INTERNATIONAL FINANCIAL INTEGRATION AND RISK SHARING AND THE CROSS-COUNTRY CONSUMPTION-OUTPUT CORRELATION PUZZLE: A PRODUCTION-BASED APPROACH

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Abstract. This paper develops a multi-country, multi-factor model for analyzing a role of asset trade in pooling production risks among countries. The model is characterized as a state-contingent intertemporal production problem by viewing countries as producers of goods and services in small open economies. The social planner minimizes the sum of expected costs of an individual country over time for efficient intertemporal allocation of output under uncertainty. Efficient risk sharing rules among countries are the same as the conditions for full financial integration. It is found that input prices and interest rates as well as technology shocks are the driving variables for cross-country output co-movements. The international correlation puzzle reflects an inability to account for production risk sharing among countries in previous studies. The degree of international risk sharing is substantial relative to earlier estimates and largely realized from pooling production risks rather than consumption risks among countries.

Key Words: Production risks, Financial market integration, Risk sharing, Stochastic discount factors, International consumption-output correlation puzzle

JEL Numbers: F41, F36, G15, D92

I. Introduction

Recently there has been growing interest in international risk sharing (see Obstfeld, 1994; Tesar, 1995; Canova and Ravn, 1996; Sorensen and Yosha, 1998; Lewis, 1996; Crucini, 1999) as well as in financial market integration or capital mobility among countries (see Feldstein and Horioka, 1980; Obstfeld, 1989; Ghosh, 1995; Bayoumi and MacDonald, 1995) in the areas of international macroeconomics and finance.[1] These studies typically rest on consumption (or endowment)-based models in which consumers maximize expected utility of consumption over time under the condition of uncertainty. Although the analyses are clearly important for understanding how the world economy operates, evidence for international risk sharing and financial integration is mixed and inconclusive. In particular, measured cross-country correlations of consumption growth are rather low – far from perfect as predicted by the model – and, more importantly, tend to be even lower than the corresponding output correlations, contrary to the implication that integrated world financial markets should help individuals to smooth consumption in response to idiosyncratic fluctuations in income (Backus, Kehoe, and Kydland, 1992; Baxter and Crucini, 1993; Obstfeld, 1994; Tesar, 1995). This phenomenon has become known as "the international or cross-country consumption-output correlation anomaly or puzzle" (Backus, Kehoe, and Kydland, 1992). Many attempts have been made to resolve this puzzle, but results are, by and large, not satisfactory (see Tesar, 1995; Lewis, 1996, 1999).

In an effort to shed some light on the well-known but unsettled cross-country correlation riddle, this paper develops an altogether different approach suitable for explaining financial market integration and risk sharing among countries or regions from the vantage point of the production side, rather than the consumption side, of the economy. In particular, we analyze a multi-country, multi-factor model with a focus on a hypothesized role for asset trade in pooling production risks among countries. We view each country as a producer of goods and services, instead of a consumer taken by traditional consumption-based models, in a small open economy under conditions of production uncertainty or risk.[2] The model is characterized as a state-contingent intertemporal production problem using the familiar cost function. The producer's intertemporal marginal rate of substitution of output supply is described by the ratio of discounted marginal costs of output in two successive periods, and the production Euler equation, which is shows that the asset returns are determined by the producer's production decisions across time and states of nature, is derived. If countries are fully integrated financially, growth rates of marginal cost of output must be the same for their producers across states of nature, which is equal to the (negative) world interest rate. The international production risk sharing problem is modeled as the problem facing a social (world) planner who minimizes the sum of expected costs of an individual country over time for efficient intertemporal allocation of output under production risk. The first-order conditions yield a set of rules for efficient output sharing among producers in different countries under uncertainty. In particular, efficiency in production requires that producers in different countries equalize their marginal cost of output at every state and time. This condition implies that the growth rate of marginal cost is constant across countries and does not depend on idiosyncratic shocks but rather on common shocks affecting all countries. If all shocks are common shocks, opportunities for risk sharing among countries are limited. Moreover, if international financial markets are complete or fully integrated, there is perfect risk sharing among countries. For a Cobb-Douglas cost function, efficient risk sharing implies that when countries experience common technology shocks (in addition to common input prices and interest rates), output growth rates should be perfectly correlated across them.

The thesis of the proposed model is that production shocks are the driving force for output co-movements across countries and that international risk sharing, which is captured through asset trade in world financial markets, is possibly realized from diversifying production risks rather than consumption risks among countries. The country's cost minimization problem that forms the basis of analysis is the dual to the production problem in international real business cycle models. However, unlike earlier studies, this paper provides some new and critical results. International real business cycle models (see Backus, Kehoe, and Kydland, 1992), based on a production function, consider technology or productivity shocks as the sole determinant of cross-country dynamics. The proposed production-based model, on the other hand, employs the familiar cost function for a small open economy and suggests a role for input prices and interest rates (or intertemporal substitution in production) as well as technology shocks to be driving variables for cross-country output co-movements. The model has the similar structure of consumption-based models for financial integration and risk sharing. However, the production-based approach can be more useful than consumption-based models because it identifies social institutions that are likely to act as social planners and because the assumptions/conclusions of the model are more closely approximated by stylized facts including the cross-country consumption-output correlation puzzle. In particular, there is a high correlation of output growth rates among countries, giving clear evidence of risk sharing in production among countries. Further, high cross-country output correlations relative to consumption correlations suggest that while countries face more consumption risks than production risks, they diversify production risks much better than consumption risks. The international consumption-output correlation puzzle reflects a failure to allow for risk sharing in production among countries in previous analyses, while accounting only for risk sharing in consumption. The extent of financial integration or diversification captures the degree of international risk sharing. The estimated degree of international risk sharing is quite substantial and much better than consumption data show, and is, in large measure, realized from pooling production risks rather than consumption risks among countries.

II. The Country's State-Contingent Intertemporal Production Problem and the Condition for International Financial Market Integration

Each country produces a homogenous output and is inhabited by a single representative producer of goods and services who makes intertemporal production decisions under uncertainty. Uncertainty is described by a finite number of states of nature, indexed by $s = 1,..., S$, for each time period, $t = 1, ..., T$. There are complete global financial markets that countries can use to hedge against exogenous country risks, and perfect competition is assumed for the markets for outputs and productive inputs, implying that prices are such that product and input markets clear at every state and that producers and input suppliers act as price takers. Thus each country faces exogenous product and input prices, but capital is free to move across countries with no transactions costs.

There are K countries, indexed by $k = 1,..., K$. The representative producer's production technology for country k over the T period planning horizon under uncertainty is represented by the following state-contingent product transformation function:

$$F^k(y^k_{1s},\ x^k_{1,1s},...,\ x^k_{n,1s};\ ...;\ y^k_{Ts},\ x^k_{1,Ts},\ ...,\ x^k_{n,Ts}) = \sum_{t=1}^{T} F^k_{ts}(y^k_{ts},\ x^k_{1,ts},\ ...,\ x^k_{n,ts}) = 0, \quad \textbf{(1)}$$

where y^k_{ts} is the planned quantity of output by the producer of the kth country at time-state ts and $x^k_{i,ts}$ is the planned quantity of the ith ($i = 1, ..., n$) input use by the producer of the kth country at time-state ts. All inputs are assumed to adjust fully to their optimizing levels within a given period, and intertemporal production technology is assumed to be strongly separable, with $F^k_{ts}(y^k_{ts}, x^k_{1,ts}..., x^k_{n,ts}) = 0$ defined as a state-contingent intratemporal or within-period transformation function, which has a time subscript to allow for a change in technology over time. If this function can be solved for output, we have the familiar, but state-contingent, production function: $y^k_{ts} = f(x^k_{1,ts}..., x^k_{n,ts})$. The intertemporal transformation function (1) is differentiable with continuous derivatives of the first and second order, is increasing in inputs and decreasing in outputs, and is strictly quasi-convex in outputs.

We can derive a within-period state-contingent cost function as a solution to the following cost minimization problem:

$$\begin{aligned} &\min_{x^k_{i,ts}} \sum_{t=1}^{T} \sum_{i=1}^{n} \hat{w}_{i,ts} x^k_{i,ts} \\ &s.t. \quad \sum_{t=1}^{T} F^k_{ts}(y^k_{ts},\ x^k_{1,ts},\ ...,\ x^k_{n,ts}) = 0, \end{aligned} \quad \textbf{(2)}$$

where $\hat{w}_{i,ts}$ is the state-contingent price of the ith input at time-state ts, which is the same for all countries. The resulting cost function is defined as

$$C^k_{ts}(y^k_{ts},\ \hat{w}_{1,ts},\ ...,\ \hat{w}_{n,ts}) \equiv \sum_{i=1}^{n} \hat{w}_{i,ts} x^k_{i,ts}(y^k_{ts},\ \hat{w}_{1,ts},\ ...,\ \hat{w}_{n,ts}). \quad \textbf{(3)}$$

This cost function is well known (except for the fact that it depends on the state of nature): it is increasing, linear homogenous, and concave with respect to input prices, and increasing in output.

Application of Shephard's lemma to the cost function yields the input demand functions:

$$\frac{\partial C_{ts}^{k}}{\partial \hat{w}_{i,ts}} = x_{i,ts}^{k}(y_{ts},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts}). \tag{4}$$

Moreover, intertemporal separability of production technology implies an intertemporal cost function of the form:

$$\begin{aligned} &C^{k}(y_{1s}^{k},\ \hat{w}_{1,1s},\ \ldots,\ \hat{w}_{n,1s};\ \ldots;\ y_{Ts},\ \hat{w}_{1,Ts},\ \ldots,\ \hat{w}_{n,Ts}) \\ &= \sum_{t=1}^{T} C_{ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts}) = \sum_{t=1}^{T} \sum_{i=1}^{n} \hat{w}_{i,ts} x_{i,ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts}). \end{aligned} \tag{5}$$

In a dual context, this cost function contains all the information about the intertemporal transformation function in (1). In particular, the producer's intertemporal marginal rate of transformation or, more precisely, intertemporal marginal rate of substitution of output supply is equal to the ratio of marginal costs of output in two successive periods:

$$-\frac{dy_{ts}^{k}}{dy_{t+1s}^{k}} = \frac{\partial F_{t+1s}^{k}(y_{t+1s}^{k},\ x_{1,t+1s}^{k},\ \ldots,\ x_{n,t+1s}^{k})/\partial y_{t+1s}^{k}}{\partial F_{ts}^{k}(y_{ts}^{k},\ x_{1,ts}^{k},\ \ldots,\ x_{n,ts}^{k})/\partial y_{ts}^{k}} = \frac{\lambda_{t+1s}^{k}(y_{t+1s}^{k},\ \hat{w}_{1,t+1s},\ \ldots,\ \hat{w}_{n,t+1s})}{\lambda_{ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts})}, \tag{6}$$

where $\lambda_{ts}^{k}(y_{ts}^{k}, w_{1,ts}^{k}, \ldots, w_{n,ts}^{k}) \equiv \partial C_{ts}^{k}(y_{ts}^{k}, w_{1,ts}^{k}, \ldots, w_{n,ts}^{k}) / \partial y_{ts}^{k}$ is the marginal cost of output for the producer of the *k*th country at time-state *ts*.

Given the cost function (3), state-contingent within-period profit for the producer of the kth country, $\hat{\Phi}_{ts}^{k}$, is defined as

$$\hat{\Phi}_{ts}^{k} \equiv \hat{p}_{ts}^{k} y_{ts}^{k} - C_{ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts}), \tag{7}$$

where $\hat{p}_{ts}^{k}$ is the state-contingent price of output for country *k* at time-state *ts*. Suppose that the representative producer of the kth country chooses output over time so as to maximize expected utility of the sum of profits:

$$\max_{y_{ts}^{k}} E_1\left[\sum_{t=1}^{T} U_{ts}^{k}(\hat{\Phi}_{ts}^{k})\right] = \max_{y_{ts}^{k}} \sum_{s=1}^{S} \sum_{t=1}^{T} \pi_{ts} U_{ts}^{k}(\hat{p}_{ts}^{k} y_{ts}^{k} - C_{ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts})), \tag{8}$$

where E_1 is the expectation operator conditional on the information set available at time 1 and B_{ts} is the probability at time-state *ts*, with $E_S B_{ts} = 1$. Producers have common probability assessment about future states of nature. The utility function $U_{ts}^{k}(\hat{\Phi}_{ts}^{k})$ in (8) is an increasing and concave function satisfying the von Neuman-Morgenstern postulates. It has a time subscript to allow for, among others, discounting and changing preferences.

The solution to the problem (8) gives rise to the within-period first-order condition:

$$B_{ts}\,\mu_{ts}^{k}(\hat{\Phi}_{ts}^{k})(\hat{p}_{ts}^{k} - \lambda_{ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts})) = 0, \qquad \textbf{(9)}$$

which yields the familiar profit maximization condition:

$$\hat{p}_{ts}^{k} = \lambda_{ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts}), \qquad \textbf{(10)}$$

where $\mu_{ts}^{k}(\hat{\Phi}_{ts}^{k}) \equiv \partial U_{ts}^{k}(\hat{\Phi}_{ts}^{k}) / \partial \hat{\Phi}_{ts}^{k}$ is the marginal utility of profit at time-state *ts*. Since this condition also holds for next period, it implies that, between two periods *t* and *t +1*, the following intertemporal equilibrium condition holds which plays a crucial role in this analysis:

Lemma. *The intertemporal equilibrium condition in production is defined by the production Euler equation of the form:*

$$\lambda_{ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts}) = \frac{\hat{p}_{ts}^{k}}{\hat{p}_{t+1s}^{k}}\lambda_{t+1s}^{k}(y_{t+1s}^{k},\ \hat{w}_{1,t+1s},\ \ldots,\ \hat{w}_{n,t+1s}), \qquad \textbf{(11)}$$

which can be rewritten as

$$\lambda_{ts}^{k}(y_{ts}^{k},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts}) = (1 + r_{t+1s}^{k})\lambda_{t+1s}^{k}(y_{t+1s}^{k},\ \hat{w}_{1,t+1s},\ \ldots,\ \hat{w}_{n,t+1s}), \qquad \textbf{(12)}$$

where r_{t+1s}^{k} *is the state-contingent real rate of return for country k at time t realized at time t+1, defined by the relation (see Rouwenhorst, 1995):*[3]

$$1 + r_{t+1s}^{k} \equiv \frac{\hat{p}_{ts}^{k}}{\hat{p}_{t+1s}^{k}}. \qquad \textbf{(13)}$$

The production Euler equation (12) is a generalization of Fisher's intertemporal production equilibrium condition under certainty which requires that the interest rate is equal to the intertemporal marginal rate of transformation. In particular, interest is a reward for foregoing present production for future production. The left side of (12) is the marginal cost of producing one less unit of output at time t; the right side is the marginal benefit from investing the output and selling it at t+1 for $(1 + r_{t+1})$ dollars at every state. The producer equates marginal cost and marginal benefits, so (12) expresses the intertemporal production equilibrium condition. Under certainty with risk neutrality, (13) describes the Fisher parity relation linking the real interest rate to the nominal interest rate and inflation. These results demonstrate the Fisher separation theorem, which says that, if asset markets are complete, the production decision is governed by maximizing the firm's profit maximization without regard to individuals' subjective or risk preferences, so that production and consumption decisions can be completely separated.[4]

If countries trade a complete set of contingent claims in world capital markets, they face the same output as well as input prices at every time and state. Since, in equilibrium, producers in different countries equate the output price to marginal cost of output, then from (11), we find

$$\frac{\lambda^k_{t+1s}(y^k_{t+1s},\ \hat{w}_{1,t+1s},\ \ldots,\ \hat{w}_{n,t+1s})}{\lambda^k_{ts}(y^k_{ts},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts})} = \frac{\hat{p}_{t+1s}}{\hat{p}_{ts}}, \qquad \textbf{(14)}$$

where $\hat{p}$ is the state-contingent output price that is common to every country. Condition (14) requires that the ratio of marginal costs of output be equalized ex post across countries at every state. Moreover, financial markets are fully integrated if assets with identical risk command the same expected returns irrespective of the market. If financial markets are complete and fully integrated globally, investors in different countries have access to the complete menu of financial assets and evaluate risk in the same way. As a result, comparable assets issued in different locations will command the same rate of return at every state, i.e., $r^1_{ts} = \ldots = r^K_{ts} = r_{ts}$, where r_{ts} is the world rate of interest or return at time-state *ts*. Perfect capital mobility allows the rates of returns to be equalized across countries.[5] Then from (12), we have

$$\frac{\lambda^k_{t+1s}(y^k_{t+1s},\ \hat{w}_{1,t+1s},\ \ldots,\ \hat{w}_{n,t+1s})}{\lambda^k_{ts}(y^k_{ts},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts})} = \frac{1}{1 + r_{t+1s}}. \tag{15}$$

When condition (14) is satisfied, it will also ensure (15) to be met (see equation (13)). Taking logs on both sides of (15) now gives the result: $\ln(\lambda^k_{t+1s} / \lambda^k_{ts}) = -\ln(1 + r_{t+1s}) \approx -r_{t+1s}$, which says that growth rates of marginal cost are the same across countries at every state and are equal to the (negative) world interest rate.

Thus we have proved the following theorem:

Theorem 1. *Suppose that countries have access to complete international or global financial markets and capital is perfectly mobile across countries. If international financial markets are completely or fully integrated, then the intertemporal marginal rate of substitution in production given by the ratio of marginal costs of output in two successive periods is equal for producers in different countries across states of nature, and countries' marginal cost growth rates are the same and equal to the (negative) world rate of return on assets. If international capital market linkages are incomplete, this reflects differences in countries' intertemporal marginal rates of substitution in production.*

Recent studies on asset pricing rely on the stochastic discount factor framework to account for equity returns or equity premiums. In an intertemporal equilibrium analysis, the stochastic discount factor is the intertemporal marginal rate substitution. For consumption-based models, it is given by the ratio of marginal utilities of consumption in two periods. For the production-based model, it is described by the ratio of marginal costs in two periods. However, when the economy is in equilibrium, the country's intertemporal marginal rate in production is equal to the intertemporal marginal rate of substitution in consumption. Obsfeld (1989) uses a consumption-based model and examines whether the intertemporal marginal rates in consumption are equal across countries to test for international financial market integration.

To derive empirical implications of this analysis, consider the familar Cobb-Douglas cost function (with state index suppressed):

$$C_t^k = (1/B_t^k)(y_t^k)^{\alpha_y} \prod_{i=1}^{n} \hat{w}_{it}^{\alpha_i}, \qquad \textbf{(16)}$$

where B_t^k is an exogenous country-specific technology shock at time t.[6] Each country has the same cost function except for the technology shock. Here α_i measures the share of the ith input in total cost, and the linear homogeneity of the cost function implies that $\Sigma_i \alpha_i = 1$. Further, α_y measures the degree of returns to scale. When $\alpha_y < 1$, increasing returns to scale or economies of scale exist; $\alpha_y > 1$ implies decreasing returns to scale or diseconomies of scale, and $\alpha_y = 1$ implies constant returns to scale.

For (16), marginal cost of output is given by

$$\lambda_t^k = \alpha_y (1/B_t^k)(y_t^k)^{\alpha_y - 1} \prod_{i=1}^{n} \hat{w}_{it}^{\alpha_i}. \qquad \textbf{(17)}$$

Now using (17), condition (15) gives

$$\frac{1}{(B_{t+1}^k/B_t^k)} \left(\frac{y_{t+1}^k}{y_t^k}\right)^{\alpha_y - 1} \prod_{i=1}^{n} \left(\frac{\hat{w}_{it+1}}{\hat{w}_{it}}\right)^{\alpha_i} = \frac{1}{1+r_t}. \qquad \textbf{(18)}$$

Taking logs on both sides of this expression and rearranging, we obtain

$$\ln(1+r_t) = \ln\left(\frac{B_{t+1}^k}{B_t^k}\right) + (1-\alpha_y)\ln\left(\frac{y_{t+1}^k}{y_t^k}\right) - \sum_{i=1}^{n} \alpha_i \ln\left(\frac{\hat{w}_{it+1}}{\hat{w}_{it}}\right). \qquad \textbf{(19)}$$

There are many studies looking at equity returns from the production side (see Kim, 2003, for a detailed discussion). Equation (19) tells us the underlying determinants of equity returns from the production side, namely output growth, technology shocks, and input price shocks. A (positive) technology shock will lead to higher equity returns, while input price shocks will lead to lower equity returns. How output growth affects equity returns hinges on the degree of returns to scale. When there are increasing returns to scale, higher output growth is associated with higher equity returns; when there are decreasing returns to scale, higher output growth is associated with lower equity returns.

Since there are K countries (k = 1, ..., K) that are financially integrated, condition (19) implies that $\ln(B_{t+1}^{1} / B_{t}^{1}) = \ldots = \ln(B_{t+1}^{K} / B_{t}^{K})$ and $\ln(y_{t+1}^{1} / y_{t}^{1}) = \ldots = \ln(y_{t+1}^{K} / y_{t}^{K})$. When there are no country-specific technology shocks, this suggests that output growth rates must be the same for all countries. These results allow us to establish the following proposition:

Proposition 1. *Suppose that countries have the identical Cobb-Douglas cost function. If countries face the same input shocks but no technology shocks, complete global financial integration requires that countries' output growth rates be perfectly correlated (or nearly so) so that domestic output growth rates are identical to the growth rates of world output. This implies that, under completely integrated financial markets, national factors have no impact on a country's equity returns, but common global factors do. If most of the variation in a country' economic activity stems from global shocks driving world business cycles, countries should have high equity correlations. If output growth rates are excessively volatile, ceteris paribus, this should translate into an equally excessive degree of world equity returns. That is, world equity correlations should be too high to be justified by subsequent changes in domestic outputs.*

Lewis (1999) discusses implications of full financial integration in the context of international and consumption-based asset pricing models. However, there is no role for output growth as well as technology and input price shocks in these models. Dumas, Harvey, and Ruiz (2003) study the link between international stock market correlations and countries' output growth correlations in the context of a consumption-based asset pricing model. They identify the output variable by assuming a pure endowment economy in which world output equals world consumption. This has the effect of confounding production variables with consumption variables or structures. They, however, find that world output growth rates can explain cross-country equity returns (see footnote #16 for a further discussion). Our analysis provides an explicit role for output growth and demonstrates further that technology and input price shocks can also account for cross-country equity return correlations.

III. The Social (World) Planner Problem for Output Allocation among Countries under Production Risk and Efficient Risk Sharing Rules

In the preceding section, each country was concerned with the optimal production decision over time under uncertainty by participating in world financial markets. We now examine the optimal decision taken by countries as a whole under uncertainty when there is a social (world) planner who coordinates the production activities of different countries over time and across states of nature. Inputs are perfectly mobile across countries. We postulate a small open economy in which each country faces the same input prices[7] and world interest rate which are determined exogenously. There are no technological externalities among countries, i.e., countries' production technologies are independent so that inputs used by one country do not affect outputs of other countries. Moreover, producers in different countries are subjected to two kinds of production risk or shock: idiosyncratic shock that is random and independent across countries and aggregate (global) or common shock hitting all countries simultaneously in a similar way. In this situation, while countries cannot diversify away aggregate shocks, they can fully pool or share the idiosyncratic shocks among themselves so that these shocks, whether anticipated or not, do not impinge on each country's production decision. Then efficient sharing of risk is possible across countries, so the impact of the idiosyncratic shocks on production averages to zero across countries at all times and states. Interestingly, risk that is systematic in the context of the domestic economy may be unsystematic or idiosyncratic in the context of the world economy. For example, an oil price shock that hurts the U.S. economy helps the economies of oil-exporting countries, and vice versa, with its effect that may be canceling out each other. A global oil price shock (such as those in 1970s), on the other hand, has a systematic effect across all countries with its effect not canceling each other.

Formally, the social (world) planner minimizes the sum of the expected cost of an individual country by their choice of outputs and inputs across countries subject to the production technology in (1) and the feasible output constraint:

$$\sum_{k=1}^{K} y_{ts}^{k} = \overline{y}_{ts}, \qquad \textbf{(20)}$$

where $\bar{y}_{ts}$ is an aggregate (world) output to be allocated among countries across time and state. We assume that world output equals world consumption and that each country consumes its allocated output.

Definition 1. *The following problem summarizes the social (world) planner's problem for intertemporal production allocation among countries under uncertainty*:

$$
\begin{aligned}
&\min_{x_{i,ts}^k,\, y_{ts}^k} \sum_{k=1}^{K} \sum_{s=1}^{S} \sum_{t=1}^{T} B_{ts} \sum_{i=1}^{n} \hat{w}_{i,ts} x_{i,ts}^k \\
&s.t. \quad \sum_{t=1}^{T} F_{ts}^k(y_{ts}^k,\ x_{1,ts}^k,\ \ldots,\ x_{n,ts}^k) = 0 \qquad \textbf{(21)} \\
&\sum_{k=1}^{K} y_{ts}^k = \bar{y}_{ts}.
\end{aligned}
$$

This problem can be solved using a two stage procedure. In the first stage, each country minimizes cost subject to a predetermined allocation of output, and in the second stage, the social planner makes an efficient allocation of aggregate output among countries.[8]

The first stage problem, discussed in the previous section, is stated in (2), which gives the cost function (3). Given this cost function, the second stage problem for the social planner is now:

$$
\begin{aligned}
&\min_{y_{ts}^k} \sum_{k=1}^{K} \sum_{s=1}^{S} \sum_{t=1}^{T} B_{ts} C_{ts}(y_{ts}^k,\ \hat{w}_{1,ts},\ldots,\hat{w}_{n,ts}) \\
&s.t. \quad \sum_{k=1}^{K} y_{ts}^k = \bar{y}_{ts}. \qquad \textbf{(22)}
\end{aligned}
$$

The first-order condition with respect to output is

$$8_{ts}^k(y_{ts}^k,\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts}) = D_{ts} \ \textit{for all ts}, \qquad \textbf{(23)}$$

where D_{ts} is the Lagrange multiplier associated with the output constraint divided by B_{ts}.

Solving (23) for y_{ts}^k, we get

$$y_{ts}^{k} = g_{ts}^{k}(\hat{w}_{1,ts}, \ldots, \hat{w}_{n,ts}, D_{ts}). \qquad \textbf{(24)}$$

Substituting (24) into the input demand functions (4) gives

$$x_{i,ts}^{k} = x_{i,ts}^{k}(\hat{w}_{1,ts}, \ldots, \hat{w}_{n,ts}, D_{ts}). \qquad \textbf{(25)}$$

Note that, in (24) and (25), D_{ts} is constant across countries. Now substituting (24) into the output constraint (20), we have

$$\sum_{k=1}^{K} g_{ts}^{k}(\hat{w}_{1,ts}, \ldots, \hat{w}_{n,ts}, D_{ts}) = \bar{y}_{ts}, \qquad \textbf{(26)}$$

which can be solved for D_{ts} to yield

$$D_{ts} = D_{ts}(\hat{w}_{1,ts}, \ldots, \hat{w}_{n,ts}, \bar{y}_{ts}). \qquad \textbf{(27)}$$

Substituting (27) into (24) and (25), we find that the country's output supply and input demand depend on input prices and world output that act as aggregate shocks.

All this can be summarized in the following result:

Theorem 2. *Suppose that countries are exposed to production shocks and that inputs are perfectly mobile across countries. An efficient sharing rule for output among producers in different countries requires that the marginal cost of output be equated across countries at every state and time, which depend only on aggregate shocks served by world output and input prices, as they diversify all idiosyncratic variation in production. If all shocks are common shocks, there are very limited opportunities for risk sharing among countries.*

In addition, equation (23) implies that, between two periods, *t* and *t+1*, the following intertemporal equilibrium condition holds:

$$\frac{\lambda^{k}_{t+1s}(y^{k}_{t+1s},\ \hat{w}_{1,t+1s},\ \ldots,\ \hat{w}_{n,t+1s})}{\lambda^{k}_{ts}(y^{k}_{ts},\ \hat{w}_{1,ts},\ \ldots,\ \hat{w}_{n,ts})} = \frac{\rho_{t+1s}}{\rho_{ts}}, \tag{28}$$

which says that the ratio of marginal costs of output in two successive periods is equal across countries. If there are complete or fully integrated global financial markets, equating (15) and (28) yields

$$\frac{\rho_{t+1s}}{\rho_{ts}} = \frac{1}{1 + r_{t+1s}}. \tag{29}$$

This condition implies that full risk sharing among countries can be achieved by complete global financial markets. Thus we have established the following theorem:

Theorem 3. *An efficient sharing rule for output among countries under production uncertainty requires that the ratio of marginal costs of output in two successive periods be equalized across countries, which does not depend on idiosyncratic shocks but on aggregate shocks affecting all countries. The risk sharing rule among countries is the same as the condition for complete financial integration. Thus when countries are completely integrated financially, there is perfect risk sharing among them, and vice versa.*[9] *By implication, trade in world financial markets, while promoting equality of asset returns across countries, allows producers in a country to share their idiosyncratic risks and smooth production internationally by reducing production volatility, i.e., the variability of the marginal cost over time, across countries. Conversely, increased risk sharing among countries requires greater international asset trade and financial integration or diversification.*

The underlying concept of the production-based model of financial integration and risk sharing is the familiar cost function. To derive empirical implications of risk sharing, consider the aforementioned Cobb-Douglas cost function (16). Then condition (28) coupled with (29) gives

$$\ln\left(\frac{y_{t+1}^{k}}{y_{t}^{k}}\right) = \beta_A \ln\left(\frac{B_{t+1}^{k}}{B_{t}^{k}}\right) - \beta_\rho \ln\left(\frac{\rho_{t+1}}{\rho_t}\right) + \sum_{i=1}^{n} \beta_i \ln\left(\frac{\hat{w}_{it+1}}{\hat{w}_{it}}\right) \qquad \textbf{(30)}$$

or

$$\ln\left(\frac{y_{t+1}^{k}}{y_{t}^{k}}\right) = \beta_A \ln\left(\frac{B_{t+1}^{k}}{B_{t}^{k}}\right) + \beta_\rho \ln(1 + r_{t+1}) + \sum_{i=1}^{n} \beta_i \ln\left(\frac{\hat{w}_{it+1}}{\hat{w}_{it}}\right), \qquad \textbf{(31)}$$

where $\beta_A = -1/(1 - \alpha_y)$, $\beta_\rho = 1/((1 - \alpha_y)$, and $\beta_i = \alpha_i/(1 - \alpha_y)$. Since ρ_t depends on world output and input prices (see equation (27)), equation (30) shows that a country's output growth varies with aggregate shocks as represented by world output and input prices, after controlling for the undiversifiable country-specific technology shock. This means that while idiosyncratic shocks can be diversified away, aggregate and country-specific technology shocks can affect the individual country's production decisions. Moreover, (31) shows that the world interest rate is a proxy for world output growth under full financial integration with the parameter β_ρ describing the degree of intertemporal substitution in output supply. When there are no technology and input price shocks, the absence of intertemporal substitution accounts for production smoothing. Importantly, (31) can also explain the effect of financial diversification on a country's economic growth. In particular, financial diversification encourages small countries to specialize and more generally to shift production from safe, low-return projects toward higher-risk, higher return projects (see Obstfeld, 1994; Acemoglu and Zilibotti, 1997). When there are increasing returns to scale, this will increase a country's output growth rate. Alternatively, to the extent that financial integration reduces the cost of equity capital, it will increase investment and raise output (see Henry, 2003).

Since there are K countries (k = 1, ..., K) that pool risk among themselves, when there are no country-specific technology shocks or when countries face common technology shocks (in addition to common interest rate or world output and common input prices), equation (30) or (31) implies that $\ln(y_{t+1}^{1} / y_{t}^{1}) = \ldots = \ln(y_{t+1}^{K} / y_{t}^{K})$, which implies the same output growth rate for all countries. These results allow us to state the following proposition:

Proposition 2. *Suppose that world financial markets are completely integrated so that countries face the same world interest rate. Then an efficient risk sharing rule for output among countries under production risk implies that an individual country's output varies with the world interest rate and input prices. For a Cobb-Douglas cost function, under full risk sharing, output growth rates are perfectly correlated (or nearly so) across countries in the absence of country-specific technology shocks as they diversify all idiosyncratic variation in production. Moreover, to the extent that countries can fully insure risk, domestic output growth rates should mirror world growth rates, yielding a ratio of 1. When there are country-specific technology shocks that are uncorrelated, output growth rates will not be perfect across countries, pointing to imperfect international risk sharing. If world financial markets are not completely integrated, on the other hand, output growth rates will not be equalized and countries cannot achieve full risk sharing either.*[10]

International risk sharing is, in effect, related to cross-country business cycle co-movements or synchronization, and the driving force underlying common cyclical behavior across countries is common or global shocks. We can draw the following implications from the above proposition.

Corollary. *While countries can diversify away their idiosyncratic shocks, undiversifiable production risks (such as technology and input price shocks) and the degree of financial integration can account for cross-country output or business cycle co-movements across countries. In particular, when there are technology shocks that are correlated across countries, ceteris paribus, there will be perfect cross-country output correlations.*[11] *When technology shocks are uncorrelated across countries, however, cross-country output correlations will not be perfect. Moreover, to the extent that greater financial integration or diversification increases risk sharing among countries, ceteris paribus, it should have a positive effect on cross-country output correlations or business cycle co-movements across countries when there are increasing returns to scale.*

The importance of technology or productivity shocks in generating cross-country business co-movements is well recognized in two-country international real business cycle models (see Backus, Kehoe, and Kydland, 1992), which arises as long as the assumption of perfectly correlated technology shocks is maintained.[12] The present model based on the cost minimization problem that is dual to the production problem in international real business cycle models, on the other hand, demonstrates that for output grow rates to be perfectly correlated across countries we also need to assume common interest rates and input prices. Mendoza (1991) recognizes that the world interest rate is potentially an important mechanism for transmitting international shocks to small open economies. For small open economies, this variable is exogenously determined. Blankenau, Kose, and Yi (2002) show that world interest shocks are able to explain a significant fraction of the observed fluctuations in output in a small open economy (Canada). Heathcote and Perri (2003) consider technology shocks and financial integration in explaining observed changes in international consumption and output growth correlations and find that increasing financial integration or linkages is the key factor, clearly helping countries to better share consumption and production risks. Our analysis bolsters this finding. Also, fluctuations in the terms of trade – the price of a country's exports relative to the price of its imports – are viewed as a source of business cycles in small open economies (Mendoza, 1995). This variable can be seen as reflecting input price shocks. Obstfeld (1994) includes world output and oil price shocks in an international consumption regression equation for risk sharing and finds them significant. These variables, however, constitute production, not consumption, shocks identified in the present analysis – see equation (27). Thus it appears that earlier studies have believed, though imperfectly, that the production variables and the world interest rate were important for determining cross-country co-movements. However, their analyses are couched in the consumption-based framework and lack clear theoretical underpinnings of the intertemporal cost minimization problem inherent in the producer's behavior. As a result, they confound production variables with consumption variables or structures and fail to identify a separate contribution of production decisions on risk sharing from consumption decisions.

IV. How Useful Is the Production-Based Model Relative to Consumption-Based Models? The Cross-Country Consumption-Output Correlation Puzzle and Some Evidence on International Risk Sharing

The state-contingent intertemporal production model and the social planner's problem of output allocation under production risk are particularly relevant for analyzing international financial integration and international risk sharing by viewing countries as producers of goods and services. If countries have access to complete global financial markets, rates of return on assets are the same for all countries. Moreover, if there is perfect risk sharing among countries, correlations of output growth rates are perfect across countries and thus output growth in each country should be identical to the growth rate of world output. There is perfect risk sharing among countries under fully integrated financial markets.

Existing studies on international capital mobility or financial integration (see Obstfeld, 1989; Bayoumi and MacDonald, 1995; Ghosh, 1995) and on international risk sharing (see Obstfeld, 1994; Tesar, 1995; Canova and Ravn, 1996; Lewis, 1996, 1999; Crucini, 1999) hinge on a consumption-based model in which consumers maximize expected utility of consumption over time under uncertainty subject to the endowment constraint. Trade in international financial markets allows people in a country to insure country-specific risk and smooth consumption internationally. The principal implication of the international consumption risk sharing model is that marginal utility of consumption is equalized across countries. If consumers' preferences are characterized by a constant relative risk aversion, this further implies that consumption growth rates are perfectly correlated across countries. Importantly, with no technology and input price shocks, these predictions are the same as those found for the production-based risk sharing model when output is treated as consumption. However, since in equilibrium the intertemporal marginal rate of substitution in consumption is equal to the intertemporal marginal rate of substitution in output supply, which is the same as the world interest rate, the consumption or production-based model can equally be used to investigate issues involving international financial integration or risk sharing among countries.

Yet the proposed production-based approach offers many advantages over consumption-based models. Production proxies for the cash flows generated by stock securities and current and past production is the information variable that investors use in their investment decisions (Cochrane, 1996; Dumas, Harvey, and Ruiz, 2003). Moreover, production variables such as output or investment are more volatile and more characteristic of economic fluctuations than consumption, and stock returns are found to be significantly related to production or real activity (Cochrane, 1996; Kim, 2003). Also, difficulties in measuring consumption are well known and, as a result, production or output variables tend to be measured more accurately than consumption data. These facts may favor the production-based model relative to consumption-based models in empirical analysis. There are, however, some fundamental reasons for the choice of the production-based model. First, while the concept of the social planner is not clear in consumption-based models, the multinational corporation can operate as the social planner in the production-based model. Consumers are widely dispersed with different utility functions and each consumer represents a small share of total GDP or consumption spending. Each consumer thus has little to gain from risk reduction strategies. Instead, multinational corporations are directed by a small number of managers who have a strong interest in risk reduction because these activities increase expected profitability of the firm – there is a high reward for risk reduction. Thus the multinational corporation could be looked at as a social institution that coordinates production to improve the mobility of resources across national boundaries.

Next, efficiency in production across countries requires that marginal cost be equal for all countries at every state and time. The growth of international production and multinational enterprises in particular suggests that this efficiency condition is more likely to be met than the condition about equal marginal utilities of consumption implied by consumption-based models.[13] The theory of multiplant production indicates that the firm equalizes marginal costs across all plants to achieve efficient production allocation. The transfer pricing model also suggests that firms set transfer prices equal to the marginal cost of production in order to achieve efficient allocation across plants. Further, the transfer of capital and technology can help equalize factor prices (i.e. lead to similar marginal costs) across nations and reduce the risk of production operations for the firm.

In addition, corporations and producers are more likely to use international financial markets to smooth production than consumers are likely to use those markets to smooth consumption. There are substantial information problems (i.e., adverse selection, moral hazard, principal agent problems) in financial markets, and search models often predict that the information cost and transactions costs of using these markets might be greater than the expected benefits of risk reduction (see Lewis, 1999). This is especially true of international financial markets where information problems could be more acute and the risk of market involvement is greater because of ambiguities about international law, local customs governing labor relations, etc. (see Gordon and Bovenberg, 1996). This suggests that consumers might have to incur high costs but have little to gain by hedging against risk associated with international transactions.[14] The transactions cost and information problems favor larger participants over the smaller ones, i.e., large international corporations over consumers, in financial markets. In sum, international financial markets may not be an adequate mechanism for consumers to share the risk of consumption, but they do provide opportunities for firms to diversify the risk of international production.

To provide some empirical support for the production-based model relative to consumption-based models, Table 1 documents some stylized facts for cross correlations for equity returns, consumption growth, and output growth, and relative variability of these variables for industrialized countries, taken from Tesar (1995) (see also Backus, Kehoe, and Kydland, 1992; Devereus, Gregory, and Smith, 1992; Obstfeld, 1994; Baxter, 1995; Canova and Ravn, 1996; Lewis, 1996, 1999; Pakko, 1998). In contrast to developing countries, these countries have highly diversified capital markets and are mostly likely to engage in international risk sharing. Estimated cross-country correlations of rates of return are positive but fall far short of unity, with an average correlation of 0.56. If capital is internationally mobile, the rates of return in different countries will tend to move in a synchronized fashion as investors shift their portfolios toward assets offering relatively high yields. The evidence suggests that world capital markets, even for industrialized countries, are not fully integrated, exhibiting a lack of "international portfolio diversification" or the presence of a substantial "home bias" in equity holdings of domestic countries (see Lewis, 1999, for many possible explanations). On the other hand, since domestic equity returns move significantly with world returns, domestic and world capital markets are not completely segmented.

Estimated cross-country correlations of consumption growth are positive but far from perfect as predicted by intertemporal consumption risk sharing models. The average correlation between world consumption growth and consumption growth rates in industrialized countries is 0.32. Thus the evidence is weak to support perfect or a high degree of consumption risk sharing among countries. Estimated cross-country correlations of output growth are also positive but fall short of unity, with an average correlation of 0.48.[15] By implication, risk sharing is clearly present, though imperfect, in production among countries. There are, however, large variations in cross-country consumption and output growth correlations, which may reflect varying degrees of risk sharing in consumption and production among countries. The finding of imperfect consumption and production risk sharing among countries can be taken as indirect evidence of imperfect world financial market integration or imperfect portfolio diversification.[16]

Remarkably, however, the cross-country output correlations tend to be higher than the cross-country consumption correlations. Further, the relative variability of consumption growth rates is, by and large, higher than that of output growth rates,[17] and consumption fluctuations are found to be more highly correlated with domestic production rather than world output (Backus, Kehoe, and Kydland, 1992; Devereus, Gregory, and Smith, 1992; Obstfeld, 1994; Pakko, 1998; for a detailed discussion, see Lewis, 1999). These results are strongly at odds with predictions of the consumption-based model, a phenomenon known as “the international or cross-country consumption-output correlation puzzle” in international business cycle and risk sharing models (Backus, Kehoe, and Kydland, 1992). (The same evidence is also found at the regional or intranational levels – see van Wincoop, 1996; Hess and Shin, 1998; Crucini, 1999. However, risk sharing tends to be stronger across regions within a country’s boundaries than across national boundaries – see Asdrudali, Sorensen, and Yosha, 1996; Crucini, 1999; Bayoumi and Klein, 1997.) To the extent that countries can fully insure against idiosyncratic shocks, this may be a reflection of incomplete markets (see Kollman, 1996). Many attempts have been made to resolve the puzzle by modifying the model to allow for, among others, nontraded goods and leisure (labor supply), consumer durable goods, and capital market restrictions, but the results are inconclusive (see Devereus, Gregory, and Smith, 1992; Tesar, 1995; Stockman and Tesar, 1995; Canova and Ravn, 1996; Lewis, 1996, 1999).[18]

The production risk-sharing model instead can provide an explanation for this puzzle. The fact that the cross-country correlation of output growth is positive and large, especially for G-7 or major industrialized countries (see Baxter and Crucini, 1993; Stockman and Tesar, 1995) clearly suggests a substantial degree of production risk sharing among countries. As long as the factors of production are perfectly mobile across countries, there will be production risk sharing opportunities and hence producers of one country have less reason to be concerned about production shocks in their country. In particular, there has been a significant increase in the fraction of firms operating in multiple national markets. These multinational corporations can mitigate risk occurring in one country by shifting resources from other countries (see Otto, Voss, and Willard, 2001, for other aspects of multinational firms in production risk sharing). International trade and an associated change in a country's terms of trade adjustments can also provide insurance against country-specific shock and hence help reduce the country's output variability. Financial markets also offer many risk sharing opportunities for producers and firms engaged in international production.

Risk sharing in production among countries implies strong cross-country output correlations. The nature of the puzzle is that consumption-based risk sharing models predict that consumption correlations will be higher than output correlations, while the data show otherwise. The issue then is one of the relative magnitudes of cross-country correlations. The model of this paper focuses only on producers' cost minimization problems with no account of the consumption side of the economy. As such, it is not specific about the relationship between production and consumption, and it may be difficult to draw any firm conclusions about the relative magnitudes of cross-country correlations. Yet, in contrast to consumption-based models where consumption is subject to the endowment constraint with an exogenous production process, the production-based model presumes that the production process is endogenous, subject to the constraint that all output produced in a country is consumed by that country. In this case, the model would predict identical cross-country consumption and output correlations. To the extent that a country could produce more than it consumes due to capital formation or export, it would even predict that cross-country production correlations could exceed the consumption correlations. The international consumption-output correlation puzzle then may not be so puzzling after all. It simply reflects an inability to account for risk sharing among producers in countries in previous studies, while allowing only for risk sharing among consumers.

Although comparisons of relative volatility and consumption and output growth correlations give us some general idea of consumption and production risk sharing among countries, they do not tell us the quantitative importance of international risk sharing. We now undertake such an analysis by applying the international risk sharing index developed by Brandt, Cochrane, and Santo-Clara (2001) which is grounded in the stochastic discount factor framework. The use of this index begs the following questions: What is the actual degree of international risk sharing? What is the extent of financial market integration or diversification in international risk sharing? And given the importance of production risk sharing, can it be used as a valid measure of international risk sharing? Since Brandt, Cochrane, and Santo-Clara (2001)'s proposed index is a new, but useful, concept, we briefly introduce it here and apply it to our problem.

Definition 2. *The degree of international risk sharing (IRS) is measured by the index*

$$IRS = 1 - \frac{\sigma^2(\ln m_{t+1}^{f} - \ln m_{t+1}^{d})}{\sigma^2(\ln m_{t+1}^{f}) + \sigma^2(\ln m_{t+1}^{d})}, \qquad \textbf{(32)}$$

where σ^2 *denotes variance, and* m_{t+1}^{f} *and* m_{t+1}^{d} *are foreign and domestic stochastic discount factors between time t and t+1.*

The numerator in the above formula measures the amount of risk that is not shared, while the denominator measures the amount of risk to share between domestic and foreign countries. This is clear when we note that the numerator is $\sigma^2(\ln m_{t+1}^{f} - \ln m_{t+1}^{d}) = \sigma^2(\ln m_{t+1}^{f})$ $-2Cov(\ln m_{t+1}^{f}, \ln m_{t+1}^{d}) + \sigma^2(\ln m_{t+1}^{d})$. Then we can express the international risk sharing index (32) as $IRS = 2Cov(\ln m_{t+1}^{f}, \ln m_{t+1}^{d}) / (\sigma^2(\ln m_{t+1}^{f}) + \sigma^2(\ln m_{t+1}^{d}))$ or $IRS = 2\sigma_{fd}\sigma(\ln m_{t+1}^{f})\sigma(\ln m_{t+1}^{d}) /$

$(\sigma^2(\ln m^f_{t+1}) + \sigma^2(\ln m^d_{t+1}))$ where σ_{fd} is the correlation between $\ln m^f_{t+1}$ and $\ln m^d_{t+1}$. Thus the risk sharing index accounts for volatilities as well as correlation of foreign and domestic stochastic discount factors. The risk sharing index is bounded by 0 and ± 1. It is equal to 0 if foreign and domestic discount factors, $\ln m^f_{t+1}$ and $\ln m^d_{t+1}$, are uncorrelated. It is equal to +1 if $\ln m^f_{t+1} = \ln m^d_{t+1}$, which implies that international risk sharing is perfect if foreign and domestic discount factors are perfectly correlated *and* if their variances are identical. The index is equal to -1 if $\ln m^f_{t+1} = -\ln m^d_{t+1}$, which is an unlikely case.

Brandt, Cochrane, and Santo-Clara (2001) develop the risk sharing index (32) in the context of consumption-based models, but it can be adopted to the present production-based model. Here the stochastic discount factor is the ratio of marginal costs in two successive periods; hence $\ln m_{t+1} = \ln(\lambda_{t+1} / \lambda_t)$ describes a country's marginal cost growth rate. Since the marginal cost growth rate is equal to the (negative) rate of return in equilibrium (see equation (15) and the attendant discussion), this means that the degree of international risk sharing can be measured by looking at equity returns in two countries.[19] In effect, then, the extent of financial integration or linkages accounts for the degree of international risk sharing. When domestic and foreign stock markets are perfectly correlated or fully integrated (and when their return volatilities are identical), the degree of international risk sharing is 1. When domestic and foreign stock markets are not integrated at all, the degree of international risk sharing is 0. However, since the marginal cost growth rate is a function of output growth as well as technology and input price shocks, if countries face no technology and input price shocks but have the same degree of returns to scale, the degree of international risk sharing can also be measured by looking at domestic and foreign output growth rates. If output growth rates are equal for domestic and foreign countries, there will be perfect risk sharing. When there are technology and input price shocks, however, the output or production measure of international risk sharing in general will not be the same as the equity measure .

Table 2 presents three different measures of international risk sharing for selected countries using the information in Table 1. Each country is related to other countries or the rest of the world (ROW). Some important results emerge from this table. First, the equity measure of risk sharing shows that no country has perfect risk sharing with the rest of the world, as evidenced by the value less than 1. Perfect international risk sharing would characterize a world with complete markets with free and costless international asset and commodity trade. Since world financial markets are incomplete or imperfectly integrated (as was seen from Table 1), countries cannot pool all idiosyncratic risks. However, they *can* realize some (imperfect) degree of risk sharing among themselves through the existing, though imperfect, asset markets via greater financial integration or diversification. The equity measure provides this information. The degree of international risk sharing varies for countries, but it *does* suggest that a country, in general, pools a substantial amount of risk with other countries. The U.S. has the highest value but Italy has the lowest value of international risk sharing. Thus it appears that U.S. has the least, while Italy has the most potential to realize possible gains accruing from unexploited risk sharing opportunities with other countries through greater financial diversification.

Second, the index of international risk sharing is also less than one for the consumption or production measure, but the degree of international risk sharing implied by equity returns is higher than that based on consumption or output growth. If world financial markets are complete and fully integrated and if there are no non-market risks, international risk sharing will be perfect for all measures. Also, to the extent that increasing financial integration allows countries to better share consumption and production risks (see Section III), the three measures of international risk sharing should be close to each other. While the production measure of international risk sharing is quite close to the equity measure, the degree of international risk sharing based on the consumption measure is apparently low, meaning that risks are poorly shared among countries. This suggests that asset trade in world financial markets enables countries to achieve most of the production risk sharing and that the consumption measure is a poor indicator for international risk sharing; in fact, the consumption measure would severely bias the degree of international risk sharing. The evidence is that the degree of international risk sharing is quite substantial and much higher than consumption data reveal.

Finally, the degree of international risk sharing based on output growth is dramatically higher than that based on consumption growth for all countries. This result was also confirmed in Table.

In essence, the evidence shows that while countries face more consumption risks than production risks and, as such, have more opportunities to pool consumption risks than production risks among themselves, they are able to pool production risks much better than consumption risks. This could mean that international financial markets aid in allocating production risks more than consumption risks.

These results are worth summarizing here:

Results. *There is clearly a substantial amount of international risk sharing. Although countries experience more consumption risks than production risks, international risk sharing is, in large measure, realized from pooling production risks rather than consumption risks among countries. Production risk sharing, therefore, likely reveals the degree of international risk sharing much better than does consumption risk sharing.*

This is an important finding – one that previous studies have failed to uncover – but it is consistent with our earlier conjecture. We stressed the growing importance of international production and multinational enterprises and pointed out that financial markets might offer greater opportunities for firms to diversify the risk of international production than for consumers to share the risk of consumption among countries. Despite many efforts, previous studies based on consumption-based models have failed to deliver a definitive answer to low international risk sharing (see Lewis, 1999, for a survey), and evidence about the gains from international risk sharing is less than conclusive (see Tesar, 1995; Lewis, 1999). The weight of the evidence unearthed here suggests that international risk sharing is much better than consumption data show[20] but significant unexploited opportunities for risk sharing among countries remain. Obstfeld (1994) finds that financial integration can bring large welfare gains if diversification has effects on countries' investment and output growth rates. We have demonstrated that this is the case. However, with a clear trend toward increasingly closer integration of goods and asset markets, there will be greater risk sharing among countries but incremental gains from unexploited risk sharing opportunities are likely to be smaller.

V. Summary and Conclusion

This paper has proposed a multi-country, multi-factor production-based model capable of explaining financial integration and risk sharing among countries. The model is based on producers' cost minimization problems with the familiar Cobb-Douglas cost function, which is easily amenable to empirical analysis following the consumption-based methodology (see Obstfeld, 1994; Lewis, 1996). The model has allowed us to find a possible resolution for the international consumption-output correlation puzzle. There is clear evidence – presumptive as well as empirical – that strongly supports the production-based model, and in fact, the production-based model does a better job of explaining world financial integration or risk sharing than do consumption-based models. The production-based model is even more relevant to analyze intranational or regional issues than international issues because there is greater factor or capital mobility among regions within a country than among countries and because regional production or output data are more readily available than consumption data (see Asdrudali, Sorensen, and Yosha, 1996). The cost function employed in this study can also be used to evaluate gains from risk sharing in contrast to the utility function analyzed in traditional consumption-based models (see Tesar, 1995). Although the production-based model is considered as an alternative to consumption-based models, the two models can be used as complements to examine many issues in the economy because they rest on different behavioral assumptions.

We should note, however, that, like most widely-used consumption-based models, the proposed production-based risk sharing model represents a partial equilibrium framework focusing only on producers' cost minimization problems. An important finding of the analysis is a role played by interest rates and input price (in addition to technology shocks) as the driving variables for cross-country dynamics. These prices are assumed to be exogenous. Ideally we need a general equilibrium analysis in which input prices and the interest rate are endogenous, suggesting that the markets for productive inputs and capital need to be modeled. However, when world capital markets are fully integrated, countries face the same world interest rate which is exogenously determined. Moreover, it might be true that shocks to the factor endowment processes, which would comprise an independent source of fluctuations, could be reflected in input prices. Also in a small open-economy framework postulated in this paper, countries face exogenous input prices as well as interest rates. The exogeneity of the prices and interest rates then is an innocuous assumption and is adopted in many international business cycle models. These models do an adequate job of replicating observed business cycle co-movements in many countries (see Mendoza, 1991, 1995; Blankenau, Kose, and Yi, 2002; Kose, 2002).

A number of simplifying assumptions are made to develop the model in this paper, but these assumptions can be relaxed to enrich it. For instance, all inputs are assumed to fully adjust to their optimal levels in response to changes in the economic environment. This may be true for most inputs, but not for capital. Capital can be treated as a quasi-fixed input and adjustment costs can be explicitly incorporated into the cost function. Also, although inputs are perfectly mobile across producers, they are arbitrarily allocated across producers. The model can be extended to allow inputs, especially labor and capital, to be efficiently allocated across producers. In this case, there are feasibility constraints on inputs in addition to the output constraint. The effect is to make some input prices subject to idiosyncratic shocks, in contrast to the assumption made in the present analysis that all input prices are subject to common shocks for all countries. This makes the model more realistic because there is enough evidence that input prices are unequal across countries. Moreover, while the model is based on intertemporal separability, this assumption can be relaxed. With these extensions, the full utility of the proposed model can be ascertained by firm empirical analysis, which is a topic to be explored in future research.

Appendix

The Fisher separation theorem holds when asset markets are complete. If asset markets are incomplete, equation (9) does not hold for every state. Instead we have

$$E_t[\mu_{ts}^k(\hat{\varphi}_{ts}^k)\hat{p}_{ts}] = E_t[\mu_{ts}^k(\hat{\varphi}_{ts}^k)\hat{\lambda}_{ts}^k(y_{ts}^k, \hat{w}_{1,ts}, \ldots, \hat{w}_{n,ts})], \tag{A1}$$

which implies that, between two periods t and $t+1$, the following intertemporal equilibrium condition holds:

$$\mu_{ts}^k(\hat{\varphi}_{ts}^k)\lambda_{ts}^k(y_{ts}^k, \hat{w}_{1,ts}, \ldots, \hat{w}_{n,ts}) = E_t[(1 + r_{t+1s}^k)\mu_{t+1s}^k(\hat{\varphi}_{t+1s}^k)\lambda_{t+1s}^k(y_{t+1s}^k, \hat{w}_{1,t+1s}, \ldots, \hat{w}_{n,t+1s})], \tag{A2}$$

where r_{t+1s}^k is defined by (13). Thus intertemporal production decisions depend on individuals' subjective risk preferences. However, when consumers smooth consumption such that consumption follows a martingale or random walk property (see Hall 1978) and the marginal utility of consumption from profits is constant over time, i.e., $\mu_{ts}^k = \mu_{t+1,s}^k$, then (A2) yields

$$\lambda_{ts}^k(y_{ts}^k, \hat{w}_{1,ts}, \ldots, \hat{w}_{n,ts}) = E_t[(1 + r_{t+1s}^k)\lambda_{t+1s}^k(y_{t+1s}^k, \hat{w}_{1,t+1s}, \ldots, \hat{w}_{n,t+1s})], \tag{A3}$$

so that individuals' preferences do not affect intertemporal production decisions.

These results give rise to the following lemma, which is a generalization of the Fisher separation theorem:

Lemma A. *If asset markets are perfect and complete, the production decision is governed by maximizing the firm's profit maximization without regard to individuals' subjective preferences. If asset markets are incomplete but if the marginal utility of profits follows a martingale process so that there is perfect consumption smoothing, then the production decision is still governed by maximizing the firm's profit maximization without regard to individuals' preferences so that production and consumption decisions can be completely separated.*

Footnotes

[*] The author likes to thank Paul Natke for very helpful comments and suggestions.

[1] There are also studies conducted at the regional or intranational level to examine risk sharing (see van Wincoop, 1995; Asdrudali, Sorensen, and Yosha, 1996; Hess and Shin, 1998; Crucini, 1999) and capital mobility (see Bayoumi and Klein, 1997)

[2] There are many recent production-based studies to examine asset returns (see Cochrane, 1991; Baxter and Jermann, 1997; Bottazzi, Pesenti, and van Wincoop, 1996; Kim, 2003) and capital mobility across countries (see Gordon and Bovenberg, 1996). This underscores the importance of a production-based approach. These studies are, however, based on a simple production function framework which is not grounded in the intertemporal cost minimization problem (Kim, 2003, is an exception) and do not analyze international risk sharing.

[3] This relation can also be defined in terms of security prices (see Altug and Labadie, 1994).

[4] When markets are incomplete, the separation result still obtains when the marginal utility of profits follows a martingale process (see the Appendix for a proof).

[5] In our analysis, the interest rate is a reward for foregoing present production for future production and is related through asset trade to the intertemporal marginal rate of substitution in production or the ratio of marginal costs in two periods. The equilibrium condition for capital allocation, however, requires that the interest rate is equal to the marginal product of capital. Since productive investments that are being undertaken at any point in time will result in greater output and profits at various rates in the future, this means that asset trade implicitly equates the marginal product of capital to the intertemporal marginal rate of substitution in production across countries at every state.

[6] The technology shock specified with the cost function is not the same in form as that commonly identified with the production function in most studies. Consider a Cobb-Douglas production function of the form: $y_t = A_t \Pi_{i=1}^{n} x_{it}^{\beta i}$, where A_t is a technology shock. Then, under constant returns to scale, B_t in the cost function (16) is related to A_t in the production function by $B_t = A_t \Pi_{i=1}^{n} \beta_i^{\beta i}$ (see Henderson and Quandt, 1980, p. 118).

[7] When inputs are completely mobile across countries and the production functions themselves are intertemporally separable, free trade implies complete factor-price equalization.

[8] It is possible that the allocation of output across locations alters factor prices across locations and therefore has an impact on the cost minimization problem.

[9] This result is an application of fundamental welfare theorems to the production side of the economy. Strictly speaking, complete integration of financial markets is only a sufficient but not necessary condition for full risk sharing among countries.

[10] Moroever, this study assumes that countries face the same input prices (common shocks). However, when they face different input prices, output correlations will not be perfect among

countries (see Kose, 2002).

[11] The present model shows that efficient allocation of output across countries based on cost minimization necessarily implies high correlations of output across countries. Yet a puzzle in the international business cycle literature can arise because when productivity is high in one location, physical capital is reallocated there from the less productive location. The reallocation effect tends to produce output correlations lower than technology or productivity correlations. Of course, if technology shocks are perfectly correlated, then output growth rates would be perfectly correlated. Empirically, productivity shocks are not perfectly correlated across countries – if anything, they are less correlated across countries than output growth rates (Stockman and Tesar, 1995), contrary to what the standard model predicts.

[12] An important question in international or open-economy business cycle models is whether worldwide shocks or country-specific shocks are more important in explaining business fluctuations across countries. Ahmed, et al. (1993) find that country-specific shocks contribute more than worldwide shocks to generating international business cycles. Further, international real business cycle models argue that exogenous technology shocks, though country-specific, are transmitted to other countries, driving output comovements across countries (see Backus, Kehoe, and Kydland, 1992). If there are strong international transmission or spillover of technology shocks, virtually all shocks are common shocks. According to Baxter (1995), however, common or aggregate shocks are more likely to be responsible for observed international comovements than transmission of technology shocks over time. Moreover, while movements of technology shocks are positively correlated across countries, they are lower than output correlations (Stockman and Tesar, 1995). Costello (1993) found that a substantial proportion of changes in productivity can be attributed to country-specific factors that are common across industries.

[13] See Markusen (1995) for a discussion of a role of multinational enterprises in international trade.

[14] For example, it has been suggested that GDP growth in the U.S. has fallen about ½ of one percent because of the Asian financial crisis in 1997. Is that a substantial risk that U.S. consumers would find beneficial to mitigate through international financial markets?

[15] Obstfeld (1994) re-examine Tesar's (1995) analysis for the Group of Seven (G-7) countries by including earlier periods and splitting the sample into 1951-72 and 1973-88 periods. He notes that the cross-country correlations for consumption and output increased sharply in the 1973-88 period relative to the 1951-72 period. For industrial countries, these correlations on average rose further in the 1990s. For developing countries, however, these correlations are in general much lower compared to industrial countries and, surprisingly, declined in the 1990s (Kose, Prasad, and Terrones, 2003).

[16] This result, nevertheless, indicates that equity returns or stock market correlations across countries can be explained by economic fundamentals such as consumption or output. Under full risk sharing, cross-country consumption or output correlations would perfectly explain stock market correlations across countries. However, the cross-country output correlations are closer in magnitude to the cross-country return correlations than are the cross-country consumption correlations. Also, relative variability of output growth is closer to the relative variability of rates of return than is the relative variability of consumption growth (see Table 1). This suggests that

stock market correlations across countries are too high to be justified by the (low) level of cross-country consumption correlations. Instead, they can be better explained by the cross-country output correlations (see also Dumas, Harvey, and Ruiz, 2003). This result is consistent with the evidence that stock returns are significantly related to production or real activity. It is also related to a later discussion about international risk sharing, which shows that production risk sharing better characterizes the degree of international risk sharing than does consumption risk sharing.

[17] This seems to be a direct contradiction of the implications of the theoretical models of consumption behavior, which suggests a consumption smoothing motive. Instead, it suggests that countries tend to engage more in production smoothing than consumption smoothing.

[18] Stockman and Tesar (1995) argue that low cross-country consumption correlations can be rationalized, even with full risk sharing, when countries are subject to idiosyncratic taste shocks (see also Sorensen and Yosha, 1998). Pakko (1997) provides a different explanation (see also Boileau, 1996). Meanwhile, Gordon and Bovenberg (1996) argue that asymmetric information is primarily attributable to international immobility of capital.

[19] Although Brandt, Cochrane, and Santa-Clara (2001) base their analysis on the international risk sharing index (32), their actual implementation is different from ours. They use the growth of marginal utility of consumption as a measure of the stochastic discount factor but do not relate it to equity returns as is done in this study. They assume that the exchange rate reflects the difference between growth rates of domestic and foreign marginal utility – the numerator in the index formula (32). (If (uncovered) interest parity holds, the interest rate differential between two countries is the same as a change in the exchange rate.) They then develop a method of estimating the growth of marginal utility of consumption and use it to measure the variances of marginal utility in the denominator in (32). This tends to yield a much higher value of international risk sharing (see footnote #20).

[20] Brandt, Cochrane, and Santa-Clara (2001) obtain a much higher value than the one found here. They use a different estimation methodology. First, they used country pairs rather than comparing one country against the rest of the world. Second, they equate stochastic discount factors to exchange rates rather than equity returns. However, whether the degree of international risk sharing is low or high is an unsettled issue, and there are many possible explanations (see Lewis, 1999). Fuhrer and Klein (2000) incorporate habit formation in a consumption-based risk sharing model and found that in the presence of a common shock, habit formation can generate positive cross-country consumption correlations even in the absence of any risk sharing among countries (see also Canova and Ravn, 1996). Thus if habit formation is a good characterization of consumer behavior, this implies that consumption correlations are almost always larger than output correlations, leading them to conclude that international risk sharing is worse than "you think." This result is at odds with many attempts to rescue the relevance of international consumption risk sharing from its empirical performance. Moreover, there are some notable studies which take a production-based approach to try to explain the home bias puzzle. In particular, Baxter and Jermann (1997) estimate an aggregate production function using labor and capital as inputs in contrast to the intertemporal cost function employed in this study and compute factor returns for human and physical capital. Here the return process is driven by productivity shocks but not by cost or input price shocks. Baxter and Jermann (1997), however, find that human capital cannot explain the home bias puzzle. In fact, it worsens the puzzle rather than help resolve it (see Bottazzi, Pesenti, and van Wincoop, 1996, for a divergent result).

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TABLE 1

International Correlations and Relative Variability for Equity Returns and Consumption and Output Growth for Industrialized Countries

	International Correlations			Relative Variability		
	corr(rk,rw) (80-91)	corr(ck,cw) (73-88)	corr(yk,yw) (73-88)	sd(rk)/sd(rw) (80-91)	sd(ck)/sd(cw) (73-88)	sd(yk)/sd(yw) (73-88)
Australia	0.51	0.00	0.72	0.93	1.40	1.24
Austria	0.30	0.29	0.55	2.33	1.84	1.17
Belgium	0.64	0.49	0.58	1.90	1.91	0.60
Canada	0.70	0.10	0.30	0.62	3.91	1.95
Denmark	0.52	0.60	0.39	1.42	2.76	1.70
Finland	0.49	0.19	0.06	0.18	3.64	1.65
France	0.65	0.50	0.56	1.63	1.16	0.99
Germany	0.68	0.72	0.87	1.27	1.50	1.30
Greece	0.16	0.13	0.41	2.25	2.70	1.88
Iceland	NA	0.05	0.27	NA	5.49	2.19
Ireland	0.63	0.48	0.57	2.16	3.68	1.58
Italy	0.52	0.27	0.61	1.23	1.90	1.71
Japan	0.75	0.62	0.71	1.20	1.99	1.35
Luxembourg	NA	0.21	0.73	NA	1.21	1.59
Netherlands	0.75	0.56	0.59	1.30	1.97	1.24
New Zealand	0.26	-0.03	0.16	0.22	2.70	2.25
Norway	0.59	0.05	0.37	0.94	2.74	1.06
Portugal	0.40	0.06	0.44	1.91	5.79	3.06
Spain	0.56	0.32	0.39	1.78	2.31	1.60
Sweden	0.59	0.18	0.04	1.43	1.92	1.08
Switzerland	0.71	0.64	0.53	1.11	1.21	1.87
UK	0.76	0.59	0.66	1.33	2.63	1.59
US	0.79	0.31	0.67	0.90	1.84	1.69
Group Average	0.56	0.32	0.48	1.33	2.53	1.62
Standard Error	0.08	0.26	0.26			

Source: Tesar (1995, p.101).

Notes: rk=individual country return, rw=world return, ck=individual country consumption growth, cw=rest of the world consumption growth, yk=individual country output growth, yw=rest of the world output growth, sd=standard deviation

TABLE 2

DIFFERENT INTERNATIONAL RISK SHARING MEASURES FOR SELECTED COUNTRIES

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Index	US vs ROW	UK vs ROW	Italy vs ROW	Japan vs ROW
Equity returns	0.786	0.730	0.509	0.738
Consumption growth	0.260	0.392	0 .223	0.498
Output growth	0.587	0.595	0.532	0.679

Source: The author’s calculation based on Table 1.