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# 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 widespread financial liberalization. We show that the key to understanding this puzzling observation is that conventional wisdom assumes frictionless international financial markets, while actual markets are far from frictionless: financial contracts are incomplete and contract enforceability is limited. When countries remove official capital controls, default risk is still present as an implicit barrier to capital flows. If default risk were eliminated, capital flows would be six times greater, and international risk sharing would increase substantially.



## 1. Introduction

Over the last two decades, the world has witnessed widespread removal of capital controls in both developed and developing countries. Consequently, countries have become more financially integrated over time. In particular, debt as the major form of international capital flows has risen substantially: in a cross section of 43 countries, the ratio of net debt position to GDP has more than doubled from 8% in 1970–1986 to 18% in 1987–2004.[1] Conventional wisdom predicts that countries can better insure macroeconomic risk when they are more financially integrated. Puzzlingly, an extensive empirical literature finds little evidence that countries increased consumption smoothing and risk sharing despite widespread financial liberalization.[2]

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 flows across countries, even when countries remove capital controls. Thus, the observed increase in capital flows under financial liberalization is too limited to significantly improve consumption smoothing and risk sharing.[3]

We study a dynamic stochastic general equilibrium model with a continuum of small open economies and production. Countries experience idiosyncratic total factor productivity (TFP) shocks and share risk through international financial markets that have two frictions. The first 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.[4] Recurrent episodes of sovereign default in the

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

[2] For a detailed discussion, see Kose et al. (2009).

[3] Henceforth we use the word "risk sharing" to stand for both risk sharing and consumption smoothing.

[4] Kraay et al. (2005) also document that roughly three-quarters of net north–south capital flows take the form of net lending. Equity and FDI flows are 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.

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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[5] and calibrate the tax to match the observed capital flows 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 flows of similar magnitude to that found in the data from the less-integrated to more-integrated period. The model also reproduces many salient 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.

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 (henceforth *risk sharing coefficient*) in a panel regression of consumption growth rates on output growth rates, as is prevalently used in the empirical literature. The smaller the risk sharing coefficient, the higher the degree of international risk sharing. The model produces limited international risk sharing in both the less-integrated and more-integrated period: 0.64 and 0.63. More importantly, even though capital flows double across these two periods as in the data, international risk sharing improves little.

Financial frictions are the key to understanding limited risk sharing in both periods. When only non-contingent bonds are available, countries have limited access to insure against risk. Default risk on these bonds further restricts risk sharing. Though equilibrium default helps complete markets by making non-contingent repayments somewhat contingent,[6] default risk greatly constrains ex-ante borrowing, especially in bad times when countries need insurance the most. Borrowing is constrained 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. Countries in bad times face a higher interest rate schedule because with persistent shocks they are more likely to stay in bad times tomorrow, and so they are more likely to default tomorrow.

Default risk is the key to generating little improvement in international risk sharing across the two periods. When the tax on foreign asset holdings is eliminated, the model generates an increase in the debt-output ratio from 8% to 18% as observed in the data. The increase, however, is limited by default risk, and so the model produces little improvement in international risk sharing.[7] If default risk were also eliminated in the more-integrated period, the debt-output ratio would be 110%, six times larger than the observed ratio. Consequently, international risk sharing would improve substantially even with only non-contingent bonds; the risk sharing coefficient would be lowered to 0.53 instead of 0.63.

Consistent with our finding of little improvement in risk sharing, the implied welfare gain from the removal of capital controls is small; permanent consumption increases by 1.2%. In contrast, if default risk were also eliminated in the more-integrated period, permanent consumption would increase by 42% even with only non-contingent bonds. If, in addition, a full set of assets were also available in the more-integrated period, permanent consumption would increase by 68%. Thus, relative to the potential welfare gains, the welfare gain from the removal of capital controls is small when international financial markets are characterized by limited enforceability of debt contracts.

We also evaluate the model performance in replicating capital flow and risk sharing for emerging market economies and OECD countries. In the data, the OECD countries have less volatile TFP processes than the emerging markets. We calibrate a two-regime shock process to capture this feature: a high-volatility regime and a low-volatility regime. The model predicts that countries in the low-volatility regime have lower asset-output ratios and better risk sharing than those in the high-volatility regime in both periods, which is consistent with the data for the OECD and emerging market countries. Moreover, the model predicts that risk sharing improves little for countries in both regimes in response to removal of capital controls. This observation is also consistent with the empirical finding.

Our paper contributes to the sovereign debt literature[8] in three dimensions. First, our paper studies production economies and addresses the common criticism of this literature: a pure exchange economy allows no consumption smoothing in autarky or after default. This criticism is particularly severe when one aims to quantify the impact of financial integration on risk sharing: a quantitative model will attribute any consumption smoothing to financial integration. In contrast, a production economy allows consumption smoothing even in autarky. Second, we examine the world interest rate that comes out of the general equilibrium model, while previous works take the world interest rate as given. The production framework and the general equilibrium aspect make the model much more difficult to compute. Third, our paper provides a theory explaining the phenomenon of lack of improvement in risk sharing after financial integration in both emerging markets and developed economies through the presence of default risk and the general equilibrium effect. In contrast, the existing works focusing on emerging markets are silent on developed countries.

This work is related to the international business cycle literature on the impact of financial integration. With a small open economy model and incomplete markets, Mendoza (1994) 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. Heathcote and Perri (2004) study why consumption co-movement between the United States and Europe declines as cross-border equity flow rises over time. Complimentary to their work, our paper studies why risk sharing between developed and emerging market economies improves little as international debt flow rises over time.

The default model in this paper is close to the bond-enforcement model in Bai and Zhang (2010). Both models assume that the asset market is incomplete and that countries can renege on their debt. In Bai and Zhang (2010), default never occurs in equilibrium under the implicit assumption that competitive lenders cannot discriminate between borrowers. Thus, only risk-free borrowing and lending arise in equilibrium. In this paper, we instead assume that competitive lenders can discriminate borrowers. Thus, country-specific interest rates and default arise in equilibrium. In the absence of equilibrium default, the bond-enforcement model in general produces tighter borrowing constraints and worse risk sharing than the default model.

Our model abstracts from relative prices across countries. Cole and Obstfeld (1991) show that theoretically changes in relative prices can provide risk sharing across countries. This raises the concern whether our empirical finding is robust to movements in relative prices. We find that even after controlling for changes in relative prices, our measure of international risk sharing still barely improves in the more-integrated period. This finding is consistent with Corsetti et al. (2008), who document empirically that movements in relative prices are not in the direction required to enhance insurance.

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

[6] For detailed arguments, see Grossman and van Huyck (1988).

[7] Kraay et al. (2005) show that default risk is important for understanding the limited North–south capital flow in a framework with exogenous default.

[8] Pioneered by Eaton and Gersovitz (1981), the sovereign debt literature has been advanced more recently in the quantitative dimension by Aguiar and Gopinath (2006), Arellano (2007), Yue (2010), Benjamin and Wright (2009), Chatterjee and Eyigungor (2010), Hatchondo and Martinez (2009), and many others.

The organization of the paper is straightforward. Section 2 lays out the theoretical model. We present the empirical facts and parameterize the model in Section 3 . Section 4 analyzes the quantitative results, 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 non-contingent 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. To highlight the frictions on the international financial markets and international risk sharing, we abstract from frictions in domestic financial markets and assume perfect domestic risk sharing.[9]

### 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 $\alpha$ the capital share parameter. The TFP shock follows a first-order Markov process with finite support $A$ and transition matrix $\Pi$. 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.[10] Also, centralized borrowing provides lower credit costs and higher welfare than *decentralized borrowing*, where individual consumers make decisions on borrowing, lending and default.[11] Thus, by modeling centralized borrowing, we allow more room for international risk sharing.

[9] A complementary work by Broner et al. (2011) studies theoretically the impact of financial integration on domestic risk sharing.

[10] Eaton et al. (1995) provide a detailed discussion of the empirical motivation for centralized borrowing.

[11] As pointed by Jeske (2006) and Kim and Zhang (2011), individual consumers fail to endogenize the impact of their borrowing on aggregate borrowing terms under decentralized borrowing.

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 by 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 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, so we examine their problems in turn.

#### 2.1.1. 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 tk 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

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

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. $\Phi$ denotes the capital adjustment costs, and $\gamma$ the penalty parameter capturing the drop in TFP.

If it repays, the country enjoys access to financial markets today and remains in the normal phase next period. The country can issue one period discount bonds $b'$ at price $q(a, k', b')$, which is endogenous to the country's default incentives. The bond price $q(a, k', b')$ depends on TFP shock $a$, capital $k'$ and bond holding $b'$ because they affect default probabilities. Country $s$ chooses consumption $c$, next period's capital stock $k'$, and bond holding $b'$ 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

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

and the non-negativity constraints (5), where $\tau$ is the real resource cost to access international financial markets. This parameter $\tau$, therefore, captures the degree of capital controls in this economy. Infinitely large $\tau$ produces a closed economy, i.e. financial autarky; zero $\tau$ 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 an interest equalization tax from 1963 to 1974; investment returns on foreign stocks and bonds were taxed at 1% to 15% 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 have similar quantitative implications for international risk sharing. We present the implications of price controls for most of the paper and show those of quantity controls in Section 4 . In addition, we observe capital controls on both inflows and outflows 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.

*2.1.2. Country in the penalty phase*

A country in the penalty phase suffers a drop in TFP each period; 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 $\lambda$ 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

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

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. Thus, the bond price schedule $q(a, k', b')$ is such that the intermediaries break even

$$q\left(a,k',b'\right) = \left[1-p\left(a,k',b'\right)\right]/R, \tag{9}$$

where $p(a, k', b')$ denotes the expected default probability of a country with TFP shock $a$, capital $k'$ and bond holding $b'$.[12] The default probability is the sum of the probabilities of the states under which this country will choose to default on its debt $b'$ next period. More specifically, the default probability is

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

*2.3. Stationary recursive equilibrium*

We first define the stationary recursive equilibrium, and then provide some characterization of the equilibrium. Let $\mu$ be the probability measure on $(X, \aleph)$, where $\aleph$ is the Borel $\sigma$-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 $q(a, k', b')$, 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 $\mu$, such that,

- Given $q(a, k', b')$, 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 $\mu$ 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 $\gamma$ 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

[12] The bond price can be alternatively modeled as a function of the country's current state $s$ and bond holding $b'$. The financial intermediary computes the optimal capital stock $k'$ associated with bond holding $b'$ and then calculate the default probability next period. We find that the quantitative results are almost identical under both specifications.

**Table 1**
Financial integration and risk sharing.

| Sample | World asset-output ratio | | Regression coefficient $\beta_1$ | |
|---|---|---|---|---|
| | Less-integrated 1970–1986 | More-integrated 1987–2004 | Less-integrated 1970–1986 | More-integrated 1987–2004 |
| Full sample (43 countries) | 0.08 | 0.18 | 0.76 (0.03) | 0.84 (0.02) |
| OECD (21 countries) | 0.06 | 0.18 | 0.62 (0.04) | 0.60 (0.03) |
| Emerging (22 countries) | 0.21 | 0.28 | 0.79 (0.05) | 0.88 (0.02) |

Note: numbers in parentheses are standard errors.

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 $\gamma$ after default, a country with a debt-output ratio less than $\gamma$ 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 $\gamma$ may also choose to repay with probability one, and thus the safe debt-output ratio is at least as large as $\gamma$.

## 3. Data and calibration

In this section, we first present empirical evidence on financial integration and international risk sharing. Despite substantial financial integration in the past two decades, we find that international risk sharing shows little improvement for the full sample, OECD countries and emerging market economies. The OECD countries have better risk sharing though their capital flow is smaller than the emerging markets. 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.

### *3.1. Data*

Financial integration has 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 flows.[13] 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 flows across countries, in terms of either gross (or net) foreign flows 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 to world GDP (later referred to as the *world asset-output ratio*). The net debt position is 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 (also referred to as emerging markets later) based on the classification in Prasad et al. (2003).[14] 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. Specifically, we examine the OLS regression of the form

$$\Delta \ln c_t^i - \Delta \ln \bar{c}_t = \beta_0 + \beta_1 \left( \Delta \ln y_t^i - \Delta \ln \bar{y}_t \right) + u_t^i, \tag{11}$$

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 $x$.[15] 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 $\beta_1$; the lower the regression coefficient, the better countries share risk. Perfect risk sharing, generated by the standard complete markets model, implies that consumption growth should not respond to individual income growth, i.e., $\beta_1$ should be zero.

Our findings are summarized in Table 1. First, the regression coefficient $\beta_1$ 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. Though the panel regression assumes separability between consumption and leisure in the utility function, the result holds more generally. We delegate the regression controlling leisure to Appendix 3, which shows that allowing for non-separability between leisure and consumption cannot explain the apparent lack of risk sharing across countries. This is consistent with the finding by Lewis (1996).

Second, international risk sharing shows no statistically significant improvement over the two periods; an F-test rejects the hypothesis that the regression coefficient $\beta_1$ is smaller in the more-integrated period. This finding is robust to different sample groups of countries: emerging markets and OECD countries. For both groups, risk sharing

[13] 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.

[14] See Data Appendix 1 for details on the country sample.

[15] See Data Appendix 1 for details on the data sources.

shows no improvements despite an increase in the asset-output ratio from the less-integrated to more-integrated period.

Empirical 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. (2009) 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)). Fig. 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. (2009). 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. This conclusion is robust when we allow for nonseparable utility, as shown in Appendix 3.

We also examine two alternative measures of international risk sharing for robustness checks. One is the average ratio of consumption volatility and output volatility across countries, which is commonly used in the international business cycle literature. The other is the cross-country regression of average consumption growth on average output growth, which is proposed by Cochrane (1991). We find that there is no sign of better risk sharing in the more financially integrated period using either alternative measure. See Data Appendix 3 for detailed results.

Our model and empirical analysis abstract from relative prices across countries. Cole and Obstfeld (1991) show that theoretically changes in relative prices can provide risk sharing across countries. This raises the concern whether our empirical finding is robust to movements in relative prices. To address this concern, we include changes in real exchange rates as an additional independent variable in the regression Eq. (11). We find that even after controlling for changes in relative prices, our measure of international risk sharing still barely improves in the more-integrated period. See Data Appendix 3 for detailed results. This finding is consistent with Corsetti et al. (2008), who document empirically that movements in relative prices are not in the direction required to enhance insurance.

### 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

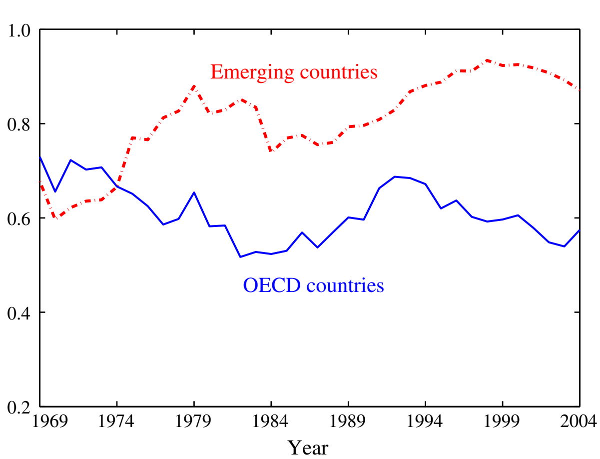


**Fig. 1.** Regression coefficient $\beta_1$ (9-year rolling panel).

keep the same shock process and structural parameters across the two periods except for the tax on foreign asset holdings. All countries have the same parameter values describing tastes and technology. The period utility function takes the standard CRRA form of

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

where the risk aversion parameter $\sigma$ is chosen to be 2. The discount factor $\beta$ is set at 0.89 to match the equilibrium interest rate in the less-integrated period with the average real return of 1% on US treasury bills over the same period. The capital share $\alpha$ is set at 0.33 and the capital depreciation rate $\delta$ is set at 10% per year to match the U.S. equivalents. The capital adjustment cost takes the standard quadratic form of

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

where $\phi$ 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 $\lambda$ 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 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 (2010), but we need to incorporate the TFP drop parameter $\gamma$ 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.

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. We de-trend the TFP series using the average world TFP growth rate of 1.3%. Let $a_t^i$ denote the logged and de-trended 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 de-trended individually. Thus, our way of de-trending leaves in more heterogeneity across countries and allows for a greater incentive to share risk.

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 0.01 before 1980, but 3.02 and 0.07 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

$$a_t^i = \mu_{\Re_t^i}\left(1-\rho_{\Re_t^i}\right) + \rho_{\Re_t^i} a_{t-1}^i - \gamma h_t^i + \sigma_{\Re_t^i}\epsilon_t^i, \qquad (12)$$

where $\epsilon_t^i$ 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 $\gamma$. Details of these observations are reported in Table 10 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%. Note that with probabilities of switching regimes, the estimated TFP process is not that persistent even though each regime has a persistent level higher than 0.99. The unconditional autocorrelation of the simulated series from our TFP process is 0.86, close to 0.89 in the data.

With the above TFP process and structural parameters, we calibrate the tax $\tau$ at 3.8% to match the world debt-output ratio of 8% in the less-integrated period. Directly measuring the degree of capital controls $\tau$ from the data is hard for two reasons. First, typically governments impose more than one form of capital control at each point in 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. To mimic financial liberalization, we set $\tau$ to be zero in the more-integrated period. Table 3 summarizes the above 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 | $\lambda=0.20$ |
| Taxes | Less-integrated period | $\tau_1=3.8\%$ |
| | More-integrated period | $\tau_2=0$ |

## 4. Quantitative results

We solve the model equilibrium with a non-linear recursive technique twice: one for $\tau$ at 3.8% and one for $\tau$ at 0%. For the detailed computational algorithm see Technical Appendix 3. We then compute the model statistics based on the invariant distribution and decision rules. The main findings are reported in Table 4.

When the tax $\tau$ drops from 3.8% 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 0.65 and 0.64 in these two experiments, respectively. 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 looks at only 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 and constrains the increase in capital flows too much to improve risk sharing. To demonstrate this mechanism, we first focus on the experiment with zero tax to illustrate how default risk affects risk sharing. We next look across the two experiments to understand why there is no improvement in international risk sharing. We then evaluate the model in terms of subgroup and sovereign default implications. We finally conduct the sensitivity analysis of our main result.

### 4.1. Default risk and imperfect risk sharing

To see the role of sovereign default risk, we contrast our benchmark model (labeled as 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. Specifically, the natural borrowing constraint is given by

$$b' \geq -B\left(a, k'\right) = -max\left\{\frac{\underline{a}(a)k'^{\alpha} + (1-\delta)k' - min_{k''}\left\{\Phi\left(k'', k'\right) + k''\right\}}{1-\frac{1}{R}}, 0\right\},$$

where $\underline{a}(a)$ denotes the lowest possible shock next period conditional on current shock $a$. Thus, borrowing terms are based on the *incentive* of countries to repay in the default model, but on the *ability* of countries to repay in the no-default model.

To isolate the impact of the default risk, we solve the no-default model under the same set of parameters as in the default model with $\tau$ at zero. Table 5 compares the implications of the default

**Table 2**
Estimated productivity process.

| Regime | Innovation $\sigma$ | Persistence $\rho$ | Mean $\mu$ | Switching prob. $P$ | |
|---|---|---|---|---|---|
| | | | | High | Low |
| High volatility | 0.05 (0.000) | 0.996 (0.007) | 2.66 (1.45) | 0.89 (0.14) | 0.11 (0.14) |
| Low volatility | 0.02 (0.000) | 0.991 (0.001) | 4.40 (0.10) | 0.05 (0.06) | 0.95 (0.06) |
| TFP drop parameter $\gamma$ 0.02 (0.006) | | | | | |

Note: numbers in parentheses are standard errors.

**Table 4**
Simulation results.

| | Data | | Model | |
|---|---|---|---|---|
| | 1970–1986 | 1986–2004 | $\tau_1=3.8\%$ | $\tau_2=0\%$ |
| World asset-output ratio | 0.08 | 0.18 | 0.08 | 0.18 |
| Risk sharing coefficient | 0.76 | 0.84 | 0.65 | 0.64 |
| | (0.03) | (0.02) | | |

Note: numbers in parentheses are standard errors.

**Table 5**
Default vs. no-default model with $\tau=0$.

| | Default model | No-default model |
|---|---|---|
| Risk sharing coefficient | 0.64 | 0.59 |
| Maximum safe debt-output ratio | 0.32 | 18.64 |
| Maximum debt-output ratio | 1.73 | 18.64 |
| World asset-output ratio | 0.18 | 1.12 |
| Fraction of countries in the penalty phase | 0.14 | 0.00 |
| Discount factor | 0.89 | 0.89 |
| Equilibrium interest rate | 1.00 | 1.04 |

Note: The statistics on the debt-output ratio are computed over the states with positive measures in the invariant distribution.

model and the no-default model. The regression coefficient is lower in the no-default model than the default model: 0.59 versus 0.64. Thus, the no-default model provides better risk sharing than the default model. Sovereign default risk affects risk sharing through two channels: constrained borrowing and countercyclical borrowing terms.

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 with certainty in the next period (referred to as the *risky debt limit*). The risky debt limit is the debt capacity of the country. In Fig. 2, the left panel plots the safe debt limit and the risky debt limit as a function of future capital stock for countries with the median shock and zero current 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 equilibrium maximum safe and risky debt-output ratio are 0.31 and 1.73 in the default model, much smaller than those in the no-default model, 18. This difference helps explain why the equilibrium world asset-output ratio in the no-default model is 5 times larger than that in the default model: 1.12 versus 0.18.

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 in bad times than in good times. Countries thus have higher incentives to default in 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. Fig. 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 0.10. This larger price discount in 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 bad times to smooth consumption.

We now illustrate the patterns of risky borrowing and equilibrium default in the default model. When a country receives a better shock, especially when it switches from the high-volatility regime to the low-volatility regime, it has a large incentive to borrow to build up capital 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. In each period, however, there is some probability that the country is hit by a bad shock and switches back to the high-volatility regime. With large outstanding debt and a low current output, the country might end up in default. Thus, countries default in bad times in the high-volatility regime with large debt. These model dynamics broadly capture the boom-bust cycle of capital flows to the emerging markets.

The main model predictions on sovereign default, in both pre- and post-liberalization periods, are broadly consistent with the data. First, the model predicts that default occurs only in the high-volatility regime. In the data, all default episodes happen in emerging markets, and none in OECD countries between 1970 and 2004. Second, the model predicts that default occurs in bad times when TFP shocks are low. Tomz and Wright (2007) document empirically that default often occurs when countries' output is below the trend. Third, the model predicts that defaulting countries have larger debt than non-defaulting countries. Reinhart et al. (2003) 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%.

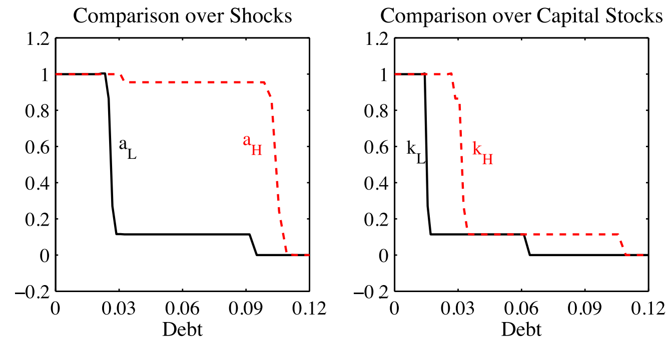


**Fig. 3.** Bond price schedule. The left panel plots the bond prices of countries with median capital and zero debt under diferent shock realizations. The right panel plots the bond prices of countries with the median shock and zero debt under different capital stocks.

### 4.2. Impact of financial integration

The above discussion illustrates how sovereign default risk prevents countries from risk sharing through endogenous constraints

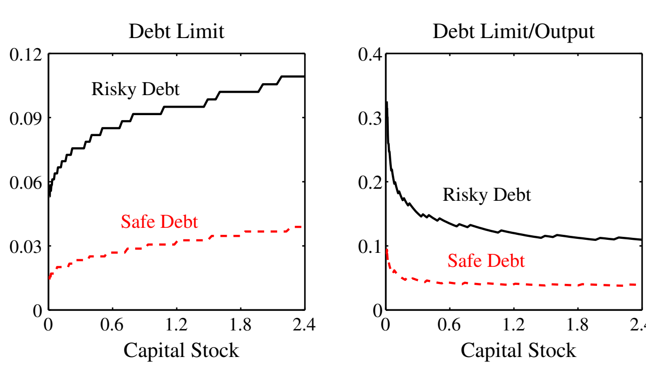


**Fig. 2.** Endogenous debt constraints.

**Table 6**
Implications of the default model across the two periods.

| Default model | Less-integrated period | More-integrated period |
|---|---|---|
| | $\tau = 3.8\%$ | $\tau = 0$ |
| World asset-output ratio | 0.08 | 0.18 |
| Maximum safe debt-output ratio | 0.19 | 0.32 |
| Maximum debt-output ratio | 1.12 | 1.73 |
| Interest rate premium | 0.02 | 0.03 |
| Newly defaulted rate | 0.02 | 0.03 |
| Fraction of countries in the penalty phase | 0.09 | 0.14 |
| Risk sharing coefficient | 0.65 | 0.64 |
| Discount factor | 0.89 | 0.89 |
| Equilibrium interest rate | 1.01 | 1.00 |

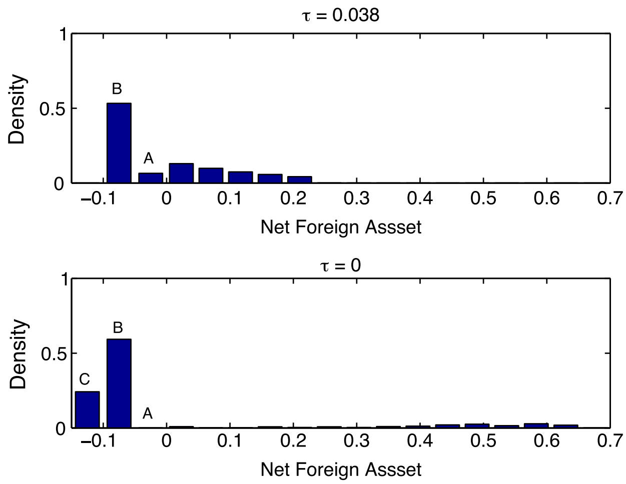


**Fig. 4.** Distribution over foreign assets.

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 experiment with $\tau=3.8\%$ with the one with $\tau=0\%$ to show why international risk sharing improves little when financial integration increases in the default model. Table 6 reports key statistics.

The removal of capital controls boosts international borrowing and lending. International financial markets become more attractive without the tax. With more attractive financial markets, the borrowing constraints become looser because countries are more willing to repay their debt. Consequently, the maximum safe debt-output ratio increases from 19% to 32% and the maximum debt-output ratio increases from 112% to 173%. Foreign savings levels increase more than foreign debt levels in response to the removal of capital controls, as is shown in Fig. 4. Though the maximum amounts of both borrowing and savings increase, the maximum savings increases from 0.26 to 0.72, but the maximum borrowing only moves from 0.08 to 0.11. This is because the endogenous borrowing constraint is still present from default risk. Consequently, the equilibrium interest rate goes down from 1.01 in the less-integrated period to 1.00 in the more-integrated period.

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 Fig. 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.[16] Furthermore, the fraction of countries in the penalty phase is also higher in the more-integrated period than that in the less-integrated period: 14% versus 9%.

We test the model implication of a higher fraction of countries in the penalty phase in the more-integrated period in the data. 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. Detailed statistics are reported in Table 10 of Appendix 2. For our 43 sample countries, the average fraction of countries in the penalty phase almost doubles over the two periods from 5% to 9%. When looking at a larger sample of 202 countries in Beers and Chambers (2004), 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.[17]

Note that the simple average statistics above mask dynamic and time-varying patterns of sovereign default in the data. Empirically, defaults usually happen in waves and tend to cluster temporally and regionally. Our model, based on two stationary cross sections, cannot accommodate dynamic, non-monotonic frequencies of defaults. On the other hand, the default rate and the fraction of countries in the penalty phase in the data are driven by many other variables outside our model, such as time-varying global macro shocks, and institutional changes in the sovereign debt markets (the move from bank debt to bond debt financing by emerging markets, the development of the secondary markets, the reduction in duration of sovereign debt renegotiations, etc.). If the main objective were to account for time-varying frequencies of default, one would have introduced into the model some of these features of the data.

Despite the 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 flows across countries. To demonstrate this, we conduct similar experiments in the no-default model. We calibrate the tax at 5.9% to match the observed debt-output ratio of 8% in the less-integrated period in the no-default model. We also recalibrate the discount rate $\beta$ to generate an equilibrium risk-free interest rate at 1%.[18] We then eliminate this tax in the no-default model. These results are reported in the first and third columns of Table 7. When there is no default risk, the removal of capital controls leads to an increase in the world asset-output ratio by about 23 times from 8% to 190%. As a result, international risk sharing improves significantly; the regression coefficient $\beta_1$ decreases from 0.61 to 0.39. In contrast, the default model only leads to the doubling of the world asset-output ratio, and this seemingly large increase in capital flows is too small to increase international risk sharing significantly.

We also calibrate the tax to match the observed capital flow ratio in the more-integrated period. The results are reported in the second column of Table 7. When the tax rate decreases from 5.9% to 4.8%, the capital flow ratio increases from 8% to 18% as in the data, and the degree of risk sharing improves little. Though both models generate little improvement in risk sharing when taxes are calibrated to match the observed capital flows in the two periods, the no-default and default models provide different interpretation about the frictions. From the default model, it appears that policy makers have removed as much of barriers to capital flows as they can, but risk sharing improves little due to implicit barriers of sovereign default risk. In contrast, in the no-default model it appears that there is still room for policy intervention.

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

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

[17] The finding of the rising average fraction of countries in the penalty phase over the two periods is not very sensitive to our cutoff year of 1986. In the data, most of our sample countries liberalized their capital markets before 1990. When experimenting with different cutoff years for the two periods, we find that the fraction of countries in the penalty phase among 202 countries increases in the second period when the pre- and post-periods are split in 1995 or earlier.

[18] We also conduct an experiment in which the shock process is re-calibrated for the no-default model by removing the dummy variable for the state of default. The results are similar and available upon request from the authors.

**Table 7**
Implications of the no-default model.

| | $\tau=5.9\%$ | $\tau=4.8\%$ | $\tau=0\%$ |
|---|---|---|---|
| World asset-output ratio | 0.08 | 0.18 | 1.90 |
| Risk sharing coefficient | 0.61 | 0.59 | 0.39 |
| Discount factor | 0.94 | 0.94 | 0.94 |
| Equilibrium interest rate | 1.01 | 1.01 | 1.02 |

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.

### 4.3. Risk sharing across subgroups

The two-regime shock process allows us to examine capital flow and risk sharing for countries in different regimes. Empirically, we can examine these statistics for OECD countries and emerging markets. Loosely speaking, we interpret the low-volatility regime as the OECD countries and the high-volatility regime as the emerging markets. The data statistics are reported in Table 8 under the data panel. The OECD countries have a lower asset-output ratio and better risk sharing than emerging markets in both periods. Moreover, both groups of countries show no significant improvement in risk sharing after financial liberalization. The regression coefficient is around 0.60 for the OECD countries and around 0.80 for the emerging market economies in both periods.

The model statistics for the default and no-default models are also reported in Table 8. Both models predict that countries in the low-volatility regime have a lower foreign asset-output ratio and better risk sharing than those in the high-volatility regime. However, the no-default model generates capital flow ratios much higher than the data for the emerging markets: 86% versus 28% in the more-integrated period and 40% versus 21% in the less-integrated period. It also generates a higher degree of risk sharing than the data for emerging markets; the average regression coefficient over the two periods is 0.65 in the no-default model and 0.84 in the data. By contrast, the default model produces capital flows and risk sharing closer to the data for the emerging markets. Default risk constrains capital flow to countries in the high-volatility regime and limits substantially their risk sharing, which is not present in the no-default model.

The default model predicts that risk sharing does not improve in both regimes as capital controls are removed and capital flow rises. For both groups, the regression coefficient is identical across the two periods. 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 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.

We also examine capital flow and risk sharing for debtor and creditor countries separately. We classify a country as a creditor (debtor) country if on average its foreign asset position is positive (negative). As shown in the lower panel of Table 8, empirically creditor countries have lower capital flow ratios but better risk sharing in both periods. Both models capture this pattern of the data. However, again the no-default model produces too much capital flow for debtor countries than the default model: 56% versus 9% in the less-integrated period and 81% versus 19% in the more-integrated period. The default model constrains borrowing and moves capital flow ratios for the debtor countries close to the data.

We finally look at countries that have a default history (defaulters) versus countries that never default (non-defaulters). Results are reported in the bottom panel of Table 8. In the model, risk sharing is more for defaulters than for non-defaulters because default mitigates consumption declines under bad shocks. By contrast, in the data, non-defaulters have more risk sharing than defaulters. The counterfactual model implication is the result of the standard modeling choices: defaulting countries have their debt fully written off and face the same borrowing costs as the never-defaulting countries when they regain the access to the markets. In the data, defaulting countries still need to repay part of their debt and face higher borrowing costs after re-access to the markets. Incorporating these dimensions of the data might help correct the counterfactual model implication.

**Table 8**
Sub-group statistics.

| | Data | | Default model | | No-default model | |
|---|---|---|---|---|---|---|
| | 1970–1986 | 1987–2004 | $\tau=3.8\%$ | $\tau=0\%$ | $\tau=5.9\%$ | $\tau=4.8\%$ |
| Foreign asset-output ratio | | | | | | |
| Low-vol. (OECD) | 0.06 | 0.18 | 0.08 | 0.16 | 0.05 | 0.12 |
| High-vol. (emerging) | 0.21 | 0.28 | 0.12 | 0.32 | 0.40 | 0.86 |
| Risk sharing coefficient | | | | | | |
| Low-vol. (OECD) | 0.62 (0.04) | 0.60 (0.03) | 0.59 | 0.59 | 0.58 | 0.56 |
| High-vol. (emerging) | 0.79 (0.05) | 0.88 (0.02) | 0.74 | 0.74 | 0.67 | 0.64 |
| Foreign asset-output ratio | | | | | | |
| Creditors | 0.05 | 0.19 | 0.08 | 0.39 | 0.04 | 0.10 |
| Debtors | 0.09 | 0.19 | 0.09 | 0.11 | 0.56 | 0.81 |
| Risk sharing coefficient | | | | | | |
| Creditors | 0.65 (0.06) | 0.65 (0.07) | 0.56 | 0.53 | 0.58 | 0.55 |
| Debtors | 0.77 (0.04) | 0.77 (0.04) | 0.71 | 0.68 | 0.70 | 0.65 |
| Foreign asset-output ratio | | | | | | |
| Non-defaulters | 0.06 | 0.18 | 0.08 | 0.17 | | |
| Defaulters | 0.27 | 0.31 | – | – | | |
| Risk sharing coefficient | | | | | | |
| Non-defaulters | 0.68 (0.04) | 0.62 (0.04) | 0.66 | 0.66 | | |
| Defaulters | 0.84 (0.07) | 0.91 (0.08) | 0.60 | 0.57 | | |

Note: numbers in parentheses are standard errors.

### 4.4. Other model implications

We now examine the implications of the default model on accumulation of capital and net foreign asset (NFA) positions before and after financial integration. We find that financial integration has little impact on the distribution of the capital–labor ratio, but shifts the distribution of the NFA-GDP ratio to the right. These findings are broadly consistent with the data.

#### 4.4.1. Default risk and capital decision

In Kehoe and Perri (2002) with a complete set of assets, the enforcement frictions distort capital decisions and shrink dispersions in capital stocks relative to the complete markets model. Countries with good shocks tend to face binding enforcement constraints and

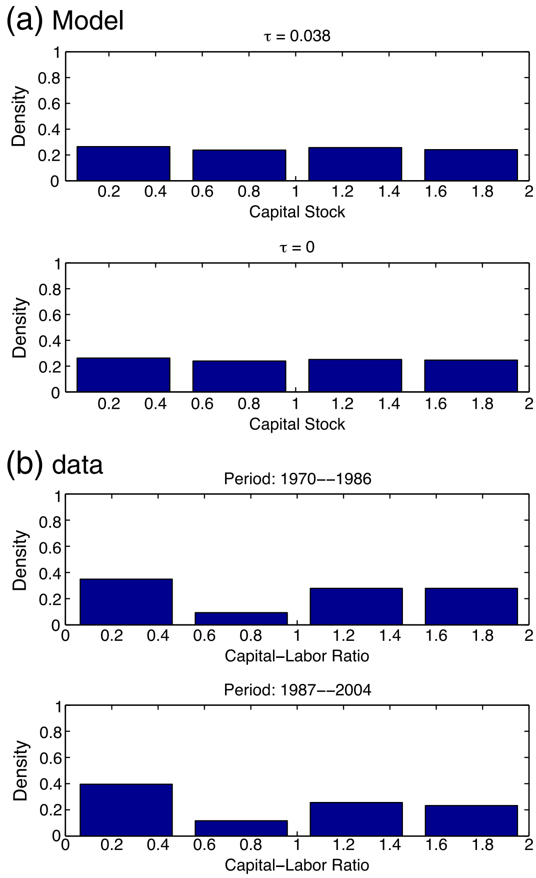


**Fig. 5.** Distribution of capital–labor ratio.

reduce capital to relax the constraints, while countries with bad shocks increase capital because the interest rate is lower in equilibrium. In our default model with only non-contingent bonds, however, the enforcement frictions distort capital decisions differently and enlarge dispersions in capital stocks relative to the no-default model. Countries with good shocks tend not to face binding constraints and increase capital under a lower interest rate; the average capital-output ratio for these countries is 1.46 in the default model and 1.25 in the no-default model. There are two effects on countries with bad shocks. First, the enforcement constraints tend to bind, which reduce capital stocks. Second, the lower interest rate increases capital stocks. Overall, these two counteracting effects cancel out; countries with bad shocks on average have a similar capital-output ratio across the two models.

We now compare the implication of the default model on the capital–labor ratio with the data. To make the model and the data comparable, we normalize capital–labor ratios of both periods by the average capital–labor ratio in the first period.[19] In the model, the average capital–labor ratios are almost identical across the two periods, and so is the distribution of the capital–labor ratio (see panel (a) of Fig. 5). When the transaction cost is removed, two mechanisms are at work in the model. One is that the precautionary use of capital reduces as saving in bonds is costless now. This effect tends to lower the capital–labor ratio. The other is that the risk-free rate becomes lower, which tends to increase the capital–labor ratio. On net, the two effects roughly offset each other in the quantitative exercise, and the capital–labor ratios are similar. The panel (b) of Fig. 5 plots the distribution of the capital–labor ratio in the data. The distributions are relatively similar across the two periods, though the mass of the first bin is larger, while the mass of the second bin is smaller, than the average.

We also examine the distribution of the capital–labor ratio for countries in the two regimes separately. The figures are reported in Appendix A.3. The density is decreasing with the capital–labor ratio for the high-volatility regime, but it is increasing for the low-volatility regime. The distributions are similar across the two periods for both regimes. Consistent with the model implications, the density overall decreases with the capital–labor ratio in the emerging markets, but increases in the OECD countries. In addition, the distributions are relatively similar over the two periods for both country groups.

#### *4.4.2. Net foreign asset position over GDP*

We compare the model implications on the distribution of the average NFA-GDP ratio with the data. The panel (b) of Fig. 6 plots the data distribution of the NFA-GDP ratio for the two periods separately. There are two major changes in the distribution over time. First, the weighted cross-country average of the absolute NFA-GDP ratio increases from 0.08 in the less-integrated period to 0.18 in the more-integrated period. Second, the NFA-GDP ratio becomes more dispersed and shifts more to the right than to the left in the more-integrated period. The average positive NFA-GDP ratio more than triples, increasing from 0.16 to 0.57,

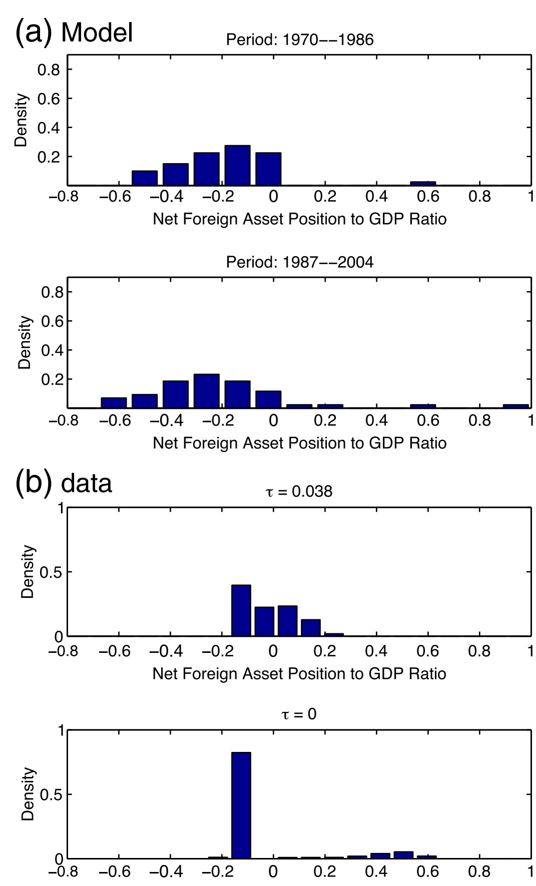


**Fig. 6.** Net foreign asset position over GDP.

[19] For the capita-labor ratio in the data, we take out a deterministic trend of 2%, which is implied by the deterministic growth rate of the TFP process.

while the average negative NFA-GDP only changes from −0.23 to −0.29.

We plot the model distribution of the NFA-GDP ratio under $\tau = 3.8\%$ and $\tau = 0$ in panel (a) of Fig. 6. The NFA-GDP ratio is less dispersed in the default model than in the data. On the other hand, the model captures the two observed changes in the distribution of the NFA-GDP ratio qualitatively. First, our calibration strategy produces an increase in the weighted average of the absolute NFA-GDP ratio from 0.08 to 0.18 after financial integration. Second, the distribution becomes more dispersed and shifts more to the right than to the left when we lower the tax from 3.8% to 0. The average positive NFA-GDP ratio increases from 0.08 to 0.40, while the average negative NFA-GDP changes from −0.09 to −0.11.

## 5. Sensitivity analysis

We now conduct sensitivity analysis of our quantitative result: international risk sharing improves little in response to financial integration under sovereign default risk. Our quantitative result is robust to a higher level of capital flows in the more-integrated period, an alternative form of capital controls, a higher discount factor, and a less persistent TFP shock process.

### 5.1. Higher level of capital flows

We start by examining the sensitivity of the results to alternative calibration. Instead of producing the average world asset-output ratio of 18% in the more-integrated period, we recalibrate the model to match the world asset-output ratio of 28% in 2004 and then check the implied degree of risk sharing. Since $\tau$ has already reached zero in our benchmark experiment, we boost the world asset-output ratio in the model by increasing the output drop parameter $\gamma$. When $\gamma$ is set at 3.5%, the model generates a world asset-output ratio of 28% and a regression coefficient of 0.64. The degree of risk sharing is almost identical to that in the less-integrated period. Thus, our main quantitative result is robust to this alternative calibration.

### 5.2. Alternative form of capital controls

We also 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

$$-B_M \le b' \le B_M, \tag{13}$$

where $B_M > 0$. As in the benchmark case, we first calibrate $B_M$ and the discount factor to match the observed asset-output ratio and interest rate in the less-integrated period. We next keep the same discount factor and remove the quantity restriction in the second experiment to mimic financial liberalization. Table 9 reports the risk sharing coefficients together with the interest rate and discount factor. We find that the degree of international risk sharing is almost the same across the two experiments: 0.64 in the less-integrated period and 0.63 in the more-integrated period. Thus, our conclusion of little improvement in international risk sharing despite financial liberalization is robust to different modeling choices of capital controls.

**Table 9**
Sensitivity Analysis.

| | Alternative Capital Controls | | High Discount Factor | | Low Persistence | |
|---|---|---|---|---|---|---|
| | $B_M = 0.08$ | $B_M = 0.95$ | $\tau = 2.4\%$ | $\tau = 0\%$ | $\tau = 1\%$ | $\tau = 0\%$ |
| World asset-output ratio | 0.08 | 0.18 | 0.08 | 0.18 | 0.08 | 0.13 |
| Risk sharing coefficient | 0.64 | 0.63 | 0.53 | 0.52 | 0.66 | 0.66 |
| Discount factor | 0.90 | 0.90 | 0.96 | 0.96 | 1.01 | 1.00 |
| Equilibrium interest rate | 1.01 | 0.99 | 0.97 | 0.96 | 0.93 | 0.93 |

### 5.3. Higher discount factor

The annual discount factor of 0.89 in our benchmark calibration is much higher than the value commonly used in the sovereign debt literature. The implied annual discount factor is 0.41 in Aguiar and Gopinath (2006), 0.27 in Yue (2010), and 0.82 in Arellano (2008). On the other hand, our discount factor is relatively low, compared to the commonly used value of 0.96 in the business cycle literature.[20] We conduct an experiment in which we set the discount rate to be 0.96. We calibrate the transaction cost twice to match the capital flow ratio in the two periods. Table 9 reports results. The risk sharing coefficient is 0.53 and 0.52 under $\tau = 2.4\%$ and $\tau = 0\%$, respectively. When the discount factor is high, precautionary savings are large, and the equilibrium interest rates are low. As a result of larger precautionary savings, the degree of risk sharing is higher under a higher $\tau$. Importantly, the default model under a high discount factor still shows little improvement in risk sharing as the capital flow ratio more than doubled from 8% to 18%.

### 5.4. Lower persistence of world TFP process

Persistence of the TFP process affects countries' incentive to default and thus the degree of international risk sharing. We experiment with a lower persistence parameter of 0.9 for both regimes, while keeping all the other parameter values of the TFP process the same as in the benchmark calibration. We recalibrate the taxes and the discount factor similarly as in the benchmark, and report the results in Table 9. A lower persistence level of the shock process produces smaller capital flows across countries. When the tax is zero, the capital flow ratio is only 13%, while it is 18% in our benchmark result. The risk sharing coefficients of this experiment are similar to those in the benchmark. Importantly, there is no improvement in risk sharing.

## 6. 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 endogenously constrains borrowing and makes borrowing more difficult in bad

[20] In our model, since we specify a common discount factor for all countries, the calibrated discount factor of 0.89 is in between the values in the two strands of literature. Introducing heterogeneity in the discount factor in addition to TFP shocks might be an interesting extension for the future work.

times. As a result, the observed increase in financial integration is too limited to significantly improve 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.

In this work, we focus on the puzzling observation that international risk sharing improves little in response to rising debt flows after financial liberalization. In the data, financial liberalization has led to an increase in all types of capital flows. Besides debt flows, foreign direct investment (FDI) and equity flows also rise rapidly, though their volumes are still far less than debt volumes. Presumably, FDI and equity offer greater opportunities to share risk across countries. Thus, the lack of improvement in risk sharing becomes even more puzzling if one takes into account the rising FDI and equity flows. An interesting research direction for the future is to investigate the portfolio choice of countries following Devereux and Saito (2007) and to understand why FDI and equity flows also fail to improve international risk sharing.

Our model cannot explain why risk sharing worsens for emerging market economies after financial integration. A richer model is needed to produce this pattern of the data. The key to producing lower risk sharing is to generate strong countercyclical interest rates for emerging markets in the more-integrated period. One potential solution is to introduce risk averse international lenders together with aggregate uncertainty for emerging markets. Since financial integration is associated with more defaults, interest rates would become more countercyclical with risk averse lenders than in our model. Another potential solution is to introduce trade integration together with financial integration. Trade integration might lead to specialization of production and thus might increase output risk and default risk. As a result, interest rates become more countercyclical in the second period. It would be interesting to evaluate these hypotheses in future work.

## Appendix A

### A.1. 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*

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 are from various sources. The national accounts data (real GDP, real final consumption and real gross capital formation) are primarily from the World Bank's publication *World Development Indicators 2004* (WDI); for missing years in WDI, we use the Penn World Table 6.2. For the 21 OECD countries, employment data are from the OECD 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*

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 10. 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 was 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.

*3. Robustness analysis of international risk sharing*

This appendix first considers a robustness check over the risk sharing regression by allowing for a nonseparable utility function between leisure and consumption. We show that adding leisure cannot explain lack of international risk sharing. We then examine whether considering movements in relative prices changes our empirical finding. We find that even after controlling for movements in relative prices, international risk sharing does not improve over time. Lastly, this appendix presents two alternative 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 alternative measures indicate no substantial increase in international risk sharing in the more-integrated period relative to the less-integrated period.

One attempt to explain lack of international risk sharing in the literature assumes that leisure in the utility function is not separable from consumption. Here we follow Lewis (1996) and run a regression to control leisure in a nonseparable utility function,

$$\Delta \ln c_t^i = \alpha(t) + \beta_0 \Delta \ln n_t^i + \beta_1 \Delta \ln y_t^i + u_t^i, \tag{14}$$

**Table 10**
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 |

**Table 11**
Measurement of risk sharing with labor.

| Country group | Less-integrated period 1970–1986 | | More-integrated period 1987–2004 | |
|---|---|---|---|---|
| | $\beta_0$ | $\beta_1$ | $\beta_0$ | $\beta_1$ |
| 43 countries | −0.01 (0.02) | 0.81 (0.03) | 0.006 (0.02) | 0.82 (0.02) |
| 21 OECD countries | 0.07 (0.05) | 0.72 (0.03) | 0.110 (0.03) | 0.60 (0.03) |
| 22 emerging countries | −0.03 (0.06) | 0.84 (0.05) | 0.005 (0.03) | 0.86 (0.02) |

Note: numbers in parentheses are standard errors.

**Table 13**
Median regression coefficient on output growth $\beta_1$.

| Country group | Less-integrated period 1970–1986 | More-integrated period 1987–2004 |
|---|---|---|
| 43 countries | 0.70 (0.10) | 0.91 (0.07) |
| 21 OECD | 0.75 (0.15) | 0.79 (0.17) |
| 22 Emerging | 0.68 (0.13) | 0.90 (0.10) |

Note: numbers in parentheses are standard errors.

where $n_t^i$ denotes employment of country $i$ at period $t$ and $\alpha(t)$ is a time-dummy variable. Table 11 reports the regression coefficients $\beta_0$ and $\beta_1$ for different country groups and different time periods. For our sample of 43 countries, the regression coefficients on labor growth $\beta_0$ are not significantly different from zero in both the less-integrated period and the more-integrated period, while the regression coefficients on output growth $\beta_1$ remain large and significantly different from zero. This implies that assuming non-separability in leisure and consumption cannot explain apparent lack of risk sharing across countries, as documented by Lewis (1996). More importantly, there is still no significant improvement in risk sharing after financial liberalization, with $\beta_1$ of 0.81 in the less-integrated period and 0.82 in the more-integrated period. The results hold similarly for the 22 emerging markets. For the 21 OECD countries, consumption growth responds to labor growth, but adding labor still cannot explain imperfect risk sharing across OECD countries. When controlling for non-separability in leisure and consumption, we observe a decrease in the regression coefficient $\beta_1$ and thus an increase in international risk sharing. The improvement, however, is still modest relative to the prediction of the no-default model.

We next examine whether our empirical finding is robust to movements in relative prices since Cole and Obstfeld (1991) show that theoretically changes in relative prices can provide risk sharing across countries. Specifically, we include changes in real exchange rates as an additional independent variable in the regression:

$$\Delta \ln c_t^i = \alpha(t) + \beta_0 \Delta \ln e_t^i + \beta_1 \Delta \ln y_t^i + u_t^i, \tag{15}$$

where $e_t^i$ denotes the real exchange rate of country $i$ in period $t$ relative to the United States, and a rise in $e_t^i$ denotes a depreciation of country $i$'s real exchange rate. The results are reported in Table 12. We find that even after controlling for changes in relative prices, our measure of international risk sharing does not improve in the more-integrated period. For OECD countries, the risk sharing coefficient barely changes over the two periods: 0.63 versus 0.61. For emerging market economies, the risk sharing coefficient goes up from 0.63 in the first period to 0.87 in the second period, implying a worsening of risk sharing over time. Coefficients on changes in the real exchange rate are significantly negative, which implies that a depreciation of domestic real exchange rate is associated with a decline in domestic consumption in the data. In contrast, standard international business cycle models would predict that a depreciation of domestic real exchange rate is associated with a rise in domestic consumption. Thus, empirical movements in relative prices are not in a direction that enhances risk sharing.

One alternative way to estimate the degree of risk sharing is to use the cross-section regression, proposed by Cochrane (1991). We run the 3-year rolling cross-country regression of the average consumption growth rate on the average GDP growth rate:

$$\Delta \ln c^i = \beta_0 + \beta_1 \Delta \ln y^i + u^i. \tag{16}$$

Table 13 reports the average cross-section regression coefficients $\beta_1$ for each sub-period and for each country group. 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.

Besides the regression-based measurements of international risk sharing, another commonly used measurement is the ratio of consumption volatility to GDP volatility, as in Backus et al. (1992). With more financial integration, countries should have lower consumption volatility relative to output since countries can insure better their idiosyncratic shocks. Table 14 reports the average ratio of consumption volatility to 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.

### *A.2. 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. ■

**Table 12**
Measurement of risk sharing with relative prices.

| Country group | Less-integrated period 1970–1986 | | More-integrated period 1987–2004 | |
|---|---|---|---|---|
| | $\beta_0$ | $\beta_1$ | $\beta_0$ | $\beta_1$ |
| 43 countries | −0.05 (0.01) | 0.63 (0.04) | −0.03 (0.01) | 0.82 (0.02) |
| 21 OECD countries | −0.03 (0.01) | 0.63 (0.04) | −0.02 (0.01) | 0.61 (0.03) |
| 22 emerging countries | −0.06 (0.02) | 0.63 (0.07) | −0.02 (0.01) | 0.87 (0.03) |

Note: numbers in parentheses are standard errors.

**Table 14**
Mean ratio of consumption volatility and output volatility.

| Country group | Less-integrated period 1970–1986 | More-integrated period 1987–2004 |
|---|---|---|
| 43 countries | 1.08 (0.29) | 0.92 (0.17) |
| 21 OECD | 1.07 (0.23) | 0.88 (0.16) |
| 22 Emerging | 1.10 (0.35) | 0.95 (0.17) |

Note: numbers in parentheses are standard errors.

**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

$$W^R(a,k,b) = u(c_r) + \beta\sum\pi\left(a'\middle|a\right)V\left(a',k'_r,b'_r,N\right)\geq u(c_d) + \beta\sum\pi\left(a'\middle|a\right)V\left(a',k'_d,0,N\right).$$

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

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

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 (12). This is an extension of Hamilton (1989). The log-likelihood function is given by

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

where $\Psi^i=\{a^i_T, a^i_{T-1}, \ldots, a^i_1\}$ denotes country $i$'s TFP series, $\Theta = \left\{\{\mu_{\Re},\rho_{\Re},\sigma_{\Re}\}_{\Re=1,2},\gamma,P\right\}$ 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

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

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 $\Theta_{n-1}$. We then update the conditional probabilities of regimes in each period for each country using Bayes' rule. Given the conditional probabilities, we next compute $\Theta_n$ 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:

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

where $h^i_t$ denotes the score given by

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

*3. Solution algorithm*

We use the discrete state space and grid search methods to compute the default model. In the discretization, we choose 12 shock grids, 120 capital grids and 160 asset grids. According to Hatchondo and Martinez (2009), the statistics of the interest rate and the trade balance are sensitive to the number of grid points, while the statistics of output and consumption are not. To confirm this, we double the number of grid points, and find that the capital flow ratios and the risk sharing coefficients are almost unchanged.

To compute the model, we start with a guess of the world interest rate $R$ and a guess of the bond price schedule $q(a, k', b')$ as the reciprocal of $R$. We then solve each country's value functions and decision rules using value function iterations. Specifically, with an initial guess of the value functions, we use the grid search method to find the optimal default decision, the optimal consumption, investment and bond decisions, and then update the next-round value functions. We repeat these procedures until the value functions converge. Given the optimal default decision under the normal phase, we update the bond price schedule as $q^{n+1}(a, k', b')=(1-p^n(a, k', b'))/R$, where $p^n(a, k', b')$ is the default probability constructed from the optimal default choices $d^n(a', k', b')$. We iterate the above procedures until $q$ converges, i.e., $|q^{n+1}(a, k', b')-q^n(a, k', b')|<\epsilon$. After the bond price schedule converges, we next compute the invariant distribution $\mu^*$ as a solution to $\mu^*=Q\mu^*$, 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 whether the bond markets clear. If not, we update the interest rate and repeat the above procedure.

*A.3. Capital–labor distribution of the two regimes*

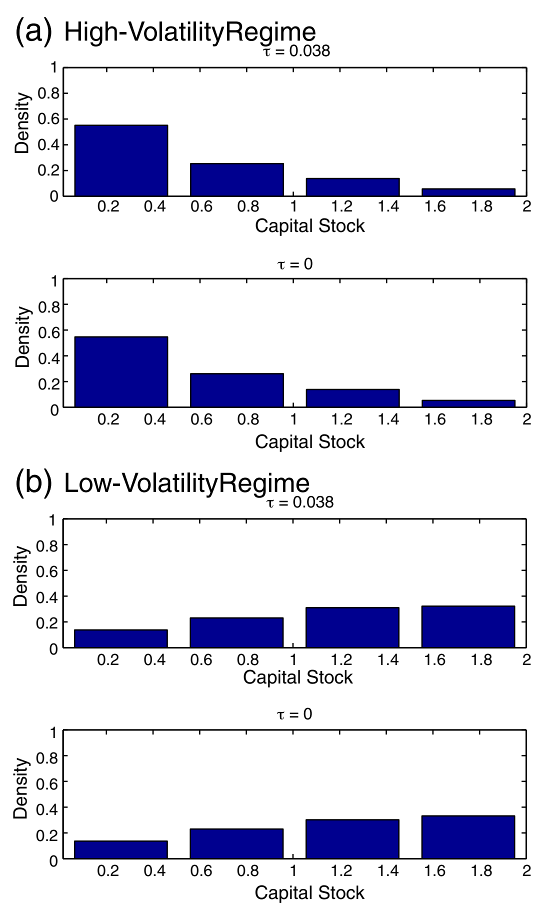


**Fig. 7.** Distribution of capital–labor ratio by regime, model.

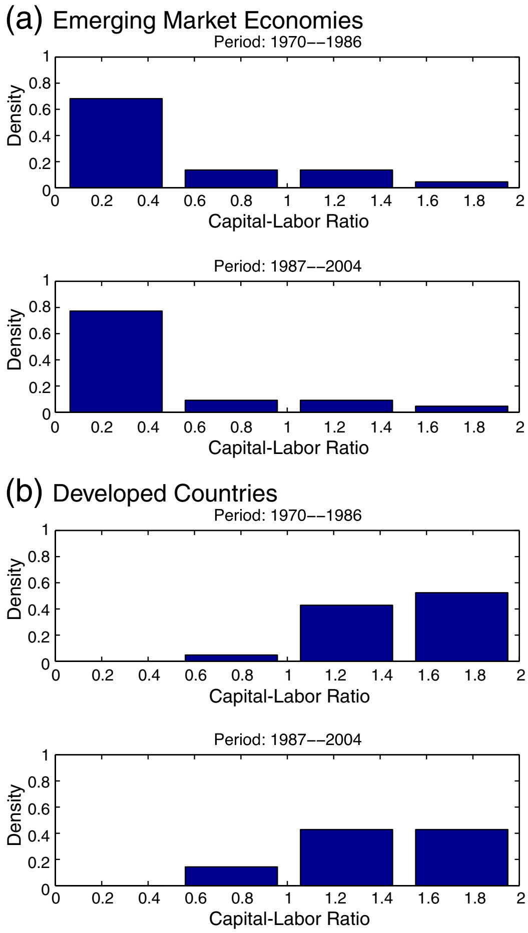


**Fig. 8.** Distribution of capital–labor ratio by group, data.

## References


Aguiar, Mark, Gopinath, Gita, 2006. Defaultable debt, interest rates, and the current account. Journal of International Economics 69 (1), 64–83 (June).

Arellano, Cristina, 2007. Default risk and income fluctuations in emerging economies. The American Economic Review 98 (3), 690–712 (June).

Backus, David K., Kehoe, Patrick J., Kydland, Finn E., 1992. International real business cycles. Journal of Political Economy 100 (4), 745–775 (August).

Bai, Yan, Zhang, Jing, 2010. Solving the Feldstein–Horioka puzzle with financial frictions. Econometrica 78 (2), 603–632 (March).

Beers, David T., Chambers, John, 2004. Sovereign defaults: heading lower into 2004. Standard & Poor's Research.

Benjamin, David, Wright, Mark L.J., 2009. Recovery before redemption: a theory of delays in sovereign debt renegotiations. UCLA working paper.

Broner, Fernando A., Ventura, Jaume, 2011. Globalization and Risk Sharing. Review of Economic Studies 78 (1), 49–82.

Chatterjee, Satyajit, Eyigungor, Burcu, 2010. Maturity, indebtness, and default risk. Federal Reserve Bank of Philadelphia Working Paper No. 10–12.

Cochrane, John H., 1991. A simple test of consumption insurance. Journal of Political Economy 99 (5), 957–976 (October).

Cohen, Daniel, 1992. The debt crisis: a postmortem. NBER Macroeconomics Annual, 7, pp. 65–105.

Cole, Harold L., Obstfeld, Maurice, 1991. Commodity trade and international risk sharing: how much do financial markets matter? Journal of Monetary Economics 28 (1), 3–24 (August).

Corsetti, Giancarlo, Dedola, Luca, Leduc, Sylvain, 2008. International risk sharing and the transmission of productivity shocks. The Review of Economic Studies 75, 443–473.

Devereux, Michael B., Saito, Makoto, 2007. A portfolio theory of international capital flows. University of British Columbia Working Paper.

Eaton, Jonathan, Gersovitz, Mark, 1981. Debt with potential repudiation: theoretical and empirical analysis. The Review of Economic Studies 48 (2), 289–309 (April).

Eaton, Jonathan, Gersovitz, Mark, Fernandez, Raquel, 1995. Sovereign debt. In: Grossman, Gene M., Rogoff, Kenneth (Eds.), Handbook of International Economics, Vol. 3. North-Holland, Amsterdam, pp. 2031–2077.

Edison, Hali, Klein, Michael W., Ricci, Luca A., Slok, Torsten, 2004. "Capital account liberalization and economic performance: survey and synthesis," *IMF Staff Papers*, 51.

Gelos, R. Gaston, Sahay, Ratna, Sandleris, Guido, 2004. Sovereign borrowing by developing countries: what determines market access? IMF Working Paper, 04/221.

Grossman, Herschel I., van Huyck, John B., 1988. Sovereign debt as a contingent claim: excusable default, repudiation and reputation. The American Economic Review 78 (5), 1088–1097 (December).

Hamilton, James D., 1989. A new approach to the economic analysis of nonstationary time series and the business cycle. Econometrica 57 (2), 357–384 (March).

Hamilton, James D., 1996. Specification testing in Markov-switching time-series models. Journal of Econometrics 70 (1), 127–157 (January).

Hatchondo, Juan Carlos, Martinez, Leonardo, 2009. Long-duration bonds and sovereign defaults. Journal of International Economics 79 (1), 117–125 (September).

Heathcote, Jonathan, Perri, Fabrizio, 2004. Financial globalization and real regionalization. Journal of Economic Theory 119 (1), 207–243.

Jeske, Karsten, 2006. Private international debt with risk of repudiation. Journal of Political Economy 114 (3), 576–593 (June).

Kehoe, Patrick J., Perri, Fabrizio, 2002. International business cycles with endogenous incomplete markets. Econometrica 70 (3), 907–928 (May).

Kim, Yun Jung, Jing Zhang, 2011. Decentralized borrowing and centralized default. University of Michigan Working Paper.

Kose, M. Ayhan, Prasad, Eswar S., Terrones, Marco E., 2009. Does financial globalization promote risk sharing? Journal of Development Economics 89 (2), 258–270 (July).

Kraay, Aart, Loayza, Norman, Servėn, Luis, Ventura, Jaume, 2005. Country portfolios. Journal of the European Economic Association 3 (4), 914–945 (June).

Lane, Philip R., Milesi-Ferretti, Gian Maria, 2007. The external wealth of nations mark II: revised and extended estimates of foreign assets and liabilities, 1970–2004. Journal of International Economics 73 (2), 223–250 (November).

Lewis, Karen K., 1996. What can explain the apparent lack of international consumption risk sharing. Journal of Political Economy 104 (2), 267–297 (April).

Mace, Barbara, 1991. Full insurance in the presence of aggregate uncertainty. Journal of Political Economy 99 (5), 928–956 (October).

Mendoza, Enrique G., 1994. The robustness of macroeconomic indicators of capital mobility. In: Leiderman, Leonardo, Razin, Assaf (Eds.), Capital Mobility: The Impact on Consumption, Investment and Growth. Cambridge University Press, pp. 83–111.

Moser, Gabriel, Pointner, Wolfgang, Scharler, Johann, 2004. International risk sharing in Europe: has anything changed? In: Liebscher, Klaus, Christl, Josef, Mooslechner, Peter, Ritzberger—Gr:uenwald, Doris (Eds.), The Economic Potential of a Larger Europe. Edgar Elger Publishing Inc.

Neely, Christopher J., 1999. An introduction to capital controls. Federal Reserve Bank of St. Louis Review. (November/December).

Prasad, Eswar, Rogoff, Kenneth, Wei, Shang-Jin, Ayhan Kose, M., 2003. The effects of financial globalization on developing countries: some empirical evidence. International Monetary Fund Occasional Papaer, 220.

Reinhart, Carmen M., Rogoff, Kenneth S., Savastano, Miguel A., 2003. Debt intolerance. Brookings Papers on Economic Activity, 2003, (1), pp. 1–62.

Sorensen, Bent E., Wu, Yi-Tsung, Oved, Yosha, Yu, Zhu, 2007. Home bias and international risk sharing: twin puzzles separated at birth. Journal of International Money and Finance 26 (4), 587–605 (June).

Tesar, Linda L., Werner, Ingrid M., 1995. Home bias and high turnover. Journal of International Money and Finance 14 (4), 467–492 (August).

Tomz, Michael, Wright, Mark L.J., 2007. Do countries default in 'bad times'? Journal of the European Economic Association 5 (2–3), 352–360 (April-May).

Wright, Mark L.J., 2006. Private capital flows, capital controls and default risk. Journal of International Economics 69 (1), 120–149 (June).

Yue, Vivian, 2010. Sovereign default and debt renegotiation. Journal of International Economics 80 (2), 176–187 (March).