Economic Growth, the High-Tech Sector, and the High Skilled: Theory and Quantitative Implications

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Motivation & Empirical evidence (I)

- Europe 2020 Strategy rests on the conventional view that **increases in the shares of high-skilled workers and of the high-tech sector** are major intermediate goals to **improve the economic growth rate** of the European Union.

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- Europe 2020 Strategy rests on the conventional view that **increases in the shares of high-skilled workers and of the high-tech sector** are major intermediate goals to **improve the economic growth rate** of the European Union.
  - One of the 2020 headline targets of the Europe 2020 Strategy states that "*... at least 40% of the younger generation (30-34 years old) should have a tertiary degree.*"
  - Another major target is to *reduce the gap over the relative importance of the high-tech sector* as compared with the US (*EC, 2010*)

Motivation & Empirical evidence (II)

- However, cross-country evidence for Europe shows there is a **weak relationship between the economic growth rate** and both **the skill structure** and **the technology structure** (relative production or relative number of firms in the high-tech vis-à-vis the low-tech sector):
  - Growth-skill elasticity of -0.026 (s.e. of 0.172);
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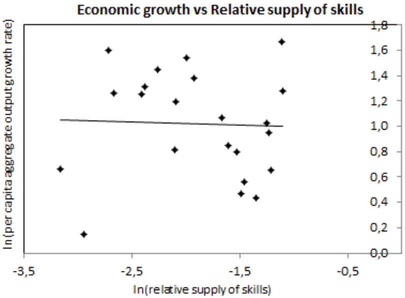
Figure 1.



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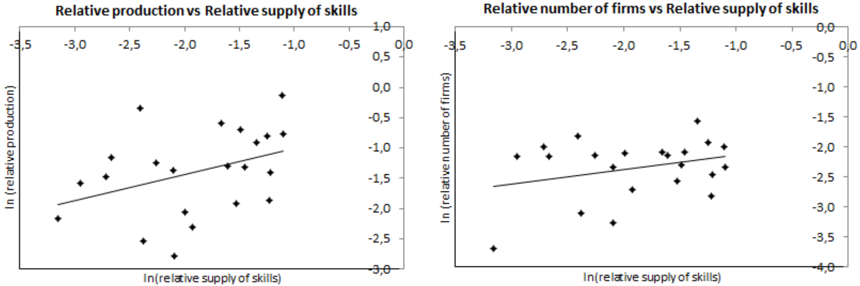

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- Thus, the conventional view underlying Europe's "2020 Strategy" is not fully supported by the data.
- What can explain that? Are there any policy instruments that would allow for all the "right" correlations?
- The available literature does not provide an answer if we consider all the three elasticities (and the two variants using the data on production and the number of firms).

Our paper

- **Analytics**: we adopt an agnostic approach by extending a benchmark endogenous growth model (*e.g.*, *Acemoglu and Zilibotti*, 2001) with a very flexible structure.
    - Allows us to **identify the structural relationships** between growth, technology structure and skill structure underlying the cross-country data.

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  - Allows us to **identify the structural relationships** between growth, technology structure and skill structure underlying the cross-country data.

- **Quantification**: we find consistency with the empirical relationships if we allow for the simultaneous existence of:
  - **Some scale effects on growth** (associated with positive but small market-complexity costs in vertical R&D);
  - **High barriers to entry into the high-tech vis-à-vis the low-tech sector** (associated with relatively large fixed R&D costs in the high-tech sector).

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- Households make consumption decisions and invest in firms' equity.

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- Assumption: the **high- and low-skilled labour-specific** intermediate-good sectors in the model $\rightarrow$ theoretical counterpart of the **high- and low-tech** sectors in the data (e.g., *Cozzi and Impuliti,* 2010).

Model (III): final-good production function

- For firm n in the final-good sector at time t:

$$Y(n,t) = \left[\int_0^{N_L(t)} \left(\lambda^{j_L(\omega_L,t)} \cdot X_L(n,\omega_L,t)\right)^{1-\alpha} d\omega_L\right] [(1-n)\cdot l \cdot L(n)]^{\alpha} + \\ + \left[\int_0^{N_H(t)} \left(\lambda^{j_H(\omega_H,t)} \cdot X_H(n,\omega_H,t)\right)^{1-\alpha} d\omega_H\right] [n \cdot h \cdot H(n)]^{\alpha}$$

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  - Quality level of an existing variety in the m-specific intermediate-good sector: $j_m(t)$;
  - Absolute-productivity advantage of H over L implies $h > l \geq 1$.

Model (IV): horizontal R&D

- **Horizontal R&D** increases the number of varieties / firms, $N_m(t)$, $m \in \{L, H\}$, in the m-specific intermediate-good sector, according to:

$$\dot{N}_m(t) = R_{h,m}(t) \frac{1}{\phi_m \cdot m^{\delta} \cdot N_m(t)^{\sigma} / F_{h,m}},$$

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  - Market complexity cost factor: m^{δ}, $\delta \in \mathbb{R}$.

Model (V): vertical R&D

- **Vertical R&D** increases the quality level, $j_m(t)$, $m \in \{L, H\}$, of the good of an existing industry in the m-specific intermediate-good sector, according to:

$$I_m(j_m) = R_{v,m}(j_m) \cdot \frac{1}{\zeta_m \cdot m^{\epsilon} \cdot q_m(j_m + 1)/F_{v,m}},$$

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  - Flow fixed cost: $\zeta_m \Rightarrow$ **relative barriers to (vertical) entry**: ζ_H/ζ_L;
  - Market complexity cost factor: m^{ϵ}, $\epsilon \in \mathbb{R} \Rightarrow$ **net scale effects on growth**: $1 - \epsilon$.

Analytical results (I): BGP growth and skill structure

$$\mathcal{E}^{\tilde{g}}_{H/L}(\epsilon,\zeta) = (1-\epsilon)\left(\frac{h/l \cdot (H/L)^{1-\epsilon}}{\zeta/F_v + h/l \cdot (H/L)^{1-\epsilon}}\right), \zeta \equiv \frac{\zeta_H}{\zeta_L}.$$

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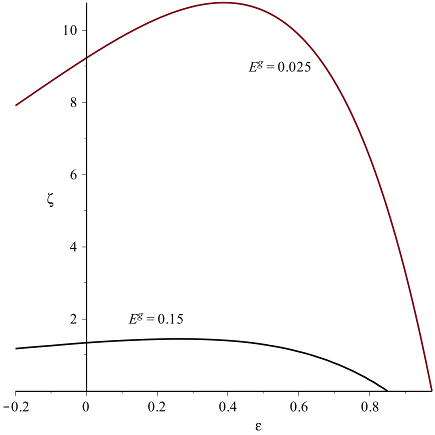
Figure 3. Curves $\mathcal{E}_{H/L}^{\tilde{g}}(\epsilon,\zeta) = 0.025$ and $\mathcal{E}_{H/L}^{\tilde{g}}(\epsilon,\zeta) = 0.15$.



Analytical results (II): BGP technology structure and skill structure

- Relative number of firms:

$$\tilde{N} \equiv \left(\frac{\tilde{N}_H}{N_L}\right) = Z_0 \cdot \left(\frac{H}{L}\right)^{D_0} \cdot \Omega(F_v, F_h),$$

$$D_0 \equiv (1 - \epsilon - \delta)/(\sigma + 1)$$

$$Z_0 \equiv (h/l)^{\frac{1}{\sigma+1}} \, \phi^{\frac{-1}{\sigma+1}} \zeta^{\frac{-1}{\sigma+1}}, \, \phi \equiv \frac{\phi_H}{\phi_L}, \zeta \equiv \frac{\zeta_H}{\zeta_L}$$

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- Relative production:

$$\tilde{\mathfrak{X}} \equiv \left(\frac{\tilde{\mathfrak{X}_H}}{\mathfrak{X}_L}\right) = Z_1 \cdot \left(\frac{H}{L}\right)^{D_1} \cdot \Omega(F_v, F_h),$$

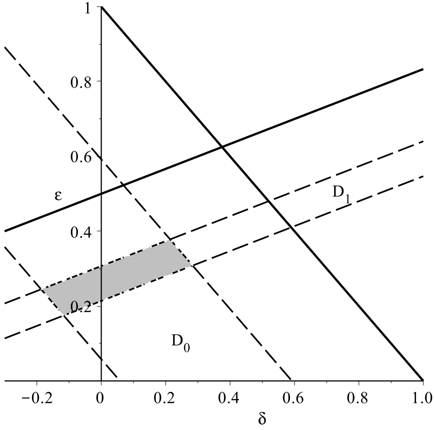
$$D_1 \equiv \{\alpha\delta + 1 - \alpha + \sigma - \epsilon\,[1 + (1+\alpha)\,\sigma]\}\,/\,[(\sigma+1)\,(1-\alpha)]$$

$$Z_1 \equiv (h/l)^{\left[1+\left(\frac{\sigma}{\sigma+1}\right)\left(\frac{\alpha}{1-\alpha}\right)\right]} \phi^{\frac{\alpha}{(\sigma+1)(1-\alpha)}} \zeta^{-\left[1+\left(\frac{2\sigma+1}{\sigma+1}\right)\left(\frac{\alpha}{1-\alpha}\right)\right]}$$

Quantification of ϵ and ζ (I)

Figure 4. Confidence intervals for ϵ and δ implicit in the OLS estimates of the **elasticities** $D_0(\epsilon, \delta)$ and $D_1(\epsilon, \delta)$ (dashed lines)

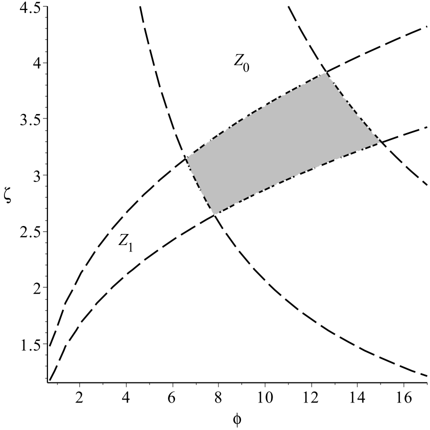
$$\Rightarrow \epsilon \in [0.175; 0.378]$$



Quantification of ϵ and ζ (II)

Figure 5. Confidence intervals for $\phi \equiv \phi_H/\phi_L$ and $\zeta \equiv \zeta_H/\zeta_L$ implicit in the OLS estimates of the **intercepts** $Z_0(\zeta,\phi)$ and $Z_1(\zeta,\phi)$.

With $h/l = 1.3 \Rightarrow \zeta \in [2.642; 3.915]$



The predicted growth-skill and growth-production elasticities

Table 1. Simulation results: OLS estimates of the elasticity of the *predicted* growth rate, $\tilde{\mathcal{G}}$, w.r.t. the *observed* skill structure and *predicted* relative production (estimated elasticities from the *observed* data: -0.026 (s.e. 0.172) and -0.003 (s.e. 0.118)).

ϵ	ζ	$\hat{\mathcal{E}}^{\tilde{\mathcal{G}}}_{H/L}$ (s.e.)	$\hat{\mathcal{E}}^{\tilde{\mathcal{G}}}_{\tilde{\tilde{\mathfrak{X}}}}$ (s.e.)
0.175	2.642	-0.0786 (0.283)	-0.0915 (0.330)
	3.915	-0.1051 (0.284)	-0.1225 (0.331)
0.378	2.642	-0.0384 (0.210)	-0.0663 (0.362)
	3.915	-0.0627 (0.211)	-0.1081 (0.365)

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- The magnitude is well approximated in the scenarios with the largest value of ϵ and the smallest value of ζ.
  - The **larger the relative barriers to entry, the smaller the impact of the proportion of high-skilled labour on a country's growth rate**.

- **Robustness check** (besides considering the extreme bounds of the confidence intervals of the estimates of the structural parameters):
  - Consider the **initial (1995) value for the skill-structure** regressor to account for a possible simultaneity bias issue. The results vary very little across scenarios.

Policy implications (I)

Table 2. Counterfactual: reduction of ζ that leads to a **significant positive estimate of the growth-skill elasticity**.

ϵ	0.175		0.378	
ζ old	2.642	3.915	2.642	3.915
ζ new	0.520	0.615	0.380	0.470
chg in ζ	-80.3%	-84.3%	-85.6%	-88.0%
Avg $\tilde{\mathcal{G}}$	4.789%	4.678%	6.522%	6.135%
$\hat{\mathcal{E}}^{\tilde{g}}_{H/L}$	0.171	0.171	0.170	0.170
$\hat{\mathcal{E}}^{\tilde{\mathcal{G}}}_{\tilde{\tilde{\mathfrak{X}}}}$	0.200	0.199	0.293	0.293

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$\hat{\mathcal{E}}^{\tilde{g}}_{H/L}$	0.171	0.171	0.170	0.170
$\hat{\mathcal{E}}^{\tilde{\mathcal{G}}}_{\tilde{\tilde{\mathfrak{X}}}}$	0.200	0.199	0.293	0.293

- A reduction in relative barriers to entry is effective in increasing the growth-skill elasticity: **growth in countries with a larger proportion of high-skilled workers benefits more from such a reduction**. [*e.g., Ireland versus Portugal*].

Policy implications (II)

Table 3. Counterfactual: reduction of ζ or increase in H/L such that the **average European share of the high-tech sector is raised to the US level** (0.440 for relative production and 0.215 for relative number of firms, 1995-2007 avg).

	Observed	$\phi = 16.56$ $\zeta = 3.22$	$\phi = 6.48$ $\zeta = 2.14$	$\phi = 16.56$ $\zeta = 3.22$
		$H/L = 0.178$	$H/L = 0.178$	$H/L = 0.345$
Relative production	0.310	0.273	0.440 [target]	0.440 [target]
Relative n. of firms	0.105	0.099	0.215 [target]	0.133
GDPpc growth rate	2.993%	2.993% [target]	3.213%	3.260%

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Relative production	0.310	0.273	0.440 [target]	0.440 [target]
Relative n. of firms	0.105	0.099	0.215 [target]	0.133
GDPpc growth rate	2.993%	2.993% [target]	3.213%	3.260%

- An increase of the European growth rate by 0.1 percentage points requires a change in H/L or in ζ and ϕ of, respectively, 35.1% or -15.4% and -27.7% $\Rightarrow$ It is more efficient for policy to **target relative barriers to entry** than skill structure.

Country-specific barriers (I)

- We allow relative barriers to entry to comprise both an **homogeneous** and a **country-specific component**: $\phi_i = \bar{\phi} \cdot \phi_i^c$ and $\zeta_i = \bar{\zeta} \cdot \zeta_i^c$.

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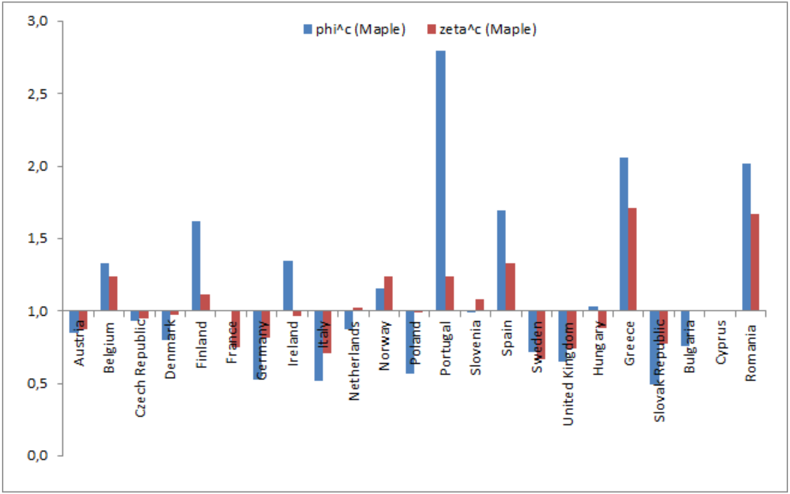
- The addition of country-specific barriers does not affect our results $\Rightarrow$ the **homogeneous component is the most relevant** to explain the observed cross-country growth-skill elasticity.

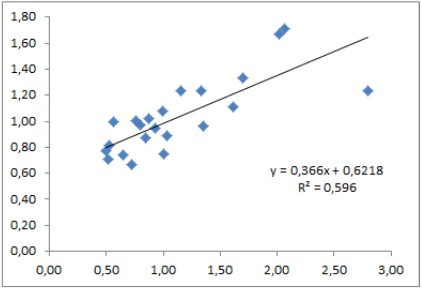
Country-specific barriers (II)

Figure 6. Country-specific components of relative barriers to entry (horizontal entry [blue] and vertical entry [red]) per country



Country-specific barriers (III)

Figure 7. Country-specific components of relative barriers to entry (horizontal versus vertical entry)



Country-specific barriers (IV)

Table 4. Selected countries from our sample.

	$\bar{\phi} = 16.557$	$\bar{\zeta} = 3.216$	Impact of a 85% reduction in ζ on growth	
Country	ϕ_i^c	ζ_i^c	Homogeneous case	Country-specific case
Belgium	1.3298	1.2359	102%	88%
Czech Republic	0.9304	0.9510	60%	64%
Finland	1.6172	1.1142	115%	108%
France	1.0031	0.7497	76%	99%
Germany	0.5231	0.8138	102%	123%
Greece	2.0633	1.7093	59%	37%
Ireland	1.3493	0.9634	128%	135%
Italy	0.5144	0.7065	38%	54%
Netherlands	0.8716	1.0205	87%	88%
Norway	1.1566	1.2374	81%	69%
Poland	0.5656	0.9996	65%	67%
Portugal	2.7977	1.2352	30%	25%
Spain	1.6942	1.3308	89%	72%
United Kingdom	0.6497	0.7409	88%	115%

Country-specific barriers (V)

Table 5. Correlation of the country-specific relative barriers to entry with the countrywide regulatory costs to create a business and financial depth indicators.

		ζ_i^c	ϕ_i^c
Regulatory costs to create a business	Number of procedures 1999	0.261 (1.210)	0.212 (0.970)
	Number of days 1999	0.284 (1.325)	0.301 (1.413)
	Cost 1999 (% pcGDP)	0.199 (0.910)	0.141 (0.637)
Financial depth indicators	Liquid liabilities 1995 (% GDP)	-0.297 (-1.393)	-0.300 (-1.406)
	Gross portfolio debt liabilities 1999 (“)	-0.243 (-1.120)	-0.256 (-1.187)
	Gross portfolio equity liabilities 1999 (“)	-0.156 (-0.708)	-0.217 (-0.992)
	Stock market capitalization 1995 (“)	-0.140 (-0.634)	-0.237 (-1.089)
	Domestic credit to private sector 1995 (“)	-0.262 (-1.213)	-0.276 (-1.284)
	Banks' assets 1995 (“)	-0.224 (-1.028)	-0.234 (-1.077)

Final remarks (I)

- The effects of a country's **education policy** (e.g., incentives for households to improve their educational attainment level), or say of measures to revert **brain-drain** flows, on economic growth may be effectively **leveraged by barriers-reducing industrial policy** (and vice versa);

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- The latter should aim to reduce the fixed-entry costs originating relatively larger **barriers to entry in the high-tech sectors** [*e.g., the alleviation of the regulatory and IPR bureaucratic environment faced by technology-intensive firms* or *the reduction of their information and management flow fixed costs at firm creation, say through the promotion of mentoring and business-angels activities*];

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- However: the effectiveness of the barriers-reducing policy is negatively related to the initial level of those barriers, which implies that **barriers must be brought down to considerable low levels before they start producing significant results**.

Final remarks (II)

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  - Regulatory costs versus non-regulatory costs?
  - As our data set comprises only European countries, this may be a **consequence of the common, supranational, regulatory framework impinged on the EU production sectors**.
- Our reduced-form results also suggest that a **reduction of overall regulatory costs to create a business** or an **increase in a country's financial development** may be associated with the **reduction of relative barriers to entry into the high-tech sector**. Given the exploratory nature of our results in this regard, this is a topic that deserves further investigation in future work.

Thank you!