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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, while poor countries specialize in industries that use traditional technologies operated by unskilled workers. Since new technologies are difficult to imitate, the industries of rich countries enjoy more market power and face more inelastic product demands than those of poor countries. Since skilled workers are less likely to exit employment as a result of changes in economic conditions, industries in rich countries face more inelastic labour 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.

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Business cycles are not the same in rich and poor countries. A first 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 downwards. 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 it slopes upwards. Table 1, which is self-explanatory, shows that these facts apply within different sub-samples 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, they are less open or more distant from the geographical center, and they also have a higher share of their economy 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, although they 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 behind the strong patterns depicted in Figure 1 beyond differences in political instability, remoteness and the importance of natural resources.

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[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. They 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.

In this paper, we develop two alternative but non-competing 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, while 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 since the relative importance of global shocks is lower. To the extent that the business cycles of countries reflect those of their industries, differences in industrial structure could potentially 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 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 degree of product-market competition 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 non-market activities are relatively more attractive to unskilled workers whose market wage is lower than that of skilled ones. Changes in labour demand might induce some unskilled workers to enter or abandon the labour force, but are not likely to affect the participation of skilled workers. A second reason for the asymmetry in labour supply across skill categories is the imposition of a minimum wage. Changes in labour demand might force some unskilled workers in and out of unemployment, but are not likely to affect the employment of skilled workers.

The wage-elasticity of the labour 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 therefore raise the labour demand. Since the supply of unskilled workers is elastic, these shocks lead to large fluctuations in 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. Since 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 labour 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 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 one a world in which differences in both factor endowments à la Heckscher-Ohlin and industry technologies à la Ricardo combine to determine a country's comparative advantage and, therefore, 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).[2] In section two, we characterize the cross-section of business cycles and show how asymmetries in the elasticity of product demand and/or labour 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 the elasticity in the labour supply.

We explore these results further in sections three and four. In section three, we extend the model to allow for monetary shocks that have real effects since 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 about 40 percent of the variation in comovement as the data. In section four, 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 the product-demand elasticity seems quantitatively more important than the asymmetry in the labour-supply elasticity.

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[2] Our research is related to the large literature on open-economy real business cycle models that studies how productivity shocks are transmitted across countries. See Baxter (1995) and Backus, Kehoe and Kydland (1995) for two alternative surveys of this research. We differ from this literature in two respects. Instead of emphasizing the aspects in which business cycles are similar across countries, we focus on those aspects in which they are different. 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.

The main theme of this paper is that the properties of business cycles differ across countries because they have different industrial structures. There are many determinants of the industrial structure of a country. We focus here on perhaps the most important of such determinants, that is, a country's ability to trade. In section five we explore further the connection between international trade, industrial structure and the nature of business cycles. We introduce trade frictions in the form of "iceberg" transport costs and study how globalization (modeled here as parametric reductions in transport costs) changes the nature of the business cycles that countries experience. If transport costs are high enough, all countries have the same industrial structure and the cross-section of business cycles is flat. As transport costs decline, the prices of products in which a country has comparative advantage increase and so does their share in production. As a result, industrial structures diverge. One should therefore expect globalization to lead to business cycles that are more different across countries.

1. 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 industrial structure, and therefore income, translates into cross-country variation in the properties of the business cycle.

We consider a world with a continuum of countries with mass one; 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 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 non-market 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:

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

where U(.) 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 $p_F\cdot c(i)=w\cdot I(i)$ for unskilled workers and $p_F\cdot c(i)=r\cdot I(i)$ 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 that are employed. Under the assumption that the distribution of skills and reservation wages are independent, we have that

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

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

If the real wage of any type of worker is less than one, the aggregate labour 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 one, the entire labour force of this type is employed and the aggregate labour supply for this type of workers becomes vertical. Throughout, we consider equilibria in which the real wage for skilled workers exceeds one, $\frac{r}{p_F} > 1$, while the real wage for unskilled workers is less than one, $\frac{w}{p_F} < 1$.[3] That is, all countries operate in the vertical region of their supply of skilled workers and the elastic region of their supply of unskilled workers. This assumption generates an asymmetry in the wage-elasticity of the aggregate labour supply across skill categories. This elasticity is zero 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 the final good according to this cost function:

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[3] This is the case in equilibrium if skilled (unskilled) workers are sufficiently scarce (abundant) in all countries, i.e. $\delta \ll 1$.

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

The elasticity of substitution between industries is one, while the elasticity of substitution between any two varieties within an industry is θ, with $\theta>1$.

Since there are always some workers that participate in the labour force, the demand for the final product is always strong enough to generate positive production in equilibrium. Our assumptions on technology imply that firms in the final good 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 $\left[\frac{p_\alpha(z)}{p_\alpha(z')}\right]^{1-\theta}$; and the ratio of spending on any two β-products z and z' is $\left[\frac{p_\beta(z)}{p_\beta(z')}\right]^{1-\theta}$, 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, i.e. $P_\alpha = \left[\int_0^1 p_\alpha(z)^{1-\theta} \cdot dz\right]^{\frac{1}{1-\theta}}$ and $P_\beta = \left[\int_0^1 p_\beta(z)^{1-\theta} \cdot dz\right]^{\frac{1}{1-\theta}}$; and define the following numeraire rule:

(5) $$1 = P_\alpha^{\nu} \cdot P_\beta^{1-\nu}$$

Since firms in the final goods sector are competitive, they set price equals cost. This implies that:

(6) $$p_F = 1$$

Since all intermediates are traded and the law of one price applies, the price of the final good is the same in all countries. In this world economy, purchasing power parity applies. An implication of this is that the assumption that the final good is not traded is not binding.

Each country also contains two intermediate industries. The α-industry uses sophisticated production processes that require skilled workers. Each variety 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 labour. As mentioned, 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 the 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, $p_\alpha(\mu,\delta,\pi)$:

(7) $$p_\alpha = \frac{\theta}{\theta - 1} \cdot r \cdot e^{-\pi}$$

As usual, the markup depends on the elasticity of demand for their 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 labour of any kind. Since 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. They set 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, $p_\beta(\mu,\delta,\pi)$:

(8) $$p_\beta = w \cdot e^{-\pi}$$

With this formulation, we have introduced an asymmetry in the price-elasticity of product demand. This elasticity is θ in the α-industry and infinity in the β-industry. As $\theta \to \infty$, this 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, π-Π. 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 $\eta \cdot \sigma^2$ and $(1-\eta) \cdot \sigma^2$ 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, we have that the cross-sectional distribution of π-Π is time invariant.[4] We refer to this distribution as $G(\pi-\Pi)$. While π has been defined as an index of domestic productivity, Π serves as an index of world average productivity. The parameter σ regulates the volatility of the domestic shocks. The instantaneous correlation between domestic shocks, $d\pi$, and foreign shocks, $d\Pi$, is therefore $\sqrt{\eta}$.[5] The parameter η therefore regulates the extent to which the variation in domestic productivity is due to global or country-specific components, i.e. 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.

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[4] See Harrison (1990), Chapter 5.
[5] This is true except when either π or Π are at their respective boundaries. These are rare events since the dates at which they occur constitute a set of measure zero in the time line.

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 and a (μ',δ',π')-country, $\frac{\mu}{\mu'}\cdot\left[\frac{p_\alpha(z)}{p_\alpha(z')}\right]^{-\theta}$, must equal the ratio of supplies is $\frac{s\cdot e^{\pi}}{s'\cdot e^{\pi'}}$. Using this condition plus Equation (2) and the definition of P_α we find that:

$$(9) \qquad \frac{p_\alpha}{P_\alpha}=\left(\frac{\Psi_\alpha\cdot\mu}{\delta}\right)^{\frac{1}{\theta}}\cdot e^{-\frac{\pi-\Pi}{\theta}}$$

where $\Psi_\alpha=\left(\int\int\mu^{\frac{1}{\theta}}\cdot\delta^{\frac{\theta-1}{\theta}}\cdot e^{\frac{\theta-1}{\theta}\cdot(\pi-\Pi)}\cdot dF\cdot dG\right)^{\frac{\theta}{\theta-1}}$. Since the distribution functions $F(\mu,\delta)$ and $G(\pi-\Pi)$ are time-invariant, Ψ_α is a constant. Since 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 their 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. But this is not a possible equilibrium given the technology described in Equation (4). Therefore, it follows that:

$$(10) \qquad \frac{p_\beta}{P_\beta}=1$$

Finally, we compute the relative price of both industries. To do this, equate the ratio of world spending in the α- and β-industries, $\frac{\nu}{1-\nu}$, to the ratio of the value of their productions, $\frac{\int\int p_\alpha \cdot s \cdot e^{\pi} \cdot dF \cdot dG}{\int\int p_\beta \cdot u \cdot e^{\pi} \cdot dF \cdot dG}$. Using Equations (2)-(3) and (5)-(10), we then find that:

$$(11) \qquad \frac{P_\alpha}{P_\beta} = \left(\frac{\nu}{1-\nu} \cdot \frac{\Psi_\beta}{\Psi_\alpha} \right)^{\frac{1}{1+\lambda\cdot\nu}} \cdot e^{\frac{\lambda}{1+\lambda\cdot\nu}\cdot\Pi}$$

where $\Psi_\beta = \int\int (1-\delta) \cdot e^{(1+\lambda)\cdot(\pi-\Pi)} \cdot dF \cdot dG$, and is constant. If $\lambda>0$, high productivity is associated with high relative prices for α-products as 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 the income and the share of the α-industry in a (μ,δ,π)-country, i.e. $y = (p_\alpha \cdot s + p_\beta \cdot u) \cdot e^{\pi}$ and $x = \frac{p_\alpha \cdot s \cdot e^{\pi}}{y}$. Not surprisingly, countries with better technologies (high μ) and more human capital (high δ) have high values for both y and x. We therefore refer to countries with high values of x as rich countries. Since 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 ν-x and x-ν, respectively. Therefore, the share of trade in income is max[ν,x]. As usual, this trade can be decomposed into intraindustry trade, min[ν,x], and interindustry trade, $|x-\nu|$. The former consists of trade in products that have similar factor proportions. The later consists of trade in products with different factor proportions.The model therefore 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.

2. The Cross-section of Business Cycles

In the world economy described in the previous section, 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 differ in ways that go 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 could potentially be explained by the simple model of the previous section? Perhaps surprisingly, the answer is between one and two thirds of all the variation.

The first step towards 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 (demeaned) growth rate of income of a (μ,δ,π)-country as a linear combination of country-specific and global shocks:

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

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. Equation (12) shows that poor countries are more sensitive to country-specific shocks, i.e. $\left.\frac{\partial d\ln y}{\partial d(\pi - \Pi)}\right|_{d\Pi=0}$ is decreasing in x. Equation (12) also shows that all countries are equally sensitive to global shocks, i.e. $\left.\frac{\partial d\ln y}{\partial d\Pi}\right|_{d(\pi-\Pi)=0}$ 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 one percent country-specific increase in productivity has no effects on employment or product prices. As a result, production and income also increase by one percent. This is why $\left.\frac{\partial d\ln y}{\partial d(\pi-\Pi)}\right|_{d\Pi=0}=1$ if $\lambda\to 0$ and $\theta\to\infty$. If λ is positive, a country-specific increase in productivity of one percent leads to an increase in employment of λ percent in the β-industry and, as a result, production and income increase by more than one percent. This employment response magnifies the expansionary effects of increased productivity in the β-industry. As a result, the shock has stronger effects in poor countries, i.e. $\left.\frac{\partial d\ln y}{\partial d(\pi-\Pi)}\right|_{d\Pi=0}=1+(1-x)\cdot\lambda$ if $\theta\to\infty$. If θ is finite, a country-specific increase in productivity of one percent leads to a θ^{-1} percent decrease in prices in the α-industries. This price response counteracts the expansionary effects of increased productivity in the α-industry. Consequently, the shock has weaker effects in rich countries, i.e. $\left.\frac{\partial d\ln y}{\partial d(\pi-\Pi)}\right|_{d\Pi=0}=1-\frac{x}{\theta}$ if λ=0. If λ>0 and θ is finite, we have that both the employment and price responses combine to make poor countries react more to country-specific shocks, i.e. $\left.\frac{\partial d\ln y}{\partial d(\pi-\Pi)}\right|_{d\Pi=0}=x\cdot\frac{\theta-1}{\theta}+(1-x)\cdot(1+\lambda)$ 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 one. 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 poor countries, after a positive global shock. But the increase in relative supply lowers the relative price of β-products. This reduces the share of world income that goes to the β-industry, and hence 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. Therefore, in our framework differences in industrial structure do not generate differences in how countries react to global shocks.[6]

We are ready to use the model to interpret the evidence in Figure 1. Define dlnY as the world average growth rate, i.e. $d\ln Y = \int\int d\ln y \cdot dF \cdot dG$. Then, it follows from Equation (12) that:

$$(13) \qquad d\ln Y - E[d\ln Y] = \frac{1+\lambda}{1+\lambda\cdot\nu}\cdot d\Pi$$

Since 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.[7]

Let V(μ,δ,π) denote the standard deviation of income growth of a (μ,δ,π)-country, and let C(μ,δ,π) 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)-(13) and the properties of the shocks, we find that:

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[6] While 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 higher than one, poor countries would be more sensitive to global shocks than rich countries as 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 one, the opposite would be true.

[7] Once again, this result rests on the Cobb-Douglas assumption. If the elasticity of substitution between α- and β-products were higher than one, the very rich countries might exhibit business cycles that are milder than those of the world.

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

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

Figure 3 plots the volatility and comovement graphs as functions of x, for different parameter values. Except in the limiting case where both λ=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 labour 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. Since countries inherit the cyclical properties of their industries, the incomes of rich countries are 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 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 a very undemanding criterion. One can impose more discipline by restricting the analysis to combinations of parameter values that seem reasonable. To do this, 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 to draw strong conclusions from a calibration exercise like this in a model as stylized as ours. As noted above, in the real world countries experience different types of shocks and also differ in ways that go beyond technology and factor proportions. Moreover, available estimates of the key parameters λ and θ are based on non-representative samples of countries and industries, so that caution is in order when generalizing to the large cross-section of countries we study here. Despite these caveats, we shall see that 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. Since this share is around 60 percent 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 $x<\nu$. Since the share of exports in GDP is around 20 percent 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, since 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.[8] This means that this calibration exercise can only tell us 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 encompass existing microeconomic estimates. Available industry estimates of the elasticity of export demand range from 2 to 10 (see Trefler and Lai (1999), Feenstra, (1994)), while available estimates for the labour supply elasticity of unskilled workers range from 0.3 to 0.35 (See Juhn, Murphy and Topel (1991)). The table also reports the values for σ and η that result from the calibration procedure.

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

Table 2 shows that, using values for θ and λ of θ=2 and λ=0.35, the model can account for nearly two-thirds of the cross-country difference in volatility between rich and poor countries (-0.016 versus -0.026), and slightly less than one-third of the cross-country differences in comovement (0.129 versus 0.382). These values for the parameters are within the range suggested by existing microeconomic studies. If the industry asymmetries are assumed to be even stronger, say θ=1.2 and λ=0.7, the predicted differences in volatility and comovement are closer to their predicted values. These results seem 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, we shall see in the next section that a simple extension of the model that allows 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 the labour supply. Within the range of parameter values considered in Table 2, changes in θ have strong effects on the slope of the two graphs, while changes in λ to have little or no effect. To the extent that this range of parameter values we consider is the relevant one, this calibration exercise suggests that the asymmetry in asymmetries in the elasticity of product demands constitutes the more promising hypothesis of why business cycles are different across countries. We return to this point in section four where we attempt to distinguish between hypotheses by examining terms of trade data.

3. 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 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 modelling 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. This is the goal of this section, where we show that by 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 to follow this route because the elements that this extension highlights 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 quintuplet, $(\mu,\delta,\pi,\kappa,\iota)$, 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.[9] In particular, firms have to use cash or domestic currency in order to pay a fraction κ of their wage bill before production starts, with $0\leq\kappa\leq1$. The parameter κ therefore measures how underdeveloped are credit markets. As $\kappa\rightarrow0$ 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.[10] In particular, we assume that the interest rate is a reflecting Brownian motion on the interval $[\underline{\iota}, \bar{\iota}]$, with changes that have zero drift, instantaneous variance ϕ^2, and are independent across countries and also independent of changes in π. Let the initial distribution of interest rates be uniform in $[\underline{\iota}, \bar{\iota}]$ 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 only to minor changes in the description of world equilibrium in section one. Equations (2)-(3) describing the labour-supply decision and the numeraire rule in Equation (5) still apply. Since firms in the final 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 since they now face financing costs in addition to labour costs. As a result, the pricing equations (7)-(8) have to be replaced by:[11]

$$(16) \qquad p_\alpha = \frac{\theta}{\theta - 1} \cdot r \cdot e^{-\pi + \kappa \cdot \iota}$$

$$(17) \qquad p_\beta = w \cdot e^{-\pi + \kappa \cdot \iota}$$

Note 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 $\Psi_\beta = \int\int\int (1-\delta) \cdot e^{(1+\lambda)\cdot(\pi - \Pi) - \kappa \cdot \iota} \cdot dF \cdot dG \cdot dH$,

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[9] See Christiano, Eichenbaum and Evans (1997) for a discussion of related models.
[10] 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, 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, shocks to foreign investors' confidence in the country are translated into shocks to the nominal interest rate, as the monetary authorities use the latter to manage the exchange rate.
[11] We are using the following approximation here: $\kappa \cdot \iota \approx \ln(1 + \kappa \cdot \iota)$.

which converges to the earlier 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 only a transfer from firms to consumers via the government. Consequently, income and the share of the α-industry are still defined as $y = (p_\alpha \cdot s + p_\beta \cdot u) \cdot e^\pi$ and $x = \frac{p_\alpha \cdot s \cdot e^\pi}{y}$, respectively. Now rich countries are those that have better technologies (high μ), more human capital (high δ) and better financial systems (low κ). Remember 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 rich. However, we have now 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 therefore a weaker labour demand for all types of workers. In the market for skilled workers, this weak demand is translated fully into low in 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 to us reasonable to assume that technology and factor proportions are more important determinants of a country's industrial structure than the degree of financial development.

We are 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 (demeaned) growth rate of income for the $(\mu,\delta,\pi,\kappa,\iota)$-country:

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

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 describe the reaction of the country to productivity shocks and have 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, $\left.\frac{\partial d\ln y}{\partial d\iota}\right|_{\substack{d(\pi-\Pi)=0 \\ d\Pi=0}}$ is decreasing in x and increasing in κ (holding constant x).

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). Just because of this, poor countries are more sensitive to interest-rate shocks than rich countries. But there is more. In the α-industry, the supply of labour is inelastic and the additional financing costs are fully passed to workers in the form of lower wages. Production is therefore not affected. In the β-industry, the supply of labour is elastic and the additional financing costs are only partially passed to wages. Employment and production therefore decline. In the aggregate, production and income decline after a positive interest-rate shock. But if the asymmetry in the labour supply elasticity is important, this reaction should be stronger in poor countries that have larger β-industries. This provides a second reason why poor countries are more sensitive to interest-rate shocks than rich countries.

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 $d\ln Y = \iiint d\ln y \cdot dF \cdot dG \cdot dH$. Equation (13) still applies since monetary shocks are country-specific and the law of large numbers eliminates their effects in the aggregate. Then, rewrite the volatility and comovement graphs as follows:

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

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

These equations are natural generalizations of Equations (14)-(15). They show that, ceteris paribus, countries with low financial development will be both 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 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 the standard deviation of shocks to monetary policy is 0.1 and that κ=1 in the poorest countries in our sample and κ=0.5 in the richest countries. For θ=2 and λ=0.35, the extended model now delivers cross-country differences in volatility that are nearly identical to the ones we estimated in Table 1 (-0.024 versus -0.026), and cross-country differences in comovement are now 40 percent of those we observe in reality (0.165 versus 0.382). Looking further down the table, we can further improve the fit of the model in the comovement dimension by considering more extreme parameter values. However, this is achieved at the cost of over-predicting 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 simple objective here.

4. The Cyclical Behavior of the Terms of Trade

From the standpoint of the evidence reported in Table 1 and the theory developed in the 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 of why business cycles are different across countries than the asymmetry in the elasticity of the labour supply. In this section, we show that these two asymmetries have different implications for the cyclical properties of the terms of trade, and then confronting these implications with the data. The evidence on the cyclical behavior of the terms of trade is consistent with the results of our calibration exercise. Namely, a strong asymmetry in the elasticity of product demand helps the model provide a more accurate description of the terms of trade data than a strong asymmetry in the elasticity of the labour 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 (detrended) growth rate in the terms of trade is equal to:[12]

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

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 shocks to productivity affect negatively the terms of trade, and this effect is larger (in

[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 constant prices. The growth rate of the terms of trade measures income growth that is due to changes in prices, holding constant production. We follow usual convention and define the terms of trade of a country 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.

absolute value) the richer is the country, i.e. $\left.\frac{\partial d\ln T}{\partial d(\pi-\Pi)}\right|_{d\Pi=0}$ is negative and decreasing in x. Equation (21) also shows that positive global shocks to productivity worsen the terms of trade of poor countries and improve those of rich countries, i.e. $\left.\frac{\partial d\ln T}{\partial d\Pi}\right|_{d(\pi-\Pi)=0}$ is negative if x<ν and positive if x>ν. 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 they 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. Since this set is small, the increase in the production of each variety is large. Since 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. But if the asymmetry in the elasticity of product demand is important, the terms of trade should deteriorate more in rich countries.

Global shocks influence all countries equally and, consequently, they 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. We saw earlier that this shock lowers the price of all β-products relative to all α-products (See Equation (11)). 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 labour supply is important, 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, their relative price 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 they do not affect export prices either. As discussed earlier, interst-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) makes clear how the two industry asymmetries shape the cyclical behavior of the terms of trade. In the absence of asymmetries in the elasticity of the labour 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. This has implications for the volatility and comovement graphs for the terms of trade. Let $V^T(\mu,\delta,\pi,\kappa,\iota)$ denote the standard deviation of the (detrended) 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), (21) and the properties of the shocks, we find that:

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

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

To understand the intuition behind these formulae, 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 the only reason why business cycles differ across countries is the asymmetry in the elasticity of product demand, i.e. $\lambda=0$. Then, $V^T = \frac{x}{\theta} \cdot \sigma \cdot \sqrt{1-\eta}$ and $C^T = 0$. The volatility graph is upward sloping. Since all the volatility in prices is due to changes in the domestic varieties of α-products, 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. While the terms of trade respond only to country-specific shocks, world income responds only to global shocks. As a result both variables are uncorrelated.

Assume next that the only reason why business cycles are different across countries is the asymmetry in the elasticity of the labour supply, i.e. $\theta \to \infty$. Then, $V^T = \frac{|x-\nu| \cdot \lambda}{1+\lambda \cdot \nu} \cdot \sigma \cdot \sqrt{\eta}$ 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 $x=\nu$. Since 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, i.e. $|x-\nu|$ is large. These are the very rich and very poor countries whose factor proportions and technology differ the most from world averages. The comovement graph is a step function with a single step at $x=\nu$. Since 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, this correlation is positive. If the country is a net exporter of β-products, this correlation is negative.

The volatility and comovement graphs for the terms of trade are in general a combination 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 counter-clockwise, while the comovement graph slopes upwards 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 to determine 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 the slope of the volatility graph and the flatter the slope of the comovement graph. The more important is the asymmetry in the elasticity of the labour supply, the closer is the volatility graph to a V-shape and the higher is the slope of the comovement graph.

Before going to the data however, note that there is an alternative interpretation of these patterns within our theory. Independently of the values for θ and λ, the larger is 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 η=0, $V^T = \frac{x}{\theta} \cdot \sigma$ 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 η=1, $V^T = \frac{|x - \nu| \cdot \lambda}{1 + \lambda \cdot \nu} \cdot \sigma$ 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, instead of the relative importance of the two industry asymmetries.

Figure 5 plots the empirical analogs of the terms of trade volatility and comovement graphs. In contrast with the very 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 the introduction, there is a significant positive partial correlation between the volatility of the terms of trade and income, while 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 prediction of the theory that when the asymmetry in the labour supply elasticity is important, the volatility and comovement graphs are non-linear 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. When we do this, we find no evidence of the non-linearity 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).

In light of the discussion above, this pattern of an upward sloping volatility graph and a flat comovement graph for the terms of trade could be interpreted either as evidence in favour of the relative importance of asymmetries in the elasticity of product demand, or as evidence in favour of 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 to us that cross-country correlations in productivity shocks are an important part of the story, and so the evidence on terms of trade volatility and comovement should be interpreted as favouring the relative importance of the asymmetry in the elasticity of product demand over the asymmetry in the elasticity of the labour supply.

Finally we 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 right 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 θ=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 labour supply is λ=0 or λ=0.35 respectively. This compares favourably with the predicted difference of 0.009 from the regression with controls in Table 3. Regarding comovement, the theory predicts no cross-country differences in terms of trade comovement whatsoever whenever λ=0, but it somewhat overpredicts cross-country differences in comovement when λ=0.35.

5. Trade Integration

The postwar period has seen a substantial reduction in both physical and policy barriers to international trade in goods. Remember that the main theme of this paper is that the nature of business cycles that a country experiences depends on its industrial structure. As transport costs decline, the prices of products in which a country has comparative advantage increase and the share in production of these industries increases. As a result, industrial structures diverge. A natural conclusion of this argument is that one should expect that reductions in transport costs (globalization?) should increase cross-country differences in business cycles. In this section, we add transport costs to the model and confirm this intuition.

We generalize the model by assuming that trade is subject to “iceberg” transport costs $\tau>1$. If τ units of output are shipped from origin, only one unit arrives at the destination and the rest “melt” in transit. The presence of transport costs implies that domestic and international product prices might differ. Define $p_\alpha(z)$ and $p_\beta(z)$ as the f.o.b. or international price of variety z in the α- and β-industries, respectively. We re-define P_α and P_β as the ideal price indices of the α- and β-industries using international prices, and keep the numeraire rule in Equation (5). Let $p_\alpha^D(z)$ and $p_\beta^D(z)$ be the c.i.f. or domestic price of variety z in the α- and β-industries in the $(\mu,\delta,\pi,\kappa,\iota)$-country, respectively. The domestic price of imported varieties is $p_\alpha^D(z)=\tau\cdot p_\alpha(z)$ and $p_\beta^D(z)=\tau\cdot p_\beta(z)$, while that of exported varieties is $p_\alpha^D(z)=p_\alpha(z)$ and $p_\beta^D(z)=p_\beta(z)$. If there are some varieties that are not traded, their price is bounded as follows: $p_\alpha(z)\leq p_\alpha^D(z)\leq\tau\cdot p_\alpha(z)$ and $p_\beta(z)\leq p_\beta^D(z)\leq\tau\cdot p_\beta(z)$. As $\tau\to 1$, domestic and international prices converge and the model of section three obtains as a special case of the one here. As $\tau\to 1$ and $\kappa\to 0$ in all countries, the model of section one obtains.

The introduction of transport costs leads to some changes in the description of the world equilibrium. The maximization problem of the consumer is not affected and Equations (2)-(3) describing the labour-supply decision are still valid. But now the relevant prices for firms are the domestic ones. First, we must replace the pricing rule of the firms in the final goods sector in Equation (6) by the following one:

(24) $$p_F = (P_\alpha^D)^\nu \cdot (P_\beta^D)^{1-\nu}$$

where $P_\alpha{}^D$ and $P_\beta{}^D$ are the ideal price indices of the α- and β-industries using domestic prices. Consider next the pricing decisions of firms in the α- and β-industries. Given the cost function in (4) and the fact that foreign firms cannot produce the domestic varieties of α-products, firms in the α-industry always export almost all of their production and the domestic price is the international one, i.e. $p_\alpha{}^D(z)=p_\alpha(z)$. Therefore, Equation (7) describing the pricing behavior of domestic producers of α-products still applies. We must however replace Equation (8) by the following:

(25) $$p_\beta^D = w \cdot e^{-\pi}$$

To complete the description of the model, we need to compute the set of equilibrium prices. A straightforward extension of the arguments in section two shows that Equation (9) is still valid as description of the relative prices of different varieties in the α-industry. However, finding the prices of β-products in different countries and the international relative price of the α- and β-products is quite involved. The appendix provides a detailed derivation of these prices. Here we simply discuss the intuition behind them and their implications.

In equilibrium, poor countries export β-products to rich countries. In middle-income countries, β-products are not traded. The appendix shows that we can classify countries into these three groups as follows:

$$(\mu,\delta,\pi,\kappa,\iota)\in M \qquad \text{iff} \qquad \frac{\Psi_\beta}{\Psi_\alpha^{\frac{\theta-1}{\theta}}} \cdot \frac{\mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}}}{\tau^{-\lambda\cdot\nu} \cdot (1-\delta)} \cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota} < 1$$

(26) $(\mu,\delta,\pi,\kappa,\iota)\in N$ iff $$1\leq\frac{\Psi_\beta}{\Psi_\alpha^{\frac{\theta-1}{\theta}}}\cdot\frac{\mu^{\frac{1}{\theta}}\cdot\delta^{\frac{\theta-1}{\theta}}}{\tau^{-\lambda\cdot\nu}\cdot(1-\delta)}\cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota}\leq\tau^{1+\lambda\cdot\nu}$$

$(\mu,\delta,\pi,\kappa,\iota)\in X$ iff $$\tau^{1+\lambda\cdot\nu}<\frac{\Psi_\beta}{\Psi_\alpha^{\frac{\theta-1}{\theta}}}\cdot\frac{\mu^{\frac{1}{\theta}}\cdot\delta^{\frac{\theta-1}{\theta}}}{\tau^{-\lambda\cdot\nu}\cdot(1-\delta)}\cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota}$$

where Ψ_α is defined as before and Ψ_β is a new constant that depends on τ and generalizes the previous one. An important characteristic of this classification is that it is time-invariant in an important sense: the fraction of countries of each type that belongs to each group does not vary with the world cycle.

The appendix shows that we can still use Equation (11) as a description of international relative prices, but we must replace Equation (10) by the following one:

(27) $$\frac{p_\beta^D}{P_\beta}=\begin{cases}1 & \text{if } (\mu,\delta,\pi,\kappa,\iota)\in X\\ \left[\dfrac{\Psi_\beta\cdot\mu^{\frac{1}{\theta}}\cdot\delta^{\frac{\theta-1}{\theta}}}{\Psi_\alpha^{\frac{\theta-1}{\theta}}\cdot\tau^{-\lambda\cdot\nu}\cdot(1-\delta)}\right]^{\frac{1}{1+\lambda\cdot\nu}}\cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota} & \text{if } (\mu,\delta,\pi,\kappa,\iota)\in N\\ \tau & \text{if } (\mu,\delta,\pi,\kappa,\iota)\in M\end{cases}$$

Unlike the previous models, purchasing power parity no longer applies. To see this, note that the price of the final good is now given by:

(28) $$p_F=\tau^\nu\cdot\left(\frac{p_\beta^D}{P_\beta}\right)^{1-\nu}$$

To understand this equation, remember that domestic α-products constitute an infinitesimal part of the total expenditure in α-products, so that the price of the ideal basket of α-products is $\tau\cdot P_\alpha$. The price of β-products however is p_β^D. Finally, use the numaraire rule in Equation (5). Since the prices of β-products vary across countries purchasing power parity no longer applies and the cost of living is higher in countries that import β-products. Consistent with existing evidence on the cost of living, the theory predicts these countries to be the rich ones.[13]

We are ready to characterize the cross-section of business cycles in this extended model. Now income and the share of α-products are measured in domestic prices. That is, $y = \left(p_\alpha^D \cdot s + p_\beta^D \cdot u\right) \cdot e^\pi$ and $x = \frac{p_\alpha^D \cdot s \cdot e^\pi}{y}$. Applying Ito's lemma to y, we find that the (demeaned) growth rate of income is still given by Equation (18). Consequently, Equations (19) and (20) relating the properties of business cycles to a country's industrial structure still hold. And Equations (22)-(23) describing the cyclical properties of the terms of trade also apply. So, what are the effects of transport costs on the cross-section of business cycles? Transport costs reduce the volume of trade and, as a result, the cross-sectional dispersion in x. To see this, we compute the cross-section of shares:

$$(29) \qquad \frac{x}{1-x} = \begin{cases} \tau^{-1} \cdot \dfrac{\nu}{1-\nu} \cdot \dfrac{\Psi_\beta \cdot \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}}}{\Psi_\alpha^{\frac{\theta-1}{\theta}} \cdot \tau^{-\lambda \cdot \nu} \cdot (1-\delta)} \cdot e^{-(\lambda+\theta^{-1})\cdot(\pi-\Pi)-\lambda\cdot\kappa\cdot\iota} & \text{if } (\mu,\delta,\pi,\kappa,\iota) \in X \\ \dfrac{\nu}{1-\nu} & \text{if } (\mu,\delta,\pi,\kappa,\iota) \in N \\ \dfrac{\nu}{1-\nu} \cdot \dfrac{\Psi_\beta \cdot \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}}}{\Psi_\alpha^{\frac{\theta-1}{\theta}} \cdot \tau^{-\lambda \cdot \nu} \cdot (1-\delta)} \cdot e^{-(\lambda+\theta^{-1})\cdot(\pi-\Pi)-\lambda\cdot\kappa\cdot\iota} & \text{if } (\mu,\delta,\pi,\kappa,\iota) \in M \end{cases}$$

If τ is high enough, trade in β-products disappears and x=ν in all countries. The cross-section of business cycles becomes flat.[14] The lower the transport costs, the greater are the differences in industrial structures of countries. Lower transport

[13] The assumption that the final good is nontraded is still not binding, provided that the latter is subject to the same transport cost τ.
[14] If the elasticity of substitution between α- and β-products were different than one, industrial structures would still vary and there would still be some differences in business cycles across countries even if there is no trade in β-products.

costs mean higher relative prices of those products in which a country has comparative advantage, i.e. the α-products in rich countries and the β-products in poor ones. Higher relative prices imply higher industry shares for those products, even if production remains constant. But changes in relative prices also affect employment and production. The lower are transport costs, the lower is the production of β-products in rich countries and the higher is in poor ones.[15] Through these two channels, increased trade integration magnifies differences in the industrial structures of countries.

An interesting result that follows from this discussion is that trade integration affects differently the business cycles of rich and poor countries. In rich countries, trade integration increases the share of α-industries and makes them less sensitive to country-specific shocks. This leads to business cycles that are less volatile and more synchronized with the world cycle. In poor countries, trade integration increases the share of β-products and makes them more sensitive to country-specific shocks. This leads to business cycles that are more volatile and less synchronized with the world.

The welfare consequences of trade integration for a given country are difficult to assess. As usual, there are the standard welfare effects that would occur even in the absence of fluctuations in productivity. Trade integration increases efficiency and raise welfare everywhere. But it also might change the relative price of α- and β-products and therefore re-distribute income among countries. But the theory here shows that there are also welfare effects that come from changes in the nature of business cycles. Remember that we have assumed away trade in assets and capital accumulation. As a result, income is equal to consumption. To the extent that

[15] These increases in employment could come from increased participation or reduced unemployment, as is the case in the model presented here. Or they could come from employment in other industries, as it would be the case if we changed our assumptions and allowed both industries to use both types of workers.

consumers are risk averse, in rich countries welfare improves as a result of trade integration as income volatility declines. The opposite is true in poor countries.[16]

6. Concluding Remarks

This paper 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 labour supplies. Under these conditions the income effects of country-specific supply shocks tend to be moderate, since 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 labour supplies. Under these conditions, the income effects of country-specific supply shocks tend to be large, since they generate little effects 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 have the potential to account for observed cross-country differences in business cycles. Also, we find that cross-industry differences in product-demand elasticities are quantitatively more important than cross-industry differences in labour-supply elasticities in accounting for observed cross-country differences in business cycles. The model turns out to be quite flexible and allows us to analyze a number of related issues. For instance, we

[16] If there were some trade in assets, it is not clear whether the welfare effects of trade integration would be always positive in rich countries and negative in poor ones. On the one hand, volatility increases in poor countries and this lowers the value of their assets. On the other hand, comovement with the world declines in poor countries and this increases the value of their assets.

examined how differences in financial development affect the way countries react to shocks, the implications of the theory for the cyclical behavior of the terms of trade, and the effects of globalization on the nature of business cycles.

The next step however should be empirical. The theory developed here provides a rich set of testable hypotheses relating the industrial structure of countries with the properties of their business cycles. These hypotheses are promising, but still preliminary. They should be thoroughly confronted with the data.

References

Acemoglu, D. and F. Zilibotti (1997) “Was Prometheus Unbound by Chance? Risk, Diversification and Growth,” *Journal of Political Economy* 105: 709-751.

Backus, D.K., P.J. Kehoe and F.E. Kydland (1995), “International Business Cycles: Theory and Evidence” in T.F.Cooley (ed.) *Frontiers of Business Cycle Research*, Princeton University Press.

Baxter, M. (1995), “International Trade and Business Cycles” in G.M. Grossman and K. Rogoff (eds.) *Handbook of International Economics*, Volume 3, North-Holland.

Banks, A. (1979), *Cross-National Time-Series Data Archive*, Center for Social Analysis, State University of New York, Binghamton.

Christiano, L., M. Eichenbaum and C. Evans (1997), “Sticky Price and Limited Participation Models of Money: A Comparison,” *mimeo*.

Davis, D. (1995), “Intraindustry Trade: A Heckscher-Ohlin-Ricardo Approach,” *Journal of International Economics* 39: 201-226

Feenstra, R. (1994), “New Product Varieties and the Measurement of International Prices,” *American Economic Review* 84: 157-77.

Frankel, J. and D. Romer (1999). “Does Trade Cause Growth?”. American Economic Review. 89(3):379-399.

Harrison, J.M. (1990), Brownian Motion and Stochastic Flow Systems, Krieger.

Juhn, C., K.M. Murphy and R.H. Topel (1991), “Why Has the Natural Rate of Unemployment Increase Over Time?” *Brookings Papers on Economic Activity*, Vol.2, pp.75-143.

Kydland, F.E. and E.C. Prescott (1992),”Time to Build and Aggregate Fluctuations,” *Econometrica*, 50: 1345-1370.

Trefler, D. and H. Lai (1999). “The Gains from Trade: Standard Errors With the CES Monopolistic Competition Model”. Manuscript, University of Toronto.

Appendix 1: Data Description

Our sample consists of 76 countries for which we have 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, less 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 the World Bank World Development Indicators, and PPP conversion factors are from the Penn World Tables. Prior to computing income and terms of trade volatility and comovement, we discard 33 country-year observations constituting about 1 percent of the sample where measured growth in the terms of trade exceeds 20 percent. Each of these cases occurs during episodes of very high inflation where growth in the import and export deflators is extreme and provides a very noisy signal of 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 one if the country is classified as an oil exporter or a commodity exporter in the World Bank World Development Indicators. 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) dataset. The standard deviation of inflation is computed as the standard deviation of growth rates of the GDP deflator taken from the World Bank World Development Indicators. To avoid extreme outliers in this variable we discard 204 country-year observations constituting seven percent of the sample where inflation exceeds 100 percent per year prior to computing the standard deviation of inflation.

The data are available from the authors upon request.

Appendix 2: Equilibrium Prices with Transport Costs

In this appendix, we compute the world equilibrium in the model with transport costs in section five. Define the following object:

$$\text{(A1)} \qquad \Psi_\beta = \iiint \left(\frac{p_\beta^D}{P_\beta}\right)^{1+\lambda\cdot\nu} \cdot \tau^{-\lambda\cdot\nu} \cdot (1-\delta) \cdot e^{(1+\lambda)\cdot(\pi-\Pi)-\kappa\cdot\iota} \cdot dF \cdot dG \cdot dH$$

If $p_\beta^D = P_\beta$, Ψ_β is constant over time. This is the case studied in the monetary model of section four. If $p_\beta^D = P_\beta$ and $\kappa \to 0$ in all countries, Ψ_β simplifies to the corresponding constant of the real model in section two. We show next that in the general model of section five, the world equilibrium can be computed as a fixed-point problem for Ψ_β.

First, we derive a relationship that ensures that international prices clear world markets, for a given set of domestic prices. Equating the ratio of world spending in the α- and β-industries, $\frac{\nu}{1-\nu}$, to the ratio of the value of their productions, $\frac{\iiint p_\alpha \cdot s \cdot e^\pi \cdot dF \cdot dG \cdot dH}{\iiint p_\beta \cdot u \cdot e^\pi \cdot dF \cdot dG \cdot dH}$, we find that Equation (11) is still valid, provided we use the definition of Ψ_β in Equation (A1). Define $Z = \left(\frac{P_\alpha}{P_\beta}\right)^{1+\lambda\cdot\nu} \cdot \frac{1-\nu}{\nu} \cdot e^{-\lambda\cdot\Pi}$. Then, we can re-write Equation (11) as follows:

(A2) $\Psi_\beta = \Psi_\alpha \cdot Z$

where $\Psi_\alpha = \left(\int\int \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}} \cdot e^{\frac{\theta-1}{\theta}\cdot(\pi-\Pi)} \cdot dF \cdot dG \right)^{\frac{\theta}{\theta-1}}$, as in the text. This equations defines a linear relationship between Ψ_β and Z that has a simple economic interpretation: Taking as given the set of domestic prices (remember that the distribution of $\frac{p_\beta^D}{P_\beta}$ is implicit in Ψ_β), Equation (A1) describes the international prices (remember that $\frac{P_\alpha}{P_\beta}$ is implicit in Z) that equilibrate world markets.

Second, we derive a relationship that ensures that domestic prices clear domestic markets, for given international prices. To do this, assume first that in the (μ,δ,π,κ,ι)-country β-products are nontraded goods. Then, equating the ratio of spending in the α- and β-industries, $\frac{\nu}{1-\nu}$, to the ratio of the income of both industries, $\frac{p_\alpha^D \cdot s \cdot e^\pi}{p_\beta^D \cdot u \cdot e^\pi}$, we find that:

(A3) $$\frac{p_\beta^D}{P_\beta} = Z \cdot \frac{\Psi_\alpha^{\frac{1}{\theta}} \cdot \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}}}{\tau^{-\lambda\cdot\nu} \cdot (1-\delta)} \cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota}$$

This domestic price of β-products holds in equilibrium if and only if: (i) it exceeds the price at which domestic β-firms can sell β-products abroad; and (ii) it does not exceed the price at which firms in the final goods sector can purchase β-products abroad. These conditions define three sets of countries: X(Z), N(Z), M(Z). We say that (μ,δ,π,κ,ι)∈M(Z) if and only if $Z \cdot \frac{\Psi_\alpha^{\frac{1}{\theta}} \cdot \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}}}{\tau^{-\lambda\cdot\nu} \cdot (1-\delta)} \cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota} < 1$. We also say that $(\mu,\delta,\pi,\kappa,\iota)\in N(Z)$ if and only if $1 \le Z \cdot \frac{\Psi_\alpha^{\frac{1}{\theta}} \cdot \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}}}{\tau^{-\lambda\cdot\nu} \cdot (1-\delta)} \cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota} \le \tau^{1+\lambda\cdot\nu}$.

Finally, $(\mu,\delta,\pi,\kappa,\iota)\in X(Z)$ if and only if $\tau^{1+\lambda\cdot\nu} < Z \cdot \frac{\Psi_\alpha^{\frac{1}{\theta}} \cdot \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}}}{\tau^{-\lambda\cdot\nu} \cdot (1-\delta)} \cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota}$. Define the membership of a group as the fraction of countries of each type that belongs to each group. Since the distribution functions $F(\mu,\delta,\kappa)$, $G(\pi-\Pi)$ and $H(\iota)$ are constant, the membership of the different groups varies only with Z. In particular, we have that the membership of M(Z) is non-increasing in Z and the membership of X(Z) is non-decreasing in Z. The membership of N(Z) could increase, decrease or stay constant with Z depending on the distribution of country characteristics.

With this notation at hand, we can write the relative prices of β-products that as a function of Z as follows:

$$\text{(A4)} \qquad \left(\frac{p_\beta^D}{P_\beta}\right)^{1+\lambda\cdot\nu} = \begin{cases} \tau^{1+\lambda\cdot\nu} & \text{if } (\mu,\delta,\pi,\kappa,\iota)\in M(Z) \\ Z \cdot \frac{\Psi_\alpha^{\frac{1}{\theta}} \cdot \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}}}{\tau^{-\lambda\cdot\nu} \cdot (1-\delta)} \cdot e^{-\frac{\lambda+\theta^{-1}}{1+\lambda\cdot\nu}\cdot(\pi-\Pi)-\frac{\lambda}{1+\lambda\cdot\nu}\cdot\kappa\cdot\iota} & \text{if } (\mu,\delta,\pi,\kappa,\iota)\in N(Z) \\ 1 & \text{if } (\mu,\delta,\pi,\kappa,\iota)\in M(Z) \end{cases}$$

Equation (A4) also has a simple economic interpretation: Taking as given international prices, this equation describes the set of domestic prices that equilibrate domestic markets. Substituting Equation (A4) into Equation (A1) we find:

$$\text{(A5)} \qquad \begin{aligned} \Psi_\beta = & \iiint_{X(Z)} (1-\delta) \cdot e^{(1+\lambda)\cdot(\pi-\Pi)-\kappa\cdot\iota} \cdot dF \cdot dG \cdot dH + \\ & + \Psi_\alpha^{\frac{1}{\theta}} \cdot Z \cdot \iint_{N(Z)} \mu^{\frac{1}{\theta}} \cdot \delta^{\frac{\theta-1}{\theta}} \cdot e^{\frac{\theta-1}{\theta}\cdot(\pi-\Pi)} \cdot dF \cdot dG + \\ & + \tau \cdot \iiint_{M(Z)} (1-\delta) \cdot e^{(1+\lambda)\cdot(\pi-\Pi)-\kappa\cdot\iota} \cdot dF \cdot dG \cdot dH \end{aligned}$$

* Equation (A5) defines a function $\Psi_\beta = \Psi_\beta(Z)$ that is continuous and non-decreasing and bounded: $\lim_{Z\to 0}\Psi_\beta = \iiint (1-\delta)\cdot e^{(1+\lambda)\cdot(\pi-\Pi)-\kappa\cdot\iota}\cdot dF\cdot dG\cdot dH > 0$ and $\lim_{Z\to\infty}\Psi_\beta = \tau\cdot\iiint (1-\delta)\cdot e^{(1+\lambda)\cdot(\pi-\Pi)-\kappa\cdot\iota}\cdot dF\cdot dG\cdot dH < \infty$.

The world equilibrium is obtained by crossing (A2) and (A5). That is, the constant Ψ_β that we refer to in the text is implicitly defined by:

(A6)
$$\begin{aligned}\Psi_\beta = & \iiint_{X\left(\frac{\Psi_\beta}{\Psi_\alpha}\right)} (1-\delta)\cdot e^{(1+\lambda)\cdot(\pi-\Pi)-\kappa\cdot\iota}\cdot dF\cdot dG\cdot dH + \\ & + \Psi_\beta\cdot\Psi_\alpha^{\frac{1-1}{\theta}}\cdot \iint_{N\left(\frac{\Psi_\beta}{\Psi_\alpha}\right)} \mu^{\frac{1}{\theta}}\cdot\delta^{\frac{\theta-1}{\theta}}\cdot e^{\frac{\theta-1}{\theta}\cdot(\pi-\Pi)}\cdot dF\cdot dG + \\ & + \tau\cdot \iiint_{M\left(\frac{\Psi_\beta}{\Psi_\alpha}\right)} (1-\delta)\cdot e^{(1+\lambda)\cdot(\pi-\Pi)-\kappa\cdot\iota}\cdot dF\cdot dG\cdot dH\end{aligned}$$

It is straightforward to show that an equilibrium exists. But it might not be unique. In the text, we assume this is the case. This is equivalent to imposing enough degree of smoothness to the distribution functions $F(\mu,\delta,\kappa)$, $G(\pi\text{-}\Pi)$ and $H(\iota)$.

Table 1: Volatility and Comovement

	Basic			Poor Countries			Rich Countries			1960-79			1980-97			With Controls		
	Coef	Std.Err		Coef	Std.Err		Coef	Std.Err		Coef	Std.Err		Coef	Std.Err		Coef	Std.Err	
Volatility Graph																		
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	***
ln(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	
Std.Dev. Inflation																0.100	0.030	***
R-Squared	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	***
ln(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	
Std.Dev. Inflation																-0.388	0.377	
R-Squared	0.222			0.000			0.101			0.282			0.047			0.250		
Number of Observations	76			38			38			76			76			76		

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 labelled 1960-79 and 1980-97 volatility and comovement are calculated over the indicated subperiods. The control variables consist of a dummy variable which takes the value one 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. *** (**) (*) indicate significance at the 1 (5) (10) percent level

Table 2: Calibrations

Cross-Country Differences in Volatility and Comovement

				Income Growth		Terms of Trade Growth	
				Volatility	Comovement	Volatility	Comovement
Empirical							
Point Estimate				-0.026	0.382	0.009	0.037
Theoretical, Basic Model							
q	l	s	Öh				
∞	0	0.04	0.40	0.000	0.000	0.000	0.000
∞	0.35	0.03	0.38	-0.005	0.047	0.001	2.000
∞	0.7	0.03	0.37	-0.009	0.078	0.002	2.000
2	0	0.05	0.31	-0.011	0.098	0.012	0.000
2	0.35	0.04	0.30	-0.016	0.129	0.010	0.343
2	0.7	0.04	0.31	-0.019	0.149	0.009	0.623
1.2	0	0.06	0.25	-0.025	0.186	0.026	0.000
1.2	0.35	0.05	0.25	-0.027	0.200	0.020	0.171
1.2	0.7	0.04	0.26	-0.028	0.208	0.016	0.330
Theoretical, Monetary Model with k(x)=1.1-x, f =0.1							
q	l	s	Öh				
∞	0	0.04	0.40	0.000	0.000	0.000	0.000
∞	0.35	0.03	0.38	-0.015	0.108	0.001	2.000
∞	0.7	0.03	0.37	-0.038	0.189	0.002	2.000
2	0	0.05	0.31	-0.011	0.098	0.012	0.000
2	0.35	0.04	0.30	-0.024	0.165	0.010	0.343
2	0.7	0.04	0.31	-0.045	0.219	0.009	0.623
1.2	0	0.06	0.25	-0.025	0.186	0.026	0.000
1.2	0.35	0.05	0.25	-0.034	0.219	0.020	0.171
1.2	0.7	0.04	0.26	-0.052	0.249	0.016	0.330

This table compares empirical differences in volatility and comovement of real income growth (left panel) and terms of trade growth (right panel) with the predictions of the basic model of Section 2 (top panel) and the model with monetary shocks of Section 4 (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) 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.

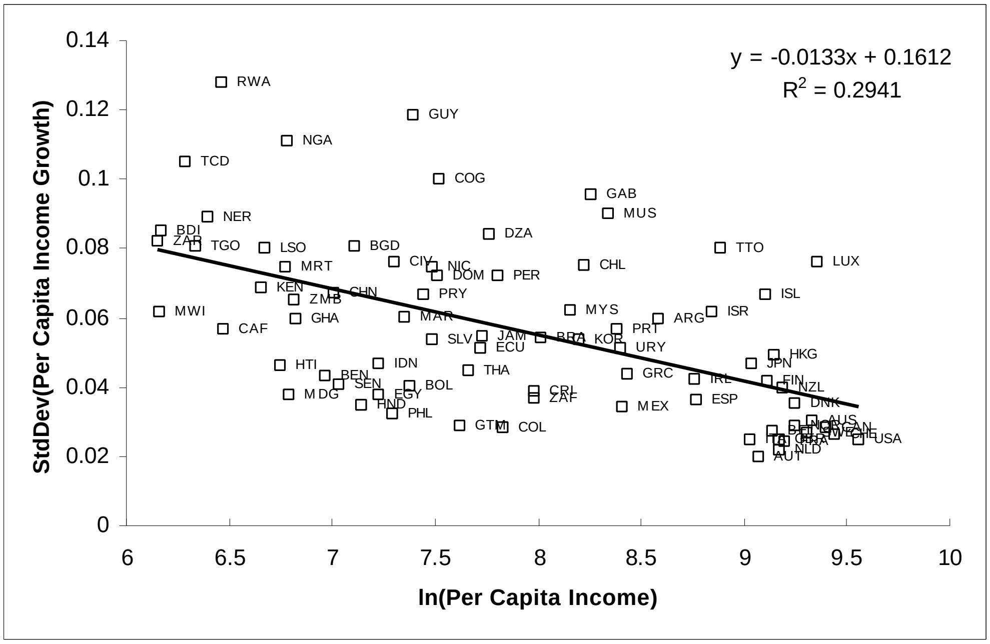
Table 3: Volatility and Comovement of Terms of Trade Growth

	Basic			With Controls			With Controls, Nonlinearities		
	Coef	Std.Err		Coef	Std.Err		Coef	Std.Err	
Volatility									
Intercept	0.023	0.013	*	-0.034	0.013	**	-0.048	0.030	
ln(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	
Std.Dev. Inflation				0.145	0.020	***	0.138	0.025	***
Dummy for Rich Countries							0.036	0.043	
Dummy for Rich Countries x ln(Per Capita GDP at PPP)							-0.004	0.006	
R-Squared	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	
ln(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	
Std.Dev. Inflation				-0.089	0.427		-0.318	0.478	
Dummy for Rich Countries							0.644	0.775	
Dummy for Rich Countries x ln(Per Capita GDP at PPP)							-0.068	0.096	
R-Squared	0.005			0.012			0.036		
Number of Observations	76			76			76		

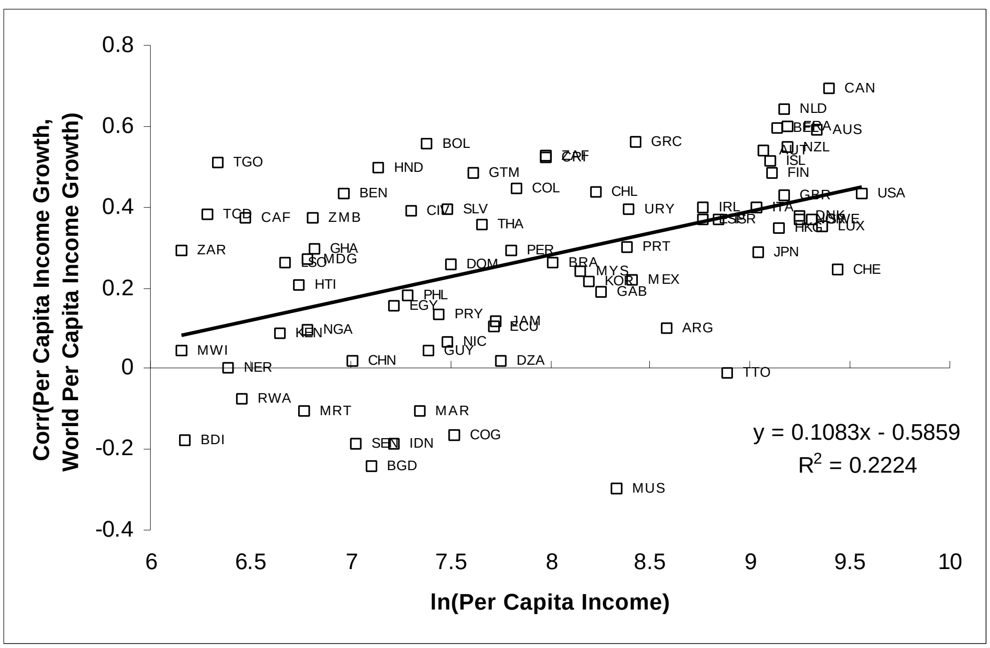
This table reports the results of cross-sectional regressions of the standard deviation of terms of trade growth (top panel) and the correlation of terms of trade growth with world average income growth excluding the country in question (bottom panel) on the indicated variables, for different samples and control variables. Poor (rich) countries refer to countries below (above) median per capita GDP. In the columns labelled 1960-79 and 1980-97 volatility and comovement are calculated over the indicated subperiods. The control variables consist of a dummy variable which takes the value one 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. *** (**) (*) indicate significance at the 1 (5) (10) percent level.

Figure 1: Volatility and Comovement

Volatility



Comovement



The top panel plots the standard deviation of the growth rate of real per capita income over the period 1960-97 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 1960-97 against the log-level of average per capita GDP in 1985 PPP dollars over the same period. See Appendix for data definitions and sources.

Figure 2: Sample Paths of the Productivity Index

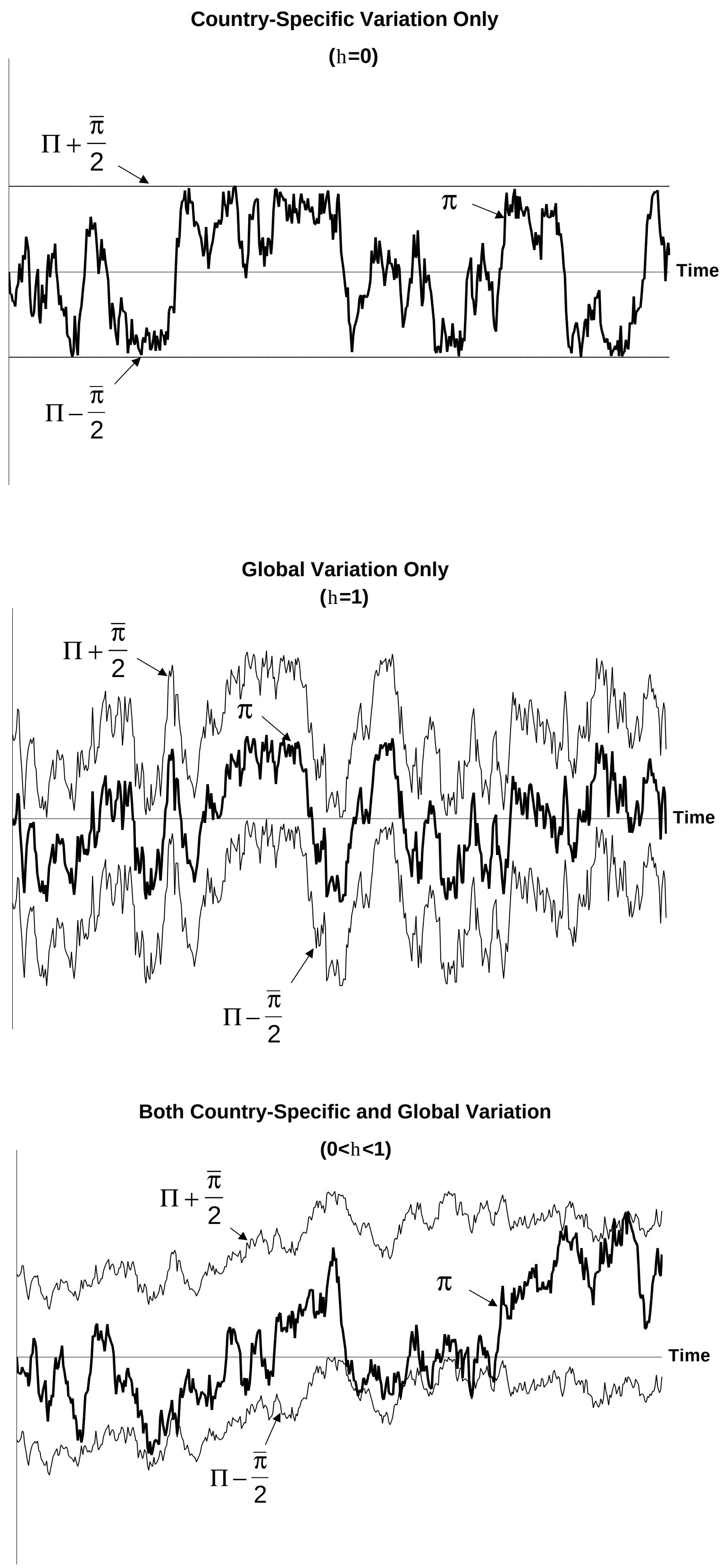
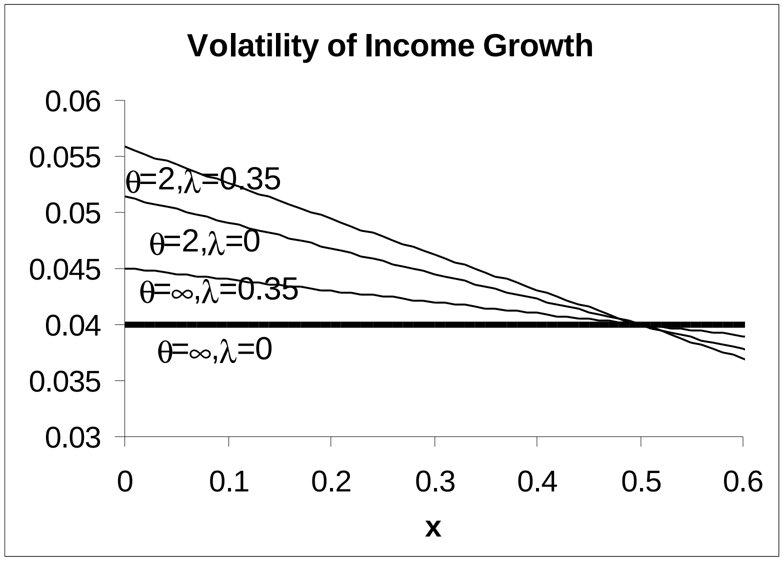
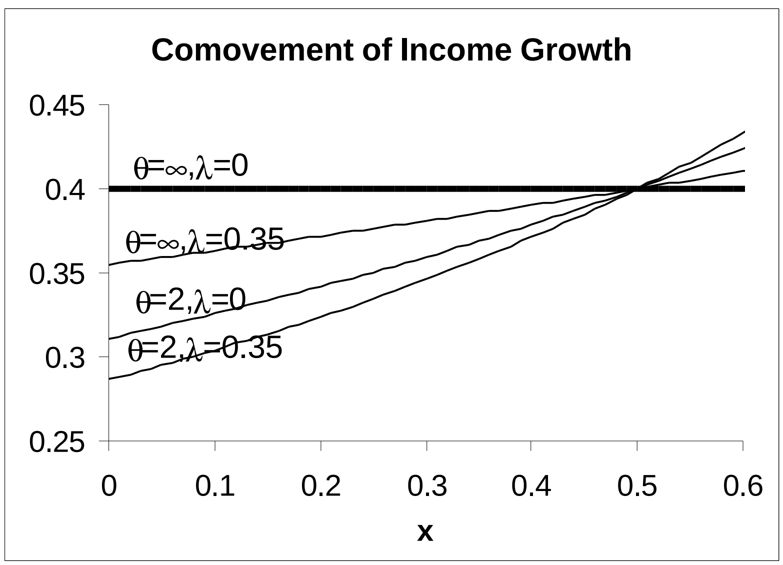


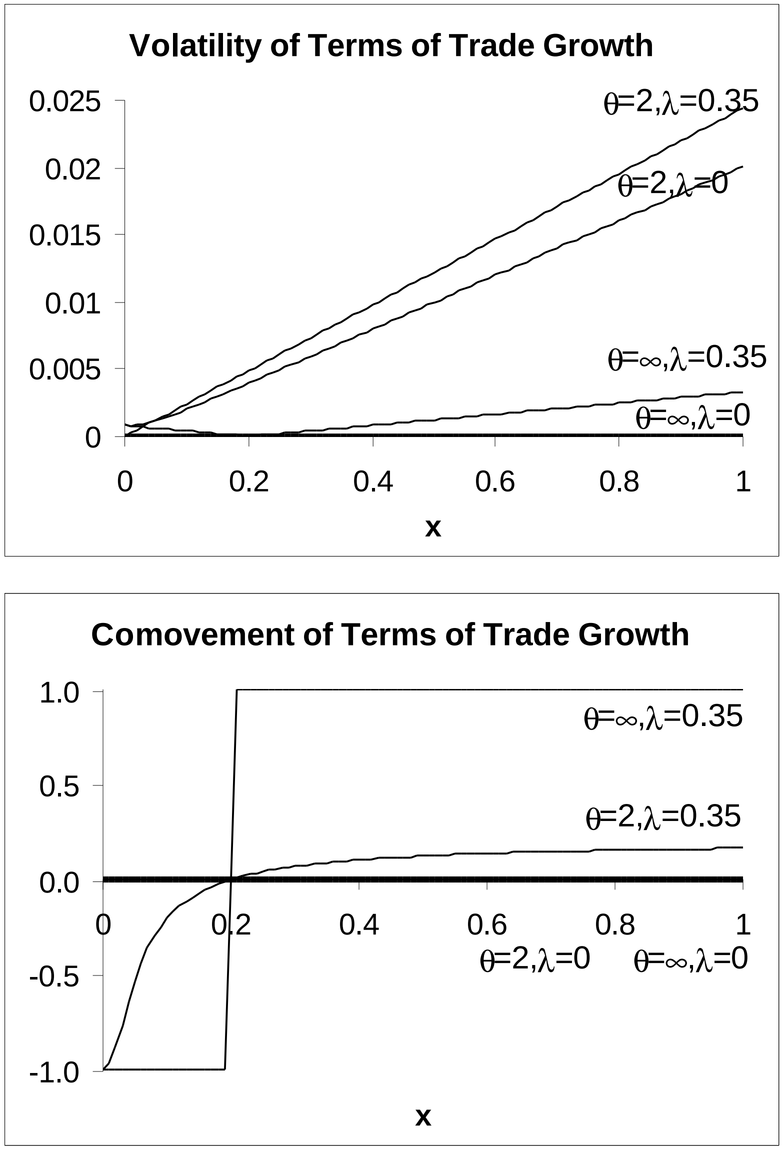
Figure 3: Theoretical Volatility and Comovement Graphs





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 ν=0.2 and the parameters of the productivity process are set as discussed in the text below.

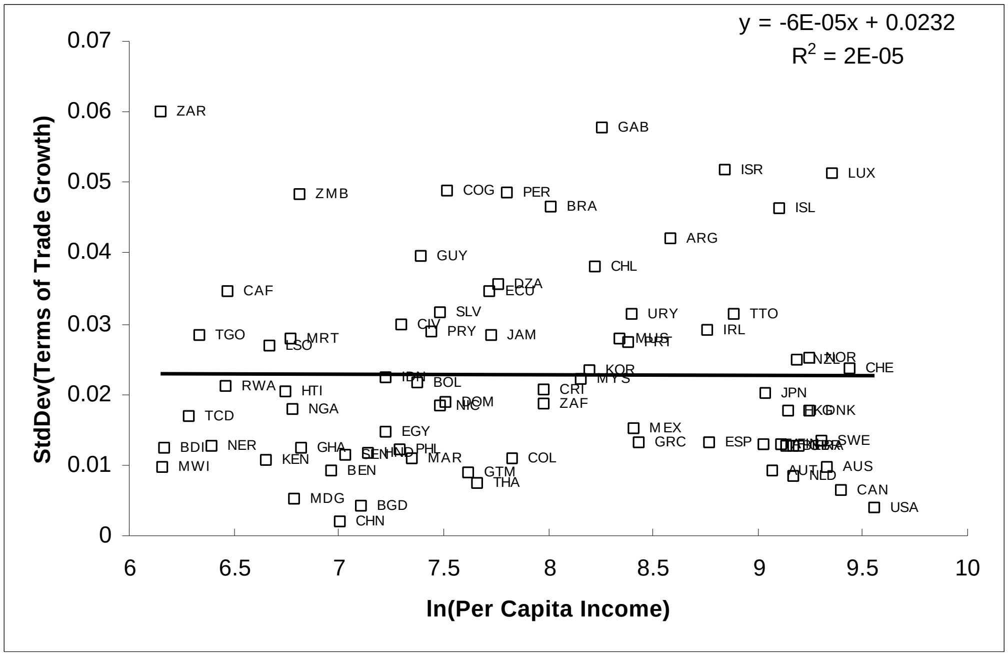
Figure 4: Theoretical Terms of Trade Volatility and Comovement Graphs



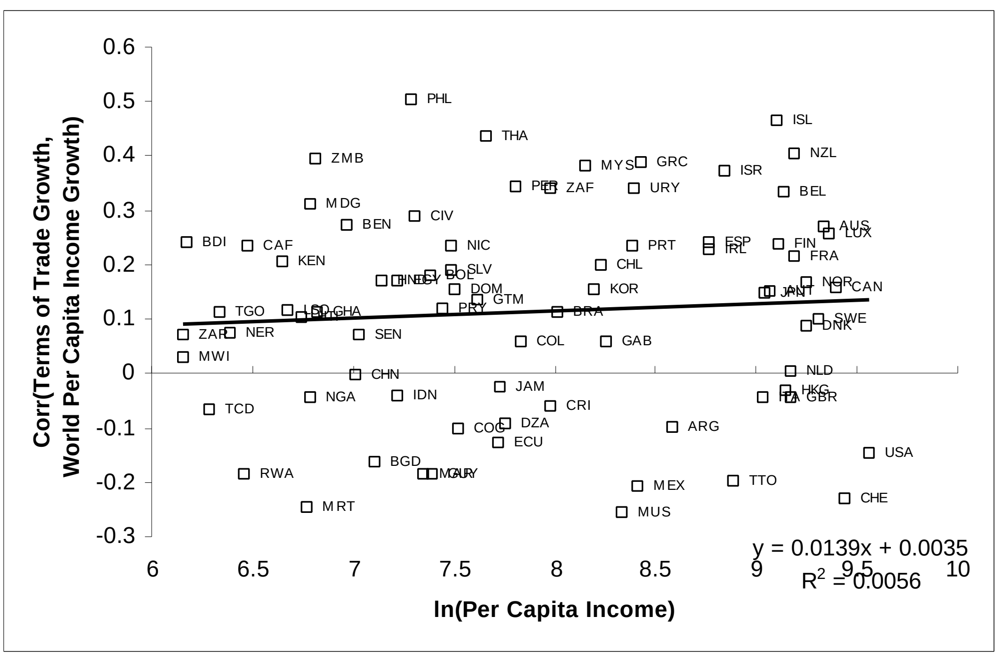
This figure plots Equations (17) and (18) as a function of x for the indicated values of θ and λ. The share of α-products in consumption is set equal to ν=0.2 and the parameters of the productivity process are set as discussed in the text.

Figure 5: Volatility and Comovement of Terms of Trade

volatility



comovement



The top panel plots the standard deviation of the growth rate of terms of trade over the period 1960-97 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 1960-97 against the log-level of average per capita GDP in 1985 PPP dollars over the same period. See Appendix for data definitions and sources.