WEB APPENDIX TO: DOES IDIOSYNCRATIC BUSINESS RISK MATTER FOR GROWTH?

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Abstract

This is the web appendix to the paper "Does Idiosyncratic Business Risk Matter for Growth?', published on the *Journal of the European Economic Association*. Arabic numbers refer to the main text, lettered numbers to the appendix.

Appendix A: Sectoral concordance procedure

We construct the volatility measure for 49 different industries, following the industry classification of Fama and French (1997), which is also used by Campbell, Lettau, Malkiel and Xu (2001). STAN use the ISIC revision 3 sectoral classification, while Thomson Datastream use the ICB industry classification at the four digit level. Unfortunately, this does not match exactly with the industry classification used by Fama and French (FF). The table on the next page provides the sectoral concordance used to link the three classifications. In some cases, it was not possible to find a satisfactory correspondence for sectors; in some others, we were forced to aggregate sectors to achieve concordance across classifications. Specifically:

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1. The following FF sectors had no clear correspondence in STAN or in Thomson Datastream and were dropped: toys (FF classification 6); motion pictures, amusement and recreation services (7); consumer goods (9); construction materials (17); fabricated products (20); precious metals (28); and shipping containers (40).
2. We aggregated the following FF sectors to match a corresponding sector in STAN and Thomson Datastream: food, soda and beer (FF 2, 3, 4); measuring equipment and medical equipment (12, 38); and defense, spacecraft, and aircraft (25, 27).
3. Four STAN sectors had no clear correspondence in FF and were dropped: fishing (STAN 05); wood and cork, excluding furnishing (20); other non-metallic mineral products (Thomson 266); and sales of motor vehicles (STAN 50).
4. The following Thomson Datastream sectors had no clear correspondence in FF and were dropped: recreational products (Thomson 3745); consumer electronics (3743); toys (3747); consumer goods (3767); gambling (5752); and recreational services (5755).

We ended up with a classification system based on 38 sectors, reported in the table below. In the regressions we also excluded personal services (34) and health care (11), as in many countries they are mostly provided out of the market (public provision, etc.).

To compute volatility, for each month, we take the observed return for each firm in the sample. For each country we then separately run a regression of firm returns on a full set of time dummies. The regression is weighted by using the previous period firm's market value. The residuals of this regression measures the firm's excess market return in the month. For each sector we then take the weighted average of the square of the residuals in a year where the weights are again the market value of the firm. This is our measure for the observed idiosyncratic risk of the sector in the given country and year, see Campbell et al. (2001) for further details.

Rajan and Zingales (1998) use the ISIC revision 2 classification system (restricted to manufacturing), while STAN is based on ISIC revision 3. We use a sectoral concordance table supplied by the OECD to match the two classifications. When one STAN sector corresponds to more than one ISIC sector, external dependence for the STAN sector is computed as a simple mean of its value in the corresponding ISIC sectors. The concordance procedure is reported in the "ISIC" column on the Sectoral concordance table A.1 below.

Appendix B: Ownership data and other diversification measures

La-Porta, Lopez-De-Silanes and Shleifer (1999) compute their indicators considering only the largest 20 firms in each stock market, while the other papers discussed in the main text cover a much larger fraction of publicly traded companies. This latter approach is of course more informative, as the representation of large companies for the whole economy is limited. We will therefore use these indicators. For some countries, however, only the indicators based on the largest 20 firms are available. We follow Mueller and Philippon (2011) and we harmonize the data by running a regression of family ownership on comparable indicators of ownership structure using

Table A.1. Sectoral concordance

Fama French	STAN	Datastream	ISIC	Sector Name
1	01-02	3573		Agriculture
2,3,4	15	3533-7, 3577	311,313	Food and beverages
5	16	3785	314	Tobacco
8	22	5557	342	Printing and publishing
10	18,19	3765	322,323,324	Apparel and leather
11	85	4533		Health care
12,38	33	4537-73	385	Medical equipment
13	2423	4577	3522	Pharmaceutical
14	24ex2423	1353, 1357	3511,3513,352	Chemicals
15	25	3357	355,356	Rubber and plastic
16	17	3763	321,3211	Textile
18	45	1357, 1733, 2357, 3728		Construction materials
19	27	1753-7	371,372	Basic metals
21	29	573, 2753	382	Machinery
22	31	2733, 3722	383	Electrical machinery
23	36	2727,3724	332,390	Miscellaneous
24	34	3353-5, 2753	3843	Autos
25,27	353	2713,2717	384	Aircraft
26	351,352+359	2753	3841	Ships and railroad
29	13-14	1775		Mining of non energy prods.
30	10-12	1771		Mining of energy materials
31	23	533, 537, 577	353,354	Petroleum and natural gas
32	40-41	7535-77		Electricity, gas and water
33	64	5553, 6535-75		Post and telecom
34	80,90-93	5377		Personal services
35	71-74	2791-5, 2799, 5555, 9533-7		Other business activs.
36	30	9572-4	3825	Office equipment
37	32	2737, 9576-8	3832	Electronic equipment
39	21	1737	341,3411	Paper
41	60-63	2771-9, 5751, 5759		Transport and storage
42	51	2797, 5379		Wholesale trade
43	52	5333-75		Retail
44	55	5753, 5757		Hotel and restaurants
45	65	8355, 8773, 8779		Financial intermediation
46	66	8532-75		Insurance and pension funds
47	70	8733		Real estate
48	67	8737-71, 8775-7, 8985-95		Auxiliary to finance
7,9,17, 20, 28,40	No match	No match		See text
No match	5,20,26,28,50	2753, 3726, 3767, 5752		See text

all countries where the data cover a large pool of companies. We then impute the value for the other countries by using the predicted values from this regression. Specifically, we regress the family ownership indicator based on the large fraction of firms on the fraction of medium-sized firms controlled by families, the fraction of value of top 20 firms controlled by families and the fraction of top 20 firms controlled by families, that are available for all countries. For countries for which the family indicator is missing (Australia, Canada, Denmark, Greece, Mexico,the Netherlands and New Zealand), we then use the predicted values from this regression. See Mueller and Philippon (2011) for further details.

Appendix C: Descriptive analysis

Table C.1 reports the average, across sectors and years, of the value of idiosyncratic volatility in each country. Values vary from around .005 to 0.015 and are in the range of values computed by Campbell et al. (2001) for the US (see the last row in the table). As in Castro, Clementi and Lee (2010) we also find substantial cross-sectoral variation, indicating that sectors do differ in terms of observed risk. Sectoral coverage varies across countries (see last column in Table C.1), although in most countries we have data for at least 20 sectors. An exception is New Zealand, for which only three sectors are available.

Table C.2 reports descriptive statistics for average productivity growth for each country (excluding the US, which is not used in the regressions to avoid endogeneity problems induced by the volatility measure). Overall, average productivity growth is around 2% per year, with a minimum of .5% in New Zealand and a maximum of 3.2% in Finland. Of course, these comparisons are just illustrative of the data and should not be taken as indicators of the country's overall performance, as average growth may refer to different periods and sectors in different countries. The country dummies

Table C.1. Volatility measures, descriptive statistics

Country	Mean	S.D.	N. sectors
AUS	.0055	.0020	26
AUT	.0064	.0029	16
BEL	.0076	.0050	20
CAN	.0142	.0249	30
DNK	.0053	.0018	11
ESP	.0089	.0050	28
FIN	.0136	.0061	20
FRA	.0088	.0079	32
GBR	.0122	.0220	31
GER	.0061	.0028	28
GRC	.0144	.0097	18
ITA	.0075	.0037	28
JPN	.0075	.0036	34
KOR	.0131	.0038	23
MEX	.0106	.0048	13
NLD	.0097	.0090	22
NOR	.0165	.0225	17
NZL	.0042	.0041	3
PRT	.0141	.0127	15
SWE	.0095	.0049	23
USA	.0066	.0026	35
USA (Camp.)	.0086	.0036	38

The table reports the cross-sectoral average volatility at the country level. Volatility of individual stocks is computed as the yearly standard deviation of monthly returns (net of the aggregate component). Sectoral volatility is the weighted average (according to market capitalization) of individual volatility. The last row reports the volatility computed by Campbell et al. (2001). See Subsection 4.1 and Appendix B for sources and definitions.

in the regressions control for cross-country differences in average growth. In total, we have 428 observations on productivity growth at the country-sector level.

Appendix D: First stage estimation

To improve the relevance of instruments, we use data on the US idiosyncratic volatility from both Thompson Datastream and CRSP. Here we discuss how we generalize equation (5) to the case where both measures are used. To maximize degree of

TABLE C.2. Descriptive statistics for productivity growth, by country

AUS	.015	.013	.021	7	1975	2001
AUT	.023	.016	.016	30	1977	2003
BEL	.020	.018	.018	9	1971	2003
CAN	.014	.009	.017	24	1971	2003
DNK	.025	.016	.020	33	1971	2003
ESP	.016	.009	.038	32	1981	2003
FIN	.032	.025	.021	33	1971	2003
FRA	.018	.021	.027	34	1979	2003
GBR	.016	.010	.020	10	1972	2003
GER	.016	.010	.029	30	1992	2003
GRC	.028	.026	.026	31	1996	2003
ITA	.016	.012	.018	26	1971	2003
JPN	.017	.020	.018	17	1971	2003
KOR	.028	.023	.026	5	1971	2003
MEX	.009	.017	.021	24	1981	2003
NLD	.010	.008	.015	23	1971	2003
NOR	.025	.031	.023	31	1971	2003
NZL	.005	.006	.030	4	1990	2002
PRT	.025	.017	.020	6	1978	2003
SWE	.024	.019	.025	19	1971	2003
Total	.019	.016	.022	428	1971	2003

The table reports descriptive statistics for average yearly productivity growth for the observations used in the regressions of Table 3 and 4. The data come from the OECD Stan database. Statistics are computed across sectors within country, using national sectoral employment as weight. "N. of sects." is the number of sectors for which data are available in a given country; "first" and "last year" are the first and last year for which productivity growth in any sector is available in a given country.

freedom, we also exploit time series variation. Equation (5) then becomes:

$$\sigma_{jit} = b_{0i} + \sum_{k=1}^{3} \sum_{z=1}^{2} b_{kiz} \left(\sigma_{jUzt}\right)^k + v_{jit} \tag{D.1}$$

where $z = 1$ indicates Thompson Datastream and $z = 2$ CRSP. Using equation (6) to substitute for σ in equation (4), we obtain:

$$\omega_{jit} = d_i + \sum_{k=1}^{3} \sum_{z=1}^{2} b_{kiz}(1 - c\beta_i) \left(\sigma_{jUzt}\right)^k + \eta_{jit} \tag{D.2}$$

where d_i captures any country specific effect and $\eta_{jit} = \varepsilon_{ji} + (1 - c\beta_i)v_{jit}$, which is by assumption orthogonal to all independent variables. As explained in the text, to identify c we impose that the relationship between underlying risk in the four Scandinavian countries, (Denmark, Norway, Sweden and Finland) and in the US is the same. This leaves us with 17 different b's coefficients to be estimated for each regressor. To reduce the dimensionality of the estimation procedure, we impose that the quadratic and cubic terms are common across countries: $b_{kiz} = b_{kz}$ for $k > 1$. We then estimate equation (D.2), which involves a nonlinear estimation problem with 59 parameters to be estimated (i.e., c, 17 b_{1i1}'s , 17 b_{1i2}'s, b_{2i1}, b_{2i2}, b_{3i1}, b_{3i2}, the 19 country dummies b_{0i}'s and the constant). Note however that, conditional on c, the estimation becomes linear, as we can compute all terms $(1 - c\beta_i)\,(\sigma_{jUzt})^k$. We therefore carry out the estimation using a line search method: we fix c, we compute the OLS estimates of the resulting linear estimation problem and we then search for the value of c that minimizes the residual sum of squares of the linear estimation. To implement the line search method we restrict the search for c over the range minus five to plus two and a half. This is reasonable since a value of c greater than two and a half would imply that more than three-quarters of the countries in the sample are on the negative side of the underlying-observed risk relationship, which may be regarded as highly implausible. The standard errors, in Table 2 are those of the linear estimation procedure; the standard error for c is instead calculated by bootstrapping. Finally, many countries miss observations for some sectors. To avoid loosing too many observations, we use out-of-sample fitted values, that is we calculate the measure of volatility also for sector-country observations for which no volatility is available from Thompson Datastream but it is available for the corresponding sector in the US data. For comparability with the cross-sectional growth regressions, the correlations in columns three and six of Table 2 use average risk over all available years. Results are similar when also using time series variability.

Appendix E: Model Details

The model informally discussed in Section 2 in the main text builds on Holmstrom and Tirole (1997). Growth is endogenous due to technological spillovers as in the Schumpeterian paradigm reviewed in Aghion and Howitt (1998). For the sake of exposition, the model is simplified so that the economy is always in a steady state; see Acemoglu and Zilibotti (1997), Acemoglu and Zilibotti (1999), and Koren and Tenreyro (2008) for models where the degree of financial market imperfections and market incompleteness depends on the development level of the economy.

E.1. Assumptions

To keep notation simple we consider a representative sector in an economy with n independent sectors that differ only in the level of underlying idiosyncratic business risk. The sector at time t is characterized by a given technological level A_t, which determines the size of entrepreneurial projects. There is a measure one of entrepreneurs who live one period. Entrepreneurs born at time t have an initial amount of wealth equal to A_t and quadratic consumption preferences:

$$E\left[U_t(c)\right] = E\left(c - \frac{1}{\tau A_t}c^2\right).$$

Entrepreneurs differ in terms of risk propensity τ, which is draw from a uniform distribution with support $[\underline{\tau}, \bar{\tau}]$. Moreover, the propensity to take risk is scaled by the state of technology A_t to guarantee that the coefficient of relative risk aversion is constant, a necessary condition for a balanced growth equilibrium. We would obtain identical results by postulating a Constant Relative Risk Aversion utility function and then take a second order expansion around the steady state equilibrium. Entrepreneurs live one period and after death they are replaced by a new independent identical cohort.

Entrepreneurs can invest in a project that costs A_t unit of wealth. Projects could be risky or safe, with expected returns per unit of capital invested μ_r and $\mu_s < \mu_r$, respectively. Project choice is irreversible. The safe project yields $\mu_s A_t$ with certainty while, if the entrepreneur behaves diligently, the risky project yields an output level of λA_t with probability q and zero otherwise. If instead the entrepreneur shirks, no output is produced while the entrepreneur obtains some private benefits $\beta\lambda A_t$ with probability q, with $\beta < 1$. This means that private benefits are just a fraction of the output that would be obtained in the case of success of the project, which implies that behaving diligently is socially optimal. Private benefits are measured in output units and they cannot be sized by external investors. The entrepreneur's behavior is not observable, so private benefits induce an agency problem. This limits entrepreneurs' ability to diversify business risk. The assumption that private benefits are obtained with probability q implies that shirking has no advantage in terms of risk relative to being diligent. We are also implicitly assuming that the safe project cannot generate any private benefit. As it will become clear below, the assumption is without loss of generality, provided that behaving diligently is socially optimal. Given this formulation, the expected return of a unit of capital invested in the risky project (if the entrepreneur behaves diligently) is equal to

$$\mu_r = q\lambda$$

while the *variance* of the project return is equal to

$$\sigma = \mu_r \lambda - \mu_r^2.$$

Increasing λ, while keeping μ_r fixed, implies an increase in the risk of the project for given expected return: as λ increases the success probability of the project falls but, in the case of success, its return is higher. So the parameter λ measures the *underlying idiosyncratic risk* in the sector: changes in λ have no consequences on the return of a well diversified portfolio, but they can influence the choices of an undiversified entrepreneur. A higher λ implies that a successful innovation is more valuable, but its probability of success is lower. This may be the result of fiercer competition in the markets served by the firm (say due to globalization), or by faster technological progress, that makes innovation more competitive.

Funds are provided by *investors* who are risk-neutral and discount future payments at an interest rate that for simplicity we normalize to zero. The individual supply is infinitesimal, but the aggregate number of investors is large enough to guarantee that the aggregate supply of funds is perfectly elastic at the given interest rate. This implies that financial markets are perfectly competitive and the equilibrium interest rate is zero. This could characterize an open economy with perfect capital mobility. Alternatively, one could think this corresponds to the equilibrium of our economy under autarky, since with a zero interest rate the capital market clears—i.e., the within period aggregate demand and aggregate supply of capital are both equal to A_t.

We also make the following two simplifying assumptions:

$$\mu_r > \mu_s \geq 1, \tag{E.1}$$

$$\underline{\tau} > 2\lambda. \tag{E.2}$$

Assumption E.1 implies that, in the absence of financial frictions, operating the risky project would be socially optimal. Assumption E.2 guarantees instead that the marginal utility of consumption is positive for any possible relevant value of consumption and propensity to take risk of entrepreneurs. Finally notice that the assumption that entrepreneurs have A_t unit of wealth and that a project involves A_t unit of investment implies that no entrepreneur is financially constrained. In the closed economy interpretation of the model, this assumption also guarantees that the capital market clears at the zero interest rate. So suboptimal investment decisions could result only from lack of risk diversification opportunities.

Business risk affects entrepreneurial activity and innovation, which are key determinants of productivity growth as in the Schumpeterian paradigm reviewed by Grossman and Helpman (1991) and Aghion and Howitt (1998). Similar specifications have been commonly used in the endogenous growth literature, at least since Romer (1990). We suppose that innovation is risky so that the rate of growth of aggregate sectoral technology γ_t is proportional to the number of successful risky projects with a factor of proportionality η per unit size of the innovation so that

$$\frac{A_{t+1} - A_t}{A_t} = \gamma_t = \eta\lambda q(1 - \rho_t) \tag{E.3}$$

where ρ_t denotes the fraction of entrepreneurs investing in the safe project. For simplicity here we are assuming that each successful risky project induces an intertemporal technological externality equal to $\eta\lambda > 0$ where λ is the size of the innovation, while safe projects produce no externality. The key assumption is that risky projects generate stronger technological spillovers than safer, more conservative projects.

E.2. The entrepreneur's problem

The entrepreneur must decide the type of project (risky or safe) and how to invest his wealth (whether in the project or in financial markets). To finance the project, the entrepreneur can sell equity in financial markets. Equity entitles external investors to a fraction $1 - \alpha$ of the revenue (if any) generated by the project. Selling equity allows the entrepreneur to fund a fraction $1 - i$ of the project investment with external finance. The entrepreneur can also reinvest the proceeds of selling shares in financial markets. This can guarantee the entrepreneur some income even if the project fails. One can also think of this income as a wage paid to the entrepreneur for managing the firm. Thus the combination of equity and reinvestment in financial markets allows the entrepreneur both to appropriate a fraction α of the cash flow generated by the project and a constant income θ per unit of capital invested in the project. The risk-free component of the project return θ reflects the insurance possibilities induced by institutional arrangements. Notice that, since any other wealth of the entrepreneur cannot be seized by external investors, θ has to be non-negative. The analysis below makes clear however that this constraint will never bind in equilibrium.

Once divided by A_t the time t expected consumption of the entrepreneur, conditional on the choice of the risky project ($j = r$) or the safe project ($j = s$), can be expressed as

$$E_j\left(c/A_t\right) = E\left[\alpha\tilde{\lambda} + \theta + (1-i)\right] = \alpha\mu_j + \theta + (1-i) \tag{E.4}$$

where $1 - i$ denotes the part of the project financed externally and $E_j(\tilde{\lambda}) \equiv \mu_j$. Analogously the second moment of the entrepreneur's consumption, once divided by A_t^2 is given by

$$E_j\left(c/A_t\right)^2 = E\left[\alpha\tilde{\lambda} + \theta + (1-i)\right]^2 \tag{E.5}$$

which is again conditional on the type of project j chosen. Now notice that the participation constraint for financiers implies that

$$(1-\alpha)\mu_j = \theta + (1-i),$$

which says that the expected payments received by financiers must be equal to the present value of their disbursements. This constraint holds as an equality because of perfect competition in financial markets. Using this result to substitute for $\theta + (1-i)$ into (E.4) and (E.5) and after some algebra, we obtain that, if the safe project is chosen, the expected utility of consumption once divided by A_t is equal to

$$E_s\left[U_t(c)/A_t\right] = \mu_s - \frac{1}{\tau}\mu_s^2, \tag{E.6}$$

which is independent of α. For the risky project, an analogous substitution yields:

$$E_r\left[U_t(c)/A_t\right] = \mu_r - \frac{1}{\tau}\left[\mu_r^2 + \alpha^2\mu_r\left(\lambda - \mu_r\right)\right]. \tag{E.7}$$

If the risky project is chosen, the problem of the entrepreneur can then be written as

$$\max_{\alpha} E_r\left[U_t(c)/A_t\right] \tag{E.8}$$

subject to

$$\alpha \geq \beta \tag{E.9}$$

where this last constraint is the incentive compatibility constraint for the entrepreneur, which imposes that the entrepreneur prefers behaving diligently to shirking. This expression is so simple because of the assumptions that private benefits are stochastic and measured in output units. To solve the problem note that (E.9) will always hold as an equality, since (E.7) implies that $E_r\left[U_t(c)/A_t\right]$ is strictly decreasing in α. Thus the equilibrium expected utility under the choice of a risky project is given by (E.7) with $\alpha = \beta$.

Now we can come back to the first stage of the entrepreneur's problem, which determines the choice of the project. Clearly the entrepreneur will choose to invest in the risky project if $E_s\left[U_t(c)\right] \leq E_r\left[U_t(c)\right]$, which after using (E.6) and (E.7) can be simplified to

$$(\mu_r - \mu_s) - \frac{1}{\tau}\left(\mu_r^2 - \mu_s^2\right) \geq \frac{1}{\tau}\beta^2\sigma,$$

that is less likely to hold if either σ or β are high. From the previous expression we obtain a critical threshold

$$\tau^* = \frac{\beta^2\sigma + \left(\mu_r^2 - \mu_s^2\right)}{\mu_r - \mu_s} \tag{E.10}$$

such that the entrepreneur will invest in the safe project only if his propensity to take risk is lower than τ^*. As a result the fraction of entrepreneurs investing in the safe project is given by

$$\rho = \max\left[0, \min\left(1, \frac{\tau^* - \underline{\tau}}{\overline{\tau} - \underline{\tau}}\right)\right], \tag{E.11}$$

which is constant and independent of time. Given (E.3), the constant over time productivity growth rate is equal to

$$\gamma = \eta\mu_r(1-\rho) \tag{E.12}$$

The average variability of projects returns depend on the idiosyncratic risk of risky projects and on the share of entrepreneurs that invest in them. The *observed* average idiosyncratic risk of project returns can therefore be expressed as

$$\omega = (1-\rho)\,\sigma, \tag{E.13}$$

since just a fraction $(1-\rho)$ of entrepreneurs invest in risky projects, each of them having idiosyncratic risk of returns σ.

E.3. The two main text implications

The previous model has two key empirical implications discussed as Proposition 1 and 2 in the main text. One is that the observed average idiosyncratic risk in the sector ω is endogenous to the risk diversification opportunities β and the level of underlying risk σ. Another is that the effect of idiosyncratic risk on the sectoral growth rate varies depending on the level of underlying idiosyncratic risk σ and risk diversification opportunities β.

Proposition E.1. *In economies with high risk diversification opportunities (low β) the observed level of idiosyncratic risk ω accurately measures the underlying idiosyncratic risk σ. When risk diversification opportunities are low, observed risk is endogenous and moves less than one-for-one with underlying risk. The attenuation effect is larger the lower the risk diversification opportunities. In a regression of productivity growth on observed risk, the sign of the endogeneity bias can go either way, and it can be strong enough to lead to the erroneous conclusion that higher idiosyncratic risk improves economic performance.*

Proof. Assumption E.2 guarantees that there exists a sufficiently low (yet positive) value of β such that τ^* in (E.10) is equal to $\underline{\tau}$, so that $\rho = 0$. For this (or any lower) value of β the observed idiosyncratic risk in the sector ω is equal to the underlying idiosyncratic risk σ. But when risk diversification opportunities are sufficiently low and idiosyncratic volatility high enough to make $\rho > 0$, ω becomes a generally (very) imperfect measure of σ. To see this, assume that $0 < \rho < 1$, then, after using (E.10), taking derivatives in equation (2) yields

$$\frac{\partial \omega}{\partial \sigma} = 1 - \rho - \frac{\beta^2 \sigma}{(\bar{\tau} - \underline{\tau})(\mu_r - \mu_s)} < 1. \tag{E.14}$$

Moreover, using (E.11) and (E.2), we can also see that

$$\lim_{\beta \to 0} \frac{\partial \omega}{\partial \sigma} = 1. \tag{E.15}$$

Equation (E.14) implies that for sufficiently large β the derivative $\partial\omega/\partial\sigma$ is strictly less than one, possibly negative, and, since ρ is decreasing in β, decreasing in the level of risk diversification opportunities, β. When β is low enough, $\partial\omega/\partial\sigma = 1$, which means that the observed level of idiosyncratic risk accurately measures the underlying idiosyncratic risk in the sector. The fact that the derivative of ω with respect to σ could be smaller than one implies an endogeneity bias of generally uncertain sign, when running a regression of γ on ω. To see this point more clearly assume that risk diversification opportunities are high (but not so high as to induce $\rho = 0$), so that $\partial\omega/\partial\sigma$ is positive and strictly less than one. In this case, a higher σ (due to an increase in λ) tends to lead to a fall in γ and to a less than a one-for-one increase in ω, so that an OLS estimate of the ω-coefficient tends to over-estimate the negative effects of an increase in idiosyncratic risk σ on γ. When instead risk diversification opportunities are so low that $\partial\omega/\partial\sigma$ turns negative, an increase in σ makes γ and ω both fall. In this case an OLS regression of γ on ω would yield a positive coefficient on the variable ω, which would misleadingly suggest that higher risk leads to higher productivity growth. □

Proposition 2 instead says that:

PROPOSITION E.2. *An increase in underlying idiosyncratic risk σ reduces productivity growth γ. The effect is stronger the worse the risk diversification opportunities (larger β).*

Proof. Suppose that we are not at a corner solution so that $0 < \rho < 1$. Using (E.10) to substitute for τ^* in the expression for ρ in (1) yields

$$\gamma = \frac{\eta\mu_r\left(\bar{\tau} - \mu_r - \mu_s\right)}{\bar{\tau} - \underline{\tau}} - \frac{\eta\mu_r}{\left(\mu_r - \mu_s\right)\left(\bar{\tau} - \underline{\tau}\right)} \cdot \beta^2\sigma, \tag{E.16}$$

which says that, when σ increases, less entrepreneurs invest in the high-risk-high-return project, so that the productivity growth rate falls. The effect is stronger the less diversified the entrepreneurs are. When instead ρ is equal to zero or one, σ has marginally no effect on γ. □

E.4. Biases in Rajan and Zingales regressions

Consider now the n independent sectors, each characterized by a different level of idiosyncratic business risk, denoted by σ_j, $j = 1, ..., n$. Sectoral differences in business risk might be due to differences in technology, in the degree of competition or in the riskiness of innovation activities. Entrepreneurs have project opportunities in one sector. Sectoral productivity growth depends on the number of successful risky projects within the sector, exactly as in (1). The key assumption is that an innovation induces stronger technological spillovers within the sector than across sectors. Now consider two countries that differ in risk diversification opportunities β. Proposition 2 predicts that the country with worse diversification opportunities will grow relatively less in sectors with greater idiosyncratic risk. We can therefore relate the growth performance of a sector within a country to the corresponding level of idiosyncratic risk in the sector and then check how the relationship differs for countries with different risk diversification opportunities. In terms of the model this amounts to checking how $\partial\gamma/\partial\sigma$ differs for countries with different β, which measures the sign and magnitude of the second order partial derivative $\frac{\partial^2\gamma}{\partial\beta\partial\sigma}$. Based on this logic, we test whether sectors with higher idiosyncratic risk perform relatively worse in countries with less risk diversification opportunities. The empirical challenge is that observed risk ω is endogenous, see Proposition 1. Failing to recognize this leads to an important endogeneity bias.

To emphasize the distinction between observed and underlying risk, we have focused the discussion on the sign and magnitude of the correlation between observed risk and growth. But as discussed, our empirical strategy is based on cross-country industry data. In this context, the bias will depend both on how observed and underlying risk are related—i.e the sign and magnitude of the $\partial\omega/\partial\sigma$ derivative—and on how underlying risk differs in countries with different risk diversification opportunities. To see the determinants of the bias more formally, we can use (E.16) and (E.14) to express the derivative of sectoral performance with respect to observed risk ω as equal to

$$\frac{\partial\gamma}{\partial\omega} \equiv \frac{\partial\gamma/\partial\sigma}{\partial\omega/\partial\sigma} = -\frac{(\mu_r - \mu_s)}{(\mu_r - \mu_s)(1-\rho)(\bar{\tau} - \underline{\tau})\beta^{-2} - \sigma}. \tag{E.17}$$

This corresponds to the OLS estimates of the a_1 coefficient in the regression analysis with cross-country industry data. It is easy to check that, if $\partial\omega/\partial\sigma > 0$, the denominator is positive and decreasing in β. But whether the above derivative will be higher or lower in countries with different risk diversification opportunities will now also depend on how β covaries with σ. For example, if underlying risk σ is sufficiently lower in countries with higher β, using observed risk could misleadingly lead to even reject the hypothesis that idiosyncratic risk has bigger negative effects on economic performance in countries with lower risk diversification opportunities—i.e., $\frac{\partial^2\gamma}{\partial\beta\partial\omega}$ could be found to be positive. Generally, a positive $\frac{\partial^2\gamma}{\partial\beta\partial\omega}$ derivative (which is equivalent to the OLS estimates of the a_1 coefficient in the regression analysis) and a negative $\frac{\partial^2\gamma}{\partial\beta\partial\sigma}$ derivative (which is equivalent to the IV estimates of the a_1 coefficient in the regression analysis) are due to the fact that observed risk is endogenous, and that countries with worse risk diversification opportunities happen to have lower underlying risk.

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