COMPARATIVE ADVANTAGE AND THE CROSS-SECTION OF BUSINESS CYCLES

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Abstract
Business cycles are both less volatile and more synchronized with the world cycle in rich countries than in poor ones. We develop two alternative explanations based on the idea that comparative advantage causes rich countries to specialize in industries that use new technologies operated by skilled workers whereas poor countries specialize in industries that use traditional technologies operated by unskilled workers. (1) Because new technologies are difficult to imitate, the industries of rich countries enjoy more market power and face more inelastic product demand than those of poor countries. (2) Because skilled workers are less likely to exit employment as a result of changes in economic conditions, industries in rich countries face more inelastic labor supplies than those of poor countries. We show that either asymmetry in industry characteristics can generate cross-country differences in business cycles that resemble those we observe in the data. (JEL: E32, FA5, F41)

1. Introduction

Business cycles are not the same in rich and poor countries. One difference is that fluctuations in per capita income growth are smaller in rich countries than in poor ones. In the top panel of Figure 1, we plot the standard deviation of per capita income growth against the level of (log) per capita income for a large sample of countries. We refer to this relationship as the *volatility graph* and note that it slopes downward. A second difference is that fluctuations in per capita income growth are more synchronized with the world cycle in rich countries than in poor ones. In the bottom panel of Figure 1, we plot the correlation of per capita income growth rates with world average per capita income growth, excluding the country in question, against the level of (log) per capita income for the same set of countries. We refer to this relationship as the *comovement graph* and note that

Acknowledgments: We are grateful to Daron Acemoglu and Fabrizio Perri for useful comments. The views expressed here are the authors' and do not necessarily reflect those of The World Bank.
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Journal of the European Economic Association December 2007 5(6):1300–1333

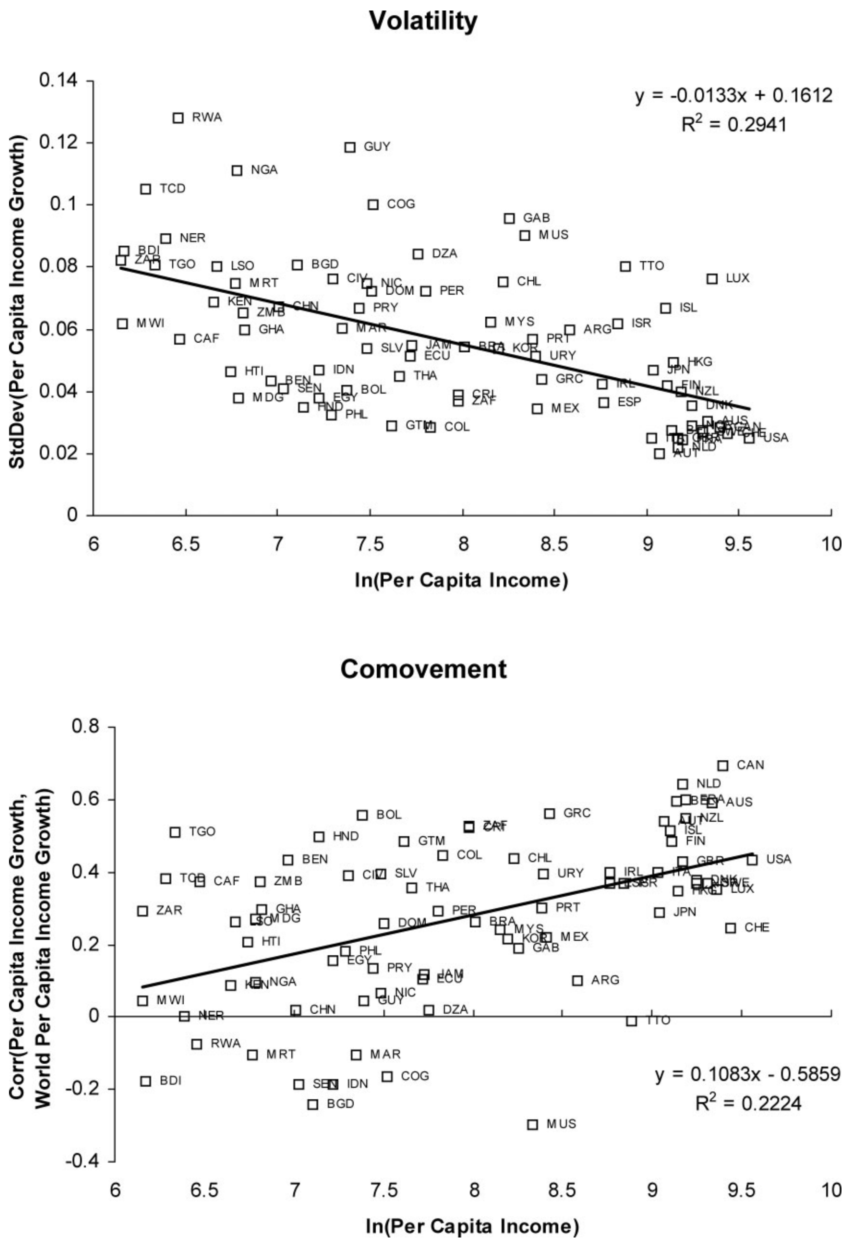

FIGURE 1. Volatility and comovement.

Notes: The top panel plots the standard deviation of the growth rate of real per capita income over the period 1960–1997 against the log-level of average per capita GDP in 1985 PPP dollars over the same period. The bottom panel plots the correlation of the growth rate of real per capita income growth with world average income growth excluding the country in question over the period 1960–1997 against the log-level of average per capita GDP in 1985 PPP dollars over the same period. See Appendix for data definitions and sources.

it slopes upward. Table 1, which is self-explanatory, shows that these facts apply within different subsamples of countries and years.[1]

Why are business cycles less volatile and more synchronized with the world cycle in rich countries than in poor ones? Part of the answer must be that poor countries exhibit more political and policy instability, are less open or more distant from the geographical center, and have a higher share of their economies devoted to the production of agricultural products and the extraction of minerals. Table 1 shows that, in a statistical sense, these factors explain a substantial fraction of the variation in the volatility of income growth but do not explain much of the variation in the comovement of income growth. More important for our purposes, the strong relationship between income and the properties of business cycles reported in Table 1 is still present after we control for these variables. In short, there must be other factors underlying the strong patterns depicted in Figure 1 beyond differences in political instability, remoteness, and the importance of natural resources.

In this article, we develop two alternative but noncompeting explanations for why business cycles are less volatile and more synchronized with the world in rich countries than in poor ones. Both explanations rely on the idea that comparative advantage causes rich countries to specialize in industries that require new technologies operated by skilled workers whereas poor countries specialize in industries that require traditional technologies operated by unskilled workers. This pattern of specialization opens up the possibility that cross-country differences in business cycles are the result of asymmetries between these types of industries. In particular, both of the explanations advanced here predict that industries that use traditional technologies operated by unskilled workers will be more sensitive to country-specific shocks. Ceteris paribus, these industries will not only be more volatile but also less synchronized with the world cycle because the relative importance of global shocks is lower. To the extent that the business cycles of countries reflect those of their industries, it is possible that differences in industrial structure could explain the patterns in Figure 1.

One explanation of why industries react differently to shocks is based on the idea that firms using new technologies face more inelastic product demands than those using traditional technologies. New technologies are difficult to imitate quickly for technical reasons and also because of legal patents. This difficulty confers a cost advantage on technological leaders that shelters them from potential entrants and gives them monopoly power in world markets. Traditional technologies are easier to imitate because enough time has passed since their adoption and

1. With the exception that the comovement graph seems to be driven by differences between rich and poor countries and not within each group. Acemoglu and Zilibotti (1997) also present the volatility graph and provide an explanation for it based on the observation that rich countries have more diversified production structures. We are unaware of any previous reference to the comovement graph.

TABLE 1. Volatility and comovement of income growth.

	Volatility graph																	
	Basic			Poor countries			Rich countries			1960–1979			1980–1997			With controls		
	Coef	Std.Err.		Coef	Std.Err.		Coef	Std.Err.		Coef	Std.Err.		Coef	Std.Err.		Coef	Std.Err.	
Intercept	0.161	0.018	***	0.183	0.051	***	0.199	0.056	***	0.179	0.024	***	0.129	0.021	***	0.090	0.023	***
In (per capita GDP at PPP)	−0.013	0.002	***	−0.017	0.007	**	−0.017	0.006	***	−0.016	0.003	***	−0.010	0.002	***	−0.009	0.002	***
Primary product exporter																0.018	0.005	***
Trade-weighted distance																0.007	0.003	**
Revolutions and coups																−0.011	0.024	
SD inflation																0.100	0.030	***
R^2	0.294			0.107			0.198			0.244			0.172			0.510		
Number of observations	76			38			38			76			76			76		
	Comovement Graph																	
Intercept	−0.586	0.184	***	0.135	0.518		−0.643	0.496		−1.091	0.216	***	−0.161	0.224		−0.758	0.280	***
In (per capita GDP at PPP)	0.108	0.022	***	0.004	0.073		0.116	0.055	**	0.173	0.028	***	0.048	0.027	*	0.127	0.031	***
Primary product exporter																0.041	0.067	
Trade-weighted distance																0.005	0.028	
Revolutions and coups																0.318	0.204	
SD inflation																−0.388	0.377	
R^2	0.222			0.000			0.101			0.282			0.047			0.250		
Number of observations	76			38			38			76			76			76		

Notes: This table reports the results of cross-sectional regressions of the standard deviation of real per capita income growth (top panel) and the correlation of real per capita income growth with world average income growth excluding the country in question (bottom panel) on the indicated variables for different samples and control variables. Poor (rich) countries refer to countries below (above) median per capita GDP. In the columns labeled 1960–1979 and 1980–1997, volatility and comovement are calculated over the indicated subperiods. The control variables consist of a dummy variable that takes the value 1 if the country is an oil or commodity exporter, a measure of trade-weighted distance from trading partners, the average over the period of the number of revolutions or coups and the standard deviation of inflation. See Appendix for data definitions and sources. Standard errors are heteroskedasticity-consistent. SD = Standard deviation.

* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

also because patents have expired or have been circumvented. This implies that incumbent firms face tough competition from potential entrants and enjoy little or no monopoly power in world markets.

The price elasticity of product demand affects how industries react to shocks. Consider, for instance, the effects of country-specific shocks that encourage production in all industries. In industries that use new technologies, firms have monopoly power and face inelastic demands for their products. As a result, fluctuations in supply lead to opposing changes in prices that tend to stabilize industry income. In industries that use traditional technologies, firms face stiff competition from abroad and therefore face elastic demands for their products. As a result, fluctuations in supply have little or no effect on their prices and industry income is more volatile. To the extent that this asymmetry in the elasticity of product demand is important, incomes of industries that use new technologies are likely to be less sensitive to country-specific shocks than those of industries that use traditional technologies.

Another explanation for why industries react differently to shocks is based on the idea that the supply of unskilled workers is more elastic than the supply of skilled workers. A first reason for this asymmetry is that nonmarket activities are relatively more attractive to unskilled workers, whose market wage is lower than that of skilled ones. Changes in labor demand might induce some unskilled workers to enter or abandon the labor force but are not likely to affect the participation of skilled workers. A second reason for the asymmetry in labor supply across skill categories is the imposition of a minimum wage. Changes in labor demand might force some unskilled workers in and out of unemployment but are less likely to affect the employment of skilled workers.

The wage elasticity of the labor supply also has implications for how industries react to shocks. Consider again the effects of country-specific shocks that encourage production in all industries and thereby raise the labor demand. Because the supply of unskilled workers is elastic, these shocks lead to large fluctuations in the employment of unskilled workers. In industries that use them, fluctuations in supply are therefore magnified by increases in employment that make industry income more volatile. Because the supply of skilled workers is inelastic, the same shocks have little or no effects on the employment of skilled workers. In industries that use them, fluctuations in supply are not magnified and industry income is less volatile. To the extent that this asymmetry in the elasticity of labor supply is important, incomes of industries that use unskilled workers are likely to be more sensitive to country-specific shocks than those of industries that use skilled workers.

To order to study these hypotheses we construct a stylized world equilibrium model of the cross-section of business cycles. Inspired by the work of Davis (1995), we consider in Section 2 a world in which differences in both in factor endowments à la Heckscher–Ohlin and industry technologies à la Ricardo combine to determine a country's comparative advantage and hence the patterns of specialization and trade. To generate business cycles, we subject this world economy to the sort of productivity fluctuations that have been emphasized by Kydland and Prescott (1982). In Section 3, we characterize the cross-section of business cycles and show how asymmetries in the elasticity of product demand and/or labor supply can be used to explain the evidence in Figure 1. Using available microeconomic estimates of the key parameters, we calibrate the model and find that: (i) The model exhibits slightly less than two-thirds and one-third of the observed cross-country variation in volatility and comovement, respectively; and (ii) the asymmetry in the elasticity of product demand seems to have a quantitatively stronger effect on the slopes of the volatility and comovement graphs than does the elasticity in the labor supply.

We explore these results further in Sections 4 and 5. In Section 4, we extend the model to allow for monetary shocks that have real effects because firms face cash-in-advance constraints. We use the model to study how cross-country variation in monetary policy and financial development affect the cross-section of business cycles. Once these factors are considered, the calibrated version of the model exhibits roughly the same cross-country variation in volatility and almost half of the variation in comovement as the data. In Section 5, we show that the two industry asymmetries emphasized here lead to quite different implications for the cyclical behavior of the terms of trade. When we confront these implications with the data, the picture that appears is clear and confirms our earlier calibration result. Namely, the asymmetry in product demand elasticity seems quantitatively more important than the asymmetry in labor supply elasticity. Finally, we discuss the implications of the theory for cross-country differences in production fluctuations.

Our article is related to several lines of recent research. There is a large literature on open-economy real business cycle models that studies how productivity shocks are transmitted across countries (see Backus, Kehoe, and Kydland 1995 for a survey). We differ from this literature in two respects. First, instead of emphasizing the aspects in which business cycles are similar across countries, we focus on those aspects in which they are different. Second, instead of focusing primarily on the implications of international lending, risk sharing, and factor movements for the transmission of business cycles, we emphasize the role of commodity trade.

There is also a large literature that seeks to explain the volatility graph by appealing to cross-country differences in financial development. Theoretical models such as Greenwood and Jovanovic (1990), Acemoglu and Zilibotti (1997), and Aghion, Banerjee, and Piketty (1999) have all emphasized various mechanisms through which improvements in financial development allow risk-averse agents to adopt a more diversified mix of riskier but higher-return projects. Financial development thus leads to higher incomes and lower volatility, providing an alternative account of the volatility graph. Unlike this literature, in our basic model we generate greater volatility (and also lower comovement) in poor countries without recourse to differences in financial development. Moreover, in the extended version of our model, financial development operates through a different channel: by dampening the sensitivity of domestic production to shocks to monetary policy.

Our work is also related to two recent papers by Koren and Tenreyro (2006, 2007). In the latter empirical paper, these authors show that richer countries tend to specialize in industries that are less volatile and that this channel accounts for roughly half of the observed cross-country differences in volatility between rich and poor countries. This finding is consistent with our emphasis on the role of comparative advantage in generating cross-country differences in industrial structure that in turn drive cross-country differences in business cycles. The earlier paper provides another purely technological account of the volatility graph; in this model, technological progress is based on an expanding number of varieties of intermediates that are subject to random fluctuations. Richer countries choose more sophisticated production processes that are also less volatile because they rely on a larger set of intermediates. In contrast with our article, comparative advantage plays no role.

2. A Model of Trade and Business Cycles

In this section, we present a stylized model of the world economy. Countries that have better technologies and more skilled workers are richer and also tend to specialize in industries that use these factors intensively. That is, the same characteristics that determine the income of a country also determine its industrial structure. Our objective is to develop a formal framework that allows us to think about how cross-country variation in income, and therefore industrial structure, translate into cross-country variation in the properties of the business cycle.

We consider a world with a continuum of countries with mass 1; with one final good and two continuums of intermediates indexed by $z \in [0, 1]$, which we refer to as the α- and β-industries; and with two factors of production, skilled and unskilled workers. There is free trade in intermediates, but we do not allow trade in the final good. To emphasize the role of commodity trade, we rule out trade in financial instruments. To simplify the problem further, we also rule out investment. Jointly, these assumptions imply that countries do not save.

Countries differ in their technologies, their endowments of skilled and unskilled workers, and their level of productivity. In particular, each country is defined by a triplet (μ, δ, π), where μ is a measure of how advanced the technology of the country is, δ is the fraction of the population that is skilled, and π is an index of productivity. We assume that workers cannot migrate and that cross-country differences in technology are stable, so that μ and δ are constant.

Let $F(\mu, \delta)$ be their time-invariant joint distribution. We generate business cycles by allowing the productivity index π to fluctuate randomly.

Each country is populated by a continuum of consumers who differ in their level of skills and their personal opportunity cost of work, or reservation wage. We think of this reservation wage as the value of nonmarket activities. We index consumers by $i \in [1, \infty)$ and assume that this index is distributed according to this Pareto distribution: $F(i) = 1 - i^{-\lambda}$ with $\lambda > 0$. A consumer with index i maximizes the following expected utility:

$$E \int_0^\infty U\left(c(i) - \frac{I(i)}{i}\right) e^{-\rho \cdot t} dt, \tag{1}$$

where $U(\cdot)$ is any well-behaved utility function, $c(i)$ is consumption of the final good, and $I(i)$ is an indicator function that takes value 1 if the consumer works and 0 otherwise. Let $r(\mu, \delta, \pi)$ and $w(\mu, \delta, \pi)$ be the wages of skilled and unskilled workers in a (μ, δ, π)-country. Also define $p_F(\mu, \delta, \pi)$ as the price of the final good. The budget constraint is simply $p_F c(i) = wI(i)$ for unskilled workers and $p_F c(i) = rI(i)$ for skilled ones.

The consumer works if and only if the applicable real wage (skilled or unskilled) exceeds a reservation wage of i^{-1}. Let $s(\mu, \delta, \pi)$ and $u(\mu, \delta, \pi)$ be the measure of skilled and unskilled workers who are employed. Under the assumption that the distribution of skills and reservation wages are independent, we have:

$$s = \begin{cases} \delta \left(\frac{r}{p_F}\right)^\lambda & \text{if } r < p_F, \\ \delta & \text{if } r \geq p_F, \end{cases} \tag{2}$$

$$u = \begin{cases} (1-\delta) \left(\frac{w}{p_F}\right)^\lambda & \text{if } w < p_F, \\ 1-\delta & \text{if }, w \geq p_F. \end{cases} \tag{3}$$

If the real wage of any type of worker is less than 1, then the aggregate labor supply of this type exhibits a wage-elasticity of λ. This elasticity depends only on the dispersion of reservation wages. If the real wage of any type of worker reaches 1, then the entire labor force of this type is employed and the aggregate labor supply for this type of worker becomes vertical. Throughout, we consider equilibria in which the real wage for skilled workers exceeds one, $r/p_F > 1$, and the real wage for unskilled workers is less than unity, $w/p_F < 1$.[2] That is, all countries operate in the vertical region of their supply of skilled workers and in

2. This is the case in equilibrium if skilled (unskilled) workers are sufficiently scarce (abundant) in all countries—that is, if $\delta \ll 1$.

the elastic region of their supply of unskilled workers. This assumption generates an asymmetry in the wage elasticity of the aggregate labor supply across skill categories. This elasticity is 0 for skilled workers and $\lambda > 0$ for unskilled ones. As $\lambda \to 0$, this asymmetry disappears.

Each country contains many competitive firms in the final goods sector. These firms combine intermediates to produce a final good according to the cost function

$$B(p_\alpha(z), p_\beta(z)) = \left[\int_0^1 p_\alpha(z)^{1-\theta} dz\right]^{\nu/1-\theta} \left[\int_0^1 p_\beta(z)^{1-\theta} dz\right]^{(1-\nu)/(1-\theta)}. \tag{4}$$

The elasticity of substitution between industries equals 1, and the elasticity of substitution between any two varieties within an industry is $\theta > 1$. It follows from equation (4) that firms in the final-goods sector spend a fraction ν of their revenues on α-products and a fraction $1 - \nu$ on β-products. Moreover, the ratio of spending on any two α-products z and z' is given by $[p_\alpha(z)/p_\alpha(z')]^{1-\theta}$; the ratio of spending on any two β-products z and z' is $[p_\beta(z)/p_\beta(z')]^{1-\theta}$, where $p_\alpha(z)$ and $p_\beta(z)$ denote the price of variety z of the α- and β-products, respectively.

Define P_α and P_β as the ideal price indices for the α- and β-industry; that is,

$$P_\alpha = \left[\int_0^1 p_\alpha(z)^{1-\theta} dz\right]^{1/1-\theta} \quad \text{and} \quad P_\beta = \left[\int_0^1 p_\beta(z)^{1-\theta} dz\right]^{1/1-\theta}.$$

Because there are always some workers that participate in the labor force, the demand for the final product is always strong enough to generate positive production in equilibrium. This allows us to define the following numéraire rule:

$$1 = P_\alpha^\nu P_\beta^{1-\nu}. \tag{5}$$

Because firms in the final-goods sector are competitive, they set price equal to cost. This implies that

$$p_F = 1. \tag{6}$$

All intermediates are traded and the law of one price applies, so the price of the final good is the same in all countries. In this world economy, purchasing power parity obtains. As a result, that the final good is not traded is no longer a binding assumption.

Each country also contains two intermediate industries. The α-industry uses sophisticated production processes that require skilled workers. Each variety of product requires a different technology that is owned by one firm only. To produce one unit of any variety of α-products, the firm that owns the technology requires $e^{-\pi}$ units of skilled labor. As mentioned previously, the productivity index π

fluctuates randomly and is not under the control of the firms. Let μ be the measure of α-products in which the technology is owned by a domestic firm. We can interpret μ as a natural indicator of how advanced the technology of a country is. It follows from our assumptions on the technology and market structure in the final-goods sector that the elasticity of demand for any variety of α-product is θ. As a result, all firms in the α-industry face downward-sloping demand curves and behave monopolistically. Their optimal pricing policy is to set a markup over unit cost. Let $p_\alpha(z)$ be the price of product variety z of the α-industry. Symmetry ensures all the firms located in a (μ, δ, π)-country set the same price for their varieties of α-products, $p_\alpha(\mu, \delta, \pi)$:

$$p_\alpha = \frac{\theta}{\theta - 1} r e^{-\pi}. \tag{7}$$

As usual, the markup depends on the elasticity of demand for these products.

The β-industry uses traditional technologies that are available to all firms in all countries and can be operated by both skilled and unskilled workers. To produce one unit of any variety of β-products, firms require $e^{-\pi}$ units of labor of any kind. Because we have assumed that (in equilibrium) skilled wages exceed unskilled wages, only unskilled workers produce β-products. Since all firms in the β-industry have access to the same technologies, they all face flat individual demand curves and behave competitively, setting price equal to cost. Let $p_\beta(z)$ be the price of the variety z of the β-industry. Symmetry ensures that all firms in the β-industry of a (μ, δ, π)-country set the same price for all varieties of β-products, $p_\beta(\mu, \delta, \pi)$:

$$p_\beta = w e^{-\pi}. \tag{8}$$

With this formulation, we have introduced an asymmetry in the price elasticity of product demand. This elasticity is θ in the α-industry and ∞ in the β-industry. As $\theta \to \infty$, the asymmetry disappears.

Business cycles arise as π fluctuates randomly. We refer to changes in π as productivity shocks. The index π is the sum of a global component, Π, and a country-specific component, $\pi - \Pi$. Each of these components is an independent Brownian motion reflected on the interval $[-\bar{\pi}, \bar{\pi}]$ with changes that have zero drift and instantaneous variance equal to $\eta\sigma^2$ and $(1 - \eta)\sigma^2$, respectively, with $\bar{\pi} > 0$, $0 < \eta < 1$, and $\sigma > 0$. Let the initial distribution of country-specific components be uniformly distributed on $[-\bar{\pi}, \bar{\pi}]$ and assume this distribution is independent of other country characteristics. Under the assumption that changes in these country-specific components are independent across countries, it follows that the cross-sectional distribution of π minus Π is time invariant.[3] We refer to this distribution as $G(\pi - \Pi)$. Whereas π has been defined as an index of

3. See Harrison (1990, ch. 5).

domestic productivity, Π serves as an index of world average productivity. The instantaneous volatility of the domestic shock, $d\pi$, is σ, and its instantaneous correlation with foreign shocks, $d\Pi$, is $\sqrt{\eta}$.[4] The parameter η therefore regulates the extent to which the variation in domestic productivity is due to global or country-specific components—that is, whether it comes from $d\Pi$ or $d(\pi - \Pi)$. Figure 2 shows possible sample paths of π under three alternative assumptions regarding η.

A competitive equilibrium of the world economy consists of a sequence of prices and quantities such that consumers and firms behave optimally and markets clear. Our assumptions ensure that a competitive equilibrium exists and is unique. We prove this by constructing the set of equilibrium prices.

In the α-industry, different products command different prices. The ratio of world demands for the (sum of all) α-products of a (μ, δ, π)-country to those for a (μ', δ', π')-country, $\mu p_\alpha(z)/\mu' p_\alpha(z')^{-\theta}$, must equal the ratio of supplies, $se^\pi/s'e^{\pi'}$. Using this condition together with equation (2) and the definition of P_α, we find that

$$\frac{p_\alpha}{P_\alpha} = \left(\frac{\psi_\alpha \mu}{\delta}\right)^{1/\theta} e^{-(\pi-\Pi)/\theta}, \tag{9}$$

where $\psi_\alpha = (\iint \mu^{1/\theta}\delta^{(\theta-1)/\theta}e^{(\theta-1)/\theta(\pi-\Pi)}\theta dF dG)^{\theta/(\theta-1)}$. Because the distribution functions $F(\mu, \delta)$ and $G(\pi - \Pi)$ are time-invariant, it follows that ψ_α is a constant. Because each country is a "large" producer of its own varieties of α-products, the price of these varieties depends negatively on the quantity produced. Countries with many skilled workers (high δ) with relatively high productivity (high $\pi - \Pi$) producing a small number of varieties (low μ) produce large quantities of each variety of the α-products and, as a result, face low prices. As $\theta \to \infty$, the dispersion in prices disappears and $p_\alpha(z) \to p_\alpha$.

In the β-industry, all products command the same price; otherwise, low-price varieties of β-products would not be produced. Because this is not a possible equilibrium given the technology described in equation (4), it follows that

$$\frac{p_\beta}{P_\beta} = 1. \tag{10}$$

Finally, we compute the relative price of the two industries. To do this, equate the ratio of world spending in the α- and β-industries, $\nu/(1-\nu)$, to the ratio of the value of their productions, $\iint p_\alpha s e^\pi dF dG / \iint p_\beta u e^\pi dF dG$. Using equations (2)–(3) and (5)–(10), we then find that

$$\frac{P_\alpha}{P_\beta} = \left(\frac{\nu}{1-\nu}\frac{\psi_\beta}{\psi_\alpha}\right)^{1/(1+\lambda\nu)} e^{\Pi\lambda/(1+\lambda\nu)}, \tag{11}$$

4. This is true except when either π or Π are at their respective boundaries. These are rare events because the dates at which they occur constitute a set of measure zero in the time line.

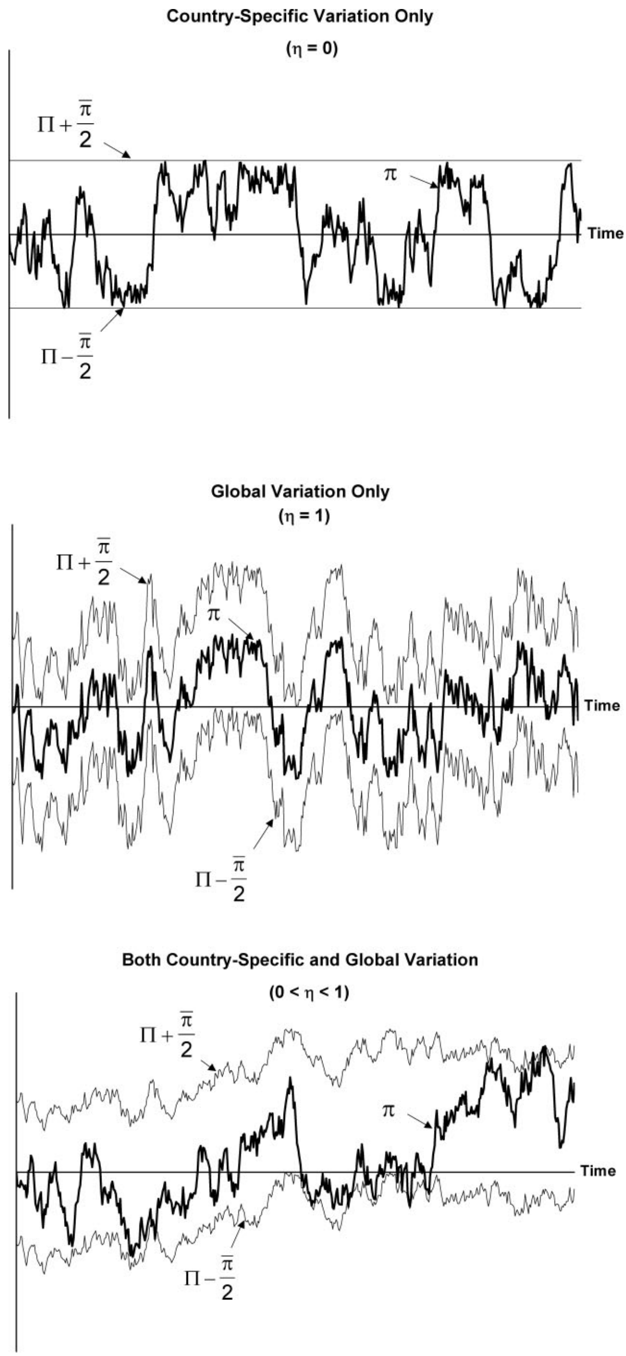

FIGURE 2. Sample paths of the productivity index.

where $\psi_\beta = \iint (1-\delta)e^{(1+\lambda)\cdot(\pi-\Pi)} dFdG$, and is constant. If $\lambda > 0$, then high productivity is associated with high relative prices for α-products because the world supply of β-products is high relative to that of α-products. This increase in the relative supply of β-products is due to increases in employment of unskilled workers. As $\lambda \to 0$, the relative prices of both industries are unaffected by the level of productivity.

What are the patterns of trade in this world economy? Let $y(\mu, \delta, \pi)$ and $x(\mu, \delta, \pi)$ be, respectively, the income and the share of the α-industry in a (μ, δ, π)-country: that is, $y = (p_\alpha s + p_\beta u)e^\pi$ and $x = p_\alpha s e^\pi / y$. Not surprisingly, countries with better technologies (high μ) and more human capital (high δ) have high values for both y and x. We thus refer to countries with high values of x as "rich countries". Because each country produces an infinitesimal number of varieties of α-products and uses all of them in the production of final goods, all countries export almost all of their production of α-products and import almost all of the α-products used in the domestic production of final goods. As a share of income, these exports and imports are x and ν, respectively. To balance their trade, countries with $x < \nu$ export β-products and countries with $x > \nu$ import them. As a share of income, these exports and imports are $\nu - x$ and $x - \nu$, respectively. Therefore, the share of trade in income is $\max\{\nu, x\}$. As usual, this trade can be decomposed into intraindustry trade, $\min\{\nu, x\}$, and interindustry trade, $|x - \nu|$. The former consists of trade in products that have similar factor proportions, the latter of trade in products with different factor proportions. Hence our model captures in a stylized manner three broad empirical regularities regarding the patterns of trade: (a) a large volume of intraindustry trade among rich countries, (b) substantial interindustry trade between rich and poor countries, and (c) little trade among poor countries.

3. The Cross-Section of Business Cycles

In the world economy described in Section 2, countries are subject to the same type of country-specific and global shocks to productivity. Any difference in the properties of their business cycles must be ultimately attributed to differences in their technology and factor proportions. This is clearly a simplification. In the real world, countries experience different types of shocks and also have many differences beyond technology and factor proportions. With this caveat in mind, in this section we ask: How much of the observed cross-country variation in business cycles can be explained by the simple model of the Section 2?

The first step toward answering this question is to obtain an expression that links income growth to the shocks that countries experience. Applying Ito's lemma to the definition of y and using equations (2)–(11), we obtain the (de-meaned) growth rate of income of a (μ, δ, π)-country as a linear combination of country-specific and global shocks:

$$d \ln y - E[d \ln y] = \left[x\frac{\theta - 1}{\theta} + (1 - x)(1 + \lambda)\right] d(\pi - \Pi) + \frac{1 + \lambda}{1 + \lambda\nu} d\Pi. \quad (12)$$

Equation (12) provides a complete characterization of the business cycles experienced by a (μ, δ, π)-country as a function of the country's industrial structure (as measured by x). The equation shows that poor countries are more sensitive to country-specific shocks; that is, $\partial d \ln y / \partial d(\pi - \Pi)|_{d\Pi=0}$ is decreasing in x. Equation (12) also shows that all countries are equally sensitive to global shocks; that is, $\partial d \ln y / \partial d\Pi|_{d(\pi-\Pi)=0}$ is independent of x. We next discuss the intuition behind these results.

Why are poor countries more sensitive to country-specific shocks? Assume that $\lambda \to 0$ and $\theta \to \infty$, so that the α-and β-industry face both perfectly inelastic factor supplies and perfectly elastic product demands. In this case, a 1% country-specific increase in productivity has no effect on employment or product prices. As a result, production and income also increase by 1%. This is why $\partial d \ln y / \partial d(\pi - \Pi)|_{d\Pi=0} = 1$ if $\lambda = 0$ and $\theta = \infty$. If λ is positive, then a country-specific increase in productivity of 1% leads to an increase in employment of λ% in the β-industry and, as a result, production and income increase by more than 1%. This employment response magnifies the expansionary effects of increased productivity in the β-industry. Consequently, the shock has stronger effects in poor countries, that is, $\partial d \ln y / \partial d(\pi - \Pi)|_{d\Pi=0} = 1 + (1 - x)\lambda$ if $\theta = \infty$. If θ is finite, then a country-specific increase in productivity of 1% leads to a $(1/\theta)$% decrease in prices in the α-industries. This price response counteracts the expansionary effects of increased productivity in the α-industry. Hence, the shock has weaker effects in rich countries: $\partial d \ln y / \partial d(\pi - \Pi)|_{d\Pi=0} = 1 - x/\theta$ if $\lambda = 0$. If $\lambda > 0$ and θ is finite, then both the employment and price responses combine to make poor countries react more to country-specific shocks; that is, $\partial d \ln y / \partial d(\pi - \Pi)|_{d\Pi=0} = x(\theta - 1)/\theta + (1 - x)(1 + \lambda)$ is decreasing in x.

Why are all countries equally responsive to global shocks? This result rests on the assumption that the elasticity of substitution between α- and β-products is unity. Consider a global increase in productivity. On the one hand, production of β-products expands relative to the production of α-products as more unskilled workers are employed. Ceteris paribus, this would increase the share of world income that goes to the β-industry (and hence to poor countries) after a positive global shock. But the increase in relative supply lowers the relative price of β-products, and this reduces the share of world income that goes to the β-industry (and hence to poor countries) after a positive global shock. The assumption of a Cobb-Douglas technology for the production of the final good implies that these two effects cancel and the share of world spending in the α- and

β-industries remains constant over the cycle. Thus, in our framework differences in industrial structure do not generate differences in how countries react to global shocks.[5]

We are now ready to use the model to interpret the evidence in Figure 1. Define $dlnY$ as the world average growth rate $d \ln Y = \iint d \ln y dF dG$. Then, by equation (12), we have:

$$d \ln Y - E[d \ln Y] = \frac{1+\lambda}{1+\lambda\nu} d\Pi. \tag{13}$$

Because the law of large numbers eliminates the country-specific component of shocks in the aggregate, the world economy exhibits milder cycles that any of the countries that belong to it.[6]

Let $V(\mu, \delta, \pi)$ denote the standard deviation of income growth of a (μ, δ, π)-country, and let $C(\mu, \delta, \pi)$ denote the correlation of its income growth with world average income growth. These are the theoretical analogs to the volatility and comovement graphs in Figure 1. Using Equations (12) and (13) together with the properties of the shocks, we find that

$$V = \sigma \sqrt{\left[x\frac{\theta-1}{\theta} + (1-x)(1+\lambda)\right]^2 (1-\eta) + \left(\frac{1+\lambda}{1+\lambda\nu}\right)^2 \eta}, \tag{14}$$

$$C = \frac{\dfrac{1+\lambda}{1+\lambda\nu}\sqrt{\eta}}{\sqrt{\left[x\dfrac{\theta-1}{\theta} + (1-x)(1+\lambda)\right]^2 (1-\eta) + \left(\dfrac{1+\lambda}{1+\lambda\nu}\right)^2 \eta}}. \tag{15}$$

Figure 3 plots the volatility and comovement graphs as functions of x, for different parameter values. Except in the limiting case where both $\lambda = 0$ and $\theta = \infty$, the volatility graph is downward sloping and the comovement graph is upward-sloping. The intuition is clear: As a result of asymmetries in the elasticity of product demand and labor supply, the α-industry is less sensitive to country-specific shocks than the β-industry. This makes the α-industry less volatile and more synchronized with the world cycle than the β-industry. Because countries inherit the cyclical properties of their industries, the incomes of rich countries are

5. Although the Cobb–Douglas formulation is special, it is not difficult to grasp what would happen if we relaxed it. If the elasticity of substitution between industries were greater than 1, then poor countries would be more sensitive to global shocks than rich countries because the share of world income that goes to the β-industry increases after a positive global shock and decreases after a negative one. If the elasticity of substitution were less than 1, then the opposite would be true.

6. Once again, this result rests on the Cobb–Douglas assumption. If the elasticity of substitution between α- and β-products were greater than 1, then the very rich countries might exhibit business cycles that are milder than those of the world.

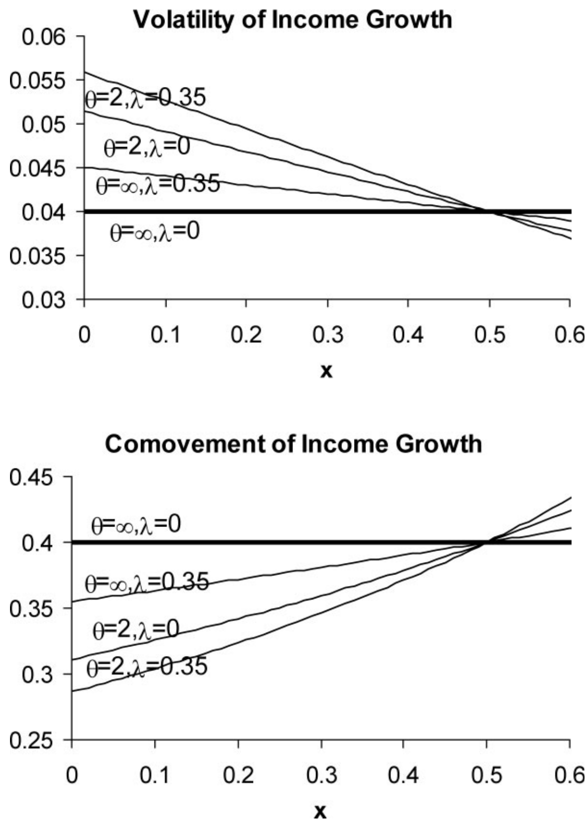

FIGURE 3. Theoretical volatility and comovement graphs.

Notes: This figure plots equations (14) and (15) as a function of x for the indicated values of θ and λ. The share of α-products in consumption is set equal to $\nu = 0.2$, and the parameters of the productivity process are set as discussed in the text.

also less volatile and more synchronized with the world cycle than those of poor countries. The magnitude of these differences is more pronounced as λ increases and/or θ decreases.

A simple inspection of Equations (14) and (15) reveals that there exist various combinations of parameters capable of generating (at least approximately) the data patterns displayed in Figure 1 and Table 1. In this sense, the model is able to replicate the evidence that motivated the paper. But this is an undemanding criterion, and one can impose more discipline by restricting the analysis to combinations of parameter values that seem reasonable. Toward this end, we next choose values for σ, η, ν, and a range for x. With these choices at hand, we then examine how the cross-section of business cycles varies with λ and θ. Needless to say, one should be cautious when drawing conclusions from such a calibration exercise in a model as stylized as ours. As noted before, in the real world countries experience different types of shocks and also differ in ways other than technology and factor proportions. Moreover, available estimates of the key parameters λ and θ are based on nonrepresentative samples of countries and industries, so caution is also in order when generalizing to the large cross-section of countries we study here. Despite these caveats, some useful insights can be gained from this exercise.

To determine the relevant range of variation for x, we use data on trade shares. The model predicts that the share of exports in income in rich countries is x. Because this share is around 60% in the richest countries in our sample, we use 0.6 as a reasonable upper bound for x. The model also predicts that ν is the share of exports in income in poor countries and that, in these countries $x < \nu$. Because the share of exports in GDP is around 20% in the poorest countries in our sample, we choose $\nu = 0.2$ and use 0.1 as a lower bound for x. The choice of σ and η is more problematic, as there are no reliable estimates of the volatility and cross-country correlation of productivity growth for this large cross-section of countries. We circumvent this problem by choosing σ and η to match the observed level of volatility and comovement of income growth for the typical rich country, given the rest of our parameters.[7] This means that this calibration exercise can tell us only about the model's ability to match observed cross-country differences in volatility and comovement of income growth.

The top-left panel of Table 2 reports the results of this calibration exercise, and selected cases are shown in Figure 3. The first row reports the predicted difference in volatility and comovement between the richest country (with log per capita GDP of around 9.5) and the poorest country (with log per capita GDP of around 6.5), based on the regressions with controls in Table 1. The remaining rows report the difference in volatility and comovement between the richest ($x = 0.6$) and poorest ($x = 0.1$) countries that the model predicts for different values of λ and θ. These values are compatible with existing microeconomic estimates. Available industry estimates of the elasticity of export demand range from 2 to 10 (Feenstra 1994; Trefler and Lai 1999), and available estimates for the labor supply elasticity of unskilled workers range from 0.3 to 0.35 (Juhn, Murphy, and Topel 1991). The table also reports the values for σ and η that result from the calibration procedure.

Table 2 shows that, using values of $\theta = 2$ and $\lambda = 0.35$, the model can account for nearly two thirds of the cross-country difference in volatility between rich and poor countries (-0.016 vs. -0.026), and slightly less than one-third of the cross-country differences in comovement (0.129 vs. 0.382). These values for the parameters are within the range suggested by existing microeconomic studies.

7. In particular, σ and η are chosen to ensure that $V = 0.04$ and $C = 0.4$, for $x = 0.5$ and $\nu = 0.2$ and for the given choices for λ and θ.

TABLE 2. Calibrations. Cross-country differences in volatility and comovement.

				Income growth		Terms of trade growth		Production growth	
				Volatility	Comovement	Volatility	Comovement	Volatility	Comovement
Empirical									
Point estimate				−0.026	0.382	0.009	0.037	−0.029	0.398
Lower bound				−0.040	0.195	0.002	−0.130	−0.042	0.229
Upper bound				−0.012	0.569	0.017	0.203	−0.016	0.566
Theoretical, basic model									
θ	λ	σ	$\sqrt{\eta}$						
∞	0	0.04	0.40	0.000	0.000	0.000	0.000	0.000	0.000
∞	0.35	0.03	0.38	−0.005	0.047	0.001	2.000	−0.006	0.002
∞	0.7	0.03	0.37	−0.009	0.078	0.002	2.000	−0.010	0.007
2	0	0.05	0.31	−0.011	0.098	0.012	0.000	0.000	0.000
2	0.35	0.04	0.30	−0.016	0.129	0.010	0.343	−0.007	0.002
2	0.7	0.04	0.31	−0.019	0.149	0.009	0.623	−0.012	0.006
1.2	0	0.06	0.25	−0.025	0.186	0.026	0.000	0.000	0.000
1.2	0.35	0.05	0.25	−0.027	0.200	0.020	0.171	−0.009	0.002
1.2	0.7	0.04	0.26	−0.028	0.208	0.016	0.330	−0.014	0.005
Theoretical, monetary model with $\kappa(x) = 1.1 - x$, $\phi = 0.1$									
θ	λ	σ	$\sqrt{\eta}$						
∞	0	0.04	0.40	0.000	0.000	0.000	0.000	0.000	0.000
∞	0.35	0.03	0.39	−0.015	0.115	0.001	2.000	−0.015	0.071
∞	0.7	0.02	0.43	−0.039	0.235	0.002	2.000	−0.040	0.165
2	0	0.05	0.31	−0.011	0.098	0.012	0.000	0.000	0.000
2	0.35	0.04	0.32	−0.023	0.172	0.010	0.358	−0.015	0.043
2	0.7	0.03	0.37	−0.044	0.263	0.007	0.741	−0.039	0.123
1.2	0	0.06	0.25	−0.025	0.186	0.026	0.000	0.000	0.000
1.2	0.35	0.05	0.26	−0.033	0.227	0.019	0.178	−0.015	0.027
1.2	0.7	0.03	0.32	−0.049	0.291	0.014	0.400	−0.038	0.094

Notes: This table compares empirical differences in volatility and comovement of real income growth (left panel) and terms of trade growth (center panel) and production growth (right panel) with the predictions of the basic model of Section 3 (top panel) and the model with monetary shocks of Section 5 (bottom panel). The first row reports the estimated difference in volatility and comovement between the richest countries in the sample (with log per capita GDP $= 9.5$) and the poorest countries in the sample (with log per capita GDP $= 6.5$) based on the regressions with controls in Tables 1 and 3. The remaining rows report the predictions of the model for the difference in volatility and comovement between a rich country (with $x = 0.6$) and a poor country (with $x = 0.1$) for the indicated parameter values.

If the industry asymmetries are assumed to be even stronger, say $\theta = 1.2$ and $\lambda = 0.7$, the predicted differences in volatility and comovement are closer to their predicted values. These results are encouraging. The two hypotheses put forward here can account for a sizeable fraction of cross-country differences in business cycles even in such a stylized model as ours. Moreover, in Section 4, we show that simply extending the model—to allow for monetary shocks and cross-country differences in the degree of financial development—can move the theoretical predictions closer to the data.

A second result in Table 2 is that the asymmetry in the elasticity of product demand seems quantitatively more important than the asymmetry in the elasticity of labor supply. Within the range of parameter values considered in Table 2, changes in θ have strong effects on the slope of the two graphs whereas changes in λ have weaker effects. To the extent that our considered range of parameter values is the relevant one, this calibration exercise suggests that the asymmetry in the elasticity of product demands constitutes the more promising hypothesis of why business cycles differ across countries. We return to this point in Section 5, where we attempt to distinguish between hypotheses by examining data on terms of trade.

4. Monetary Shocks and Financial Development

Our simple calibration exercise tells us that the two industry asymmetries can account for almost two-thirds of the cross-country differences in volatility and for nearly one-third of the cross-country variation in comovement. One reaction to this finding is that the model is surely too stylized to be confronted with the data. After all, most of our modeling choices were made to maximize theoretical transparency rather than model fit. Now that the main mechanisms have been clearly stated and the intuitions behind them developed, it is time to build on the stylized model and move closer to reality by adding details. Hence our goal in this section is to show that introducing monetary shocks and cross-country variation in financial development helps to significantly narrow the gap between model and data. This is not the only way to narrow this gap, but we choose this route because the elements highlighted by this extension are both realistic and interesting in their own right.

We now allow countries to differ also in their degree of financial development and their monetary policy. Each country is therefore defined by a 5-tuple, $(\mu, \delta, \pi, \kappa, \iota)$, where κ is a measure of the degree of financial development and ι is the interest rate on domestic currency. We assume that κ is constant over time and re-define $F(\mu, \delta, \kappa)$ as the time-invariant joint distribution of μ, δ, and κ. We allow for an additional source of business cycles by letting ι fluctuate randomly.

We motivate the use of money by assuming that firms face a cash-in-advance constraint.[8] In particular, firms must use cash or domestic currency to pay a fraction κ of their wage bill before production starts, with $0 \leq \kappa \leq 1$. The parameter κ thus measures how underdeveloped are credit markets. As $\kappa \to 0$ in all countries, we reach the limit in which credit markets are so efficient that cash is never used. This is the case we have studied so far. In those countries where $\kappa > 0$, firms borrow cash from the government and repay the cash plus interest after production is completed and output is sold to consumers.

Monetary policy consists of setting the interest rate on cash and then distributing the proceeds in a lump-sum fashion among consumers. As is customary in the literature on money and business cycles, we assume that monetary policy is random.[9] In particular, we assume that the interest rate is a reflecting Brownian motion on the interval $[\underline{\iota}, \overline{\iota}]$, with changes that have zero drift and instantaneous variance ϕ^2 and that are independent across countries and also independent of changes in π. Let the initial distribution of interest rates be uniform in $[\underline{\iota}, \overline{\iota}]$ and independent of the distribution of other country characteristics. Hence, the cross-sectional distribution of ι, $H(\iota)$, does not change over time.

The introduction of money leads to only minor changes in the Section 2 description of world equilibrium. Equations (2)–(3) describing the labor supply decision and the numéraire rule in equation (5) still apply. Because firms in the final-goods sector do not pay wages, their pricing decision is still given by equation (6). The cash-in-advance constraints affect the firms in the α- and β-industries because they now face financing costs in addition to labor costs. As a result, the pricing equations (7)–(8) must be replaced by:[10]

$$p_\alpha = \frac{\theta}{\theta - 1} r e^{-\pi + \kappa \iota}; \tag{16}$$

$$p_\beta = w e^{-\pi + \kappa \iota}. \tag{17}$$

Observe that changes in the interest rate affect the financing costs of firms and are therefore formally equivalent to supply shocks such as changes in production or payroll taxes. Formally, this is the only change required. A straightforward extension of earlier arguments shows that Equations (9)–(11) describing the set of equilibrium prices are still valid provided we re-define

8. See Christiano, Eichenbaum, and Evans (1997) for a discussion of related models.

9. This simplification is adequate if one takes the view that monetary policy has objectives other than stabilizing the cycle. For instance, if the inflation tax is used to finance a public good, then shocks to the marginal value of this public good are translated into shocks to the rate of money growth. Alternatively, if a country is committed to maintaining a fixed parity, then shocks to foreign investors' confidence in the country are translated into shocks to the nominal interest rate because the monetary authorities use the latter to manage the exchange rate.

10. Here we use the approximation $\kappa \cdot \iota \approx \ln(1 + \kappa \cdot \iota)$.

$\psi_\beta = \iiint (1-\delta)e^{(1+\lambda)(\pi-\Pi)-\kappa\iota} dF\, dG\, dH$, which converges to our previous definition of ψ_β in the limiting case in which $\kappa \to 0$ in all countries.

Financing costs are not a direct cost for the country as a whole but instead are simply transferred from firms to consumers via the government. Consequently, income and the share of the α-industry are still defined as $y = (p_\alpha s + p_\beta u)e^\pi$ and $x = p_\alpha s e^\pi / y$, respectively. Now rich countries are those that have better technologies (high μ), more human capital (high δ), and better financial systems (low κ). Recall that, ceteris paribus, a high value for μ and δ lead to a high value of x. This is why have been referring to countries with high values for x as being rich. However, we now have that a low value for κ leads to both higher income and a lower value for x. The intuition is simple: A high value of κ is associated with higher financing costs and hence with a weaker labor demand for all types of workers. In the market for skilled workers, this weak demand is translated fully into lower wages and has no effects in employment. The size of the α-industry is therefore not affected by cash-in-advance constraints. In the market for unskilled workers, this weak demand is translated into both lower wages and employment. The latter implies a smaller β-industry. Despite this, we shall continue to refer to countries with higher values of x as "rich." That is, it seems reasonable to assume that technology and factor proportions are more important determinants of a country's industrial structure than the degree of financial development.[11]

We are now ready to determine how interest-rate shocks affect income growth and the cross-section of business cycles. Applying Ito's lemma to the definition of y, we find this expression for the (de-meaned) growth rate of income for the $(\mu, \delta, \pi, \kappa, \iota)$-country:

$$d \ln y - E[d \ln y] = \left[x \frac{\theta - 1}{\theta} + (1-x)(1+\lambda) \right] d(\pi - \Pi) + \frac{1+\lambda}{1+\lambda\nu} d\Pi - (1-x)\lambda\kappa\, d\iota. \tag{18}$$

Equation (18), which generalizes equation (12), describes the business cycles of a $(\mu, \delta, \pi, \kappa, \iota)$-country as a function of its industrial structure. The first two terms, which describe the reaction of the country to productivity shocks, have already been discussed at length. The third term is new and shows how the country reacts to interest-rate shocks. In particular, it shows that interest-rate shocks have larger effects in countries that are poor and have a low degree of financial development. That is, $(\partial d \ln y / \partial d\iota)_{d(\pi-\Pi)=0, d\Pi=0}$ is decreasing in x and is increasing in κ when holding x constant.

11. However, our model is consistent with the empirical evidence in Raddatz (2007), who shows that countries with low levels of financial development—that is, countries with high values of κ—tend to have a smaller share of production in industries that are more sensitive to financial development—that is, the β-industry.

An increase in the interest rate raises financing costs in the α- and β-industries. This increase is larger in countries with low degrees of financial development (high κ). For this reason alone, poor countries are more sensitive to interest-rate shocks than are rich countries. But there is more. In the α-industry, the supply of labor is inelastic and the additional financing costs are fully transferred to workers in the form of lower wages. As a result, production is not affected. In the β-industry, the supply of labor is elastic and the additional financing costs are only partially reflected in wages. Employment and production therefore decline. In the aggregate, production and income decline after a positive interest-rate shock. If the asymmetry in the labor supply elasticity is important, however, then this reaction should be stronger in poor countries, that have larger β-industries. This provides a second reason why poor countries are more sensitive than rich countries to interest-rate shocks.

The introduction of interest-rate shocks provides two additional reasons why country-specific shocks have stronger effects in poor countries: one also works through their industrial structure and another is a consequence of their lack of financial development. Both of these considerations reinforce the results of the previous model. To see this, re-define $d \ln Y = \iiint d \ln y dF\, dG\, dH$. Equation (13) still applies because monetary shocks are country specific and the law of large numbers eliminates their effects in the aggregate. We may thus rewrite the volatility and comovement graphs as

$$V = \sqrt{\sigma^2 \left\{ \left[x\frac{\theta - 1}{\theta} + (1-x)(1+\lambda) \right]^2 (1-\eta) + \left(\frac{1+\lambda}{1+\lambda\nu} \right)^2 \eta \right\} + \phi^2\kappa^2(1-x)^2\lambda^2}, \tag{19}$$

$$C = \frac{\frac{1+\lambda}{1+\lambda\nu}\sigma\sqrt{\eta}}{\sqrt{\sigma^2 \left\{ \left[x\frac{\theta - 1}{\theta} + (1-x)(1+\lambda) \right]^2 (1-\eta) + \left(\frac{1+\lambda}{1+\lambda\cdot\nu} \right)^2 \eta \right\} + \phi^2\kappa^2(1-x)^2\lambda^2}}. \tag{20}$$

These equations are natural generalizations of (14) and (15). Equations (19) and (20) show that, ceteris paribus, countries with low financial development will be more volatile and less correlated with the world. They also show the new channel through which industrial structure affects the business cycles of countries.

With these additional forces present, the model is now able to come much closer to the observed cross-country variation in volatility and comovement when using values for θ and λ that are consistent with available microeconomic studies. This is shown in the bottom panel of Table 2, where we assume that (i) the standard deviation of shocks to monetary policy is 0.1 and (ii) that $\kappa = 1$ in the poorest countries in our sample and $\kappa = 0.5$ in the richest countries. For $\theta = 2$ and

$\lambda = 0.35$, the extended model now delivers cross-country differences in volatility that are nearly identical to the ones we estimated in Table 1 (−0.023 vs. −0.026); cross-country differences in comovement are almost half of those we observe in reality (0.172 vs. 0.382). Looking down the table, we can improve the fit of the model (in the comovement dimension) by considering more extreme parameter values. However, this is achieved at the cost of overpredicting cross-country differences in volatility.

We could try to further narrow the gap between theory and data by considering additional extensions to the model. But we think that the results obtained so far are sufficient to establish that the two hypotheses considered here have the potential to explain, at least in part, why business cycles are different in rich and poor countries. This is our sole objective here.

5. The Cyclical Behavior of the Terms of Trade

From the standpoint of the evidence reported in Table 1 and the theory developed in previous sections, the two industry asymmetries studied here are observationally equivalent. However, using microeconomic estimates for θ and λ as additional evidence to calibrate the model, we found that the asymmetry in the elasticity of product demand seems a more promising explanation for why business cycles differ across countries than the asymmetry in the elasticity of the labor supply. In this section, we show that these two asymmetries have different implications for the cyclical properties of the terms of trade and then confront them with the data. The evidence on the cyclical behavior of the terms of trade is consistent with the results of our calibration exercise: A strong asymmetry in the elasticity of product demand helps the model provide a more accurate description of terms-of-trade data than does a strong asymmetry in the elasticity of labor supply.

We first derive the stochastic process for the terms of trade. Let $T(\mu, \delta, \pi, \kappa, \iota)$ denote the terms of trade of a $(\mu, \delta, \pi, \kappa, \iota)$-country. Using Equations (9)–(11), we find that the (de-trended) growth rate in the terms of trade is equal to:[12]

$$d \ln T - E[d \ln T] = -\frac{x}{\theta} d(\pi - \Pi) + \frac{(x - \nu)\lambda}{1 + \lambda\nu} d\Pi. \tag{21}$$

Equation (21) describes the cyclical behavior of the terms of trade as a function of the country's industrial structure. It shows that positive country-specific

12. It is possible to decompose income growth into the growth rates of production and the terms of trade. The growth rate of production (or GDP growth rate) measures income growth that is due to changes in production, holding prices constant. The growth rate of the terms of trade measures income growth that is due to changes in prices, holding production constant. We follow the usual convention and define a country's terms of trade as the ideal price index of production relative to the ideal price index of expenditure. The growth rate of the terms of trade is equal to the share of exports in income times the growth rate of their price minus the share of imports in income times the growth rate of their price.

shocks to productivity have a negative effect on the terms of trade, and this effect is larger (in absolute value) the richer is the country, i.e. $\partial d \ln T / \partial d(\pi - \Pi)|_{d\Pi=0}$ is negative and decreasing in x. Equation (21) also shows that positive global shocks to productivity worsen the terms of trade of poor countries while improving those of rich countries: $\partial d \ln T / \partial d\Pi|_{d(\pi-\Pi)=0}$ is negative if $x < \nu$ or positive if $x > \nu$. Finally, Equation (21) shows that interest-rate shocks have no effects on the terms of trade. We discuss the intuition behind these results in turn.

Country-specific shocks to productivity have no effect on import prices because countries are small. But such shocks do affect export prices. Consider a positive country-specific shock to productivity. In the α-industry, firms react to the shock by producing more of each variety they know how to produce. Because this set is small, the increase in the production of each variety is large. Because domestic and foreign varieties are imperfect substitutes, the increase in production lowers the price of the country's α-products. In the β-industry, firms know how to produce all varieties. They react to the shock by spreading their production among a large number of varieties (or by forcing some firms abroad to do this). As a result, the increase in the production of each variety is infinitesimally small and the prices of the country's β-products are not affected. In the aggregate, the terms of trade worsen as a result of the shock. And if the asymmetry in the elasticity of product demand is important, the terms of trade should deteriorate more in rich countries than in poor ones.

Global shocks influence all countries equally and so do not affect the prices of different varieties of α- and β-products relative to their corresponding industry aggregates. Consider a positive global shock to productivity. Equation (11) shows that this shock lowers the price of all β-products relative to all α-products. The reason is simple: In both industries, the increase in productivity leads to a direct increase in production. But if the asymmetry in the elasticity of the labor supply is important, then the increase in productivity raises employment of unskilled workers and leads to a further increase in the production of β-products. As the world supply of β-products increases relative to that of α-products, the relative price of β-products declines. This is why the terms of trade of net exporters of β-products, $x < \nu$, deteriorate while the terms of trade of net importers of β-products, $x > \nu$, improve.

Finally, equation (21) states that country-specific interest-rate shocks have no effects on the terms of trade. These shocks do not affect import prices because the country is small, but neither do they affect export prices. As discussed previously, interest-rate shocks do not affect the production of α-products. As a result, they do not affect the prices of domestic varieties relative to the industry aggregate. Interest-rate shocks affect the production of β-products. However, firms in the β-industry cannot change their prices in the face of perfect competition from firms abroad. Therefore, country-specific monetary shocks do not affect the terms of trade.

Equation (21) shows how the two industry asymmetries shape the cyclical behavior of the terms of trade. In the absence of asymmetries in the elasticity of labor supply, $\lambda \to 0$, only country-specific shocks affect the terms of trade. In the absence of asymmetries in the elasticity of product demand, $\theta \to \infty$, only global shocks affect the terms of trade. These facts have implications for the volatility and comovement graphs of the terms of trade. Let $V^T(\mu, \delta, \pi, \kappa, \iota)$ denote the standard deviation of the (de-trended) growth of terms of trade of a $(\mu, \delta, \pi, \kappa, \iota)$-country, and let $C^T(\mu, \delta, \pi)$ denote its correlation with world average income growth. Using equations (13) and (21) together with the properties of the shocks, we obtain

$$V^T = \sigma\sqrt{\left(\frac{x}{\theta}\right)^2 (1-\eta) + \left(\frac{(x-\nu)\lambda}{1+\lambda\nu}\right)^2 \eta}, \tag{22}$$

and

$$C^T = \frac{\dfrac{(x-\nu)\lambda}{1+\lambda\nu}\sqrt{\eta}}{\sqrt{\left(\dfrac{x}{\theta}\right)^2 (1-\eta) + \left(\dfrac{(x-\nu)\lambda}{1+\lambda\nu}\right)^2 \eta}}. \tag{23}$$

To understand the intuition behind these formulas, it is useful to consider two extreme cases. Both are illustrated in Figure 4, which plots the volatility and comovement graphs of the terms of trade as functions of x for different parameter values. Assume first that business cycles differ across countries only because there is asymmetry in the elasticity of product demand, (i.e., set $\lambda = 0$). Then, $V^T = (x/\theta)\sigma\sqrt{1-\eta}$ and $C^T = 0$. The volatility graph is upward sloping. Because all the volatility in prices is due to changes in the domestic varieties of α-products, it follows that the terms of trade are more volatile in rich countries, where the share of the α-industry is large. The comovement graph is flat at zero. Whereas the terms of trade respond only to country-specific shocks, world income responds only to global shocks. This is why the two variables are uncorrelated.

Assume next that business cycles differ across countries only because there is asymmetry in the elasticity of the labor supply (i.e., $\theta \to \infty$). Then,

$$V^T = \frac{|x-\nu|\lambda\sigma\sqrt{\eta}}{1+\lambda\nu} \text{ and } C^T = \begin{cases} -1 & \text{if } x < \nu, \\ 1 & \text{if } x > \nu. \end{cases}$$

The volatility graph looks like a V, with a minimum when $x = \nu$. Because all the volatility in prices is due to changes in the aggregate industry prices, the terms of trade are more volatile in countries where the share of interindustry trade in overall trade is large—that is, where $|x - v|$ is large. These are the very rich and very poor countries, whose factor proportions and technology differ the most

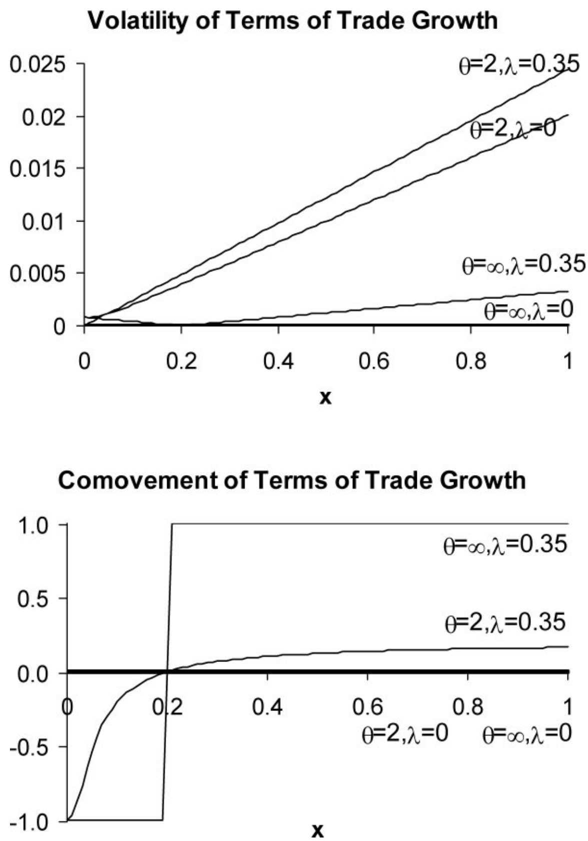

FIGURE 4. Theoretical terms of trade, volatility and comovement graphs.

Notes: This figure plots equations (17) and (18) as a function of x for the indicated values of θ and λ. The share of α-products in consumption is set equal to $\nu = 0.2$, and the parameters of the productivity process are set as discussed in the text.

from world averages. The comovement graph is a step function with a single step at $x = \nu$. Because global shocks drive both the world cycle and the terms of trade, these variables are perfectly correlated. If the country is a net exporter of α-products, then this correlation is positive; if the country is a net exporter of β-products, then this correlation is negative.

The volatility and comovement graphs for the terms of trade combine the features of these two extreme cases, as shown in Figure 4. The volatility graph looks like a V that has been shifted to the right of $x = \nu$ and rotated counterclockwise; the comovement graph slopes upward with flat tails and a steep slope around ν. The extreme cases are useful not only to build intuition but also because they point to a criterion for determining the relative importance of the two asymmetries as a source of differences in business cycles. The more important is the asymmetry in the elasticity of product demand, the higher is the slope of the volatility graph and the flatter is the slope of the comovement graph. The more important is the asymmetry in the elasticity of the labor supply, the closer is the volatility graph to a V-shape and the higher is the slope of the comovement graph.

Before examining the data, however, we remark that there is an alternative interpretation of these patterns within our theory. Independent of the values for θ and λ, the larger the country-specific component of productivity shocks, the higher the slope of the volatility graph and the flatter the slope of the comovement graph. If $\eta = 0$, $V^T = (x/\theta)\sigma$ and $C^T = 0$. Also, the more important is the global component of productivity shocks, the closer is the volatility graph to a V-shape and the higher is the slope of the comovement graph. If $\eta = 1$, then

$$V^T = \frac{|x - \nu|\lambda\sigma}{1 + \lambda\nu} \text{ and } C^T = \begin{cases} -1 & \text{if } x < \nu, \\ 1 & \text{if } x > \nu. \end{cases}$$

Therefore, one could also interpret the shape of the volatility and comovement graphs for the terms of trade as providing evidence on the relative importance of the country-specific and global components of shocks—rather than evidence on the relative importance of the two industry asymmetries.

Figure 5 plots the empirical analogues of the terms-of-trade volatility and comovement graphs. Table 3 looks at these graphs after controlling for the usual variables. In contrast with the clear unconditional patterns apparent in Figure 1 for the volatility and comovement of income growth, in Figure 5 we see that the volatility and comovement of fluctuations in the terms of trade are not significantly correlated with income. However, in the second column of Table 3 we find that, controlling for other potential sources of volatility and comovement discussed in Section 1, there is a significant positive partial correlation between the volatility of the terms of trade and income; however, the partial correlation between terms of trade comovement and income remains insignificantly different from zero. In the third column of Table 3 we take seriously the theory's prediction that, when the asymmetry in the labor supply elasticity is important, the volatility and comovement graphs are nonlinear functions of income (V-shaped and a step function, respectively). We do this by interacting both the intercept and the coefficient on income with a dummy variable that divides the sample in two at the median level of income. The procedure yields no evidence of the nonlinearity predicted by this version of the theory. Moreover, our results do not change when we split the sample at different points (not reported for brevity).[13]

13. The model also has implications for the cyclicality of the terms of trade: If the asymmetry in the elasticity of product demand is important, then the terms of trade will react more to domestic productivity shocks in rich countries than in poor countries. The evidence on this point is mixed and still incomplete. On the one hand, Acemoglu and Ventura (2002) find that exogenous shocks to supply worsen the terms of trade on average in a large cross-section of countries. On the other hand, Corsetti, Dedola, and Leduc (2006) use VAR techniques to extract shocks to domestic productivity and find that they are not correlated with the terms of trade in a handful of industrial countries.

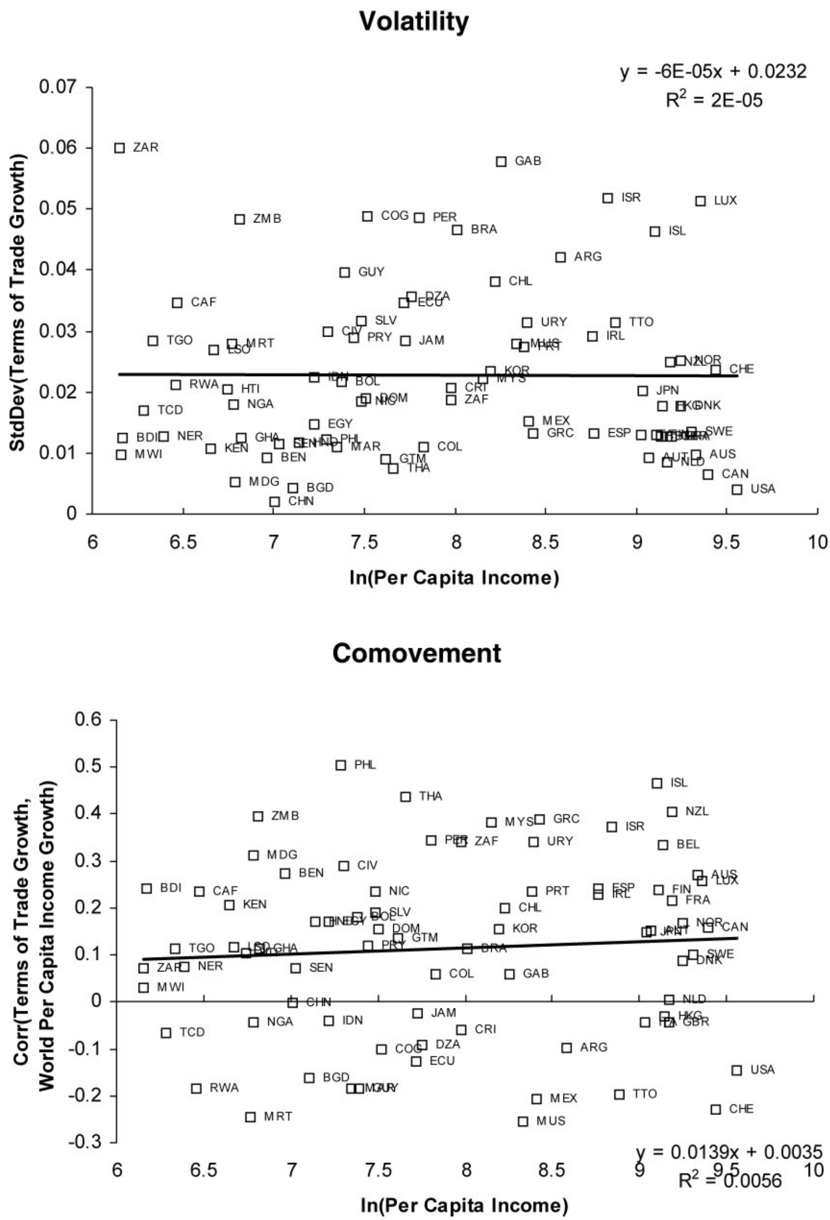

FIGURE 5. Volatility and comovement of terms of trade.

Notes: The top panel plots the standard deviation of the growth rate of terms of trade over the period 1960–1997 against the log level of average per capita GDP in 1985 PPP dollars over the same period. The bottom panel plots the correlation of the growth rate of the terms of trade with world average income growth excluding the country in question over the period 1960–1997 against the log-level of average per capita GDP in 1985 PPP dollars over the same period. See Appendix for data definitions and sources.

TABLE 3. Volatility and comovement of terms-of-trade growth.

	Volatility								
	Basic			With controls			With controls, nonlinearities		
	Coef	Std.Err.		Coef	Std.Err.		Coef	Std.Err.	
Intercept	0.023	0.013	*	−0.034	0.013	**	−0.048	0.030	
In (per capita GDP at PPP)	0.000	0.002		0.003	0.001	**	0.005	0.004	
Primary product exporter				0.004	0.003		0.005	0.003	
Trade-weighted distance				0.006	0.002	***	0.006	0.002	***
Revolutions and coups				−0.007	0.010		−0.008	0.010	
SD inflation				0.145	0.020	***	0.138	0.025	***
Dummy for rich countries							0.036	0.043	
Dummy for rich countries × In (per capita GDP at PPP)							−0.004	0.006	
R^2	0.002			0.565			0.570		
Number of observations	76			76			76		
	Comovement								
Intercept	0.004	0.159		−0.026	0.252		0.062	0.419	
In (per capita GDP at PPP)	0.014	0.020		0.012	0.028		−0.001	0.060	
Primary product exporter				−0.001	0.063		0.012	0.064	
Trade-weighted distance				0.018	0.028		0.021	0.028	
Revolutions and coups				0.032	0.221		0.058	0.238	
SD inflation				−0.089	0.427		−0.318	0.478	
Dummy for rich countries							0.644	0.775	
Dummy for rich countries × In (per capita GDP at PPP)							−0.068	0.096	
R^2	0.005			0.012			0.036		
Number of observations	76			76			76		

Notes: This table reports the results of cross-sectional regressions of the standard deviation of terms of trade growth (top panel) and the correlation of terms of trade growth with world average income growth excluding the country in question (bottom panel) on the indicated variables for different samples and control variables. The control variables consist of a dummy variable that takes the value 1 if the country is an oil or commodity exporter, a measure of trade-weighted distance from trading partners, the average over the period of the number of revolutions or coups, the standard deviation of inflation, a dummy for countries with income greater than the median, and an interaction of this dummy with per capita GDP. See Appendix for data definitions and sources. Standard errors are heteroskedasticity-consistent. SD = Standard deviation.

* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

In light of the preceding discussion above, this pattern of an upward sloping volatility graph and a flat comovement graph for the terms of trade could be interpreted as evidence in favor of either the relative importance of asymmetries in product demand elasticity or the unimportance of global shocks. However, there are good reasons to prefer the former interpretation over the latter. Consider for example the calibrations in Table 2. In order to replicate the observed comovement of income growth, it was necessary to assume that the cross-country correlation in productivity shocks, $\sqrt{\eta}$, ranged from 0.25 to 0.40. This suggests that cross-country correlations in productivity shocks are an important part of the story, so the evidence on terms-of-trade volatility and comovement should be interpreted as favoring the relative importance of the asymmetry in the elasticity of product demand over the asymmetry in the elasticity of the labor supply.

We also observe that the model is able to replicate the observed cross-country differences in the volatility and comovement of the terms of trade fairly well for reasonable parameter values. The middle panel of Table 2 reports the results for the terms of trade of the same calibration exercised discussed previously in the context of the volatility and comovement of income growth. For a value of $\theta = 2$, we find that the theory predicts cross-country differences in terms-of-trade volatility of 0.012 and 0.010 when the elasticity of unskilled labor supply is $\lambda = 0$ or $\lambda = 0.35$, respectively. This compares favorably with the predicted difference of 0.009 from the regression with controls in Table 3. The theory predicts no cross-country differences whatsoever in terms of trade comovement when $\lambda = 0$, but it overpredicts cross-country differences in comovement when $\lambda = 0.35$.

A final issue concerns the implications of the theory for cross-country differences in the volatility and comovement of production. The (de-trended) growth rate of production is simply the difference between income growth and growth in the terms of trade:

$$d \ln q - E[d \ln q] \equiv (d \ln y - E[d \ln y]) - (d \ln T - E[d \ln T]).$$

The patterns of income and terms of trade volatility and comovement we have described are consistent with two very different patterns of fluctuations in production. On the one hand, if increases in the terms of trade raise income primarily by increasing the value of production, then we should expect to see only minimal cross-country differences in the volatility and comovement of production growth. On the other hand, if increases in the terms of trade elicit strong supply responses, then the cross-country patterns in production volatility and comovement will mimic those of income.

Table 4 shows how the volatility and comovement of production growth rates vary across countries. As with income growth, the volatility graph is significantly downward sloping and the comovement graph is significantly upward sloping, both unconditionally and also holding constant the same set of controls used in Table 1. The most striking feature of Table 4 is the similarity of the slopes of the

TABLE 4. Volatility and comovement of production growth.

	Volatility of production					
	Basic			With controls		
	Coef	Std.Err.		Coef	Std.Err.	
Intercept	0.155	0.016	***	0.108	0.021	***
ln (per capita GDP at PPP)	−0.013	0.002	***	−0.010	0.002	***
Primary product exporter				0.015	0.005	***
Trade-weighted distance				0.002	0.002	
Revolutions and coups				−0.017	0.023	
SD inflation				0.069	0.027	**
R^2	0.389			0.563		
Number of observations	76			76		
	Comovement of production					
Intercept	−0.665	0.177	***	−0.784	0.252	***
ln (per capita GDP at PPP)	0.118	0.021	***	0.132	0.028	***
Primary product exporter				0.044	0.061	
Trade-weighted distance				0.002	0.027	
Revolutions and coups				0.0398	0.192	**
SD inflation				−0.744	0.338	**
R^2	0.261			0.323		
Number of observations	76			76		

Notes: This table reports the results of cross-sectional regressions of the standard deviation of production growth (top panel) and the correlation of production growth with world average income growth excluding the country in question (bottom panel) on the indicated variables for different samples and control variables. The control variables consist of a dummy variable that takes the value 1 if the country is an oil or commodity exporter, a measure of trade-weighted distance from trading partners, the average over the period of the number of revolutions or coups, the standard deviation of inflation, a dummy for countries with income greater than the median, and an interaction of this dummy with per capita GDP. See Appendix for data definitions and sources. Standard errors are heteroskedasticity-consistent. SD = Standard deviation.

* Significant at 10%. ** Significant at 5%. *** Significant at 1%.

income and production graphs. In the regression with controls, the coefficients on per capita income in the production volatility and comovement graphs are −0.009 and 0.127, respectively; in the case of income, they are −0.010 and 0.132. In short, cross-country differences in income and production fluctuations are very similar.

Turning now to the theory, the final columns of Table 2 report the calibrated production volatility and comovement graphs under the same set of assumptions as before. We have seen that, when $\theta = 2$ and $\lambda = 0.35$, the model does a reasonable job of matching cross-country differences in income and terms of trade volatility and comovement. However, for these parameter values the model predicts cross-country differences in production volatility that are only half those observed in the data as well as differences in production comovement that are but a tenth of their empirical counterparts. However, it is not hard to see how this gap between theory and evidence could be narrowed. Because we observe in the data that income and production fluctuations are so similar despite significant fluctuations in the terms of trade, it must be that the latter elicit substantial supply responses. Yet in our stylized model, production can respond to prices only via increases in the supply of unskilled workers. Extending the model to allow an elastic supply of skilled labor and/or variations in capacity utilization would likely yield closer matches to actual cross-country patterns in production fluctuation. We are confident that the insights of our basic model will carry through in this more general framework as well.

6. Concluding Remarks

This article started with the observation that business cycles are different in rich and poor countries. In particular, fluctuations in per capita growth are less volatile and more synchronized with the world cycle in rich countries than in poor ones. We explored the possibility that these patterns might be due to differences in industrial structure. Comparative advantage leads rich countries to specialize in industries that use new technologies operated by skilled workers. We argued that these industries face inelastic product demands and labor supplies. Under these conditions, the income effects of country-specific supply shocks tend to be moderate because they generate reductions in prices and only small increases in employment. Comparative advantage also leads poor countries to specialize in industries that use traditional technologies operated by unskilled workers. We argued that these industries face elastic product demands and labor supplies. Under these conditions, the income effects of country-specific supply shocks tend to be large because they have little effect on prices and large effects on employment.

Our contribution has been to frame these hypotheses and provide a formal model to study their implications. A simple calibration using available microeconomic estimates of the key parameters suggests that these hypotheses could account for a reasonable fraction of observed cross-country differences in business cycles. Also, in accounting for observed cross-country differences in business cycles, we find that cross-industry differences in product demand elasticities are quantitatively more important than cross-industry differences in labor supply elasticities. Although the model we consider is clearly too stylized to capture all of the relevant differences in business cycles across countries, it has proved to be a useful tool for considering these issues. The model we study is quite flexible and allows us to analyze a range of issues, such as (i) how differences in financial development affect the way countries react to shocks and (ii) the theory's implications for the cyclical behavior of the terms of trade.

Appendix: Data Description

Our sample consists of 76 countries for which we have the complete annual data over the period 1960–1997 required to construct income growth and terms-of-trade growth. We measure per capita income growth as the sum of real per capita GDP growth plus growth in the terms of trade. Data on real per capita GDP growth are drawn from the *Penn World Tables* and are extended through 1997 using per capita GDP growth in constant local currency units from the World Bank *World Development Indicators*. We construct growth in the terms of trade as the growth in the local currency national accounts deflator for exports multiplied by the share of exports in GDP in current prices adjusted for differences in purchasing power parity minus the growth in the local currency national account deflator for imports multiplied by the share of imports in GDP in current prices adjusting for differences in purchasing power parity. Data on import and export deflators and current price trade shares are from WDI, and PPP conversion factors are from the *Penn World Tables*. Prior to computing income and terms of trade volatility and comovement, we discarded 33 country-year observations (about 1% of the sample) where measured growth in the terms of trade exceeds 20%. Each of these cases occurs during episodes of high inflation and extreme growth in the import and export deflators, which masks true movements in import and export prices.

The control variables are obtained from the following sources. Primary product exporter is a dummy variable taking the value 1 if the country is classified as an oil exporter or a commodity exporter in the WDI. Trade-weighted distance is a weighted average of countries' distances from all other countries, where the weights are proportional to their bilateral trade; this variable is taken from Frankel and Romer (1999). Data on revolutions and coups are taken from the Banks (1979) data set. The standard deviation of inflation is computed as the standard deviation of growth rates of the GDP deflator listed in WDI. To avoid extreme outliers in this variable, we discarded 204 country-year observations (7% of the sample) where inflation exceeds 100% per year and only then computed the standard deviation of inflation.

The data are available from the authors upon request.

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