Teacher Quality and Cross Country Differences in Student Achievements: An application of PIAAC data

Gonzalo Zunino & Ana Hidalgo-Cabrillana

UDELAR, CINVE & UAM

6th PIAAC International Conference, Rome

Motivation

- Teachers quality is arguably one of the main determinants in the process of student learning (Hanushek, 2003; Hanushek and Rivkin 2007; Hanushek, 2010; Hanushek and Rivkin 2010)
  - Good teachers improves not only the standardized test scores but also generates long-term effects, both economic and social (Chetty et al., 2011)
- Yet it is notoriously hard to measure:
  - Observables teacher variables are not related to student test scores
- This paper infers the average teacher quality (TQ thereafter) in 22 OECD countries for 2000, 2003, 2006, 2009, 2012 and 2015
  - Countries for which we have data about adults' skill measured in PIAAC
- To do this inference the paper propose and calibrate a theoretical model of occupational choice for teachers

Questions

- How can we proxy the average quality of the stock of teachers across countries?
- Is our proposed measure of TQ a good one?
- What is the role of TQ to explain cross-country differences in student outcomes?
- Why is TQ different across countries?

Findings

- Our proposed measure of TQ presents big differences across countries
- Cross-country differences in TQ are related with differences in student test scores:
  - 1sd in TQ imply a rise fo 0,121 sd in student test scores
- Cross-country differences in TQ explains approximately 22% of the observed cross-country variance in observed student outcomes
  - Its importance is quite similar to the family background effect and clearly higher than the importance of other school inputs
  - But, contrary to teacher effects, family background is extremely difficult for policy makers to influence, at least in the short term
- Dispersion in TQ across countries is mainly due to
  - Distribution of skills in the population
  - This suggest a hysteresis in the cross-country differences among adult skills in the population

The theoretical approach

General Assumptions

- Every individual chooses between working in the teaching sector or the non-teaching sector
- Schools select γ candidates to fill in their vacancies
- We assume rationing in the teachers market with supply of teachers exceeding demand (Borjas, 2002; Falch et al. 2009; Bacolod 2007)
  - compensation of teachers is relatively high
  - candidates value job security especially in economic downturns
  - working hours are more compatible with parenting which is especially valuable for women

The theoretical approach

General Assumptions

- We assume individuals have two skills
  - $\widehat{\theta}$ is the general skill: *observable*
  - $\widehat{t}$ is the innate teacher ability: *non-observable*
  - joint distribution of both skills log-normal
  - $\rho_{\theta t} \geq 0$ the correlation between both skills
- We assume that the variance of wages in the non-teaching sector is larger than in the teaching sector
  - $\widehat{w}_{\theta}=\theta^{\alpha}$ the market wage in the non-teaching sector
  - α is the wage elasticity to the general skill θ (we assume that $\alpha > 0$)
  - $\widehat{w}_0$ the teacher wage (the same for all teachers)

Self-selection stage

Individual "i" has the following utility function:

$$u_i = \begin{cases} \ln(\widehat{w}_0) + \ln(\widehat{t})^{\tau} \text{ if teach} \\ \ln(\widehat{w}_\theta) \text{ otherwise} \end{cases}$$

- $\ln(\widehat{w}_0)$ and $\ln(\widehat{w}_\theta)$ indicates the pecuniary utility in each sector
- $\ln(\widehat{t})^{\tau}$ captures a non-pecuniary utility of teaching
  - we assume that innate teaching ability is positively correlated with teachers vocation
  - τ measures the elasticity of the non-pecuniary utility respect to the individual teacher skill. We assume that $\tau \geq 0$

$\Rightarrow$Individuals will apply for a teaching position $(I = 1)$ if:

$$\ln(\widehat{w}_0) + \tau \ln(\widehat{t}) > \alpha \ln(\widehat{\theta})$$

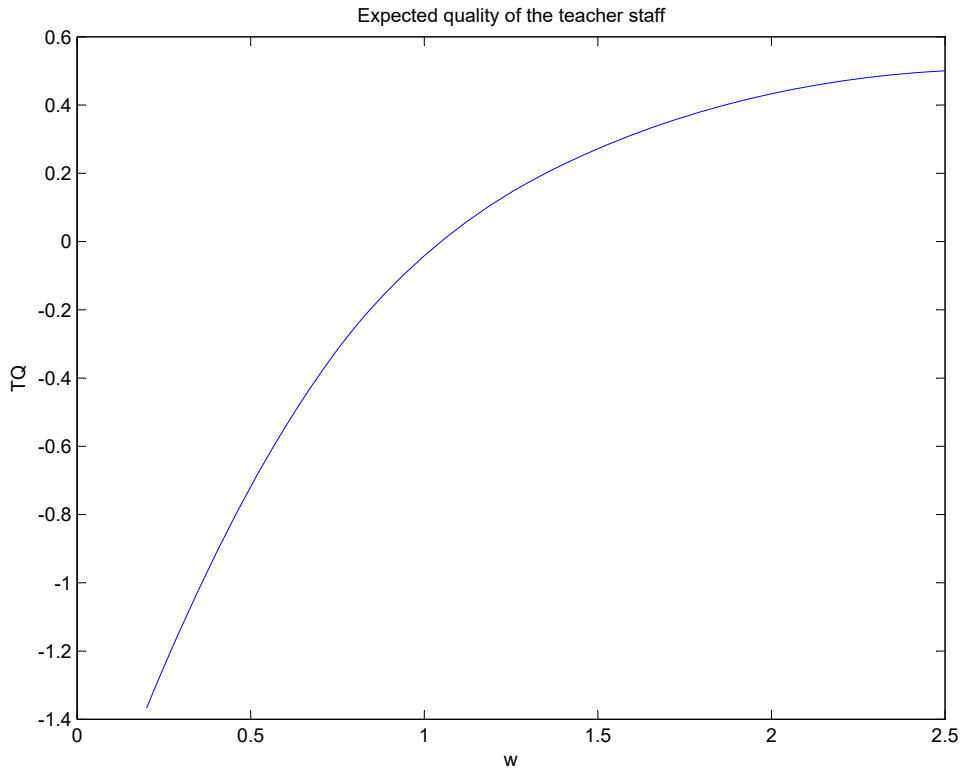
School selection stage

- School problem
  - Schools select γ individuals from the teacher supply to maximize student achievements (y) taking teacher salary (w_θ) as given
    - ★ $y = y(t; R)$ is the educational production function (EPF)
    - ★ y depends positively on the unobserved teacher skills (endogenous), t; and of individual characteristics, family and school resources (exogenous), R
- School strategy
  - First, sort the teacher supply based on θ
  - Second, hire the fraction γ of individuals with the higher level of θ
    - ★ $\widetilde{\rho}_{\theta t}$: the correlation between θ and t *among applicants* becomes a key parameter
    - ★ It determines how accurate is θ in the screening process. The larger $\widetilde{\rho}_{\theta t}$ the better the signal

Equilibrium

- Once individuals apply for a teacher position and the school recruit their teacher, we identify who are the teachers and compute their expected average ability (TQ) for a baseline economy
- Quantity of teachers is given (γ)
- We focus on the relationship between teacher wage and teacher quality because in the data teacher salaries varies *across countries*
- Solving the model for different levels of teacher salary, we build a "Teaching Wage-Teaching Quality" (TW-TQ) equilibrium curve

Theoretical TW-TQ equilibrium curve



Notes: Teacher wage is expressed relative to the median wage in the non-teaching sector. The TW-TQ curve states the equilibrium of the model for different levels of teacher salary for a baseline Economy.

▸ See details

Theoretical TW-TQ Equilibrium curve

- Increasing: As salaries increase more individuals apply to become teachers. When the correlation between the two abilities ($\rho_{\theta t}$) is high, those individuals have, on average, better teaching skills

- Concave: When salaries are relatively high,
  - motivated individuals into the teaching profession (i.e. those with a high t and a given τ) already decided to become teachers even with low salaries
  - (Could become) non-monotonic with a low $\rho_{\theta t}$. Higher salaries does not always attract individuals with better teaching skills because the signal used to screen candidates is quite noisy

Understanding the empirical literature

- Our model help us to understand the ambiguous finding in the empirical literature of teacher salaries and student achievement (Hanushek 2003, Loeb and Page 2000, Dolton and Marcenaro-Guiterrez 2010)
- Salaries are not a reliable proxy of TQ, since most of studies do not find a statistically significant effect between salaries and student outcomes
- Our TW-TQ equilibrium curve is non-linear and may be non-monotonic
  - teacher wage dispersion is small within countries
  - different countries could be in different parts of the curve
  - parameters controlling the teacher selection process differ across countries

Calibration

- We calibrate the model for 22 OECD countries for the years 2000, 2003, 2006, 2009, 2012 and 2015
  - countries for which we have PIAAC data
  - years for which we have PISA data
- Observable parameters directly approximated by country data
- Unobservable parameters (μ_t, σ_t, $\rho_{\theta t}$ and τ)
  - We assume $\sigma_t = \sigma_\theta$
  - (μ_t, $\rho_{\theta t}$ and τ) were approximated indirectly through an iterative process. The strategy was based on minimizing distance between a theoretical TW-TQ curve for the average country with an empirical estimation of the TW-TQ curve Details

Observable Parameters for the 22 OECD countries

Parameter	Definition	Source
μ_θ	mean of the general skill distribution	PIAAC
σ^2_θ	variance of the general skill distribution	PIAAC
γ	share of teacher into the labour force	EG
α	elasticity of wages with respect to the general skill	EG
$\widehat{w}_0$	teacher salary relative to the median wage in the non-teaching sector	EG and IMF

Furthermore $(\alpha, \widehat{w}_0)$ change over time for 2000, 2003, 2006, 2009, 2012, 2015.

Calibration of unobservable parameters

- $\rho_{\theta t}$=0.57: correlation between the teacher and general skills is significantly positive
  - but clearly weaker than the correlation among core skills assessed in PIAAC
- $\tau = 0.24$: utility of teaching is weakly related to the individual teacher skill
  - motivational factors are important but not determinant
- μ_t: significant cross-country differences in the calibrated mean of the unobservable innate ability among the population

Model results: TQ

- Average TQ presents big differences across countries
  - Japan, Canada, Korea the highest TQ
  - In the lower bound of the distribution Slovak Replublic, US See graph
- Countries also differ in the position (average percentile) where teachers are located
  - Teachers from Japan, Canada, Korea belong to a higher percentile
  - Teachers worse positioned in Slovak Republic, Norway, US See graph

Are our theoretical results a good approximation to Teacher Quality?

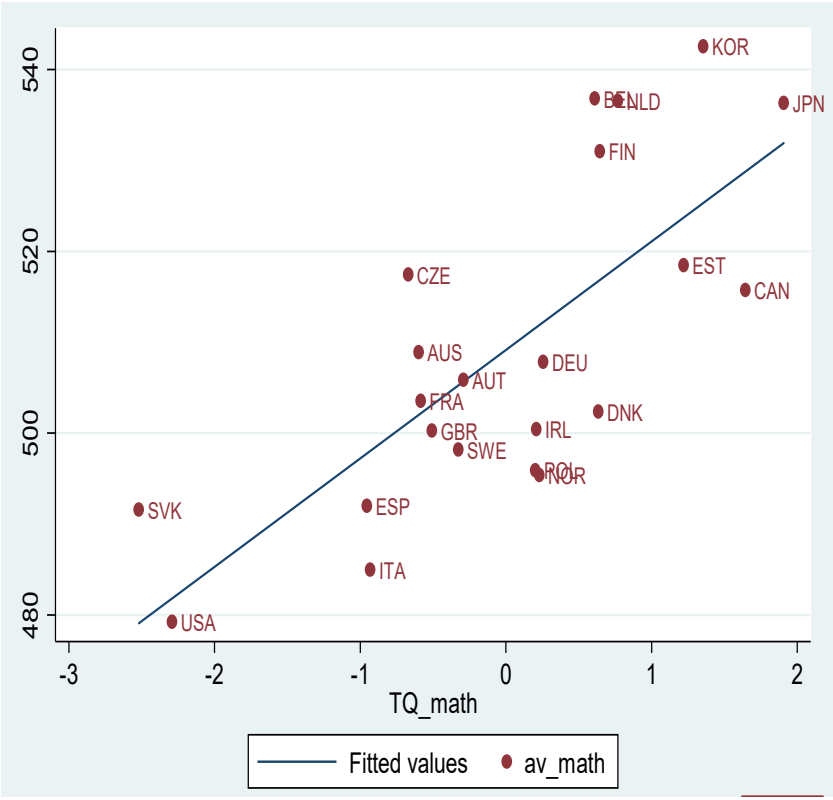
It is difficult to answer this question

- There are not quantitative measures of teacher quality
- Teacher quality is not strongly related with observable characteristics of teachers
- The only consensus in previous literatures states that teacher quality impact student outcomes

Is our measure of TQ correlated with student outcomes in PISA?

Validation

Model estimation of TQ and PISA (Maths)



Sources: Own computations and PISA (average 2000-2015).

Validation

Estimation of the Educational Production Function (EPF)

$$y_{isct} = \beta_0 TQ_{cts} + \beta_1 I_{ict} + \beta_2 F_{ict} + \beta_3 SCH_{ict} + \beta_4 M_{ct} + S_s + T_t + C_c + u_{isct},$$

- y_{isct} is the student score for individual i, in subject s, country c, and year t
- TQ_{cst} is the simulated TQ for country c, subject s and period t
- I_{ict} represents a set of individual characteristics
- F_{ict} states the family background, ESCS index PISA
- SCH_i states the school characteristics, school autonomy index PISA
- M_{ct} represents macro variables for country c, in period t
- S_s is a subject dummy
- T_t is a time dummy
- C_c is a country fixed effect
- u_{isct} is the error term

Identification strategy: TQ dispersion within-country across-time and between subjects

Validation

Concerns

- Having unobserved time-invariant omitted variables: educational attitude, educational culture, institutions in a country $\Rightarrow$ country FE
- Subject-specific attitude in a country ???
- Sorting of students/teachers across schools (within countries) and within school $\Rightarrow$ interested in TQ at the country level
- Country specific measurement of TQ such that the OLS estimate is biased toward zero $\Rightarrow$ estimated coefficient of TQ is positive, significant and far away from zero

$\Rightarrow$ We refuse to interpret β_0 as causal

Validation

	student score in PISA		
	(1)	(2)	(3)
TQ	9.4332***	10.28***	11.307***
Student characteristics	no	yes	yes
Family background	no	yes	yes
School characteristics	no	yes	yes
Macroeconomic variables	no	yes	yes
Country fixed effects	yes	yes	yes
Time dummies	yes	yes	yes
R-Squared	0.0344	0.2473	0.2509
Sample	2000-2015	2000-2015	2006-2015
Observations	1580069	1135585	953240

Note: Appendix IV reports the complete estimation. Significance levels: *p<0.1, **p<0.05, ***p<0.001. Data source: PISA 2000-2015; OECD, IMF.

Counterfactual Exercises

Importance of TQ vs other determinants

$$y_{isct} = \beta_0 TQ_{cts} + \beta_1 SCH_{ict} + \beta_2 STR_{ict} + \beta_3 Spend_{ct} + \beta_4 F_{ict} + \beta_5 M_{ct} + S_s + T_t + C_c + u_{isct},$$

y: student score; SCH: school characteristics, index of school autonomy PISA; STR: student-teacher ratio; $Spend$: education spending; F_i: family background, ESCS index PISA; M: macro variables; T: time dummy; C: country fixed effect; Sub-indexes, i: individual; s: subject; c: country; t: year

Consist on:

1. Removing all the input differences (by imputing the panel mean) except in one (for instance TQ)
2. Compute the variance in test scores explained by only one input (for instance TQ)

Counterfactual Exercises

Importance of TQ vs other determinants

	% of the observed variance explained by each component
Teacher Quality	22%
School Organization	5%
Student-teacher ratio	1%
Education Spending (% of GDP)	8%
Family Background	20%

- TQ is the single school input with highest impact on student achievements (Hanushek et al. 2014)
- Its effect is quite similar to the family background effect (Björklund and Salvanes 2011 and Woessmann, et al. 2009)

Counterfactual Exercises

Sources of TQ differences across countries

Our model allows us to identify (quantify) the main drivers of cross-country dispersion in TQ:

- Differences in teacher salaries ($\widehat{w}_0$)
- Differences in other labour market conditions (γ, α)
- Differences in population distributions of skills (μ_θ, μ_t, σ_θ, σ_t)

We evaluate the importance of each determinant using the theoretical model to simulate new vectors of TQ under different exercises

Counterfactual Exercises

Sources of TQ differences across countries

	Modified parameters	Imputed value	Variance in our proxy of TQ
Ex. 1	$\widehat{w}_0$	panel mean	-6.6%
Ex. 2	α	panel mean	-0.2%
Ex. 3	γ	panel mean	-3.5%
Ex. 4	μ_t, μ_θ,σ_t, σ_θ	panel mean	-91%

Most of current cross country differences in TQ follows from differences in the population distribution of skills

Conclusions

This paper developed a micro-founded model which is a useful tool in several dimensions:

- To proxy TQ at the country level
  - We build time series of TQ at a country level for 22 OECD countries
  - Our proxy of TQ is an important determinant of student outcomes
- To understand the ambiguous findings in the empirical literature that study teacher salaries and student achievements
  - The equilibrium relationship between teacher salaries and TQ is non-linear and may be non-monotonic
- To identify the main variables affecting the TQ

Conclusions

- Our theory shows that it is not always the case that better salaries translate into better TQ
- Most of current cross country differences in TQ follows from differences in the population distribution of skills
  - Initial differences in the skills of the population introduces some kind of hysteresis in TQ, and then on test scores which in turn affect adult skills
- Our results shows that policies that influence teachers and teaching will have a strong effect in the economy

Thank you for listening !!!!!

...if you still are

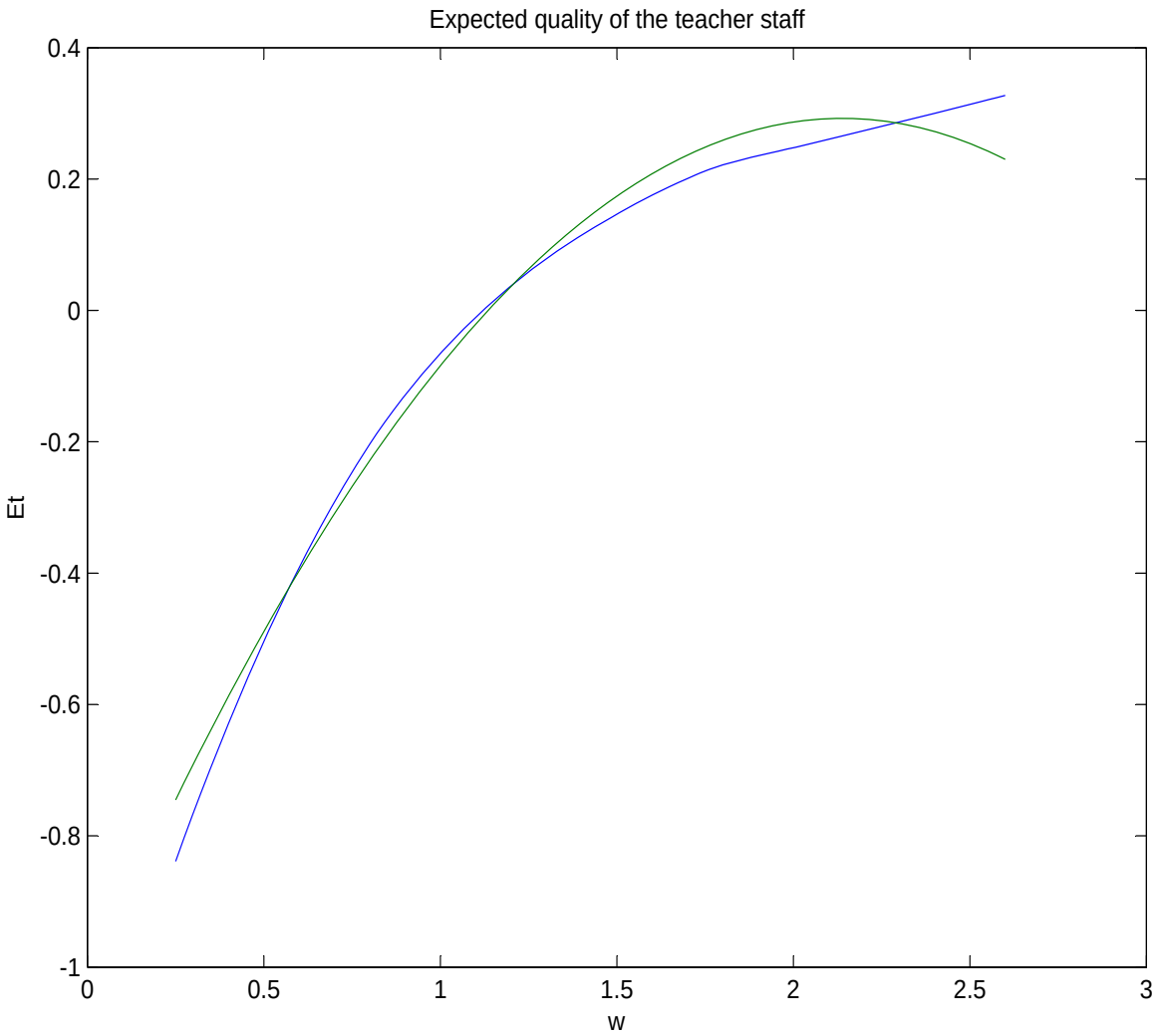
hidalgocabrillana@gmail.com

Table 1 - Parameters of a baseline Economy

Parameter	Definition	Value
μ_t	mean of the teacher skill distribution	0
σ_t^2	variance of the teacher skill distribution	1
μ_θ	mean of the general skill distribution	0
σ_θ^2	variance of the general skill distribution	1
$\rho_{\theta t}$	correlation between the teacher and general skill	0.5
α	elasticity of wages with respect to the general skill	1
τ	elasticity of non-pecuniary utility with respec to the teacher skill	0.1
γ	share of teachers in total labour force	0.05

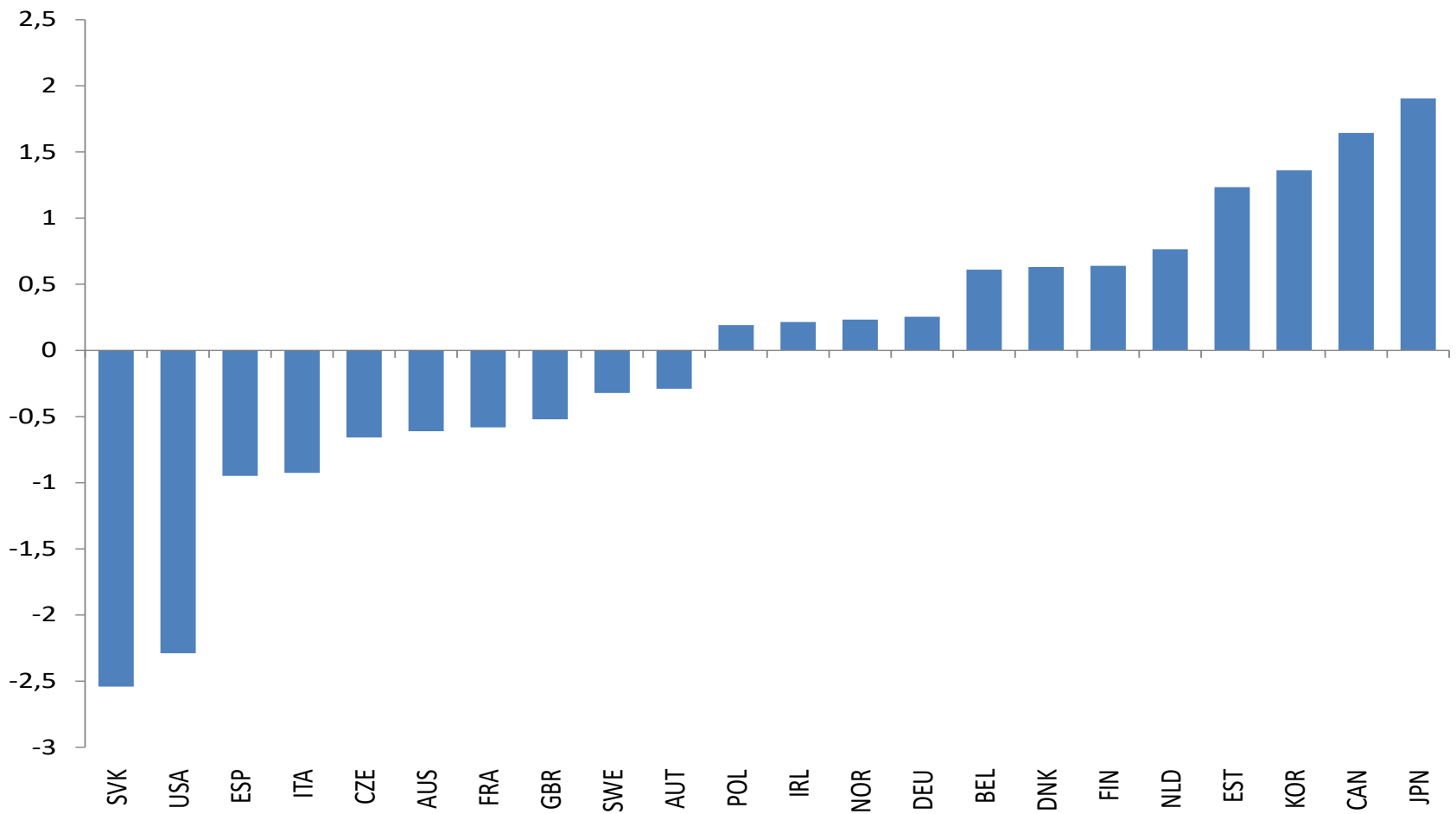
back

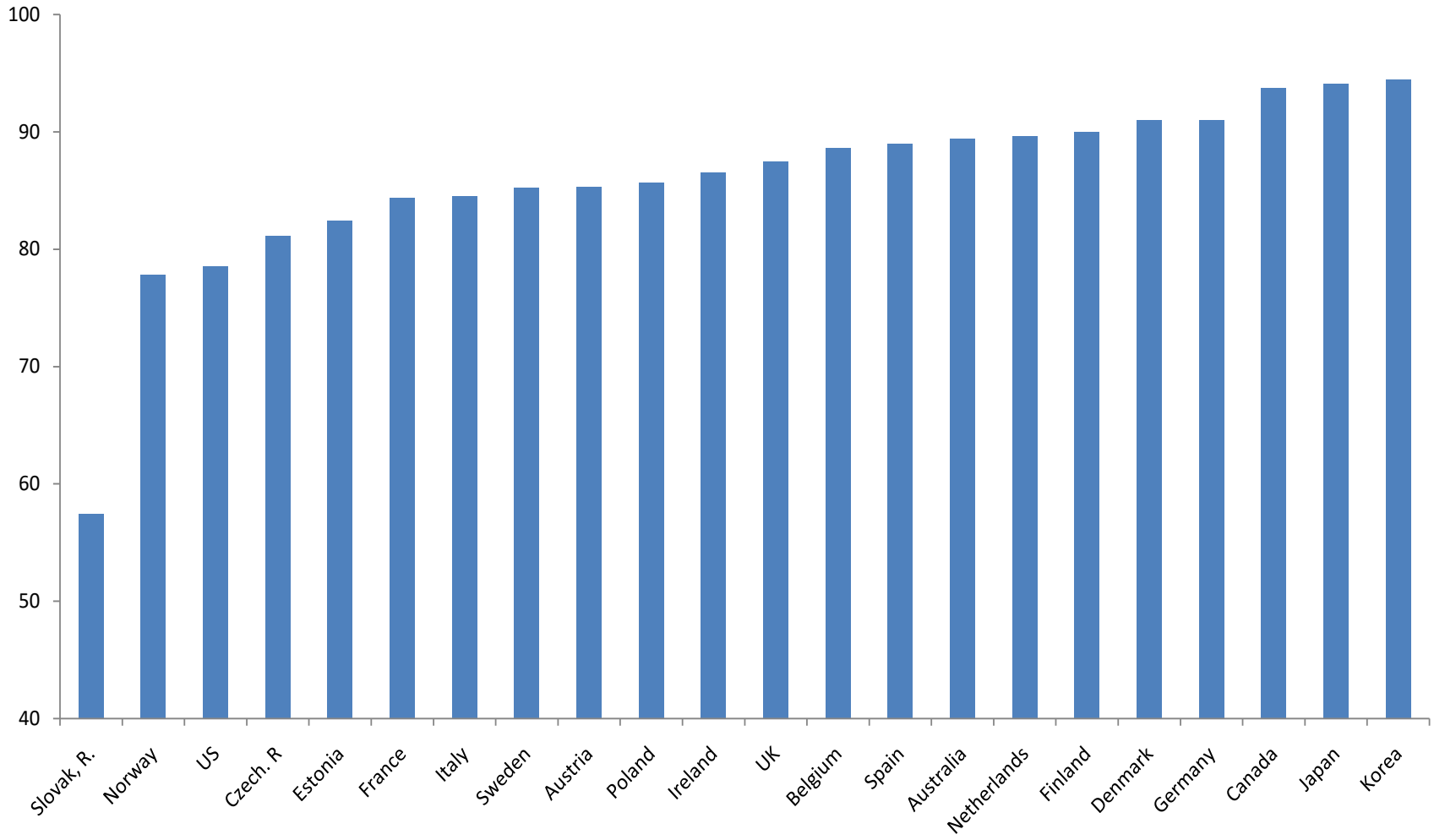
Theoretical vs Empirical TW-TQ



Theoretical curve (blue) vs Empirical curve (green)

Figure: Estimation of average TQ by countries. Math average 2000-2015





The position of teacher refers to the median percentile of teachers in the population distribution of teaching skills. Math average 2000-2015

back