Financial Integration and International Risk Sharing

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Abstract

Conventional wisdom suggests that financial liberalization can help countries insure against idiosyncratic risk. There is little evidence, however, that countries have increased risk sharing despite recent widespread financial liberalization. This work shows that the key to understanding this puzzling observation is that conventional wisdom assumes frictionless international financial markets, while actual international financial markets are far from frictionless. In particular, financial contracts are incomplete and enforceability of debt repayment is limited. Default risk of debt contracts constrains borrowing, and more importantly, it makes borrowing more difficult in bad times, precisely when countries need insurance the most. Thus, default risk of debt contracts hinders international risk sharing. When countries remove their official capital controls, default risk is still present as an implicit barrier to capital flow; the observed increase in capital flow under financial liberalization is in fact too limited to improve risk sharing. If default risk of debt contracts were eliminated, capital flow would be six times greater, and international risk sharing would increase substantially.

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1 Introduction

In the 1980s and early 1990s, financial liberalization was the almost unanimous policy advice given to developing countries. Conventional wisdom suggests that countries are able to better insure against idiosyncratic risk with access to international financial markets. Indeed, we observe widespread financial liberalization in both developed and developing countries. As a result, countries became more financially integrated over time; in a cross section of 43 countries, the ratio of the net asset position and GDP more than doubled from 8% in the less-integrated period of 1970–1986 to 18% in the more-integrated period of 1987–2004.[1] An extensive empirical literature, however, finds little evidence that countries increased risk sharing despite widespread financial liberalization; this is puzzling to conventional wisdom and policy expectation.

This paper argues that the key to understanding this puzzling observation is that conventional wisdom assumes frictionless international financial markets, while actual markets are far from frictionless. In particular, international financial contracts are incomplete and have limited enforceability. These frictions endogenously constrain capital flow across countries, even when countries remove capital controls. Thus, the increase in capital flow under financial liberalization is too limited to significantly improve international risk sharing.

We study a dynamic stochastic general equilibrium model with a continuum of small open economies and production. Motivated by empirical observations, we model international financial markets with two frictions. One is incomplete contracts which take the form of non-contingent bonds. The other is limited enforceability of contracts, where countries have the option to default on their debt but lose access to financial markets and suffer from drops in output for some period if they default. We focus on debt contracts because debt accounts for the majority of foreign asset positions across countries: over 70% in terms of gross positions and over 60% in terms of net positions for our 43 countries.[2] Recurrent episodes of sovereign default in the data motivate us to study default risk and to model default as an equilibrium phenomenon.

To proxy a wide class of capital controls in the data, we impose a tax on foreign asset holdings[3] and calibrate the tax to match observed capital flow in the less-integrated period. We model financial liberalization as an exogenous elimination of this tax. In response to financial liberalization, the model generates an increase in capital flow of similar magnitude to that from the less-integrated to more-integrated period in the data. The model also reproduces main features of sovereign default in the data. Default tends to occur in bad and volatile times, and defaulting countries have higher debt to output ratios than non-defaulting countries. Moreover, default occurs more frequently in the more-integrated period.

[1] The sample consists of 21 developed countries and 22 more-financially-integrated developing countries based on Prasad et al. (2003).

[2] Kraay et al. (2005) also document that roughly three-quarters of net north-south capital flow takes the form of net lending. Equity and FDI flow is rather limited, as reflected by the well-established equity home bias puzzle (Tesar and Werner, 1995) and the fact that equity markets in emerging economies remain relatively underdeveloped.

[3] See Neely (1999) for a detailed discussion.

Given its success in producing observed financial integration and sovereign default, we use this model to assess the quantitative implications of financial liberalization on international risk sharing. We measure the degree of international risk sharing with the coefficient on output growth in a panel regression of consumption growth rates on output growth rates, as is prevalently used in the empirical literature. We find that the degree of international risk sharing is limited in both the less-integrated and more-integrated period. More importantly, even though capital flow doubles across these two periods as in the data, international risk sharing improves little.

The key to understanding limited risk sharing in both periods is the presence of the financial frictions. Default risk on sovereign debt constrains borrowing because creditors never offer debt contracts that will be defaulted upon with certainty and they charge an interest rate premium on debt that carries a positive default probability. Moreover, borrowing is more difficult at bad times, precisely when countries need insurance the most. This is characteristic of incomplete markets: at bad times it is more costly to repay non-contingent debt and countries are more likely to default. Thus, default risk generates a time-varying impediment to international risk sharing. In addition, we find that equilibrium default to be costly in terms of risk sharing. Though they tend to default in bad times to avoid a sharp drop in current consumption,[4] countries lose access to markets for some period and cannot smooth consumption over the exclusion period after default.

When countries remove capital controls, capital flow increases, but the increase is too limited to improve international risk sharing. The reason behind this limited increase is default risk on sovereign debt, which endogenously constrains borrowing and capital flow. In addition, the incidence of default increases as countries borrow more in the more-integrated period, which worsens international risk sharing. If default risk on sovereign debt were eliminated, capital flow in the more-integrated period would be six times larger than the observed flow and international risk sharing would improve substantially. Thus, international risk sharing improves little when financial integration is plagued with sovereign default risk and incomplete markets.

Our model introduces production into the sovereign debt literature, pioneered by Eaton and Gersovitz (1981) and advanced by Aguiar and Gopinath (2006), Arellano (2007), and Yue (2005). Existing works study a pure exchange economy without storage. This model framework is unsatisfactory when used to evaluate the impact of financial integration on international risk sharing. The model attributes any observed consumption smoothing to financial integration because there is no other means to smooth consumption. Our production setup, however, allows countries to self-insure with capital even when they are closed. Moreover, the production framework captures the two important roles of international capital flow: an efficient allocation of capital and risk sharing in consumption across countries.

This work is related to the international business cycle literature, which studies risk sharing between two countries after taking out country-specific trends. We instead look at risk sharing among a large number of

[4]As argued by Grossman and van Huyck (1988), the option to default helps complete markets by making uncontingent payments state-contingent.

countries, taking out only a common trend across countries. This leads to greater country heterogeneity and permits more opportunities and incentives for risk sharing. In addition, our multi-country framework allows us to examine international risk sharing in the model in the same way as the empirical literature does for a large number of countries using the cross-section or panel regression analysis. Moreover, few quantitative works study the impact of financial liberalization on international risk sharing. One exception is Mendoza (1994). With a small open economy model and incomplete markets, he finds that consumption variability is not sensitive to a calibrated change in exogenous borrowing constraints. Our work endogenizes borrowing constraints and points out that default risk is the key to the limited increase in capital flow in response to financial liberalization.

The organization of the paper is straightforward. Section 2 lays out the theoretical model. We parameterize the model, present and analyze the quantitative results in section 3. Section 4 provides further analysis on the model implications and section 5 concludes.

2 Model

This section presents the theoretical framework designed to model the impact of financial liberalization on international risk sharing. The world economy consists of a continuum of small open economies and a large number of international financial intermediaries. All economies produce a homogeneous good that can be either consumed or invested. Financial intermediaries perform the functions of international financial markets, pooling savings and loaning funds across countries. Two key frictions exist in international financial markets. First, the markets are incomplete; only uncontingent debt claims are traded between financial intermediaries and countries. Second, debt contracts have limited enforcement; that is, countries have the option to default on their debt. We model the default choice explicitly and allow default to arise in equilibrium.

2.1 Individual Countries

Each country consists of a benevolent government, a continuum of identical consumers and a production technology. Countries face different shocks to their production technologies. The production function is given by the standard Cobb-Douglas, $aK^{\alpha}L^{1-\alpha}$, where a denotes the country-specific idiosyncratic shock to total factor productivity (TFP), K the capital input, L the labor input, and α the capital share parameter. The TFP shock follows a first-order Markov process with finite support A and transition matrix Π. Given our focus on the abilities of countries to share idiosyncratic risk, we abstract from world aggregate uncertainty.

The benevolent government chooses consumption, investment, borrowing (lending), and whether to default on existing debt to maximize utility of the domestic consumers given by

$$E_0 \sum_{t=0}^{\infty} \beta^t u(C_t), \tag{1}$$

where C denotes consumption, $0 < \beta < 1$ the discount factor, and $u(\cdot)$ utility which satisfies the usual Inada conditions. Labor supply is inelastic. We normalize each country's allocation by its labor endowment and let lowercase letters denote variables after normalization. Thus, the production function simplifies to $f(k) = ak^{\alpha}$.

We model *centralized borrowing*, where the domestic government makes international borrowing, lending and default decisions for two reasons. Empirically, international loans typically involve the domestic government (implicitly or explicitly), which motivates the sovereign debt literature to prevalently model centralized borrowing.[5] Also, centralized borrowing provides larger capital flow and higher welfare than *decentralized borrowing*, where individual consumers make decisions on borrowing, lending and default.[6] Thus, by modeling centralized borrowing, we allow more room for international risk sharing.

In each period, a country is either in the *normal phase* or in the *penalty phase*. Countries in the normal phase have access to international financial markets and remain in this phase if they repay outstanding debt. Upon default, however, countries are thrown into the penalty phase where they lose their access to financial markets, suffer from a drop in TFP, but have some probability of returning to the normal phase.

The default penalties are modeled to capture two key empirical features of sovereign default. First, defaulting countries often regain access to markets after some period of exclusion, as documented by Gelos et al. (2004). We capture this by allowing countries to return to the market with some exogenous probability in each period. Second, output falls during sovereign default. Cohen (1992) documents an "unexplained" productivity slowdown in the 1980s debt crisis. Tomz and Wright (2007) report that output is below trend about 1.4% during the entire period of renegotiation for a sample of 175 countries during 1820–2004. Potential channels through which sovereign default causes aggregate output to fall are disruptions to international trade and to the domestic financial system. Theoretically these disruptions could lead to a drop in output if foreign intermediate goods or financing for working capital are inputs for production. Empirical work, however, has not fully explored these channels. Agnostic about the channels of costs associated with default, we instead capture these losses as a drop in total factor productivity.

The timing is as follows. At the beginning of each period, agents observe each country's TFP shock. Next, countries in the normal phase decide whether to default and also choose their consumption, investment and bond holdings according to their default decisions. Countries in the penalty phase cannot borrow or save abroad and so only decide on consumption and investment. Countries in different phases face different constraints, and so we examine their problems in turn.

[5]Eaton and Fernandez (1995) provide a detailed discussion of the empirical motivation for centralized borrowing.

[6]As pointed out by Jeske (2006), individual consumers fail to endogenize the impact of their borrowing on aggregate borrowing terms under decentralized borrowing.

Country in the Normal Phase

The state of each country is summarized by $x = (s, h)$, where h denotes its phase with $h = N$ indicating the normal phase and $h = P$ indicating the penalty phase; $s = (a, k, b)$ denotes its productivity shock a, capital stock k and bond holding b. Let $X = S \times H$ be the state space with $S = A \times \mathbb{R}_+ \times \mathbb{R}$ and $H = \{N, P\}$.

A country s in the normal phase can choose whether to default on its outstanding debt by comparing the respective welfares, so its value function $V(s, N)$ is given by

$$V(s, N) = \max\{W^R(s), W^D(a, k)\} \tag{2}$$

where $W^R(s)$ denotes the repayment welfare and $W^D(a, k)$ the default welfare. Let d denote the default decision with $d = 0$ indicating repaying and $d = 1$ indicating defaulting. Country s chooses to repay if and only if $W^R(s) \geq W^D(a, k)$.

If it defaults, the country gets its debt written off, but it will be penalized. Today the country suffers a loss in TFP and cannot access international financial markets. From the next period on the country will stay in the penalty phase until it returns to the normal phase. Thus, country s can choose only consumption c and next-period capital stock k' to maximize the default welfare given by

$$W^D(a, k) = \max_{c,k'} u(c) + \beta \sum_{a'|a} \pi(a'|a) V(a', k', 0, P) \tag{3}$$

subject to

$$c + k' - (1 - \delta)k \leq (1 - \gamma)ak^\alpha - \Phi(k', k), \tag{4}$$

and

$$c, k' \geq 0, \tag{5}$$

where $V(a', k', 0, P)$ denotes the value of a country in the penalty phase with productivity shock a', capital stock k' and zero debt. Φ denotes the capital adjustment costs, and γ the penalty parameter capturing the drop in TFP.

If it repays, the country enjoys the access to financial markets today and remains in the normal phase next period. Given the country-specific bond price schedule $q(s, b')$, country s chooses consumption c, next period's capital stock k', and bond holdings b' to maximize the repayment welfare given by

$$W^R(s) = \max_{c,k',b'} u(c) + \beta \sum_{a'|a} \pi(a'|a) V(s', N) \tag{6}$$

subject to

$$c + k' - (1 - \delta)k + q(s, b')b' + \tau|b'| \leq ak^\alpha + b - \Phi(k', k), \tag{7}$$

and the non-negativity constraints (5), where τ is the real resource cost to access international financial markets. This parameter τ, therefore, captures the degree of capital controls in this economy. Infinitely large τ produces a closed economy, i.e. financial autarky; zero τ produces an open economy with no capital controls, i.e., full financial liberalization.

Capital controls in reality can be classified into two categories. One is the price control which takes the form of taxes on returns to international investment, taxes on certain types of transactions, or a mandatory reserve requirement. For example, the U.S. imposed the interest equalization tax from 1963 to 1974; investment returns on foreign stocks and bonds were taxed at 1 percent to 15 percent depending on the maturity. The other is the quantity control which takes the form of quotas or outright prohibitions. For example, the Mexican government restricted commercial banks to hold no more than 10% of their loan portfolio as foreign liabilities in 1992. We find that both types of capital controls deliver similar quantitative implications on international risk sharing. We present implications of the price control for most of the paper and show those of the quantity control in Section 4. In addition, we observe capital controls on both inflow and outflow in reality. Thus, we impose taxes on both international borrowing and lending.

For some countries with large amounts of debt relative to their income today, it is possible that given the set of available contracts, they cannot satisfy their budget constraints (7) together with the non-negativity constraints (5). In such cases, countries default on their debt.

Country in the Penalty Phase

A country in the penalty phase suffers a drop in TFP each period, and so its production becomes $(1-\gamma)ak^{\alpha}$. It has no access to international financial markets. Note that though countries in the penalty phase are not allowed to save abroad, they still can save in domestic capital stocks. Empirically, defaulting countries often regain access to markets after some period of exclusion. We thus assume that countries in the penalty phase have some exogenous probability λ of returning to the normal phase. Country $(a, k, 0)$ in the penalty phase chooses consumption c and capital stock k' to maximize the utility given by

$$V(a, k, 0, P) = \max_{c,k'} u(c) + \beta \sum_{a'|a} \pi(a'|a) \left[(1-\lambda)V(a', k', 0, P) + \lambda V(a', k', 0, N)\right] \quad (8)$$

subject to the budget constraints (4) and the non-negativity constraints (5).

2.2 International Financial Intermediaries

International financial intermediaries are assumed to be able to commit to loan contracts. They are competitive, risk-neutral, and discount the future at the inverse of the risk-free interest rate R. They behave passively and are willing to finance any non-defaulting countries in the normal phase as long as they are compensated for the expected loss in case of default. The set of contracts is country-specific. For each country s, the bond price schedule $q(s, b')$ is such that for every b' the intermediaries break even

$$q(s, b') = \left[1 - p(s, b')\right]/R, \quad (9)$$

where $p(s, b')$ denotes the expected default probability of country s with bond holding b'. The default probability is the sum of the probabilities of the states under which country s will choose to default on its debt b' next period. More specifically, the default probability is given by

$$p(s, b') = \sum_{a'|a} \pi(a'|a) d(a', k'(s, b'), b'), \tag{10}$$

where $k'(s, b')$ is the optimal capital stock that country s will choose if it decides to borrow b' this period and is the solution to the following problem

$$\max_{c,k'} u(c) + \beta \sum_{a'|a} \pi(a'|a) V(s', N), \tag{11}$$

subject to the non-negativity constraints (5) and the budget constraints (7). Note that the bond price schedule is specified for all possible borrowing b', not just for equilibrium borrowing.

2.3 Stationary Recursive Equilibrium

We first define the stationary recursive equilibrium, and then provide some characterization of the equilibrium. Let μ be the probability measure on $(X, \aleph)$, where $\aleph$ is the Borel σ-algebra on X. For any $M \in \aleph$, $\mu(M)$ indicates the mass of countries whose states lie in M. Denote the transition matrix across states by $Q : X \times \aleph \to [0, 1]$, where $Q(x, M)$ gives the probability of a country x switching to the set M next period.

Definition 1. A *stationary recursive equilibrium* consists of a world risk-free interest rate R, a bond price schedule $\{q(s, b')\}$, decision rules of countries $\{c(x), k'(x), b'(x), d(s)\}$, value functions of countries $\{V(x), W^D(a, k), W^R(s)\}$ and a distribution over countries μ, such that,

- Given $q(s, b')$, the decision rules and the value functions solve each country's problem.
- Given R and the decision rules, the bond price schedule makes financial intermediaries break even in each contract.
- Bond markets clear: $\int_{\{x:h=N,d(x)=0\}} q(s, b'(x))b'(x)d\mu = 0$.
- The distribution μ is stationary: $\mu(M) = \int_X Q(x, M)d\mu$ for any $M \in \aleph$.

Here we examine the stationary equilibrium under centralized borrowing. One can support the equilibrium allocation under decentralized borrowing with taxes on foreign borrowing and domestic capital returns of each consumer, following Wright (2006). The analytical characterization of the equilibrium is limited under the general equilibrium model with production. Still, the following provides two theoretical propositions characterizing the equilibrium. We will present detailed numerical characterization of the equilibrium in the next section.

Proposition 1. *If a country in the normal phase defaults on bond holding b_2, it will default also on b_1 for any $b_1 < b_2$ fixing (a, k).*

Proposition 2. *A country with a debt-output ratio smaller than γ will never default.*

Detailed proofs of the above two propositions are presented in Technical Appendix 1. Proposition 1 simply states that when a country defaults on some amount of debt, it will default for any larger amount of debt. Defaulting welfare is independent of debt while the repayment welfare decreases with debt. Thus, for countries with shock a and capital stock k, there exists a cutoff level of debt, above which they will default.

Proposition 2 offers a sufficient condition for safe debt. Given that output drops by a fraction of γ after default, a country with a debt-output ratio less than γ will never default because the debt relief is less than the output drop and the country also loses access to future borrowing after default. Note that this condition is not necessary for safe debt. Countries with debt-output ratios larger than γ may also choose to repay with probability one, and thus the safe debt-output ratio is at least as large as γ.

3 Quantitative Analysis

In this section, we assess the model's quantitative implication of financial liberalization on international risk sharing. First, we present evidence that financial integration increases substantially and empirical evidence that international risk sharing shows little improvement. We then calibrate the model economy to set up the laboratory where we eliminate the tax on foreign asset holdings to endogenously generate financial integration. Finally, we present and investigate the model's implication that the observed degree of financial integration leads to little increase in international risk sharing.

3.1 Data

Financial integration undoubtedly increased over time. The literature commonly uses two direct measures of financial integration. One is a restriction measure which offers a qualitative index of official capital controls on cross-border capital flow.[7] The restriction measure indicates more financial integration over time; a large number of countries have removed capital controls and deregulated financial markets (Prasad et al., 2003). The other is an openness measure using actual cross-border capital flow across countries, in terms of either gross (or net) foreign flow or gross (or net) foreign positions. These statistics present the same picture: a dramatic increase in financial integration.

To quantify the degree of financial integration over time, we adopt the openness measure. More precisely, we measure the degree of financial integration at any period as the ratio of the world sum of absolute net debt positions and the world GDP (later referred as the *world asset-output ratio*). The net debt position is

[7] Most restriction measures are constructed based on the IMF publication *Annual Report on Exchange Arrangements and Exchange Restrictions* (AREAER). See Edison et al. (2004) for a thorough survey.

the difference between the debt asset position and the debt liability position, constructed by Lane and Milesi-Ferretti (2007). We use this measure of financial integration because it is the closest empirical counterpart to our model. Our sample consists of 21 OECD countries and 22 more-financially-integrated countries (referred also as emerging markets later) based on the classification in Prasad et al. (2003).[8] The world asset-output ratio more than doubles from 8% in 1970–1986 to 18% in 1987–2004.

Conventional wisdom suggests that countries should be able to share idiosyncratic risk better in a more-financially-integrated world, which motivates a large empirical literature examining the degree of international risk sharing over recent decades. To measure the degree of risk sharing, the prevailing empirical literature uses a panel or cross-country regression of consumption growth rates on GDP growth rates. Cochrane (1991) and Mace (1991) regress individual consumption growth on individual income growth to study the extent of risk sharing across domestic agents. Lewis (1996) introduces this regression analysis to the international setting and rejects perfect risk sharing across countries.

We present panel regression analysis for the less-integrated period and the more-integrated period with our sample countries. All the conclusions are robust to alternative measures of risk sharing, e.g. consumption variability and the cross-country regression. See Data Appendix 3 for details. Specifically, we examine the OLS regression of the form

$$\Delta \ln c_t^i - \Delta \ln \bar{c}_t = \beta_0 + \beta_1(\Delta \ln y_t^i - \Delta \ln \bar{y}_t) + u_t^i, \tag{12}$$

where c_t^i denotes real final consumption of country i at period t, y_t^i real GDP, $\bar{c}_t$ and $\bar{y}_t$ average real final consumption and average real GDP over the sample countries, and u_t^i the error term and $\Delta x_t = x_t - x_{t-1}$ for any variable x. All variables are in per-capita U.S. dollars obtained from the World Bank's *World Development Indicators*. The regression focuses on the relation between country-specific consumption and output by controlling for the world aggregate components with world average consumption and output. The degree of international risk sharing is measured by the regression coefficient β_1; the lower the regression coefficient, the better countries share risk. Note that perfect risk sharing, generated by the standard complete markets model, implies that consumption growth should not respond to individual income growth, i.e., β_1 should be zero.

Our findings are summarized in Table 1. First, the regression coefficient β_1 is significantly different from zero in both periods; it is 0.76 in the less-integrated period, and 0.84 in the more-integrated period, both significant at the 5% level. The null hypothesis of perfect international risk sharing is rejected in both periods, consistent with the consensus in the literature that international risk sharing is far from perfect.

Second, international risk sharing shows no statistically significant improvement over the two periods; an F-test rejects the hypothesis that the regression coefficient β_1 is smaller in the more-integrated period. The result is robust to different sample groups of countries: emerging markets and OECD countries. Empirical

[8]See Data Appendix 1 for details.

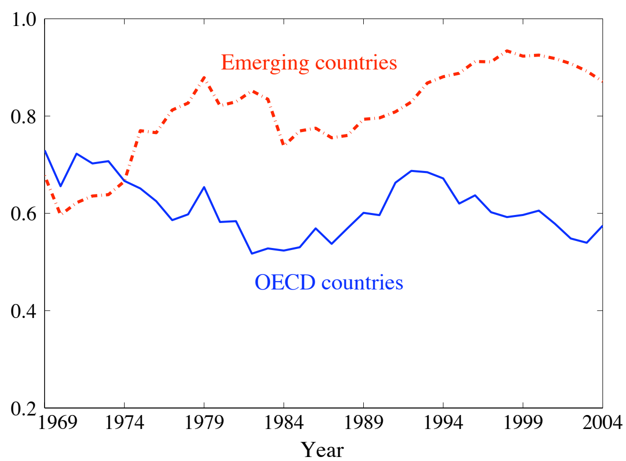
Table 1: Measurement of Risk Sharing: Regression Coefficient β_1

Sample	Less-Integrated Period 1970–1986	More-Integrated Period 1987–2004
43 countries	.76 (.03)	.84 (.02)
21 OECD	.62 (.04)	.60 (.03)
22 emerging	.79 (.05)	.88 (.02)

Note: numbers in parentheses are standard errors.

studies on emerging markets all document little improvement or even a decline in risk sharing over the period of financial integration. See Kose et al. (2006) for a comprehensive review. Thus, our result is consistent with the existing studies. Empirical studies on OECD countries document mixed results. Some studies argue that risk sharing improves after 1990 (e.g., Sorensen et al. (2007)), while other studies have found little evidence of better risk sharing when looking at a longer period (e.g., Moser et al. (2004)). Figure 1 illustrates the reason for the different conclusions by plotting the 9-year rolling window panel regression coefficient for each year, as in Kose et al. (2006). The regression coefficient becomes smaller after the 1990s for the OECD countries, which tends to lead to the conclusion that risk sharing increases. Nevertheless, the extent of risk sharing, even in 2000, is similar to that in the 1970s. Thus, when comparing the two periods, we find it hard to argue that risk sharing improves substantially in the more-integrated period.

Figure 1: Regression Coefficient β_1 (9-Year Rolling Panel)



3.2 Calibration

In this subsection, we calibrate the model and set up the laboratory to explore the impact of financial liberalization on international risk sharing. To isolate the impact of financial liberalization, we conduct two model experiments with different taxes τ while keeping the shock process and all the structural parameters the same. Directly measuring the degree of capital controls τ from the data is hard for two reasons. First, typically governments impose more than one form of capital controls at each point of time, and capital controls vary across time and across countries. Second, even if one could perfectly measure all the official controls, it is difficult to gauge the effectiveness of these capital controls. We instead calibrate τ in the first experiment to match the world debt-output ratio in the less-integrated period, and set τ to be zero in the second experiment to mimic financial liberalization in the more-integrated period.

We calibrate the world productivity process in two steps. We first compute the TFP series for each sample country, and then estimate a regime-switching process on the TFP series using maximum likelihood. The basic approach is similar to Bai and Zhang (2005), but we need to incorporate the TFP drop parameter γ in the regime-switching process. According to our model, the computed TFP series of these countries over the exclusion period embody the drop in productivity. Thus, to infer the shock process we need to estimate the world TFP process jointly with the TFP drop parameter.

Compute the TFP processes

The TFP series for country i at period t is computed using the standard growth accounting method:

$$\log A_t^i = \log Y_t^i - \alpha \log K_t^i - (1-\alpha)\log L_t^i,$$

where A_t^i denotes the TFP level, Y_t^i real GDP, K_t^i the capital stock and L_t^i employment. The capital stock is constructed perpetually using gross capital formation data (see Data Appendix 1). We detrend the TFP series using the average world TFP growth rate of 1.3 percent. Let a_t^i denote the logged and detrended TFP level. Note that we take out only the common TFP trend from the world TFP series, unlike the international business cycle literature, where each country is detrended individually. Thus, our way of detrending leaves in more heterogeneity across countries and allows for a greater incentive to share risk.

Estimate World Productivity Process

The calibrated TFP series have two key features. First, different subgroups of countries have different characteristics. In particular, the coefficient of variation of the TFPs series is 2% for the OECD countries and 5% for the emerging markets. Second, some countries display different characteristics across different periods of time. For example, the mean level and the coefficient of variation of Peruvian TFP series are, respectively, 3.49 and 1% before 1980, but, respectively, 3.02 and 7% after 1980. These features of the data motivate us to adopt a regime-switching process to estimate the world TFP process.

We assume that there are two regimes, $\Re \in \{1, 2\}$. Each regime $\Re$ has its own mean $\mu_\Re$, persistence $\rho_\Re$ and innovation standard deviation $\sigma_\Re$. The TFP shock a_t^i of country i in regime $\Re_t^i$ at period t follows a first-order autoregressive process given by

$$a_t^i = \mu_{\Re_t^i}(1 - \rho_{\Re_t^i}) + \rho_{\Re_t^i} a_{t-1}^i - \gamma h_t^i + \sigma_{\Re_t^i} \epsilon_t^i, \tag{13}$$

where ϵ_t^i is independently and identically distributed and drawn from a standard normal distribution $N(0,1)$, and h_t^i is a dummy variable (1 if a country is in the state of default and 0 otherwise). In our data sample, there are 102 observations in the state of default, which helps us identify γ. Details of these observations are reported in Table 8 of the Data Appendix. At any period, country i has some probability of switching to the other regime, governed by the transition matrix P.

Given the calibrated TFP panel series $\{a_t^i\}$ and the dummy panel series $\{h_t^i\}$, we use maximum likelihood to estimate the unknown parameters: $\Theta = \{(\mu_{\Re}, \rho_{\Re}, \sigma_{\Re}), P, \gamma\}$. We use an extension of the technique in Hamilton (1989) from one time series to panel series. Technical Appendix 2 describes the algorithm in detail. The estimates of the parameter values are reported in Table 2. We label the two regimes according to their volatilities as the low-volatility and the high-volatility regime. The high-volatility regime can be interpreted as emerging countries, and the low-volatility regime as OECD countries. The TFP drop parameter is estimated to be 2%.

Table 2: Estimated Productivity Process

Regime	Innovation σ	Persistence ρ	Mean μ	Switching Prob. P	
				High	Low
High-volatility	.05 (.001)	.99 (.004)	3.17 (.05)	.88 (.07)	.12 (.02)
Low-volatility	.02 (.013)	.99 (.021)	4.39 (.10)	.05 (.27)	.95 (.19)
TFP drop parameter γ	.02 (.005)				

Note: numbers in parentheses are standard errors.

Calibrate Other Structural Parameters

All countries have the same parameter values. The period utility function takes the standard CRRA form of

$$u(c) = \frac{c^{1-\sigma} - 1}{1-\sigma},$$

where the risk aversion parameter σ is chosen to be 2. The discount factor β is set such that the equilibrium risk-free rate in the less-integrated period equals the average real return on US Treasury Bills, about 1 percent per year, over the same period. The capital share α is set at 0.33 and the capital depreciation rate δ is set at 10 percent per year to match the U.S. equivalents. The capital adjustment cost takes the standard quadratic form of

$$\Phi(k', k) = \frac{\phi}{2}\left(\frac{k' - (1-\delta)k}{k}\right)^2 k,$$

where ϕ is set at 3 to match the average ratio of investment volatility and output volatility across countries. We choose the probability of reentry to markets after default λ to be 0.20, following Gelos et al. (2004). They document that defaulting countries are denied access to markets for about 5 years on average. We set the tax parameter τ in the first experiment to match the world asset-output ratio in the less-integrated period:

8 percent. We then set the tax τ in the second experiment to be zero to mimic financial liberalization in the more-integrated period. Table 3 summarizes all parameter values.

Table 3: Summary of Parameter Values

Preferences	Risk aversion	$\sigma = 2$
	Discount factor	$\beta = 0.89$
Technology	Capital share	$\alpha = 0.33$
	Depreciation	$\delta = 0.10$
	Capital adjustment cost	$\phi = 3$
Default penalty	Re-entry probability	$\lambda = 0.20$
	Output drop	$\gamma = 0.02$
Transaction cost	1970–1986	$\tau_1 = 4\%$
	1987–2004	$\tau_2 = 0$

3.3 Simulation Results

After calibrating the model, we first use a non-linear recursive technique to compute the model equilibrium twice: one for τ at 4 percent and one for τ at 0 percent. For the detailed computational algorithm see Technical Appendix 3. We then simulate the model for the two experiments and examine implications on international risk sharing. For each experiment, we simulate the model 1,000 times with 17 periods and 43 countries in each simulation, to be consistent with the data. Each simulation starts from the invariant stationary distribution of the corresponding experiment. The main findings are reported in Table 4.

Table 4: Simulation Results

	Data		Model	
	1970–1986	1986–2004	$\tau_1 = 4\%$	$\tau_2 = 0\%$
World asset-output ratio	0.08	0.18	0.08	0.18
Regression coefficient β_1	0.76	0.84	0.64	0.63
	(.03)	(.02)	(.04)	(.03)

Note: numbers in parentheses are standard errors.

When the tax τ drops from 4% to 0%, the model generates an increase in the world asset-output ratio from 8% to 18%. This increase is similar to what we observed in the data from the less-integrated to more-integrated period. There is little improvement, however, in international risk sharing; the panel regression coefficients are 0.64 and 0.63 in these two experiments, respectively, and not statistically different from each other. Perfect risk sharing is clearly rejected in each experiment as in the data. Note that the degree of risk sharing in our model is higher than that observed in the data because our model abstracts from all other types of frictions and only looks at financial frictions. We find, however, that financial frictions are important in accounting for the deviation from perfect risk sharing. This is consistent with the empirical finding in Lewis (1996).

The key to understanding the results is default risk, which is present even with removal of capital controls. Default risk constrains the increase in capital flow too much to improve international risk sharing. To demonstrate this mechanism, we first focus on the experiment with zero tax to illustrate how default risk affects risk sharing. Default risk endogenously constrains capital flow across countries, and borrowing is more difficult at bad times. It also gives rise to explicit sovereign defaults. We then look across the two experiments to understand why there is no improvement in international risk sharing. We find that with sovereign default risk the degree of financial integration, generated by removal of the tax, is too small to improve risk sharing. Moreover, more borrowing under a lower tax leads to more equilibrium default, which hurts international risk sharing.

3.4 Default Risk and Imperfect Risk Sharing

To see the role of sovereign default risk, we contrast our benchmark model with default risk (labeled the *default model*) with a model without default risk, basically the incomplete markets model with the natural borrowing constraints (labeled as the *no-default model*). The natural borrowing constraints guarantee the existence of equilibrium by ruling out the Ponzi scheme, and are set such that countries at the maximum borrowing limits are able to repay their debt without incurring negative consumption. The implicit assumption behind the natural borrowing constraints is that countries will always repay their debt, which is within their ability to repay. To make two models comparable, we set all the parameters to be the same and τ at zero. Table 5 compares the implications of the default model and the no-default model. Risk sharing in the no-default model is not perfect with the regression coefficient of 0.45. The no-default model, however, provides much better risk sharing than the default model: 0.45 versus 0.63.

Table 5: Default vs. No-Default Model

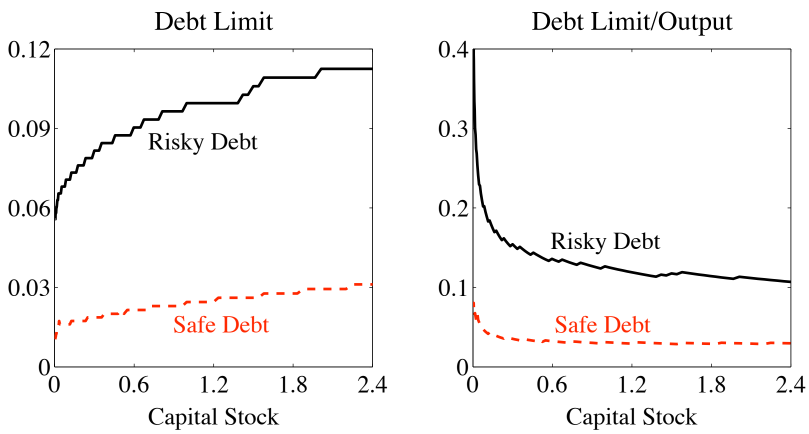
	Default Model	No-Default Model
Regression coefficient β_1		
Full Sample	0.63 (.03)	0.45 (.03)
Defaulting countries	0.65 (.03)	–
Non-defaulting countries	0.57 (.02)	–
Maximum safe debt-output ratio	0.06	6.80
Maximum debt-output ratio	0.14	6.80
World asset-output ratio	0.18	1.21
Fraction of countries in the penalty phase	0.15	0.00

Note: numbers in parenthesis are standard errors.

Sovereign default risk affects international risk sharing through three channels: constrained borrowing, counter-cyclical borrowing terms and equilibrium default. Default risk endogenously constrains borrowing. For each country, there exists a cutoff debt level, below which it will repay for sure next period (referred to as the *safe debt limit*). The country has to pay a premium for any debt above the safe debt limit. There also exists a cutoff debt level, above which it will default for sure next period (referred to as the *risky debt limit*).

The risky debt limit is the debt capacity of the country. In Figure 2, the left panel plots the safe debt limit and the risky debt limit for countries with the median shock and zero debt, and the right panel illustrates these limits in terms of ratio to output. Richer countries (higher capital stocks) have larger borrowing capacities both in terms of safe debt and risky debt, but these borrowing capacities increase slower than output when capital stocks increase. The averages of the maximum safe and risky debt-output ratio are 6% and 14% across countries in the default model, much smaller than those in the no-default model, 680%.[9] This helps explain why the equilibrium world asset-output ratio in the no-default model is 6 times larger than that in the default model: 1.2 versus 0.18.

Figure 2: Endogenous Debt Constraints

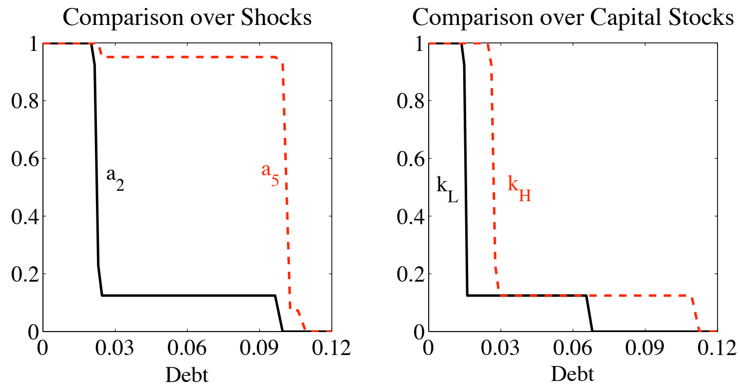


Borrowing is more difficult in bad times due to higher default risk. This is a common feature of the default model with incomplete markets. Because repayment is non-contingent and non-negotiable, it is more painful at bad times than at good times. Countries thus have higher incentives to default at bad times. Under the persistent shock process, risk-neutral international financial intermediaries endogenize this pattern of default by charging a higher interest rate premium during bad times. Figure 3 plots the bond price schedule, i.e., the inverse of the interest rates. The bond price decreases in loans with everything else fixed; it is $1/R$ for safe debt, lower than $1/R$ for risky debt, and zero for loans above the risky debt limit. Moreover, the bond price is low when output is low; it is low for low shocks (as illustrated in the left panel) and for small capital stocks (as illustrated in the right panel). In particular, risky debt is offered at a much lower price under bad shocks than under good shocks, as is shown in the left panel for the debt range between 0.03 and 0.09. This larger price discount at bad times makes the country even more constrained because an additional unit of risky debt provides much fewer resources from the lenders. Thus, sovereign default risk generates time-varying impediments to international risk sharing; borrowing is the most costly when countries need it the most in

[9] The maximum safe debt-output ratio and the maximum debt-output ratio in the no-default model are the average ratio of the natural borrowing limit and output.

bad times to smooth consumption.

Figure 3: Bond Price Schedule



The left panel plots the bond prices of countries with median capital and zero debt under different shock realizations. The right panel plots the bond prices of countries with the median shock and zero debt under different capital stocks.

Default risk gives rise to equilibrium default, which hurts risk sharing. Equilibrium default provides some state contingency in debt repayment; default usually occurs in bad times and so stopping servicing debt helps mitigate drops in current consumption. Equilibrium default, however, hinders risk sharing in that defaulting countries are excluded from financial markets for a long random period. Since shocks are serially correlated, countries are likely to remain in bad times in this exclusion period and want to borrow, but they cannot. When we compare countries with a default history with those without a default history in our simulation, the first group has lower risk sharing than the second group; the regression coefficient β_1 is 0.65 for the first group and 0.57 for the second group.[10] Thus, actual default in fact hurts overall risk sharing. The default model generates 15% of countries in the state of default (see Table 5), which also contributes to the low degree of risk sharing.

Given the importance of default risk and equilibrium default on international risk sharing, we illustrate the patterns of risky borrowing and equilibrium default in the model economy. When a country receives a better shock, especially when it switches from the high-volatilty regime to the low-volatility regime, it has large incentive to borrow to build up capital stock and to increase consumption given the highly persistent shock process. The country might borrow risky loans given favorable bond prices at good times. This leads to a borrowing boom. If the good shock is around for a long enough period, the country will gradually pay off its debt and start to lend to the rest of the world. Before the country pays off its debt, however, each period there is some probability that the country is hit by a bad shock or switches back to the high-volatility regime. With large outstanding debt and a low current output, the country might end up in default. Thus,

[10] The F-test cannot reject the hypothesis that the regression coefficient for defaulters is larger than that for non-defaulters at the 5 percent significance level.

the model predicts that countries default in bad times at the high-volatility regime with large debt. Later we will test these model implications with empirical observations on sovereign default.

3.5 Impact of Financial Integration

The above discussion illustrates how sovereign default risk prevents countries from risk sharing through endogenous constraints on borrowing, which is more difficult in bad times, and costly equilibrium default. These mechanisms are the inherent features of a world with default risk and incomplete markets, independent of capital controls. Now we compare the two experiments to show why international risk sharing improves little when financial integration increases. Table 6 reports comparison of key statistics.

Table 6: Model Implications across the Two Experiments

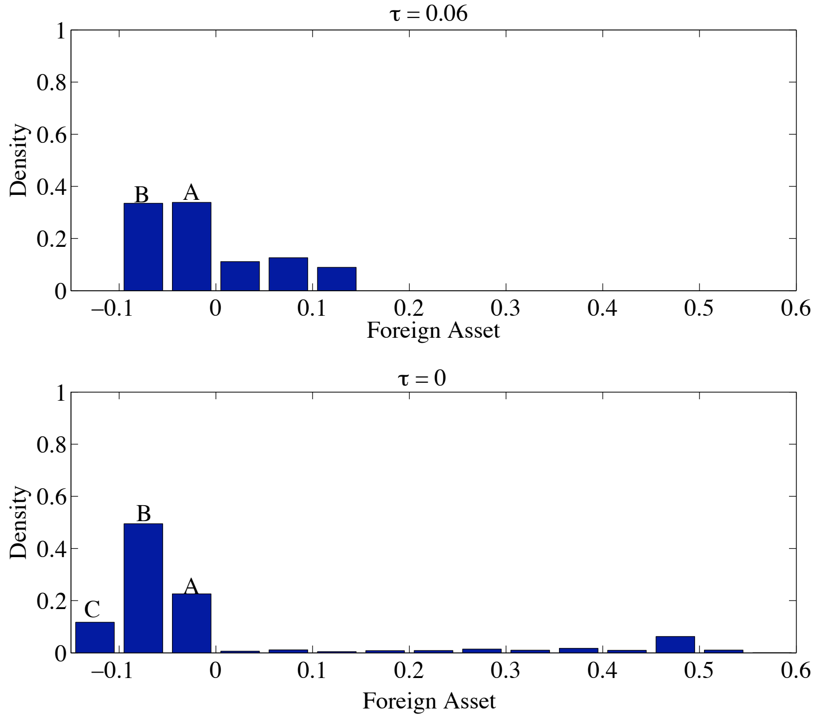
	Less-Integrated Period $\tau = 4\%$	More-Integrated Period $\tau = 0$
World asset-output ratio	0.08	0.18
Maximum safe debt-output ratio	0.05	0.06
Maximum debt-output ratio	0.10	0.14
Interest rate premium	0.02	0.03
Newly defaulted rate	0.02	0.03
Fraction of countries in the penalty phase	0.10	0.15
Regression coefficient β_1	0.64 (0.04)	0.63 (0.03)
Consumption equivalence $\tilde{c}$	0.325	0.329

Notes: numbers in parentheses are standard errors.

The removal of capital controls boosts international borrowing and lending. The direct effect is that it eliminates the tax on foreign capital flow and makes international financial markets more attractive. The indirect effect is that it loosens the borrowing constraints because countries are more willing to repay their debt with more attractive financial markets. When τ decreases from 4% to 0%, the average maximum safe debt-output ratio increases from 5% to 6% and the average maximum debt-output ratio increases from 10% to 14%. Foreign savings levels increase more than foreign debt levels in response to the removal of capital controls, as is shown in Figure 4. Though the maximum amounts of both borrowing and savings increase, the maximum savings increases from 0.15 to 0.65, but the maximum borrowing only moves from 0.1 to 0.14. This is the result of the endogenous borrowing constraint still present from default risk. In sum, financial integration increases, and the world asset-output ratio also rises from 8% to 18% as in the data.

Despite this increase in the world asset-output ratio, there is no significant improvement in international risk sharing. The key behind this result is again sovereign default risk. Default risk constrains the increase of capital flow across countries. To demonstrate this, we conduct an experiment with the same reduction of the tax in the no-default model. The world asset-output ratio increases by about six times from 18% to 121% in the no-default model. As a result, international risk sharing improves significantly; the regression

Figure 4: Distribution over Foreign Assets



coefficient β_1 decreases from 0.56 to 0.45.[11] In contrast, the default model only leads to the doubling of the world asset-output ratio. This seemingly large increase in capital flow is too small to increase international risk sharing significantly.

Moreover, countries also do more risky borrowing under a lower tax, which leads to more frequent sovereign defaults. In particular, countries with debt levels in region B and C of Figure 4 have a 5% probability of default. A higher density of countries in region B and C, induced by the removal of capital controls, leads to more frequent default episodes. Consequently, we observe a higher average risk premium and a higher default rate in the more-integrated period, reported in Table 6. The average risk premium is 1% higher, and the newly defaulted rate is 1% higher in the more-integrated period.[12] Furthermore, the fraction of countries in the penalty phase is also higher in the more-integrated period than that in the less-integrated period: 15% versus 10%. Our previous discussion shows that both the higher risk premia and the actual defaults hurt the degree of risk sharing.

We also look at welfare in the default model across the two periods. Following the standard approach, we measure welfare with consumption equivalence $\tilde{c}$, given by

$$\frac{u(\tilde{c})}{1-\beta} = \sum_x V(x)\mu(x). \tag{14}$$

[11]The standard errors of both coefficients are 0.02.

[12]The newly defaulted rate is the fraction of countries in the normal phase that decide to default.

Consumption equivalence is the permanent constant consumption level that gives the same level of welfare as that of an average country in the model. We find that the removal of capital controls leads to welfare gains of a 1.2% increase in permanent consumption. Note that this increase in welfare includes the gains from the reduction in taxes, an efficient allocation of capital and risk sharing in consumption. Thus, actual gains in terms of consumption risk sharing are even smaller. This small magnitude of welfare gains also illustrates why international risk sharing improves little across the two experiments.

In summary, contrary to the conventional wisdom, we show that financial integration does not necessarily lead to increased risk sharing using our quantitative model. This helps reconcile why the extensive empirical studies find little evidence of better risk sharing in the more-integrated period. The numerical analysis also shows that the observed degree of financial integration seems large, but it is far smaller than the degree needed to increase risk sharing significantly. Thus, the commonly proposed policy—the removal of capital controls—cannot automatically deliver increased international risk sharing, if financial contracts are incomplete and imperfectly enforced.

4 Further Analysis

In the previous section, we demonstrated the impacts of sovereign default risk on financial integration and international risk sharing. In this section we conduct further tests and analysis of the model mechanism. First, we show that the model implications on sovereign default are consistent with empirical observations. Second, we illustrate that the model implications on differential degrees of risk sharing across subgroups are consistent with the data. Third, we experiment with an alternative modeling of capital controls, the quantity mechanism, and find that our conclusion is robust.

Model Implications on Sovereign Default

Our model has three main implications on sovereign default. First, all default episodes in the model happen in the high-volatility regime, and none in the low-volatility regime. The high-volatilty regime has lower and more volatile TFP realizations than the low-volatility regime. This is broadly consistent with the empirical findings. After 1970, all default episodes happen in emerging markets, and none in OECD countries. Furthermore, emerging markets have much more volatile TFP processes than OECD countries.

Second, the model predicts that defaulting countries have larger debt than non-defaulting countries: 56% versus 13% of their output. This is consistent with the finding in Reinhart et al. (2003). They document that for a sample of 27 middle-income countries, defaulting countries on average borrow more in terms of output than non-defaulting countries: around 41% versus 34%.

Third, the model produces a higher fraction of countries in the penalty phase in the more-integrated period. Empirically, we construct the fraction of countries in the penalty phase using the sovereign default episodes collected by Standard & Poor's. We classify a country as "in the penalty phase" if it has not resumed its normal debt services and regained access to markets after the event of default. Among our 43 countries, the fraction of countries in the penalty phase almost doubles over the two periods: 5% in the less-integrated period and 9% in the more-integrated period.[13] When looking at a larger sample of 202 countries, for which Beers and Chambers (2004) provide the detailed information on sovereign default, we find a similar pattern: the fraction of countries in the penalty phase is 10% in the less-integrated period and 26% in the more-integrated period.

Risk Sharing Across Subgroups

Our model predicts that countries in the low-volatility regime have better risk sharing than those in the high-volatility regime. Countries in the low-volatility regime never default because their TFP is of high levels and low volatility. Thus, they face looser borrowing constraints and lower interest rate schedules than those in the high-volatility regime, and so enjoy better risk sharing. In addition, these countries also accumulate a large amount of precautionary savings to insure against the likelihood of switching to the high-volatility regime, which also provides self-insurance. To demonstrate this prediction, we simulate a large number of countries from the invariant distribution and divide countries into two groups according to their regimes for each experiment. We then look at the degree of risk sharing for each subgroup, and report the results in Table 7 under the model panel. The regression coefficient for countries in the low-volatility regime is around 0.64 and statistically lower than that for countries in the high-volatility regime, 0.85.

Table 7: Risk Sharing β_1 Across Sub-groups

	Data		Model	
	1970-1986	1987-2004	$\tau = 0.04$	$\tau = 0$
Low-volatility regime (OECD)	0.62 (.04)	0.60 (.03)	0.64 (.01)	0.63 (.02)
High-volatility regime (emerging)	0.79 (.05)	0.88 (.02)	0.85 (.02)	0.85 (.03)

Note: numbers in parentheses are standard errors.

We investigate this prediction empirically by dividing our sample into two groups: OECD countries and emerging markets. Loosely speaking, the low-volatility regime can be interpreted as the OECD countries and the high-volatility regime as the emerging markets. We measure the degree of risk sharing for each subgroup and report the empirical results in Table 7 under the data panel. The OECD countries have better risk sharing than emerging markets in each sub-period, which is consistent with our model's implication.

When examining the model implications before and after financial liberalization, we find that both groups show little improvement in risk sharing. This finding is not surprising for countries in the high-volatility regime because they are on average borrowers and greatly constrained in borrowing due to default risk both before and after liberalization. It is surprising, however, for countries in the low-volatility regime

[13]See Data Appendix 2 for detailed documentation.

because they are on average savers and financial liberalization remove all constraints on savings. The key to understanding this finding is the general equilibrium effect. After financial liberalization, the increase in borrowing is limited due to the presence of default risk. Thus, in equilibrium the increase in savings is also limited; this occurs through a lower risk free interest rate which lowers saving incentives of countries in the low-volatility regime. This finding is consistent with the data: both the OECD and emerging countries show no significant improvement in risk sharing after financial liberalization.

Alternative Form of Capital Controls

We conduct a robustness check of our result on an alternative form of capital controls: the quantity control. Instead of imposing taxes on international borrowing and lending, we impose a quantity restriction on international borrowing and lending, given by

$$-B_M \leq b' \leq B_M, \tag{15}$$

where $B_M > 0$ is the maximum amount of international transactions. We first calibrate B_M to match the observed asset-output ratio in the less-integrated period. We next remove the quantity restriction in the second experiment to mimic financial liberalization in the more-integrated period. We find that the degree of international risk sharing is almost the same across the two experiments: β_1 is 0.66 with a standard error 0.04 in the less-integrated period and 0.63 with a standard error of 0.03 in the more-integrated period. Thus, our conclusion that international risk sharing shows little improvement despite financial liberalization is robust to different modeling choices of the capital controls.

5 Conclusion

Over the last two decades, the world witnessed a widespread reduction in capital controls. As a result, countries became more financially integrated over time. Conventional wisdom predicts that countries can better insure macroeconomic risk when they are more financially integrated. The large empirical literature on this subject, however, finds little evidence of increased international risk sharing over time despite widespread financial deregulation.

This work shows that the liberalization of financial markets does not necessarily lead to a significant increase in international risk sharing if contracts are incomplete and enforceability of debt repayment is limited. Default risk on sovereign debt acts as an impediment to capital flow and constrains the degree of financial integration. Thus, the observed increase in financial integration, while seemingly large, is too limited to significantly improve risk sharing.

We demonstrate this idea using a calibrated DSGE model with a continuum of countries and their default choices on sovereign debt. We quantify the degree of capital controls by matching the observed capital flow in the less-integrated period in the first experiment, and eliminating capital controls in the second experiment. We find that when countries remove capital controls, capital flow increases, but the increase is quantitatively too small to significantly improve risk sharing. In addition, financial integration leads to more sovereign defaults, which hurts risk sharing.

Limited enforceability on debt contracts profoundly impacts international capital flow and international risk sharing. Sovereign default risk endogenously constrains borrowing, makes borrowing more difficult in bad times, and generates costly equilibrium default. Thus, default risk is a time-varying impediment to international risk sharing. The commonly proposed policy—the removal of capital controls and deregulation of financial markets—cannot automatically deliver significant improvements in international risk sharing so long as financial contracts are incomplete and imperfectly enforced.

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Data Appendix

In this appendix, we first describe the data sources and the country coverage in detail, then show the empirical facts on sovereign defaults, and finally present different measures of international risk sharing.

1. Data Description

Country Sample

Given our interest in how financial integration affects risk sharing, we focus on countries with relatively open financial markets. Following Prasad et al. (2003), we include 21 OECD countries and 22 more-financially-integrated countries in our sample. The 21 OECD countries are Australia, Austria, Belgium, Canada, Denmark, Finland, Germany, France, Greece, Ireland, Italy, Japan, the Netherlands, Norway, New Zealand, Portugal, Spain, Sweden, Switzerland, the United Kingdom, and the United States. The 22 more-financially-integrated countries are Argentina, Brazil, Chile, China, Colombia, Egypt, Hong Kong, India, Indonesia, Israel, Korea, Malaysia, Mexico, Morocco, Pakistan, Peru, the Philippines, Portugal, Singapore, South Africa, Thailand, Turkey, and Venezuela.

Data Sources

The national account data (real GDP, real final consumption and real gross capital formation) are primarily from the World Bank's publication *World Development Indicators* (WDI) 2004; for missing years in WDI, we use the Penn World Table 6.2. For the 21 OECD countries, employment data are from the OECD (various years) databases. For the following 13 countries, employment data are from national statistics: Chile, Colombia, Egypt, India, Israel, Korea, Malaysia, Pakistan, the Philippines, Singapore, Thailand, Turkey, and Venezuela. For the remaining 9 countries, employment data are supplemented by the Penn World Table. The data used to measure financial integration are from the data set constructed by Lane and Milesi-Ferretti (2007). All variables except employment are in terms of the U.S. dollar.

2. Sovereign Defaults over 1970–2004

In this appendix, we construct the overall statistics of the fraction of countries in default over the less-integrated and the more-integrated period. We collect the episodes of sovereign defaults on foreign-currency bank or bond debt. According to Standard & Poor's, sovereign default is defined as "the failure to meet a principal or interest payment on the due date (or within the specified grace period) contained in the original terms of the debt issue". Beers and Chambers (2004) report sovereign default episodes for 202 sovereign countries from 1975 to 2002 using data from Standard & Poor's. We expand the year coverage of their data set to 1970–2004 for our 43 sample countries. In particular, only Argentina defaulted in 2003, and there are no countries defaulting during 1970–74 and 2004.

The default episodes are summarized in Table 8. A country is classified as "in default" until its normal debt services resume after negotiation and it regains the access to markets. For example, Argentina defaulted in 1982 and is in default until 1993 according to Standard & Poor's. Using this table, we can construct the fraction of countries in default for each period. The average number of countries in default is 2.35 (about 5% of the 43 countries) in the less-integrated period and is 5.35 (about 9% of the 43 countries) in the more-integrated period. The fraction of countries in default almost doubles over the two periods.

Table 8: Default Episodes in the Data

Country	Years in Default
Argentina	1982–93, 2001–03
Brazil	1983–94
Chile	1983–90
Egypt	1984
Indonesia	1998–99, 2000, 2002
Mexico	1982–90
Morocco	1983, 86–90
Pakistan	1998–99
Peru	1976, 78, 80, 84–97
Philippines	1983–92
South Africa	1985–87, 89, 93
Turkey	1978–79, 82
Venezuela	1983–88, 90, 95–97

3. Alternative Measurement of Risk Sharing

This appendix presents two popular ways of measuring international risk sharing in the literature. One uses cross-section regression analysis. The other uses consumption volatility relative to output volatility. Both methods indicate no substantial increase in international risk sharing in the more-integrated period relative to the less-integrated period.

Cross-Section Regression

One alternative way to estimate the degree of risk sharing is to use cross-section regression, proposed by Cochrane (1991). For each year, we run the same regression as specified in equation (12). Table 9 shows the median of the cross-section regression coefficients β_1 in the less-integrated period and the more-integrated period. Again, international risk sharing is far from perfect for each period and each country group. More importantly, there is no significant increase in international risk sharing for both OECD countries and emerging countries over the two periods.

Consumption Volatility

Besides the regression-based measurements of international risk sharing, another commonly used measurement is the ratio of consumption volatility and GDP volatility, as in Backus et al. (1992). With more

Table 9: Median Regression Coefficient on Output Growth β_1

Country Group	Less-Integrated Period 1970–1986	More-Integrated Period 1987–2004
43 countries	.75 (.12)	.86 (.07)
21 OECD	.59 (.16)	.62 (.12)
22 Emerging	.74 (.17)	.87 (.11)

Note: numbers in parentheses are standard errors.

financial integration, countries should have lower consumption volatility relative to output since countries can insure better their idiosyncratic shocks. Table 10 reports the average ratio of consumption volatility and GDP volatility across different groups of countries over the two periods. There is no statistically significant decrease in the relative consumption volatility over the two periods.

Table 10: Mean Ratio of Consumption Volatility and Output Volatility

Country Group	Less-Integrated Period 1970–1986	More-Integrated Period 1987–2004
43 countries	1.08 (.29)	0.92 (.17)
21 OECD	1.07 (.23)	0.88 (.16)
22 Emerging	1.10 (.35)	0.95 (.17)

Note: numbers in parentheses are standard errors.

Technical Appendix

1. Characterization of Equilibrium

Proof of Proposition 1: Since country (a, k, b_2, N) chooses to default, we have

$$V(a, k, b_2, N) = W^D(a, k) > W^R(a, k, b_2).$$

Since the repaying welfare W^R is increasing in b, we have

$$W^R(a, k, b_2) > W^R(a, k, b_1) \text{ for any } b_1 < b_2.$$

This implies $W^D(a, k) > W^R(a, k, b_1)$ for any $b_1 < b_2$. Thus, country (a, k, b_1, N) will also choose to default. Q.E.D.

Proof of Proposition 2: For any country (a, k, b, N) with $b > -\gamma a k^\alpha$, the budget set under repayment is larger than that under default. This implies that the optimal allocation of $W^D(a, k)$ is feasible under $W^R(a, k, b)$. Let (c_r, k'_r, b'_r) and $(c_d, k'_d, 0)$ denote the optimal choices of the recursive problems W^R and W^D respectively. Thus, we have

$$\begin{aligned} W^R(a, k, b) &= u(c_r) + \beta \sum \pi(a'|a) V(a', k'_r, b'_r, N) \\ &\geq u(c_d) + \beta \sum \pi(a'|a) V(a', k'_d, 0, N). \end{aligned}$$

Furthermore, we know that the repaying welfare is higher than the defaulting welfare when $b \geq 0$, and in particular, $V(a, k, 0, N) \geq V(a, k, 0, P)$. Therefore, we have

$$W^R(a, k, b) \geq u(c_d) + \beta \sum \pi(a'|a) V(a', k'_d, 0, P) = W^D(a, k).$$

Hence, any country with $b > -\gamma a k^\alpha$ will not default. Q.E.D.

2. Estimation of the World Productivity Process

This appendix describes the EM algorithm, used to obtain the maximum likelihood estimates of parameters in the regime-switching process (13). This is an extension of Hamilton (1989). The log-likelihood function is given by

$$L(\Psi; \Theta) = \sum_{i=1}^{N} \log\left(f(\Psi^i; \Theta)\right),$$

where $\Psi^i = \{a^i_T, a^i_{T-1}, ..., a^i_1\}$ denotes country i's TFP series, $\Theta = \{\{\mu_\Re, \rho_\Re, \sigma_\Re\}_{\Re=1,2}, \gamma, P\}$ the set of the parameters to be estimated, N the number of countries, T the total number of periods, $\Re$ the regime and f the density function given by

$$f(\Psi^i; \Theta) = \sum_{\Re^i} f(a^i_T|\Re^i_T, a^i_{T-1}; \Theta) \cdots f(a^i_2|\Re^i_2, a^i_1; \Theta) p(\Re^i_T|\Re^i_{T-1}) \cdots p(\Re^i_2|\Re^i_1) p(\Re^i_1).$$

Due to the nonlinearity of the maximum likelihood function, we cannot solve the parameters analytically. Instead, we use the EM algorithm to solve the maximum likelihood estimates iteratively. We start with an initial guess of the parameters Θ_{n-1}. We then update the conditional probabilities of regimes in each period for each country using Bayes' rule. Given the conditional probabilities, we next compute Θ_n with maximum likelihood. We iterate these procedures until $\{\Theta_n\}$ converges.

Following Hamilton (1996), we compute the standard errors of the estimated parameters as follows:

$$\phi_{OP} = \frac{1}{T \times N} \sum_{i=1}^{N} \sum_{t=1}^{T} \left[h^i_t(\hat{\Theta}) h^i_t(\hat{\Theta})'\right],$$

where h^i_t denotes the score given by

$$h^i_t(\Theta) \equiv \frac{\partial \log f(a^i_t|\Psi_i; \Theta)}{\partial \Theta}.$$

3. Solution Algorithm

To compute the model, we start with a guess of the world interest rate R and a bond price schedule $q(s, b')$ as the reciprocal of R for each country s with loan demand b'. We then solve each country's value function and decision rules under both the normal and penalty phase using value function iteration. Given the value function under the normal phase, we can compute the optimal capital stock $k'(s, b')$ for country s with the intention of borrowing b'. The bond price schedule is then updated as $q^{n+1}(s,b') = (1 - p^n(s,b'))/R$, where $p^n(s,b')$ is the default probability constructed from the optimal default choices and $k'(s,b')$. We iterate the above procedures until q converges, i.e., $|q^{n+1}(s,b') - q^n(s,b')| < \epsilon$.

Given the converged bond price schedule, we next compute the invariant distribution μ^*, which is the solution to $\mu^* = \mu^* Q$, where Q denotes the transition matrix over states governed by the optimal decision rules. Finally, we calculate the excess demand of bonds over the invariant distribution and check if the bond markets clear. If not, we update the interest rate and repeat the above procedure.