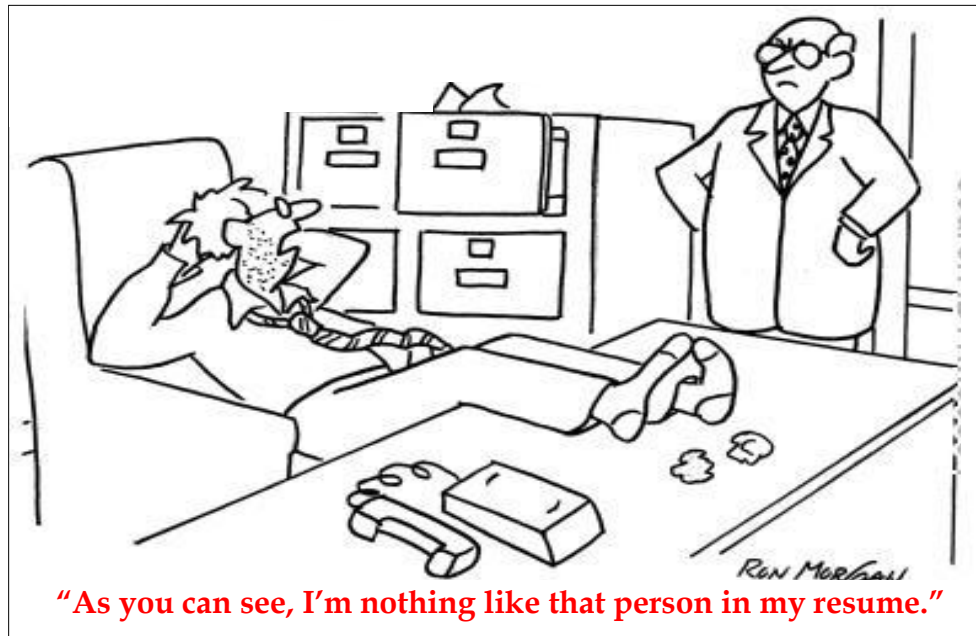


The Impact of Educational Mismatch on Firm Productivity:

First Evidence from Linked Panel Data

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Motivation

- Educational mismatch (or simply “over- and under-education”) refers to the **difference between the worker’s attained level of education and the education required in a job.**
- The **incidence and earnings effects** of this important phenomenon **are well documented** in the economic literature and findings are quite consistent (Hartog 2000 , McGuinness 2006).
- In contrast, the evidence regarding the **impact** of over- and under-education **on firm productivity is mixed, indirect and subject to various potential biases.**



Aim of the paper

- Provide a first attempt at **measuring the direct impact of educational mismatch on firm productivity**.
- Richness of our data (Belgian linked employer-employee panel data) allows us to **control for important econometric issues** that are often neglected in other studies, such as the existence of firm unobserved fixed effects, the potential endogeneity of educational mismatch, the state dependence of firm productivity, and the presence of cohort effects.
- As educational mismatch is more likely to represent a real mismatch in skills for new labour market entrants, we also add to the literature by **investigating whether the effects of educational mismatch on firm productivity vary according to the age of over- and under-educated workers**.

Background

- **Two approaches** to examine the impact of educational mismatch on productivity in a microeconomic framework :

- **'Human capital' approach**

Theory

- a) Education develops skills that make workers more productive.
 - b) Wage differentials reflect differences in productivity.
- ⇒ Impact of over- and under-education might be inferred from the latter's effect on wages.

Empirical results (with ORU specification)

In a given job, with a specific level of required education, over- (under-) educated workers earn more (less) than those who have just the required education for the job (e.g. Bauer 2002, Chevalier 2003, McGuinness 2003, Frenette 2004, Dolton and Silles 2008).

⇒ Over-education increases worker's productivity (and *vice versa*).

Background (Cont.)

- 'Job satisfaction' approach

Theory

Over-educated workers, as a result of frustration, are less satisfied, have more health problems and higher rates of shirking, absenteeism and turnover than their adequately educated colleagues (Büchel 2002).

⇒ Over-educated workers are less productive.

Empirical results (with ORU specification)

No consensus (e.g. Tsang 1987, Hersch 1991, Tsang et al. 1991, Büchel 2002). However, Verhaest and Omey (2009) suggest that over-educated workers in Flanders (largest Belgian region) are less satisfied than their colleagues in similar jobs.

⇒ Ambiguous prediction.

Background (Cont.)

- **Methodological limitations**

- **'Human capital' approach**

Based on assumption that both education and earnings are directly proportional to individual productivity on the job (Rumberger 1987).

Yet, in practice, schooling may not always raise productivity and workers with identical productive characteristics not necessarily receive the same wages (e.g. Bayard et al. 2003, Manning 2003, Mortensen 2003, Martins 2009).

- **'Job satisfaction' approach**

Correlation between job satisfaction and job performance reaches at most 30% (Iaffaldano and Muchinsky 1985, Judge et al. 2001).

Educational mismatch may affect productivity through other channels than job satisfaction (and correlated workers' attitudes and behaviours).

Methodology

- **Three different measures**, based respectively on job analysis, worker self-assessment and realized matches, have been **proposed in the literature** to estimate the required education for a job and the incidence of educational mismatch. Each measure has its own advantages and weaknesses (see e.g. Hartog 2000).
- We use **realized matched**:
 - **Required education** for a job is computed by taking the **mode of** workers' years of **education within** each ISCO 3 digit occupation (113 categories).
 - **Worker** defined as **over-educated (under-educated)** if his **attained** level of **education** (7 categories) is **higher (lower) than that required in his occupation**.
- Next, to examine the impact of educational mismatch on firm productivity, we use the so-called '**ORU** (i.e. Over-Required and Under-education) **specification**' that has been **aggregated at the level of the firm**.

Methodology (Cont.)

$$\ln VA_work_{j,t} = \beta_0 + \underbrace{\beta_1 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} REQ_{i,j,t} \right)}_{(a)} + \underbrace{\beta_2 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} OVER_{i,j,t} \right)}_{(b)} + \underbrace{\beta_3 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} UNDER_{i,j,t} \right)}_{(c)} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + u_{j,t} \quad (1)$$

with,

- $VA_work_{j,t}$: the value added per worker in firm j at time t .
- $m_{j,t}$: the number of workers employed in firm j at year t .
- $REQ_{i,j,t}$: required years of education for the job of worker i in firm j at year t , i.e. the mode of years of education in worker's i occupation at the ISCO 3-digit level (in the entire economy) at time t .

⇒ **(a)**: sum of required years of education for all jobs in firm j at time t divided by total employment in firm j at time t , i.e. **average required years of education in firm j at time t** .

Methodology (Cont.)

$$\ln VA_work_{j,t} = \beta_0 + \underbrace{\beta_1 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} REQ_{i,j,t} \right)}_{(a)} + \underbrace{\beta_2 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} OVER_{i,j,t} \right)}_{(b)} + \underbrace{\beta_3 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} UNDER_{i,j,t} \right)}_{(c)} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + u_{j,t} \quad (1)$$

with,

(...)

- $OVER_{i,j,t} = [(Attained_education_{i,j,t} - REQ_{i,j,t}) \text{ if } > 0; 0 \text{ otherwise}]$.
- $Attained_education_{i,j,t}$: the number of years corresponding to the highest level of education attained by worker i employed in firm j at time t .

⇒ **(b)**: sum of years of over-education for all workers employed in firms j at time t , divided by total employment in firm j at time t ; i.e. **average years of over-education in firm j at time t** .

Methodology (Cont.)

$$\ln VA_work_{j,t} = \beta_0 + \underbrace{\beta_1 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} REQ_{i,j,t} \right)}_{(a)} + \underbrace{\beta_2 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} OVER_{i,j,t} \right)}_{(b)} + \underbrace{\beta_3 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} UNDER_{i,j,t} \right)}_{(c)} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + u_{j,t} \quad (1)$$

with,

(...)

- $UNDER_{i,j,t} = [(Attained_education_{i,j,t} - REQ_{i,j,t}) \text{ if } < 0; 0 \text{ otherwise}]$.
- $Attained_education_{i,j,t}$: the number of years corresponding to the highest level of education attained by worker i employed in firm j at time t .

$\Rightarrow$ (c): sum of years of under-education for all workers employed in firms j at time t , divided by total employment in firm j at time t ; i.e. **average years of under-education in firm j at time t** .

Methodology (Cont.)

$$\ln VA_work_{j,t} = \beta_0 + \underbrace{\beta_1 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} REQ_{i,j,t} \right)}_{(a)} + \underbrace{\beta_2 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} OVER_{i,j,t} \right)}_{(b)} + \underbrace{\beta_3 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} UNDER_{i,j,t} \right)}_{(c)} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + u_{j,t} \quad (1)$$

with,

(...)

- X_{jt} : a vector of aggregated characteristics of workers (i.e. share of the workforce that has at least 10 years of tenure, the fraction of workers respectively younger than 25 and older than 49 years, and the share of women, blue-collar and part-time workers).
- Z_{jt} : a vector of firm characteristics (i.e. sectoral affiliation, age and size of the firm, conditional intra-firm wage dispersion and level of wage bargaining).
- γ_t : a set of year dummies (7 dummies).
- u_{jt} : the error term.

Methodology (Cont.)

$$\ln VA_work_{j,t} = \beta_0 + \underbrace{\beta_1 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} REQ_{i,j,t} \right)}_{(a)} + \underbrace{\beta_2 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} OVER_{i,j,t} \right)}_{(b)} + \underbrace{\beta_3 \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} UNDER_{i,j,t} \right)}_{(c)} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + u_{j,t} \quad (1)$$

To sum up: equation (1) describes the relationship between average years of over-, required and under-education within firms and the average productivity of the latter, when controlling for year dummies and mean worker and firm characteristics.

Note:

$$\begin{aligned} & \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} REQ_{i,j,t} \right) + \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} OVER_{i,j,t} \right) + \left(\frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} UNDER_{i,j,t} \right) \\ &= \frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} [REQ_{i,j,t} + OVER_{i,j,t} + UNDER_{i,j,t}] \\ &= \frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} Attained_education_{i,j,t} \end{aligned}$$

Econometric issues

1. Benchmark

Equation (1) describes the relationship between average years of over-, required and under-education within firms and the productivity of the latter, controlling for year effects and mean worker and firm characteristics.

⇒ **OLS estimator.**

2. Firm fixed effects

OLS estimates likely to be biased since time variant unobserved characteristics (such as an advantageous location or firm specific assets like the ownership of a patent) may affect simultaneously the firm's value added and ORU variables.

⇒ **FE estimator.**

Econometric issues (Cont.)

3. Simultaneity

“Employers might exploit cyclical downturn to improve the average skill level of their work force” (Gautier et al., 2002, p. 523). There might be some cyclical ‘crowding out’, i.e. a process by which during recessions - because of excess labour supply - highly educated workers take the jobs that could be occupied by less educated ones.

This assumption, supported empirically for certain countries including Belgium (Teulings and Koopmanschap 1989, Cockx and Dejemeppe 2002, Dolado et al. 2000), suggests that mean years of over-education within firms may increase as a result of a lower labour productivity (and *vice versa*).

⇒ **Dynamic system GMM estimator:**

- One year lagged productivity is used as an additional explanatory variable.
- Variables in the differenced equation are instrumented by their lagged levels and variables in the level equation are instrumented by their lagged differences.

Robustness tests (Cont.)

1. Birth cohort of workers

Years of education have substantially increased over time and labour market experience could be a substitute to formal education $\Rightarrow$ it may be more appropriate to determine whether a workers is over- or under-educated by comparing his level of education with the mode of the education among workers of *a similar generation* employed in the same occupation.

To control for cohort effects, we considered two age groups (threshold at 35 years) and reformulate equation (1) as follows:

$$\ln VA_{work_{jt}} = \beta_0 + \beta_1 REQ^*_{j,t} + \beta_2 OVER^*_{j,t} + \beta_3 UNDER^*_{j,t} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + v_{j,t} \quad (2)$$

In this equation (more details in the paper):

- The **required education** is **computed separately for young and older workers**.
- A worker is defined as over-educated (under-educated) if his level of education is higher (lower) than that required for workers *belonging to the same age group* and occupation at the ISCO 3-digit level.

Robustness tests

2. Effects according to workers' age

Hypotheses:

- ✓ Relationship stronger for younger workers
 - a) **Older workers** may more easily compensate their lack of formal schooling (their 'undereducation') by additional work experience and training.
 - b) **Young workers** who do not possess the required education for their job and who are not able to catch up (through training and work experience) will probably have (or choose) to exercise a less demanding job (in the same company or elsewhere) as they get older.
 - c) **Skills learned at school** tend to depreciate and to become obsolete over time so that older workers are less likely to have skills in excess of those required for their job.
 - d) **Workers whose 'over-education'** is really beneficial for firm productivity are more likely to get promoted and to exercise a job matching their skills as they grow older.

Robustness tests (Cont.)

✓ **Counter-arguments:**

a) Older under-educated workers may still exert a negative impact on firm productivity if experience is an imperfect substitute to formal education and that under-educated workers who are not able to catch-up remain in their jobs.

b) Older over-educated workers may still exert a positive impact on productivity if the latter have a higher level of competence all over their career.

They may persistently: i) be more creative and independent, ii) adapt easier to changing environments, iii) learn new skills faster, and iv) have more ability to perform complex tasks and to interact with colleagues than workers who have just the required level of education for the job.

To test these hypotheses, we reformulate equation (2) as follows:

$$\begin{aligned} \ln VA_{work_{j,t}} = & \beta_0 + \beta_1 REQ^*_{j,t} + \beta_2 YOUNG-OVER^*_{j,t} + \beta_3 OLDER-OVER^*_{j,t} \\ & + \beta_4 YOUNG-UNDER^*_{j,t} + \beta_5 OLDER-UNDER^*_{j,t} \\ & + x_{jt} \beta_4 + z_{jt} \beta_5 + \gamma_t + p_{j,t} \end{aligned} \quad (3)$$

Data set

- **Combination of two large data sets for 1999-2006:**
 - **'Structure of Earnings Survey'** (SES): information, provided by the management of firms, both on:
 - ✓ Firm-level characteristics (e.g. sector of activity, size of the firm, level of wage bargaining),
 - ✓ Individual and job characteristics (e.g. age of the worker, level of education, years of tenure, sex, occupation, working time, employment contract).
 - **'Structure of Business Survey'** (SBS): firm-level survey providing annual information on financial variables (e.g. value added and gross operating surplus per worker).

Data set (Cont.)

- Information in the **SES refers to the month of October** of each year, while data in the **SBS** are measured over **all month from January to December of each year**.

To avoid running a regression where information on the dependent variable precedes (to a large extent) the date on which the explanatory variables have been recorded, **all explanatory variables are lagged by one year** $\Rightarrow$ information on educational mismatch relative to the month of October in year t used to explain firm-level productivity in year $t+1$.

This restricts our sample to firms that are observed at least two consecutive years $\Rightarrow$ **over-representation of medium-sized and large firms** given that sampling percentages of firms in our data increase with the size of the latter.

- To guarantee that the required education is computed on a reasonable number of data points, **occupations at ISCO 3 digit level with less than 10 observations** have been **deleted** (robustness tests performed with 30 and 50 observations).

Data set (Cont.)

- **Firms with less than 10 observations have been dropped**, due to the use of average values at the firm level as control variables.
- Final sample consists of an unbalanced panel of **8,954 firm-year-observations from 3,062 firms**.
- It is representative of **all medium-sized and large firms in the Belgian private sector**, with the exception of large parts of the financial sector (NACE J) and the electricity, gas and water supply industry (NACE E).

Descriptive statistics (controlling for cohort effects)

Variables:	Mean	Std. Dev.
Value added per worker (€ ¹)	89,788	649,572
Required education (years) :	11.54	1.37
Over-education:		
% workers	24.87	22.46
Years	0.67	0.64
Under-education:		
% workers	24.17	23.21
Years	-0.78	0.87
Intra-firm wage dispersion (€ ¹):	0.17	0.09
Workers with 10 years of tenure or more (%)	38.06	24.38
Women (%)	26.94	23.91
Share of workers < 30 years	8.10	8.74
Share of workers between 30 and 49 years	75.69	12.59
Share of workers > 49 years	16.25	12.18
Blue-collar workers (%)	54.60	33.93
Part-time (less than 30 hours per week, %)	16.18	16.75
Size of the firm (number of workers)	252.57	275.04
Number of observations		8,954
Number of firms		3,062

¹ At 2006 constant prices. Number observations per firm = 31.69 (Std. dev. = 47.97, Min = 10, Max = 1,128).

Results: Dynamic System GMM estimates (controlling for cohort effects)

Dependent variable:	Value-added per worker (ln)	
	(1)	(2)
Required education	0.023***	0.021***
(one year lagged, in years)	(0.008)	(0.008)
Over-education	0.033***	
(one year lagged, in years)	(0.010)	
Under-education	0.015*	
(one year lagged, in years)	(0.08)	
Value-added per worker	0.553***	0.557***
(one year lagged, in ln)	(0.048)	(0.048)
Over-education among young workers		0.031*
(one year lagged, in years)		(0.019)
Over-education among older workers		0.027**
(one year lagged, in years)		(0.011)
Under-education among young workers		0.035**
(one year lagged, in years)		(0.014)
Under-education among older workers		0.001
(one year lagged, in years)		(0.013)
Worker characteristics:	Yes	Yes
Firm characteristics:	Yes	Yes
Year dummies (7):	Yes	Yes
Sig. Model (p-value)	0.000	0.000
Hansen statistic	352.4	386.1
p-value	0.15	0.15
Arellano-Bond statistic (AR2)	1.32	1.35
p-value	0.19	0.18
Number of observations	8,954	8,954
Number of firms	3,062	3,062

Notes: ***/**/* significant at the 1, 5 and 10% level, respectively. Robust standard errors between brackets.

Discussion

- **Results seem compatible with standard human capital theory (Becker, 1964).**
 - ✓ According to this theory, education (as well as formal training and informal work experience) develops skills that make workers more productive. From a firm perspective, this implies that : i) productivity will depend positively on the mean required education, ii) educational mismatch will affect the firm's value added positively for over-education and negatively for under-education.
- **Yet, they also appear in line with the assignment model (Sattinger, 1993), especially as regards under-education.**
 - ✓ The assignment model differs from human capital theory in that it relaxes the hypothesis that the productivity return on an additional year of ORU should necessarily be identical (in absolute value).

Discussion

- **Results according to workers' age suggest that:**
 - ✓ Older workers can compensate their lack of formal schooling (their 'under-education') by additional work experience and/or training.
 - ✓ Under-educated workers who are not able to catch through training and work experience tend to exercise less demanding jobs as they get older.
 - ✓ Young and older over-educated workers have a higher level competence than their colleagues who have just the required level of education to perform the job. Over-educated workers thus appear to have additional skills and capabilities acquired through schooling that do not depreciate with workers' age.
- **Results can easily be reconciled with the literature on the wage effects of educational mismatch.**
 - ✓ In line with competitive wage setting models, they suggest that over-educated and young under- educated workers earn respectively more and less than those who have just the required education for the job because on average they are respectively more and less productive than the latter.



Discussion

- **Results do not support the hypothesis that over-educated workers are less productive because of frustration and a lower degree of job satisfaction.**
 - ✓ Of course, we may not exclude that, for a given job, educational mismatch may lead to less job satisfaction (and worse correlated workers' attitudes and behaviours).
 - ✓ However, it appears that the *net* effect of over-education on productivity is significant and positive.

Along the lines of human capital and assignment theories, results thus suggest that even if over-educated workers are less satisfied with their jobs, they are more productive than their adequately educated colleagues in similar jobs because they have more years of education (i.e. additional skills and capabilities acquired in school).

Thank you !

Descriptive Statistics (not controlling for cohort effects)

Variables:	Mean	Std. Dev.
Value added per worker (€ ¹)	89,788	649,572
Required education (years) :	11.77	1.35
Over-education:		
% workers	22.53	23.28
Years	0.59	0.65
Under-education:		
% workers	27.60	26.53
Years	-0.93	1.01
Intra-firm wage dispersion (€ ¹):	0.17	0.09
Workers with 10 years of tenure or more (%)	38.06	24.38
Women (%)	26.94	23.91
Share of workers < 30 years	8.10	8.74
Share of workers between 30 and 49 years	75.69	12.59
Share of workers > 49 years	16.25	12.18
Blue-collar workers (%)	54.60	33.93
Part-time (less than 30 hours per week, %)	16.18	16.75
Size of the firm (number of workers)	252.57	275.04
Number of observations		8,954
Number of firms		3,062

¹ At 2006 constant prices. Number observations per firm = 31.69 (Std. dev. = 47.97, Min = 10, Max = 1,128).

Descriptive Statistics: ORU variables (with mode) controlling for cohort effects

Variables:	Mean	Std. Dev.
Required education (years):	11.54	1.37
Over-education:		
<u>Among all worker</u>		
% workers	24.87	22.46
Years	0.67	0.64
<u>Among young workers</u> (i.e. age $\leq$ 35 years)		
% workers	8.33	11.78
Years	0.21	0.32
<u>Among older workers</u> (i.e. age $>$ 35 years)		
% workers	16.54	16.65
Years	0.45	0.49
Under-education:		
<u>Among all worker</u>		
% workers	24.17	23.21
Years	-0.78	0.87
<u>Among young workers</u> (i.e. age $\leq$ 35 years)		
% workers	9.86	12.93
Years	-0.31	0.46
<u>Among older workers</u> (i.e. age $>$ 35 years)		
% workers	14.31	16.81
Years	-0.47	0.62
Number of observations	8,954	
Number of firms	3,062	

Results: OLS, FE & GMM-SYS (not controlling for cohort effects)

Dependent variable:	Value-added per worker (ln)		
	(1) OLS	(2) FE	(3) GMM-SYS
Required education	0.095***	0.009*	0.024***
(one year lagged, in years)	(0.006)	(0.005)	(0.008)
Over-education	0.083***	0.004	0.035***
(one year lagged, in years)	(0.008)	(0.006)	(0.010)
Under-education	0.049***	0.000	0.012*
(one year lagged, in years)	(0.006)	(0.005)	(0.007)
Value-added per worker (one year lagged, in ln)			0.553*** (0.049)
Constant	9.451*** (0.110)	10.98*** (0.084)	
Worker characteristics:	Yes	Yes	Yes
Firm characteristics:	Yes	Yes	Yes
Year dummies (7):	Yes	Yes	Yes
R ²	0.345		
Within R ²		0.023	
Sig. Model (p-value)	0.000	0.000	0.00
Hansen statistic			346.1
p-value			0.21
Arellano-Bond statistic (AR2)			1.36
p-value			0.18
Number of observations	8,954	8,954	8,954
Number of firms	3,062	3,062	3,062

Notes: ***/**/* significant at the 1, 5 and 10% level, respectively. Robust standard errors between brackets.

Dynamic GMM-SYS, controlling for cohort effects and using the mean of education by ISCO 3 as proxy for required education and the mean +/- 1 standard deviations to define ORU

Dependent variable:	Value added per worker (ln)
	GMM-SYS
Value added per worker	0.581***
(one year lagged, in ln)	(0.047)
Required education	0.037***
(one year lagged, in years)	(0.010)
Over-education among young workers	0.182***
(one year lagged, %)	(0.070)
Over-education among older workers	0.046
(one year lagged, %)	(0.040)
Under-education among young workers	-0.252**
(one year lagged, %)	(0.102)
Under-education among older workers	0.085
(one year lagged, %)	(0.057)
Worker characteristics:	Yes
Firm characteristics:	Yes
Year dummies (7):	Yes
Sig. Model (p-value)	0.00
Hansen statistic	384.7
p-value	0.16
Arellano-Bond statistic (AR2)	1.35
p-value	0.18
Number of observations	8,954
Number of firms	3,062

Notes: ***/**/* significant at the 1, 5 and 10% level, respectively. Robust standard errors between brackets.

Results for Profits: GMM-SYS, controlling for cohort effects

Dependent variable:	Gross operating surplus per worker (ln)	
	(5)	(6)
	GMM-SYS	GMM-SYS
Gross operating surplus per worker	0.361***	0.386***
(one year lagged, in ln)	(0.087)	(0.083)
Required education	-0.019	0.001
(one year lagged, in years)	(0.059)	(0.056)
Over-education	0.079	
(one year lagged, in years)	(0.097)	
Under-education	0.050	
(one year lagged, in years)	(0.068)	
Over-education among young workers		0.206
(one year lagged, in years)		(0.146)
Over-education among older workers		0.013
(one year lagged, in years)		(0.108)
Under-education among young workers		0.067
(one year lagged, in years)		(0.106)
Under-education among older workers		0.039
(one year lagged, in years)		(0.090)
Worker characteristics:	Yes	Yes
Firm characteristics:	Yes	Yes
Year dummies (7):	Yes	Yes
Sig. Model (p-value)	0.000	0.00
Hansen statistic	243.2	262.0
p-value	0.38	0.40
Arellano-Bond statistic (AR2)	1.34	1.61
p-value	0.18	0.11
Number of observations	7,720	7,720
Number of firms	2,813	2,813

Notes: ***/**/* significant at the 1, 5 and 10% level, respectively. Robust standard errors between brackets.

How to interpret findings for profits?

- ✓ Results may suggest that the positive impact of **over-education** on productivity is neutralized by a comparable upward effect on wages, so that in the end no impact is found on profits.
 - ✓ Findings are compatible with the idea that the negative impact of **young under-educated workers** on firm productivity is counterbalanced by a wage penalty for those workers so that profits remain unaffected.
- ⇒ Over- and under-educated workers may thus to be paid at (or close to) their marginal productivity.

Birth Cohort of Workers, equation (2)

$$\ln VA_work_{jt} = \beta_0 + \beta_1 REQ^*_{j,t} + \beta_2 OVER^*_{j,t} + \beta_3 UNDER^*_{j,t} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + v_{j,t}$$

- ✓ $REQ^*_{j,t}$ is the average of the years of required education in firm j at time t , controlling for cohort effects. It is equal to the employment weighted sum of the required years of education for all jobs occupied respectively by young (i.e. workers that are at most 35 years old) and older workers (i.e. those that are at least 36 years old) in firm j at time t .

Mathematically:

$$REQ^*_{j,t} = \frac{1}{m_{young,j,t}} \sum_{i=1}^{m_{j,t}} REQ_young_{i,j,t} + \frac{1}{m_{older,j,t}} \sum_{i=1}^{m_{j,t}} REQ_older_{i,j,t}$$

with:

- $m_{young,j,t}$ ($m_{older,j,t}$) the number of young (older) workers employed in firm j at year t .
- $REQ_young_{i,j,t}$ = [mode of education among young workers that are in the same occupation than worker i (at the NACE 3-digit level in the entire economy) at time t] if worker i is young, 0 otherwise.
- $REQ_older_{i,j,t}$ = [mode of education among older workers that are in the same occupation than worker i (at the NACE 3-digit level in the entire economy) at time t] if worker i is older than 35 years, 0 otherwise.

Birth Cohort of Workers (Cont.)

$$\ln VA_work_{jt} = \beta_0 + \beta_1 REQ^*_{j,t} + \beta_2 OVER^*_{j,t} + \beta_3 UNDER^*_{j,t} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + v_{j,t}$$

- ✓ **$OVER^*_{j,t}$** is the average of the years of over-education in firm j at time t , controlling for cohort effects. It corresponds to sum of the years of over-education among young and older workers in firm j at time t , divided by the total number of workers employed in firm j at time t .

Mathematically:

$$OVER^*_{j,t} = \frac{1}{m_{j,t}} \left(\sum_{i=1}^{m_{j,t}} OVER_young_{i,j,t} + \sum_{i=1}^{m_{j,t}} OVER_older_{i,j,t} \right)$$

with:

- $m_{j,t}$: the total number of workers employed in firm j at time t .
- $OVER_young_{i,j,t} = [(Attained_education_{i,j,t} - REQ_young_{i,j,t}) \text{ if } > 0 \text{ \& worker } i \text{ is young; } 0 \text{ otherwise}]$.
- $OVER_older_{i,j,t} = [(Attained_education_{i,j,t} - REQ_older_{i,j,t}) \text{ if } > 0 \text{ \& worker } i \text{ is older than 35 years; } 0 \text{ otherwise}]$.
- $Attained_education_{i,j,t}$: the number of years corresponding to the highest level of education attained by worker i employed in firm j at time t .

Birth Cohort of Workers (Cont.)

$$\ln VA_work_{jt} = \beta_0 + \beta_1 REQ^*_{j,t} + \beta_2 OVER^*_{j,t} + \beta_3 UNDER^*_{j,t} + X_{j,t} \beta_4 + Z_{j,t} \beta_5 + \gamma_t + v_{j,t}$$

- ✓ **UNDER***_{j,t} is the average of the years of under-education in firm j at time t , controlling for cohort effects. This variable is equal to the sum of the years of under-education among young and older workers in firm j at time t , divided by the total number of workers employed in firm j at time t .

Mathematically:

$$UNDER^*_{j,t} = \frac{1}{m_{j,t}} \left(\sum_{i=1}^{m_{j,t}} UNDER_young_{i,j,t} + \sum_{i=1}^{m_{j,t}} UNDER_older_{i,j,t} \right)$$

with:

- $m_{j,t}$: the total number of workers employed in firm j at time t .
- $UNDER_young_{i,j,t} = [(Attained_education_{i,j,t} - REQ_young_{i,j,t}) \text{ if } < 0 \text{ \& worker } i \text{ is young; } 0 \text{ otherwise}]$.
- $UNDER_older_{i,j,t} = [(Attained_education_{i,j,t} - REQ_older_{i,j,t}) \text{ if } < 0 \text{ \& worker } i \text{ is older than 35 years; } 0 \text{ otherwise}]$.
- $Attained_education_{i,j,t}$: the number of years corresponding to the highest level of education attained by worker i employed in firm j at time t .

Effects of ORU variables by workers' age, equation (3)

$$\begin{aligned}\ln VA_work_{j,t} = & \beta_0 + \beta_1 REQ^*_{j,t} + \beta_2 YOUNG-OVER^*_{j,t} + \beta_3 OLDER-OVER^*_{j,t} \\ & + \beta_4 YOUNG-UNDER^*_{j,t} + \beta_5 OLDER-UNDER^*_{j,t} \\ & + \mathbf{x}_{jt} \boldsymbol{\beta}_4 + \mathbf{z}_{jt} \boldsymbol{\beta}_5 + \gamma_t + p_{j,t}\end{aligned}\quad (2)$$

- ✓ **REQ^{*}_{j,t}** is the average of the years of required education in firm *j* at time *t*, controlling for cohort effects (see equation (2)).
- ✓ **YOUNG-OVER^{*}_{j,t}** is the average of the years of over-education among young workers in firm *j* at time *t*, controlling for cohort effects. It corresponds to the sum of the years of over-education among young workers (i.e. workers that are at most 35 years old) in firm *j* at time *t*, divided by the total number of workers employed in firm *j* at time *t*.

Mathematically:

$$YOUNG-OVER^*_{j,t} = \frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} OVER_young_{i,j,t}$$

with:

- $m_{j,t}$ the total number of workers employed in firm *j* at time *t*.
- $OVER_young_{i,j,t} = [(Attained_education_{i,j,t} - REQ_young_{i,j,t}) \text{ if } > 0 \text{ \& worker } i \text{ is young; } 0 \text{ otherwise}]$.

Effects of ORU by workers' age (Cont.)

- ✓ **OLDER-OVER***_{j,t} is the average of the years of over-education among workers older than 36 years in firm j at time t , controlling for cohort effects. It is equal to the sum of the years of over-education among older workers in firm j at time t , divided by the total number of workers employed in firm j at time t .

Mathematically:

$$OLDER-OVER^*_{j,t} = \frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} OVER_older_{i,j,t}$$

with:

- $m_{j,t}$ the total number of workers employed in firm j at time t .
- $OVER_older_{i,j,t} = [(Attained_education_{i,j,t} - REQ_older_{i,j,t}) \text{ if } > 0 \text{ \& worker } i \text{ is at least 36 years old; } 0 \text{ otherwise}]$.

- ✓ **YOUNG-UNDER***_{j,t} is the average of the years of under-education among young workers in firm j at time t , controlling for cohort effects. It is equal to the sum of the years of under-education among young workers in firm j at time t , divided by the total number of workers employed in that firm j at time t .

Mathematically:

$$YOUNG-UNDER^*_{j,t} = \frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} UNDER_young_{i,j,t}$$

with:

- $m_{j,t}$ the total number of workers employed in firm j at time t .
- $UNDER_young_{i,j,t} = [(Attained_education_{i,j,t} - REQ_young_{i,j,t}) \text{ if } < 0 \text{ \& worker } i \text{ is young; } 0 \text{ otherwise}]$.

Effects of ORU by workers' age (Cont.)

- ✓ **OLDER-UNDER***_{*j,t*} is the average of the years of under-education among older workers in firm *j* at time *t*, controlling for cohort effects. To obtain this measure, we sum the years of under-education among older workers in firm *j* at time *t* and divide by the total number of workers employed in firm *j* at time *t*.

Mathematically:

$$OLDER-UNDER^*_{j,t} = \frac{1}{m_{j,t}} \sum_{i=1}^{m_{j,t}} UNDER_{i_older,j,t}$$

with:

- $m_{j,t}$ the total number of workers employed in firm *j* at time *t*.
- $UNDER_older_{i,j,t} = [(Attained_education_{i,j,t} - REQ_older_{i,j,t}) \text{ if } < 0 \text{ \& worker } i \text{ is at least 36 years old; 0 otherwise}]$.