

VOLATILITY, LABOR MARKET FLEXIBILITY, AND THE PATTERN OF COMPARATIVE ADVANTAGE

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Abstract

This paper studies the link between volatility, labor market flexibility, and international trade. International differences in labor market regulations affect how firms can adjust to idiosyncratic shocks. These institutional differences interact with sector specific differences in volatility (the variance of the firm-specific shocks in a sector) to generate a new source of comparative advantage. Other things equal, countries with more flexible labor markets specialize in sectors with higher volatility. Empirical evidence for a large sample of countries strongly supports this theory: the exports of countries with more flexible labor markets are biased towards high-volatility sectors. We show how differences in labor market institutions can be parsimoniously integrated into the workhorse model of Ricardian comparative advantage of Dornbusch, Fischer, and Samuelson (1977, *American Economic Review*, 67, 823–839). We also show how our model can be extended to multiple factors of production. (JEL: F1, F16)

1. Introduction

Comparative advantage is usually attributed to international differences in production capabilities *stricto sensu*. Such differences stem from international differences in either technology (as in the Ricardian model) or relative factor endowments (as in the Heckscher–Ohlin model). But institutional differences can give way to comparative advantage, too, even when technologies and relative factor endowments are identical across countries. In particular, this paper studies the role of labor market flexibility as a source of comparative advantage.

Cross-country differences in labor market flexibility—as with other measures of institutional differences—are correlated with country income levels. Nevertheless,

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TABLE 1. Country labor market flexibility index, by GDP per capita cutoff.

2,000 < GDPPC_c = 5,000		5,000 < GDPPC_c = 10,000		GDPPC_c > 10,000	
Name	FLEX_c	name2	FLEX_c	name2	FLEX_c
Morocco*	30	Mexico	28	Spain	31
Ukraine*	36	Brazil	28	France	34
Guinea*	41	Paraguay	41	Greece	34
Uzbekistan*	42	Venezuela	44	Portugal	42
Indonesia	43	Turkey	45	Germany*	45
Peru	45	Belarus*	46	Slovenia*	47
Algeria	45	Tunisia	46	Argentina	49
Moldova*	46	South Africa	48	Italy	50
Egypt	47	Colombia	49	Finland	56
El Salvador	48	Latvia*	51	Netherlands	57
Ecuador	49	Estonia*	56	Sweden	57
Georgia*	51	Thailand	58	Austria	60
India	52	Lithuania*	59	Oman*	65
Philippines	59	Hungary	60	Republic of Korea	66
Bolivia	60	Iran	60	Israel	67
Dominican Republic	60	Costa Rica	65	Norway	70
Guatemala	60	Poland	66	Ireland	71
Sri Lanka	60	Uruguay	69	Czech Republic*	72
Kyrgyzstan*	62	Bulgaria*	72	Japan	76
Azerbaijan*	62	Kazakhstan*	73	Belgium	80
Macedonia*	62	Russian Federation*	73	United Kingdom	80
Syria	63	Fiji	79	Kuwait*	80
Armenia*	64	Chile	81	Switzerland	83
Jordan	66	Slovakia*	90	Australia	83
Honduras	69	Malaysia	97	Denmark	83
China	70			Saudi Arabia*	87
Albania*	70			New Zealand	93
Lebanon*	72			Canada	96
Zimbabwe	76			United States	97
Papua New Guinea	83			Singapore	100
Jamaica	90			Hong Kong	100

Notes: *Countries with missing data on physical or human capital abundance.

substantial differences in labor market flexibility persist within groups of countries with similar income levels. Within the OECD, for example, North America, the British Isles and Oceania have much more flexible labor markets than most of continental Europe. Table 1 illustrates these differences within income groups using an index of labor market flexibility constructed by the World Bank.¹ These institutional differences are associated with important cross-country differences in the flows of workers between employment and unemployment and, more importantly for our purposes, across jobs. Table 2, taken from Blanchard and Portugal (2001), compares job flows in the United States (a country with a flexible labor market) and Portugal (a country

1. We discuss this index in detail in Section 4.

TABLE 2. Job reallocation: Comparing the United States and Portugal.

Quarterly job creation and destruction, all manufacturing sectors			
	Job Creation	Job Destruction	Job Reallocation
Portugal (1991:1-1995:4)	4	3.9	7.9
US (1972:2-1993:4)	6.8	7.3	14

Source: Blanchard and Portugal (2001).

TABLE 3. Variation in job reallocation rates across sectors.

Average annual excess job reallocation rates, US manufacturing sectors	
Percentile	Excess Job Reallocation
1%	4.1
5%	6.2
10%	7.4
25%	9.9
50%	12.9
75%	15.8
90%	19.4
95%	21.7
99%	25.6
Size-Weighted Mean	13.2
Industry Observations	514

Source: Davis, Haltiwanger, and Schuh (1997).

with a substantially more rigid labor market).² Although the US and Portuguese unemployment rates were similar during the early 1990s, the Portuguese labor market exhibited much smaller flows of workers across different jobs. This finding is echoed in the OECD Employment Outlook (1999, Chart 2.3) covering the 1990s, which shows a significant negative correlation across OECD countries between employment protection and job turnover rates.³

Worker flows vary importantly also across industries. Table 3, taken from Davis, Haltiwanger, and Schuh (1997), summarizes the distribution of average annual excess job reallocation rates (as a percentage of employment) across four-digit (US SIC) manufacturing industries in the United States. Excess job reallocation reflects

2. Job creation at time t equals employment gains summed over all plants that expand or start up between $t - 1$ and t . Job destruction at time t equals employment losses summed over all plants that contract or shut down between $t - 1$ and t . Net employment growth equals the job creation rate minus the job destruction rate. Job reallocation at time t is the sum of job creation and job destruction. Excess job reallocation equals the difference between job reallocation and the absolute value of net employment change.

3. Bertola and Rogerson (1997) argue that additional institutional differences across countries—such as those generating wage compression—may counteract the effects of differences in employment protection and generate much smaller differences in the observed job reallocation rates across countries. In a different context (across regions in a country), Aghion et al. (2008) also highlight the important effects of differences in labor market institutions within India. They find that the growth effects of product market liberalization depend on differences in labor market regulation across states.

simultaneous job creation and destruction within industries. It represents the excess portion of job reallocation—over and above the amount required to accommodate net industry employment changes. Table 3 shows that the within-industry reallocation process exhibits a remarkable degree of cross-industry variation. Clearly, this variation cannot be attributed to differences in labor market regulation. We interpret this cross-industry variation as reflecting differences in the needed adjustments, at the firm-level, to idiosyncratic demand and productivity shocks: a higher within-industry dispersion of shocks entails a larger response in the within-industry reallocation of employment between firms.

We formalize a theory of comparative advantage in this context. For simplicity, we frame our insights within a one-factor model of trade between two countries with different labor market institutions (a flexible and a rigid economy). These differences interact with industry-level differences in the dispersion of firm-level shocks to generate industry-level differences in relative productivity, and hence a *Ricardian* source of comparative advantage. Again for simplicity, we do not model any technological differences between countries. Thus, in the absence of shocks, differences in labor market flexibility are irrelevant. There is then no source of comparative advantage, and no motive for trade. However, in the presence of firm-level shocks, the country with flexible labor markets can reallocate labor across firms more easily—leading to higher industry average productivity levels relative to the country with rigid labor markets. This productivity difference is then magnified by the dispersion of the within-industry shocks, which we refer to as industry volatility. The latter thus interacts with the institutional labor market differences to induce a pattern of comparative advantage across industries.

We also extend our model to incorporate a second factor, capital, whose reallocation across firms is not affected by the labor market institutions. Provided that this reallocation of capital across firms is subject to the same degree of rigidity in both countries, then the pattern of comparative advantage driven by industry volatility becomes more muted for capital-intensive industries. In other words, rigid economies face less of a comparative disadvantage in capital-intensive industries—holding industry volatility constant. This extended model also explains how capital intensity affects comparative advantage based on differences in labor market institutions—separately from the standard Heckscher–Ohlin effect via interactions with a country's capital abundance.

We then empirically test the predictions of our model on the observed pattern of comparative advantage for a large sample of countries, using country-level export data at a detailed level of sector disaggregation (hundreds of sectors).⁴ We thus test whether countries with relatively flexible labor markets concentrate their exports relatively more intensively in sectors with higher volatility. We also test the additional prediction of our model that capital intensity reduces this effect of volatility for countries with relatively rigid labor markets. Naturally, we also control for other determinants of comparative

4. Production data from UNIDO are not available at this level of disaggregation.

advantage such as the interactions between country-level factor abundance and sector-level factor intensities. We use two distinct estimation approaches towards these goals. The first approach, in the spirit of Romalis (2004), uses the full cross-section of exports flows across countries and sectors to test for interactions effects between the country-level and sector-level characteristics that jointly determine comparative advantage.⁵ Recognizing some important limitations (both theoretical and empirical) associated with this method, we also use a second more robust approach based on a country-level analysis. Both approaches strongly confirm our theoretical results.

The potential links between labor markets and comparative advantage have received an increasing level of attention in the recent trade literature. Saint-Paul (1997) analyzes the links between firing costs and international specialization according to the life-cycle of goods: countries with flexible labor markets exhibit a comparative advantage in new industries subject to higher aggregate demand volatility (relative to more mature industries). Haaland and Wooton (2007) also focus on differences in firing costs across countries, and examine their implications for the location of multinational affiliates. Davidson, Martin, and Matusz (1999) present an equilibrium unemployment model in which the country with a more efficient search technology has a comparative advantage in the good produced in high-unemployment/high-vacancy sectors. This is due to the differences in prices required to induce factors to search for matches in sectors with different break-up rates. Galdón-Sánchez (2002) shows that labor market rigidities can also affect specialization through long-term unemployment, which reduces the skills workers may need in new-economy sectors. In the current paper, we focus on a relatively more tractable theoretical framework that generates a richer set of predictions and lends itself to direct empirical testing. In particular, we highlight the role of firm-level volatility and labor market flexibility in shaping the pattern of comparative advantage.⁶ We show how measurable differences in firm-level volatility across sectors interact with capital intensity differences to generate a pattern of comparative advantage across countries with difference levels of labor market flexibility.

Our paper is also related to a growing literature that studies the effects of international differences in institutions on trade patterns. Kletzer and Bardhan (1987), Beck (2002), Matsuyama (2005), and Manova (2008) show how credit market imperfections lead to comparative advantage when industries differ in their borrowing needs. Levchenko (2004) shows that the quality of institutions (e.g. property rights, the quality of contract enforcement, shareholder protection) affects both trade flows and the distribution of the gains from trade between rich and poor countries. Costinot (2009) and Nunn (2007) extend models of trade with imperfect contracts, highlighting a link between country institutions (linked to contract enforcement) and the pattern

5. There is also a substantial earlier literature, starting with the work of Baldwin (1971, 1979), which examined the relationship between the structure of commodity exports and patterns of factor abundance.

6. Koren and Tenreyro (2005) and di Giovanni and Levchenko (2008) also study the relationship between industry volatility and specialization, but do not relate it to international differences in labor market institutions.

of comparative advantage across sectors with different technological characteristics (which affect the sector's reliance on contract enforcement, such as the complexity of production or the need for relation-specific investments by workers).

The rest of the paper is structured as follows. Section 2 formalizes the paper's basic insights in a one-factor model. Section 3 extends the model by incorporating a second factor, capital, whose flexibility is not affected by the labor market institutions—and derives the implications for the pattern of comparative advantage. In Section 4, we present the empirical evidence. Section 5 concludes. The Appendix discusses several additional properties of the theoretical model and some of its extensions.

2. The Model

There are two countries, denoted by $c = F, H$. Each country is endowed with \bar{L} units of labor, which are supplied inelastically (for any positive wage) and internationally immobile. Preferences are identical across countries. Agents maximize utility over a Cobb–Douglas aggregate Q of a continuum of final goods $q(i)$, indexed by i :

$$Q \equiv \exp \left\{ \int_0^1 \ln q(i) di \right\}.$$

In each industry i , the final good is produced using a continuum of intermediate goods $y(i, z)$ according to the technology

$$y(i) = \left[\int_0^1 y(i, z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}}, \quad (1)$$

where $y(i)$ denotes production of the final good i . We assume that these intermediate goods are gross substitutes: $\varepsilon > 1$ (and thus that the intermediate goods used to produce a given final good are less differentiated than the final goods across industries). Each intermediate good is produced with labor only:

$$y(i, z) = e^{\pi} L(i, z),$$

where π is a stochastic term. Within each final-good industry, the π terms are i.i.d. draws from a common distribution $G_i(\cdot)$ in both countries, with mean 0 and variance $\sigma^2(i)$. We refer to $\sigma^2(i)$ as industry i 's volatility. This formulation emphasizes shocks to intermediate-good producers on the production side, but is nonetheless isomorphic to a formulation emphasizing demand shocks for the intermediate good stemming from a stochastic quality term in the production of the final good (1).

We assume two different institutional scenarios. In country F , all markets are competitive, and the determination of all prices and the allocation of all resources take place after the realization of π . This captures the idea of a flexible economy that can costlessly reallocate resources towards their most efficient use. In country H , intermediate-good producers must hire workers before the realization of π ; no labor adjustment is allowed thereafter. This corresponds to the idea that rigidities prevent

firms from adjusting to changing circumstances. The intermediate good producer is contractually committed to paying the hired number of workers the economy-wide ex-ante market clearing wage (regardless of the realization of π).⁷ After the realization of π , production and commodity market clearing take place in a competitive setting, subject to the wage and employment restrictions.⁸ Intermediate-good producers anticipate this equilibrium, and adjust their contracted labor demand accordingly. Given ex-ante free entry into the intermediate goods sector, expected profits of the intermediate-good producers are driven to zero.⁹ In the working paper version of our work, Cuñat and Melitz (2007), we also allow for the possibility of unemployment in the rigid economy.

2.1. Autarky in the Flexible Country

Let $p_{F,\pi}(i, z)$ be the price of the intermediate good z in country F receiving a productivity draw π . That good is priced at marginal cost $e^{-\pi} w_F$. The sector-level price is then given by the CES aggregator of the intermediate good prices:

$$p_F(i) = \left[\int_{-\infty}^{\infty} p_{F,\pi}(i, z)^{1-\varepsilon} dG_i(\pi) \right]^{\frac{1}{1-\varepsilon}} = \frac{w_F}{\left[\int_{-\infty}^{\infty} e^{(\varepsilon-1)\pi} dG_i(\pi) \right]^{\frac{1}{\varepsilon-1}}}$$

where $\tilde{\pi}_F(i) \equiv \left[\int_{-\infty}^{\infty} e^{(\varepsilon-1)\pi} dG_i(\pi) \right]^{\frac{1}{\varepsilon-1}}$ represents the productivity level in industry i . This is a weighted average of the productivity levels of the intermediate good producers e^π , where the weights are proportional to the intermediate good’s cost share in the production of the final good. The corresponding goods and factor market clearing conditions close the model.

2.2. Autarky in the Rigid Country

Notice that the law of large numbers ensures there is no aggregate uncertainty within each industry. We assume that agents hold a diversified portfolio across firms, and hence that firms maximize expected profits. Given that all intermediate-good sectors

7. One can think of a rigid economy as an economy where institutions prohibit the enforcement of employment contracts contingent on the realization of the shock π . Following this interpretation, for both the flexible and rigid economy, employment contracts must be agreed upon before the realization of the shock π . The key difference between the two economies is that such contracts in the flexible economy can be made contingent upon the future realization of the shock. This setup obviates the need to appeal to any wage setting institution in the rigid economy. The equilibrium in the rigid economy is then the competitive outcome contingent on the contractual incompleteness.

8. Both the final-good and intermediate-good sectors are perfectly competitive. In a given intermediate-good sector, all firms produce with the same realization of π .

9. The institutional differences outlined above between the two countries are rather stark. In a companion paper, Cuñat and Melitz (2009), we show that our entire analysis can be extended to many countries with varying degrees of labor market flexibility. This degree of labor market flexibility can vary continuously between the extremes of the flexible and rigid economy as already described.

in industry i are ex-ante identical, there is no variation in the employment levels $L_H(i, z)$ across producers. Of course, the prices $p_{H,\pi}(i, z)$ and output levels $y_{H,\pi}(i, z)$ will vary with the ex-post productivity draw π .

The ex-ante zero-profit condition for an intermediate good producer equates its known labor cost with expected revenue, hence

$$w_H L_H(i, z) = \int_{-\infty}^{\infty} p_{H,\pi}(i, z) y_{H,\pi}(i, z) dG_i(\pi). \quad (2)$$

Market clearing for each intermediate good equates ex-post supply and demand:

$$e^\pi L_H(i, z) = \left[\frac{p_{H,\pi}(i, z)}{p_H(i)} \right]^{-\varepsilon} y_H(i), \quad (3)$$

where the industry-level price $p_H(i)$ is given by the CES aggregator of the intermediate good prices:

$$p_H(i) = \left[\int_{-\infty}^{\infty} p_{H,\pi}(i, z)^{1-\varepsilon} dG_i(\pi) \right]^{\frac{1}{1-\varepsilon}}. \quad (4)$$

Jointly, equations (2), (3), and (4) determine the industry-level price

$$p_H(i) = \frac{w_H}{\left[\int_{-\infty}^{\infty} e^{\frac{(\varepsilon-1)\pi}{\varepsilon}} dG_i(\pi) \right]^{\frac{\varepsilon}{\varepsilon-1}}},$$

where $\tilde{\pi}_H(i) \equiv \left[\int_{-\infty}^{\infty} e^{\frac{(\varepsilon-1)\pi}{\varepsilon}} dG_i(\pi) \right]^{\frac{\varepsilon}{\varepsilon-1}}$ represents the productivity level in industry i for the rigid economy.

As with the productivity $\tilde{\pi}_F(i)$ in the flexible economy, this productivity is a weighted average of the productivity levels of the intermediate-good producers. Although the distribution of these intermediate-good productivity levels are identical in both countries (for each sector i), the productivity averages are different as the cost shares of the intermediate goods in final-good production systematically vary across countries. Final-good producers in the flexible country can take full advantage of the dispersion of productivity levels among intermediate-good producers by optimally shifting their expenditures towards the more productive ones (with lower prices). This reallocation process is constrained by the labor market rigidities in the other country. This, in turn, confers an absolute advantage to the flexible economy across all sectors: $\tilde{\pi}_F(i) \geq \tilde{\pi}_H(i)$ for all i , where this inequality is strict whenever $G_i(\pi)$ is nondegenerate (and there are idiosyncratic productivity shocks).¹⁰

Notice that our assumptions on the production of the final good imply a built-in love of volatility: in both countries, average industry productivity increases with $\sigma(i)$. Since cost shares of intermediate goods in the final good's production depend positively on π , a higher volatility $\sigma(i)$ raises industry productivity in the two countries. The flexible country benefits from this volatility proportionately more than the rigid country, as the cost shares of intermediate goods are more sensitive to π in the flexible labor market.

10. This is a direct application of Jensen's inequality.

2.3. *Parametrization of Productivity Draws*

In order to simplify some of the ensuing analysis in an open-economy equilibrium, we parametrize the productivity draws to the normal distribution, thus assuming that $\pi(i) \sim N[0, \sigma^2(i)]$. Without loss of generality we assume that the industries are ranked in order of increasing volatility such that $\sigma(i)$ is increasing in i . We further assume that $\sigma(i)$ is differentiable and positive. The average industry productivity levels can then be written as

$$\begin{aligned} \tilde{\pi}_F(i) &= \exp \left\{ (\varepsilon - 1) \frac{\sigma^2(i)}{2} \right\}, \\ \tilde{\pi}_H(i) &= \exp \left\{ \frac{(\varepsilon - 1) \sigma^2(i)}{\varepsilon} \right\}. \end{aligned}$$

2.4. *Free Trade*

We assume free trade in final goods, but assume that intermediate goods remain non-traded. Following Dornbusch, Fischer, and Samuelson (1977), we define the productivity differential

$$A(i) \equiv \frac{\tilde{\pi}_H(i)}{\tilde{\pi}_F(i)} = \exp \left\{ -\frac{(\varepsilon - 1)^2}{2\varepsilon} \sigma^2(i) \right\}.$$

As previously mentioned, labor market flexibility confers an absolute advantage to the flexible economy: $A(i) \leq 1$. However, the labor market institutions also interact with industry volatility to engender a pattern of Ricardian comparative advantage: $A(i)$ is decreasing in industry volatility $\sigma^2(i)$. The productivity differential between the flexible and rigid economy increases with industry volatility. This confers a comparative advantage to the flexible economy in high-volatility industries.

The free-trade equilibrium is characterized by a wage ratio w_H/w_F and a marginal commodity \bar{i} . For $i \leq \bar{i}$, $w_H/w_F \leq A(i)$, and good i is produced by country H . For $i > \bar{i}$, $w_H/w_F > A(i)$, and good i is produced by country F . In equilibrium, the value of world consumption must equal the value of world output, which is also world labor income: $P(Q_F + Q_H) = w_F L_F + w_H L_H$, where P denotes the price of Q . The value of country H 's output, equal to country H 's labor income, must also equal world expenditure on those goods produced in H .¹¹ If H produces goods in the range $[0, i]$, then

$$w_H L_H = iP(Q_F + Q_H) = i(w_F L_F + w_H L_H).$$

Therefore we can write

$$\frac{w_H}{w_F} = \frac{i}{1 - i} \equiv B(i),$$

where $B'(i) > 0$.

11. This condition is also equivalent to balanced trade.

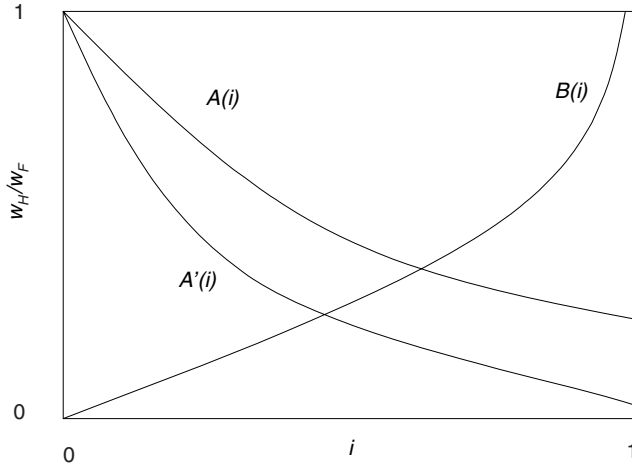


FIGURE 1. One-factor model: equilibrium and comparative statics.

The intersection of $A(i)$ and $B(i)$ determines the free-trade equilibrium (see Figure 1). An overall increase in volatility such that $\sigma'(i) > \sigma(i), \forall i$, causes $A(i)$ to shift down while $B(i)$ remains unchanged (see again Figure 1). This leads to a decrease in the range of final goods produced in H (i.e. a lower \bar{i}) and a lower relative wage w_H . Such an overall increase in volatility (as has been empirically measured in the last half-century for the United States) thus alters the pattern of comparative advantage, inducing relative welfare gains for the economy with flexible labor markets.

3. Two Factors

We now develop a two-factor version of our model. We assume that countries are endowed with both capital and labor, and that industries differ in terms of capital intensity as well as volatility. The Cobb–Douglas aggregate good Q is now defined according to

$$Q \equiv \exp \left\{ \int_0^1 \int_0^1 \ln q(i, j) di dj \right\},$$

where an industry is now characterized by a pair (i, j) representing an index for both volatility (i) and capital intensity (j) . The final good in each industry is still produced from a CES continuum of intermediate goods indexed by z :

$$y(i, j) = \left[\int_0^1 y(i, j, z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

Intermediate goods are now produced with both capital and labor, according to

$$y(i, j, z) = e^\pi \left[\frac{K(i, j, z)}{\alpha(j)} \right]^{\alpha(j)} \left[\frac{L(i, j, z)}{1 - \alpha(j)} \right]^{1-\alpha(j)},$$

where $\alpha(j) \in [0, 1]$ is the industry's cost share of capital and the index of capital intensity. As in the one-factor model, the π terms are i.i.d. draws from a common distribution, identical across countries, but different across industries. We maintain the Normal parametrization for the productivity draws $\pi(i) \sim N[0, \sigma^2(i)]$. Labor market institutions are identical to the single-factor case previously developed. We assume that, in both countries, the rental rate and the allocation of capital to intermediate-good producers are determined prior to the realization of π ; no adjustment is allowed thereafter. In other words, we assume that capital is a fully rigid factor in both countries. In the Appendix, we show how all our main comparative statics (the ones we test empirically) remain unchanged when we extend the model to a third factor, which is flexible across countries. Additionally, similar comparative statics also hold for this fully flexible factor. Thus, the key differentiating aspect for any factor other than labor is that its degree of rigidity is independent of differences in labor market rigidities across countries. These other factors could represent any combination of factors that are either fully flexible or fully rigid.

3.1. Autarky in the Flexible Country

In the Appendix, we show that the final good price is given by

$$p_F(i, j) = \frac{r_F^{\alpha(j)} w_F^{1-\alpha(j)}}{\tilde{\pi}_F(i, j)},$$

where the numerator is the standard Cobb–Douglas unit cost function. The industry average productivity level $\tilde{\pi}_F(i, j)$ is then

$$\tilde{\pi}_F(i, j) = \exp \left\{ \frac{\varepsilon - 1}{1 + \alpha(j)(\varepsilon - 1)} \frac{\sigma^2(i)}{2} \right\}.$$

Notice that for $\alpha(j) = 0$, $\tilde{\pi}_F(i, j)$ is identical to the previously derived $\tilde{\pi}_F(i)$ for the one-factor case. As the capital intensity increases, the ability of the final good producer to reallocate expenditures across intermediate goods is reduced (since capital is assumed to be rigid), leading to decreases in average productivity.

3.2. Autarky in the Rigid Country

Since factor prices and the allocation of both factors are determined before the realization of π , all intermediate good producers in an industry hire the same amount of capital and labor. The determination of the final good price is an immediate extension of the one-factor rigid-country case:

$$p_H(i, j) = \frac{r_H^{\alpha(j)} w_H^{1-\alpha(j)}}{\tilde{\pi}_H(i, j)},$$

where average productivity $\tilde{\pi}_H(i, j)$ is identical to the single factor case:

$$\tilde{\pi}_H(i, j) = \exp \left\{ \frac{(\varepsilon - 1) \sigma^2(i)}{\varepsilon} \frac{1}{2} \right\}.$$

3.3. The Pattern of Comparative Advantage

Without loss of generality, we assume that $\alpha(j)$ is an increasing and differentiable function of j . As in the one-factor case, we can define

$$A(i, j) \equiv \frac{\tilde{\pi}_H(i, j)}{\tilde{\pi}_F(i, j)} = \exp \left\{ -\frac{(\varepsilon - 1)^2}{2\varepsilon} \frac{1 - \alpha(j)}{1 + \alpha(j)(\varepsilon - 1)} \sigma^2(i) \right\}$$

as the ratio of productivity levels for a given industry across the two countries. This ratio highlights, once again, the absolute productivity advantage of the flexible economy in all sectors: $A(i, j) < 1, \forall i, j$. It also highlights how the pattern of comparative advantage varies with both volatility and capital intensity. $\partial A(i, j)/\partial i < 0$ as in the one factor case: the productivity advantage is larger in more volatile industries. However, $\partial A(i, j)/\partial j > 0$: holding volatility constant, this productivity advantage is reduced in relatively more capital intensive industries. This is intuitive, as a larger capital share reduces the ability of the flexible economy to take full advantage of the dispersion in productivity levels.¹² Needless to say, international factor price differences will also affect the pattern of comparative advantage. In our empirical work we separately control for these effects in order to isolate the effect of labor market flexibility on country specialization patterns via relative productivity differences.

4. Empirical Evidence

4.1. Data Construction and Description

Country-Level Data The key new country-level variable needed to test the predictions of our model is a measure of labor market rigidity across countries. Following the work of Botero et al. (2004), the World Bank has collected such measures, which capture different dimensions of the rigidity of employment laws across countries.¹³ These measures cover three broad employment areas: hiring costs, firing costs, and restrictions on changing the number of working hours. The World Bank also produces a combined summary index for each country (weighing the measures in all areas). This variable is coded on a 100-point integer scale indicating increasing levels of rigidity. We subtract this variable from 100 to produce a measure of flexibility and use this as our main country labor market flexibility index, FLEX_c (see Table 1). Unfortunately, historical data are not available, so we only have data for 2004. We will thus use the most recent data available from other sources to combine with these data.

Most of our remaining country-level variables come from the Penn World Tables (PWT 6.1). We measure capital abundance (K.c) as the physical capital stock per

12. As was previously noted, these last two comparative statics also hold for a third factor whose use is flexible across countries.

13. These data, along with more detailed descriptions on their collection, is available online at <http://www.doingbusiness.org/ExploreTopics/HiringFiringWorkers/>

capita.¹⁴ Capital stock is taken from Caselli (2005) and is constructed from the investment data reported in PWT 6.1 (based on the perpetual inventory method). Human skill abundance (S_c) is calculated as the average years of schooling in the total population from Barro and Lee (2000).¹⁵ We also record data on real GDP (GDP_c) and real GDP per capita ($GDPPC_c$). All of the above measures are available over time, up to 1996 (when data for some countries in our sample are then no longer available). We thus use the data for 1996 for all countries (and the Barro–Lee data for 1995). The GDP and capital stock variables are measured in 1996 international dollars. Lastly, we use a measure of financial development to control for potential confounding effects of volatility on the pattern of comparative advantage operating through a financial channel (such as those resulting from financial frictions). Following Beck (2002), we measure financial development ($FINDEV_c$) as the total credit extended by banks and other non-bank financial intermediaries to the private sector, as a fraction of GDP. We use these data for 1996 to concord with the remaining data from PWT6.1 and Barro and Lee (2000). When we combine these sources of country-level data, we are left with 81 countries. However, we will most often restrict our analysis to countries with available GDP per capita levels above \$2,000, leaving us with 61 countries.¹⁶ Other countries are excluded from this sample because the Penn World Tables do not have capital stock data for them (most notably, for Germany and other countries that have recently merged or split-up).¹⁷ However, we will include these countries in our additional robustness checks with our country-level analysis.

Sector-Level Data Our empirical approach also requires a measure of firm-level volatility across sectors, as well as standard measures of factor intensities in production. This type of data is not available across our large sample of countries (at the needed detailed level of sectoral disaggregation), so we rely on the commonly used assumption that the ranking of measures do not vary across countries. We therefore use a reference country, the United States, to measure all these needed sector characteristics. Factor intensity data in manufacturing are available over time from the NBER-CES Manufacturing Industry Database at the four-digit US SIC level (459 industrial

14. We use capital stock per capita, as opposed to per worker, for consistency with the definition of human capital. Although the correlation between the two measures is very high (0.98), we found that the capital abundance measure per capita had slightly more explanatory power than its usual measure per worker. Needless to say, this difference is barely noticeable for our main results.

15. We also tried alternate measures of skill abundance, such as the fraction of workers that completed high school, or attained higher education (from Barro and Lee 2000). These measures were clearly dominated by the one based on average years of schooling in explaining the pattern of comparative advantage across skill-intensive sectors.

16. The excluded countries are Benin, Bangladesh, Central African Republic, Cameroon, Congo, Ghana, Kenya, Mali, Mozambique, Malawi, Niger, Nicaragua, Nepal, Pakistan, Rwanda, Senegal, Sierra Leone, Togo, Uganda, and Zambia. United Arab Emirates, Bosnia and Herzegovina, and Kiribati are excluded due to missing GDP per capita data.

17. The full list of excluded countries with GDP per capita above \$2,000 falling in this category are: Albania, Armenia, Azerbaijan, Bulgaria, Belarus, Czech Republic, Germany, Estonia, Georgia, Guinea, Guyana, Kazakhstan, Kyrgyzstan, Kuwait, Lebanon, Lithuania, Latvia, Morocco, Republic of Moldova, Macedonia, Oman, Russian Federation, Saudi Arabia, Slovakia, Slovenia, Ukraine, Uzbekistan.

sectors). For each sector, we measure capital intensity (K_s) as capital per worker and skill intensity (S_s) as the ratio of non-production wages to total wages. We have experimented with other formulations for these factor intensities, such as those based on the 3-factor model in Romalis (2004), but found that the latter had much less explanatory power for the pattern of comparative advantage than our preferred measures.¹⁸ Again, we use the most recent data available, but also average out the data across the latest five available years, 1992–1996, in order to smooth out any small yearly fluctuations (especially for very small sectors).¹⁹ All measures are also aggregated to the three-digit SIC level (140 sectors).

Concerning firm-level volatility, the Appendix shows there is a direct relationship between the standard deviation of firm-level shocks, $\sigma(i)$, and the standard deviation of the growth rate of firm sales (VOL_s).²⁰ We measure differences in firm-level volatility across sectors using COMPUSTAT data from Standard & Poor's. This data covers all publicly traded firms in the US, and contains yearly sales and employment data since 1980 (the past 24 years). We use the standard deviation of the annual growth rate of firm sales (measured as year-differenced log sales) as our benchmark measure of firm volatility.²¹ Thus, our volatility measure is purged of any trend growth rate in firms sales. COMPUSTAT records the 4-digit SIC classification for each firm, although some firms are only classified into a three-digit, and in rarer instances, into a two-digit SIC classifications. As expected, the distribution of firms across sectors is highly skewed. In order to obtain data on the largest possible number of sectors, we include in our analysis all firms with at least five years of data (using all the data going back to 1980) and all sectors with at least ten firms.²² However, we do not include any observation where the absolute value of the growth rate is above 300%. This leaves us with 5,216 firms in our sample.

We compute the sector-level measure as the average of the firm-level volatility measures, weighted by the firm's average employment over time. This yields volatility measures for 94 of the 459 four-digit sectors and 88 of the 140 three-digit sectors. (Table 4 provides some descriptive statistics for this variable.) We use volatility measures at the two-digit level for the remaining sectors (there are 20 such classifications, and there are always enough firms to compute volatility measures at

18. Another commonly used measure of skill intensity is the ratio of non-production workers to total workers (whereas we use the ratio of the payments to these factors). These measures have a correlation coefficient of 0.94, and yield nearly identical results.

19. These factor intensity measures are highly serially correlated (the average serial correlation is 0.99 for capital intensity and 0.97 for skill intensity), so this averaging does not substantially change any of our results.

20. The Appendix also shows that rewriting the model in terms of VOL_s does not alter the model's comparative statics discussed above.

21. For robustness, we experimented with another measure of volatility based on firm productivity: the standard deviation of the annual growth rate of sales per worker. Both volatility measures are highly correlated across firms (.83 correlation ratio). We only report the results obtained with the volatility measure based on sales, as those obtained with the volatility measure based on sales per worker were very similar.

22. We have also experimented with a more stringent requirement of ten years of data and 20 firms per sector. Our main results remain unchanged.

TABLE 4. The ten least and most volatile sectors at the three-digit SIC level.

SIC-3	VOL _s	# firms	Description
203	0.084	33	Preserved Fruits & Vegetables
386	0.096	42	Photographic Equipment & Supplies
285	0.097	16	Paints & Allied Products
271	0.100	24	Newspapers
276	0.103	15	Manifold Business Forms
358	0.103	52	Refrigeration & Service Machinery
267	0.105	48	Misc. Converted Paper Products
342	0.105	24	Cutlery, Handtools, & Hardware
314	0.112	25	Footwear, Except Rubber
327	0.115	25	Concrete, Gypsum & Plaster Product

SIC-3	VOL _s	# firms	Description
333	0.236	20	Primary Nonferrous Metals
302	0.247	10	Rubber & Plastics Footwear
355	0.255	104	Special Industry Machinery
274	0.262	16	Miscellaneous Publishing
332	0.263	13	Iron & Steel Foundries
346	0.265	20	Metal Forgings & Stampings
202	0.287	17	Dairy Products
369	0.300	59	Misc. Electrical Equipment & Supplies
367	0.306	316	Electronic Components & Accessories
361	0.336	17	Electric Distribution Equipment

this level). Often, in these cases, there is only one dominant four-digit sector within this two-digit classification.²³ We construct both a four-digit and a three-digit level measure of volatility. Whenever a volatility measure is not available at the desired level of disaggregation, we use the measure from the next lower level of aggregation.

We favor this measure of volatility based on firms sales over the excess job reallocation measure by Davis, Haltiwanger, and Schuh (1997) for both theoretical and empirical reasons. First, from a theoretical perspective, some of our comparative statics results can no longer be signed when we replace our volatility variable $\sigma(i)$ with the excess job reallocation proxy. Second, a worker-based measure of volatility such as excess job reallocation does not capture some of the firm labor adjustments that occur through the margin of work hours and effort. Such expansions and contractions in work hours are common in US manufacturing.

Country-Sector Exports Instead of only measuring each country's exports into the United States (as in Romalis 2004), we follow the approach of Nunn (2007) and measure each country's aggregate exports across sectors. This country export data is available from the World Trade Flows Database (see Feenstra et al. 2005) for the

23. If COMPUSTAT only records a firm's sector at the two- or three-digit level, then we use that firm for the relevant classification. We also aggregate all firms with four-digit level sector information into their respective two- and three-digit classifications.

years 1962–2000 and is classified at the four-digit SITC rev.2 level. There are 768 distinct such sectors with recorded trade in the 1990s across all countries. Once we exclude non-manufacturing sectors, and concord the remaining sectors to the US SIC classification, we are left with 370 sectors.²⁴ Again, we wish to use the most recent data available, but also want to smooth the effects of any year-to-year fluctuations in the distribution of exports across sectors (again, we are mostly concerned with smaller sectors where aggregate country exports can be more volatile). For this reason, we average exports over the last ten years of available data, for 1991–2000. This yields our measure of aggregate exports, X_{sc} , across sectors and countries. We also aggregate this variable to the three-digit SIC level (134 distinct classifications are available).

4.2. Pooled Country-Sector Analysis

Our baseline specification is

$$\begin{aligned} \log X_{sc} = & \beta_0 + \beta_{vf} (\text{VOL}_s * \log \text{FLEX}_c) + \beta_{kf} (\log \text{K}_s * \log \text{FLEX}_c) \\ & + \beta_{kk} (\log \text{K}_s * \log \text{K}_c) + \beta_{ss} (\log \text{S}_s * \log \text{S}_c) + \chi_s + \chi_c + \varepsilon_{sc}, \end{aligned} \quad (5)$$

where χ_s and χ_c are sector and country level fixed effects. Given these fixed effects, our specification is equivalent to one where exports are measured as a share or as a ratio relative to the exports of a given reference country. Similarly, the specification is also equivalent to one where the country characteristics are measured as differences relative to a reference country. All data measures (except for VOL_s) are entered in logs (VOL_s is a summary statistic of a logged variable).

Our model predicts $\beta_{vf} > 0$: countries with more flexible labor markets export relatively more in relatively more volatile sectors.²⁵ Additionally, our model predicts $\beta_{kf} < 0$: after controlling for the effects of volatility across sectors, countries with *less* flexible labor markets export relatively more in relatively more capital intensive sectors (since the effect of volatility is relatively less severe as capital intensity increases). The similar traditional comparative advantage predictions, based on factor abundance and

24. Since publicly available concordances from SITC rev.2 to US SIC do not indicate proportions on how individual SITC codes should be allocated to separate SIC codes, we construct our own concordance. We use export data for the United States, which is recorded at the Harmonized System (HS) level (roughly 15,000 product codes). For each HS code, both an SITC and an SIC code is listed. We aggregate up the value of US exports over all HS codes for the last ten available data years (1991–2000) across distinct SITC and SIC pairs. For each SITC code, we record the percentage of US exports across distinct SIC codes. We then concord exports for all countries from SITC to SIC codes using these percentage allocations. In most cases, this percentage is very high, so our use of US trade as a benchmark cannot induce any serious biases. For 50% of SITC codes, the percentage assigned to one SIC code is above 98%. For 75% of SITC codes, this percentage is above 76%.

25. This is a very demanding interpretation of the theory, since the latter does not imply a monotonic relationship across sectors and countries in a multi-country world. For example, a country with mid-range labor market flexibility could concentrate its exports in sectors with mid-range volatility. This effect would not get picked up by our regression analysis, which is searching for differences in slopes, given a monotonic linear response of export shares across sectors for a country.

TABLE 5. Pooled regression—baseline.

SIC aggregation GDPPC cutoff	SIC-4 2000	SIC-3 2000	SIC-4 5000	SIC-3 5000
VOL _s * log FLEX _c	0.300 (0.060)***	0.298 (0.073)***	0.356 (0.070)***	0.382 (0.083)***
log K _s * log FLEX _c	-0.239 (0.069)***	-0.300 (0.094)***	-0.173 (0.080)**	-0.223 (0.114)*
logK _s * logK _c	0.773 (0.092)***	1.055 (0.119)***	0.546 (0.169)***	1.057 (0.232)***
log S _s * log S _c	0.802 (0.063)***	0.961 (0.091)***	0.822 (0.077)***	0.973 (0.102)***
Observations	13203	6513	9739	4675
R-squared	0.7016	0.7481	0.6913	0.7472

Notes: Beta coefficients are reported. Country and sector dummies suppressed. Heteroskedasticity robust standard errors in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%.

factor intensity, are $\beta_{kk} > 0$ and $\beta_{ss} > 0$. Since our volatility measure is not uniformly available at the four-digit SIC level, we test these predictions using both the data at the four-digit level and three-digit level. To ensure that our results are not dominated by low-income countries, we also include specifications where we exclude all countries with GDP per capita below \$5,000 (leaving us with 42 countries with available capital stock data).

The results from the OLS regressions of equation (5) across the different data samples are listed in Table 5. We find strong confirmation both for the predictions of our model and the traditional forces of specialization according to comparative advantage. The table lists the standardized beta coefficients, which capture the effects of raising the independent variables by one standard deviation (measured in standard deviations of the dependent variable). The magnitude of the coefficient on the volatility-flexibility interaction is of the same magnitude, though higher, than those reported by Nunn (2007) and Levchenko (2004) for the effects of institutional quality on the pattern of comparative advantage. Table 5 shows that the level of sector disaggregation does not greatly influence the results, though the magnitude of the coefficients are a little higher at the more aggregated three-digit level. We thus continue our analysis using only the three-digit level data.

Since the regressions in Table 5 do not include observations where no exports are recorded for a given country, the results should be interpreted as capturing the pattern of comparative advantage for countries across all of its export sectors—and not the effect of comparative advantage on the country-level decision to export in particular sectors (which are likely affected by other additional sector and country characteristics). We maintain this interpretation throughout our analysis, but also provide an additional robustness check in Table 6, where the reported regressions have used all potential country-sector combinations: we add missing export observations with zero exports, then add 1 to all export values before taking logs. (Tobit specifications censored at zero yield extremely similar results to those reported in Table 6.) This table shows

TABLE 6. Pooled regression—including observations with no exports.

SIC aggregation GDPPC cutoff	SIC-4 2000	SIC-3 2000	SIC-4 5000	SIC-3 5000
VOL _s * log FLEX _c	0.097 (0.039)**	0.165 (0.059)***	0.113 (0.038)***	0.189 (0.060)***
log K _s * log FLEX _c	-0.168 (0.039)***	-0.141 (0.063)**	-0.162 (0.041)***	-0.121 (0.069)*
log K _s * log K _c	0.803 (0.050)***	0.800 (0.082)***	0.829 (0.085)***	0.737 (0.148)***
log S _s * log S _c	0.286 (0.041)***	0.353 (0.065)***	0.242 (0.040)***	0.424 (0.062)***
Observations	22753	8235	14574	5544
R-squared	0.8041	0.8288	0.8564	0.8667

Notes: Beta coefficients are reported. Country and sector dummies suppressed. Heteroskedasticity robust standard errors in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%. All potential country-sector combinations are represented.

that all our results remain strongly significant, though the magnitude of most of the coefficients drops substantially. This effect is most pronounced for the skill intensity (\times skill abundance coefficient), whereas the capital intensity (\times capital abundance coefficient) is mostly unaffected.

We next confirm that our results are not driven by other country and sector characteristics outside of our model. In recent work, Koren and Tenreyro (2005) have shown that increasing levels of economic development across countries are associated with a pattern of comparative advantage towards less volatile sectors—where this volatility is measured as the aggregate sector volatility of output per worker. We replicate their results by computing a similar measure of aggregate productivity volatility from the NBER-CES Manufacturing Productivity database. We measure the volatility of sector-level output per worker (VOLPROD_AGG_s) using the same methods as the firm-level volatility measures: taking the standard deviation of its annual growth rate. We then add an additional control for the interaction between this measure of aggregate productivity volatility and development (measured as the log of GDP per capita). The results are reported in the first two columns of Table 7. They show that a country's level of development is correlated with its pattern of comparative advantage across sectors with lower aggregate productivity volatility. This effect is very significant and important when the low-income countries, with GDP per capita between \$2,000 and \$5,000, are included in the sample (the results for this added regressor are also substantially stronger at the four-digit level for countries above the \$5,000 GDP per capita threshold). Nonetheless, the table also shows that our main results on the effect of labor market flexibility on the pattern of comparative advantage remain unaffected.

We next show that the driving force behind the effect of volatility on the pattern of comparative advantage operates at the firm level and not at the sector level. We construct a sector-level measure of sales volatility, VOL_AGG_s, following the same

TABLE 7. Pooled regression—robustness checks.

SIC aggregation GDPPC cutoff	SIC-3 2000	SIC-3 5000	SIC-3 2000	SIC-3 5000	SIC-3 2000	SIC-3 5000
VOL _s * log FLEX _c	0.289 (0.073)***	0.374 (0.083)**	0.304 (0.074)***	0.373 (0.084)***	0.235 (0.090)***	0.262 (0.111)**
log K _s * log FLEX _c	-0.297 (0.094)***	-0.219 (0.114)*	-0.323 (0.094)***	-0.218 (0.112)*	-0.307 (0.095)***	-0.245 (0.121)**
log K _s * log K _c	1.155 (0.123)***	1.139 (0.236)***	1.165 (0.123)***	1.138 (0.236)***	1.258 (0.541)**	0.177 (0.745)
log S _s * log S _c	0.936 (0.091)***	0.959 (0.102)***	0.938 (0.091)***	0.959 (0.102)***	0.445 (0.148)***	0.299 (0.144)**
VOLPROD_AGG _s * log GDPPC _c	-0.287 (0.097)***	-0.238 (0.177)	-0.314 (0.099)***	-0.235 (0.193)	-0.274 (0.100)***	-0.138 (0.195)
VOL_AGG _s * log FLEX _c			0.124 (0.102)	-0.005 (0.127)	0.111 (0.103)	-0.0313 (0.128)
VOL _s * log K _c					0.444 (0.433)	1.591 (0.679)**
VOL _s * log S _c					0.0728 (0.077)	0.0688 (0.090)
VOL _s * log FINDEV _c					0.0200 (0.035)	0.0350 (0.046)
VOL _s * log GDPPC _c					-0.355 (0.342)	-1.059 (0.565)*
log K _s * log GDPPC _c					-0.115 (0.429)	0.720 (0.612)
log S _s * log GDPPC _c					0.805 (0.171)***	1.333 (0.235)***
Observations	6513	4675	6513	4675	6513	4675
R-squared	0.7487	0.7474	0.7488	0.7474	0.7499	0.7502

Notes: Beta coefficients are reported. Country and sector dummies suppressed. Heteroskedasticity robust standard errors in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%.

procedure as that outlined for aggregate productivity volatility (also using the NBER-CES Manufacturing data). We then interact this sector-level variable with labor market flexibility and include it as an additional regressor. The results, reported in the third and fourth columns of Table 7, clearly show that this aggregate volatility has no measurable effect on the pattern of comparative advantage.

Lastly, we add two additional sets of controls. One set includes interactions of country factor abundance measures (K_c and S_c) with sector volatility VOL_s. This controls for any other possible interactions between factor abundance (and their effects on factor prices) and sector level volatility. For example, Bernard, Redding, and Schott (2007) show how there can be a possible interaction between comparative advantage (via differences in factor abundance) and volatility (via higher levels of simultaneous entry and exit due to a higher survival threshold). The other set is comprised of interactions between the level of development and all three sector-level measures, VOL_s, K_s, and S_s. We used GDP per capita as our main measure of development and add interactions between that variable and all three sector-level measures. Since volatility may also interact with financial development, we add a

separate interaction between financial development and our sector-level volatility variable. These additional interactions control for other country-level determinants driving the pattern of comparative advantage. This last set of results is reported in the last two columns of Table 7. The addition of the interactions with GDP per capita strongly affects the magnitude of the predictions for the standard sources of comparative advantage (capital and skill abundance interacted with that factor's intensity in production): these coefficients drop significantly in almost all cases (except for the capital interaction coefficient in the larger sample including the lower-income countries).²⁶ Most importantly, however, the key coefficients of interest for labor market flexibility are not substantially affected by the additional controls; they retain their strong statistical significance.²⁷

4.3. Country-Level Analysis

We now address some potential limitations in the pooled country-sector analysis by moving to a country-level analysis. Our main concern is that the previous results do not adequately reflect the very skewed pattern of country exports across sectors—as they can be influenced by country-sector pairs with relatively very low exports. We are also concerned that our key measure of volatility is available at different levels of aggregation (representing different overall levels of economic activity). To address these concerns, we construct a country average level of volatility: for each country, sector level volatility is averaged using its export share as a weight. Specifically, average country volatility VOL_c is obtained as

$$VOL_c = \sum_s \frac{X_{sc}}{X_c} VOL_{s.}$$

Thus, countries with higher export shares in more volatile sectors will have higher levels of this volatility average. This average also naturally handles the skewness of the distribution of country-level exports by assigning larger weights to more important sectors. We use the four-digit measure of volatility, as the averaging also naturally handles the different levels of aggregation, by essentially splitting off sectors with available four-digit volatility data into separate sectors, and keeping the other sectors grouped by their inherent level of disaggregation. We can thus test whether countries with more flexible labor markets have a comparative advantage in relatively more

26. The results further show that GDP per capita, rather than direct measures of skill abundance, captures relatively more of the variation across countries explaining specialization in skill-intensive sectors.

27. Using some additional parametrization assumptions, Chor (2009) develops an empirical estimation of the determinants of comparative advantage using bilateral export data (instead of country-level exports). In some specifications, he includes a very large set of institutional determinants of comparative advantage that have been highlighted in recent work (including the interaction between labor market flexibility and volatility motivated by our work). In those specifications, Chor (2009) finds that this interaction term remains significant, even when all the other institutional determinants of comparative advantage are also included (i.e. also controlled for).

TABLE 8. Country-level analysis.

GDPPC cutoff	10000	5000	2000	NONE (weighted)
FLEX_c	0.820 (0.259)***	0.574 (0.169)***	0.292 (0.137)**	0.275 (0.109)**
GDPPC_c	-0.394 (0.412)	-0.657 (0.428)	-0.212 (0.361)	-0.259 (0.183)
S_c	-0.215 (0.207)	-0.216 (0.205)	0.187 (0.208)	0.341 (0.178)*
log K_c	0.469 (0.337)	1.052 (0.412)**	0.382 (0.361)	0.259 (0.235)
Observations	25	42	61	81
R-squared	0.4728	0.4354	0.2744	0.4690

Notes: Beta coefficients are reported. Standard errors in parentheses. *significant at 10%; **significant at 5%; ***significant at 1%. Last column is weighted by RGDP

volatile sectors by examining the correlation across countries between VOL_c and FLEX_c.²⁸

We control for the influence of other comparative advantage forces in two separate ways. By introducing other country-level controls in a regression of VOL_c on FLEX_c; and alternatively by first purging the sector volatility measure VOL_s of any correlation with other relevant sector characteristics, and then looking at the direct correlation between the country level average of this purged volatility measure (VOL_PURGED_c) and FLEX_c. Table 8 reports the results corresponding to the regression of the unpurged country volatility average (VOL_c) on labor market flexibility, also including additional country controls (GDPPC_c, S_c, and log(K_c)).²⁹ Here, we add two additional sample groups of countries: one with a higher GDP per capita cutoff of \$10,000, and another including the full sample of available countries by weighting them using the log of real GDP. The results show the strong independent contribution of labor market flexibility on the pattern of comparative advantage—across all country sample groups.

Lastly, we turn to the second approach discussed earlier. We use all the previously used sector-level measures (K_s, S_s, VOL_AGG_s), as well as measures of the intensity of intermediate goods (material cost per worker) and energy use (energy spending per worker). We also include a measure of external finance dependence for the sector based on COMPUSTAT data from 1990–1999.³⁰ This controls for an effect of volatility on the pattern of comparative advantage via a financial channel. We run an initial

28. One other advantage of this country-level method is that, unlike in the pooled country-sector analysis above, it does not require a monotonic response in a country's share of exports across sectors to detect a pattern of comparative advantage.

29. We introduce the capital stock per worker variable in logs, since it varies by an order of magnitude greater than for the other independent country-level variables. Entering this control in levels instead does not substantially change the results.

30. Following the methodology of Rajan and Zingales (1998), the measure of external finance dependence is calculated as the fraction of a firm's total capital expenditures that is not financed by internal cash flows. The value for the median firm in each SIC sector is used.

TABLE 9. Country-level analysis: correlation between purged average volatility and country flexibility.

	OECD	10000	5000	2000	NONE (weighted)
	0.5831 (0.0055)	0.5379 (0.0018)	0.4471 (0.0006)	0.3092 (0.0036)	0.4773 (0.0000)
Observations	21	31	56	87	121

Notes: Correlation coefficients are reported; *p*-values in parentheses. Last column is weighted by RGDP

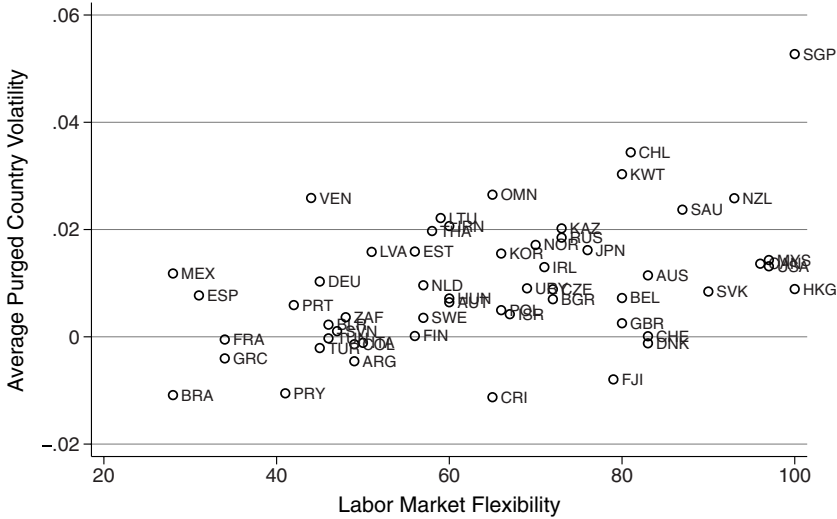


FIGURE 2. Average volatility and labor market flexibility (GDP per capita > \$5,000).

regression of VOL_s on all these sector level controls, and construct the residual as VOL_PURGED_s (its correlation coefficient with VOL_s is 0.93). Table 9 reports the correlation coefficients (which are also the standardized beta coefficients) between VOL_PURGED_c and FLEX_c across all the country samples from Table 8, including an additional group of OECD countries (with membership in the 1990s).³¹ As the table results clearly show, there is a very strong correlation between country-level flexibility and this average volatility, across all sub-samples of countries: all correlation coefficients are significant well beyond the 1% level. Figures 2–4 show the scatter plots for these relationships for different country samples.

31. We can use this much smaller sample of countries since we are not losing any degrees of freedom with additional country covariates.

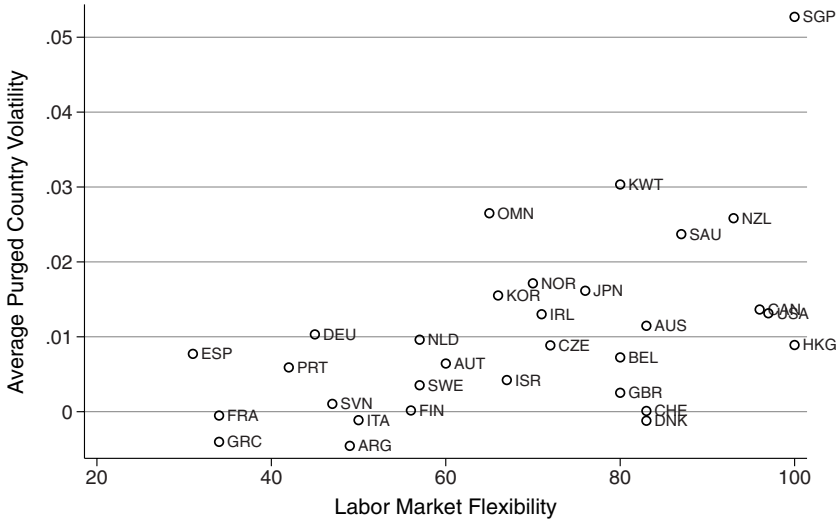


FIGURE 3. Average volatility and labor market flexibility (GDP per capita > \$10,000).

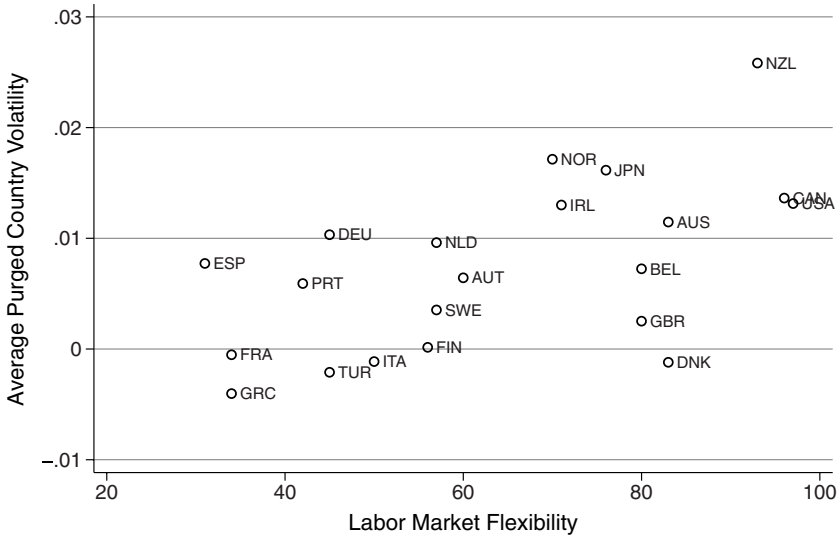


FIGURE 4. Average volatility and labor market flexibility (OECD countries in 1990s).

5. Concluding Remarks

Comparative advantage can arise even when the genuine production capabilities (resources and technologies) of countries are identical, provided they differ in labor market institutions. Countries with more-flexible labor markets should display a comparative advantage precisely where the ability to adjust is more important, that is, industries subject to high-variance shocks. The empirical evidence presented above

supports the validity of this intuition for a large sample of countries: more-flexible countries export relatively more in high-volatility industries.

This result has some interesting implications. First, labor market reform is likely to have asymmetric effects across industries. Second, a rigid economy has an alternative to the liberalization of its labor market to improve its welfare: it can always liberalize trade and “import flexibility” from a more flexible trading partner. Finally, an extension of the model might provide an additional explanation for the outsourcing phenomenon: production of intermediate goods may be relocated to more-flexible labor markets in high-volatility industries.

Appendix A: Two-Factor Model: Autarky in the Flexible Country³²

Since the rental rate and the allocation of capital are predetermined prior to the realization of π , all intermediate good producers in an industry hire the same amount of capital K . Hence,

$$\frac{y_\pi}{y_0} = e^\pi \left[\frac{L_\pi}{L_0} \right]^{1-\alpha}. \quad (\text{A.1})$$

Market clearing for each firm’s output y_π and price p_π implies

$$\frac{y_\pi}{y_0} = \left[\frac{p_\pi}{p_0} \right]^{-\varepsilon}. \quad (\text{A.2})$$

Firms hire labor until the value of its marginal product is equal to the common wage:

$$w = \mu(\alpha) p_\pi (1 - \alpha) e^\pi K^\alpha L_\pi^{-\alpha}, \quad (\text{A.3})$$

where $\mu(\alpha) = \alpha^{-\alpha} (1 - \alpha)^{\alpha-1}$. Equations (A.1), (A.2) and (A.3) yield

$$\frac{p_\pi}{p_0} = \exp \left\{ \frac{-\pi}{1 + \alpha(\varepsilon - 1)} \right\} \quad (\text{A.4})$$

and

$$\frac{L_\pi}{L_0} = \exp \left\{ \frac{(\varepsilon - 1)}{1 + \alpha(\varepsilon - 1)} \pi \right\}.$$

Equations (A.2) and (A.4) imply

$$\frac{p_\pi y_\pi}{p_0 y_0} = \exp \left\{ \frac{(\varepsilon - 1)}{1 + \alpha(\varepsilon - 1)} \pi \right\}. \quad (\text{A.5})$$

Since labor is paid the value of its marginal product, the Cobb–Douglas production function and zero-profit condition imply that each firm pays a share $(1 - \alpha)$ of its

32. In what follows, country and industry notation is suppressed for simplicity wherever unnecessary. It is understood that α and σ will vary across industries.

revenue $p_\pi y_\pi$ to labor: $wL_\pi = (1 - \alpha)p_\pi y_\pi$. This relationship also holds in the aggregate for the industry: $wL = (1 - \alpha)py$. As there are no ex-ante profits, wages adjust such that the aggregate capital cost rK equals the remaining α share of revenue:

$$rK = \alpha \int_{-\infty}^{\infty} p_\pi y_\pi dG(\pi) = \alpha p_0 y_0 \exp \left\{ \left[\frac{(\varepsilon - 1)}{1 + \alpha(\varepsilon - 1)} \right]^2 \frac{\sigma^2}{2} \right\}. \quad (\text{A.6})$$

Using expressions $w = \mu(\alpha)(1 - \alpha)p_0(K/L_0)^\alpha$ and $wL_0 = (1 - \alpha)p_0 y_0$, which imply that

$$p_0 y_0 = [\mu(\alpha)]^{1/\alpha} \left[\frac{w}{(1 - \alpha)} \right]^{\frac{\alpha-1}{\alpha}} p_0^{1/\alpha} K,$$

equation (A.6) can be written as

$$r^\alpha w^{1-\alpha} = p_0 \exp \left\{ \alpha \left[\frac{(\varepsilon - 1)}{1 + \alpha(\varepsilon - 1)} \right]^2 \frac{\sigma^2}{2} \right\}, \quad (\text{A.7})$$

where the left-hand side is the standard Cobb–Douglas unit cost function. Finally, note that (A.4) implies that the price index for the final good is given by

$$p = p_0 \exp \left\{ - \left[\frac{(\varepsilon - 1)}{1 + \alpha(\varepsilon - 1)} \right]^2 \frac{1}{\varepsilon - 1} \frac{\sigma^2}{2} \right\}.$$

Solving out for p_0 using equation (A.7) yields

$$p = \exp \left\{ - \frac{(\varepsilon - 1)}{1 + \alpha(\varepsilon - 1)} \frac{\sigma^2}{2} \right\} r^\alpha w^{1-\alpha}.$$

One can think of our static set-up as a steady-state equilibrium: the law of large numbers ensures that aggregate outcomes are invariant over time, but the realizations of π experienced by an individual firm vary from period to period. Assume π is i.i.d. over time. From equation (A.5), the growth rate of a firm’s sales between periods t and t' can be expressed as

$$\gamma \equiv \log \frac{p_{\pi'} y_{\pi'}}{p_\pi y_\pi} = \frac{(\varepsilon - 1)(\pi' - \pi)}{1 + \alpha(\varepsilon - 1)}.$$

The standard deviation of γ is then

$$\text{vol}_F(i, j) = \frac{\sqrt{2}(\varepsilon - 1)}{1 + \alpha(j)(\varepsilon - 1)} \sigma(i). \quad (\text{A.8})$$

The one-factor/flexible-country counterpart to equation (A.8) can be obtained by assuming $\alpha(j) = 0$: $\text{vol}_F(i) = \sqrt{2}(\varepsilon - 1)\sigma(i)$. Assuming $\alpha(j) = 1$ yields the case of a one-factor model in which the factor is rigid: $\text{vol}_F(i) = \sqrt{2}(\varepsilon - 1)\sigma(i)/\varepsilon$. In the two-factor/rigid-country case, we can think of the two rigid factors as combining into a composite rigid factor. The prediction for volatility is clearly the same in this case:

$$\text{vol}_H(i, j) = \frac{\sqrt{2}(\varepsilon - 1)}{\varepsilon} \sigma(i) < \text{vol}_F(i, j).$$

Not surprisingly, firm sales in the rigid country vary less than in the flexible country, as firms cannot adjust their employment in the rigid country.

Appendix B: Three Factors

Assume now that countries use three factors in the production of intermediates: a rigid factor (capital), a flexible factor (materials), and labor. Industries differ in terms of factor intensities and volatility. The Cobb–Douglas aggregate good Q is now defined according to

$$Q \equiv \exp \left\{ \int_0^1 \int_0^1 \int_0^1 \ln q(i, j, m) di dj dm \right\},$$

where an industry is now characterized by a triple (i, j, m) . The final good in each industry is still produced from a CES continuum of intermediate goods indexed by z :

$$y(i, j, m) = \left[\int_0^1 y(i, j, m, z)^{\frac{\varepsilon-1}{\varepsilon}} dz \right]^{\frac{\varepsilon}{\varepsilon-1}}.$$

Intermediate goods are now produced with capital, materials, and labor, according to

$$y(i, j, m, z) = e^\pi \left[\frac{K(i, j, m, z)}{\alpha(j)} \right]^{\alpha(j)} \left[\frac{M(i, j, m, z)}{\beta(m)} \right]^{\beta(m)} \\ \times \left[\frac{L(i, j, m, z)}{1 - \alpha(j) - \beta(m)} \right]^{1 - \alpha(j) - \beta(m)},$$

where $\alpha(j)$, $\beta(m)$, $1 - \alpha(j) - \beta(m) \in [0, 1]$ are the industry's cost shares of capital, materials, and labor, respectively. As in the one-factor model, the π terms are i.i.d. draws from a common distribution, identical across countries, but different across industries. We maintain the Normal parametrization for the productivity draws $\pi(i) \sim N[0, \sigma^2(i)]$. Labor market flexibility varies across countries in the same way as before. We assume that, in both countries, the rental rate and the allocation of capital to intermediate good producers are determined prior to the realization of π ; no adjustment is allowed thereafter. Materials are instead allocated after the realization of π in both countries.³³

B.1. Autarky in the Flexible Country

This case is similar to the two-factor model with flexible labor and rigid capital: we can rewrite the firm-level production function as

$$y(i, j, m, z) = e^\pi \left(\frac{K(i, j, m, z)}{\alpha(j)} \right)^{\alpha(j)} \\ \times \left[\left[\frac{M(i, j, m, z)}{\beta(m)} \right]^{\frac{\beta(m)}{1 - \alpha(j)}} \left[\frac{L(i, j, m, z)}{1 - \alpha(j) - \beta(m)} \right]^{\frac{1 - \alpha(j) - \beta(m)}{1 - \alpha(j)}} \right]^{1 - \alpha(j)},$$

33. Assuming $\beta(m) = 0$ for all m would yield the two-factor model with rigid capital that we discussed in Section 3. Assuming instead $\alpha(j) = 0$ for all j would yield a two-factor model with the second factor, materials, being flexible in both countries. As we mentioned earlier, the properties of these models are qualitatively similar. Finally, $\alpha(j) = \beta(m) = 0 \forall j, m$ yields the one-factor model of Section 2.

where the term in brackets can be understood as a composite flexible factor, and K as a rigid factor. Therefore,

$$p_F(i, j, m) = \frac{r_F^{\alpha(j)} s_F^{\beta(m)} w_F^{1-\alpha(j)-\beta(m)}}{\tilde{\pi}_F(i, j, m)},$$

where s denotes the price of materials, the numerator is the standard Cobb–Douglas unit cost function, and the industry average productivity level $\tilde{\pi}_F(i, j, m)$ is now given by

$$\tilde{\pi}_F(i, j, m) = \exp \left\{ \frac{\varepsilon - 1}{1 + \alpha(j)(\varepsilon - 1)} \frac{\sigma^2(i)}{2} \right\}.$$

From the two-factor analysis above, we also derive

$$\text{vol}_F(i, j, m) = \frac{\sqrt{2}(\varepsilon - 1)\sigma(i)}{1 + \alpha(j)(\varepsilon - 1)}. \tag{B.1}$$

B.2. Autarky in the Rigid Country

We can rewrite the firm-level production function as

$$y(i, j, m, z) = e^\pi \left(\frac{M(i, j, m, z)}{\beta(m)} \right)^{\beta(m)} \times \left[\left[\frac{K(i, j, m, z)}{\alpha(j)} \right]^{\frac{\alpha(j)}{1-\beta(m)}} \left[\frac{L(i, j, m, z)}{1 - \alpha(j) - \beta(m)} \right]^{\frac{1-\alpha(j)-\beta(m)}{1-\beta(m)}} \right]^{1-\beta(m)},$$

where the term in brackets can be understood as a composite rigid factor, and M as a flexible factor. Therefore,

$$p_H(i, j, m) = \frac{r_H^{\alpha(j)} s_H^{\beta(m)} w_H^{1-\alpha(j)-\beta(m)}}{\tilde{\pi}_H(i, j, m)},$$

where the industry average productivity level $\tilde{\pi}_H(i, j, m)$ is now given by

$$\tilde{\pi}_H(i, j, m) = \exp \left\{ \frac{(\varepsilon - 1)}{1 + [1 - \beta(m)](\varepsilon - 1)} \frac{\sigma^2(i)}{2} \right\}.$$

From the earlier two-factor analysis, we also know that

$$\text{vol}_H(i, j, m) = \frac{\sqrt{2}(\varepsilon - 1)\sigma(i)}{1 + [1 - \beta(m)](\varepsilon - 1)}.$$

B.3. The Pattern of Comparative Advantage

Without loss of generality, we assume that $\beta(m)$ is an increasing and differentiable function of m . As in the one-factor and two-factor cases, we can define

$$\begin{aligned}
 A(i, j, m) &\equiv \frac{\tilde{\pi}_H(i, j, m)}{\tilde{\pi}_F(i, j, m)} \\
 &= \exp \left\{ -\frac{(\varepsilon - 1)^2}{2} \frac{1 - \alpha(j) - \beta(m)}{[1 + \alpha(j)(\varepsilon - 1)][1 + [1 - \beta(m)](\varepsilon - 1)]} \sigma^2(i) \right\}
 \end{aligned}
 \tag{B.2}$$

as the ratio of productivity levels for a given industry across the two countries. This ratio highlights, once again, the absolute productivity advantage of the flexible economy in all sectors: $A(i, j, m) < 1$ for all i, j, m . It also highlights how the pattern of comparative advantage varies with both volatility and factor intensity. $\partial A(i, j, m)/\partial i < 0$ as in the one-factor case: the productivity advantage is larger in more volatile industries. However, $\partial A(i, j, m)/\partial j > 0$, $\partial A(i, j, m)/\partial m > 0$: holding volatility constant, this productivity advantage is reduced in relatively less labor intensive industries. A smaller labor share reduces the ability of the flexible economy to take full advantage of the dispersion in productivity levels.

B.4. Empirical Measurement of Volatility and Comparative Advantage

In this section, we show how the same comparative statics for comparative advantage are obtained when they are evaluated in terms of our observed measure of volatility $\text{vol}_F(i, j, m)$: the standard deviation of log sales across firms in a sector, for an economy with a flexible labor market (the United States).³⁴ Substituting equation (B.1) into equation (B.2) yields

$$A(i, j, m) = \exp \left\{ -\frac{1}{4} \rho(j, m) \text{vol}_F^2(i, j, m) \right\},$$

where

$$\rho(j, m) = \frac{[1 - \alpha(j) - \beta(m)][1 + \alpha(j)(\varepsilon - 1)]}{[1 + [1 - \beta(m)](\varepsilon - 1)]} > 0.$$

Thus, the comparative statics for $A(i, j, m)$ in terms of vol_F are identical to those in terms of $\sigma^2(i)$: relative productivity $A(i, j, m)$ varies negatively with volatility for both measures. We now turn to the secondary effect of labor market flexibility based on

34. We note that the same comparative statics would also hold if they were evaluated for a country with a rigid labor market. Choosing the case of a flexible labor market seemed most appropriate since the empirical measure is based on US firms.

variations in factor intensities. Some tedious algebra yields

$$\frac{\partial \rho[\alpha(j), \beta(m)]}{\partial \alpha(j)} = \frac{(\varepsilon - 1)[1 - 2\alpha(j) - \beta(m)] - 1}{[(1 - \beta(m))\varepsilon + \beta(m)]},$$

$$\frac{\partial \rho[\alpha(j), \beta(m)]}{\partial \beta(m)} = - \left[\frac{\alpha(j)\varepsilon + 1 - \alpha(j)}{(1 - \beta(m))\varepsilon + \beta(m)} \right]^2.$$

Clearly, $\partial \rho[\alpha(j), \beta(m)]/\partial \beta(m) < 0$. The sign of $\partial \rho[\alpha(j), \beta(m)]/\partial \alpha(j)$ is analytically ambiguous, but we document that this derivative is negative for virtually all empirical measures of $\alpha(j)$ and $\beta(m)$ across sectors, combined with plausible values for ε . Observe that $\partial \rho[\alpha(j), \beta(m)]/\partial \alpha(j) < 0$ if and only if

$$2\alpha(j) + \beta(m) > \frac{\varepsilon - 2}{\varepsilon - 1}. \tag{B.3}$$

The RHS of (B.3) is increasing in ε . Even for an upper-bound value for ε of 10, the RHS is below 0.9.³⁵ We can evaluate the empirical distribution of the LHS of (B.3) across all US SIC sectors that we use in our empirical analysis. We use expenditures on energy and materials as a share of the gross value of production to represent $\beta(m)$. We compute a similar share for expenditures on labor, and compute $\alpha(j)$ as the residual share, 1 minus the sum of the other shares (labor and $\beta(m)$). At the SIC-3 level, the LHS for all sectors is bounded below by 0.9. At the SIC-4 level, 98% of sectors have a LHS value above 0.9. Thus, empirically, (B.3) will be satisfied for all SIC-3 sectors and almost all the SIC-4 sectors. We therefore conclude that our secondary comparative statics also hold when evaluated in terms of our empirical measure of volatility, vol_F .

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