Estimating Cross-Industry Cross-Country Interaction Models Using Benchmark Industry Characteristics

Supplementary Appendix

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Supplementary Appendix A: Contributions to the Cross-Industry Cross-Country Literature

#	Topic	Paper	Industry Characteristic	Country Characteristic	Main Finding
Finance and Industry Growth					
1	Finance and growth	Rajan and Zingales (1998)	Industry dependence on external finance [ratio of capital expenditures minus cash flow over capital expenditures]	Country financial development [market capitalization, private credit, measure of accounting standards]	Sectors that depend for inherent technological reasons more on external sources of finance (debt and equity), as compared to internal sources (retained earnings), grow faster in financially developed countries
2	Finance and growth	Claessens and Laeven (2003)	Industry intangible intensity [ratio of intangible assets to net fixed assets]	Country-level property rights protection [index of intellectual property rights, patent rights, risk of expropriation]	Sectors with an asset mix tilted towards intangibles grow faster in countries with better property rights
3	Finance and growth	Fisman and Love (2003)	Industry dependence on trade credit [accounts payable to total assets]	Country financial development [market capitalization, private credit, measure of accounting standards]	Industries with higher reliance on trade credit grow faster in countries with weaker financial institutions
4	Finance and growth	Fisman and Love (2007)	Industry growth opportunities [sales growth]	Country financial development [sum of domestic credit to private sector and market capitalization as a share of GDP]	Industries with better growth opportunities grow faster in more financially developed countries
5	Finance and growth	Beck, Demirgüc-Kunt, Laeven and Levine (2008)	Industry share of small firms [percentage of firms in each sector with less than 5, 10, 20, and 100 employees]	Country financial development [private credit to GDP]	Industries with a larger share of small firms grow faster in more financially developed countries
6	Firm size and growth	Pagano and Schivardi (2003)	Sector R&D intensity [share of R&D personnel in total employment, ratio of R&D to total investment and value added]	Average firm size of firm in sector in country [measured by employment]	Sectors with larger average firm size grow faster; particularly in R&D intense sectors
7	Financial dependence and business cycles	Braun and Larrain (2005)	Industry dependence on external finance	Recession in country c at time t	Industries that are more dependent on external finance are hit harder during recessions

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8	Credit constraints, entry	Aghion, Fally and Scarpetta (2007)	Industry dependence on external finance	Country financial development [sum of private credit and stock market capitalization as a share of GDP, state ownership of banks]	More small firms enter in more externally dependent sectors in more financially developed countries
9	Impact of debt accumulation on total factor productivity in Europe	Levine and Warusawitharana (2012)	Debt growth	Industry external finance dependence	Firms in industries that are more dependent on external finance have a greater sensitivity of productivity growth to lagged debt growth
10	Finance and R&D investment	Brown, Martisson and Petersen (2013)	Industry dependence on external finance	Country financial development [value of IPOs as a share of GDP, accounting standards, anti-self-dealing index of shareholder protection]	Firms in more externally financially dependent industries invest more in R&D in more financially developed countries and in countries with stronger shareholder protection
11	Finance and innovation	Hsu-Hsuan, Tian and Xu (2014)	Industry dependence on external finance and industry high-tech intensity	Country financial development [stock market capitalization, bank credit]	High-tech sectors that depend more on external sources of finance innovate more in financially developed countries
12	Finance and innovation	Acharya and Xu (2017)	Industry dependence on external finance	Public/Private Firm Indicator in the United States	Listed firms spend more on R&D in external-finance-dependent sectors
13	Firms' cash holdings, financial development, and firm growth	Lei, Qiu and Wan (2018)	Industry asset tangibility	Private credit to GDP, contract enforcement, accounting standards, and log GDP p.c.	Sectors with a smaller proportion of tangible assets grow faster in countries with more developed financial markets
14	Access to long-term finance and volatility	Demirguk-Kunt, Horvath, and Huizinga (2017)	Sectoral measure of loan maturity	Various proxies of financial development and institutional quality	Financial development reduces firm growth volatility especially in external-finance-dependent sectors
15	Role of insider trading enforcement legislation on investment	Edmans, Jayaraman and Schneemeier (2017)	Industry dependence on external finance	Insider trading enforcement legislation	The investment-Tobin's Q sensitivity increases after the enforcement of insider trading legislation in finance-dependent sectors and especially in emerging markets

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16	Collateral laws and lending (loan-to-value)	Calomiris, Larrain, Liberti and Sturgess (2017)	Sectoral index of real estate intensity	Laws shaping collateral and contract enforcement	Weak movable collateral laws create distortions in the allocation of resources that favor immovable-based production and investment
17	Real effects of banking crises	Dell'Ariccia, Detragiache and Rajan (2008)	Industry dependence on external finance	Banking crisis in country c at time t	Sectors relatively more dependent on external finance perform worse during banking crises
18	Investment effect of the subprime mortgage crisis	Duchin, Ozbas and Sensoy (2010)	Industry dependence on external finance	Before/after sub-prime crisis	Decline in corporate investment is sharpest in industries with high external financial dependence
19	Transmission of financial crises	Claessens, Tong and Wei (2012)	Industry dependence on external finance and trade sensitivity [global GDP elasticity of global exports at 3-digit sector level]	Country trade openness and fiscal and monetary policy	Crisis hit firms more sensitive to trade and business cycles hardest, especially in countries more open to trade
20	Firm growth and bank recapitalization	Laeven and Valencia (2013)	Industry dependence on external finance	Country bank recapitalization policies [committed amounts of public recapitalization funds]	Growth of finance dependent firms is disproportionately positively affected by bank recapitalization
21	Capital account liberalization, capital allocation, and productivity	Larrain and Stumpner (2017)	Industry dependence on external finance	Financial (capital account) liberalization	Within-sector misallocation (dispersion in marginal product of capital) falls when countries open their capital markets, especially in external finance dependent sectors
22	Monetary policy and growth	Aghion, Farhi and Kharroubi (2015a)	Industry credit or liquidity constraints [asset tangibility measured by value of net property, plant and equipment to total assets for credit constraints; labor-cost to sales for liquidity constraints]	Degree of counter-cyclicality of short-term interest rates [coefficient on output gap in regression with ST-rates on LHS]	Credit or liquidity constrained industries grow more quickly in countries with more counter-cyclical short-term interest rates
23	Fiscal policy and industry growth	Aghion, Hemous and Kharroubi (2014)	Industry dependence on external finance	Countercyclicality of country fiscal policies [coefficient on output gap in regression with fiscal balance to GDP on LHS]	More externally dependent industries grow faster in countries that implement more countercyclical fiscal policies

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24	Financial expansion (credit growth) and crowding out of output growth	Cecchetti and Kharroubi (2018)	Industry asset tangibility and industry R&D intensity	Credit growth	Credit growth disproportionately harms output per worker growth in industries that have either less tangible assets or are more R&D intensive
25	Dollar exchange rate and investment in emerging markets	Avdjiev, Bruno, Koch and Shin (2019)	Industry dependence on external finance	Nominal and real exchange rates in emerging markets	A US dollar appreciation reduces investment in external finance dependent sectors in emerging markets implying a global dollar supply effect
26	Determinants of vertical integration	Alfaro, Conconi, Fadinger and Newman (2016)	Industry external finance dependence	Financial development (and legal quality)	Financial development is associated with a higher level of vertical integration in external finance dependent sectors
27	Role of insider trading on innovation and patenting	Levine, Lin and Wei (2017)	Industry innovation intensity based on R&D growth expenses for publicly-traded US firms. Industry innovation propensity based on patents filed in the US	Country-level enforcement of insider trading legislation	Innovation and patent-filing rise much more in high-tech industries after a country first enforces its insider trading laws
28	Finance and CO2 Emissions	De Haas and Popov (2019)	Industry CO2 emissions per unit of output in the United States	Financial structure [value of all listed stocks divided by the sum of all listed stocks and all private credit]	Lower carbon dioxide emissions in high CO2 emission industries in countries with a market-based financial system
29	Banking crises and exports	Iacovone, Ferro, Pereira-López and Zavacka (2019)	Industry dependence on external finance	Banking crisis in country c at time t	During a crisis, exports of sectors more dependent on external finance grow relatively less than those of other sectors
30	Economic effects of stock market concentration	Bae, Bailey and Kang (2021)	Stock market concentration. Sum of the stock market capitalization of the largest ten or five list firms divided by the total stock market capitalization of country's domestic stock exchanges	Industry External finance dependence	Greater stock market concentration disproportionately hampers the growth of industries that are more in need of external financing
31	Financial liberalization and innovation	Moshirian, Tian, Zhang and Zhang (2021)	Sectoral equity finance dependence	Stock Market Liberalization	Innovation output of more innovative industries increases more substantially after the country opens its stock market to foreign investor

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International Trade and Industrial Specialization					
32	Factor proportions and trade	Romalis (2004)	Industry factor intensities in skilled labour, unskilled labour, and physical capital	Country factor endowments [human capital, physical capital, labour]	Countries specialize in industries that intensively use factors that (a) they are already abundant in; (b) they are accumulating rapidly
33	Human capital and growth	Ciccone and Papaioannou (2009)	Industry skill intensity [average years of employee schooling, share of high-school and college graduates]	Country initial human capital [average years of schooling]	Countries with higher initial education levels grew faster in schooling-intensive industries
34	Institutions and trade	Levchenko (2007)	Industry institutional dependence [concentration-Herfindahl index of intermediate input use]	Country institutional quality [rule of law]	Countries with better institutions have a greater share of US imports in more institutionally dependent sectors
35	Institutions and trade	Nunn (2007)	Industry contract intensity-complexity [reflecting relationship-specific investments]	Quality of contract enforcement and the judiciary [perception based rule of law index]	Countries with good contract enforcement specialize in goods for which relationship-specific investments are most important
36	Institutions, trade and organizational choice	Ferguson and Formai (2013)	Industry vertical integration-propensity and industry contract intensity	Country judicial quality [rule of law]	Benefits of judicial quality [high quality contractual institutions] for exports of contract-intensive goods are smaller in industries where firms are more likely to be integrated with their input suppliers
37	Institutions and comparative advantage	Nunn and Trefler (2014)	Industry cost sensitivity to quality of contracting institutions	Country quality of contracting institutions	Institutional sources of comparative advantage [as reflected by the interaction of country-level rule of law with industry-level contract intensity] are quantitatively as important as the impact of human capital and physical capital
38	Trade policy in services and productivity of downstream manufacturing	Beverelli, Fiorini and Hoekman (2017)	Industry reliance on services as intermediate inputs	Index reflecting restrictiveness on trade in services; control of corruption	lower services trade restrictiveness is associated with higher downstream manufacturing labor and total-factor productivity, with the estimated effect increasing with country-level institutional capacity

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39	Financial liberalization and trade	Manova (2008)	Industry dependence on external finance and industry asset tangibility [share of net property, plant and equipment in total book-value assets]	Time-varying country equity-market openess and liberalization	Liberalization increases exports disproportionately in sectors more dependent on outside finance or using fewer collateralized assets
40	Credit constraints and trade	Manova (2013)	Industry dependence on external finance and industry asset tangibility	Country financial development [private credit to GDP]	More financially developed countries export more in sectors more dependent on outside finance or using fewer collateralized assets
41	Finance and choice of export destinations	Chan and Manova (2015)	Industry dependence on external finance and industry asset tangibility	Country financial development [private credit to GDP]	More financially developed countries have more trading partners and particularly so in financially dependent sectors
42	Credit constraints and trade	Manova, Wei and Zhang (2015)	Sector financial vulnerability [external financial dependence, asset tangilibity, inventory/sales ratio, reliance on trade credit]	Firm indicators for JV, MNC affiliates, firms with foreign ownership	Foreign affiliates and JVs in China have better export performance than private domestic firms in financially more vulnerable sectors
43	Financial frictions and product quality in international trade	Crinò and Oglirari (2017)	Industry measures of financial vulnerability (asset tangibility, external-finance-dependence, capital intensity)	Financial development (private credit)	Financial development shapes comparative advantage in quality goods. The positive effect of financial development on the quality of exports is especially strong in finance-dependent sectors, in sectors with intangible assets, and capital intensive sectors
44	Role of foreign banks on trade	Claessens, Hassib and van Horen (2017)	Industry dependence on external finance	Foreign banks from importing countries	For emerging markets, greater local foreign bank presence, especially from the importing country, is associated with higher exports in sectors more dependent on external finance
45	Employment protection and investment	Cingano, Leonardi, Messina and Pica (2010)	Sector worker reallocation intensity [average of normalized firm changes in employment in a country-industry cell]	Country employment protection legislation [OECD produced weighted average of 18 basic items]	EPL reduces investment in high reallocation- relative to low reallocation-sectors
46	Volatility, labour market flexibility and specialization	Cuñat and Melitz (2012)	Volatility of firm output growth [standard deviation of annual growth rate of firm sales]	Country labour market flexibility [hiring-costs, firing costs, and restrictions on changing working hours as captured by World Bank index]	Exports of countries with more flexible labor markets are biased towards high-volatility sectors

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47	Labor relations and family firms	Mueller and Philippon (2011)	Industry labor intensity	Labor market regulation (cooperative labor relations)	Sclerotic labor market regulation and institutions increase the share of family firms in labor intensive sectors
48	Labour markets, education and trade	Tang (2012)	Industry firm-specific skill intensity [estimated from Mincer wage regression with interaction of worker job tenure with industry dummy]	Country labour market protection	Countries with more protective labour laws export more in firm-specific skill intensive sectors at both intensive and extensive margins
49	Labour market institutions and innovation	Griffith and Macartney (2014)	Industry propensity to adjust to external labour market [layoff rate for 3-digit industry above or below the median layoff rate]	Country employment protection legislation [weighted sum of sub-indicators for regular and temporary contracts and collective dismissals]	Fewer radical innovations are done by high-layoff industries in countries with high EPL
50	Pollution and comparative advantage	Broner, Bustos and Carvalho (2016)	Industry pollution intensity [EPA-computed total air pollution per unit of output]	Country laxity of air pollution regulation [proxied by outcome measure: grams of lead content per liter of gasoline]	Countries with laxer environmental regulation have a comparative advantage in polluting industries
51	Natural resources and comparative advantage	Debaere (2014)	Sector water intensity [sector water withdrawals both direct and indirect (inputs) from US Geological Survey]	Country water resources [volume of renewable fresh water per capita]	Relatively water abundant countries export more water-intensive products
52	Impact of financial frictions on firm size, heterogeneity, and exports	Bonfiglioli, Crinò and Gancia (2019)	Industry external finance dependence and sector asset tangibility	Country-level financial development	Sales dispersion is increasing in financial development, especially in financially vulnerable industries, where firms are more dependent on external finance or have fewer tangible assets
53	Employment protection and industry labor share	Ciminelli, Duval and Furceri (2018)	Employment protection legislation for regular workers, based on over one hundred legislative and regulatory features	Industry "natural" layoff rate. Sectoral rate of substitution between capital and labor	Job protection deregulation tends to reduce the labor share in industries with a high layoff rate relative to those with a low-layoff-rate
Other Applications					

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54	Vertical vs horizontal, intra vs inter industry FDI	Alfaro and Charlton (2009)	Industry skill intensity [ratio of non-production to total workers]	Country skill abundance [average years of schooling]	Vertical FDI appears driven by comparative advantage at 2-digit level but not at 4-digit level
55	Boundaries of the firm	Costinot, Oldenski and Rauch (2011)	Sector task-routineness [importance of "making decisions and solving problems" for occupations within sectors]		Less-routine sectors have a higher share of intra-firm trade
56	Sourcing of goods of different complexity	Carluccio and Fally (2012)	Product complexity [measured with different indicators of R& D expenditures]	Country financial development [private credit to GDP]	Complex goods are more likely sourced from more financially developed countries
57	Offshoring	Basco (2013)	Industry R&D intensity [average industry R&D expenditure]	Country financial development [share of domestic credit to private sector over GDP]	More R&D intense industries use more intermediate inputs (offshore more) in more financially developed countries
58	Infrastructure and FDI	Blyde and Molina (2015)	Industry dependence logistic services [firm-in-industry willingness to pay for air shipping to avoid an additional day of ocean transport]	Country logistic infrastructure [number of ports and airports above a certain size normalized by country population]	Countries with better logistic infrastructure attract more vertical FDI in more time-sensitive industries
59	Corruption and innovation	Paunov (2016)	Industry usage intensity of quality certificates and patents [share of firms holding quality certificates; fractional patent count to value added]	Country corruption [share of firms reporting gift required to obtain operating license]	Firms in industries with greater reliance on quality certificates own less such certificates in more corrupt countries
60	Technology on outsourcing and production fragmentation	Fort (2017)	Industry use of advanced design and manufacturing software	Electronic networks at the firm level	firm's adoption of communication technology is associated with an increase in its probability of fragmentation. The effect of firm technology is higher, relative to the mean, in industries with production specifications that are easier to codify in an electronic format
61	Regulation and entry	Klapper, Laeven and Rajan (2006)	Industry natural propensity to high entry [fraction of firms in industry that is one or two years old]	Country entry regulation [cost of business registration; in per capita GNP, time, or procedures]	Costly regulations reduce firm creation, especially in industries with naturally high entry

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62	Determinants of vertical Acemoglu, Johnson and Mitton (2009)	Industry capital intensity as a proxy for vulnerability to holdup problems [fixed assets to sales]	Country-level contracting costs [procedural complexity, contract enforcement procedures, legal formalism]	Firms in more capital-intense industries are more vertically integrated in countries with higher contracting costs	
63	Competition and Ownership Structure	Bena and Xu (2017)	Industry external finance sensitivity	Change in import penetration at the country-industry level	The effect of competition on ownership dispersion is higher is larger in sensitive to external finance sectors
64	Regulatory reforms and short-term employment costs	Bassanini and Cingano (2019)	Industry worker dismissal rate (in the US)	Employment protection legislation and product market regulation and business cycle conditions	Employment in dismissal-intensive sectors falls considerably more in years of labor and product market reform
65	Uncertainty and Total Factor Productivity	Choi, Furceri, Huang and Loungani (2018)	Sectoral dependence of external finance and industry asset tangibility	Uncertainty (based on stock market volatility)	Uncertainty reduces productivity in external-finance-dependence sectors and sectors with intangible assets
66	Aid and manufacturing growth	Rajan and Subramanian (2011)	Industry sensitivity to exchange rate appreciation [industry ratio of exports to value above or below the median]	Country receipts of foreign aid	Industries more sensitive to exchange rate appreciations grew relatively more slowly in countries receiving larger aid inflows
67	Aid and firm growth	Chauvet and Ehrhart (2018)	Industry reliance on exports, contract intensity, extremal-finance-dependence, transport-intensity, and reliance on electricity	Foreign aid	Aid spur firm growth in external finance dependent sectors and industries that use intensively electricity and rely on transportation infrastructure
68	The legacy of Africa's slave trades on finance	Pierce and Snyder (2018)	Industry dependence on sales credit	Slave trades as a share of country land area	Lower firm credit in sectors that depend on intensively on sales credit
69	The legacy of Africa's slave trades on firm's financial constraints and investment	Ross Levine (2018)	Industry dependence on external finance and sectoral capital intensity	Slave trades as a share of countries' land area and population	Firms in countries affected the most from African slave trades get lower levels of bank credit (for investment and working capital); this effect is especially strong for firms in capital intensive and external finance dependent sectors

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70	International financial flows and growth	Aizenman and Sushko (2011)	Industry dependence on external finance	Portfolio equity, debt, and FDI inflows in country c at time t	Equity inflows have negative aggregate growth impact but positive impact in more financially constrained industries; FDI inflows have positive impact, both at the aggregate level and more external finance dependent industries
71	Human capital and trade	Bombardini, Gallipoli and Pupato (2012)	Industry skill substitutability [residual wage dispersion; rankings on teamwork, impact on co-woker output and communication / contact]	Country skill dispersion [within-country standard deviation of log scores on standardised tests]	Countries with more dispersed skill distributions export more in sectors with high substitutability of workers' skills
72	Business risk and growth	Michelacci and Schivardi (2013)	Sector idiosyncratic risk [sectoral component of volatility of firm stock returns]	Country lack of diversification opportunities [importance of family firms in the economy; share of widely held firms in the economy]	OECD countries with low levels of risk diversification opportunities perform relatively worse in sectors with high idiosyncratic risk
73	Capital account opening and inequality	Larrain (2014)	Industry dependence on external finance and capital-skill complementarity [external financial dependence as Rajan and Zingales (1998); capital intensity elasticity of skilled wage share]	Timing of country capital account opening	Capital account opening increases sectoral wage inequality, particularly in industries with both high external finance dependence and strong capital-skill complementarity
74	Intellectual property rights and innovation	Aghion, Howitt and Prantl (2015b)	Industry reliance on patents [R&D expenditure to nominal value added; patent count]	EU wide product market reform interacting with country-level strength of patent rights [data on patent law reforms]	1992 EU product market reform led to more innovation in countries with stronger patent protection and in particular in industries relying more on patents
75	Entry and access to finance	Cetorelli and Strahan (2006)	Industry external financial dependence	Degree of concentration in local banking markets [two policy variables on within-state branching and inter-state-banking restrictions; deposit Herfindahl concentration index]	Sectors with greater external financial dependence have larger and fewer firms in more concentrated local banking markets

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76	Real effects of banking deregulation	Bertrand, Schoar and Tesmar (2007)	Industry reliance on bank financing [all debt excluding trade credit and bonds over total outside financing (debt and book value of equity)]	Before/after 1985 French bank reform	Industries more reliant on bank financing before 1985 deconcentrated and experienced faster employment growth post bank-reform
77	Corporate tax reform and growth	Hsieh and Parker (2007)	Industry dependence on external finance	Before / after 1984 Chilean corporate tax reform	Post-reform investment boom occurred primarily in industries more dependent on external finance
78	Credit constraints and cylicality of R&D investment	Aghion, Askenazy, Berman, Cette and Eymard (2012)	Industry dependence on external finance or asset tangility	Business cycle in France	For industries more reliant on external finance or with low asset tangibility, R&D investment is countercyclical without credit constraitns, and becomes pro-cyclical with tighter credit constraints
79	Institutions and trade in China	Feenstra, Hong, Ma and Spencer (2013)	Industry reliance on contracts [from Nunn (2007), differentiation of intermediate inputs]	Cross-provincial variation in institutional quality in China [court efficiency as measured by overall quality, delays of verdicts and court costs]	Institutions matter more for processing trade and foreign firms, both of which rely more on contracts
80	Firm growth and access to finance in Morocco	Fafchamps and Schündeln (2013)	Sectoral growth opportunities [value added growth 1998-2003]	Local bank availability	Firms in sectors with better growth opportunities grow faster in localities with bank availability
81	Unemployment, recessions and financing constraints	Duygan-Bump, Levkov and Montoriol-Garriga (2015)	Industry dependence on external finance	US recessions 1990-1991, 2001, 2007-2009	Workers in small firms are more likely to become unemployed if they work for firms in industries with high dependence on external finance during recessions in which loan supply contracts
82	Trade credit chains and corporate failure	Jacobson and von Schedvin (2015)	Industry dependence on external finance and liquidity [latter measured by inventory/ sales ratio]	Failure of trade credit debtors in Sweden	Propagation of corporate failure from trade-debtor to creditor is particularly severe in finanically constrained industries
83	Trust, firm organization, and comparative advantage	Cingano and Pinotti (2016)	Industry need on delegation in the production process	Trust	European countries with higher mean levels of trust export more and specialize more in delegation-intensive sectors. Also Italian regions with high levels of trust specialize in delegation-requiring sectors

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84	Impact of major educational reforms in China	Che and Zhang (2018)	Industry human capital intensity	Provincial stock of college graduates	Following the educational reforms, total factor productivity increased more in skill-intensive sectors in relatively human capital abundant Chinese provinces
85	Inequality and industry growth	Erman and te Kaat (2019)	Country-level inequality, Gini coefficient	Industry physical capital intensity; industry human-capital intensity	An unequal income distribution increases the growth rates of physical-capital-intensive industries and reduces the growth rates of human-capital-intensive industries by lowering human capital and raising physical capital accumulation
86	Contract enforcement and Intermediate Input Use	Boehm (2020)	Cost of enforcing contracts via courts and financial development	Industry dependence on contract enforcement, based on litigation (court cases); also allowing for litigation between pairs of sectors (upstream and downstream)	In countries where enforcement costs are high, firms use less intermediate inputs in sector-pairs where litigation is more prevalent in the United States
87	Courts and vertical integration	Boehm and Oberfield (2020)	Industry reliance on relationship-specific intermediate goods	Congestion in Indian courts; average age of pending cases of the state in which the plant is located	Plants' materials cost shares decline more steeply with court congestion in industries that tend to rely more heavily on relationship-specific input. In states with more-congested courts, plants in industries that tend to rely more on relationship-specific intermediate inputs have larger vertical spans of production
88	Judicial Reforms and firm productivity	Chemin (2020)	Sector's technological propensity for dealing in specific versus generic goods	Country-level judiciary reforms targeting quality, speed, and access	Legal reforms increase productivity in sectors relying more the judiciaries due to their need for relationship-specific investments
89	Impact of exchanger rate depreciation on firm investment	Dao, Minoiu and Ostry (2021)	Real exchange rate movements (depreciation)	Industry use of imported intermediate goods; sectoral reliance on external finance and industry labor share	Real depreciation is associated with lower investment when the firm operates in an industry more reliant on imported intermediates in emerging markets; a real depreciation provides a greater boost to the growth rate of sales per worker in industries that are more labor intensive and, for a given labor intensity, more so in countries where firms face greater financial frictions.

B Proofs

B.1 Detailed Derivation of Equation (8) in the Main Text

Using (2) in (1) in the main text yields that the demeaned outcome in the numerator of (7) can be written as

$$y_{in} - \overline{y}_i - \overline{y}_n + \overline{y} = \beta(z_i - \overline{z})(x_n - \overline{x}) + \upsilon_{in}$$

Here z_i is the global technological industry characteristic of industry i, $\overline{z}$ is the average technological industry characteristic across all industries, and

$$\upsilon_{in} = u_{in} - \overline{u}_n - \overline{u}_i + \overline{u} \tag{B1}$$

with

$$u_{in} = (\alpha + \beta x_n)\varepsilon_{in}, \tag{B2}$$

where $\overline{u}_n$ is the average of u_{in} across industries i for country n, $\overline{u}_i$ is the average of u_{in} across countries n for industry i, and $\overline{u}$ is the average of u_{in} both across countries and across industries. Substituting $y_{in} - \overline{y}_i - \overline{y}_n + \overline{y} = \beta(z_i - \overline{z})(x_n - \overline{x}) + \upsilon_{in}$ in (7) yields

$$\widehat{b} = \beta \frac{\frac{1}{I}\sum_{i=1}^{I}(z_{iUS} - \overline{z}_{US})(z_i - \overline{z})}{\frac{1}{I}\sum_{i=1}^{I}(z_{iUS} - \overline{z}_{US})^2} + \frac{\frac{1}{N}\frac{1}{I}\sum_{n=1}^{N}\sum_{i=1}^{I}(z_{iUS} - \overline{z}_{US})(x_n - \overline{x})\upsilon_{in}}{\frac{1}{N}\frac{1}{I}\sum_{n=1}^{N}\sum_{i=1}^{I}(z_{iUS} - \overline{z}_{US})^2(x_n - \overline{x})^2}. \tag{B3}$$

Note that the first ratio on the right-hand side of (B3) does not involve $\frac{1}{N}\sum_{n=1}^{N}(x_n - \overline{x})^2$ as this term cancels out.

Using (2), we can write demeaned US industry characteristics in terms of global and US-specific industry characteristics: $z_{iUS} - \overline{z}_{US} = (z_i - \overline{z}) + (\varepsilon_{iUS} - \overline{\varepsilon}_{US})$. Substituting in (B3) yields

$$\widehat{b} = \underbrace{\beta \frac{\frac{1}{I}\sum_{i=1}^{I}(z_i - \overline{z})^2 + \frac{1}{I}\sum_{i=1}^{I}(z_i - \overline{z})(\varepsilon_{iUS} - \overline{\varepsilon}_{US})}{\frac{1}{I}\sum_{i=1}^{I}(z_{iUS} - \overline{z}_{US})^2}}_{\text{(B4.1)}} + \underbrace{\frac{\frac{1}{N}\frac{1}{I}\sum_{n=1}^{N}\sum_{i=1}^{I}(z_i - \overline{z})(x_n - \overline{x})\upsilon_{in}}{\frac{1}{N}\frac{1}{I}\sum_{n=1}^{N}\sum_{i=1}^{I}(x_n - \overline{x})^2(z_{iUS} - \overline{z}_{US})^2}}_{\text{(B4.2)}} + \underbrace{\frac{\frac{1}{N}\frac{1}{I}\sum_{n=1}^{N}\sum_{i=1}^{I}(\varepsilon_{iUS} - \overline{\varepsilon}_{US})(x_n - \overline{x})\upsilon_{in}}{\frac{1}{N}\sum_{n=1}^{N}\frac{1}{I}\sum_{i=1}^{I}(x_n - \overline{x})^2(z_{iUS} - \overline{z}_{US})^2}}_{\text{(B4.3)}} \tag{B4}$$

We now discuss the probability limit as I goes to infinity of each of the three ratios on the right-hand side of (B4). To begin with, we show that the probability limit of (B4.1) is $\beta(1-\phi)$. To see this, note that the second term in the numerator can be written as

$$\frac{1}{I}\sum_{i=1}^{I}(z_i - \overline{z})(\varepsilon_{iUS} - \overline{\varepsilon}_{US}) = \frac{1}{I}\sum_{i=1}^{I} z_i \varepsilon_{iUS} - \overline{z}\frac{1}{I}\sum_{i=1}^{I}\varepsilon_{iUS}$$

As z_i is i.i.d., the standard version of the law of large numbers yields that the probability limit as I goes to infinity of $\overline{z}$ is Ez_i. Using the law of large numbers for independent random variables with the same expectation and bounded variances we obtain probability limits for the two averages across industries, $\frac{1}{I}\sum_{i=1}^{I} z_i\varepsilon_{iUS}$ and $\frac{1}{I}\sum_{i=1}^{I}\varepsilon_{iUS}$. The probability limit of the first average is equal to $Ez_i\varepsilon_{iUS} = Ez_i E\varepsilon_{iUS} = 0$, as z_i is independent of all other model elements and $E\varepsilon_{iUS} = 0$. The probability limit of the second average is $E\varepsilon_{iUS} = 0$. Thus, $\frac{1}{I}\sum(z_i - \overline{z})(\varepsilon_{iUS} - \overline{\varepsilon}_{US})$ goes to zero in probability as I goes to infinity. Moreover, the probability limits of $\frac{1}{I}\sum_{i=1}^{I}(z_{iUS} - \overline{z}_{US})^2$ and $\frac{1}{I}\sum_{i=1}^{I}(z_i - \overline{z})^2$ are $Var(z_{US})$ and $Var(z_i)$ respectively and the definition of ϕ implies $1 - \phi = Var(z_i)/Var(z_{US})$.

Next, we show that the probability limit of (B4.2) as I goes to infinity is zero. Using (B1), the numerator of (B4.2) can be written as

$$\frac{1}{N}\sum_{n=1}^{N}(x_n - \overline{x})\left[\frac{1}{I}\sum_{i=1}^{I}(z_i - \overline{z})(u_{in} - \overline{u}_n - \overline{u}_i + \overline{u})\right] \quad \text{(B5)}$$

and the square bracket can be written as

$$\frac{1}{I}\sum_{i=1}^{I}z_i(u_{in} - \overline{u}_i) - \overline{z}\frac{1}{I}\sum_{i=1}^{I}(u_{in} - \overline{u}_i) - (\overline{u}_n - \overline{u})\frac{1}{I}\sum_{i=1}^{I}z_i + \overline{z}(\overline{u}_n - \overline{u}). \quad \text{(B6)}$$

All weighted sums across industries in (B6) are sums of independent random variables with equal expectation and bounded variances. Hence, the law of large numbers implies that the probability limit of the first weighted sum is $Ez_i(u_{in} - \overline{u}_i) = Ez_i E(u_{in} - \overline{u}_i) = 0$, where we use that global industry characteristics z_i are independent of all other model elements and that $E(u_{in} - \overline{u}_i) = Eu_{in} - E\overline{u}_i = 0$. The probability limits of the second and third weighted sums are $E(u_{in} - \overline{u}_i) = Eu_{in} - E\overline{u}_i = 0$ and Ez_i respectively. Again, as z_i is i.i.d., the probability limit of $\overline{z}$ is Ez_i. Moreover, the terms $\overline{u}_n$ and $\overline{u}$ in (B6) go to zero in probability, as $E\overline{u}_n = E\overline{u} = 0$ and the variances

$$Var(\overline{u}_n) = \frac{1}{I}(\alpha + \beta x_n)^2\sigma^2$$
$$Var(\overline{u}) = Var(\frac{1}{I}\sum_{i=1}^{I}\overline{u}_i) = \frac{1}{I}Var(\overline{u}_i) = \frac{1}{I}\frac{1}{N^2}\sum_{n=1}^{N}\sum_{m=1}^{N}(\alpha + \beta x_n)(\alpha + \beta x_m)\rho_{nm}\sigma^2$$

go to zero as I goes to infinity. Hence, all terms in (B6) go to zero in probability as I goes to infinity. At the same time, the denominator of (B4.2) goes to some strictly positive number in probability as I goes to infinity. Hence, (B4.2) goes to zero in the probability limit.

Collecting the results we have so far, we get that the probability limit of (B4) as I goes to infinity is

$$b = (1 - \phi)\beta + \frac{\frac{1}{N}\sum_{n=1}^{N}(x_n - \overline{x})\operatorname*{plim}_{I\to\infty}\frac{1}{I}\sum_{i=1}^{I}(\varepsilon_{iUS} - \overline{\varepsilon}_{US})\upsilon_{in}}{Var(z_{US})\frac{1}{N}\sum_{n=1}^{N}(x_n - \overline{x})^2} \quad \text{(B7)}$$

where we rewrote the numerator of the last term in (B4) in terms of an outer sum across countries and an inner sum across industries. The key term in (B7) is the term in the numerator after the probability limit. Using (B1), this term can be written as

$$\frac{1}{I}\sum_{i=1}^{I}(\varepsilon_{iUS} - \overline{\varepsilon}_{US})(u_{in} - \overline{u}_i) - (\overline{u}_n - \overline{u})\frac{1}{I}\sum_{i=1}^{I}(\varepsilon_{iUS} - \overline{\varepsilon}_{US}). \quad \text{(B8)}$$

The second term in (B8) is equal to zero, as $\overline{\varepsilon}_{US} = \frac{1}{I}\sum_{i=1}^{I}\varepsilon_{iUS}$. The first term can be written as

$$\frac{1}{I}\sum_{i=1}^{I}(\varepsilon_{iUS} - \overline{\varepsilon}_{US})(u_{in} - \overline{u}_i) = \frac{1}{I}\sum_{i=1}^{I}\varepsilon_{iUS}(u_{in} - \overline{u}_i) - \overline{\varepsilon}_{US}(\overline{u}_n - \overline{u}). \quad \text{(B9)}$$

As $E\bar{\varepsilon}_{US} = E\overline{u}_n, = E\overline{u} = 0$ and the variances

$$Var(\overline{\varepsilon}_{US}) = \frac{1}{I}\sigma^2$$
$$Var(\overline{u}_n) = \frac{1}{I}(\alpha + \beta x_n)^2\sigma^2$$
$$Var(\overline{u}) = Var(\frac{1}{I}\sum_{i=1}^{I}\overline{u}_i) = \frac{1}{I}Var(\overline{u}_i) = \frac{1}{I}\frac{1}{N^2}\sum_{n=1}^{N}\sum_{m=1}^{N}(\alpha + \beta x_n)(\alpha + \beta x_m)\rho_{nm}\sigma^2$$

go to zero as I goes towards infinity, the second term on the right-hand side of (B9) goes to zero in probability. Making use of the law of large numbers for independent random variables with equal expectation and bounded variance, the probability limit of the first term on the right-hand side of (B9) is

$$E\varepsilon_{iUS}(u_{in} - \overline{u}_i) = (\alpha + \beta x_n)E\varepsilon_{iUS}\varepsilon_{in} - \frac{1}{N}\sum_{n=1}^{N}(\alpha + \beta x_n)E\varepsilon_{iUS}\varepsilon_{in}. \quad \text{(B10)}$$

Noting that $\sigma^2\rho_{nUS} = E\varepsilon_{iUS}\varepsilon_{in}$, we have

$$E\varepsilon_{iUS}(u_{in} - \overline{u}_i) = (\alpha + \beta x_n)\sigma^2\rho_{nUS} - \frac{1}{N}\sum_{n=1}^{N}(\alpha + \beta x_n)\sigma^2\rho_{nUS}. \quad \text{(B11)}$$

Using this, the numerator of the second term on the right-hand side of (B7) is

$$\frac{1}{N}\sum_{n=1}^{N}(x_n - \overline{x})(\alpha + \beta x_n)\sigma^2\rho_{nUS} - \frac{1}{N}\sum_{n=1}^{N}(x_n - \overline{x})\left(\frac{1}{N}\sum_{n=1}^{N}(\alpha + \beta x_n)\sigma^2\rho_{nUS}\right). \quad \text{(B12)}$$

As $\frac{1}{N}\sum_{n=1}^{N} x_n = \overline{x}$, the second term in (B12) is zero. Substituting the first term in (B12) for the numerator in (B7) yields

$$b = (1 - \phi)\beta + \left(\frac{\sigma^2}{Var(z_{US})}\right)\frac{\frac{1}{N}\sum_{n=1}^{N}(x_n - \overline{x})(\alpha+\beta x_n)\rho_{nUS}.}{\frac{1}{N}\sum_{n=1}^{N}(x_n - \overline{x}^2)}. \quad \text{(B13)}$$

Using the definitions for A in (9) and for B in (10) as well as the fact that $\phi = \sigma^2/(\sigma^2 + Var(z_i)) = \sigma^2/Var(z_{US})$, (B13) yields (8).

B.2 Detailed Derivation of Equation (36) in the Main Text

We are interested in the probability limit of $\frac{1}{I}\sum_{i=1}^{I}\widehat{u}_{in}\widehat{u}_{im}$ as the number of industries I goes to infinity, where

$$\widehat{u}_{in} = \upsilon_{in} - (x_n - \overline{x})\sum_{k=1}^{N}\psi_k\upsilon_{ik}, \quad \text{(B14)}$$

ψ_k is the least-squares regression weight defined in (34) in the main text, and

$$\upsilon_{in} = u_{in} - \overline{u}_n - \overline{u}_i + \overline{u}. \quad \text{(B15)}$$

In (B15), $\overline{u}_n$ is the average of u_{in} across industries i for country n, $\overline{u}_i$ is the average of u_{in} across countries n for industry i, and $\overline{u}$ is the average of u_{in} both across countries and across industries. Making use of (B14),

$$\frac{1}{I}\sum_{i=1}^{I}\widehat{u}_{in}\widehat{u}_{im} = \frac{1}{I}\sum_{i=1}^{I}\upsilon_{in}\upsilon_{im} - (x_n - \overline{x})\sum_{k=1}^{N}\psi_k\left(\frac{1}{I}\sum_{i=1}^{I}\upsilon_{ik}\upsilon_{im}\right) \tag{B16}$$
$$- (x_m - \overline{x})\sum_{k=1}^{N}\psi_k\left(\frac{1}{I}\sum_{i=1}^{I}\upsilon_{ik}\upsilon_{in}\right)$$
$$+ (x_n - \overline{x})(x_m - \overline{x})\sum_{k=1}^{N}\sum_{g=1}^{N}\psi_g\psi_k\left(\frac{1}{I}\sum_{i=1}^{I}\upsilon_{in}\upsilon_{im}\right).$$

A key term to determine the probability limit of (B16) is the probability limit as I goes to infinity of

$$\frac{1}{I}\sum_{i=1}^{I}\upsilon_{in}\upsilon_{im}. \tag{B17}$$

The probability limit turns out to be $\omega_{nm} - \overline{\omega}_n - \overline{\omega}_m + \overline{\omega}$, where ω_{nm} is the covariance $Eu_{in}u_{im}$ defined in (23) in the main text, $\overline{\omega}_p$ denotes the average of ω_{pq} across q, i.e. $\overline{\omega}_p = \frac{1}{N}\sum_{q=1}^{N}\omega_{pq}$, and $\overline{\omega}$ is the average of ω_{pq} across q and p, i.e. $\overline{\omega} = \frac{1}{N^2}\sum_{p=1}^{N}\sum_{q=1}^{N}\omega_{pq}$. To see this, it is useful to use (B1) to rewrite (B17) as the weighted sum of four terms:

$$\frac{1}{I}\sum_{i=1}^{I}\upsilon_{in}\upsilon_{im} = \frac{1}{I}\sum_{i=1}^{I}(u_{in} - \overline{u}_i)(u_{im} - \overline{u}_i) + (\overline{u}_n - \overline{u})(\overline{u}_m - \overline{u}) \tag{B18}$$
$$- (\overline{u}_m - \overline{u})\frac{1}{I}\sum_{i=1}^{I}(u_{in} - \overline{u}_i) - (\overline{u}_n - \overline{u})\frac{1}{I}\sum_{i=1}^{I}(u_{im} - \overline{u}_i).$$

All $(\overline{u}_n - \overline{u})$-terms on the right-hand side of (B18) go to zero in probability as the number of industries I goes to infinity. To see this, note that $E(\overline{u}_n - \overline{u}) = 0$ and that the variance $Var(\overline{u}_n - \overline{u})$ goes to zero as the number of industries I goes to infinity. This can be verified by writing the variance as

$$E(\overline{u}_n - \overline{u})^2 = E\overline{u}_n^2 - 2E\overline{u}_n\overline{u} + E\overline{u}^2. \tag{B19}$$

The three terms on the right-hand side of (B19) can be respectively written as

$$E\overline{u}^2 = E\left(\frac{1}{I}\sum_{i}^{I}\overline{u}_i\right)^2 = \frac{1}{I}E\overline{u}_i^2 = \frac{1}{I}\frac{1}{N^2}\sum_{g=1}^{N}\sum_{k=1}^{N}\omega_{gk}, \tag{B20}$$

$$E\overline{u}_n^2 = E\left(\frac{1}{I}\sum_{j=1}^{I}u_{jn}\right)^2 = \frac{1}{I}\omega_{nn}, \tag{B21}$$

$$2E\overline{u}_n\overline{u} = 2\frac{1}{N}\sum_{k=1}^{N}E\overline{u}_n\overline{u}_k = 2\frac{1}{N}\frac{1}{I}\sum_{k=1}^{N}\omega_{nk}. \tag{B22}$$

Therefore, all three terms go to zero in probability as the number of industries I goes to infinity.

The terms on the right-hand side of (B18) that involve weighted sums across industries can be analyzed using the law of large numbers for independent random variables with the same expectation and bounded variances. Thus,

$$\operatorname*{plim}_{I\to\infty}\frac{1}{I}\sum_{i=1}^{I}(u_{im} - \overline{u}_i) = E(u_{im} - \overline{u}_i) = Eu_{im} - E\overline{u}_i = 0 \tag{B23}$$

Combined with the properties of the term $\overline{u}_n - \overline{u}$ discussed in (B19)–(B22), this implies that the probability limit of all terms on the right-hand side of (B18) except the first one is zero. By another application of the law of large numbers, the probability limit of

$$\frac{1}{I}\sum_{i=1}^{I}(u_{in} - \overline{u}_i)(u_{im} - \overline{u}_i) \tag{B24}$$

is $E(u_{in} - \overline{u}_i)(u_{im} - \overline{u}_i)$, which can be simplified to

$$E(u_{in} - \overline{u}_i)(u_{im} - \overline{u}_i) = \omega_{nm} - \overline{\omega}_n - \overline{\omega}_m + \overline{\omega}. \tag{B25}$$

Hence, it follows that as the number of industries I goes to infinity, the probability limit of (B17) is

$$\omega_{nm} - \overline{\omega}_n - \overline{\omega}_m + \overline{\omega}. \tag{B26}$$

The probability limit of the second term in (B16) is

$$(x_n - \overline{x})\sum_{k=1}^{N}\psi_k(\omega_{km} - \overline{\omega}_k - \overline{\omega}_m + \overline{\omega}) = (x_n - \overline{x})\sum_{k=1}^{N}\psi_k(\omega_{km} - \overline{\omega}_k) \tag{B27}$$

where we have once again substituted (B26) for the probability limit of (B17) and made use of $\sum_{k=1}^{N}\psi_k = 0$. The probability limit of the third term in (B16) is equal to (B27) with n and m switched. Finally, the probability limit of the last term in (B16) is

$$\begin{aligned}&(x_m - \overline{x})(x_n - \overline{x})\sum_{k=1}^{N}\sum_{g=1}^{N}\psi_g\psi_k(\omega_{kg} - \overline{\omega}_k - \overline{\omega}_g + \overline{\omega}) \\ =&(x_m - \overline{x})(x_n - \overline{x})\sum_{k=1}^{N}\sum_{g=1}^{N}\psi_g\psi_k\omega_{kg},\end{aligned} \tag{B28}$$

where we made use of $\sum_{k=1}^{N}\psi_k = 0$ again. Collecting the results in (B26)-(B28) yields that as the number of industries I goes to infinity, the probability limit of $\frac{1}{I}\sum_{i=1}^{I}\widehat{u}_{in}\widehat{u}_{im}$ is

$$\begin{aligned}\omega_{nm} - \overline{\omega}_n - \overline{\omega}_m + \overline{\omega} - (x_m - \overline{x})&\sum_{k=1}^{N}\psi_k(\omega_{kn} - \overline{\omega}_k) \\ - (x_n - \overline{x})&\sum_{k=1}^{N}\psi_k(\omega_{km} - \overline{\omega}_k) \\ + (x_m - \overline{x})&(x_n - \overline{x})\sum_{k=1}^{N}\sum_{g=1}^{N}\psi_g\psi_k\omega_{kg}.\end{aligned} \tag{B29}$$

Defining

$$\mu_n = \overline{\omega}_n - \frac{1}{2}\overline{\omega} \tag{B30}$$

$$\lambda_n = \sum_{k=1}^{N}\psi_k(\omega_{kn} - \overline{\omega}_k) - \frac{1}{2}(x_n - \overline{x})\sum_{k=1}^{N}\sum_{g=1}^{N}\psi_g\psi_k\omega_{kg} \tag{B31}$$

(B29) can be rewritten as

$$\omega_{nm} - \mu_n - \mu_m - (x_m - \overline{x})\lambda_n - (x_n - \overline{x})\lambda_m \tag{B32}$$

which is the right-hand side of (36) in the main text.

It remains to be shown that, as claimed in the main text, $\sum_{n=1}^{N} \lambda_n = 0$. This follows immediately from the fact that $\frac{1}{N}\sum_{n=1}^{N} x_n = \overline{x}$ and $\frac{1}{N}\sum_{n=1}^{N} \omega_{kn} = \overline{\omega}_k$.

B.3 Show that Equation (36) in the Main Text Does Not Determine ω_{nm} for Arbitrary $\boldsymbol{\Omega}$

Using standard results in econometrics it can be shown that it is impossible to identify the elements ω_{nm} from the parameters π_{nm} in (36) in the main text for an arbitrary variance-covariance matrix $\boldsymbol{\Omega}$. To do so, we collect the π_{nm} in a $N \times N$ matrix $\boldsymbol{\Pi}$ and note that the equation system in (36) can be rewritten in matrix form as

$$\boldsymbol{\Pi} = \mathbf{M}\boldsymbol{\Omega}\mathbf{M} \tag{B33}$$

where $\mathbf{M} = \mathbf{I} - \mathbf{P}$, $\mathbf{I}$ is a square identity matrix of size N, $\mathbf{P}$ is the projection matrix $\mathbf{P} = \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'$, and $\mathbf{X} = (1, \mathbf{x})$ with 1 being a column vector of length N and $\mathbf{x}' = (x_1, \dots, x_N)$. The key issue then becomes whether the equation system in (B33) determines the symmetric variance-covariance matrix $\boldsymbol{\Omega}$ for given $\boldsymbol{\Pi}$ and $\mathbf{M}$. Using the fact that $\mathbf{P}$ is a projection matrix, i.e. $\mathbf{PX} = \mathbf{X}$ and thus $\mathbf{MX} = 0$, it is easy to show that if $\boldsymbol{\Omega}$ solves (B33) then so does any $\widetilde{\boldsymbol{\Omega}} = \boldsymbol{\Omega} + \mathbf{XD} + \mathbf{D}'\mathbf{X}' + \mathbf{XEE}'\mathbf{X}'$, where $\mathbf{D}$ and $\mathbf{E}$ are arbitrary $2 \times N$ matrices. Hence, (B33) does not identify $\boldsymbol{\Omega}$.

Next, we verify that equation (36) can indeed be rewritten as $\boldsymbol{\Pi} = \mathbf{M}\boldsymbol{\Omega}\mathbf{M}$. Using the definitions introduced above, we can rewrite $\boldsymbol{\Pi} = \mathbf{M}\boldsymbol{\Omega}\mathbf{M}$ as

$$\begin{aligned}\boldsymbol{\Pi} = \boldsymbol{\Omega} &- \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\boldsymbol{\Omega} - \boldsymbol{\Omega}\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}' \\ &+ \mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\boldsymbol{\Omega}\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'.\end{aligned} \tag{B34}$$

The first step to show that this corresponds to (36) in the main text is to write $\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}$ as

$$\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1} = \left(\sum_{k=1}^{N}(x_k - \overline{x})^2\right)^{-1} \begin{pmatrix} \frac{1}{N}\sum_{k=1}^{N} x_k^2 - x_1\overline{x} & x_1 - \overline{x} \\ \vdots & \vdots \\ \frac{1}{N}\sum_{k=1}^{N} x_k^2 - x_N\overline{x} & x_N - \overline{x} \end{pmatrix} \tag{B35}$$

and $\mathbf{X}'\boldsymbol{\Omega}$ as

$$\mathbf{X}'\boldsymbol{\Omega} = \begin{pmatrix} N\overline{\omega}_1 & \dots & N\overline{\omega}_N \\ \sum_{k=1}^{N} x_k\omega_{k1} & \dots & \sum_{k=1}^{N} x_k\omega_{kN} \end{pmatrix}, \tag{B36}$$

where ω_{nm} is the typical element of $\boldsymbol{\Omega}$ and $\overline{\omega}_p$ denotes the average of ω_{pq} across q. Hence the typical element of the matrix $\mathbf{X}(\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\boldsymbol{\Omega}$ in (B34) is

$$\left(\sum_{k=1}^{N}(x_k - \overline{x})^2\right)^{-1} \left[\left(\sum_{k=1}^{N} x_k^2 - N\overline{x}^2\right)\overline{\omega}_m - (x_n - \overline{x})\overline{x}N\overline{\omega}_m + (x_n - \overline{x})\sum_{k=1}^{N} x_k\omega_{km}\right] \tag{B37}$$

or, collecting terms,

$$\overline{\omega}_m + (x_n - \overline{x})\sum_{k=1}^{N} \psi_k\omega_{km} \tag{B38}$$

where ψ_k is the least-squares regression weight:

$$\psi_k = \frac{x_k - \overline{x}}{\sum_{m=1}^{N}(x_m - \overline{x})^2}. \tag{B39}$$

As $\mathbf{\Omega X(X'X)^{-1}X'}$ in (B34) is the transpose of $\mathbf{X(X'X)^{-1}X'\Omega}$, the typical element of $\mathbf{\Omega X(X'X)^{-1}X'}$ is

$$\overline{\omega}_n + (x_m - \overline{x}) \sum_{k=1}^{N} \psi_k \omega_{kn}. \tag{B40}$$

What is left to determine is the typical element of $\mathbf{X(X'X)^{-1}X'\Omega X(X'X)^{-1}X'}$ in (B34). The typical element of $\mathbf{X(X'X)^{-1}X'}$ is

$$\left(\sum_{k=1}^{N}(x_k - \overline{x})^2\right)^{-1} \left(\frac{1}{N}\sum_{k=1}^{N} x_k^2 - x_n\overline{x} + (x_n - \overline{x})x_m\right) \tag{B41}$$

or

$$\left(\sum_{k=1}^{N}(x_k - \overline{x})^2\right)^{-1} \left(\frac{1}{N}\sum_{k=1}^{N}(x_k - \overline{x})^2 + (x_n - \overline{x})(x_m - \overline{x})\right). \tag{B42}$$

Pre-multiplying $\mathbf{X(X'X)^{-1}X'\Omega}$, the typical element of which is given by (B38), with $\mathbf{X(X'X)^{-1}X'}$, the typical element of which is given by (B42), yields

$$\left(\sum_{p=1}^{N}(x_p - \overline{x})^2\right)^{-1} \left[\sum_{g=1}^{N}\left(\overline{\omega}_g + (x_n - \overline{x})\sum_{k=1}^{N}\psi_k\omega_{kg}\right)\left(\frac{1}{N}\sum_{k=1}^{N}(x_k - \overline{x})^2 + (x_g - \overline{x})(x_m - \overline{x})\right)\right] \tag{B43}$$

as typical element of $\mathbf{X(X'X)^{-1}X'\Omega X(X'X)^{-1}X'}$. This can be further rewritten as

$$\sum_{g=1}^{N}\left(\overline{\omega}_g + (x_n - \overline{x})\sum_{k=1}^{N}\psi_k\omega_{kg}\right)\left(\frac{1}{N} + \psi_g(x_m - \overline{x})\right) \tag{B44}$$

or as

$$\overline{\omega} + (x_n - \overline{x})\sum_{k=1}^{N}\psi_g\overline{\omega}_g + (x_m - \overline{x})\sum_{k=1}^{N}\psi_g\overline{\omega}_g + (x_n - \overline{x})(x_m - \overline{x})\sum_{k=1}^{N}\sum_{k=1}^{N}\psi_k\psi_g\omega_{kg}. \tag{B45}$$

Collecting terms in (B38), (B40), and (B45), and using the fact that the typical element of $\mathbf{\Omega}$ in (B34) is ω_{nm} yields that the typical element of the right-hand side of (B34) is

$$\begin{aligned}\omega_{nm} - \overline{\omega}_n - \overline{\omega}_m + \overline{\omega} - (x_m - \overline{x})\sum_{k=1}^{N}\psi_k(\omega_{kn} - \overline{\omega}_k) \\ -(x_n - \overline{x})\sum_{k=1}^{N}\psi_k(\omega_{km} - \overline{\omega}_k) + (x_m - \overline{x})(x_n - \overline{x})\sum_{k=1}^{N}\sum_{g=1}^{N}\psi_g\psi_k\omega_{kg}.\end{aligned} \tag{B46}$$

This is identical to (B29). As shown above, rewriting (B29) as (B30) yields the right-hand side of equation (36). Hence, (36) in the main text can be written as $\mathbf{\Pi} = \mathbf{M\Omega M}$.

B.4 Proof of Proposition 2

To prove the proposition it is useful to define $\phi = \sigma^2/Var(z_{US})$. As $Var(z_i) > 0$ implies $\sigma^2 < Var(z_{US})$, it follows that $\phi \in [0, 1)$. Recall that the two solutions for q in (26) in the main text are β and $\phi(\delta - 1)\beta$, implying $q_1 + q_2 = [1 + \phi(\delta - 1)]\beta$. Hence, the two solutions for q divided by $q_1 + q_2$ are $1/[1 + \phi(\delta - 1)]$ and $\phi(\delta - 1)/[1 + \phi(\delta - 1)]$. This implies that if $\delta \in [0, 2]$, then $\kappa = 1/[1 + \phi(\delta - 1)]$. Hence, using (17) in the main text, $\kappa b = b/[1 + \phi(\delta - 1)] = \beta$.

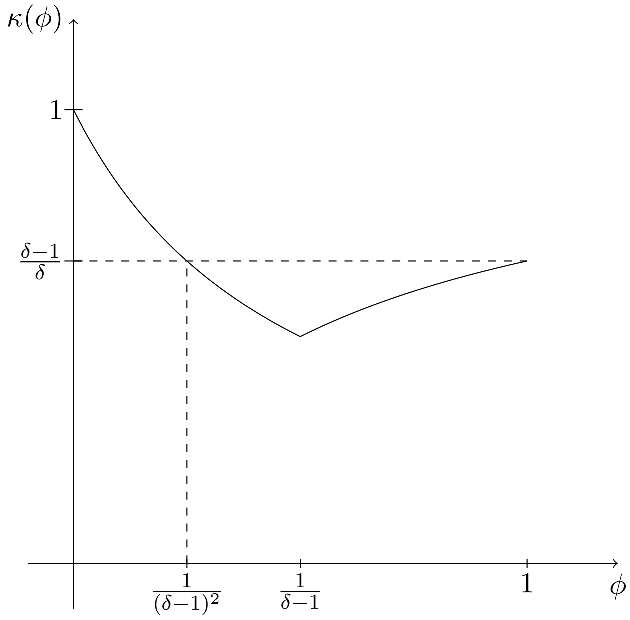

Figure B1: The shape of $\kappa(\phi)$ for $\delta > 2$.

B.5 Proof of Proposition 3

For $\delta \in [0, 2]$, see the proof of Proposition 2. To prove it for other values of δ, it is useful to distinguish the cases $\delta > 2$ and $\delta < 0$. We continue to use the definition $\phi = \sigma^2/Var(z_{US})$ with $\phi \in [0, 1)$ as $Var(z_i) > 0$ implies that $\sigma^2 < Var(z_{US})$.

Recall that the two solutions for q in (26) in the main text are β and $\phi(\delta-1)\beta$, implying $q_1 + q_2 = [1 + \phi(\delta-1)]\beta$. Hence, the two solutions for $q/(q_1 + q_2)$ are $1/[1 + \phi(\delta-1)]$ and $\phi(\delta-1)/[1+\phi(\delta-1)]$. Clearly, $1+\phi(\delta-1) \geq 0$ for $\delta > 2$. Therefore, the definition of κ in (27) implies

$$\begin{array}{ll} \kappa = \frac{1}{1+\phi(\delta-1)} & \text{if } \phi(\delta-1) \leq 1 \\ \kappa = \frac{\phi(\delta-1)}{1+\phi(\delta-1)} & \text{if } \phi(\delta-1) > 1. \end{array} \tag{B47}$$

Using the notation $\kappa(\phi)$ to capture that κ is a function of ϕ, this can be written as

$$\kappa(\phi) = \begin{cases} \frac{1}{1+\phi(\delta-1)} & \text{if } \phi \in \left[0, \frac{1}{\delta-1}\right] \\ \frac{\phi(\delta-1)}{1+\phi(\delta-1)} & \text{if } \phi \in \left[\frac{1}{\delta-1}, 1\right) \end{cases} \tag{B48}$$

where $0 < 1/(\delta-1) < 1$. The function $\kappa(\phi)$ is illustrated in Figure B1. $\kappa(\phi)$ is strictly decreasing in ϕ up to the point where $\phi = 1/(\delta-1) < 1$, and is strictly increasing in ϕ from that point on. Moreover, $\kappa(1) = (\delta-1)/\delta$. As $\kappa(\phi)$ is strictly increasing for $\phi > 1/(\delta-1)$, we get that $\kappa(\phi) < (\delta-1)/\delta$ for all $\phi \in [1/(\delta-1), 1)$.

For $\delta > 2$, the relevant version of condition (28) in Proposition 3 is

$$\kappa \geq \frac{\delta-1}{\delta}. \tag{B49}$$

It can therefore never be satisfied for $\phi \in (1/(\delta-1), 1)$. Put differently, the relevant condition in the proposition can be satisfied only if $\phi \in [0, 1/(\delta-1)]$. For ϕ in this range, (B48) implies $\kappa(\phi) = 1/[1+\phi(\delta-1)]$ and the condition in (B49) is satisfied if $\phi \leq 1/(\delta-1)^2$. Summarizing, when $\delta > 2$, the relevant condition in Proposition 3 is satisfied if and only if ϕ satisfies

$$\phi(\delta - 1)^2 \le 1. \tag{B50}$$

As $\kappa = 1/[1 + \phi(\delta - 1)]$ for ϕ in this range, the claim $\beta = \kappa b$ in Proposition 3 follows from rewriting (17) in the main text as $b = [1 + \phi(\delta - 1)]\beta$.

When $\delta < 0$, the two solutions for $q/(q_1 + q_2)$, $1/[1 + \phi(\delta - 1)]$ and $\phi(\delta - 1)/[1 + \phi(\delta - 1)]$, imply that κ in Proposition 3 is

$$\begin{array}{ll} \kappa = \frac{1}{1+\phi(\delta-1)} & \text{if } \phi(\delta-1) \ge -1 \\ \kappa = \frac{\phi(\delta-1)}{1+\phi(\delta-1)} & \text{if } \phi(\delta-1) < -1 \end{array}. \tag{B51}$$

Or, using the notation $\kappa(\phi)$ to capture that κ is a function of ϕ:

$$\kappa(\phi) = \begin{cases} \frac{1}{1+\phi(\delta-1)} & \text{if } \phi \in \left[0, -\frac{1}{\delta-1}\right] \\ \frac{\phi(\delta-1)}{1+\phi(\delta-1)} & \text{if } \phi \in \left[-\frac{1}{\delta-1}, 1\right) \end{cases} \tag{B52}$$

where $0 < -1/(\delta - 1) < 1$. The function $\kappa(\phi)$ is illustrated in Figure B2. For $\phi < -\frac{1}{\delta-1}$, κ is

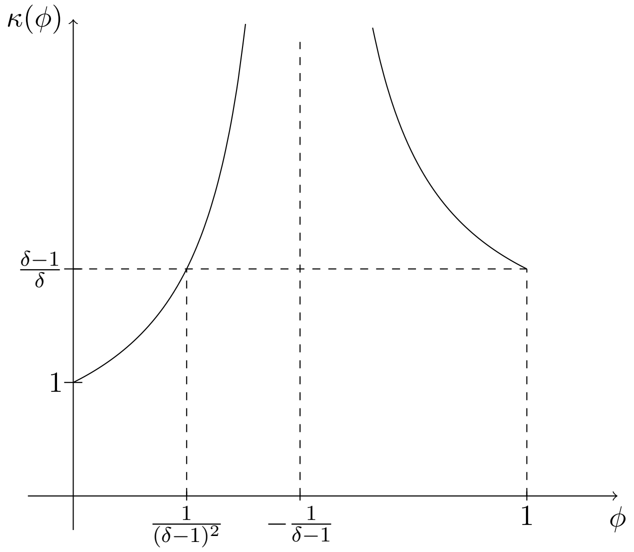

Figure B2: The shape of $\kappa(\phi)$ for $\delta < 0$.

strictly increasing in ϕ. For values of ϕ larger than $\phi = -1/(\delta - 1)$, $\kappa(\phi)$ is strictly decreasing. Furthermore, $\kappa(1) = (\delta - 1)/\delta$. As a result, we get that $\kappa(\phi) > (\delta - 1)/\delta$ for $\phi \in (-1/(\delta - 1), 1)$. For $\delta < 0$, the relevant version of condition (28) is

$$\kappa \le \frac{\delta - 1}{\delta}. \tag{B53}$$

For $\phi \in (-1/(\delta - 1), 1)$, it can never be satisfied. Put differently, the condition in (B52) can be satisfied only if $\phi \in [0, -1/(\delta - 1)]$. For ϕ in this range, (B51) implies $\kappa = 1/[1 + \phi(\delta - 1)]$ and hence that (B52) is satisfied if $\phi(\delta - 1)^2 \le 1$. Summarizing, when $\delta < 0$, the condition in Proposition 3 is satisfied if and only ϕ satisfies

$$\phi(\delta - 1)^2 \le 1. \tag{B54}$$

As we have $\kappa = 1/[1 + \phi(\delta - 1)]$ for ϕ in this range, the claim $\beta = \kappa b$ in Proposition 3 follows from rewriting (17) in the main text as $b = [1 + \phi(\delta - 1)]\beta$.

It remains to be shown that if the condition in Proposition 3 is not satisfied, then the parameters b, η, and δ do not allow us to determine which of the two solutions for q in (26) in the main text identifies β. Consider first the case $\delta > 2$. In this case, κ as defined in (27) is given by (B48). To capture that κ in (B48) is a function of ϕ, we use the notation $\kappa(\phi)$. If (i) $\delta > 2$ and (ii) κ does not satisfy the condition in Proposition 3 for the case of $\delta > 2$ (i.e. equation B49), then the equation $\kappa(\phi) = \kappa$ has two solutions for ϕ that satisfy $\phi \in [0, 1)$. Moreover, one of the two solutions for ϕ is smaller than $1/(\delta - 1)$ and the other solution for ϕ is larger than $1/(\delta - 1)$. As a result, $\beta = \kappa b$ for one of the solutions (the solution for ϕ smaller $1/(\delta - 1)$) and $\beta = (1 - \kappa)b$ for the other solution. As both solutions for q in (26) are consistent with the parameters b, η, and δ, and both solutions imply that $\phi \in [0, 1)$, it is impossible to know which of the two solutions for q in (26) identifies β. The proof for the case $\delta < 0$ is analogous.

B.6 Proof of Proposition 4

In proving Proposition 3 we have shown that the condition in (28) holds if and only if $(\delta - 1)^2\sigma^2/Var(z_{US}) \leq 1$.

B.7 Proof of Proposition 5

From Proposition 4, we know that the condition in (28) is not satisfied if and only if $\phi(\delta-1)^2 > 1$. In these circumstances we only know that β is one of the two solutions for q in (26), that is $\beta \in \{q_1, q_2\}$. As $q_1 + q_2 = b$, this implies that $\beta/b \in \{q_1/(q_1 + q_2), q_2/(q_1 + q_2)\}$. Or, making use of the definition for κ in (27) in the main text, $\beta/b \in \{\kappa, 1 - \kappa\}$.

When $\delta > 2$, it follows from (B47) that $\kappa < (\delta - 1)/\delta$ for $\phi(\delta - 1)^2 > 1$. This implies that $1 - \kappa > 1/\delta$. As $(\delta - 1)/\delta > 1/\delta$ when $\delta > 2$, it follows that $\beta/b \in \{\kappa, 1 - \kappa\}$ implies $\beta/b \in (1/\delta, (\delta - 1)/\delta)$. This establishes the part of the proposition that applies to $\delta > 2$.

When $\delta < 0$, it follows from (B51) that $\kappa > (\delta - 1)/\delta$ for $\phi(\delta - 1)^2 > 1$. This implies that $1 - \kappa < 1/\delta$. As $(\delta - 1)/\delta > 1/\delta$ when $\delta < 0$, it follows that $\beta/b \in \{\kappa, 1 - \kappa\}$ implies $\beta/b \notin [1/\delta, (\delta - 1)/\delta]$. This establishes the part of the proposition that applies to $\delta < 0$.

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