RESEARCH SEMINAR IN INTERNATIONAL ECONOMICS

Gerald R. Ford School of Public Policy
The University of Michigan
Ann Arbor, Michigan 48109-3091

Discussion Paper No. 581

The Risk Content of Exports: A Portfolio View of International Trade

Julian di Giovanni
International Monetary Fund

and

Andrei A. Levchenko
International Monetary Fund
and University of Michigan

October 23, 2008

The Risk Content of Exports: A Portfolio View of International Trade*

Julian di Giovanni
International Monetary Fund

Andrei A. Levchenko
University of Michigan &
International Monetary Fund

October 23, 2008

Abstract

It has been suggested that countries whose exports are in especially risky sectors will experience higher output volatility. This paper develops a measure of the riskiness of a country's pattern of export specialization, and illustrates its features across countries and over time. The exercise reveals large cross-country differences in the *risk content of exports*. This measure is strongly correlated with the volatility of terms-of-trade, total exports, and output, but does not exhibit a close relationship to the level of income, overall trade openness, or other country characteristics. We then propose an explanation for what determines the risk content of exports, based on the theoretical literature exemplified by Turnovsky (1974). Countries with a comparative advantage in safe sectors or a strong enough comparative advantage in risky sectors will specialize, whereas countries whose comparative advantage in risky sectors is not too strong will diversify their export structure to insure against export income risk. We use both non-parametric and semi-parametric techniques to demonstrate that these theoretical predictions are strongly supported by the data.

JEL Classifications: F15, F40

Keywords: Trade, Specialization, Volatility, Risk Content of Exports

---

[*] We would like to thank Michael Alexeev, Christian Broda, Thomas Chaney, Shawn Cole, Pierre-Olivier Gourinchas, Chang-Tai Hsieh, Jean Imbs, Ayhan Kose, Akito Matsumoto, Rodney Ramcharan, Jaume Ventura, seminar participants at various institutions, and especially Romain Rancière for helpful suggestions. Piyush Chandra provided excellent research assistance. The views expressed in this paper are those of the authors and should not be attributed to the International Monetary Fund, its Executive Board, or its management. Correspondence: International Monetary Fund, 700 19th Street NW, Washington, DC, 20431, USA. E-mail (URL): `JdiGiovanni@imf.org` (`http://julian.digiovanni.ca`), `alev@umich.edu` (`http://alevchenko.com`).

1 Introduction

As world international trade experienced dramatic growth over the past few decades, the benefits and costs of increased integration remain a hotly debated topic. In particular, the relationship between trade openness and volatility has received a great deal of attention.[1] One channel for this relationship is through the pattern of specialization: countries that come to specialize in particularly risky sectors after trade opening may experience increased macroeconomic volatility (OECD 2006, Caballero and Cowan 2007). This mechanism is also related to the finding that terms-of-trade volatility is important in explaining cross-country variation in output volatility (e.g., Mendoza 1995). Indeed, differences in terms-of-trade volatility across countries must be driven largely by patterns of export specialization.

However, there is currently no systematic empirical evidence on how countries differ in the riskiness of their export composition. The main goal of this paper is to develop and analyze a measure of the riskiness of a country's export structure, which we call *the risk content of exports*, using a large industry-level dataset of manufacturing and non-manufacturing production and trade.

Examining the patterns of the risk content of exports yields some striking conclusions. First, differences between countries are large quantitatively. Those in the top five percent of the distribution exhibit an average standard deviation of the export sector some 7.5 times larger than those in the bottom five percent. The most risky countries in our sample are typically middle-income countries whose exports are highly concentrated in volatile industries such as Mining and Metals. Advanced countries are in the middle and bottom half of the riskiness distribution. Their exports are typically in medium-risk sectors and fairly diversified. However, diversification is not the only way to achieve a low risk content of exports. Among the countries with the safest export structures are actually some of the poorest and least diversified countries in our sample. Their risk content of exports is low because they specialize in the safest sectors. Thus, differences in riskiness across sectors, in addition to simple diversification, play a big role in shaping the risk content of exports.

Second, the risk content of exports is robustly related to the variance of terms-of-trade, total exports, and GDP growth. As a preview of the results, Figure 1 shows the scatterplot of terms-of-trade volatility against our measure of the risk content of exports. Notably, all of the variation in the risk content measure comes from differences in export patterns, as it does not use any country-specific information on volatility. Nonetheless, there is a close positive relationship between the two

---

[1] A number of cross-country empirical studies analyze the relationship between trade openness and volatility. Easterly, Islam and Stiglitz (2001) and Kose, Prasad and Terrones (2003) find that openness increases the volatility of GDP growth. Kose et al. (2003) and Bekaert, Harvey and Lundblad (2004) also find that greater trade openness increases the volatility of consumption growth, suggesting that the increase in output volatility due to trade is not fully insured. Moreover, Rodrik (1998) provides evidence that higher income and consumption volatility is strongly associated with exposure to external risk, proxied by the interaction of overall trade openness and terms of trade volatility. Recent work by Bejan (2004) and Cavallo (2005) finds that openness decreases output volatility.

variables, suggesting that export specialization does exert an influence on macroeconomic volatility.

Having described the features of risk content of exports and its relationship to macroeconomic volatility, the paper then studies what in turn explains it. Surprisingly, the variation in the risk content of exports is not highly correlated with traditional country-level variables such as income, trade openness, or financial integration. Figure 2 displays the scatterplot of the risk content of exports against per capita income. There is virtually no correlation between these two variables.

What, then, determines risk content of exports? In order to guide the empirical exercise, we appeal to a well-established theoretical literature on trade patterns under uncertainty, going back to Turnovsky (1974) and Helpman and Razin (1978). We present a simple model to illustrate its key insight: when sectors differ in volatility, export patterns are conditioned not only by comparative advantage but also insurance motives. A country may be induced to diversify exports in order to insure against adverse shocks to any one industry. We show that the amount of diversification exhibits a U-shape with respect to the strength of comparative advantage in the risky sector. A country with a comparative advantage in the safe sector will specialize fully. So will the country whose comparative advantage in the risky sector is so strong that it ignores insurance considerations in favor of higher return in the risky sector. At intermediate values of strength of comparative advantage, however, the country will find it optimal to diversify exports.[2]

In order to show that the data support the portfolio view of export patterns, we must find an empirical proxy for the notion of strength of comparative advantage in risky industries. Since comparative advantage is intrinsically difficult to measure directly, our approach borrows from Balassa's (1965) index of revealed comparative advantage. We construct a measure of "risk-weighted comparative advantage" based on the shares of world exports that a country captures in each sector. That is, a country is assumed to have a strong comparative advantage in a given sector if it has a relatively large share of world exports in that sector. We then weight this proxy for strength of comparative advantage by industry-specific volatility to arrive at our main index.

We test for the presence of the U-shape between diversification and comparative advantage in risky sectors using both non-parametric and semi-parametric techniques. In the first exercise, we use locally weighted scatterplot smoothing (Lowess) to estimate this relationship. The advantage of this non-parametric procedure is that it imposes very little structure on the data, and is locally robust: observations far away in the sample have no influence on the estimated local relationship.

---

[2] Note that one of the central points of Helpman and Razin (1978) is that in the presence of international risk sharing, volatility differences across sectors become irrelevant, as countries insure through asset trade and not through production decisions. Empirical evidence brought to bear since then, however, shows that international output risk sharing is quite limited, especially in non-advanced countries. For various approaches that have reached this conclusion, see, among others, Backus, Kehoe and Kydland (1992), Kalemli-Ozcan, Sørensen and Yosha (2003), and Kaminsky, Reinhart and Végh (2005). In our own data, risk content of exports is virtually uncorrelated with available measures of financial integration. Thus, theoretical implications of uncertainty for trade patterns without asset trade are still well worth considering, especially when, as we show below, they are strongly supported by the data.

Its limitation is that it does not allow us to control for other possible determinants of diversification. In the second exercise, we turn to a semi-parametric approach, which controls for a multitude of other covariates of specialization parametrically, while still retaining a fully flexible form of the relationship between the two variables of interest. In both non-parametric and semi-parametric exercises, we present the full set of results using both a cross-sectional sample and a panel of 5-year averages with fixed effects. We show that the U-shape is present and remarkably robust under both estimation techniques, and across various subsamples of industries and time periods. The empirical results thus confirm the main implications of the portfolio view of international trade.

To summarize, the paper's contribution is twofold. First, we develop a measure of export riskiness that can be an important building block for analyzing the relationship between trade openness and volatility. Second, we propose an explanation for the observed variation in this measure across countries, and provide evidence in support of this explanation.

We use data on industry-level value added and employment for the manufacturing and non-manufacturing sectors to construct the covariance matrix. Sector-level manufacturing value added and employment data are taken from United Nations Industrial Development Organization (2005). Value added data for the Agriculture and Mining and Quarrying sectors come from the United Nations Statistical Yearbook (2003). We combine these with employment data in the two sectors from International Labor Organization (2003). The resulting dataset is a three-dimensional unbalanced panel of 69 countries and 30 sectors (28 manufacturing, plus Agriculture and Mining and Quarrying), for the period 1970–99. Trade data over the same time span come from the World Trade Database (Feenstra et al. 2005), which contains information on more than 130 countries.

In order to assess whether countries differ in export structure risk, we must first derive an empirical measure of volatility across industries in our data. We use the production data to estimate a variance-covariance matrix for our set of sectors using a methodology similar to Koren and Tenreyro (2007). The procedure extracts the industry-level time series that can be thought of as a global shock to each sector, from which a full variance-covariance matrix can be calculated. The resulting matrix is country- and time-invariant, and we interpret it as representing the "inherent" volatility and comovement properties of sectors. We then define the risk content of exports as simply the variance of the country's export pattern. Using the estimated covariance matrix and a large panel of industry-level exports data, we calculate this measure for a wide sample of countries and over time. Note that by construction, differences in the risk content of exports across countries arise purely from export patterns. A country's export structure is more risky when its exports are highly undiversified, or when it exports in riskier sectors.

This paper is related primarily to two strands of the literature. The first studies determinants of macroeconomic volatility using industry-level data. Most closely related are the papers by Imbs and Wacziarg (2003) on specialization, and by Koren and Tenreyro (2007) on the decomposition of output volatility into various subcomponents. Our work uses trade data in addition to production in order to focus on the relationship between trade patterns and volatility, the link often implicit but not examined directly in the above studies. Furthermore, we provide evidence on a particular theoretical explanation for cross-country differences in the risk content of exports. A complementary paper (di Giovanni and Levchenko 2007) studies the question of how trade openness changes the volatility of output itself, something that we hold constant here to examine specialization differences instead.

The second strand is the literature on trade patterns under uncertainty. In addition to Turnovsky (1974) and Helpman and Razin (1978), relevant theoretical contributions also include Grossman and Razin (1985) and Helpman (1988). However, so far there has been very little empirical evidence to complement theory. Exceptions include Kalemli-Ozcan et al. (2003) and Koren (2003). These examine the effect of international risk sharing on production specialization and trade volumes, respectively. In this paper we take a step back from the focus on the effects of financial liberalization, and examine instead the key predictions of theory regarding trade patterns.[3]

The paper is organized as follows. The analytical framework is presented in Section 2. Section 3 summarizes the data. Section 4 describes the construction of the risk content of exports and its components. Section 5 presents empirical evidence supporting the portfolio view of export patterns, and Section 6 concludes.

2 Analytical Framework

This section provides a theoretical illustration of what determines a country's export pattern in safe and risky sectors. The insights behind the determinants of trade patterns under uncertainty have been well understood since at least Turnovsky (1974) and Helpman and Razin (1978) (see also Grossman and Razin 1985, Helpman 1988, and more recently Koren 2003). Here we confine ourselves to a simple version of the Turnovsky model, in order to illustrate most clearly the relationships involved and guide the empirical exercise.

Consider a Ricardian economy with one factor, L, three intermediate tradeable goods, and one non-tradeable final consumption good C. There are two safe intermediates M and S, and a risky one, R. Production of all three intermediates is linear in L, such that one unit of labor produces one unit of good M or S. The output of good R is stochastic: one unit of L produces θ units of good R, where θ is a random variable with mean $\bar{\theta}$ and variance σ_{θ}^{2}. The timing of the economy is as follows: first, agents make production decisions in the tradeable intermediates sectors. Then,

---

[3] Our paper complements recent work by Cuñat and Melitz (2006). These authors model how comparative advantage in risky and safe sectors is generated by differences in countries' labor market rigidities. In this paper, we take the underlying determinants of comparative advantage as given and provide a systematic empirical test of the predictions of theory of trade under uncertainty regarding trade patterns.

uncertainty about the stochastic productivity in the R-sector is resolved, and intermediate and final good production takes place. Finally, agents trade and consume. For expositional simplicity, we assume that the country is endowed with one unit of L.

The country is small and can trade costlessly with the rest of the world at exogenously given prices of the three goods.[4] Since R is the risky good, we assume that its world price, p_R, is stochastic, with mean $\bar{p}_R$ and variance σ_p^2. Note that the good R is stochastic in both productivity and price. This is the conceptual equivalent to our empirical analysis, which cannot distinguish between price and quantity volatility. We normalize the price of good M to one, $p_M \equiv 1$, and assume that the country has a comparative advantage in goods S and R vis-à-vis good M: $p_S > 1$ and $\overline{p_R\theta} \equiv E(p_R\theta) > 1$. This ensures that the country always imports good M, and exports S, R, or both.[5]

The non-tradeable final good production uses the three intermediate goods with constant returns to scale: $C = C(c_R, c_S, c_M)$.[6] The price of the final consumption good, P, is the cost function associated with producing one unit of C. We assume that agents' utility is logarithmic in C. After uncertainty has been realized, agents maximize utility in consumption subject to the standard budget constraint given income I. Because agents simply spend their entire income on C, the resulting indirect utility function is:[7]

$$V(I, P) = \ln(I) - \ln(P).$$

Before uncertainty is realized, agents must decide in which sectors to produce. The assumptions put on world prices, namely $p_S > 1$, imply that the economy will never produce good M. The

---

[4] Alternatively, we could adopt a two-country model, and solve for prices from goods market clearing. In order to do so, we would first need to specify the correlation properties of production across countries in each sector. Because of this need to specify the exact cross-country correlation structure of shocks, a multi-country equilibrium model is in fact no more general than the small-country setup considered here. Doing so would also add analytical complexity without changing the basic insights we wish to illustrate. Thus we stick to the original Turnovsky setup.

[5] Note that none of the results will change if there is a large number of M goods, or if the production of good M is stochastic, as long as the country has an average comparative advantage in the good S.

[6] For the purposes of deriving the results, we need not specify the precise functional form of this production function, due to the fact that under the small country assumption we don't have to solve for prices, which are given exogenously. To be concrete, one can think of $C(c_R, c_S, c_M)$ as a CES aggregator, for instance.

[7] The logarithmic utility is not necessary for the results, but adds some analytical tractability. When the volatility in good R comes exclusively from uncertainty in θ (that is, price p_R is constant), all of the results in this Section go through under a wide class of utility functions. With price volatility, there is one extra complication, because both arguments in the indirect utility $V(I, P)$ are stochastic. For a general functional form, this can give rise to the well-known hedging demands: there may be an incentive for the country to specialize in the risky sector, because it provides some amount of insurance against fluctuations in the overall price level: in states when the world price realization is high, the price of the optimal consumption basket will be high, but so will the revenue from the risky sector. A convenient property of log utility is that it removes the hedging demands from the portfolio problem, and thus lets us proceed treating volatility in θ and p_R symmetrically. For a general utility function, hedging demands become weaker as the share of the risky industry in the overall domestic consumption basket decreases. All the results presented in this Section then still go through under a more general utility function and with price volatility as long as the effect of the fluctuations in the stochastic export price on the domestic consumption price level is not too strong (for more on this see Turnovsky 1974, and Helpman and Razin 1978, ch. 4).

strength of comparative advantage between the safe and risky sectors, $\overline{p_R\theta} - p_S$, as well as the volatility of the risky sector, $\text{Var}(p_R\theta) \equiv \sigma_R^2$, will determine the pattern of specialization in R and S.[8] In particular, let L_R be the share of the labor force employed in the risky sector. The economy will solve the following utility maximization problem:

$$\begin{aligned} &\max_{L_R} \text{E}\{\ln(I) - \ln(P)\} \\ &\qquad s.t. \\ &I \leq p_R\theta L_R + p_S(1 - L_R). \end{aligned} \tag{1}$$

It is immediate that when written as a planning problem, the specialization decision is identical to the textbook portfolio choice problem with one risky and one safe asset. As Appendix A demonstrates, the equilibrium allocation that solves this maximization problem is equivalent to a decentralized competitive general equilibrium outcome with many identical consumers-owners of firms and entrepreneurs, in which firms make production decisions to maximize net shareholder value (see also Helpman and Razin 1978, chs. 5–6).

This is an optimization problem with one decision variable L_R, which leads to the following familiar first-order condition:

$$\text{E}\left\{V_I\left(p_R\theta L_R + p_S(1 - L_R)\right)\left(p_R\theta - p_S\right)\right\} = 0, \tag{2}$$

where V_I denotes the derivative of $V(I, P)$ with respect to I. As a preliminary point, in the absence of uncertainty — when $p_R\theta$ always takes on a given value $\tilde{p}_R\tilde{\theta}$ — there is complete specialization as in any standard Ricardian model:

$$\begin{aligned} \tilde{p}_R\tilde{\theta} > p_S &\Longrightarrow L_R = 1 \\ \tilde{p}_R\tilde{\theta} < p_S &\Longrightarrow L_R = 0. \end{aligned}$$

When $p_R\theta$ is stochastic, a Taylor approximation for V' around $\overline{p_R\theta}$ yields the following familiar solution to the optimal portfolio problem:

$$L_R = \frac{\overline{p_R\theta} - p_S}{\sigma_R^2\lambda}, \tag{3}$$

where λ is the coefficient of absolute risk aversion, $\lambda = -V_{II}/V_I$.

There are several cases to consider. First, if the country has an average comparative advantage in the safe sector, $\overline{p_R\theta} < p_S$, it will specialize completely in the S-sector. If it has an average comparative advantage in the risky sector, $\overline{p_R\theta} > p_S$, it will optimally choose specialization, L_R, to trade off the higher return in the R-sector against the insurance provided by the S-sector. If the

---

[8] We can use the Taylor approximation to show that $\text{Var}(p_R\theta) \approx \bar{p}_R^2\text{Var}(\theta) + \bar{\theta}^2\text{Var}(p_R) + 2\overline{p_R\theta}\text{Cov}(p_R, \theta)$. We assume throughout that $\text{Cov}(p_R, \theta)$ is such that $\text{Var}(p_R\theta)$ is strictly positive.

comparative advantage $(\overline{p_R\theta} - p_S)$ is not too strong, it will reach an interior solution, $0 < L_R < 1$. Finally, for a given p_S there exists a threshold $\left[\overline{p_R\theta}\right]_H$, such that for all $\overline{p_R\theta} > \left[\overline{p_R\theta}\right]_H$ the country specializes fully in good R $(L_R = 1)$, in spite of the fact that it is more risky. That is, if the comparative advantage in the risky sector is strong enough, the country will produce only in the risky sector, ignoring insurance considerations.[9]

To summarize, $L_R = 0$ when the country's comparative advantage in the risky sector in nonexistent, and $L_R = 1$ when it is sufficiently strong. How does the optimal structure of production L_R depend on comparative advantage when L_R is interior? Using equation (3) and the functional form for $\lambda = 1/\left[\overline{p_R\theta}L_R + p_S(1 - L_R)\right]$, it is easy to check that $\frac{dL_R}{d(\overline{p_R\theta} - p_S)} > 0$: holding σ_R^2 constant, stronger comparative advantage in the risky sector raises the share of production allocated to that sector.[10]

Thus, the most important result for the purposes of this paper is that the economy will specialize if its comparative advantage is in the safe sector, or if its comparative advantage in the risky sector is sufficiently strong. In the intermediate cases, the country will diversify its exports between the risky and safe sectors. Furthermore, its allocation to the risky sector increases monotonically in the strength of its comparative advantage. This latter result implies that export diversification exhibits a U-shape with respect to comparative advantage: the country is most diversified for some intermediate value of comparative advantage in the risky sector, and it begins specializing progressively more in the safe (risky) sector as it becomes better at producing the safe (risky) good.

This result is illustrated graphically in Figure 3. On the horizontal axis is the strength of comparative advantage in the risky sector. On the vertical axis, the top panel shows the optimal factor allocation to the risky sector, L_R, while the bottom panel shows the Herfindahl index of export shares, which is our theoretical and empirical measure of export diversification.

Before turning to the data, it is worth making an additional remark. One of the central points of Helpman and Razin (1978) is that if countries are allowed to trade not only goods but also assets, there is no incentive to insure through changing the production structure, and therefore riskiness of industries is irrelevant for the export pattern (see also Saint-Paul 1992). The case of

---

[9] The easiest example is one in which the support of $p_R\theta$ has a finite and positive minimum value, $[p_R\theta]_{\min}$, and even at that worst realization of $p_R\theta$, the country still has a comparative advantage in the risky sector, $[p_R\theta]_{\min} > p_S$.

[10] This seems like a very sensible result, and while it holds for a wide range of functional forms, it may not hold for all concave utility functions. The reason is that as the mean return to the risky asset becomes higher, there are both income and substitution effects. The latter implies a shift towards the risky asset, as its relative price has decreased. But the agent now has a higher expected income achievable at any given level of risk. In some cases, the agent may choose to use the increased income to purchase additional insurance, and an increase in the return to the risky asset may actually lower its portfolio share. It turns out that L_R increases in the strength of comparative advantage in the risky sector as long as the derivative of the coefficient of absolute risk aversion with respect to wealth is less than some positive threshold. That is, what matters is not how risk averse the agents are per se, but how fast that risk aversion increases in wealth. For instance, the result will always obtain if the utility function exhibits Constant Absolute Risk Aversion (CARA), no matter how high the risk aversion. By contrast, it may fail to hold only when absolute risk aversion increases sufficiently steeply in wealth. Proof is available from the authors upon request.

no international risk sharing is still well worth considering, however. Available empirical evidence shows that there is little or no risk sharing across countries, especially non-advanced ones (Backus et al. 1992, Kalemli-Ozcan et al. 2003, Kaminsky et al. 2005). Thus, the no asset trade assumption appears to be more relevant empirically, at least when it comes to asset trade for the purposes of insurance. Furthermore, the model with asset trade delivers empirical predictions clearly distinct from ours, and we use our data to determine which set of assumptions is supported. The semi-parametric estimation exercises below control for differences in levels of financial integration across countries, leaving the results unchanged.

3 Data

In order to perform the analysis, we require industry-level panel data on both production and trade. For the manufacturing sector, industry-level value added and employment come from the 2005 UNIDO Industrial Statistics Database, which reports data according to the 3-digit ISIC Revision 2 classification for the period 1963–2002 in the best cases. There are 28 manufacturing sectors in total, plus the information on total manufacturing. We dropped observations that did not conform to the standard 3-digit ISIC classification, or took on implausible values, such as a growth rate of more than 100 percent year to year. We also corrected inconsistencies between the UNIDO data reported in U.S. dollars and domestic currency. The resulting dataset is an unbalanced panel of 59 countries, but we ensure that for each country-year there is a minimum of ten sectors, and that for each country, there are at least ten years of data.

The difficulty we face is that much of world trade is in non-manufacturing industries. Thus, we supplement the UNIDO manufacturing data with information on value added in Agriculture, Hunting, Forestry and Fishing ("Agriculture" for short), and Mining and Quarrying ("Mining") sectors from the United Nations Statistical Yearbook (2003). Unfortunately, a finer disaggregation of output data in these sectors is not available. Furthermore, this data source also does not contain information on employment in these sectors for a large enough set of countries and years. Thus, we obtain employment data from International Labor Organization (2003), and combine them with the United Nations Statistical Yearbook (2003) value added data. We inspect each data source for jumps due to reclassifications, and remove countries for which less than eight years of observations are available. The intersection of value added and employment observations for these two non-manufacturing sectors contains data for 39 countries for at most 31 years. There is not a perfect overlap with the manufacturing data: for eight countries non-manufacturing data are available, but manufacturing data are not. The non-manufacturing sample contains a number of important agricultural and natural resource exporters, such as Australia, Canada, Brazil, Chile, Indonesia, Mexico, Norway, United States, and Venezuela.

We use data reported in current U.S. dollars, and convert them into constant international dollars using the Penn World Tables (Heston, Summers and Aten 2002).[11] Appendix Table A1 reports the list of countries in our sample, along with some basic descriptive statistics on the average growth rate of value added per worker and its standard deviation. We break the summary statistics separately for Agriculture, Mining, and total Manufacturing, in order to compare growth rates coming from different datasets, and show for which countries and sectors data are available. There is some dispersion in the average growth rates of the manufacturing output per worker, with Honduras and Tanzania at the bottom with average growth rates of -5.5 percent and -3.9 percent per year over this period, and Malta at the top with 10 percent per year. The rest of the top 5 fastest growing countries in manufacturing productivity are Ireland, Korea, Indonesia and Singapore. There are also differences in volatility, with France and United States having the least volatile manufacturing sector, and Senegal and Philippines the most. The range of growth rates in Agriculture is somewhat narrower, ranging from -2.5 percent for Mexico to 8 percent for Estonia and 6.6 percent in Barbados. Mining growth rates are quite a bit more volatile, with an average growth rate of 20 percent in Portugal being the highest. Appendix Table A2 lists the sectors used in the analysis, along with the similar descriptive statistics. Growth rates of value added per worker across sectors are remarkably similar, ranging from roughly 2 percent per year for Food Products and Agriculture to 6.5 percent for Petroleum Refineries and 7.2 percent for Mining. Individual sectors have much higher volatility than manufacturing as a whole, and differ among themselves as well. The least volatile sector, Agriculture, has an average standard deviation of 11.4 percent. The most volatile sector is Mining and Quarrying, with a standard deviation of 35.7 percent.

Data on international trade flows come from the World Trade Database (Feenstra et al. 2005). This database contains bilateral trade flows between some 150 countries, accounting for 98 percent of world trade. Trade flows are reported using the 4-digit SITC Revision 2 classification. We aggregate bilateral flows across countries to obtain total exports in each country and industry. We then convert the trade flows from SITC to ISIC classification and merge them with production data. The final sample contains trade flows of 130 countries for the period 1970–99, giving three full decades.

4 The Risk Content of Exports

The main purpose of this paper is to document in a systematic way whether some countries specialize in more or less risky sectors, or perhaps in sectors that exhibit especially high or low covariances. In order to do so, it is first necessary to develop a measure of inherent sectoral volatility, or indeed

---

[11] Using the variable name conventions from the Penn World Tables, this deflation procedure involves multiplying the nominal U.S. dollar value by $(100/P) * (RGDPL/CGDP)$ to obtain the constant international dollar value.

the entire variance-covariance matrix of sectors. We thus use the production data to construct a covariance matrix for the sectors using a method similar to Koren and Tenreyro (2007), which produces a sector-level covariance matrix that is common across countries and years. We then use export shares for each available country and time period to construct a summary measure of riskiness of a country's export structure. The risk content of exports is simply the variance of the overall export structure of the economy.

This section describes in detail the steps of constructing the measure of the risk content of exports, as well as its basic features across countries and over time. We also attempt to disentangle pure diversification effects from the average riskiness of the export sector. Because it is built using information on sector riskiness and export shares, the risk content of exports will be high if a country's exports are undiversified, and/or if it specializes in risky sectors.

The main conclusions of this exercise can be summarized as follows. There is a great deal of variation in the risk content of exports among countries, but it is not related in a simple way to the usual country characteristics such as per capita income or overall trade openness. Industrial countries generally have low risk content of exports because they are well-diversified. However, among non-advanced countries, differences in diversification cannot account for the great dispersion in the risk content of exports. In that group, therefore, differences in the average riskiness of exports drive most of the variation in the total risk content. That is, among non-advanced countries, the safest ones are also often the least diversified: they are safe because they overwhelmingly specialize in safe sectors.

4.1 Construction of Sector Variance-Covariance Matrix

Using annual data on industry-level value added per worker growth over 1970–99 for $\mathcal{C}$ countries and $\mathcal{I}$ sectors, we construct a cross-sectoral variance-covariance matrix using the following procedure. Let y_{ict} be the value added per worker growth in country c, sector i, between time $t-1$ and time t.[12] First, in order to control for long-run differences in value added growth across countries in each sector, we demean y_{ict} using the mean growth rate for each country and sector over the entire time period:[13]

$$\widetilde{y}_{ict} = y_{ict} - \frac{1}{T}\sum_{t=1}^{T} y_{ict}.$$

---

[12] We use the volatility of value added per worker, and not the volatility of total value added, for two reasons. First, it is the empirical equivalent of the stochastic output per worker $p_R\theta$ in the model. That is, we must measure the volatility of a unit of investment in the sector. And second, it is the more standard approach in the literature (see, e.g., Koren and Tenreyro 2007). Alternatively, we computed the covariance matrix using the volatility of total value added growth in each sector. The resulting matrix is very similar to the one used in the paper, with a correlation coefficient of 0.76 between the sector-level volatilities obtained using total value added and value added per worker. None of the results that follow change under this alternative strategy.

[13] This is equivalent to regressing the pooled sample of value added per worker growth on country×sector dummies and retaining the residual.

Second, for each year and each sector, we compute the cross-country average of value added per worker growth:

$$Y_{it} = \frac{1}{\mathcal{C}} \sum_{c=1}^{\mathcal{C}} \widetilde{y}_{ict}.$$

The outcome, Y_{it}, is a time series of the average growth for each sector, and can be thought of as a global sector-specific shock. Using these time series, we calculate the sample variance for each sector, and the sample covariance for each combination of sectors along the time dimension. The sample variance of sector i is:[14]

$$\sigma_i^2 = \frac{1}{T-1} \sum_{t=1}^{T} (Y_{it} - \overline{Y_i})^2,$$

and the covariance of any two sectors i and j is:

$$\sigma_{ij} = \frac{1}{T-1} \sum_{t=1}^{T} (Y_{it} - \overline{Y_i})(Y_{jt} - \overline{Y_j}).$$

This procedure results in a 30 × 30 variance-covariance matrix of sectors, which we call $\mathbf{\Sigma}$. By virtue of its construction, we think of it as a matrix of inherent variances and covariances of sectors, and it is clearly time- and country-invariant. The panel data used to compute $\mathbf{\Sigma}$ is described above, and comprises of 59 countries for the manufacturing sector and 39 countries for Agriculture and Mining. We report the results in Table 1. Since presenting the full 30 × 30 covariance matrix is cumbersome, the table reports its diagonal: the variance of each sector, σ_i^2. The Mining sector is the most risky while Wearing Apparel, Machinery, and Food Products sectors are among the least risky. We should pay particular attention to how the two non-manufacturing sectors compare with the rest of the data, as they come from a different source. Mining and Quarrying is actually the most volatile sector in the sample, with a standard deviation of 11.3%. This is close to the standard deviation of the second most volatile sector, which is 9.3%. Furthermore, the second and third most volatile sectors, Miscellaneous Petroleum and Coal Products and Non-Ferrous Metals, are themselves natural-resource intensive, suggesting that our data sources are conformable. The volatility of Agriculture is comfortably in the middle of the sample.

While this risk measure has been purged of country×sector specific effects, it is nonetheless very highly correlated with the simple standard deviation reported in Appendix Table A2, in which all the observations across countries and years were pooled. The simple correlation coefficient between

---

[14] In a perfectly balanced panel of countries, sectors, and years, $\overline{Y_i} = \frac{1}{T} \sum_{t=1}^{T} Y_{it} = 0$ by construction. In our unbalanced panel, this is strictly speaking not the case when computing the sample mean, though it makes virtually no difference for the resulting variance and covariance estimates.

the two is 0.82, and the Spearman rank correlation is 0.81.[15] How does our estimate of sector-specific volatility compare to other sector characteristics? It seems to be positively correlated with average sector growth, with a rank correlation of 0.67. This is consistent with the findings of Imbs (2006) that growth and volatility are actually positively correlated at sector level. Surprisingly, sector risk seems to be uncorrelated with the external dependence from Rajan and Zingales (1998), with the Spearman rank correlation of 0.05. The same is true for the measures of liquidity needs used by Raddatz (2006). Depending on which variant of the Raddatz measure we use, the correlation is either zero or mildly negative. The correlations between sector riskiness and measures of reliance on institutions from Cowan and Neut (2007) are also close to zero.[16] Sector riskiness does seem to be weakly correlated with capital intensity, reported in Cowan and Neut (2007). The simple correlation is 0.2, while the Spearman rank correlation is 0.14.

4.2 Construction of the Risk Content of Exports

For each country and year, we construct shares of each sector in total exports, a_{ict}^{X}. Using the sectoral variance-covariance matrix $\mathbf{\Sigma}$, and the industry shares of exports for each country and each year, we define the risk content of exports as:

$$RCX_{ct} = \mathbf{a_{ct}^{X}}' \mathbf{\Sigma} \mathbf{a_{ct}^{X}},$$

where $\mathbf{a_{ct}^{X}}$ is the 30×1 vector of a_{ict}^{X}. The resulting measure is simply the aggregate variance of the entire export sector of the economy. We used production data for 69 countries to construct $\mathbf{\Sigma}$. However, using the trade data we can build measures of risk content of exports for the entire sample in the World Trade Database — a final sample of 130 countries in the present study.

Appendix Table A3 reports the risk content of exports in our sample of countries for the decade of the 1990s, along with information on the top two export sectors, the share of the top two export sectors in total exports, and the simple Herfindahl index of overall export shares. The latter is meant to be a measure of export diversification that does not take into account riskiness differences among sectors.

It is important to note that this procedure uses the same covariance matrix $\mathbf{\Sigma}$ for all countries. Lack of data availability prevents us from adopting a more direct approach. A potential alternative would be to construct separate covariance matrices for every country, and build the risk content

---

[15] Alternatively, we computed the covariance matrix while switching the order of the last two steps. That is, we first computed the variances and covariances of sectors in each individual country, and then took the average of each element in the covariance matrix across countries. The resulting matrices are very similar: the correlation between the variances obtained under these two approaches is 0.76. To help account for differences in country and sector size, we also computed the covariance matrix weighting observations by GDP and the sector size. The resulting covariance matrices were once again very similar to the one used to carry out the analysis.

[16] These authors use measures of product complexity — the number of intermediate goods used and the Herfindahl index of intermediate good shares — to proxy for reliance on contracting institutions. Our sector riskiness measure is actually somewhat positively correlated with the former, but negatively with the latter.

of exports based on those. However, this strategy is not feasible because the production data necessary to construct the covariance matrix only exists for a small number of countries. Applying the same covariance matrix allows us to "leverage" the available information on the volatility of production to build risk content of exports for some 130 countries. Though it has its limitations, a similar strategy has been used successfully in both macroeconomics (Rajan and Zingales 1998, and the large literature that followed), and trade (e.g., Romalis 2004, among others). Existing papers that adopt this approach typically use the U.S. data to build industry-specific indicators. The advantage of the approach taken in this paper is that it uses information on a large number of countries. Nonetheless, it is important to show that applying the same covariance matrix does not mask important reversals in the characteristics of the covariance matrix in individual countries or groups of countries. Appendix B describes the battery of checks that we perform in order to ensure this is the case.

4.3 Risk Content of Exports and Country Characteristics

Differences in the risk content of exports are large. Note that the risk content measure captures the variance of the output per worker growth in the export sector. Countries in the top five percent of the distribution in the 1990s have an average variance of the export sector of 0.0098, compared to 0.0002 for countries in the bottom five percent. This is equivalent to a 56-fold difference in variance, or about an 7.5-fold difference in standard deviation of output per worker growth. Countries with the highest risk content are those with a high export share in Mining and Quarrying, in these cases mainly crude oil (Angola, Nigeria, Iran). Surprisingly, in the bottom half of the risk content distribution are also some of the poorest and least diversified countries (Honduras, Ethiopia, Bangladesh). Thus, it seems that for these countries, a lower risk content of exports reflects mostly a high export concentration in the least risky industries, mainly Food Products, Textiles, and Clothing. In the bottom half of the distribution are also most of the advanced economies, with a high share of exports in medium risk industries such as Transportation Equipment and Machinery, and a diversified export base. Those characteristics are shared by a few emerging economies such as Korea, Thailand and Philippines.

Does risk content matter for macroeconomic volatility? Panel I of Table 2 presents regressions of the volatility of terms-of-trade growth, export growth, and GDP-per-capita growth on the risk content of exports and income per capita. The risk content of exports is positively associated with all three measures of volatility, and highly significant. Figure 1 displays the relationship between the risk content of exports and terms-of-trade volatility. It is evident that the relationship is quite close, with a correlation coefficient between the two variables of 0.52. What is notable about these results is that our risk content measure does not use any country-specific information on the volatility of sectors. The differences in risk content among countries are driven entirely by differences in export specialization. Thus, these results can be interpreted as displaying the relationship between export specialization patterns and overall volatility.

The risk content of exports does not exhibit a strong relationship with the usual country outcomes, such as per capita income, trade openness, or financial integration. Panel II of Table 2 regresses the risk content of exports on these measures. None of these variables is significant. Figure 2 plots the log risk content of exports against the log level of PPP-adjusted income per capita for the 1990s, along with the least squares regression line. While there does seem to be a negative relationship, it is not very pronounced. In particular, even some of the poorest countries in the sample (Tanzania, Ethiopia, Madagascar) have the same level of risk content of exports as some of the richest ones (Finland, Canada, Sweden).

4.4 Decomposition of the Risk Content of Exports

Having described the features of the risk content of exports, we now would like to examine what drives it. In particular, a higher risk content of exports can reflect a higher allocation of exports in risky sectors, or a high degree of specialization (as well as the covariance properties of the sectors in which the country specializes). We now attempt to establish whether variation in the risk content of exports is driven primarily by simple diversification of export shares (a^X_{ict}'s), or by countries' specialization in risky sectors (σ^2_i's). To do so, we first decompose the risk content of exports into the following components:

$$\begin{aligned}
\mathbf{a^X_{ct}}'\boldsymbol{\Sigma}\mathbf{a^X_{ct}} &\equiv \mathbf{a^X_{ct}}'\left(\boldsymbol{\Sigma}-\bar{\sigma}^2\mathbf{I}\right)\mathbf{a^X_{ct}} + \bar{\sigma}^2\mathbf{a^X_{ct}}'\mathbf{a^X_{ct}} \\
&= \sum_{i=1}^{\mathcal{I}}\left(a^X_{ict}\right)^2\left(\sigma^2_i-\bar{\sigma}^2\right) + 2\sum_{j\neq i}^{\mathcal{I}}\sum_{i=1}^{\mathcal{I}} a^X_{ict}a^X_{jct}\sigma_{ij} + \bar{\sigma}^2\sum_{i=1}^{\mathcal{I}}\left(a^X_{ict}\right)^2 \\
&= \bar{\sigma}^2\underbrace{\sum_{i=1}^{\mathcal{I}}\left(a^X_{ict}\right)^2}_{\text{Herfx}_{ct}} + 2\bar{a}^X\underbrace{\sum_{i=1}^{\mathcal{I}} a^X_{ict}\sigma^2_i}_{\text{MeanRisk}_{ct}} + \underbrace{2\sum_{j\neq i}^{\mathcal{I}}\sum_{i=1}^{\mathcal{I}} a^X_{ict}a^X_{jct}\sigma_{ij}}_{\text{Covariance}_{ct}} \\
&\quad + \underbrace{\sum_{i=1}^{\mathcal{I}}\left(a^X_{ict}-\bar{a}^X\right)^2\left(\sigma^2_i-\bar{\sigma}^2\right)}_{\text{Curvature}_{ct}} - \underbrace{2\bar{a}^X\bar{\sigma}^2}_{\text{Constant}}
\end{aligned}$$

The first term, Herfx, captures simple diversification that ignores riskiness differences across sectors: it is simply the Herfindahl index of export shares. The second term, which we call MeanRisk, is the average variance of a country's exports. It is a "diversification-free" measure, in the sense that two countries with the same Herfindahl of exports can nonetheless have very different values of MeanRisk, if in one of the countries the largest export sectors are riskier. MeanRisk is intended to be a complement to the "pure diversification" measure Herfx, and the two are meant to capture the main forces driving risk content.

The third term captures the covariance effect, or the off-diagonal components of $\mathbf{\Sigma}$, which are generally insignificant. The fourth term, which we call Curvature, captures the interaction between Herfx and MeanRisk. In a perfectly diversified economy ($a_{ict}^X = \bar{a}^X$ for all i), or when all sectors have the same variance, Curvature is zero. As the economy begins specializing, Curvature becomes negative if the country increases its export share in sectors that are safer than average. By contrast, Curvature becomes positive when the economy starts specializing in riskiest sectors. This term captures the notion that a more specialized economy is not necessarily riskier than a more diversified one: specializing in safe sectors results in the negative Curvature term and may reduce overall volatility. By contrast, specializing in the riskier sectors has a compounded effect: overall volatility increases due to both lack of diversification and higher than average sector risk. Finally, the last term, Constant, is common to all countries and is simply the average exports share, $\bar{a}^X$, which always equals $1/\mathcal{I}$, times the average of sector-level variances, $\bar{\sigma}^2 = \sum_{i=1}^{\mathcal{I}} \sigma_i^2/\mathcal{I}$.

Figure 5 plots the risk content of exports against the Herfindahl index of export concentration.[17] It is clear that the risk content of exports is not primarily driven by diversification. The relationship between export diversification and the risk content of exports is negative as expected. However, at low levels of diversification, there is a great deal of variation in the risk content of exports. That is, while the riskiest economies in our sample are also the least diversified (e.g., Angola, Nigeria, Iran), there are also many undiversified economies that are among the safest (e.g., Mauritius, Bangladesh, El Salvador). As expected, there is less dispersion in the risk content of exports among the well-diversified economies (e.g., OECD countries).

It appears, therefore, that diversification, while clearly important, cannot account for a large portion of the variation in the risk content of exports. The differences in the average riskiness play an important role. Figure 6 confirms this result. It plots the risk content of exports against the average riskiness of the export sector, MeanRisk, along with a quadratic regression line. The relationship is much closer. This figure reveals why the countries at the top of the risk content of exports distribution are there: it is because they specialize in the risky sectors, not simply because they are undiversified.

Table 3 presents sample medians for the five components of risk content of exports, both in levels and as shares of the total. The medians are reported for the whole sample, as well as the four quartiles of the risk content of exports distribution. Not surprisingly, Herfx, MeanRisk, and Curvature all increase as we move up in the risk content distribution. What is interesting is that the curvature term is negative at the bottom of the distribution, and positive at the top. That is, *at a given level of diversification*, countries at the low risk content of exports produce more in safer

---

[17] The Herfindahl index takes on higher values for less diversified economies. Thus, in generating the graph, we reverse the x-axis, so that more diversified economies are further to the right.

sectors, while high risk content countries produce in riskier ones.[18]

It is clear from this discussion that developing countries are not necessarily the most exposed to external risk. Indeed, a more complex picture emerges. Some of the least risky export structures are observed in the poorest and least diversified countries in our sample because they specialize in the least risky sectors. Advanced economies tend to have an intermediate level of export risk, and achieve it mainly through diversification of export structure rather than specializing in safe sectors. The countries with the highest export risk are the middle-income countries, which are highly specialized in risky industries, predominantly Mining and Quarrying.

5 A Portfolio View of International Trade

5.1 Implementation

In this section, we demonstrate empirically that the data exhibit a strong and robust U-shaped pattern consistent with the canonical model of trade patterns under uncertainty. In order to do this, we cannot perform a direct test of how the strength of comparative advantage in the risky sectors affects specialization. This is because it is not feasible to construct direct measures of $\overline{p_R\theta} - p_S$, or even relative productivity in the risky sector θ, due to severely limited coverage of production data: while risk content measures can be constructed for 130 countries, manufacturing productivity can be obtained for at most 60 countries, while there are fewer than 30 countries for which both non-manufacturing and manufacturing production data are available consistently.

However, it is possible to construct a proxy for the strength of comparative advantage in risky sectors using export data based on Balassa's (1965) measure of "revealed comparative advantage." In particular, we define risk-weighted comparative advantage as follows:

$$\text{RiskCA}_{ct} = \sum_i \sigma_i^2 \left(\frac{X_{ict}/X_{iWt}}{\frac{1}{\mathcal{I}} \sum_i \left(X_{ict}/X_{iWt} \right)} \right), \tag{4}$$

where X_{ict} are country c's exports in sector i, X_{iWt} are world exports in sector i, and σ_i^2 is the sector-level volatility as calculated in Section 4.1. That is, X_{ict}/X_{iWt} is the share of world exports in sector i captured by country c, which is normalized by the average share of world exports captured by the country, $\frac{1}{\mathcal{I}} \sum_i \left(X_{ict}/X_{iWt} \right)$, in order to control for overall country size. This is essentially Balassa's (1965) revealed comparative advantage, which is observed at the country-sector-time level.[19] To

---

[18] How are we to reconcile the fact that graphically MeanRisk seems to explain variation in risk content better than Herfx, while in the table the share of RCX taken up by Herfx is much larger? Note that in the table, the columns report the entire terms in the decomposition, that is, $\bar{\sigma}^2 \sum_{i=1}^{\mathcal{I}} \left(a_{ict}^X \right)^2$ and $2\bar{a}^X \sum_{i=1}^{\mathcal{I}} a_{ict}^X \sigma_i^2$. Thus, we can think of this as the distinction between the R-squared and a coefficient estimate: the "coefficient" on the Herfx term, $\bar{\sigma}^2$, is higher and thus it accounts for a larger share of RCX on average. The Figures show that MeanRisk can nonetheless better account for variation in RCX, that is, it has a higher "R-squared."

[19] There is one minor difference with the original Balassa measure, which uses the share of country's total exports

obtain a country-time level proxy for strength of comparative advantage in risky sectors, RiskCA_{ct}, we simply weight revealed comparative advantage in a given sector by its volatility σ_i^2. The key assumption is that the larger is the share of world exports that the country captures in a sector, the stronger is its comparative advantage in that sector. The strength of comparative advantage is then weighted by sector risk to obtain a summary measure of the riskiness of a country's pattern of comparative advantage.

In our model, we can derive the U-shaped relationship between RiskCA and Herfx, under the assumption that X_{iWt} does not change in response to changes in X_{ict}, consistent with the small open economy setup we adopted. This relationship is depicted in Figure 4. In our simple theoretical setup it is of course entirely unsurprising that a U-shaped relationship driven by the underlying comparative advantage in Figure 3 gives rise to a U-shaped relationship based on export patterns in Figure 4. This is because export patterns are completely determined by the strength of comparative advantage for a given σ_R^2. While the relationship between RiskCA and Herfx comes out naturally from the model, there could still be a concern that in the data, such an export-based index will not be a good proxy for the actual strength of comparative advantage $\overline{p_R\theta} - p_S$. Available empirical evidence does show that there is a link between export patterns and measured differences in productivity (Golub and Hsieh 2000, Choudhri and Schembri 2002, Costinot and Komunjer 2006).[20] Thus we believe that RiskCA is a meaningful proxy.

Note also that while RiskCA captures the average volatility of a country's pattern of revealed comparative advantage, it is also possible that countries can insure export income risk through the covariance properties of sectors. For instance, a country may have high shares in two especially volatile sectors, but its actual risk content of exports will be low if those sectors also exhibit strongly negative comovement with each other. This mechanism does not appear to be important quantitatively, however. Countries with the high RiskCA tend to have high export shares in positively, rather than negatively, correlated sectors: a typical pair of top two largest export sectors is Mining and Petroleum Refineries. In Section 5.4, after presenting the main results on the U-shaped relationship between comparative advantage in risky sectors and diversification, we show that the risk content of exports behaves in the way predicted by theory: it is first flat, then increasing as a function of revealed comparative advantage in risky sectors. This confirms that the covariance terms do not overturn the main conclusions of the paper.

We estimate the relationship of interest both non-parametrically and semi-parametrically. The first exercise employs the Lowess methodology to estimate the U-shaped relationship between Herfx

---

in overall world exports X_{ct}/X_{Wt}, instead of the average across sectors, $\frac{1}{\mathcal{I}}\sum_i (X_{ict}/X_{iWt})$, in the denominator to normalize sectoral export shares. Our results are not sensitive to this modification. We make this change because the unmodified Balassa index produces a few outliers, namely small countries which happen to capture relatively large shares of world exports in rare sectors (mainly tobacco).

[20] Earlier studies include MacDougall (1951), MacDougall (1952) and Balassa (1963). See also Harrigan (1997) for evidence that productivity differences affect output shares, which are presumably in turn reflected in export patterns.

and RiskCA. What is notable about this procedure is that it is locally robust: unlike a regression with a linear and a squared term, observations far away along the x-axis do not exert any influence on the estimated relationship between the two variables at each point. The second exercise estimates the U-shaped relationship using a hybrid of parametric and non-parametric models, allowing us to control for a wide variety of additional explanatory variables to reduce omitted variable concerns.

5.2 Non-Parametric Estimation

The Lowess estimator (Cleveland 1979) is an example of a local linear regression estimator. Suppose there is a data sample, indexed by $n = 1, ..., N$, of independent and dependent variable pairs — in our case, (RiskCA$_n$, Herfx$_n$). For each observation n, the procedure runs a bivariate weighted least-squares regression on a subsample of data centered around RiskCA$_n$, which is called the midpoint. The regression estimates are then used to predict the value of the dependent variable at the midpoint. This procedure is repeated using each observation in the sample as the midpoint, thereby tracing out a curve describing the non-parametric relationship between the two variables. In our implementation, the weights correspond to a tricubic kernel that places less weight on observations farther away from the midpoint. The range of the independent variable in each regression is determined by the bandwidth, that is, the proportion of the full sample used in each regression. We follow standard practice and use eighty percent of the sample to run each regression. The use of Lowess is advantageous because it has a variable bandwidth range, is robust to outliers, and uses a local polynomial estimator to minimize boundary problems (Cameron and Trivedi 2005).[21]

We run the Lowess procedure on cross-sectional data, for which Herfx and RiskCA are computed using average export shares over 1970–99, as well as five-year panel data, which gives us a larger sample size. Following Imbs and Wacziarg (2003), we use fixed effects in the Lowess procedure. In particular, each local regression includes fixed effects for all countries included in the local sample. To compute the predicted value of Herfx at the midpoint, we then average over the estimated fixed effects to obtain an average value of the fixed effect at the midpoint. It is important to note that the group of countries in each local regression changes over the whole sample. Therefore, both the average estimated fixed effect and the slope coefficient will be different at each midpoint. When tracing out the curve, the predicted Herfx will thus reflect both within- and between-country variation. Nonetheless, the estimated slope coefficients themselves are identified purely from the within-country variation in each local regression.

---

[21] There is a consistency-efficiency trade-off in choosing the size of the bandwidth: large bandwidths improve the efficiency of the estimates, but will lead to potential biases in the estimated relationship. Given our small dataset, we chose a larger bandwidth to obtain greater precision in the estimates. Moreover, the pattern in the raw data is quite pronounced, so we are willing to trade off smoothness for tighter local estimates. The estimated curves do not differ significantly when choosing a bandwidth equal to forty or sixty percent of the sample.

Deriving analytical standard errors for the estimated Lowess relationship is possible. However, given small-sample concerns, we choose to bootstrap the standard errors. In particular, we re-run the Lowess procedure 10,000 times on data sampled randomly with replacement, and use these estimates to compute the standard deviations for each point. Thus, for a cross-sectional regression on 130 countries this is equivalent to running 130×10,000 locally weighted regressions. We then compute 95 percent confidence intervals as ± two standard deviations.

Figures 6(a) and 6(b) present the cross-sectional and panel Lowess estimates computed using data for all sectors. The solid line represents the central estimate, while the dashed lines are the confidence bands. A U-shape is quite apparent in both the cross section and the panel estimates. The upward part of the curve is not surprising: it largely captures countries that are heavy exporters of risky commodities, such as oil producers. But, the existence of downward part of the curve is further evidence supporting the theory. Finally, the trough of the curve appears at approximately one-third of the maximum value of RiskCA, implying a potential asymmetry in the estimated U-shape.

Figures 6(c) and 6(d) present cross-sectional and panel Lowess estimates using Herfx and RiskCA computed from only the manufacturing sector data. The U-shaped pattern is even more pronounced compared to the one obtained using all the sectors, especially for the downward part of the curve. Furthermore, the trough of the estimated curves is closer to the midpoint of RiskCA. We also estimate the Lowess over a variety of sub-samples to check for robustness. In particular, we find that the U-shape is robust — for both all sectors and the manufacturing sector only — if we split the sample in half by income per capita; if we drop countries that specialize in the mining sector; and across different time periods. Since the production data is especially sparse for Africa, and many African countries are among the least diversified ones in the sample, we also re-ran the analysis on a sample that excludes African countries. The U-shape was still present and statistically significant. These results are available upon request.

To further demonstrate robustness of the results, following Imbs and Wacziarg (2003) we plot each estimated local slope coefficient against RiskCA, and examine their significance. If the U-shape is indeed robust in the data, we should find significant coefficients that are both positive and negative, as well a zero coefficients. We are particularly interested in the significance of the downward sloping portion of the U-shape. Figures 7(a) and 7(b) plot the slope coefficients that correspond to the Lowess estimates for all sectors of Figures 6(a) and 6(b), respectively. Thin lines plot the insignificant slope coefficients, while the bold lines denote those that are significantly different from zero. The slope coefficient is negative and significant for low values of RiskCA, then becomes insignificantly different from zero, before finally becoming positive and significant at larger values of RiskCA. Figures 7(c) and 7(d) plot the slope coefficients the Lowess estimates for manufacturing sector only, corresponding to Figures 6(c) and 6(d). These graphs provide additional empirical support for the U-shaped relationship between Herfx and RiskCA.

Could the U-shaped relationship between strength of comparative advantage and specialization arise for other reasons? After all, it is reasonable to expect countries with a strong comparative advantage to specialize, and those with weak comparative advantage to diversify, regardless of the insurance motive suggested by the Turnovsky model. Note, however, that the variation in RiskCA is driven entirely by the differences in σ's, not strength of comparative advantage per se. An index like the one in equation (4), but not weighted by the variances of individual sectors produces a value of 1 for every country. Thus, the variation in RiskCA across countries is driven by the differences across countries in *how volatile* sectors are, and not by how extreme the comparative advantage is across countries. There could still be a concern that the relationship we trace out is somehow induced mechanically by the configuration of the σ's in the data. To address this issue, we took the actual export shares that are used to compute the Herfindahl index and RiskCA for each of the 130 countries in the sample, and reassigned σ's randomly without replacement from the vector of actual σ's in the data. The goal is to see whether random assignment of the volatilities to the existing trade data would produce a U-shape. The results of simulating the data 1000 times are presented in Appendix Figure A4. The hollow dots are the actual data, while the gray area depicts the range of possible outcomes in simulated data. It is clear that there is no mechanical tendency in these data to form a U-shape. Only at the very top of the RiskCA range does it appear that there is some narrowing of the range of outcomes.[22]

Overall, the Lowess cross-sectional and panel estimates show strong evidence of a U-shaped relationship between Herfx and RiskCA. However, this relationship may be contaminated by the omission of other potential variables. To address this concern we next turn to a semi-parametric methodology.

5.3 Semi-Parametric Estimation

The Lowess methodology is a robust way to trace out the non-linear relationship between the risk-weighted comparative advantage and specialization. However, this bivariate approach ignores other variables that may potentially affect a country's Herfx, and may be correlated with RiskCA. One such variable is income per capita. In particular, Imbs and Wacziarg (2003) find a U-shape relationship between countries' specialization patterns in production and their level of development, while Koren and Tenreyro (2007) find a negative relationship between the level of development and average production risk.

A priori, we do not view the omission of income per capita to be a major concern, since the

---

[22] Note that this gray area does not represent the full range of possible (Herfx, RiskCA) pairs, which is almost surely wider than the shaded area. This explains why the countries with the highest and the lowest Herfx in the actual data are at the boundary of the shaded area.

correlation of income per capita and RiskCA is only 0.05 in our data, while the Spearman rank correlation is also very low (0.12). Thus, it is unlikely that the U-shaped relationship between diversification and RiskCA is generated by differences in per capita income. However, we can control for the influence of income as well as other potential omitted variables using semi-parametric methods. In particular, we follow the "double-residual" methodology proposed by Robinson (1988) to estimate the non-linear relationship between Herfx and RiskCA, while controlling for additional explanatory variables (see also Imbs and Rancière 2007).[23] We estimate the following empirical model:

$$\text{Herfx}_{ct} = \boldsymbol{\gamma}_c' \mathbf{X}_{ct} + g\left(\text{RiskCA}_{ct}\right) + \varepsilon_{ct}, \tag{5}$$

where $g\left(\text{RiskCA}_{ct}\right)$ captures the non-linear relationship between Herfx_{ct} and RiskCA_{ct}, and $\mathbf{X}_{ct}$ is a matrix of controls that are incorporated parametrically.

Equation (5) is estimated by a sequence of non-parametric and parametric regressions in three steps:

1. Estimate a bivariate Lowess between Herfx_{ct} and RiskCA_{ct}, and between each of the controls $\mathbf{X}_{ct}$ and RiskCA_{ct}. Retain the residuals from this procedure, denoting them $\widehat{\text{Herfx}_{ct}}$ and $\widehat{\mathbf{X}_{ct}}$.
2. Regress $\widehat{\text{Herfx}_{ct}}$ on $\widehat{\mathbf{X}_{ct}}$ using OLS to obtain an unbiased estimate of $\boldsymbol{\gamma}_c$. Use the estimated $\hat{\boldsymbol{\gamma}}_c$ to purge the influence of the additional controls from Herfx_{ct}: $\widehat{\widehat{\text{Herfx}_{ct}}} = \text{Herfx}_{ct} - \hat{\boldsymbol{\gamma}}_c' \mathbf{X}_{ct}$.
3. Finally, apply Lowess to $\widehat{\widehat{\text{Herfx}_{ct}}}$ and RiskCA_{ct} to estimate the non-linear relationship, $g(\cdot)$, between specialization and risk-weighted comparative advantage.

In other words, Step 1 eliminates the non-linear impact of RiskCA_{ct} from both Herfx_{ct} and the controls $\mathbf{X}_{ct}$. This removes the bias created by the non-linearity in the empirical model.[24] Note that in the panel specifications with country and time fixed effects, this step involves a Lowess between RiskCA_{ct} and each of the country and time dummies. Step 2 controls for the additional explanatory variables parametrically. Step 3 is the analog to the non-parametric estimation in the previous subsection. This methodology is consistent, but there are efficiency losses. We therefore bootstrap the standard errors in the final step of the estimation procedure as in the non-parametric estimations described above.[25]

The choice of variables in $\mathbf{X}_{ct}$ is based on Imbs and Wacziarg (2003) and Kalemli-Ozcan et al. (2003). These controls include the PPP-adjusted real per capita income and its square from the Penn World Tables; log of population density, defined as area divided by population; the

---

[23] An alternative strategy could be to estimate the full multivariate relationship non-parametrically, but this approach quickly runs into the "curse of dimensionality." Given our small sample size, even running the Lowess on only RiskCA and income per capita is impractical, particularly if we wish to bootstrap the standard errors.

[24] The linear coefficients will be biased even if they are stable across the sample.

[25] This approach is also suggested by Yatchew (2003).

log of population; and log of distantness. The latter is simply GDP-weighted distance to all potential trading partners. Population, area, and total GDP come from the World Bank's World Development Indicators, while the bilateral distances come from the Centre d'Etudes Prospectives et d'Informations Internationales (CEPII). These controls are meant to capture how country size and distance to trading partners affect the degree of specialization in trade.[26] We also include a measure of financial integration, defined as (total external assets + total external liabilities)/GDP from Lane and Milesi-Ferretti (2006).[27]

Equation (5) is estimated using both the cross-sectional sample of 30-year averages, and the panel sample of 5-year averages. All of the panel specifications include country and time fixed effects in $\mathbf{X}_{ct}$.[28] Just as we did under the non-parametric approach, we present a full set of results both for all sectors, and the manufacturing sectors only.

Figures 8(a)-8(d) present the cross-sectional and panel semi-parametric estimates computed using data for all sectors and manufacturing only.[29] The figures are analogous to the bivariate Lowess estimates depicted in Figure 7, but now control for a number of other variables.[30] The U-shape is quite apparent in both the cross-sectional and the panel estimates, and is similar to the bivariate estimates. Turning to the estimated slope coefficients for RiskCA in figures 9(a)-9(d), the same pattern emerges as that depicted in the non-parametric counterparts in Figure 8. The coefficients once again move from being negative and significant, to insignificantly different from zero, and then to positive and significant. However, the absolute size of the coefficients is smaller than the bivariate non-parametric estimates.

5.4 Back to the Risk Content of Exports

Both nonparametric and semi-parametric results reveal the existence of a strong U-shaped relationship between the degree of countries' export specialization and the strength of comparative advantage in risky sectors. These results provide novel evidence in support of the Turnovsky model of trade in the presence of uncertainty outlined in Section 2. What does this relationship imply for the behavior of the overall risk content of exports?

We can build an intuition as follows. Above, we found that as a country's comparative advantage in risky sectors becomes stronger, it will first diversify into riskier sectors, then specialize further in those risky sectors. This implies that at low levels of RiskCA, increasing RiskCA has conflicting effects: on the one hand the share of risky sectors in overall exports increases. On the other, there is

---

[26] We also controlled for overall trade openness directly, and the results were unchanged.

[27] We also experimented with the measure of extent of international income insurance estimated by Volosovych (2006), and the results were robust.

[28] Note that just as in the non-parametric estimations, the country fixed effects will capture both between and within variation as we trace out the non-linear effect of RiskCA on Herfx.

[29] Appendix Table A4 presents the step-2 residual OLS regression of Herfx on the controls.

[30] There are now only 109 countries in the sample due missing data for some of the explanatory variables.

more diversification. The overall effect on the risk content is ambiguous, and thus we would expect that for low levels of comparative advantage in risky sectors, the relationship between RiskCA and the overall risk content is essentially flat, or weakly increasing. On the other hand, at high levels of RiskCA, increasing comparative advantage in risky sectors will both increase the average riskiness, and reduce diversification. The two effects begin reinforcing each other at values of RiskCA greater than the minimum point on the Herfx-RiskCA curve.

Figure 11 confirms this intuition. The two left panels report the cross-sectional non-parametric estimates of the relationship between RCX and RiskCA, for all sectors as well as manufacturing only.[31] Indeed, at low levels of RiskCA, the relationship is flat, while at higher levels it is increasing. The right panels plot together the fitted non-parametric relationships between RCX and RiskCA (solid line) and Herfx and RiskCA (dashed line). It is remarkable that RCX is indeed roughly flat until the minimum point in Herfx, and then begins increasing unambiguously.

6 Conclusion

Whether increased trade openness has contributed to rising uncertainty and exposed countries to external shocks remains a much debated topic. In this paper, we use industry-level data to document a particular aspect of the relationship between openness and volatility: the riskiness of export patterns across countries and over time. We establish that the risk content of exports is strongly positively correlated with the variance of terms-of-trade, total exports, and GDP growth, suggesting that export specialization does affect macroeconomic volatility. However, it is not closely related to the usual country characteristics, such as income per capita or trade openness. The risk content of exports is determined by both differences in diversification of export structure, and the average riskiness of exporting sectors. While diversification clearly matters, much of the variation in the risk content of export is driven by the average risk. For instance, the poorest countries, while least diversified, are also among the least exposed to external risk.

We then move beyond a descriptive characterization, and propose an explanation for what determines the risk content of exports. Going back to a well-established theoretical literature in trade, we provide an illustrative example of its central insight: when sectors differ in their riskiness, there is an incentive for countries to diversify exports to insure against export income risk. The amount of export diversification exhibits a U-shape with respect to the strength of comparative advantage in risky sectors: countries with no comparative advantage in those sectors, or whose comparative advantage in those sectors is very strong, will specialize. Countries with intermediate values of comparative advantage will diversify. The final part of the paper shows that the data provide strong support for this prediction.

---

[31] Results are similar for panel estimates, but are omitted to conserve space.

Thus, we view this paper's contribution as twofold. First, it introduces a new measure of riskiness of a country's export pattern, which can become an important tool for the analysis of the relationship between trade and macroeconomic volatility. Second, it provides novel empirical evidence on an established theoretical literature in trade.

Appendix A Decentralization of the Planning Problem

This Appendix demonstrates that the planning problem analyzed in the main text is an outcome of a competitive equilibrium. The treatment closely follows Helpman and Razin (1978), chs. 5-6, which can serve as a further reference. Consider an economy comprised of households and firms.

A.1 Firms

Production is competitive and firms are price takers. The firms choose input levels to maximize their net value (Diamond 1967). They issue claims on their (possibly stochastic) output. In sector i, let q_i denote the firm's stock price. In sector S, the firm that employs L_S workers can issue up to $Z_S = L_S$ claims, each of which delivers one unit of good S. In sector R, the firm that employs L_R workers issues $Z_R = L_R$ claims, each unit delivering a stochastic amount θ of good R.[32]

Let w be the wage paid to workers. A firm in sector i issues Z_i claims to maximize its net stock market value:

$$\max_{Z_i} \{q_i Z_i - wL_i\}$$
$$s.t.$$
$$Z_i = L_i$$

That is, the firm chooses its inputs to maximize its gross stock market value $q_i Z_i$, minus the input costs wL_i. It is clear that the solution to this maximization problem is:

$$\begin{aligned} Z_i &= 0 \quad if \quad q_i < w \\ Z_i &= [0, +\infty) \quad if \quad q_i = w \\ Z_i &= +\infty \quad if \quad q_i > w. \end{aligned}$$

Since all firms in the sector are identical, and technology exhibits constant returns, this optimization problem characterizes the sector as a whole.

---

[32] We take it for granted that no firms will operate in sector M, as its production technology is the same as in sector S, while $p_S > p_M \equiv 1$. That is, the country's pattern of comparative advantage implies that producing in sector S always dominates producing in sector M.

A.2 Households

Households supply labor, own the firms in the economy, and invest in claims on future output that the firms issue (real equities). As in the main text, the total amount of labor in the economy is $L = 1$. Consumers maximize expected utility, by investing in a portfolio of stocks. Let z_i denote the number of sector i real equities purchased by the consumer. Then, the household's *ex ante* portfolio problem is:

$$\begin{aligned} &\max_{z_S, z_R} E\left[V(I, P)\right] \\ &\qquad s.t. \\ &q_S z_S + q_R z_R = w + (q_S Z_S - wL_S) + (q_R Z_R - wL_R) \\ &I = p_S z_S + p_R \theta z_R. \end{aligned}$$

Following the notation in the main text, $V(I, P)$ is the indirect utility of the consumer with income I at the price level P. The first constraint states that the household's income is the sum of labor income w and the net profits from its ownership of firms in the two sectors, $(q_S Z_S - wL_S)$ and $(q_R Z_R - wL_R)$. The household uses that income to purchase claims on the (possibly stochastic) output in each of the sectors, paying the price q_i. The second constraint implies that as a consequence of the household's investments, after the resolution of uncertainty its income consists of the total revenue from owning the claims on outputs of the two goods. Using the first constraint to express z_S as:

$$z_S = \frac{1}{q_S}\left[w + (q_S Z_S - wL_S) + (q_R Z_R - wL_R) - q_R z_R\right],$$

the first-order condition of the consumer optimization problem can be written as:

$$E\left[V_I\left(\frac{p_S}{q_S}\left[w + (q_S Z_S - wL_S) + (q_R Z_R - wL_R) - q_R z_R\right] + p_R \theta z_R\right)\left(p_R \theta - \frac{p_S}{q_S} q_R\right)\right] = 0. \quad \text{(A.1)}$$

A.3 Equilibrium

An equilibrium is a set of prices and the resource allocations (q_S, q_R, w, L_S, L_R), such that: (i) firms maximize net shareholder value; (ii) consumers maximize expected utility; and (iii) security and factor markets clear. Labor market clearing requires that:

$$L_S + L_R = 1.$$

Security market clearing implies that:

$$z_i = Z_i = L_i, \qquad i = S, R. \quad \text{(A.2)}$$

We will consider interior equilibria, such that there is some production of both S and R. The analysis of corner equilibria is straightforward. Positive but finite production of these goods implies that the share prices in both industries satisfy:

$$q_i = w, \qquad i = S, R. \tag{A.3}$$

Note that conditions (A.2)-(A.3) together imply that the net profits in the two industries are zero, $(q_S Z_S - wL_S) = (q_R Z_R - wL_R) = 0$, as expected in a competitive economy with constant returns to scale technology. Labor market clearing implies that $L_S = 1 - L_R$, and thus the economy's production structure is pinned down by a single equilibrium value, L_R, which is the amount of labor in the R-sector. Plugging equations (A.2)-(A.3) into the first-order condition for utility maximization (A.1) yields:

$$E\left[V_I\left(p_S(1-L_R) + p_R\theta_R L_R\right)(p_R\theta - p_S)\right] = 0.$$

This equation is an implicit expression for the allocation of resources, L_R, that characterizes the decentralized equilibrium of an economy in which consumers maximize expected utility, and firms maximize net shareholder value. Note that this expression is identical to the one that characterizes the planner's problem analyzed in the main text, equation (2).

Appendix B Robustness of Applying the Same Covariance Matrix to All Countries

This Appendix shows that applying the same covariance matrix does not mask important reversals in the ranking of sectors according to volatility in individual countries or groups of countries.

We do this in a number of ways. First, we calculate the covariance matrix for several subsamples, and compare the results. For instance, we break the country sample into OECD and non-OECD countries, and construct $\mathbf{\Sigma}$ for each of these country groups. The resulting matrices are quite similar: the correlation between sector-specific variances estimated on the two subsamples is 0.64, and the Spearman rank correlation is 0.78. Another key concern is that countries differ significantly according to their export specialization. For example, it could be that in individual countries, sectors that capture a large share of overall exports are systematically more volatile. Thus, by pooling across countries, we do not make any distinction based on whether a country is a net importer or exporter in a given industry. In order to see whether these differences are important, we construct $\mathbf{\Sigma}$ on the subsamples of net exporters and net importers in each sector. This way, in a given country, some of the sectors will end up in the net exporters sample, while others will be in the net importers sample. It turns out that the estimates of $\mathbf{\Sigma}$ from these subsamples are quite similar, with the correlation of 0.86 and the Spearman rank correlation of 0.78. On average, the variances computed from the net exporter sample are actually slightly larger than those from the net importer sample. Finally, we also break up the sample into two subperiods, 1970–84 and 1985–99. The results are once again quite similar, with the correlation between the two subperiods of 0.70

and Spearman rank correlation of 0.62. While the matrices calculated on individual subsamples may differ among each other, each individual subsample matrix is very similar to the full sample matrix. Correlation coefficients between sector standard deviations computed on subsamples with the full sample standard deviations range from 0.87 to 0.96. Thus, applying $\boldsymbol{\Sigma}$ to the entire sample of countries is unlikely to appreciably affect the results.

The second check we perform is to construct the covariance matrices for those countries in which some production data are available. In the entire sample of countries with some production data, the average correlation between the individual country sector-level volatilities and the volatilities in the master $\boldsymbol{\Sigma}$ matrix is about 0.45, with a similar average rank correlation. However, as mentioned above, data for many countries contain missing sectors, and thus many of the resulting correlations are calculated on highly incomplete samples of sectors. Alternatively, we isolated the 15 countries that have data on all 30 sectors. The average correlation between the country-specific volatilities and the common volatility from $\boldsymbol{\Sigma}$ in this subsample was 0.56. Also, the first principal component accounts for 65% of the variation in the country-specific volatilities among these 15 countries, implying a very high degree of correlation of the country-specific volatilities in this group of countries.

Finally, we computed the risk content of exports based on country-specific risk matrices, and compared it to the headline risk content of exports variable used in the paper. To do this, we looked country-by-country at whether missing sectors in the country-specific matrix are important export sectors. That is, if electronics is missing in the Jamaican risk matrix, it's not important because Jamaican electronics exports are negligible, so we computed the risk content of exports for Jamaica based on its matrix, in spite of missing sectors. By contrast, if the oil sector is missing from the Saudi Arabian production data, we did not compute the country-specific risk content of exports for Saudi Arabia. There are 27 countries for which enough production data are available to compute the country-specific risk content of exports. The correlation between the country-specific and the headline risk content of exports among these countries is 0.68, and the Spearman rank correlation is 0.41. Appendix Figure A1 shows the scatterplot of the two variables.

To summarize, though the approach taken in the paper has limitations, several checks of the methodology lend support to the assumption that sector-level volatility is highly correlated across countries. Thus, it is informative to analyze the risk content of exports measure introduced here.

References

Acemoglu, Daron and Fabrizio Zilibotti, "Was Prometheus Unbound by Chance? Risk, Diversification, and Growth," *Journal of Political Economy*, August 1997, *105* (4), 709–51.

Backus, David K., Patrick J. Kehoe, and Finn E. Kydland, "International Real Business Cycles," *Journal of Political Economy*, August 1992, *100* (4), 745–75.

Balassa, Bela, "An Empirical Demonstration fo the Classical Comparative Cost Theory," *Review of Economics and Statistics*, August 1963, *45* (3), 231–38.

——, "Trade Liberalization and Revealed Comparative Advantage," *Manchester School*, 1965, *33*, 99–123.

Bejan, Maria, "Trade Openness and Output Volatility," October 2004. Mimeo, ITAM.

Bekaert, Geert, Campbell R. Harvey, and Christian Lundblad, "Growth Volatility and Equity Market Liberalization," June 2004. NBER Working Paper No. 10560.

Caballero, Ricardo J. and Kevin Cowan, "Financial Integration Without the Volatility," May 2007. Mimeo, MIT.

Cameron, A. Colin and Pravin K. Trivedi, *Microeconometrics: Methods and Applications*, New York: Cambridge University Press, 2005.

Cavallo, Eduardo A., "Openness to Trade and Output Volatility: A Reassessment," 2005. Mimeo, Harvard University.

Choudhri, Ehsan U. and Lawrence L. Schembri, "Productivity Performance and International Competitiveness: an Old Test Reconsidered," *Canadian Journal of Economics*, May 2002, *35* (2), 341–62.

Cleveland, William S., "Robust Locally Weighted Regression and Smoothing Scatterplots," *Journal of the American Statistical Association*, December 1979, *74* (368), 829–36.

Costinot, Arnaud and Ivana Komunjer, "What Goods Do Countries Trade? New Ricardian Predictions," 2006. Mimeo, U.C. San Diego.

Cowan, Kevin and Alejandro Neut, "Intermediate Goods, Institutions, and Output Per Worker," 2007. Central Bank of Chile Working Papers N 420.

Cuñat, Alejandro and Mark J. Melitz, "Volatility, Labor Market Flexibility, and the Pattern of Comparative Advantage," March 2006. Mimeo, University of Essex and Harvard University.

di Giovanni, Julian and Andrei A. Levchenko, "Trade Openness and Volatility," 2007. Forthcoming, *Review of Economics and Statistics.*

Diamond, Peter A., "The Role of a Stock Market in a General Equilibrium Model with Technological Uncertainty," *The American Economic Review*, sep 1967, *57* (4), 759–776.

Easterly, William, Roumeen Islam, and Joseph E. Stiglitz, "Shaken and Stirred: Explaining Growth Volatility," in B. Pleskovic and N. Stern, eds., *Annual World Bank Conference on Development Economics*, 2001.

Feenstra, Robert C., Robert E. Lipsey, Haiyan Deng, Alyson C. Ma, and Hengyong Mo, "World Trade Flows: 1962–2000," January 2005. NBER Working Paper No. 11040.

Golub, Stephen S. and Chang-Tai Hsieh, "Classical Ricardian Theory of Comparative Advantage Revisited," *Review of International Economics*, May 2000, *8* (2), 221–34.

Grossman, Gene M. and Assaf Razin, "The Pattern of Trade in a Ricardian Model with Country-Specific Uncertainty," *International Economic Review*, February 1985, *26* (1), 193–202.

Harrigan, James, "Technology, Factor Supplies, and International Specialization: Estimating the Neoclassical Model," *American Economic Review*, September 1997, *87* (4), 475–94.

Helpman, Elhanan, "Trade Pattern under Uncertainty with Country Specific Shocks," *Econometrica*, May 1988, *56* (3), 645–659.

—— and Assaf Razin, *A Theory of International Trade under Uncertainty*, Academic Press, 1978.

Heston, Alan, Robert Summers, and Bettina Aten, "Penn World Table Version 6.1," October 2002. Center for International Comparisons at the University of Pennsylvania (CICUP).

Imbs, Jean, "Growth and Volatility," January 2006. Forthcoming, *Journal of Monetary Economics.*

____ and Romain Rancière, "The Overhang Hangover," 2007. Mimeo, HEC Lausanne and IMF.

____ and Romain Wacziarg, "Stages of Diversification," *American Economic Review*, March 2003, *93* (1), 63–86.

International Labor Organization, "Yearbook of Labour Statistics, 62nd Issue," 2003. CD-ROM.

Kalemli-Ozcan, Sebnem, Bent E. Sørensen, and Oved Yosha, "Risk Sharing and Industrial Specialization: Regional and International Evidence," *American Economic Review*, June 2003, *93* (3), 903–18.

Kaminsky, Graciela L., Carmen M. Reinhart, and Carlos A. Végh, "When It Rains, It Pours: Procyclical Capital Flows and Macroeconomic Policies," in Mark Gertler and Kenneth S. Rogoff, eds., *NBER Macroeconomics Annual 2004*, Vol. 19, Cambridge, Mass.: The MIT Press, 2005, chapter 1, pp. 11–53.

Koren, Miklós, "Financial Globalization, Portfolio Diversification, and the Pattern of International Trade," 2003. IMF Working Paper 03/233.

____ and Silvana Tenreyro, "Volatility and Development," *Quarterly Journal of Economics*, February 2007, *122* (1), 243–87.

Kose, M. Ayhan, Eswar S. Prasad, and Marco E. Terrones, "Financial Integration and Macroeconomic Volatility," *IMF Staff Papers*, 2003, *50* (Special Issue), 119–41.

Lane, Philip R. and Gian Maria Milesi-Ferretti, "The External Wealth of Nations Mark II: Revised and Extended Estimates of Foreign Assets and Liabilities, 1970-2004," March 2006. IMF Working Paper No. 06/69.

MacDougall, G.D.A., "British and American Exports: A Study Suggested by the Theory of Comparative Costs, Part I," *Economic Journal*, December 1951, *61* (244), 697–724.

____ , "British and American Exports: A Study Suggested by the Theory of Comparative Costs, Part II," *Economic Journal*, September 1952, *62* (247), 487–521.

Mendoza, Enrique, "The Terms of Trade, the Real Exchange Rate, and Economic Fluctuations," *International Economic Review*, February 1995, *36* (1), 101–137.

OECD, *The Rise of China and India: What's in it for Africa?*, OECD Publishing, May 2006.

Raddatz, Claudio, "Liquidity Needs and Vulnerability to Financial Underdevelopment," *Journal of Financial Economics*, June 2006, *80* (3), 677–722.

Rajan, Raghuram and Luigi Zingales, "Financial dependence and growth," *American Economic Review*, June 1998, *88* (3), 559–86.

Robinson, P.M., "Root-N-Consistent Semiparametric Regression," *Econometrica*, July 1988, *56* (4), 931–54.

Rodrik, Dani, "Why Do More Open Economies Have Bigger Governments?," *Journal of Political Economy*, October 1998, *106* (5), 997–1032.

Romalis, John, "Factor Proportions and the Structure of Commodity Trade," *American Economic Review*, March 2004, *94* (1), 67–97.

Saint-Paul, Gilles, "Technological choice, financial markets, and economic development," *European Economic Review*, May 1992, *32* (4), 763–781.

Turnovsky, Stephen J., "Technological and Price Uncertainty in a Ricardian Model of International Trade," *The Review of Economic Studies*, April 1974, *41* (2), 201–217.

United Nations Industrial Development Organization, "Industrial Statistics Database," 2005. CD-ROM.

United Nations Statistical Yearbook, "UN National Accounts Database," 2003. Electronic Resource.

Volosovych, Vadym, "Financial Market Integration, Risk Sharing, and Institutions: Theory and Evidence," December 2006. Working Paper 06008, Department of Economics Working Papers, Florida Atlantic University.

Yatchew, Adonis, *Semiparametric Regression for the Applied Econometrician* Themes in Modern Econometrics, New York: Cambridge University Press, 2003.

Table 1. Sector-Specific Volatility

ISIC	Sector Name	Variance	St. Dev.
1	Agriculture	0.0012	0.0342
2	Mining and quarrying	0.0127	0.1128
311	Food products	0.0006	0.0248
313	Beverages	0.0007	0.0262
314	Tobacco	0.0023	0.0475
321	Textiles	0.0014	0.0377
322	Wearing apparel, except footwear	0.0006	0.0241
323	Leather products	0.0012	0.0343
324	Footwear, except rubber or plastic	0.0010	0.0317
331	Wood products, except furniture	0.0019	0.0435
332	Furniture, except metal	0.0007	0.0264
341	Paper and products	0.0035	0.0589
342	Printing and publishing	0.0007	0.0263
351	Industrial chemicals	0.0040	0.0630
352	Other chemicals	0.0007	0.0263
353	Petroleum refineries	0.0037	0.0610
354	Misc. petroleum and coal products	0.0087	0.0933
355	Rubber products	0.0012	0.0348
356	Plastic products	0.0012	0.0345
361	Pottery, china, earthenware	0.0008	0.0279
362	Glass and products	0.0015	0.0384
369	Other non-metallic mineral products	0.0008	0.0282
371	Iron and steel	0.0060	0.0774
372	Non-ferrous metals	0.0069	0.0829
381	Fabricated metal products	0.0007	0.0267
382	Machinery, except electrical	0.0006	0.0241
383	Machinery, electric	0.0006	0.0250
384	Transport equipment	0.0015	0.0385
385	Professional & scientific equipment	0.0015	0.0389
390	Other manufactured products	0.0010	0.0321

Notes: This table reports the sector-specific variance and standard deviation of the growth rate of output per worker, i.e., the diagonal of the $\mathbf{\Sigma}$ matrix constructed as described in Section 4.1.

Table 2. The Risk Content of Exports and Macroeconomic Characteristics

I. Macroeconomic Volatility and RCX			
Dep. Var.:	TOT (1)	Exports (2)	GDP per capita (3)
RCX	0.613**	0.578**	0.236**
	(0.082)	(0.110)	(0.085)
GDP per capita	-0.773**	-0.349**	-0.497**
	(0.092)	(0.120)	(0.080)
Constant	6.192**	4.079**	-0.251
	(0.837)	(0.922)	(0.716)
Observations	114	124	114
R^2	0.547	0.318	0.345
II. RCX and Macroeconomic Determinants			
Dep. Var.:	RCX (1)	RCX (2)	RCX (3)
GDP per capita	-0.060		
	(0.090)		
Trade openness		0.184	
		(0.169)	
Financial openness			0.235
			(0.188)
Constant	-6.722**	-7.974**	-8.287**
	(0.730)	(0.672)	(0.850)
Observations	124	124	111
R^2	0.003	0.008	0.019

Notes: This table reports cross-country regressions. Panel I reports regressions of macroeconomic volatility measures on RCX, controlling for GDP per capita. Panel II relates RCX to potential macroeconomic determinants. Terms-of-trade, GDP per capita and trade openness measures are calculated using Penn World Tables data; export volatility is calculated using total exports data from the World Bank's World Development Indicators; financial openness is defined as (total external assets + total external liabilities)/GDP, and is obtained from Lane and Milesi-Ferretti (2006). All dependent and independent variables are in logs, and are calculated over 1970–99. Robust standard errors in parentheses; + significant at 10%; * significant at 5%; ** significant at 1%.

Table 3. Risk Content of Exports Decomposition: Sample Medians for All Sectors, 1970–99

	RCX	(1) Herfx	(2) MeanRisk	(3) Covariance	(4) Curvature	(5) Constant
				Levels		
Whole Sample	0.0005	0.0006	0.0002	0.0001	-0.0001	-0.0002
Quartile						
First	0.0003	0.0002	0.0001	0.0001	-0.0001	-0.0002
Second	0.0004	0.0007	0.0001	0.0001	-0.0003	-0.0002
Third	0.0007	0.0006	0.0002	0.0001	0.0000	-0.0002
Fourth	0.0033	0.0010	0.0005	0.0001	0.0020	-0.0002
				Shares		
Whole Sample	-	1.121	0.291	0.201	-0.099	-0.292
Quartile						
First	-	0.949	0.434	0.404	-0.348	-0.589
Second	-	1.538	0.233	0.274	-0.684	-0.355
Third	-	0.777	0.288	0.071	-0.049	-0.207
Fourth	-	0.291	0.145	0.037	0.609	-0.046

Notes: This table reports the median values of risk content of exports (RCX) and the components of the decomposition described in Section 4.4, calculated using trade shares in both manufacturing and non-manufacturing sectors. The table reports both the levels and shares of the different components in total RCX, for the whole cross section, as well as each of the four quartiles.

Figure 1. Terms-of-Trade Volatility and the Risk Content of Exports, 1970–99

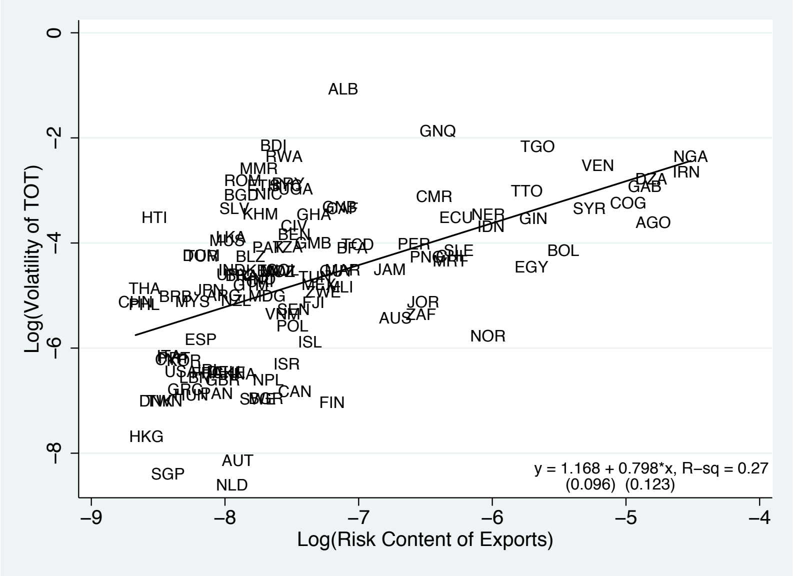
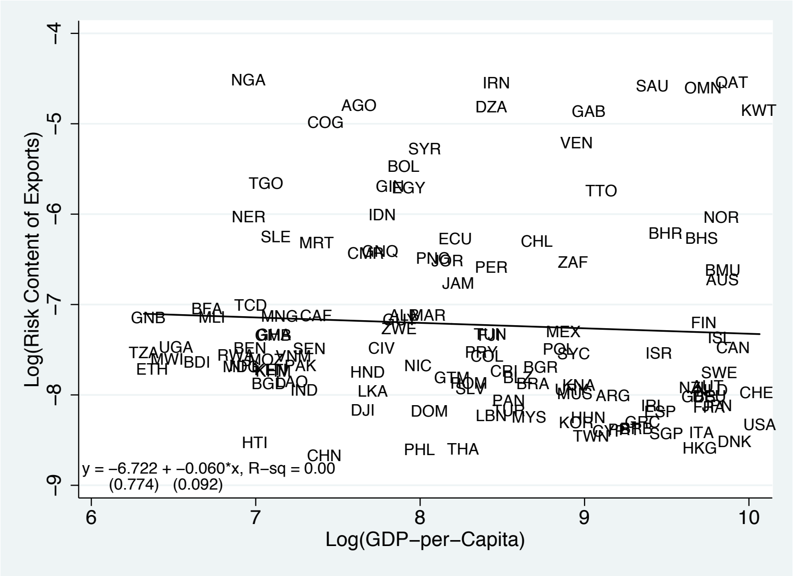


Figure 2. Risk Content of Exports and GDP per Capita, 1970–99



Notes: Terms-of-Trade Volatility is calculated over 1970–99 using Penn World Tables data. GDP per Capita is calculated as an average over 1970–99 using Penn World Tables data. The Risk Content of Exports is constructed using the average trade shares for the period 1970–99.

Figure 3. Strength of Comparative Advantage in Risky Sector and Specialization

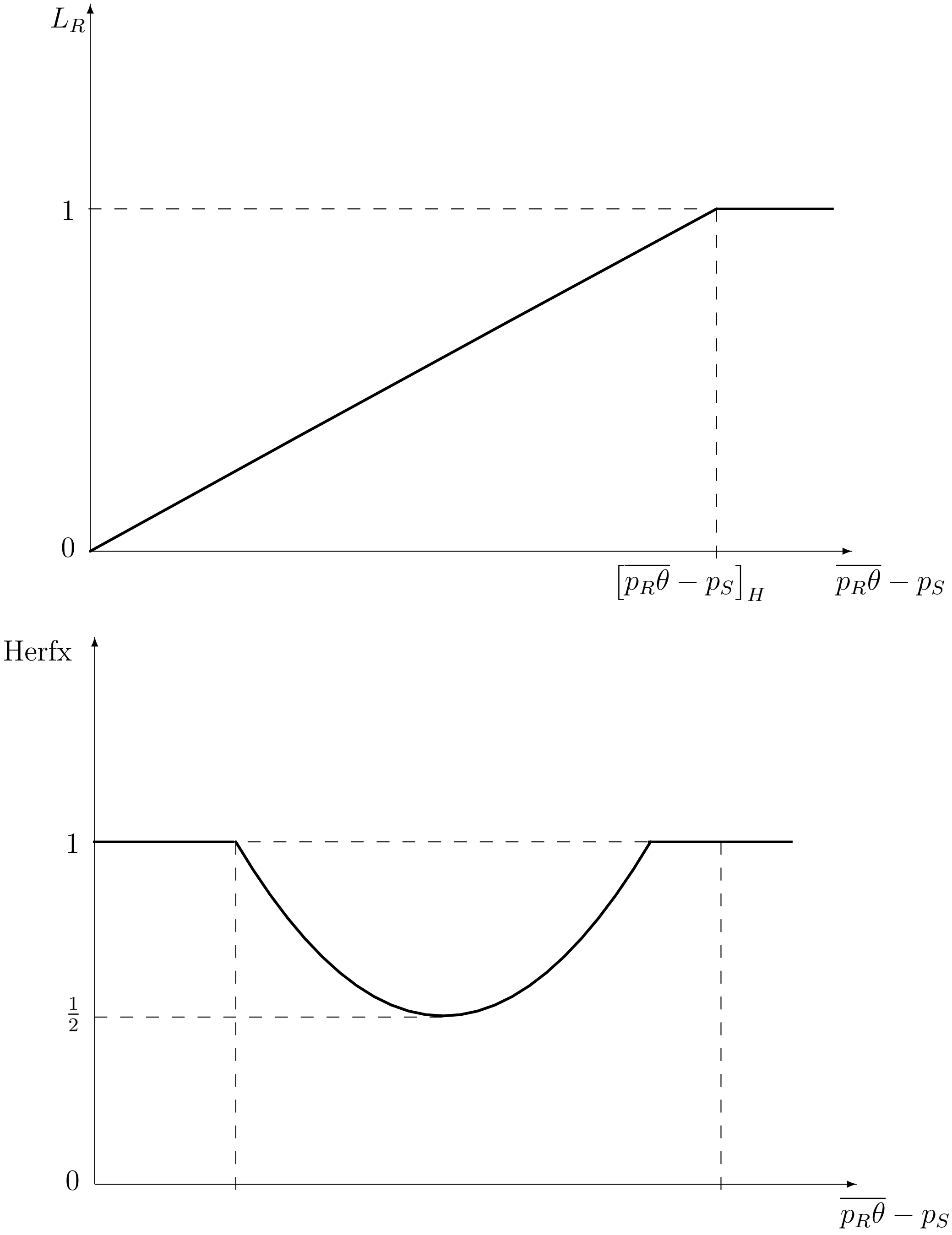


Figure 4. Risk-Weighted Comparative Advantage, the Risk Content of Exports and Specialization

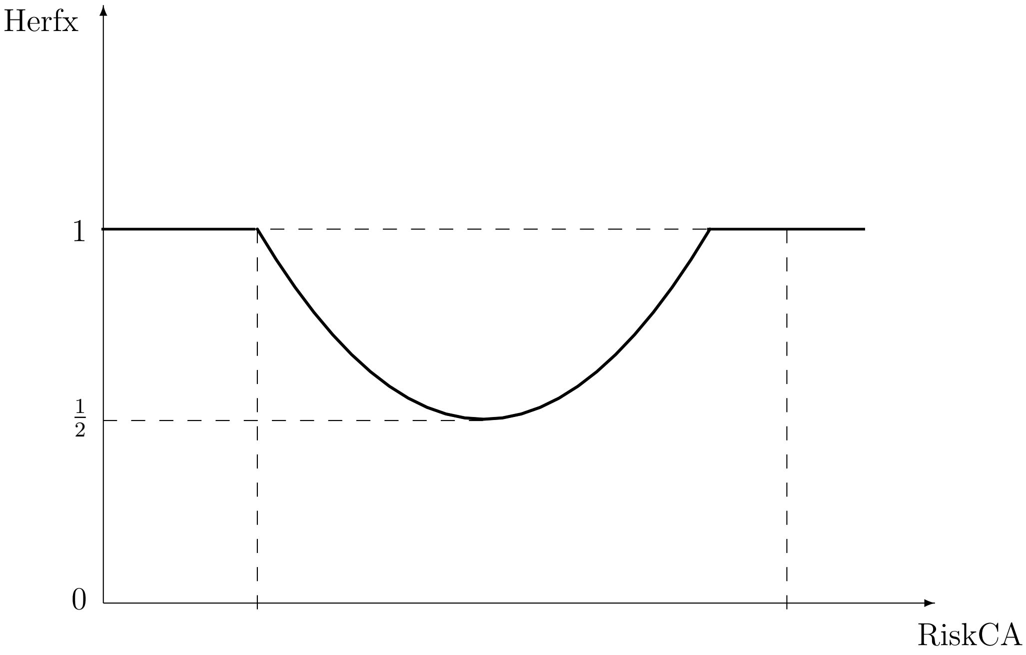
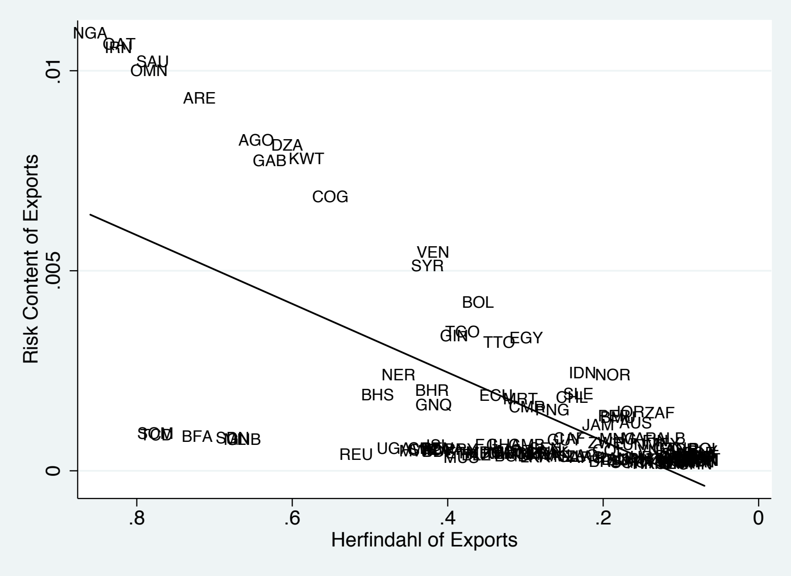
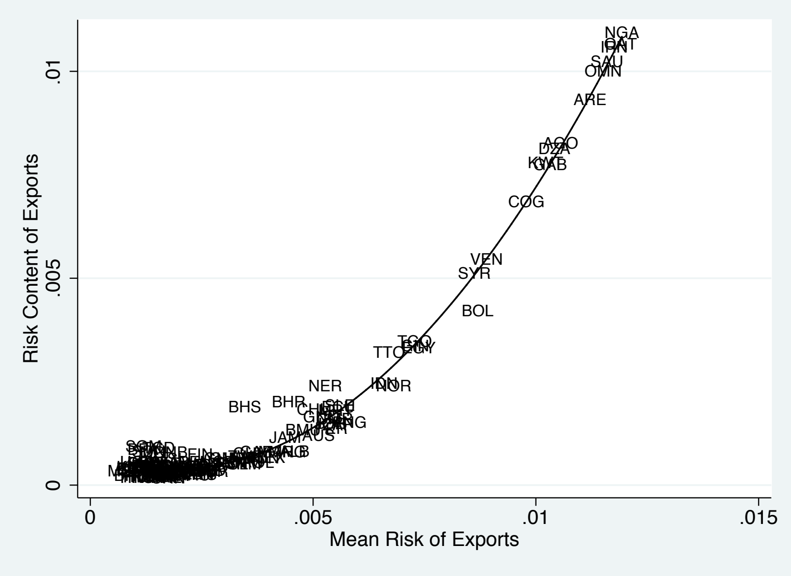


Figure 5. Risk Content of Exports and the Herfindahl of Exports, 1970–99



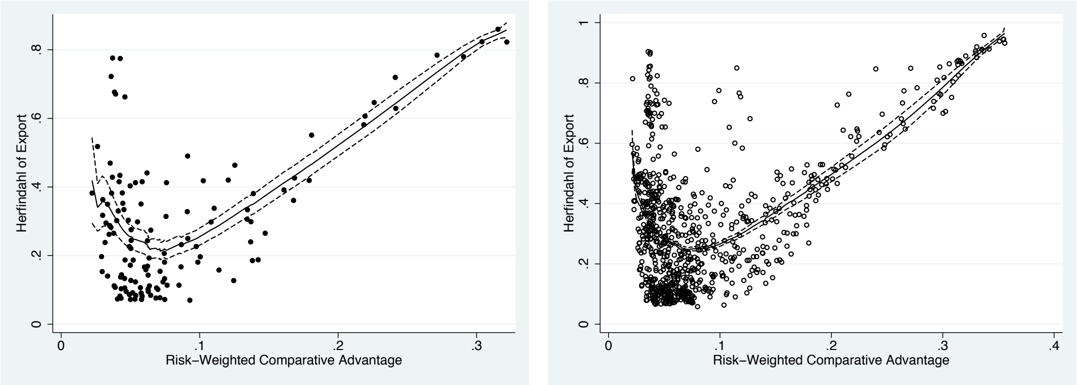
Notes: The Risk Content of Exports and the Herfindahl index of export shares are constructed using the average trade shares for the period 1970–99.

Figure 6. Risk Content of Exports and Mean Risk of Exports, 1970–99



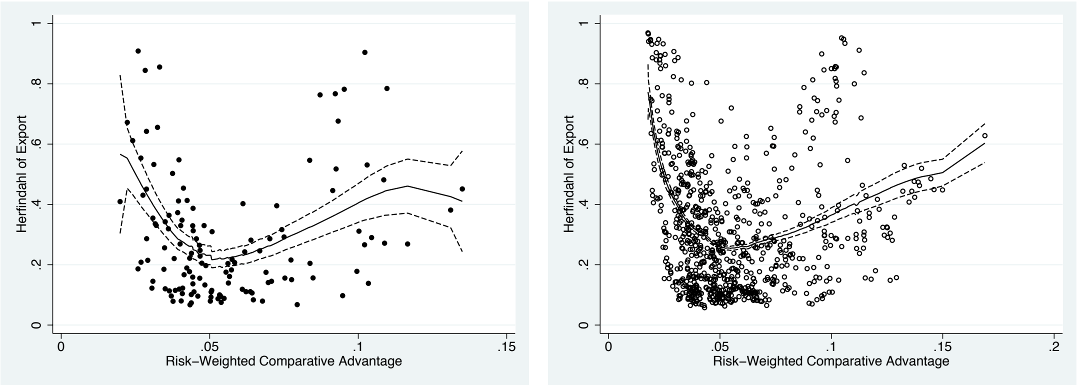
Notes: The Risk Content of Exports and the Mean Risk of export shares are constructed using the average trade shares for the period 1970–99.

Figure 7. Lowess Estimates of the Relationship Between a Country's Export Specialization and its Risk-Weighted Comparative Advantage



(a) All Sectors, Cross Section

(b) All Sectors, Panel

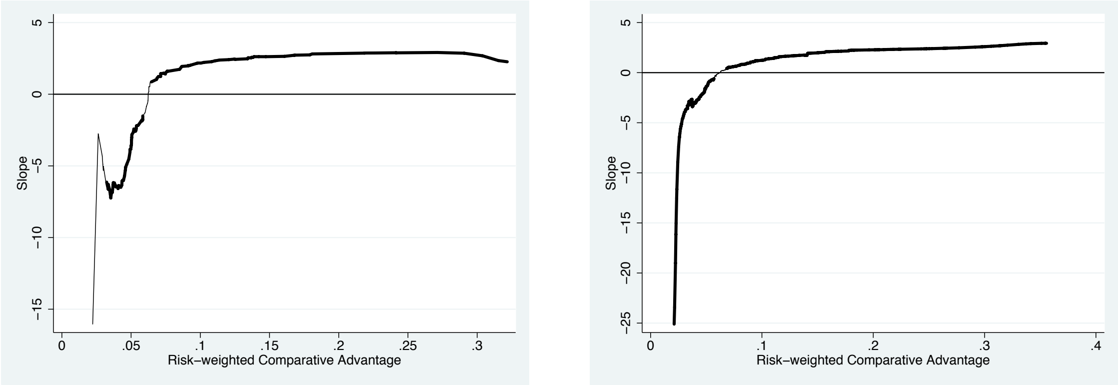


(c) Manufacturing Sectors, Cross Section

(d) Manufacturing Sectors, Panel

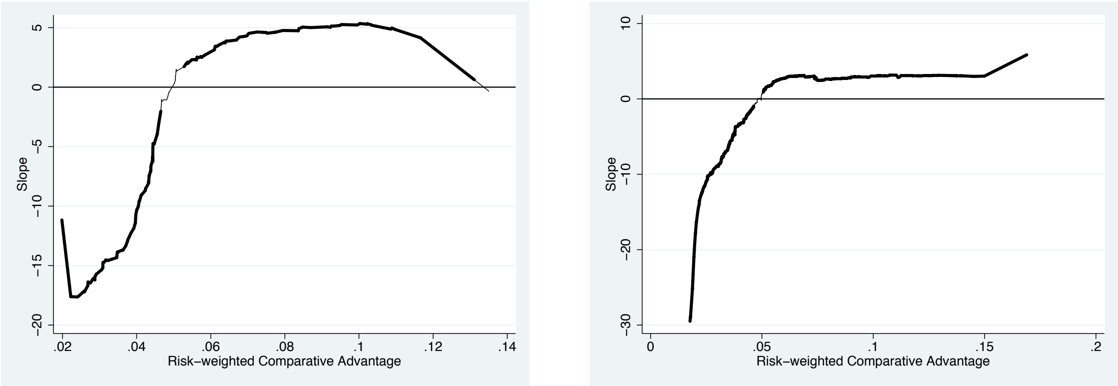
Notes: These graphs present Lowess estimates of the relationship between Herfx and RiskCA for cross-sectional (130 obs.) and five-year panels (780 obs.) data. The solid line is the estimated Herfx, and the '– –' lines represent ± two-standard deviation (95 percent) confidence bands, which are calculated by bootstrapping with 10,000 replications.

Figure 8. Estimated Lowess Slope Coefficients



(a) All Sectors, Cross Section

(b) All Sectors, Panel

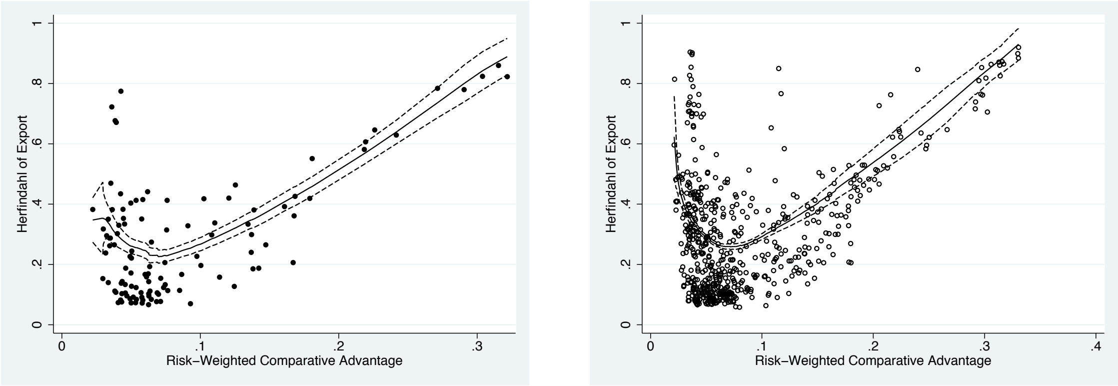


(c) Manufacturing Sectors, Cross Section

(d) Manufacturing Sectors, Panel

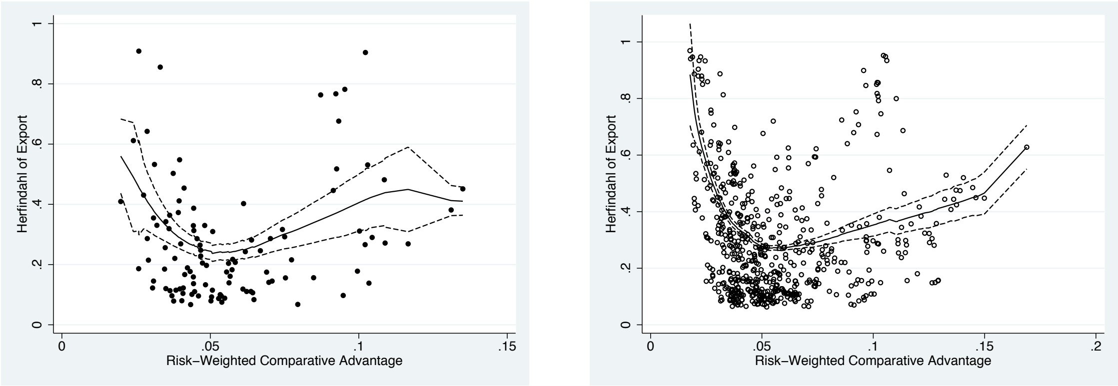
Notes: The graphs plot the estimated Lowess slope coefficients ($\hat{\beta}$) for each local linear regression of Herfx_{ct} on RiskCA_{ct}: $\text{Herfx}_{ct} = \alpha + \beta\text{RiskCA}_{ct} + \varepsilon_{ct}$, where α is a constant in the cross-sectional regressions, and a matrix of country and time dummies in the panel regressions. The thick lines are significantly different from zero at 95 percent (estimated by two standard deviations via bootstrapping 10,000 times), while the thin lines are insignificantly different from zero. Figures 7(a)-7(d) correspond to the Lowess estimations in Figures 6(a)-6(d), respectively.

Figure 9. Semi-Parametric Estimates of the Relationship Between a Country's Export Specialization and its Risk-Weighted Comparative Advantage



(a) All Sectors, Cross Section

(b) All Sectors, Panel

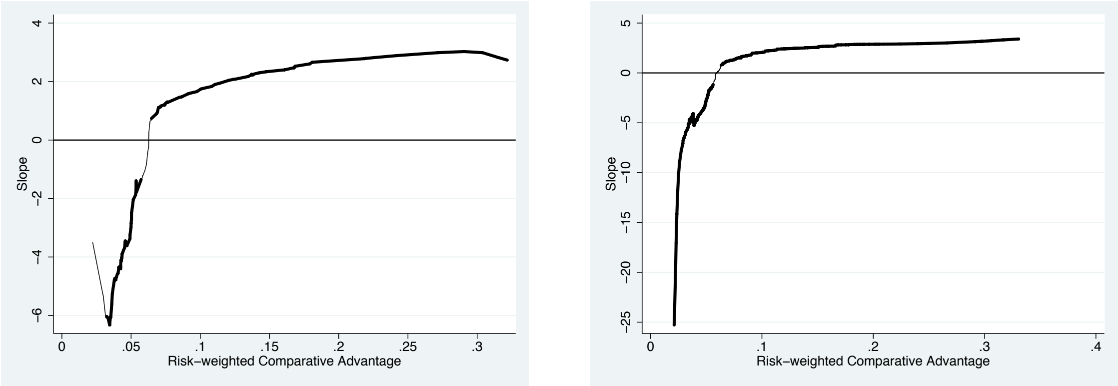


(c) Manufacturing Sectors, Cross Section

(d) Manufacturing Sectors, Panel

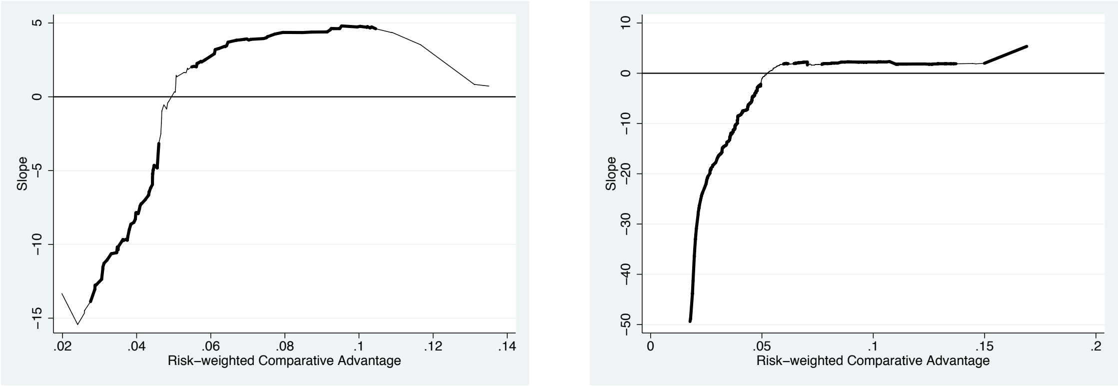
Notes: These graphs present semi-parametric estimates of the relationship between Herfx and RiskCA for cross-sectional (109 obs.) and five-year panels (579 obs.) data. The solid line is estimated Herfx, and the '– –' lines represent ± two-standard deviation (95 percent) confidence bands, which are calculated by bootstrapping with 10,000 replications.

Figure 10. Estimated Semi-Parametric Coefficients



(a) All Sectors, Cross Section

(b) All Sectors, Panel

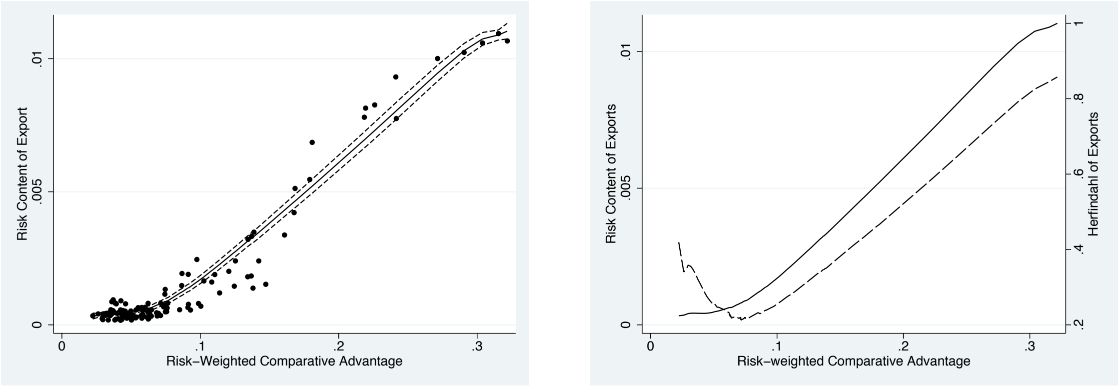


(c) Manufacturing Sectors, Cross Section

(d) Manufacturing Sectors, Panel

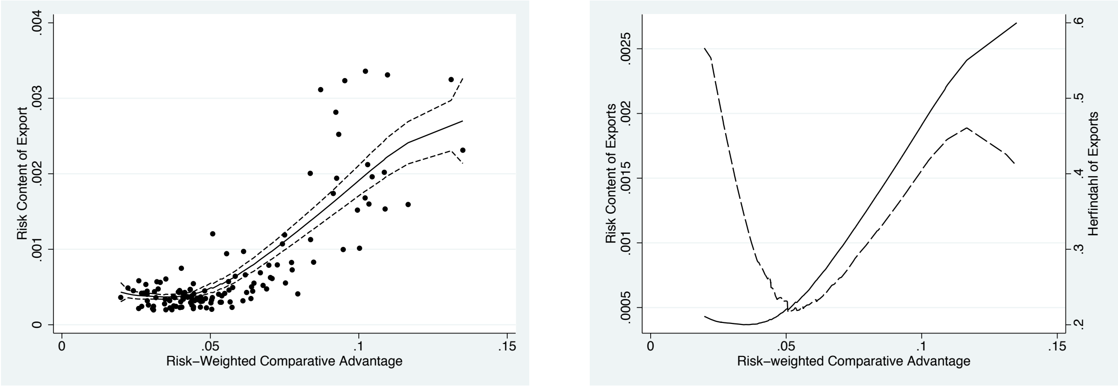
Notes: The graphs plot the estimated Lowess slope coefficients ($\hat{\beta}$) for each local linear regression of $\widehat{\widehat{\text{Herfx}}}_{ct}$ on RiskCA_{ct}: $\widehat{\widehat{\text{Herfx}}}_{ct} = \alpha + \beta\text{RiskCA}_{ct} + \varepsilon_{ct}$ from the last step of the semi-parametric procedure. The thick lines are significantly different from zero at 95 percent (estimated by two standard deviations via bootstrapping 10,000 times), while the thin lines are insignificantly different from zero. Figures 9(a)-9(d) correspond to the semi-parametric estimations in Figures 8(a)-8(d), respectively.

Figure 11. Lowess Estimates of the Relationship Between a Country's Risk Content of Exports, Specialization, and its Risk-Weighted Comparative Advantage: Manufacturing Sectors



(a) All Sectors, Cross Section

(b) All Sectors, Cross Section



(c) Manufacturing Sectors, Cross Section

(d) Manufacturing Sectors, Cross Section

Notes: These graphs present Lowess estimates of the relationship between RCX, Herfx and RiskCA for cross-sectional (130 obs.) data. For the two figures in the left column, the solid line is the estimated RCX, and the '– –' lines represent ± two-standard deviation (95 percent) confidence bands, which are calculated by bootstrapping with 10,000 replications. For the two figures in the right column, the solid line replicates the estimated RCX from the left column, while the '– –' line represents the estimated Herfxs, depicted in Figures 6(a) and 6(c), respectively.

Table A1. Country Summary Statistics by One-Digit Sector for the Growth Rate of Real Value Added per Worker: 1970–99

	Agriculture		Mining		Manufacturing	
Country	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Australia	-0.0236	0.1228	0.0477	0.1029	0.0272	0.0427
Austria	0.0137	0.0569	-0.0156	0.1753	0.0225	0.0343
Bangladesh	...	...	...	...	-0.0122	0.1528
Barbados	0.0666	0.1567	...	...	...	...
Belgium	...	...	...	...	0.0315	0.0413
Brazil	0.0345	0.1197	0.1321	0.6334	...	...
Canada	0.0215	0.1016	0.0331	0.1598	0.0255	0.0530
Chile	0.0526	0.1588	0.0467	0.2312	0.0345	0.1343
China	0.0370	0.0676	0.0847	0.0720	...	...
China, P.R.: Hong Kong	0.0160	0.1445	0.1180	0.5845	0.0433	0.0751
China, P.R.: Macao	...	...	...	...	0.0205	0.0608
Colombia	-0.0133	0.1461	0.0659	0.3046	0.0270	0.0617
Costa Rica	0.0039	0.1105	0.0060	0.1905	-0.0151	0.1086
Cyprus	0.0191	0.0864	0.0167	0.0736	0.0314	0.0597
Denmark	0.0254	0.1100	0.0445	0.2921	0.0036	0.0629
Ecuador	...	...	...	...	0.0351	0.2104
Egypt	0.0507	0.1245	...	...	0.0280	0.1115
Estonia	0.0807	0.0998	-0.0227	0.1645	...	...
Fiji	...	...	...	...	0.0037	0.1429
Finland	0.0242	0.0824	0.0467	0.1761	0.0320	0.0642
France	...	...	...	...	0.0273	0.0289
Germany	0.0502	0.0515	0.0108	0.1580	0.0285	0.0363
Greece	...	...	...	...	0.0155	0.0518
Guatemala	...	...	...	...	0.0109	0.0958
Honduras	0.0164	0.0766	0.0431	0.1770	-0.0553	0.1044
Hungary	...	...	...	...	0.0255	0.0928
Iceland	...	...	...	...	0.0304	0.1027
India	...	...	...	...	0.0455	0.0887
Indonesia	0.0413	0.0903	-0.0576	0.3505	0.0606	0.1117
Ireland	0.0027	0.0683	0.1966	0.4703	0.0681	0.0531
Israel	0.0240	0.1141	0.0684	0.1748	0.0249	0.1555
Italy	0.0307	0.0532	-0.0013	0.0947	0.0162	0.0612
Jamaica	0.0089	0.0869	-0.0462	0.2440	-0.0053	0.0795
Japan	0.0102	0.0425	0.0045	0.1509	0.0235	0.0498
Jordan	...	...	...	...	0.0108	0.1436
Korea	...	...	...	...	0.0613	0.0574
Luxembourg	...	...	...	...	0.0011	0.1189
Malawi	...	...	...	...	0.0060	0.1879
Malaysia	...	...	...	...	0.0318	0.0509
Malta	...	...	...	...	0.1009	0.0536
Mauritius	...	...	...	...	0.0032	0.0758
Mexico	-0.0251	0.1360	...	...	0.0105	0.0587
Morocco	0.0413	0.2116	0.1079	0.3324	...	...
Netherlands	0.0205	0.0718	0.0345	0.1938	...	...
New Zealand	...	...	...	...	0.0096	0.0559
Norway	0.0336	0.0733	0.1584	0.3883	0.0159	0.0540

continued on next page

continued from last page

	Agriculture		Mining		Manufacturing	
Country	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Pakistan	0.0182	0.0726	0.1890	0.5821	0.0467	0.0860
Panama	0.0250	0.0736	0.1830	0.8098	0.0116	0.0885
Peru	...	...	...	...	-0.0181	0.1347
Philippines	-0.0028	0.0677	0.0141	0.2497	0.0385	0.2113
Poland	...	...	...	...	0.0179	0.1202
Portugal	-0.0190	0.1356	0.2015	0.4029	0.0088	0.0752
Senegal	...	...	...	...	0.0217	0.2205
Singapore	0.0584	0.2448	0.0981	0.4016	0.0556	0.0570
South Africa	...	...	...	...	-0.0032	0.0713
Spain	...	...	...	...	0.0300	0.0752
Sri Lanka	0.0337	0.1746	0.1781	0.5674	0.0092	0.0733
Sweden	...	...	...	...	0.0173	0.0797
Syrian Arab Republic	...	...	...	...	0.0307	0.1965
Taiwan, P.O.C.	...	...	...	...	0.0416	0.0476
Tanzania	...	...	...	...	-0.0386	0.1348
Thailand	0.0299	0.1316	0.1698	0.5699	...	...
Trinidad and Tobago	0.0021	0.1765	0.0377	0.2395	0.0069	0.1442
Turkey	0.0411	0.1247	0.0611	0.2558	0.0363	0.0917
United Kingdom	0.0130	0.0629	0.0961	0.1730	0.0210	0.0585
United States	0.0070	0.0731	0.0239	0.1305	0.0237	0.0292
Uruguay	...	...	...	...	0.0310	0.1379
Venezuela, Rep. Bol.	0.0142	0.1211	0.0231	0.2874	...	...
Zimbabwe	...	...	...	...	0.0447	0.0907

Notes: The means and standard deviations (St. Dev.) are calculated on the growth rate of real value added per worker for 1970–99. A '...' indicates missing data for the country in the given sector for this time period. These data are used to calculate the $\boldsymbol{\Sigma}$ matrix in Section 4.1.

Table A2. Sector Summary Statistics: 1970–99

		Growth	
ISIC	Sector Name	Mean	Std. Dev.
1	Agriculture	0.0222	0.1144
2	Mining and quarrying	0.0722	0.3566
311	Food products	0.0217	0.1510
313	Beverages	0.0348	0.1864
314	Tobacco	0.0635	0.2442
321	Textiles	0.0316	0.1805
322	Wearing apparel, except footwear	0.0249	0.1618
323	Leather products	0.0291	0.2132
324	Footwear, except rubber or plastic	0.0290	0.2119
331	Wood products, except furniture	0.0312	0.2159
332	Furniture, except metal	0.0240	0.1822
341	Paper and products	0.0421	0.2129
342	Printing and publishing	0.0351	0.1721
351	Industrial chemicals	0.0522	0.2658
352	Other chemicals	0.0374	0.1739
353	Petroleum refineries	0.0648	0.3574
354	Misc. petroleum and coal products	0.0598	0.3285
355	Rubber products	0.0288	0.1859
356	Plastic products	0.0323	0.1818
361	Pottery, china, earthenware	0.0412	0.2210
362	Glass and products	0.0501	0.2501
369	Other non-metallic mineral products	0.0389	0.1799
371	Iron and steel	0.0461	0.2566
372	Non-ferrous metals	0.0408	0.2532
381	Fabricated metal products	0.0267	0.1703
382	Machinery, except electrical	0.0331	0.1853
383	Machinery, electric	0.0385	0.1793
384	Transport equipment	0.0455	0.2167
385	Professional & scientific equipment	0.0407	0.2080
390	Other manufactured products	0.0269	0.1931

Notes: The means and standard deviations (St. Dev.) are calculated on the growth rate of real value added per worker for 1970–99.

Table A3. Risk Content of Exports Across Countries for the 1990s

Country	Risk Content of Exports	Largest export sector	Second Largest Export Sector	Share of Top 2 Export Sectors	Herfx
Angola	0.0113	Mining and quarrying	Other manufactured products	0.9666	0.8791
Nigeria	0.0108	Mining and quarrying	Agriculture	0.9462	0.8406
Iran, I.R. of	0.0097	Mining and quarrying	Agriculture	0.9070	0.7632
Qatar	0.0096	Mining and quarrying	Industrial chemicals	0.9110	0.7317
Oman	0.0089	Mining and quarrying	Transport equipment	0.8835	0.7053
Saudi Arabia	0.0084	Mining and quarrying	Petroleum refineries	0.9066	0.6305
Gabon	0.0083	Mining and quarrying	Agriculture	0.9669	0.6812
Kuwait	0.0080	Mining and quarrying	Petroleum refineries	0.9697	0.5989
United Arab Emirates	0.0069	Mining and quarrying	Petroleum refineries	0.8055	0.5329
Congo, Republic of	0.0067	Mining and quarrying	Other manufactured products	0.8214	0.5291
Algeria	0.0067	Mining and quarrying	Petroleum refineries	0.9639	0.5128
Syrian Arab Republic	0.0060	Mining and quarrying	Agriculture	0.8519	0.4988
Venezuela, Rep. Bol.	0.0049	Mining and quarrying	Petroleum refineries	0.7877	0.3668
Equatorial Guinea	0.0037	Mining and quarrying	Agriculture	0.8983	0.4213
Guinea	0.0035	Mining and quarrying	Industrial chemicals	0.8029	0.3440
Norway	0.0032	Mining and quarrying	Agriculture	0.5487	0.2513
Mauritania	0.0032	Mining and quarrying	Agriculture	0.9809	0.4812
Egypt	0.0030	Mining and quarrying	Petroleum refineries	0.5785	0.2503
Sierra Leone	0.0029	Mining and quarrying	Other manufactured products	0.7139	0.3011
Niger	0.0028	Industrial chemicals	Mining and quarrying	0.9098	0.5592
Netherlands	0.0026	Petroleum refineries	Mining and quarrying	0.8563	0.5754
Togo	0.0024	Mining and quarrying	Agriculture	0.8479	0.3652
Papua New Guinea	0.0020	Mining and quarrying	Agriculture	0.7294	0.3008
Trinidad and Tobago	0.0019	Mining and quarrying	Industrial chemicals	0.5228	0.1892
Cameroon	0.0019	Agriculture	Mining and quarrying	0.7843	0.3204
Bahrain, Kingdom of	0.0018	Petroleum refineries	Non-ferrous metals	0.7538	0.3097
Central African Rep.	0.0017	Mining and quarrying	Other manufactured products	0.6722	0.2733
Jordan	0.0017	Industrial chemicals	Mining and quarrying	0.6401	0.2230
Gambia, The	0.0016	Agriculture	Mining and quarrying	0.6558	0.3176
Australia	0.0015	Mining and quarrying	Agriculture	0.4963	0.1659
Bolivia	0.0014	Mining and quarrying	Food products	0.4820	0.1761
South Africa	0.0014	Mining and quarrying	Non-ferrous metals	0.3973	0.1160
Bermuda	0.0014	Mining and quarrying	Other manufactured products	0.5781	0.2150
Chile	0.0013	Non-ferrous metals	Agriculture	0.5818	0.2003

continued on next page

continued from last page

Country	Risk Content of Exports	Largest export sector	Second Largest Export Sector	Share of Top 2 Export Sectors	Herfx
Mongolia	0.0013	Mining and quarrying	Non-ferrous metals	0.4934	0.1876
Ecuador	0.0012	Agriculture	Mining and quarrying	0.7995	0.3645
Peru	0.0011	Non-ferrous metals	Food products	0.5131	0.1789
Chad	0.0011	Agriculture	Transport equipment	0.9710	0.9002
Colombia	0.0010	Mining and quarrying	Agriculture	0.5180	0.1664
Somalia	0.0010	Agriculture	Food products	0.9354	0.8204
Indonesia	0.0010	Mining and quarrying	Wood products, except furniture	0.3705	0.1120
Malawi	0.0009	Agriculture	Food products	0.9025	0.7021
Burkina Faso	0.0009	Agriculture	Food products	0.9014	0.7291
Jamaica	0.0008	Wearing apparel, except footwear	Mining and quarrying	0.4873	0.1837
Mali	0.0008	Agriculture	Machinery, electric	0.8704	0.6933
Guinea-Bissau	0.0007	Agriculture	Mining and quarrying	0.8221	0.6208
Benin	0.0007	Agriculture	Textiles	0.8716	0.5998
Sudan	0.0007	Agriculture	Food products	0.8978	0.5897
Finland	0.0007	Paper and products	Machinery, electric	0.4190	0.1320
Guyana	0.0006	Food products	Mining and quarrying	0.5588	0.2290
Mozambique	0.0006	Agriculture	Iron and steel	0.6806	0.3263
Tanzania	0.0006	Agriculture	Food products	0.8005	0.4614
Iceland	0.0006	Agriculture	Food products	0.7927	0.4209
Kenya	0.0006	Agriculture	Food products	0.8410	0.4539
Zimbabwe	0.0006	Agriculture	Iron and steel	0.5821	0.2478
Ghana	0.0006	Agriculture	Non-ferrous metals	0.5448	0.2138
Uganda	0.0006	Agriculture	Food products	0.9855	0.4949
Myanmar	0.0006	Agriculture	Wearing apparel, except footwear	0.7589	0.4264
Djibouti	0.0006	Agriculture	Food products	0.4110	0.1315
Nepal	0.0006	Textiles	Wearing apparel, except footwear	0.8011	0.3501
Bulgaria	0.0006	Industrial chemicals	Wearing apparel, except footwear	0.2433	0.0738
Côte d'Ivoire	0.0006	Agriculture	Food products	0.8087	0.4194
Paraguay	0.0006	Agriculture	Food products	0.7798	0.3834
Burundi	0.0005	Agriculture	Food products	0.9577	0.4669
Senegal	0.0005	Agriculture	Food products	0.7558	0.3171
Pakistan	0.0005	Textiles	Wearing apparel, except footwear	0.7227	0.3223
Bahamas, The	0.0005	Transport equipment	Industrial chemicals	0.5270	0.1780
Rwanda	0.0005	Agriculture	Food products	0.9116	0.4324
Israel	0.0005	Other manufactured products	Mining and quarrying	0.3240	0.1020
Vietnam	0.0005	Mining and quarrying	Agriculture	0.3933	0.1225
Seychelles	0.0005	Agriculture	Food products	0.8827	0.4019

continued on next page

continued from last page

Country	Risk Content of Exports	Largest export sector	Second Largest Export Sector	Share of Top 2 Export Sectors	Herfx
Canada	0.0005	Transport equipment	Mining and quarrying	0.3693	0.1170
Belize	0.0005	Agriculture	Food products	0.8268	0.3514
Brazil	0.0005	Food products	Agriculture	0.2932	0.0886
Cambodia	0.0004	Wearing apparel, except footwear	Agriculture	0.8137	0.3945
Lao People's Dem.Rep	0.0004	Wearing apparel, except footwear	Wood products, except furniture	0.6936	0.2840
Belgium-Luxembourg	0.0004	Transport equipment	Industrial chemicals	0.2922	0.0757
Ethiopia	0.0004	Food products	Agriculture	0.8202	0.3434
Reunion	0.0004	Food products	Agriculture	0.8368	0.4992
Madagascar	0.0004	Agriculture	Wearing apparel, except footwear	0.6715	0.2973
Bangladesh	0.0004	Wearing apparel, except footwear	Agriculture	0.8165	0.5138
Honduras	0.0004	Wearing apparel, except footwear	Agriculture	0.8109	0.3493
Nicaragua	0.0004	Agriculture	Food products	0.6807	0.2848
Guatemala	0.0004	Agriculture	Wearing apparel, except footwear	0.6611	0.2841
Costa Rica	0.0004	Agriculture	Wearing apparel, except footwear	0.6563	0.2679
El Salvador	0.0004	Wearing apparel, except footwear	Agriculture	0.6976	0.3314
Poland	0.0004	Wearing apparel, except footwear	Food products	0.1769	0.0581
Morocco	0.0004	Wearing apparel, except footwear	Agriculture	0.4952	0.1649
Romania	0.0004	Wearing apparel, except footwear	Iron and steel	0.3335	0.0884
Panama	0.0004	Transport equipment	Agriculture	0.6407	0.2175
Sweden	0.0004	Machinery, except electrical	Transport equipment	0.3343	0.1035
India	0.0004	Wearing apparel, except footwear	Textiles	0.2877	0.0905
Ireland	0.0003	Machinery, except electrical	Industrial chemicals	0.4015	0.1212
New Zealand	0.0003	Food products	Agriculture	0.5912	0.2001
Switzerland	0.0003	Machinery, except electrical	Professional & scientific equipment	0.3454	0.1073
Mauritius	0.0003	Wearing apparel, except footwear	Food products	0.8566	0.4090
St. Kitts and Nevis	0.0003	Agriculture	Transport equipment	0.5655	0.2163
Austria	0.0003	Machinery, except electrical	Transport equipment	0.2928	0.0786
Haiti	0.0003	Wearing apparel, except footwear	Agriculture	0.6826	0.3619
Uruguay	0.0003	Food products	Agriculture	0.4507	0.1415
Germany	0.0003	Machinery, except electrical	Transport equipment	0.4023	0.1099
Argentina	0.0003	Food products	Agriculture	0.5625	0.1763
Albania	0.0003	Wearing apparel, except footwear	Leather products	0.4295	0.1299
Spain	0.0003	Transport equipment	Agriculture	0.3579	0.1053
Fiji	0.0003	Food products	Wearing apparel, except footwear	0.6982	0.2820
France	0.0003	Transport equipment	Machinery, except electrical	0.3365	0.0930
Mexico	0.0003	Machinery, electric	Transport equipment	0.4199	0.1232
Lebanon	0.0003	Other manufactured products	Agriculture	0.4044	0.1140

continued on next page

continued from last page

Country	Risk Content of Exports	Largest export sector	Second Largest Export Sector	Share of Top 2 Export Sectors	Herfx
United Kingdom	0.0003	Machinery, except electrical	Transport equipment	0.3419	0.0904
Tunisia	0.0003	Wearing apparel, except footwear	Industrial chemicals	0.5348	0.2172
Turkey	0.0003	Wearing apparel, except footwear	Agriculture	0.4004	0.1243
Sri Lanka	0.0003	Wearing apparel, except footwear	Agriculture	0.7040	0.3103
Korea	0.0003	Machinery, electric	Machinery, except electrical	0.3661	0.1120
Dominican Republic	0.0003	Wearing apparel, except footwear	Agriculture	0.5422	0.2500
Japan	0.0003	Machinery, except electrical	Transport equipment	0.4922	0.1782
Cyprus	0.0003	Transport equipment	Agriculture	0.4506	0.1396
United States	0.0002	Machinery, except electrical	Machinery, electric	0.3380	0.1024
Greece	0.0002	Wearing apparel, except footwear	Agriculture	0.3469	0.0995
Taiwan, P.O.C.	0.0002	Machinery, except electrical	Machinery, electric	0.4712	0.1367
Hungary	0.0002	Machinery, electric	Machinery, except electrical	0.2751	0.0822
Italy	0.0002	Machinery, except electrical	Transport equipment	0.3165	0.0839
Barbados	0.0002	Food products	Machinery, electric	0.4818	0.1528
Malaysia	0.0002	Machinery, electric	Machinery, except electrical	0.5262	0.1823
Portugal	0.0002	Wearing apparel, except footwear	Transport equipment	0.2905	0.0783
Denmark	0.0002	Food products	Machinery, except electrical	0.3550	0.0936
China, P.R.: Hong Kong	0.0002	Wearing apparel, except footwear	Machinery, electric	0.4190	0.1308
Singapore	0.0002	Machinery, except electrical	Machinery, electric	0.6041	0.2077
Philippines	0.0002	Machinery, electric	Machinery, except electrical	0.5401	0.1914
China, P.R.: Mainland	0.0002	Wearing apparel, except footwear	Machinery, except electrical	0.3238	0.0921
Thailand	0.0002	Machinery, except electrical	Machinery, electric	0.3543	0.1080

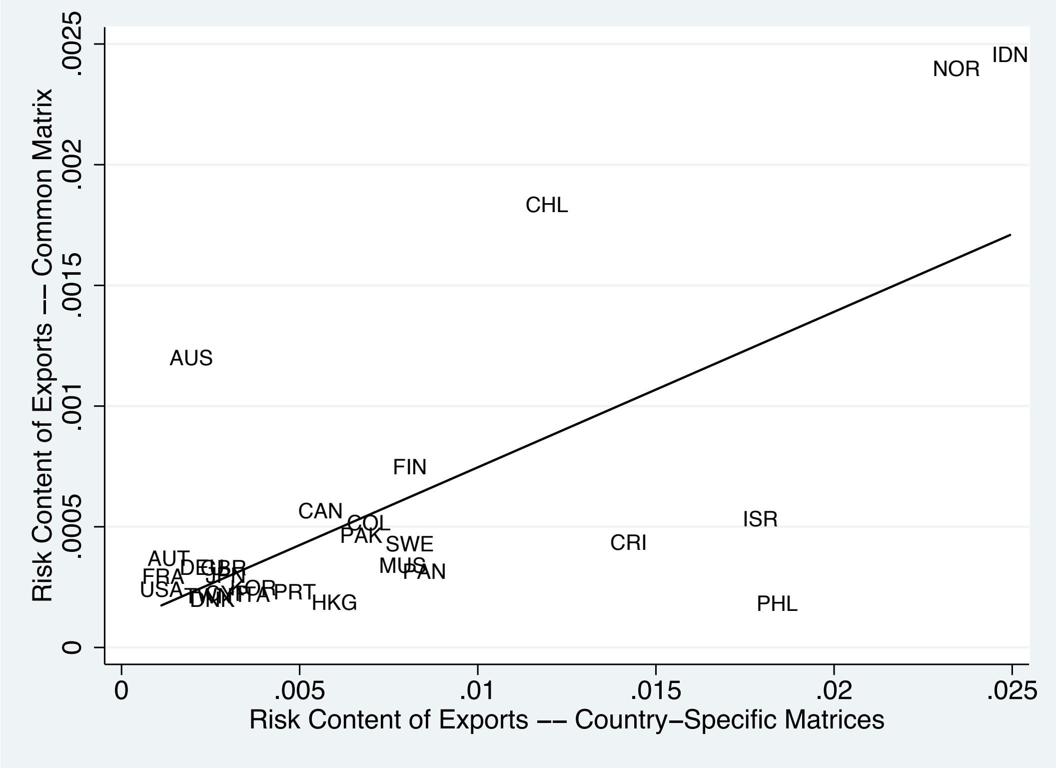
Notes: This table reports the risk content of exports, RCX_{ct}, as defined in the text, along with the information on the top two export sectors and their share in total manufacturing exports. “Herfx” is the Herfindahl index of the export shares. All figures are averages for 1990-99.

Table A4. Residual Regressions of Specialization of Exports on Controls for Semi-parametric Estimation

	All Sectors		**Mfg. Sectors**	
	Cross Section	Panel	Cross Section	Panel
Income per capita	-0.036**	-0.004	-0.032**	0.011
	(0.006)	(0.006)	(0.010)	(0.007)
(Income per capita)^2/100	0.137**	0.046**	0.121**	0.001
	(0.028)	(0.017)	(0.046)	(0.021)
Log(Population density)	0.026**	4.415	0.004	10.887
	(0.008)	(5.496)	(0.013)	(6.719)
Log(Population)	-0.029**	4.565	-0.019	11.028
	(0.008)	(5.495)	(0.013)	(6.717)
Log(Distantness)	0.024	0.066	0.023	0.024
	(0.042)	(0.133)	(0.071)	(0.163)
Log(Financial open)	0.007	0.010	0.010	0.009
	(0.019)	(0.012)	(0.031)	(0.014)
Observations	111	583	109	583
Countries	-	111	-	109
R^2	0.490	0.838	0.161	0.819
Country Effects	-	yes	-	yes
Time Effects	-	yes	-	yes

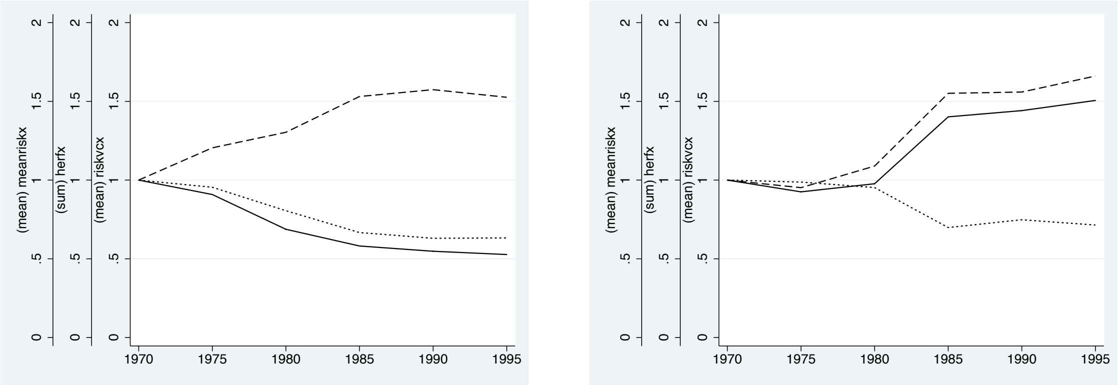
Notes: Robust standard errors in parentheses. + significant at 10%; * significant at 5%; ** significant at 1%. This table reports the unbiased linear estimated coefficients, $\hat{\boldsymbol{\gamma}}_c$, from the semi-parametric estimation $\text{Herfx}_{ct} = \boldsymbol{\gamma}_c' \mathbf{X}_{ct} + g\left(\text{RiskCA}_{ct}\right) + \varepsilon_{ct}$. The estimates come from an OLS regression in the second step of the procedure. The sample period is 1970–99. In the cross-sectional specifications, all variables are period averages. In the panel specifications, all variables are 5-year averages over 1970–74, 75–79, 80–84, 85–89, 90–94, and 95–99. Income per capita is measured in thousands real PPP-adjusted US dollars (source: Penn World Tables). Population density is area divided by population. Distantness is defined as GDP-weighted distance to all potential trading partners. Population, land area, and total USD GDP come from the World Bank's World Development Indicators, while bilateral distances come from CEPII. Financial openness is defined as (total external assets + total external liabilities)/GDP, obtained from Lane and Milesi-Ferretti (2006).

Figure A1. Comparison of Risk Content of Exports Computed using Country-Specific and Common Covariance Matrices



Notes: The Risk Content of Exports variables are constructed using the average trade shares for the period 1970–99. On the horizontal axis is the Risk Content of Exports computed using covariance matrices specific to each country. On the vertical axis is the headline Risk Content of Exports measure used in this paper, computed using the same covariance matrix for all countries.

Figure A2. Risk Content of Exports Over Time for a Selection of Countries



(a) Japan

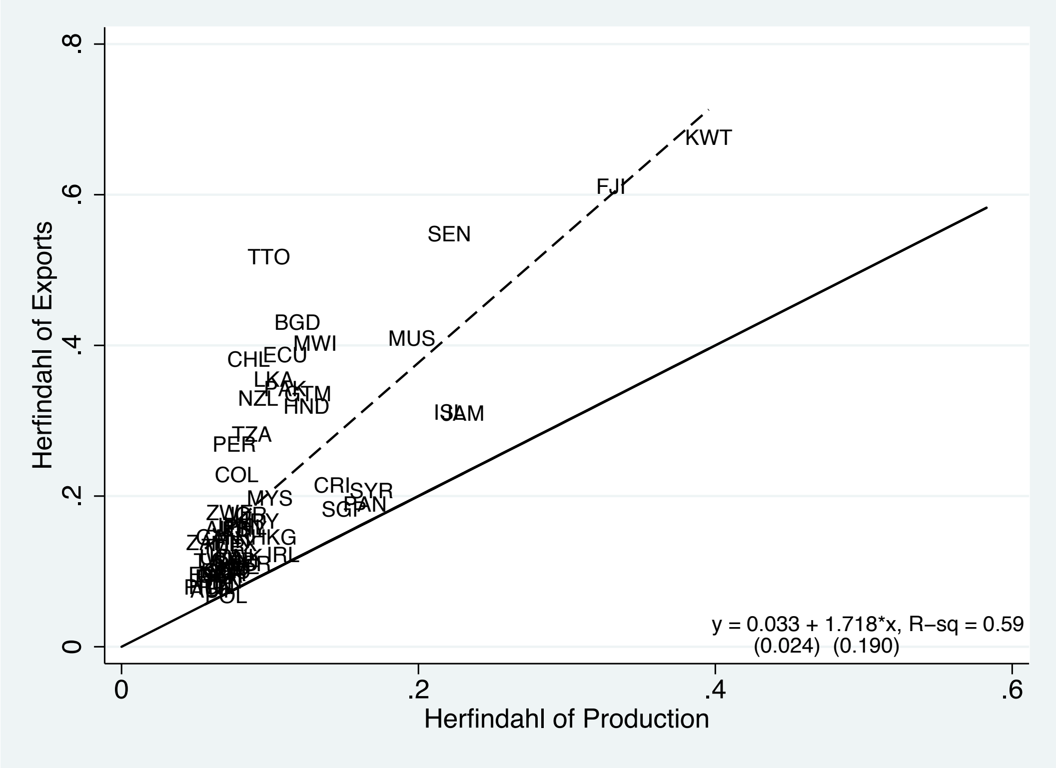
(b) Kenya

(c) Chile

(d) Norway

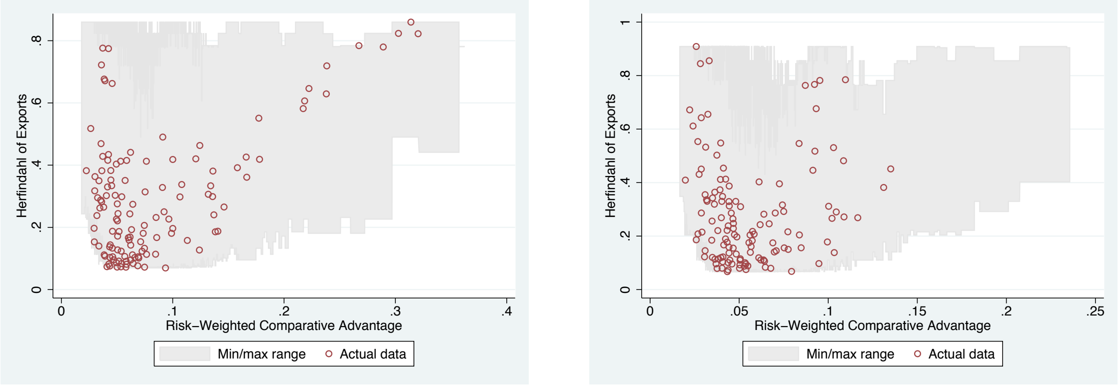
Notes: — Risk content of exports, – – Herfx, - - - MeanRisk. Measures based on five-year averages of export shares.

Figure A3. Export Specialization and Domestic Production Specialization



Notes: The Herfindahl Exports variables are constructed using the export shares in the manufacturing sector for the period 1970–99, while the Herfindahl of Production is constructed using value added shares in the manufacturing sector for the period 1970–99. The solid line is a 45-degrees line, while the dashed line represents the regression fitted line.

Figure A4. The Range of Feasible Outcomes



(a) All Sectors

(b) Manufacturing Sectors