Skill-biased technological change, unemployment and brain drain

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Motivation

- The emigration of skilled workers is a major issue in particular in the developing world.
- Skilled emigration is quantitatively large. In 1990/2000, the rate of skilled emigrating was around 5% worldwide (Docquier and Marfouk, 2006) - three times greater than the average emigration rate - and around 7% in developing countries - more than five times greater than average.

- Skilled emigration levels have increased: between 1990 and 2000, the stock of high-skilled immigrants in OECD countries increased by 70%, that of low-skilled by 30%.
- Skilled emigration rates remained roughly constant due to a sharp rise in educational attainment in many sending countries.
- In developing countries, the skilled emigration rate decreased from 7.8% to 7.4% (from 7 to 5 as a ratio of the average emigration rate) during 1990 and 2000.

Our contribution

- The effect of the size of the skilled workforce on labor market outcomes for the skilled and the brain drain - in the presence of unemployment and endogenous (skill-biased) technology.
- Idea: technological change is directed $\Rightarrow$ relative factor abundance increases relative factor-productivity, which increases relative factor demand.
- We find that, under certain conditions, a greater skill share can increase both wages and employment rates of skilled workers - and, therefore, decrease brain drain.

Stylized facts on skill-specific wages, unemployment rates and brain drain 1980-2000

- Wages: we construct wages for skilled and unskilled workers from the OWW (Occupational Wages around the World) dataset compiled by Freeman and Oostendorp from ILO data, following the method by Chor (2001).
- Unemployment rates: constructed for skilled and unskilled workers from the ILO Key Indicators of the Labor Market database.
- Human capital stocks: Barro and Lee (2000), De la Fuente and Domenech (2002).
- Migration rates: available by skill from Beine, Docquier and Rapoport (2007) for 1990 and 2000.

Figure: Skill ratio and relative unemployment

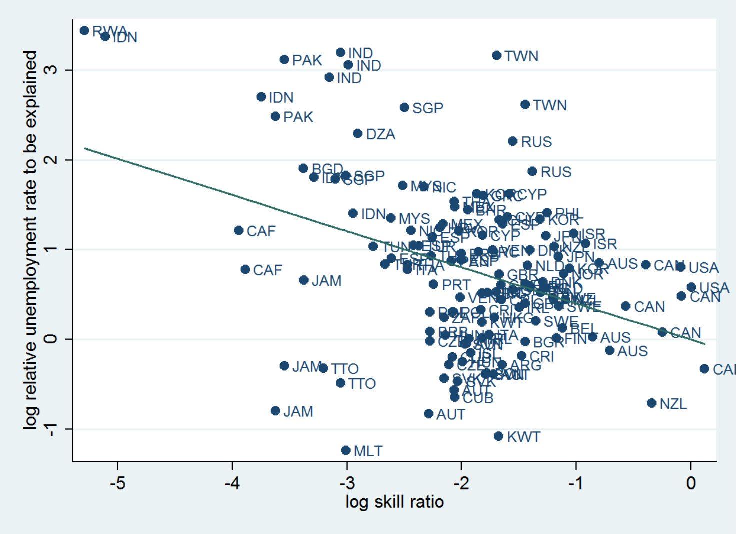


Figure: Skill ratio and brain drain

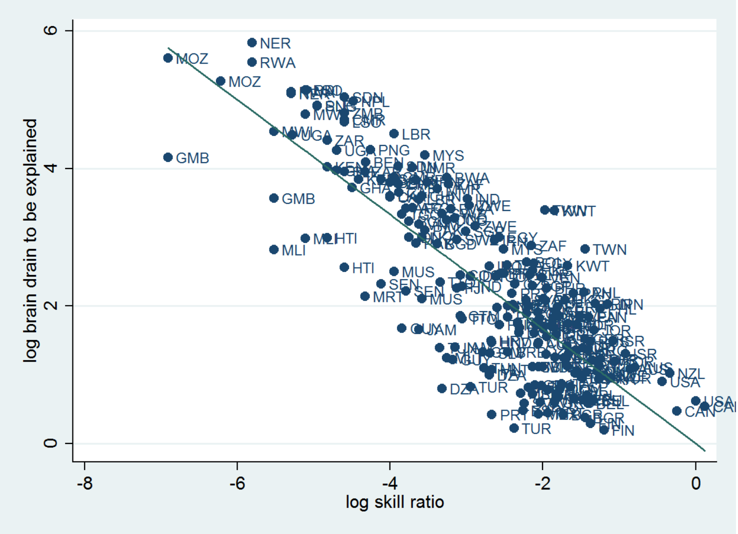


Figure: Relative unemployment and brain drain

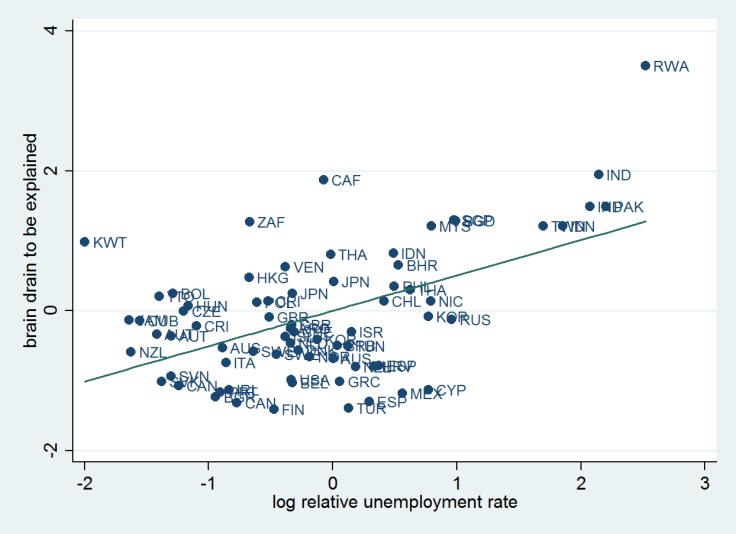
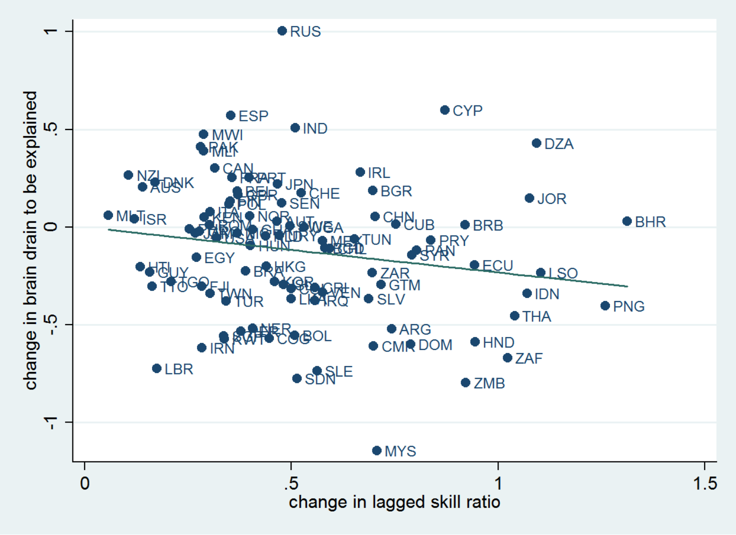


Figure: Change in lagged skill ratio and change in brain drain



The model: production

Final good (perfectly competitive):

$$Y = \left[Y_L^{\frac{\epsilon-1}{\epsilon}} + Y_H^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{1}$$

Sectoral aggregate goods (perfectly competitive):

$$Y_L = E_L \left[\int_0^{A_L} y_L(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \quad \text{and} \quad Y_H = E_H \left[\int_0^{A_H} y_H(i)^{\frac{\sigma-1}{\sigma}} di \right]^{\frac{\sigma}{\sigma-1}} \tag{2}$$

$E_j \equiv A_j^{\frac{\sigma-2}{\sigma-1}}$ (normalization)
Intermediate producers (monopolistically competitive):

$$y_L(i) = l(i) \quad \text{and} \quad y_H(i) = Zh(i). \tag{3}$$

Employment

- Firms face labor market frictions.
- To hire j workers: pay $b_j j$ hiring costs, b_j exogenous to firm.
- Hiring cost b_j, depends on labor market tightness (Helpman and Itskhoki 2007, Blanchard and Gali 2008):

$$b_j = a_j x_j^{\alpha}, \quad j \in (L, H) \quad a_j > 1, \alpha > 0, \tag{4}$$

- $x_H = H_E/H$, $(x_L = L_E/L)$,
  H_E (L_E): employed skilled (unskilled) workers, H (L): total skilled (unskilled) workers, in fixed supply.

- Showing that $w_j = b_j$ and using hiring costs (4):

$$\frac{w_H}{w_L} = \frac{a_H}{a_L}\left(\frac{H}{L}\right)^{-\alpha}\left(\frac{H_E}{L_E}\right)^{\alpha} \tag{5}$$

$\Rightarrow$ Increase in the relative supply of skilled workers decreases their relative wage.

Equilibrium with Exogenous Technology (no Migration)

- According to the relative demand for final goods $\frac{P_H}{P_L} = \left[\frac{A_L L_E}{A_H Z H_E}\right]^{\frac{1}{\epsilon}}$ and
- $p_j J_E = P_J Y_J$, sectoral output: $Y_L = A_L L_E$ and $Y_H = A_H Z H_E$, $w_j \propto p_j$ and labor market clearing conditions $J_E = \int_0^{A_j} j(i)di$ for $J \in H, L$, $j \in h, l$:

$$\frac{w_H}{w_L} \equiv \omega = \frac{P_H Z A_H}{P_L A_L} = \left[\frac{Z A_H}{A_L}\right]^{1-\frac{1}{\epsilon}} \left[\frac{L_E}{H_E}\right]^{\frac{1}{\epsilon}} \tag{6}$$

- Combine relative labor demand (6) with the matching function (5) to get:

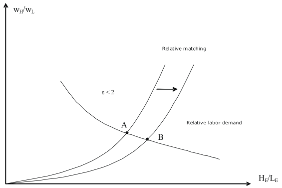
$$\frac{H_E}{L_E} = \left[\frac{a_L}{a_H} \left(\frac{H}{L} \right)^{\alpha} \left(\frac{ZA_H}{A_L} \right)^{\frac{\epsilon-1}{\epsilon}} \right]^{\frac{\epsilon}{\alpha\epsilon+1}}$$

$$\frac{w_H}{w_L} = \left[\frac{a_H}{a_L} \left(\frac{H}{L} \right)^{-\alpha} \left(\frac{ZA_H}{A_L} \right)^{\alpha(\epsilon-1)} \right]^{\frac{1}{\alpha\epsilon+1}}$$

$$\frac{x_H}{x_L} = \left[\left(\frac{a_H}{a_L} \right)^{-\epsilon} \left(\frac{H}{L} \right)^{-1} \left(\frac{ZA_H}{A_L} \right)^{\epsilon-1} \right]^{\frac{1}{\alpha\epsilon+1}}$$

Proposition. When technology is exogenous, an increase in the relative number of skilled results in a decrease in the wage and employment rate of skilled relative to unskilled workers.

Figure: Increase in skilled workers - exogenous technology



Note: The figure depicts the relationship between the skill premium w_H/w_L and the skill ratio of employed H_E/L_E according to (1) relative matching and (2) relative labor demand. If technology is exogenous (or, if technology is skill-biased but $\varepsilon < 2$), then the labor demand curve is downward-sloping. Then, an increase in the skill ratio H/L leads to a decrease in the skill premium and an increase in the skill ratio of employed via a rightward-shift of the matching function (movement from point A to point B) – compare (28) and (30). The relative employment rate of skilled $(H_E/H)/(L_E/L)$ decreases – compare (29).

Equilibrium with Endogenous Technology (no Migration)

- Free entry in the intermediate sectors:

$$\pi_L = \frac{1}{2\sigma - 1} p_L l - \mu = 0 \quad \pi_H = \tfrac{1}{2\sigma-1} p_H h - \mu = 0$$

- Using $p_j J_E = P_J Y_J$ and labor market clearing:

$$\frac{\pi_H + \mu}{\pi_L + \mu} = \frac{P_H Z H_E}{P_L L_E} = \left(\frac{A_H}{A_L}\right)^{-\frac{1}{\epsilon}} \left(\frac{Z H_E}{L_E}\right)^{\frac{\epsilon-1}{\epsilon}} = 1$$

1. *price effect*: profits are higher in sectors that produce more expensive goods
2. *market size effect*: profits are higher in larger sectors.

- Solving for relative technologies:

$$\frac{A_H}{A_L} = \left(\frac{Z H_E}{L_E}\right)^{\epsilon-1}$$

- Relative labor demand:

$$\frac{w_H}{w_L} = Z^{\epsilon-1}\left(\frac{H_E}{L_E}\right)^{\epsilon-2}$$

- combined with matching function (5):

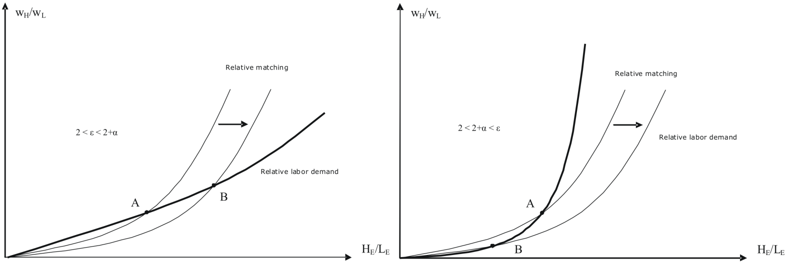
$$\frac{w_H}{w_L} = Z^{-\frac{\alpha(\epsilon-1)}{\epsilon-2-\alpha}}\left[\frac{a_H}{a_L}\left(\frac{H}{L}\right)^{-\alpha}\right]^{\frac{\epsilon-2}{\epsilon-2-\alpha}}$$

- Relative employment rates:

$$\frac{x_H}{x_L} = Z^{-\frac{\epsilon-1}{\epsilon-2-\alpha}}\left[\frac{a_H}{a_L}\left(\frac{H}{L}\right)^{-(\epsilon-2)}\right]^{\frac{1}{\epsilon-2-\alpha}}$$

Proposition. When technology is endogenous, an increase in the number of skilled results in an increase in the wage and employment rate of skilled relative to unskilled workers, if $0 < \epsilon - 2 < \alpha$, and in a decrease otherwise.

Figure: Increase in skilled workers - endogenous technology



Panel a: High Elasticity of Labor Demand

Panel b: Low Elasticity of Labor Demand

Note: The above figure represents the same relations as Figure 5. However, the relative labor demand curve is now upward-sloping, which is the case, if technology is skill-biased and $\varepsilon > 2$. Now, the effect of an increase in the skill ratio H/L depends on the elasticity of labor demand, $1/(\varepsilon\text{-}2)$, relative to the elasticity of matching, $1/\alpha$. If labor demand elasticity is relatively high (panel a), we expect an increase in the skill premium, the skill ratio of employed and the relative employment rate of skilled $(H_E/H)/(L_E/L)$ via a rightward-shift of the matching function (movement from point A to point B). If labor demand elasticity is relatively low (panel b), we expect a decrease in the skill premium, the skill ratio of employed and the

Migration

- Individual k with skill j derives utility from emigrating to the OECD:

$$U_j^M(k) = w_j^{OECD} x_j^{OECD} - c_j - \varepsilon(k), \quad j \in H, L$$

- Utility from staying in home country:

$$U_j = w_j x_j, \quad j \in H, L$$

- Probability of emigration for a skilled (unskilled) worker:

$$Prob(U_j^M(k) > U_j) = Prob(\varepsilon < w_j^{OECD} x_j^{OECD} - w_j x_j - c_j)$$

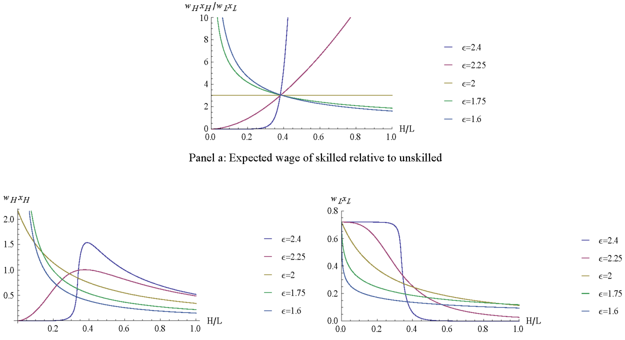
- Assume migration costs ε are logistically distributed with mean zero and variance unity.
- Then, the migration probability for skill type j is:

$$s_j = Prob(U_j^M(k) > U_j^S) = \frac{1}{1 + e^{-(w_j^{OECD} x_j^{OECD} - w_j x_j - c_j)}} \quad (7)$$

- s_j is the share of the population of skill level j that migrates.
- The two equations (7) implicitly define s_H and s_L as functions of H, L. We take $w_j^{OECD} x_j^{OECD}$ as given.

Figure: Expected wages of skilled and unskilled in general equilibrium

Figure 7: Expected Wages of Skilled and Unskilled in General Equilibrium



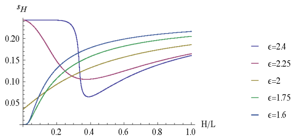
Panel a: Expected wage of skilled relative to unskilled

Panel b: Expected wage of skilled

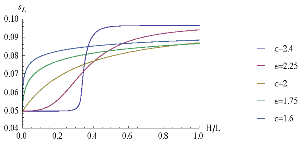
Panel c: Expected wage of unskilled

Figure: Emigration rates and brain drain in general equilibrium

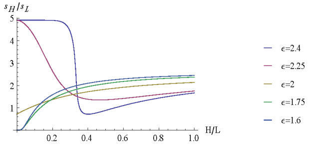
Figure 8: Emigration Rates and Brain Drain in General Equilibrium



Panel a: Emigration rate of skilled



Panel b: Emigration rate of unskilled



Panel c: Emigration rate of skilled relative to unskilled (brain drain)

- Expected wages for skilled

$$w_H x_H = a_H^{\frac{1}{\alpha}} \left[\frac{\mu_H(2\sigma - 1)}{(1 - s_H)HZ} \left(1 + Z^{\frac{(\alpha+1)(\epsilon-1)}{\epsilon-2-\alpha}} \left[\frac{a_L}{a_H} \left(\frac{(1-s_H)H}{(1-s_L)L} \right)^{\alpha} \right]^{\frac{\epsilon-1}{\epsilon-2-\alpha}} \right. \right. \tag{8}$$

- Expected wages for unskilled

$$w_L x_L = a_L^{\frac{1}{\alpha}} \left[\frac{\mu_L(2\sigma - 1)}{(1 - s_L)L} \left(1 + Z^{\frac{(\alpha+1)(1-\epsilon)}{\epsilon-2-\alpha}} \left[\frac{a_H}{a_L} \left(\frac{(1-s_L)L}{(1-s_H)H} \right)^{\alpha} \right]^{\frac{\epsilon-1}{\epsilon-2-\alpha}} \right. \right. \tag{9}$$

- increase in H first increases expected wages through endogenous adjustment of skill demand
- if H too large: negative congestion effect (increase in labor market tightness)

Skill ratio and skill-specific unemployment rates

	(1)	(2)	(3)	(4)	(5)	(6)
	Relative Unempl. Rate				Δ Relative Unempl. Rate	
Skill ratio	-0.402***	-0.426**	-0.271	-0.821***		
	(0.141)	(0.163)	(0.169)	(0.196)		
GDP per capita			0.000			
			(0.000)			
GDP Growth rate		1.405	1.286	2.855*		
		(1.339)	(1.051)	(1.549)		
Openness		-0.305	-0.229	-0.346		
		(0.263)	(0.189)	(0.329)		
ΔSkill ratio$_{t-1}$					-3.165***	
					(0.409)	
Δ Skill ratio						-22.67**
						(10.38)
Δ Growth rate					-0.358	-1.079
					(1.147)	(4.515)
Δ Openness					0.92	5.348
					(0.841)	(8.196)
Time Fixed Effects	YES	YES	YES	YES	YES	YES
Estimator	OLS	OLS	OLS	IV	OLS	IV
Instrument				Edu. Exp.$_{t-10}$		Δ Edu. Exp.$_{t-1}$
Cluster	Country	Country	Country	Country	Country	Country
Observations	134	71	71	28	23	23
Countries	63	48	48	18	18	18
R-squared	0.162	0.21	0.232		0.686	

Skill ratio and skill-specific wages

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Skill Premium				Δ Skill Premium		
Skill ratio	-0.214***	-0.201***	-0.104	-0.208***			
	(0.040)	(0.041)	(0.066)	(0.041)			
GDP per capita			-0.159*				
			(0.080)				
GDP Growth rate		0.106	0.77	0.125			
		(1.528)	(1.505)	(1.488)			
Openness		0.0357	0.111	0.035			
		-0.081	(0.095)	(0.079)			
ΔSkill ratio$_{t-1}$						-0.00756	
						(0.057)	
Δ Skill ratio					-0.0249		0.0402
					(0.097)		(0.246)
Δ Growth rate					-0.139	-0.136	
					(0.164)	(0.164)	
Δ Openness					0.0963	0.104	
					(0.110)	(0.126)	
Time Fixed Effects	YES	YES	YES	YES	YES	YES	YES
Estimator	OLS	OLS	OLS	IV	OLS	OLS	IV
Instrument				Skill			Δ*Skill*
					Exp.$_{t-10}$		Exp.$_{t-1}$
Cluster	Country	Country	Country	Country	Country	Country	Country
Observations	133	130	130	130	67	67	67
Countries	62	60	60	60	40	40	40
R-squared	0.356	0.341	0.389	0.341	0.053	0.052	0.017

Skill ratio and skilled migration rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Skilled Migration Rate				Δ Skilled Migration Rate		
Skill ratio	-0.409***	-0.456***	-0.398***	-0.578*			
	(0.085)	(0.102)	(0.116)	(0.345)			
Distance		-0.229***	-0.0936	-0.250*			
		(0.067)	(0.085)	(0.145)			
Colony		0.0507	0.036	-0.0847			
		(0.302)	(0.247)	(0.355)			
English		1.123***	0.752***	1.014***			
		(0.251)	(0.206)	(0.196)			
French		-0.153	-0.492**	-0.115			
		(0.301)	(0.238)	(0.326)			
GDP per capita			-0.0726				
			(0.185)				
GDP Growth rate			-0.316				
			(0.262)				
Openness			0.952***				
			(0.2)				
ΔSkill ratio$_{t-1}$					-0.231*	-0.206	
					(0.126)	(0.130)	
Δ Skill ratio							-0.796*
							(0.451)
Δ Growth rate						-0.112	-0.049
						(0.068)	(0.084)
Δ Openness						0.201**	0.117
						(0.100)	(0.116)
Estimator	OLS	OLS	OLS	IV	OLS	OLS	IV
Observations	232	232	170	181	95	72	54
Countries	121	121	87	101	93	72	54
R-squared	0.154	0.31	0.48		0.036	0.104	

Skill ratio and unskilled migration rate

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Unskilled Migration Rate				Δ Unskilled Migration Rate	
Skill ratio	0.523***	0.279**	0.308**	-0.276			
	(0.010)	(0.124)	(0.141)	(0.450)			
Distance		-0.463***	-0.283***	-0.663***			
		(0.083)	(0.105)	(0.190)			
Colony		-0.175	-0.382	-0.537			
		(0.354)	(0.362)	(0.463)			
English		0.810***	0.316	0.719***			
		(0.296)	(0.245)	(0.260)			
French		0.0474	-0.0333	-0.182			
		(0.373)	(0.360)	(0.425)			
GDP per capita			-0.086				
			(0.223)				
GDP Growth rate			0.0748				
			(0.386)				
Openness			1.079***				
			(0.233)				
ΔSkill ratio$_{t-1}$					0.0262	0.189	
					(0.123)	(0.157)	
Δ Skill ratio							1.099
							(0.775)
Δ Growth rate						0.284*	0.481***
						(0.166)	(0.154)
Δ Openness						0.051	0.223
						(0.112)	(0.145)
Estimator	OLS	OLS	OLS	IV	OLS	OLS	IV
Observations	232	232	170	179	93	71	53
Countries	121	121	87	101	93	71	53
R-squared	0.185	0.329	0.467		0.001	0.102	

Skill ratio and brain drain

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Brain Drain				Δ Brain Drain		
Skill ratio	-0.833***	-0.830***	-0.635***	-0.973***			
	(0.053)	(0.054)	(0.081)	(0.203)			
Distance			0.176***				
			(0.052)				
Colony			0.352				
			(0.218)				
English			0.234				
			(0.153)				
French			-0.317				
			(0.231)				
GDP per capita			-0.0107				
			(0.121)				
GDP Growth rate		-0.266	-0.26	-0.368			
		(0.203)	(0.212)	(0.373)			
Openness		-0.217	-0.242**	-0.0556			
		(0.13)	(0.108)	(0.198)			
ΔSkill ratio$_{t-1}$					-0.235*	-0.363*	
					(0.129)	(0.187)	
Δ Skill ratio							-0.457**
							(0.179)
Δ Growth rate						-0.322**	-0.106
						(0.156)	(0.183)
Δ Openness						0.106	-1.866*
						(0.132)	(0.966)
Estimator	OLS	OLS	OLS	IV	OLS	OLS	IV
Observations	232	170	170	66	93	71	54
Countries	121	87	87	66	93	71	54

Unemployment and brain drain

	(1)	(2)	(3)	(4)	(5)	(6)
			Brain Drain			ΔB.D.
Relative Unemployment	0.506***	0.457***	0.340*	0.151	0.725**	
	(0.131)	(0.169)	(0.174)	(0.126)	(0.369)	
Distance				0.253***		
				(0.0583)		
Colony				0.787***		
				(0.244)		
English				0.0386		
				(0.215)		
French				0.0468		
				(0.464)		
GDP per capita			0			
			(0.000)			
GDP Growth rate		-0.196	0.171	-0.538	0.283	
		(0.62)	(0.586)	(0.463)	(0.879)	
Openness		-0.168	-0.135	-0.0991	0.105	
		(0.198)	(0.208)	(0.134)	(0.210)	
Δ Relative Unemployment						0.0849*
						(0.047)
Estimator	OLS	OLS	OLS	OLS	IV	OLS
Observations	72	63	63	63	52	13
Countries	59	50	50	50	40	13
R-squared	0.277	0.24	0.291	0.554		0.133

Calibration

- Elasticity of substitution ϵ=2.25 (Gancia, Müller, Zilibotti (2011)), robustness with other values
- Elasticity of matching function: α=0.46 (Brüggemann (2008))
- Z=2.56 (matches skill premium for OECD average)
- Markup: $\sigma = 4$ (Broda and Weinstein (2006))
- OECD employment rates: $x_H = 0.96$, $x_L = 0.95$ for 1990 from ILO
- OECD wages: from data $w_H = 37,000\$$, $w_L = 15,000\$$
- bilateral fixed migration costs for skilled and unskilled: estimated from data from skilled/unskilled migration regressions

Can the model replicate moments of the data? - Predicted and actual correlations

		Endogenous Tech.				Exog. Tech.
	Data	ϵ =1.9	ϵ =2.1	ϵ=2.25	ϵ =2.4	ϵ =2.25
$corr(\log(u_H/u_L), \log(H/L))$	**-0.210*** **	0.275***	-0.336***	**-0.636*** **	-0.469	-0.001
$corr(\log(s_H/s_L), \log(H/L))$	**-0.826*** **	-0.030	-0.428***	**-0.479*** **	-0.378***	0.852***
$corr(\log(w_H/w_L), u_H/u_L)$	**0.778*** **	-0.118***	0.095	**0.374*** **	0.506***	0.001***
$corr(\log(w_H/w_L), H/L)$	**-0.152*** **	-0.082***	0.128***	**0.551*** **	3.080	-0.0002
$corr(\log(s_H/(1-s_H), H/L)$	**-0.396*** **	0.474***	0.041	**-0.018**	0.065***	1.175***
$corr(\log(s_L/(1-s_L), H/L)$	**0.530*** **	0.501	0.477***	**0.466*** **	0.447***	0.323***
$corr(\Delta\log(s_H/s_L), \Delta H/L)$	**-1.303*** **	-0.270***	-0.248	**-0.151**	-0.030	1.065***
$corr(A_H/A_L, H/L)$, $\epsilon = 1.9$	0.796***	-0.093***				
$corr(A_H/A_L, H/L)$ $\epsilon = 2.1$	0.622***		0.121***			
$corr(A_H/A_L, H/L)$ $\epsilon = 2.25$	0.528***			0.528***		
$corr(A_H/A_L, H/L)$ $\epsilon = 2.4$	0.454***				3.060***	

Partial correlations between relative unemployment rates, (changes of) brain drain, relative wage of skilled workers, skilled migration rate, unskilled migration rate and (changes of) skill ratios. Time-specific effects are controlled for. The first column presents the empirical correlations. Columns (2)-(6) present correlations generated by the model using different values for the elasticity of substitution between skilled and unskilled workers (ϵ). Column (2) is our baseline calibration and column (6) presents results for the case of exogenous technology.

Experiment: Effect of increasing skill endowments on migration rates for typical developing country

H/L	0.01	0.05	0.10	0.20	0.50	1
Panel a: Endogenous technology						
s_H	0.24	0.23	0.21	0.15	0.11	0.16
s_L	0.04	0.04	0.05	0.05	0.08	0.09
s_H/s_L	4.90	4.70	4.20	2.64	1.35	1.75
Panel b: Exogenous technology						
s_H	0.17	0.20	0.21	0.21	0.21	0.22
s_L	0.05	0.05	0.05	0.04	0.04	0.03
s_H/s_L	3.22	3.88	4.20	4.59	5.42	6.54

In Panel b, A_H=0.3 and A_L=0.1 were chosen such that for H/L=0.1 emigration rates are exactly the same as in the case of endogenous technology.

Conclusions

- Model that explains brain drain in the presence of skill-specific unemployment and skill-biased technological change.
- Greater skill ratio can increase the relative productivity of skill and decrease relative unemployment of skilled workers $\Rightarrow$ decrease the brain drain - depending on the elasticity of substitution between skilled and unskilled workers and the skill ratio.
- Empirical evidence is supportive of a negative effect of the skill ratio on brain drain.
- Simulations suggest that at current levels of skill ratios in developing countries, increases in the skill ratio could possibly result in sizeable decreases in the brain drain.