Risk Sharing and Industrial Specialization: Regional and International Evidence

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The benefits of industrial specialization are widely recognized, but with uninsured production risk, the higher variance of gross domestic product (GDP) resulting from specialized output may entail a welfare loss that outweighs those benefits. The argument was formulated by William Brainard and Richard Cooper (1968), Murray Kemp and Nissan Liviatan (1973), and Roy Ruffin (1974). In response, Elhanan Helpman and Assaf Razin (1978) showed that if production risk can be insured through trade in assets, the benefits of specialization will resurface.[1] This work has consequences for the theory of economic growth as shown by Jeremy Greenwood and Boyan Jovanovic (1990), Gilles Saint-Paul (1992), Maurice Obstfeld (1994a), Daron Acemoglu and Fabrizio Zilibotti (1997), and JoAnne Feeney (1999).[2] No evidence has been brought to bear on this important economic mechanism and this is the task undertaken in the present article: demonstrating empirically that more insurance is associated with higher specialization.

Insurance of production risk takes many forms. Common examples are explicit insurance against natural disasters and forward markets where commodities are sold at a fixed price for future delivery; however, the main mechanism for spreading risk among regions and countries is geographical diversification of income sources achieved via capital markets. If interregional and international capital markets are well integrated, regions and countries can insure against idiosyncratic shocks and thereby "afford" to better exploit comparative advantage whether it arises from technological differences (Ricardo), factor endowments (Heckscher-Ohlin), or increasing returns to scale [e.g., Paul Krugman (1979) and Helpman (1981)].

We adopt a simple empirical strategy. For various groups of regions and countries (e.g., U.S. states, Japanese prefectures, European Community countries), we (i) calculate the degree of insurance among members of the group, (ii) compute an index of industrial specialization for each region within the group, and (iii) check whether a high degree of insurance within a group is associated with high specialization of its regions. We use both income- and consumption-based measures of insurance. To guard against possible endogeneity bias, we search for instrumental variables that are likely to be exogenous for specialization. We use the share of the financial sector in GDP—an indicator of "financial depth"—and indices of shareholder rights from Rafael La Porta et al. (1998).

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[1] Further work on this topic includes James E. Anderson (1981), Gene M. Grossman and Razin (1984), and Helpman (1988).

[2] In Obstfeld (1994a), countries choose between investing in risky projects with high average returns or in safe projects with low average returns. International asset trade allows them to hold a diversified portfolio and to shift investment towards high return projects. Acemoglu and Zilibotti (1997) stress that developing countries have fewer opportunities to diversify production and tend to specialize in safe technologies. Insurance permits them to take risks that—with some probability—will translate into an economic take-off. In Greenwood and Jovanovic (1990), financial intermediaries pool risks and help achieve higher and safer returns on investment. In Saint-Paul (1992), the basic trade-off is between the gains from specialization due to comparative advantage in production and a lower variance of output while Feeney (1999) develops the idea that in the presence of learning-by-doing in production, specialization entails higher growth during a transition period.

These instruments can be criticized but, at the very least, the regressions confirm that our results are quite robust.

A central empirical finding is the large difference in the extent of industrial specialization of regions within "federations" versus the corresponding magnitude for countries. This is in line with Gary Hufbauer and John Chilas (1974) and Krugman (1991) who pointed out that U.S. states are more specialized than OECD countries. They interpreted this as evidence that barriers to trade are greater between countries than between U.S. states but did not perform a systematic empirical analysis. In our work, we control for as many determinants of industrial specialization as the data permit with particular focus on interregional insurance.

Another important finding is the striking difference in the amount of risk sharing among regions within federations versus the corresponding amount among countries. We confirm the well-established stylized fact that there is little risk sharing between countries[3] but we also find substantial interregional risk sharing within federations. This empirical regularity is consistent with our conjecture that better insurance of production risk entails higher specialization in production. We test it more systematically with regression analysis using the 158 regions and countries in our sample, controlling for characteristics such as population and population density and—in particular—determinants of trade volume such as geographical distance and proxies for factor endowments. The basic finding survives this scrutiny. Finally, the positive relation between risk sharing and specialization also survives when we eliminate groups of countries from the sample and perform the regressions using only regions within federations.

In the next section, we briefly discuss relevant conceptual issues. In Section II, we present our measures of specialization and risk sharing and in Section III we describe other variables that potentially affect industrial specialization. The empirical results are presented in Section IV, and Section V concludes.

I. Conceptual Issues

Insurance and Specialization.—The theoretical foundations for the effect of risk sharing on industrial specialization are well established so we will only give a simple reformulation of the theory in words to set the stage for the empirical analysis. We present a variant of the theory where production technology exhibits increasing returns to scale.

Consider a "risk-sharing group" consisting of regions of equal size inhabited by risk-averse consumers. There is one consumption good produced with inelastically supplied labor and no fixed costs. A region can use any of several *ex ante* identical technologies which exhibit increasing returns to scale and are subject to imperfectly correlated productivity shocks. The choice of how many technologies to use in each region depends on the trade-off between increasing returns in production and gains from diversification across technologies.

If there are as many technologies as regions and if there is perfect interregional income insurance, each region will specialize in one technology to fully exploit economies of scale in production; furthermore, each region will specialize in a different technology so that gains from diversification are maximized within the group. If only partial interregional insurance is possible, a region will use fewer technologies the more insurance is available. At the margin, the diversification (self-insurance) benefit from using an additional technology offsets the forgone benefit from increasing returns in production. Since this trade-off has been modeled extensively in the literature there is no need to elaborate on this intuition.[4]

[3] See, e.g., Kenneth French and James Poterba (1991) and Linda Tesar and Ingrid Werner (1995), who document the "home bias" puzzle, David Backus et al. (1992), who compare cross-country GDP correlations and consumption correlations, and Sørensen and Yosha (1998), who carry out cross-country variance decompositions of movements in GDP for EC/OECD countries.

[4] In this example, there are as many technologies as regions so full specialization is equivalent to full localization (or concentration) of production—each technology is used in exactly one region. If there are more technologies than regions (the more realistic case), and if risk aversion is sufficiently strong, then more than one technology will be used in each region as long as the added gains from diversification exceed forgone benefits from economies of scale.

Income Insurance Versus Consumption Insurance.—We consider two mechanisms for smoothing regional output fluctuations. First, residents of a region can hold claims to output in other regions. If output across regions is imperfectly correlated, the out-of-region dividend, interest, and rental revenue will insure income. Second, a region's residents can adjust their wealth portfolios in response to income fluctuations by buying and selling assets and by borrowing and lending on interregional credit markets.

The first mechanism—*ex ante* income insurance—is effective for smoothing both permanent and transitory shocks. To illustrate: if in some year Florida's GDP is drastically reduced due to a natural disaster, personal income in Florida will not fall by as much as output if many residents receive interest and dividend income from out-of-state investment funds and savings accounts. This is true regardless of the persistence of the shock to Florida's GDP. The second mechanism—*ex post* adjustment of asset portfolios—can smooth only transitory shocks. This is a well-understood implication of permanent income theory: facing an income shock, inhabitants of a region will adjust their stock of wealth in order to maintain their level of consumption only if the income shock is perceived as transitory. In practice, macroeconomic shocks contain transitory and persistent components that are hard to identify empirically. Since both mechanisms are relevant for specialization decisions, we use a measure of income insurance and, alternatively, a measure of overall consumption insurance in the empirical analysis. Which measure is more closely related to specialization in production depends, among other things, on hard-to-measure persistence and on how production decisions are made.

II. Measuring Risk Sharing and Specialization

A. *Measuring Risk Sharing*

We measure how much risk is shared within "risk-sharing groups." Each risk-sharing group is either a country consisting of regions or a group of countries (which are referred to as "regions"). The representative consumer of a region is risk averse and maximizes lifetime expected utility from consumption. With CRRA utility and a common intertemporal discount factor for all regions, perfect risk sharing implies $x_{it} = k_i X_t$ for all t and all realizations of uncertainty, where x_{it} and X_t are generic variables representing regional and groupwide income or consumption and k_i is a constant which is independent of time and "states of the world." If perfect risk sharing is achieved via income insurance, x_{it} and X_t represent both income and consumption (in this case, income equals consumption). If perfect risk sharing is achieved through income insurance *and* consumption smoothing, x_{it} and X_t represent consumption. Notice that $x_{it} = k_i X_t$ implies that x_{it} grows at the same rate as X_t.

Earlier empirical work on risk sharing focused on consumption, testing whether the condition $c_{it} = k_i C_t$ holds in the data by asking if consumption of individuals (or countries) responds only to aggregate fluctuations.[5] Pierfederico Asdrubali et al. (1996) contribute to this literature by measuring the fraction of idiosyncratic (region-specific) GDP shocks absorbed through various channels of interregional insurance. In particular, they measure the amount of insurance via capital markets by estimating the sensitivity of regional income to idiosyncratic GDP fluctuations and this is also the measure of income insurance used in the present article.[6]

We turn to a more detailed description of this measure. Consider the panel regression (across the regions that constitute a risk-sharing group), $\Delta \log y_{it} = \nu_t + \beta_1 \Delta \log \mathrm{GDP}_{it} + \varepsilon_{it}$, where y_{it} and GDP_{it} are region i's year t per capita personal income and GDP, and ν_t are time fixed effects. The coefficient β_1 measures the comovement of income with idiosyncratic (region-specific) GDP fluctuations. Including time fixed effects is crucial because they control for undiversifiable fluctuations of groupwide GDP (and any other aggregate variable). If income is perfectly insured within the group, each region's personal income grows at the same rate as the risk-sharing group's aggregate

[5] See, e.g., Sumru Altug and Robert Miller (1990), John Cochrane (1991), and Obstfeld (1994b).

[6] The International Real Business Cycles literature pioneered by Backus et al. (1992) takes a different, but related, approach: it proceeds by constructing a general-equilibrium model and simulating consumption- and GDP-growth correlations across pairs of countries. These correlations are compared to the corresponding correlations in country-level data. Typically, consumption correlations are much lower than predicted by the model.

personal income and is not affected by idiosyncratic fluctuations of GDP, implying $\beta_1 = 0$. If income is not perfectly insured within the group, $\beta_1 > 0$. In fact, β_1 measures the fraction of idiosyncratic GDP shocks that is *not* eliminated through insurance. The coefficient β_K in the regression

$$(1) \qquad \Delta \log \mathrm{GDP}_{it} - \Delta \log y_{it} = \nu_t + \beta_K \Delta \log \mathrm{GDP}_{it} + \varepsilon_{it}$$

measures the fraction of idiosyncratic shocks to GDP that *is* absorbed through interregional insurance since $\beta_K = 1 - \beta_1$.[7] In this study, we use β_K as the measure of interregional income insurance.[8]

Ideally, we would want to use Gross National Product (GNP) rather than personal income, but these data are not available for many of the regions. The main differences between GNP and personal income are that GNP includes corporate saving and depreciation while personal income includes transfers from supraregional governments. In order for the country-level data to resemble that used for regions within federations, we use Net National Income (as defined in the *OECD National Accounts*) minus corporate saving.

In a similar manner we estimate the relation

$$(2) \qquad \Delta \log \mathrm{GDP}_{it} - \Delta \log c_{it} = \nu_t + \beta \Delta \log \mathrm{GDP}_{it} + \varepsilon_{it},$$

where β measures overall income and consumption insurance (for brevity: consumption insurance). A test of $\beta = 1$ is a test of perfect risk sharing.

B. *Measuring Specialization*

We calculate a specialization index for manufacturing sectors at the 2-digit International Standard Industrial Classification (ISIC) level.[9] It is computed (for each region) for the relevant sample years and averaged over time and is calculated as follows.[10] Let GDP_i^s denote the GDP of manufacturing subsector s in region i, and GDP_i^M the total manufacturing GDP of this region. The index measures the distance between the vector of sector shares in region i, $\mathrm{GDP}_i^s/\mathrm{GDP}_i^M$, and the vector of average sector shares in the regions other than i in the risk-sharing group:

$$(3) \qquad \mathrm{SPEC}_i = \sum_{s=1}^{S} \left(\frac{\mathrm{GDP}_i^s}{\mathrm{GDP}_i^M} - \frac{1}{J-1} \sum_{j \neq i} \frac{\mathrm{GDP}_j^s}{\mathrm{GDP}_j^M} \right)^2,$$

where S is the number of sectors and J is the number of regions in the group. The index measures how the composition of manufacturing in region i differs from the composition of manufacturing in the other regions of the risk-sharing group. Thus, the different industrial composition of, say, Japan relative to other countries in the sample does not affect the specialization indices of Japanese prefectures; but the difference in the industrial composition of Japan and Canada affects the specialization indices of Japan and Canada when they are treated as regions within the OECD.[11]

III. Other Potential Determinants of Industrial Specialization

Several other variables are potentially important for industrial specialization and should be

[7] If there is no insurance, $\Delta \log \mathrm{GDP}_{it}$ and $\Delta \log y_{it}$ comove perfectly and the left-hand side of (1) does not comove with the regressor, $\Delta \log \mathrm{GDP}_{it}$, and $\beta_K = 0$. If there is perfect insurance, $\Delta \log y_{it}$ is unaffected by region-specific fluctuations in $\log \mathrm{GDP}_{it}$ and (1) boils down to a regression of $\Delta \log \mathrm{GDP}_{it}$ on itself, i.e., $\beta_K = 1$.

[8] We also estimated the relation (1) allowing for region-specific fixed effects. For all our risk-sharing groups, however, the estimated coefficient is virtually identical whether cross-sectional fixed effects are included or not.

[9] We do not use 1-digit sectors since the level of output in the agriculture and mining sectors is determined mainly by endowments of fertile soil and extractable minerals, and similarly, the size of the government is primarily determined by social and political factors. We were not able to collect consistent data at the 3-digit level.

[10] First averaging production over time and then calculating the index yields very similar results.

[11] An alternative is to use the distance of region i's vector of sector shares to the *weighted* (by manufacturing GDP) average of sector shares in other regions. We found that this has little effect on the empirical results. We also experimented with an index similarly defined except using the absolute value rather than the square in (3); this had little effect on our point estimates but resulted in somewhat lower t-statistics.

included in the empirical analysis in order to guard against left-out variable bias.

First, and foremost, the degree of regional specialization is likely to be affected by any variable that affects the *volume of interregional trade.* Indeed, in the extreme case where all regions have a similar composition of consumption, trade and specialization are one and the same and, e.g., James Harrigan and Egon Zakrajsec (2000) argue that "economists won't be able to understand trade until they understand specialization." We control for determinants of trade using variables that have been used extensively in the empirical trade literature. *Endowments:* Regions endowed with natural resources are likely to specialize in the manufacturing of related products.[12] We use region-by-region mining and agricultural production GDP shares to control for such effects.[13] *Distance:* Trade costs are likely to be higher in regions that are far away from their trading partners. Distance between pairs of countries has been extensively used in trade regressions that take country-pairs as the unit of observation; see David Hummels and James Levinsohn (1995) and Jeffrey Frankel and David Romer (1999) for prominent recent examples. We construct the variable "distantness" which is closely related to the inverse of indices used by Chauncy D. Harris (1954) and Gordon Hanson (1998). For each region, we measure the distance from the region's capital city to all other regional capital cities in the risk-sharing group[14] and define "distantness" as the weighted average of these distances using the GDP shares of the other regions as weights.[15] The weights reflect the positive relation between trade volume and GDP. *Population density:* The predicted sign of this variable is not obvious. Krugman (1991) argues that transportation costs determine where manufacturing industries locate. High-transportation-cost firms—which typically are in certain industries—tend to locate in densely populated areas to minimize transportation costs. However, such entry might drive up congestion costs making it more attractive for firms in low-transportation-cost industries to settle in less densely populated areas making the overall effect on specialization uncertain. *Other variables:* (i) The cost of shipping goods via land and water is not the same. We construct the dummy variable "coastal" that equals one if a region is located by the sea and, for U.S. states and Canadian provinces, also if it is located by the great lakes or the Mississippi river. (ii) All the regions in our sample belong to a customs union where there is free trade by agreement except the group of non-EC OECD countries. We include the dummy variable "customs union" that equals one for members of this group and zero otherwise.

Jean Imbs and Romain Wacziarg (2003) provide evidence that industrial specialization declines with GDP at earlier stages of development and increases with GDP at later stages of development.[16] To allow for such a pattern we include per capita GDP and the square of per capita GDP as regressors. We use the average per capita GDP of the risk-sharing group because regional GDP may be endogenous to regional industrial specialization.

The size of regions may also affect their specialization. Larger regions are likely to be less specialized due to greater heterogeneity of the population and of within-region geophysical characteristics such as climate, landscape, and natural resources. Furthermore, scale economies in production are more likely to be exhausted in larger regions. This suggests a negative relation between a region's size and its degree of specialization. We control for size by including region-by-region log-population as a regressor.

Gary Ramey and Valerie A. Ramey (1995)

[12] For example, oil-rich regions may specialize in chemical products and agricultural regions in food products. Harrigan and Zakrajsec (2000) provide evidence for the importance of factor endowments in determining specialization patterns.

[13] Regional-level physical and human capital intensity are not available for many of our regions and, in any event, physical and human capital are less likely to be exogenous to specialization at the regional level.

[14] We obtain the latitude and longitude of each capital city and use the Arc View software to calculate the great arc distance between each pair of cities.

[15] In symbols: denoting the distance from region i's capital city to region j's capital city by d_{ij}, region i's distantness is defined as $\frac{1}{T}\sum_{t=1}^{T}\sum_j d_{ij}\mathrm{GDP}_j^t/\mathrm{GDP}^t$ where GDP^t is the year t groupwide (total) GDP, and T is the sample length.

[16] The decline in industrial specialization for U.S. states over the past century is documented by Sukkoo Kim (1995). Acemoglu and Zilibotti (1999) provide a model that stresses the decline in specialization in early stages of development.

and Acemoglu and Zilibotti (1997) stress that in the presence of uninsured risk, countries will take fewer additional risks. Since the volatility of aggregate output cannot be insured, it may affect the regional specialization within the group. To control for this, we calculate the volatility of groupwide GDP for each risk-sharing group and include it as a regressor.

Group-level human capital may be a better indicator of development than per capita GDP.[17] We include a measure of group-level human capital (education) as a further control.

If manufacturing is only a tiny fraction of a region's GDP, the production risk of the manufacturing sector can easily be diversified within the region. In such a case, the amount of interregional risk sharing may be of little importance for specialization in manufacturing. We address this by weighting the data by real manufacturing GDP by region and by including the region-by-region manufacturing GDP share as a regressor.

IV. Empirical Analysis

A. *Data Description, Risk-Sharing Measures, and Specialization Indices*

Data sources are described in Appendix A. Descriptive statistics are available from the working paper version of this article (Kalemli-Ozcan et al., 1999). In Table 1, we display the estimated risk-sharing measures and *average* specialization indices for the risk-sharing groups in our sample. The table highlights an important empirical finding: regions within federations are much more specialized than countries. This probably reflects stronger ties between regions within federations than between countries. Such ties may be related to physical mobility of goods and factors of production or to other features that distinguish a federation of regions from a group of countries such as common language, common currency, or common institutions. Such ties may also be associated with better insurance within federations than among countries. Indeed, the table displays another important empirical finding: there is considerably more risk sharing among regions within federations than among countries, according to both income and consumption insurance measures.[18]

The sample periods for calculating specialization and risk sharing were chosen with two considerations in mind. First, we want them to overlap. Second, we want a long sample for calculating risk sharing because we later use the risk-sharing measure as a regressor. The longer the sample period, the smaller the standard errors of the risk-sharing estimates and the lower the measurement error. For countries with many regions and a reasonably long sample for calculating both measures, such as the United States and the United Kingdom, the longest overlapping sample is used. For the group of non-EC OECD countries that includes few "regions," a longer sample is used for estimating the amount of risk sharing than for calculating the specialization index.[19] Similarly, for Canadian provinces, where specialization can only be calculated for a rather short span of years, a longer sample is used for estimating risk sharing than for calculating the specialization index. The results are fortunately not very sensitive to the exact sample periods chosen.

To give an impression of the characteristics of highly specialized regions, we display facts regarding the 15 most specialized regions in Table 2—not surprisingly, these are all regions within countries. The first column shows the sector in which the region is most specialized.[20] Several of the specialized regions have a small population, as shown in the second column, although some are larger than small OECD

[17] One reason is that education improves monitoring of managers as in Acemoglu and Zilibotti (1999).

[18] We display the standard errors of the estimated measures of risk sharing (rather than the t-statistics) because it is not evident whether the appropriate null hypothesis is that the coefficient is zero (no risk sharing) or one (perfect risk sharing).

[19] For calculating this index, we used the longest sample of 2-digit manufacturing GDP data available.

[20] Specialization is not necessarily driven by one sector. The sectors reported in parentheses are mentioned for illustration only and are obtained as follows. Montana, for example, is most specialized in wood relative to other U.S. states in the sense that, in Montana, $\frac{GDP_i^s}{GDP_i^M} - \frac{1}{J-1}\sum_{j \neq i} \frac{GDP_j^s}{GDP_j^M}$ is largest (over all sectors s) for the wood sector (index i here denotes Montana).

TABLE 1—RISK SHARING AND AVERAGE SPECIALIZATION WITHIN RISK-SHARING GROUPS: FEDERATIONS VERSUS GROUPS OF COUNTRIES

Risk-sharing group	Sample for measuring risk sharing (specialization)	Number of regions	Income insurance within risk-sharing group ($100 \times \beta_K$)	Consumption insurance within risk-sharing group ($100 \times \beta$)	Average specialization within risk-sharing group ($10 \times$ SPEC)
Italy	1983–1992	20	76.4	98.1	0.46
			(4.4)	(3.0)	
United States	1977–1994	50	63.5	77.6	0.63
			(1.8)	(4.5)	
Canada	1979–1995 (1987–1993)	5	61.5	73.4	0.43
			(5.3)	(3.3)	
United Kingdom	1978–1993	11	41.6	87.5	0.32
			(5.8)	(8.5)	
Japan	1975–1993 (1979–1993)	47	21.6	97.3	0.42
			(2.2)	(3.0)	
Spain	1981–1991 (1980–1992)	16	24.3	70.3	0.73
			(6.0)	(12.4)	
Average for federations			48.2	84.0	0.50
EC countries	1971–1993 (1977–1993)	5	5.0	21.0	0.13
			(6.5)	(6.5)	
Non-EC countries	1971–1993 (1977–1993)	4	12.7	35.5	0.21
			(6.3)	(3.8)	
Average for groups of countries			8.9	23.8	0.17

Notes: β_K measures income insurance among the regions of the risk-sharing group and is obtained from the panel regression $\Delta \log \text{GDP}_{it} - \Delta \log y_{it} = \nu_t + \beta_K \Delta \log \text{GDP}_{it} + \varepsilon_{it}$, where Δ log GDP and $\Delta \log y$ are growth rates of per capita GDP and personal income. (Since personal income includes social security transfers to individuals, this measure includes some government-provided insurance.) β measures overall consumption insurance among the regions of the risk-sharing group and is obtained from the panel regression $\Delta \log \text{GDP}_{it} - \Delta \log c_{it} = \nu_t + \beta \Delta \log \text{GDP}_{it} + \varepsilon_{it}$, where $\Delta \log c$ is the growth rate of consumption. Standard errors are in parentheses. SPEC is the average across the regions within each risk-sharing group of the region-by-region specialization index, $\text{SPEC}_i = \sum_{s=1}^{S} \left[\frac{\text{GDP}_i^s}{\text{GDP}_i^M} - \frac{1}{J-1} \sum_{j \neq i} \frac{\text{GDP}_j^s}{\text{GDP}_j^M} \right]^2$, which is calculated year-by-year and averaged over time. Risk-sharing groups: Italy: all 20 regions such as Toscana, Sicilia, etc. United States: all 50 states excluding DC. Canada: 5 regions: Quebec, Ontario, Manitoba, Alberta, British Columbia. United Kingdom: all 11 regions such as East Midlands, Wales, etc. Japan: all 47 prefectures such as Tokyo, Okinawa, etc. Spain: 16 communities: Galicia, Astruias, Cantabria, Pais-Vasco, Navarra, Rioja, Aragon, Madrid, Castilla-Leon, Castilla-La-Mancha, Extremedura, Cataluna, Communidad-Valenciana, Andalucia, Murcia, Canarias. EC: 5 countries: Belgium, Denmark, France, Germany, Netherlands. Non-EC: 4 countries: Austria, Canada, Finland, United States.

countries. The most specialized regions display considerable variation in "distantness," GDP per capita, and population density. We do not show the details but the *least* specialized regions tend to be large. The two least specialized regions in our sample are countries—Canada and France—but the following three are regions—the Niigata prefecture in Japan, Quebec in Canada, and Yorkshire and Humberside in the United Kingdom.

B. *Cross-Sectional Regressions: Explaining Specialization*

In all our regressions, the dependent variable is the log of the region-by-region specialization index defined in equation (3). The log-transformed index is used to guard against outliers since a histogram revealed the raw index to be right-skewed. We normalized the log-transformed index so that the range of values in our sample

TABLE 2—FACTS ABOUT THE 15 MOST SPECIALIZED REGIONS

Region	Sector	Region's per capita GDP	Region's population	Region's population density	Region's distantness
Montana (US)	33	17,322	808	6	2.25
Alaska (US)	31	47,572	505	1	3.82
Delaware (US)	35	26,355	635	325	1.59
Asturias (SP)	37	10,674	113	274	0.57
Hawaii (US)	31	24,973	1,048	163	6.52
Louisiana (US)	35	22,073	4,273	98	1.65
Valle D'aosta (IT)	37	21,882	114	89	0.57
Wyoming (US)	35	30,726	472	5	1.80
Canarias (SP)	31	9,994	1,440	510	1.80
West Virginia (US)	35	15,507	1,878	78	1.37
Okinawa (JA)	31	14,695	1,185	1,342	0.87
Kanagawa (JA)	38	22,460	7,567	8,042	0.35
Hokkaido (JA)	31	19,068	5,647	174	0.87
Extremadura (SP)	31	6,912	1,098	68	0.51
Pais-Vasco (SP)	38	13,031	2,143	757	0.57

Notes: GDP per capita: 1990 U.S. dollars averaged over the sample period. Population: thousand persons averaged over the sample period for each region. Population density: persons/square miles averaged over the sample period. Distantness: GDP-weighted average of the distances in thousands of miles from the capital city of a region to the capital cities of the other regions in the risk-sharing group. The first column shows the sector in which the region is "most specialized"—see footnote 20 for a precise definition. 31: Food, beverages, and tobacco. 33: Wood and wood products including furniture. 35: Chemicals and chemical petroleum, coal, rubber and plastic products. 37: Basic metal industries. 38: Fabricated metal products, machinery, and equipment. IT: Italy, US: United States, SP: Spain, JA: Japan.

is from 0 to 1. In order to limit the influence of small highly specialized regions, the data are weighted by region-by-region manufacturing GDP in all regressions.[21] The risk-sharing measures are "generated regressors" and simple ordinary least-squares (OLS) standard errors may be biased. The standard errors reported are therefore estimated via a Monte Carlo procedure[22]—details are supplied in Appendix B.

In Table 3, we display results from OLS regressions. Regressors that vary by risk-sharing group, but not by region, are marked with the superscript "*."

Effect of Risk Sharing on Industrial Specialization.—We find a significant positive coefficient for both the income insurance measure, β_K, and the overall consumption insurance measure, β, as predicted by the theories that motivate this paper. The magnitude of the coefficient on β_K in the first column of the table is interpreted as follows: moving from no insurance ($\beta_K = 0$) to perfect insurance ($\beta_K = 1$) increases the log-transformed specialization index by 19 percent of its range in our sample.[23] The coefficients on income insurance (β_K) and overall consumption insurance (β) in all the columns are very similar.[24]

GDP, Population Density, Volatility.—We see a U-shaped, statistically significant, impact of group-level GDP on the specialization of regions confirming results in Imbs and Wacziarg (2003). We also see the expected negative impact on specialization of region size as mea-

[21] We obtained similar results using region-by-region log-population as weights. We also obtained similar results—with slightly lower t-statistics—using the inverse of a group-specific residual standard error (after using log-manufacturing weights in a first-stage regression). The latter weights address potential "clustering" effects.

[22] For our data, OLS standard errors turned out to be very similar.

[23] In Table 1, we displayed the risk-sharing measures in percent. In the regressions, they take values between 0 and 1.

[24] We do not tabulate the details, but we found that if "distantness" is left out from the regressions displayed in Table 3, β is no longer significant. In our data, β is negatively correlated with distantness—a result that survives when we control for other regressors—and this spatial pattern leads to a downward bias in β when "distantness" is omitted. The spatial pattern in our data is consistent with less consumption insurance between distant regions as documented for example by Andrew K. Rose and Charles Engel (2002) for country-pairs. By contrast, the estimated coefficient to income insurance, β_K, is robust to whether "distantness" is included or not.

TABLE 3—REGRESSION RESULTS (WEIGHTED OLS)
DEPENDENT VARIABLE: SPECIALIZATION INDEX log $SPEC_i$

	Full sample						Federations only	
Income insurance*, β_K	0.23	0.19	0.20	0.26	0.19	—	0.40	—
	(2.77)	(2.32)	(2.45)	(2.00)	(2.38)	—	(1.76)	—
Consumption insurance*, β	—	—	—	—	—	0.19	—	0.29
	—	—	—	—	—	(2.01)	—	(0.69)
GDP*	−1.60	−1.66	−2.00	−1.90	−1.24	−0.73	−2.72	−0.76
	(2.44)	(2.63)	(2.93)	(2.86)	(1.92)	(1.37)	(1.96)	(1.02)
$(\text{GDP*})^2$	0.43	0.45	0.54	0.53	0.32	0.16	0.74	0.16
	(2.31)	(2.51)	(2.77)	(2.74)	(1.74)	(1.08)	(1.86)	(0.80)
Population density	0.20	0.16	0.16	0.15	0.20	0.16	0.22	0.23
	(2.90)	(2.30)	(2.32)	(2.18)	(2.88)	(2.32)	(2.72)	(2.80)
Log-population	−0.03	−0.04	−0.00	−0.04	−0.04	−0.04	−0.08	−0.07
	(2.06)	(2.56)	(2.70)	(2.56)	(2.60)	(2.42)	(3.47)	(2.99)
Log-distantness	0.03	0.03	0.04	0.06	0.05	0.07	0.02	0.10
	(1.45)	(1.46)	(1.86)	(1.98)	(2.24)	(3.51)	(0.55)	(2.05)
Mining GDP share	—	0.54	0.60	0.57	0.83	0.50	0.76	0.67
	—	(1.29)	(1.43)	(1.37)	(1.93)	(1.19)	(1.58)	(1.37)
Agriculture GDP share	—	−1.49	−1.76	−1.74	−0.94	−1.62	−2.06	−2.06
	—	(2.34)	(2.63)	(2.60)	(1.41)	(2.54)	(2.71)	(2.64)
GDP volatility*	—	—	−5.64	—	—	—	—	—
	—	—	(1.22)	—	—	—	—	—
Human capital*	—	—	—	−0.04	—	—	—	—
	—	—	—	(1.01)	—	—	—	—
Manufacturing GDP share	—	—	—	—	0.51	—	—	—
	—	—	—	—	(2.31)	—	—	—

Notes: "*" indicates a variable which varies by risk-sharing group but not by region. GDP* is the per capita GDP of the risk-sharing group in 1990 U.S. dollars, averaged over the sample period. GDP volatility is the standard deviation of Δ log GDP of the risk-sharing group. Human capital is average years of secondary schooling in total population aged over 25. Mining (agriculture, manufacturing) GDP share: average (over the sample) of the share in total GDP of mining (agriculture, manufacturing) GDP in each region. For the definition of the other variables, see Tables 1 and 2. The dependent variable has been normalized to take values from 0 to 1 in our sample. 158 observations. Weights: log-manufacturing GDP in 1990 dollars averaged over the sample period. *t*-statistics are in parentheses. "Federations only" refers to the sample without the two groups of countries (EC and non-EC).

sured by log-population. To illustrate how the magnitude of these coefficients should be interpreted, recall that the dependent variable in our sample was normalized to lie between 0 and 1. An increase of 1 in log-population, which corresponds to a near-tripling of the population, will reduce specialization by 3 to 4 percent of its range.

Population density has a positive effect on specialization. This suggests that firms in sectors with high transportation costs cluster in densely populated regions while sparsely populated regions do not seem to specialize in sectors with low transportation costs.[25]

Group-level GDP volatility (the standard deviation of Δ log GDP) affects specialization negatively (with a *t*-statistic of 1.25) which is consistent with the findings in Ramey and Ramey (1995) and Acemoglu and Zilibotti (1997). An important mechanism behind this result may be that in the presence of *uninsured* risk, countries and regions are more reluctant to take on additional risks by specializing. This, in turn, can lead to lower growth.

Determinants of Trade.—The region-by-region GDP share of the mining sector has a positive impact on specialization, suggesting that manufacturers in related industries tend to agglomerate in areas rich in natural resources.

[25] If we include the region-by-region manufacturing GDP share as a further control, we obtain a positive and statistically significant coefficient. We do not have a convincing interpretation for the sign of this coefficient but, for the present purpose, the important result is that the inclusion of the manufacturing GDP share does not affect the coefficient of the risk-sharing measure.

Likely, this is due in great part to chemical industry locating in oil-rich states. The negative coefficient on the region-by-region GDP share of agriculture suggests that agglomeration of processed food manufacturers does not take place in agricultural states, or that its effect on overall specialization in manufacturing is small (and the negative significant coefficient is due to the share of agriculture proxying for some other determinant of specialization in manufacturing).

Higher human capital at the group level (average years of secondary schooling in total population aged over 25) affects specialization positively with a t-statistic of 1.17. While the coefficient is not significant at conventional levels, the result is consistent with the view that human capital provides an indication of economic development beyond that provided by the level of per capita GDP.

Including the dummy variables "coastal" that measures access to water transportation and "customs union" resulted in insignificant coefficients and almost no change in the coefficients on the other variables. For brevity, these results are not tabulated.

The coefficient on "distantness" is *positive*—contrary to the theoretical prediction—and more significant when the measure of overall consumption insurance is used. An inspection of the data reveals that, contrary to the theory, remote regions like Alaska and Montana are highly specialized.[26]

Are the Results Driven by the Dichotomy "Federations versus Groups of Countries?"—The answer is no. In the last two columns of Table 3, we display the same regressions for a restricted sample which leaves out groups of countries ("Federations only"). The t-statistics are somewhat lower due to the smaller sample size, but the coefficients are remarkably similar to those displayed in the previous columns—the coefficients to the risk-sharing measures are actually somewhat larger.[27] In Figure 1, we display the regression of the region-by-region specialization on the income insurance measure after all the other regressors have been controlled for.[28] The solid regression line is for the entire sample and the dashed line is for the sample that contains no groups of countries—both have a clear positive slope. These results show that the estimated impact of risk sharing on specialization is not driven by the effect of

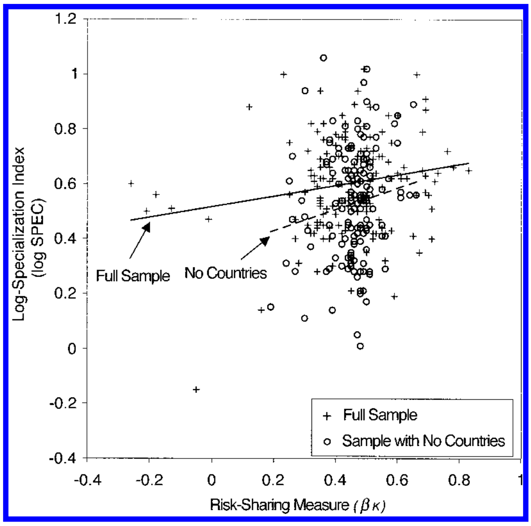

FIGURE 1. REGRESSION OF REGION-BY-REGION SPECIALIZATION ON GROUP-LEVEL RISK SHARING AFTER CONTROLLING FOR OTHER REGRESSORS.

Notes: We first regressed the specialization index on the regressors other than β_K and took the residuals, which we then regressed on the residuals from a regression of β_K on the other regressors (including a constant in both regressions). The coefficient on β_K is then exactly the same as the coefficient in the multiple regression. In the graph, we added the mean value of β_K to the observations on the horizontal axis and the mean value of the specialization index to the observations on the vertical axis for easier interpretation. The solid regression line is for the entire sample and the dashed line is for the sample that contains no groups of countries.

[26] We verified that the positive coefficient on "distantness" is not driven by the potential outliers Alaska and Hawaii.

[27] Alternatively, we ran the regressions with dummy variables for federations versus country groups, interacted and not interacted with the risk-sharing measures. We obtained similar results for federations, but insignificant results for country groups due to the small number (two) of such groups.

[28] We regressed the specialization index on the regressors other than β_K and took the residuals which we then regressed on the residuals from a regression of β_K on the other regressors (including a constant). The coefficient on β_K is then exactly the same as the coefficient in the multiple regression. In the graph, we added the mean value of β_K to the observations on the horizontal axis and the mean value of the specialization index to the observations on the vertical axis for easier interpretation.

country borders which could proxy for various forms of trading costs.

Instrumental Variables Estimation.—Causality may run in the opposite direction. For example, one might imagine a federation with geographic or demographic characteristics that render high regional specialization particularly attractive. The amount of risk sharing among regions may then respond to the need for insurance arising from the specialized regional production structure. Instruments are available that are less likely to be affected by reverse causality. In particular, we use quantitative indicators of investor protection suggested by La Porta et al. (1997, 1998).[29] They tabulate eight different measures of which we selected the two that provided the best fit to the risk-sharing measures in an initial regression. Alternatively, we use the (time-averaged) GDP share of financial services, insurance, and real estate (FIRE) which is a more direct measure of the development of the financial sector. Its drawback is that it is conceivably endogenous to specialization even more than the legal environment indicators. The empirical results, displayed in Table 4, show little sensitivity to which instrument we use and the results are very similar to those displayed in Table 3 using OLS.[30] Overall, the instrumental variables regressions support the conclusions from the OLS regressions and suggest that there may be a causal relation running from insurance to specialization.[31]

TABLE 4—REGRESSION RESULTS (WEIGHTED IV)
DEPENDENT VARIABLE: SPECIALIZATION INDEX log SPEC_i

Instrument	Shareholder rights	FIRE	Shareholder rights	FIRE
Income	0.21	0.20	—	—
insurance*, β_K	(2.37)	(2.24)	—	—
Consumption	—	—	0.25	0.28
insurance*, β	—	—	(2.06)	(2.17)
GDP*	−1.75	−1.69	−0.72	−0.70
	(2.68)	(2.63)	(1.30)	(1.24)
(GDP*)^2	0.47	0.45	0.16	0.15
	(2.52)	(2.46)	(1.04)	(0.96)
Population	0.16	0.16	0.15	0.14
density	(2.33)	(2.32)	(2.13)	(1.98)
Log-population	−0.04	−0.04	−0.03	−0.03
	(2.48)	(2.51)	(1.64)	(1.56)
Log-distantness	0.03	0.03	0.07	0.07
	(1.42)	(1.42)	(3.27)	(3.17)
Mining GDP	0.54	0.54	0.49	0.48
share	(1.29)	(1.32)	(1.17)	(1.14)
Agriculture GDP	−1.46	−1.48	−1.56	−1.53
share	(2.25)	(2.31)	(2.47)	(2.38)

Notes: See notes to Table 3. Weights: log-manufacturing GDP in 1990 dollars averaged over the sample period. *t*-statistics are in parentheses. Instruments: GDP of the FIRE (Finance, Insurance, and Real Estate) sector as a fraction of GDP* averaged over time for each risk-sharing group; Shareholder rights (also at the risk-sharing group level): (i) a dummy variable which takes the value 1 if minority shareholders (who own 10 percent of equity or less) can challenge the decisions of management, and (ii) the percentage of equity needed to call an extraordinary shareholders' meeting. The first-stage regressions on "Shareholder rights" yield an R^2 of 0.68 for β_K and 0.55 for β. (Using the two measures of "Shareholder rights," we tested for the validity of the instruments. The data easily pass this test.) The first-stage regressions on FIRE yield an R^2 of 0.45 for β_K and 0.79 for β.

Have Risk Sharing and Specialization Changed Over Time?—A panel regression of the year-by-year specialization indices of each region on a time trend yields a small negative coefficient, suggesting that specialization has been slowly decreasing over time. (For brevity, these results and those discussed next are not presented in tables.) It is also true that risk sharing has been increasing over time.[32] Does this mean that the relation between risk sharing and specialization no longer holds? To address this important question, we split our (relatively

[29] For example, an indicator of investor protection is whether a small fraction of stockholders can call an extraordinary stockholders' meeting. La Porta et al. (1997) provide evidence that shareholder protection is a determinant of national stock market capitalization (the premier institution for nationwide risk sharing). La Porta et al. (1998) argue that shareholder protection is determined by the "legal environment" which itself is historically determined. See, however, Acemoglu and Zilibotti (1999) and Raghuram Rajan and Luigi Zingales (2000) who argue that institutions that facilitate risk sharing do evolve over time.

[30] Using two measures of investor protection allows us to test for the validity of these instruments. The data easily pass this test.

[31] We ran the same regressions for the restricted sample which leaves out groups of countries. The results are similar and, in particular, the coefficients to the measures of risk sharing are larger in magnitude and marginally significant (details not shown).

[32] See Asdrubali et al. (1996), who document an increase in β_K for U.S. states during the period 1963–1990.

short) sample in two. We, indeed, find a slight decline in the average value of the specialization index, from 0.53 to 0.48, and a slight increase in the average value of β_K, our measure of income insurance, from 35 percent to 36 percent. We repeated the analysis of Table 3 for each subperiod separately. The coefficients of the various regressors are quite stable across the subperiods. The coefficient of β_K declines slightly in the late period but it is positive and statistically significant in both periods. These findings suggest that the relation between risk sharing and specialization remains important despite the slow change in these variables.

V. Summary

We provided evidence that risk sharing and industrial specialization are positively related using a large data set that combines international and intranational (interregional) information. We demonstrated that this relation is robust when we control for other regressors that might potentially affect specialization, in particular, determinants of trade. The relation is also not driven by higher barriers to international versus interregional trade. The results of instrumental variables regressions are consistent with a causal relation running from risk sharing to industrial specialization (although no perfect instruments are available).

Appendix A: Data

1. **OECD:** We use data from the *OECD National Accounts Volume 2, Revision 1996*, for population, national Consumer Price Indices (CPI), Gross Domestic Product (GDP), consumption, national income, national disposable income, and corporate saving for the years 1971–1993; and for manufacturing GDP by type of activity (at current prices) for the years 1977–1993.

   Manufacturing data are available by 2-digit ISIC sectors (see below) for 12 countries (Austria, Belgium, Canada, Denmark, Finland, France, Greece, Netherlands, New Zealand, Norway, United States, West Germany) for the period 1977–1993. We use seven of the nine ISIC 2-digit manufacturing sectors, leaving out the very heterogeneous sector "Other." No data are available for "wood and wood products."[33] We use Net National Income minus corporate saving as the country-level equivalent to personal income. Corporate saving is not available for all countries or years. To avoid using different countries in the calculation of specialization and risk sharing, we used only the countries for which we were able to calculate both. This issue is discussed below for the relevant subsets of the OECD sample. Exchange rate data are from the *IMF International Financial Statistics* database. Land area is from the *Statistical Abstract of the United States* (1997).

   We form two subsets of OECD data. **EC:** For manufacturing, data are available at the 2-digit level for six countries (Belgium, Denmark, France, Greece, Netherlands, West Germany) for the period 1977–1993. Greece is omitted since it is an outlier in the group in terms of income per capita. Corporate saving data are not available for Denmark 1971–1980, and for the Netherlands 1971–1976 and for Denmark and the Netherlands these years are not used in the measurement of risk sharing, whereas for other countries the entire sample period (1971–1993) is used. **Non-EC:** We use data for Austria, Canada, Finland, and the United States. We are restricted to this limited sample since corporate saving data are not available for several countries.
2. **United States:** We use state-level data from the Bureau of Economic Analysis (BEA). Data for manufacturing Gross State Product (GSP) at current prices at the industry level are available by state for the period 1977–1994. (Washington, DC is very atypical and is omitted.) We utilize BEA data for 21 manufacturing subsectors, which we aggregate to nine ISIC 2-digit levels. Data for total GSP, personal income, personal disposable income, retail sales, and population by state are also from the BEA for the years 1977–1994. Data are transformed to fixed prices

[33] To get a sense of how serious this omission might be, we exploited the availability of these data for U.S. states and calculated indices of specialization with and without the wood sector for all U.S. states. The results were not sensitive to the omission of the wood sector so we believe that the nonavailability of wood sector data for the OECD countries is a minor issue.

using the United States national CPI.[34] Land area is from the *Statistical Abstract of the United States* (1997).

3. **Canada:** Data for Canadian provinces are available from the CANSIM database maintained by Statistics Canada. We use manufacturing GDP at factor cost (at current prices) for each industry by province for the period 1987–1993. The 3-digit data (21 sectors) are aggregated to the same 2-digit sectors as the United States BEA data. (At the 3-digit level our data sources are not compatible.) The data are available for five provinces (Alberta, British Columbia, Manitoba, Ontario, Quebec) for 1987–1993. Personal income, consumption, population, and regional CPI are also available from CANSIM. The risk-sharing measure is computed for the period 1979–1995 for the same five provinces. Data are transformed to real terms using each province's own yearly consumer price indices. Exchange rate data are from the *IMF International Financial Statistics* database. Land area is also from CANSIM.
4. **Japan:** For the manufacturing sublevels, we use employment data from the *Statistical Yearbook for Japan,* various issues, 1979–1993. The data are available at the 3-digit level (21 sectors) and aggregated to 2-digit sectors that are consistent with the data for the United States. Total GDP, personal income, consumption, prefectural CPI, and population by prefecture are from the *National Accounts—Japanese Prefectural Data* published by Sinfonica. The risk-sharing measure is computed for the period 1975–1993. Total manufacturing GDP for Japanese prefectures is from *Annual Report on Prefectural Accounts 1997,* published by the Economic Planning Agency of Japan. It covers all prefectures in various years. We have data for all prefectures for 1975, 1980, 1985, 1990, 1991, 1992, and 1993. Current price data are deflated using the prefectural consumer price index. Exchange rate data are from the *IMF International Financial Statistics* database. Land area is from the *Statistical Yearbook.*
5. **Italy:** For regional manufacturing 2-digit sectors, we use gross value added at factor cost (at current prices) from Eurostat's regional database REGIO. The sample is 1960–1995. Unfortunately, there are no data for the wood sector. Total manufacturing GDP, population, and land area are also from this source. The data are available for all Italian regions for the years 1975–1994. The risk-sharing measure is calculated for the period 1983–1992 using all regions. The data are from *Conti economici regionali delle amministrazioni publiche e delle famiglie,* Italian National Institute of Statistics—Istituto Nazionale di Statistica (ISTAT).[35] We used total GDP, personal disposable income, consumption, population, and total CPI. Personal income is calculated as personal disposable income plus taxes. The specialization indices are also calculated for 1983–1992 to be compatible with the risk-sharing measure. ECU exchange rate data are from the *IMF International Financial Statistics* database.
6. **Spain:** For the manufacturing sectors of communities of Spain, we use gross value added at factor cost (at current prices) at the 2-digit level, from Eurostat's regional database REGIO. Again, wood sector data are not available. Total manufacturing GDP, population, and land area are also from this source. Data are available for 16 communities of Spain (out of 18) for the period 1980–1992. We do not have data for the Baleares and Ceuta y Melilla. The risk-sharing measure is calculated for the period 1981–1991 using the same 16 communities. Data for regional GDP, personal income, consumption, population, and CPI are available biannually from the Spanish National Institute of Statistics—Instituto Nacional de Estadistica (INE)—*Regional Accounts of Spain,* various issues.
7. **United Kingdom:** For the regional U.K. manufacturing sectors, we use gross value added at factor cost (at current prices) from

[34] Marco del Negro (1998) constructs price indices for individual states but finds that risk-sharing regressions are not substantially affected by using state-specific price indices rather than the U.S.-wide price index. For other risk-sharing groups we found that our results change little if national CPI is used rather than regional CPIs.

[35] The data were kindly provided by Jacques Mélitz and Frédéric Zumer to whom we are very grateful; see Mélitz and Zumer (1999).

Eurostat's regional database REGIO. The data for the wood, non-metallic mineral products, and basic metal industry sectors are not available. Total manufacturing GDP, population, and land area are also from this source. Data are available for all U.K. regions for the period 1978–1993. The risk-sharing measure is calculated for the period 1978–1993 using data from the Regional Trends 1965–1995 CD-ROM from the Office of National Statistics. We further use total GDP, personal income, personal disposable income, consumption, population, and total CPI from the same source.

The 2-digit ISIC manufacturing level codes (Revision 2) are:

ISIC Code	Category
31	Food, beverages, and tobacco
32	Textile, wearing apparel, and leather industries
33	Wood and wood products, including furniture
34	Paper and paper products, printing and publishing
35	Chemicals and chemical petroleum, coal, rubber and plastic products
36	Non-metallic mineral products, except products of petroleum and coal
37	Basic metal industries
38	Fabricated metal products, machinery, and equipment
39	Other manufactured products*

* Not included in our sample.

Appendix B: Estimation of Standard Errors

Since the risk-sharing measures are obtained from an initial estimation they are random variables, which leads to potential bias in the standard errors reported by OLS. We, therefore, use a "parametric bootstrap" procedure to calculate standard errors for all the coefficients in the cross-sectional regression. (Asymptotically, OLS t-statistics would be consistent for testing if the coefficient to risk sharing is significantly different from zero, by the logic of Adrian Pagan, 1984, although not for testing other null hypotheses.)

We use the following procedure. We regress specialization on the risk-sharing measure β_K and other regressors $\mathbf{X}$ (including a constant) using OLS (after weighting the variables):

$$\mathrm{SPEC}_i = \mathbf{X}_i'\boldsymbol{\gamma} + \beta_{K_i}\delta + e_i,$$

where $i = 1, \ldots, 158$ is an index of the regions in our sample, $\boldsymbol{\gamma}$ and δ are OLS coefficients, and β_{K_i} is the estimated amount of income insurance within the risk-sharing group to which region i belongs; see Table 1. (β_{K_i} takes the same value for regions belonging to the same risk-sharing group.) From this regression we retrieve the estimated values $\hat{\boldsymbol{\gamma}}$ and $\hat{\delta}$ and the estimated standard error s_e of the residuals e_i. We proceed to estimating the standard errors of $\hat{\boldsymbol{\gamma}}$ and $\hat{\delta}$ from the following Monte Carlo experiment. In each iteration l ($l = 1, \ldots, 25{,}000$) we draw from an independently and identically distributed (i.i.d.) $N(0, s_e)$ distribution a vector of variables, $e_i^{(l)}$ ($i = 1, \ldots, 158$). We generate the variable

$$\mathrm{SPEC}_i^{(l)} = \mathbf{X}_i'\hat{\boldsymbol{\gamma}} + \beta_{K_i}\hat{\delta} + e_i^{(l)}.$$

Then, for each risk-sharing group, we generate $\beta_{K_i}^{(l)}$ by drawing from a $N(\beta_{K_i}, \sigma_K)$ distribution where σ_K is the estimated standard error of β_{K_i} reported in percentage terms in Table 1 (for example, 0.044 for the United States). We then regress $\mathrm{SPEC}_i^{(l)}$ on $\mathbf{X}_i'$ and $\beta_{K_i}^{(l)}$ and record the estimated coefficients $\hat{\boldsymbol{\gamma}}^{(l)}$ and $\hat{\delta}^{(l)}$. We repeat this for $l = 1, \ldots, 25{,}000$ and then calculate the standard errors of $\hat{\boldsymbol{\gamma}}^{(l)}$ and $\hat{\delta}^{(l)}$. These are the standard errors reported in the tables.

Because β_K is "measured" with error, the point estimate of the coefficient to β_K is biased towards 0. The Monte Carlo procedure outlined can be used to calculate an adjustment for this bias. However, we found the bias towards zero to be negligible in our regressions.

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