	$\Delta q(Female) \rightarrow \Delta q(Male)$	9.22^{***}	
	$\lambda_{Fi} = 0$		3.75^{*}
	$\lambda_{Mi} = 0$		3.66^{*}
Italy	$\Delta q(Male) \rightarrow \Delta q(Female)$	14.93^{***}	
	$\Delta q(Female) \rightarrow \Delta q(Male)$	37.51^{***}	
	$\lambda_{Fi} = 0$		49.34^{***}
	$\lambda_{Mi} = 0$		9.55^{***}
Switzerland	$\Delta q(Male) \rightarrow \Delta q(Female)$	33.39^{***}	
	$\Delta q(Female) \rightarrow \Delta q(Male)$	42.22^{***}	
	$\lambda_{Fi} = 0$		2.56
	$\lambda_{Mi} = 0$		16.69^{***}

Conclusion

- Based on the mortality data period from year 1970 to 2007, the empirical results show that the morality rate with these five countries appear to be non-stationary and have the panel co-integration effect.

- Moreover, our study results support of bi-directional short-run causality for these five countries, which imply that the five countries may have similar life-style, environment, and the consumption of both goods and health service.

- In addition, we find the long-run relationship of mortality rates for these five countries. Thus, the mortality for these five countries share the common trend for mortality improvement.

Conclusion

- The empirical analysis demonstrates the problem of the traditional co-integration analysis to deal with for the short time spans or limited number of individual data
  - It may weaken the power of the co-integration test, thereby giving rise to distorted and mixed results.

- Further Research
  - The application of panel ECM model to deal with multi-country longevity risk.

Thank you!