Pooling Risk Among Countries

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Abstract

Based on a systematic analysis of all possible combinations of countries in a large sample, we identify the groups of countries where the potential for international risk-sharing is most attractive. We show that the bulk of this potential can be achieved in groups consisting of as few as seven members, and that further potential marginal benefits quickly become negligible. For many such small groups, the welfare gains associated with risk sharing are larger than Lucas’s classic calibration suggested for the United States, under similar assumptions on utility. Why do we not observe more arrangements of this type? Our results suggest that large welfare gains can only be achieved within groups where contracts are relatively difficult to enforce. International diversification can thus yield substantial gains in some instances, but they remain untapped owing to potential partners’ weak institutional quality and a history of default on international obligations. Noting that existing risk-sharing arrangements often have a regional dimension, we speculate that shared economic interests such as common trade may help sustain such arrangements, though risk-sharing gains are smaller when membership is constrained on a regional basis.

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I. INTRODUCTION

Under perfect international risk sharing, country-specific risk is insured away as citizens hold and consume out of an identical portfolio of state-dependent assets. Full diversification entails payments going from booming economies into ones in recession, and requires an ability to monitor and enforce contractual arrangements. If monitoring and enforcement become difficult or costly as the number of countries involved increases, then the question of who to share risk with acquires key importance. Choosing a membership then involves a tradeoff between diversification benefits and monitoring costs, and may result in groups that involve a limited number of countries. This paper focuses on the gains side, and empirically estimates the potential for risk diversification within all possible groups that exist in a sample of 74 countries. This allows us to identify, for example, the best (or the worst) groups of countries from the standpoint of diversification gains, within the whole sample, or within subsamples chosen on the basis of a variety of alternative criteria.

The relevance of the question is highlighted by the existence of a few schemes that indeed have sought to foster international sharing of macroeconomic risks within “clubs” (or “pools”) consisting of a limited number of countries, rather than worldwide. These schemes include, for example, pooling arrangements for international reserves, such as the Chiang Mai initiative, the Latin American Reserve Fund (FLAR), or networks of bilateral swap arrangements among the G-10 in the 1960s-70s and among the European countries during the run up to the establishment of the Euro. In fact a number of schemes have been proposed, which seek to achieve international sharing of GDP risk among small groups of countries, including Robert C.
Merton’s (1990, 2000) suggestions regarding networks of bilateral swaps of GDP-linked income streams.²

Our main innovation consists in running a systematic search on all possible country groupings, using the variance-covariance matrix for output growth rates observed in standard international data for 74 countries at various levels of economic and financial development. We use output rather than consumption growth rates because we want to assess the potential for risk sharing in all possible groupings of countries, rather than the effective extent of risk sharing on the basis of the observed fluctuations in consumption, as in most of the related literature.

We take the variance-covariance matrix of output growth as given and exogenous, and rely on an algorithm that makes it possible to draw up an inventory of potential income insurance opportunities and to isolate the specific country groupings that minimize poolwide output growth volatility or maximize welfare diversification gains, for any possible pool size.

We find that pooling risk among countries can potentially deliver sizable welfare gains. Substantial gains can obtain in pools consisting of a handful of countries, and the potential marginal gains decline quickly for groups beyond six or seven members. We find that many small pools—not surprisingly, involving relatively volatile economies—yield risk-sharing gains more than ten times what Lucas found for the United States, even though we use a similar theoretical framework.³ But if large welfare gains can be attained by pooling with a few other countries, why do these arrangements not emerge spontaneously more often? Unsurprisingly, the largest gains are attained among heterogeneous economies, in terms of business cycles

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² On FLAR, see Eichengreen (2006) and www.flar.net; on the Chiang Mai initiative, see Park and Wang (2005), and http://aric.adb.org; on the earlier European experience, see Eichengreen and Wyplosz (1993). On sharing of GDP risks more generally see Shiller (1993); and Borensztein and Mauro (2004) for a review of the literature.

³ Pallage and Robe (2003) show that the welfare cost of economic fluctuations is far larger in developing countries than in advanced economies. We go one step further, and investigate how quickly potential gains accrue as the number of participants increases; moreover, we estimate the gains for vast numbers of possible country groupings.
characteristics, but also institutional quality, income level, and geographic location. We show that the potential diversification gains are far smaller when pools are formed within sub-samples of countries characterized by high institutional quality and an unblemished repayment record. We conjecture that enforcement may be more difficult for heterogeneous groupings, or for groupings that involve countries whose institutional quality and perceived creditworthiness are lower.

Welfare gains are on average considerably lower when pools are constrained to be formed within a particular region or a given income category. Nevertheless, sizable welfare gains are sometimes attainable through small pools of countries within a region, especially when they include some countries whose perceived international creditworthiness is relatively low. In addition, the few pooling arrangements observed in practice often involve a regional element, reflecting presumably cultural and political ties, trade linkages, or a mutual interest in each other’s economic performance, including a desire to avoid crises in neighboring countries. Trade partners are well known to have synchronized cycles—see for example Frankel and Rose (1998). We conjecture that the positive impact of trade linkages on contract enforceability may in some cases dominate their negative impact on diversification opportunities. We also estimate the risk-sharing benefits provided by existing reserve-pooling arrangements or free trade areas, and compare them with the benefits that could be provided by pools of similar size chosen in an unconstrained manner from the whole sample. The results are consistent with the view that contract enforceability is an important consideration.

This study is closely related to three strands of the literature. First, we build on the extensive work evaluating the gains from international risk sharing (see, for example, Cole and Obstfeld, 1991; Tesar, 1993; Lewis, 1996; van Wincoop, 1999 or Athanasoulis and van Wincoop, 2000). In particular, our welfare analysis is largely based on Lewis (2000) and
Obstfeld (1994), though we focus on the relative magnitude of the risk-sharing opportunities provided by different groupings, rather than on their absolute size. Second, an important ingredient in our framework relates to the international comovement of macroeconomic variables, the object of a large empirical literature (including Backus, Kehoe and Kydland, 1994; Kehoe and Perri, 2002; Imbs, 2004; and Baxter and Kourparitsas, 2005). Third, any study on the relative desirability of different country groupings is related to the vast literature on optimum currency areas, going back to Mundell’s (1961) seminal work, and more recently including Bayoumi and Eichengreen (1994), Alesina and Barro (2002), and Alesina, Barro, and Tenreyro (2003). At the same time, optimal pools of countries from a risk-sharing point of view are certain not to coincide with optimal currency areas.4

The paper is organized as follows. Section II provides a refresher on international risk sharing in theory, and outlines how we handle the combinatorial problem. Section III presents our general results on the potential for risk-sharing gains in the sample of countries for which we have data. In Section IV, we estimate the extent to which the potential for risk sharing is reduced when countries can only choose their partners within a constrained universe: we focus, for example, on regional constraints, and on the need for countries to have sufficiently strong institutional quality in order to be trusted. Section V concludes.

II. Methodology

We first go through a quick refresher of the theory underpinning the welfare gains resulting from risk sharing. We then discuss the algorithms involved in our search for optimal pools of countries.

4 Historically, schemes to pool international reserves have often emerged—most notably in the case of the European countries—in a broader context of efforts to establish the conditions for common currencies. However, highly correlated shocks, which militate in favor of a common currency area, reduce diversification opportunities and thus the appeal of pooling arrangements.
A. Risk-Sharing, Volatility, and Welfare

We are interested in the behavior of income and consumption for the countries that are members of a “pool,” which we define as a group of countries that engage in complete risk sharing with each other. Under complete markets each country issues and trades claims on its uncertain future output. These claims pay a share of a country’s future output, regardless of the state of nature; their payment streams can be interpreted as mimicking a mutual fund that owns the totality of a country’s productive unit. The same results hold with a full set of Arrow-Debreu securities (which provide a payment in a given state of nature) or as the result of optimization by a benevolent social planner.

As is well known, under complete markets each country consumes a fixed share of aggregate output, given by the country’s share in the aggregate long-run present discounted value of future poolwide output (see, for example, Obstfeld and Rogoff, 1996). For our purposes, the key implication from this setup is that, in each period, consumption in any country in the pool will grow with the aggregate output for the pool, as it fluctuates along with uninsurable poolwide risk. This underpins our focus on the standard deviation of the growth rate of poolwide GDP – and not consumption- and its comparison with the volatility of individual country output.

Concretely, two types of arrangements could implement the type of risk sharing consistent with this setup. Under the first, countries in the pool would issue claims on their output as proposed by Shiller (1993). Capital controls vis-à-vis nonmembers would then ensure that only the residents of countries in the pool have access to such securities. A second type of arrangement would consist of GDP swaps, along the lines proposed by Merton (1990, 2000), either as a network of bilateral swaps, or as swaps intermediated by a central entity for the pool. Under the swaps, each period, each country would pay the others the net difference between its current output and its share in poolwide output, as warranted by its long-run share of poolwide
output or wealth. Differences in expected growth rates across participant countries will be reflected in their contractual shares of poolwide aggregate output. There would be no need for capital controls: participation in the network of swaps would define the pool, which might require that all participants agree to further bilateral swaps with non-members.

Under either arrangement, booming economies might have an incentive to default on their commitment to pay part of their income to foreign holders of their securities. The paper seeks to quantify the benefits of risk diversification, and does not focus on the costs of default. But if preventing default entails costly monitoring and/or enforcement, and if these costs increase in the number of participants to an insurance scheme, then a second best may obtain where sharing risk is done optimally among a few countries only. Here, we investigate how the potential benefits of international risk sharing change with the number of countries involved. This is reminiscent of Solnik (1974), who asked a similar question on diversification gains, but using asset returns.

To compute welfare we rely on a well-known framework largely based on Lewis (2000) and similar to Obstfeld (1994). We abstract from non tradability and non separability in utility, and from the possible impact of uncertainty on growth. These refinements tend to boost the welfare implications of a given amount of risk sharing, and we conjecture that the same would occur in our setup, thus strengthening our conclusions. In a related vein, Barro (2007) relies on the possibility of large, disastrous events to derive much larger welfare costs of business cycles fluctuations than originally measured by Lucas. We find substantial welfare effects, despite the relative simplicity of the framework adopted here.

As Obstfeld (1994) and Lewis (2000), we draw on the Epstein and Zin (1989) utility function. We also assume that output at time $t$ in country $j$, $Y_j^t$, is log-normally distributed. Utility at time $t$ in country $j$ is given by:
\[ U_i' = \left\{ \left( C_i' \right)^{1-\theta} + \beta \left[ E_i \left( U_{i+1}' \right)^{1-\gamma} \right] \right\}^{\frac{1}{1-\theta}} \quad \text{and} \quad y_i' = y_{i+1}' + \mu_j - \frac{1}{2} \sigma_j^2 + \epsilon_i', \quad \epsilon_i' \sim N(0, \sigma_j^2) \]

where \( y' = \ln(Y') \). \( 0 < \beta < 1 \) denotes the subjective discount rate, \( \gamma \geq 0 \) is the coefficient of relative risk aversion and \( \theta \) is the inverse of the elasticity of intertemporal substitution in consumption. \( \mu_i \) denotes the long run growth rate of output in country \( j \), and \( \sigma_j^2 \) denotes the variance of output fluctuations around trend growth.

We abstract from self insurance and saving. As in Lewis (2000), we focus the analysis on the welfare gains afforded by international diversification. Under autarky, \( C_i' = Y_i' \), so that welfare in country \( j \) at time \( t=0 \) is given by:

\[
U_0^j = C_0' \left\{ 1 - \beta \exp \left[ (1 - \theta) \left( \mu_j - \frac{1}{2} \gamma \sigma_j^2 \right) \right] \right\}^{\frac{1}{1-\theta}}
\]

We can now ask the question of the welfare gains associated with moving from autarky to pooling. Risk sharing within the pool ensures that country \( j \)'s consumption now grows with poolwide output at rate \( \mu \) and fluctuates with poolwide output volatility \( \sigma^2 \). Define \( \delta^j \), the compensating differential that would make country \( j \) indifferent between autarky and pooling. We have equation (1):

\[
U \left[ C_0' \left( 1 + \delta^j \right), \mu_j, \sigma_j \right] = U \left[ C_0, \mu, \sigma \right], \quad \text{that is,}
\]

\[
\delta^j = C_0 \frac{ \left( 1 - \beta M_j \right)^{1-\theta} }{ C_0' \left( 1 - \beta \bar{M}^{1-\theta} \right) } - 1
\]

where \( \bar{M} = \exp \left[ \mu - \frac{1}{2} \gamma \sigma^2 \right] \) and \( M_j = \exp \left[ \mu_j - \frac{1}{2} \gamma \sigma_j^2 \right] \). Under risk sharing, consumption in country \( j \) shares the features of group-wide, pooled output. The welfare gains from risk sharing
has three components. First, pure diversification gains, i.e. the difference between individual and poolwide volatilities, $\sigma_j$ and $\sigma$. Second, growth differentials, i.e., the difference between growth rates within and without the pool, $\mu$ and $\mu_j$. Third, the ratio between initial consumption in autarky, $C_0^j$, and initial consumption in the pool, $C_0$. This term reflects a (positive or negative) “entry transfer” in terms of the initial consumption that country $j$ pays to (or receives from) other members for being allowed into the pool. Obstfeld (1994) focuses on diversification and growth welfare gains, and sets $C_0 = C_0^j$.

Of course, welfare gains can also result from self-insurance, via saving and borrowing decisions, rather than internationally. We do not mean to suggest either approach dominates. Rather the paper follows the international risk-sharing literature and investigates how quickly welfare gains accrue when insurance is sought exclusively via international contracts.

Solving for entry transfers, Lewis (2000) shows that

$$\frac{C_0}{C_0^j} = \frac{H_j}{M} \frac{1 - \beta M^{1-\theta}}{1 - \beta M^{-\theta} H_j}$$

where $H_j = \exp\left[\mu_j + \frac{1}{2} \gamma \sigma^2 - \gamma \text{cov}(\epsilon_i^j, \epsilon_j)\right]$ and $\epsilon_j = \sum_j \epsilon_i^j$.\(^5\) H reflects the desirability of country $j$ from the standpoint of the pool’s hedging motive. Countries characterized by low (or negative) covariance with the pool will be more likely to receive a net transfer at the beginning of the arrangement ($C_0^j < C_0$). Conversely, countries whose output covaries strongly with poolwide output will be more likely to make a net payment in order to join the pool (that is, $C_0^j > C_0$). These transfers ensure that risk sharing is Pareto-improving. Countries whose growth or volatility performances worsen upon entry in a given pool are compensated, so that

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\(^5\) An approximation is necessary here, that assumes the sum of log-normal processes continues to be distributed log-normally. Lewis (1996) presents Monte-Carlo evidence suggestive the assumption is relatively innocuous.
consumption insurance cannot make them worse off. Perfect risk sharing is a first-best equilibrium for each given pool size. Of course, the overall first-best obtains for all countries sharing risk. Here, we ask how many parties are necessary to achieving the bulk of the first-best gains. The question becomes relevant if risk sharing arrangements entail monitoring costs that increase with the size of the membership.

For a given country $j$, the total welfare gains associated with joining a pool of countries with average growth $\mu$ and volatility $\sigma$ is given by equation (2):

$$\delta_j = \frac{H_j}{M} \left( 1 - \beta M_j^{1-\theta} \right)^{\theta} \left( 1 - \beta M_j^{1-\theta} \right)^{\theta} - 1$$

The gain associated with a pooling arrangement taken as a whole is given by a weighted average of $\delta_j$ for all countries $j$ in the pool. In appendix A, we show that under relatively mild assumptions, the expression for total poolwide welfare simplifies considerably. In particular, with no outlier country in the time average of growth or volatility,

$$\sum_{j} \omega_j \delta_j = \frac{\sum_{j} \omega_j \left( 1 - \beta M_j^{1-\theta} \right)^{\theta}}{\left( 1 - \beta M^{1-\theta} \right)^{\theta}} - 1$$

with $\omega_j = \frac{Y_j}{\sum_j Y_j}$. In other words, total poolwide welfare gains are approximately given by a weighted average of the pure volatility and growth gains obtained when setting $C_0 = C_0'$ in equation (1), i.e., shutting entry transfers down. With no country outliers for the time average of output growth and volatility, transfers across the pool approximately cancel out. The result remains valid for any weights.

This has important consequences for the questions we are asking. It suggests a weighted average of all countries’ growth and volatility gains will approximate well poolwide welfare
gains. So long as countries with extreme growth or volatility performances are excluded, a weighted sum of the volatility and growth changes for all countries in a pool will be close to the true gains given in equation (2). We later confirm that, for most samples, computing the empirical counterpart to \( \frac{C_0}{C_0^j} \) does not alter substantially the measured poolwide welfare gains.

For economies with growth and volatility not too distant from the sample cross-sectional average, focusing on the changes in volatility and in growth induced by accession to a given risk sharing pool—as Obstfeld (1994) does—can be illustrative of the overall welfare gains.

In what follows, we compare how countries fare individually and under pooling, using four approaches. First, we report the standard deviation of the growth rate for individual country GDP and its poolwide counterpart. This simple approach, focused on pure diversification gains, conveys most of the key economic intuition. Second, we compute the implied welfare gains assuming expected growth is the same for all countries (\( \mu = \mu_j \)) and abstracting from entry transfers (\( C_0^j = C_0 \)). These simplifying assumptions make it possible to focus narrowly on the welfare implications of the fall in volatility associated with pooling, and follow directly from Obstfeld (1994). There, the emphasis is on the implications of reducing or eliminating volatility, rather than on entry transfers. Under this approach, welfare is a monotonic, non-linear transformation of volatility.

Third, we report welfare allowing for entry transfers. More specifically, we compute total welfare gains as the income-weighted sum of \( \delta_j \) across the membership, as implied by equation (2). Fourth and finally, in Section V we relax the assumption that growth rates are the same for all countries, and project \( \mu \) and \( \mu_j \) using past observed growth rates. The paper thus follows a variety of alternative approaches, and does so for two reasons. First, we aim to provide a transparent presentation of where the gains are coming from. Second, and perhaps more
important, views may differ regarding the realism of the various components of a risk-sharing contract, e.g. the market determination of entry transfers, or the provision of insurance against differences in long-run growth as opposed to temporary fluctuations.

As is well known, the link between welfare and volatility depends on some key properties of the process generating uncertainty: in particular, insurance against permanent shocks has more value than against temporary ones (see, for instance, Obstfeld, 1994). We assume throughout that shocks to consumption follow a random walk. The assumption is only maintained so that we can decompose poolwide variances into meaningful elements (Section III.B). Under trend stationarity, the variance of the poolwide residual is not the variance of a sum of each member country’s residual, and the difference between the two has no reason to be negligible.

The random walk assumption is in fact not crucial to our results, as we now explain. Under the alternative assumption of trend stationarity, measured uncertainty is always higher. Indeed, if the true process for GDP has a unit root, the detrended residual will have explosive variance. If on the other hand the true process is trend stationary, the measured variance of GDP growth will be lower than the true residual variance. In both cases, measured volatility is higher when assuming trend stationarity. But under trend stationarity, the welfare costs of fluctuations are smaller for a given level of uncertainty. As is well known from Lucas’ (1987) seminal paper, the welfare costs of fluctuations are then approximately given by $\frac{1}{2} \gamma \sigma^2$, where $\gamma$ is the coefficient of risk aversion and $\sigma^2$ denotes the variance of residual uncertainty. The two effects on end welfare tend to offset one another. In fact, we ran our search algorithm under the assumption of trend stationarity, and found similar results, not reported for the sake of brevity. We reproduced almost identically the general shape of minimum variance envelopes for the various country groupings, and the relative impact of different types of constraints on the universe of countries that one can pool with. The key simplification for our purposes is therefore that the same type of
process (either stationary or random walk) applies to all countries—an assumption that may prove difficult to invalidate, given the weakness of standard unit root tests.  

B. Combinatorial Analysis

Searching for pools of countries that yield the lowest possible variance of the growth rate of aggregate (poolwide) GDP is not straightforward, in light of the vast number of possible combinations of countries. We consider the $N$ countries in our sample individually, then all of their possible combinations 2 countries at a time (which equals $C_2^N$), then 3 at a time (which equals $C_3^N$), and so on, where $C_p^N = \frac{N!}{p!(N-p)!}$. As is well known, the total number of partitions is $\sum_{p=1}^{N} C_p^N = 2^N - 1$, which quickly reaches astronomical levels as $N$ rises.

Using a computational algorithm whose details are provided in a Technical Appendix available upon request, we are able to keep track of all possible combinations for any pool size within a universe of 31 countries, i.e. 2.1 billion combinations. This algorithm can easily handle, for example, the universe of 26 emerging market countries—about 67 million combinations. However, when the universe consists of all 74 countries in our sample, the same algorithm only allows us to analyze all combinations of pools of size 7 or less ($C_7^{74} = 1.8$ billion). By symmetry, we can also draw the inventory of all combinations of size 67 or above, since $C_p^N = C_{N-p}^N$. Beyond these, we need to resort to an approximation algorithm. When $N = 74$, the total number of groups increases to $2^{74} = 1.9 \times 10^{22}$, too large for existing computing power. For each group, one needs to sum the GDP levels for all countries in the pool, to compute an aggregate growth rate and the

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6 Dezhbakhsh and Levy (2003) use frequency analysis to investigate the cross-section of spectra followed by GDP growth rates. They find substantial heterogeneity, but are unable to point to a key determining factor. Aguiar and Gopinath (2007) suggest that the random walk assumption may be more appropriate for emerging markets than for advanced countries.
corresponding standard deviation. Even if each operation took a nanosecond to complete, running an exhaustive search over all possible pools amongst 74 countries would take hundreds of centuries.

**Approximation method for large samples**

For sample sizes where exhaustive inventories are out of reach, we implement recursive searches. Combinatorial problems similar to those we are tackling are the object of a large literature in computer sciences revolving around the so-called “Traveling Salesman” problem, for which well-established approximated solution methods exist. To our knowledge however none can be applied to our baseline setup. For instance, Han, Ye and Zhang (2002) propose an approximation algorithm that can be applied to minimize the variance of a sum; but we minimize the variance of a weighted sum, where the weights themselves depend on the group’s membership. In Imbs and Mauro (2007), we use the Han, Ye and Zhang (2002) algorithm to identify risk diversification benefits for a given absolute size of the risk-sharing contract (for example, a US$1 contract). That exercise involves an unweighted average of GDP growth rates. Our conclusions are virtually identical.

We first obtain all possible combinations up to the maximum pool size where this is feasible through an exhaustive search—in our case, all pools of size 7 drawn from the universe of 74 countries. We save not only the best pool of size 7, but also the best \( W \) pools of size 7 that include each of the \( N \) countries in the universe under consideration. In our baseline results, we use \( W=1351 \) (74 times 1351 is just below 100,000).

For each of these \( W \cdot N \) “seed” pools, we analyze all groups that include the existing members, plus one of the \( (N - p) \) remaining countries. Among these, we find the best pool of size 8 (as well as the \( W \cdot N \) best new “seed” pools of size 8). We iterate the procedure. Although there is a recursive aspect to this, the fact that at each stage we consider the best \( W \) pools for each
of the $N$ countries gives plenty of opportunities for countries that are in the best pool of a given size to drop out at the next increment.

We have verified the reliability of this approximation in four different ways. First, for a number of the cases where it is possible to run exhaustive searches, we compared the groupings implied by an exhaustive inventory to the results of our approximation: they were always identical. Second, we have experimented with different values for $W$, as low as 2, and have found systematically the same results as with $W=1351$. Third, for each pool size $p$, we have checked large numbers of random samples of countries. We have not found a single instance in which a pool drawn randomly was preferable to those identified as the best through the approximation procedure. Fourth, we have run exhaustive searches for all possible combinations of 67 (or more) countries selected amongst 74. Again, we have found the same optimal pools as those obtained by running the approximation procedure throughout.

III. RESULTS

In this section we describe our dataset and present our results. We first build intuition through a simple, single country example. We then present our main results, pertaining to a “global envelope” of the groupings that achieve maximal risk-sharing gains for all group sizes.

A. Data

Data on yearly real gross domestic product and consumption, evaluated in purchasing power parity (PPP) U.S. dollars, for the period 1974–2004 are drawn from the World Bank’s World Development Indicators. Compared with the widely used Penn World Tables (PWT), the World Bank data base has similar quality, and in fact builds on usually identical information. But it provides PPP-adjusted data until 2004 rather than 2000. We cross-checked the two data bases over the period covered by both, and are confident the results are largely unaffected if we use PWT.
This yields a sample of 25 advanced countries, 26 emerging market countries, and 23 developing countries with complete coverage and data of reasonable quality. (The full country list is provided in Appendix Table 1). Advanced countries are defined as in the International Monetary Fund’s *World Economic Outlook*. The remaining countries are considered emerging if they are included in either the stock-market-based International Financial Corporation’s Major Index (2005), or JPMorgan’s EMBI Global Index (2005), which includes countries that issue bonds on international markets. The rest are classified as developing.

Throughout the paper, in line with the bulk of the literature on international risk sharing, we assume that PPP holds. This corresponds to the notion that risk sharing is contracted on a pre-agreed exchange rate, possibly one that is expected to prevail in the long run. While standard, this is an important assumption. Previous studies (for example, Backus and Smith, 1993; and Ravn, 2001) have established that real exchange rate fluctuations worsen the case for international risk sharing. Indeed, GDP data at market exchange rates would imply far higher volatility—harder to hedge through international risk sharing. To compute trade integration, the data on exports (in U.S. dollars at current prices) are drawn from the IMF’s *Direction of Trade Statistics*, and the data on GDP (in U.S. dollars at current prices) are from the IMF’s *World Economic Outlook* database.

### B. A Simple Example

To develop intuition, we begin by asking what pools of countries minimize risk from the standpoint of an individual country, chosen as an example to illustrate the general approach. We work through the case of Chile, viewed by international investors as a relatively safe emerging market (as reflected in low sovereign spreads), and whose growth and volatility experience is not an outlier. Chile is not participating in existing or prospective reserve-pooling arrangements and
its economy is not overwhelmingly linked to a single or a few other countries. The general pattern of results holds for all other countries, as will become apparent in the next section.

For each pool size, Figure 1 plots the standard deviation of the growth rate of poolwide GDP for the best groups of countries (from the standpoint of volatility) that contains Chile, chosen among all 74 countries. We also show these envelopes for various restrictions on the universe of potential partners Chile can choose from. In particular, we present the cases when Chile can pool only with other emerging markets, developing countries, or advanced economies. To give a sense of the importance of choosing well one’s risk-sharing partners, we also plot the highest-standard-deviation envelope (that is, the least desirable pools from Chile’s standpoint, for each pool size) among the 74 countries.

Several results deserve mention. First, the lowest possible standard deviation for poolwide GDP growth in a group that includes Chile is 0.61 percentage points, far below the 4.41 percentage points for Chile on its own. As it turns out, this obtains for a group of 20 countries. Second, a small number of carefully chosen partners is sufficient to yield the bulk of available risk-sharing benefits. Even with just one well-chosen partner (in this case, France), poolwide standard deviation falls to 1.26 percentage points. The standard deviation of GDP growth reaches 0.72 percentage points, already quite close to the minimum, for the best pool of 7 members.

Not surprisingly, this is a motley set of economies: Austria, Cameroon, Chile, New Zealand, Nicaragua, Sweden, and Syria.

As will become apparent, the finding that most diversification gains can be attained in relatively small pools holds for all countries. In the United States for instance, despite the large size of the U.S. economy, pooling with another five or six well-chosen economies (including Japan, in the first instance) implies a near halving of US volatility. This result is reminiscent of
the well-known finding in finance that a small set of stocks is often sufficient to provide most of the diversification opportunities available from a market portfolio (Solnik, 1974).

This is a Pareto improvement compared with the status quo: focusing exclusively on volatility reduction, each of the countries included is far better off in this pool than on its own. Indeed, the lowest-standard-deviation envelope shown in Figure 1 looks almost identical if one adds the constraint that pools should be Pareto improving, i.e. that volatility be lower for all participants under pooling than in autarky.

Marginal gains quickly become small. Based on the volatility criterion they become negative for groups above 20 members, and more visibly negative as the pool size increases further than, say, 30 members. Beyond a certain pool size, covariance benefits are no longer significant, and the pool starts having to include countries whose volatilities are far higher than the sample average. With the introduction of these increasingly volatile countries, the approximation developed in section II.A is decreasingly valid. In particular, the welfare gains from a pooling arrangement are increasingly distinct from changes in volatility, because transfers do not sum to zero across the pool any longer. These highly volatile countries need to pay (and are willing to pay) entry transfers to the rest of the pool to gain admission. Membership to the pool is Pareto-superior and welfare increases because of gains to financial trade, despite a concomitant rise in poolwide volatility. This will become clearer in Section II.C.

Finally, the (upper) envelope corresponding to the worst possible pools of each size highlights the importance of choosing one’s partners carefully: at small pool sizes, one runs the risk of achieving higher volatility in a poorly chosen pool than in autarky. In the paper, we sometimes note, but typically do not focus on, the exact identities of the countries that form the best group. In general, poolwide uncertainty for the lowest volatility group is only marginally
below that for the groups with the second or third lowest volatilities (or even higher). Given that the differences are so small, it is likely that considerations outside our analysis may lead countries not to choose the absolute best.

We emphasize the extent to which various types of (economically relevant) constraints may reduce the maximum possible risk diversification benefits. For example, Figure 1 also reports the extent to which possible gains decline when the universe of countries that Chile can choose from is constrained by the level of economic and financial development, or geographically. The lowest possible standard deviation amounts to 0.61 percentage point when Chile is allowed to choose its pooling partners among all 74 countries, but 0.87 percentage point when it is constrained to pool with advanced countries only, 1.07 percentage point within the universe of emerging markets only, and 1.91 percentage points when pooling within Latin America only. Risk-sharing agreements that are based on common geographic origins, or restricted to countries within a given range of per capita income, provide smaller gains than do pools formed by choosing from the unconstrained, worldwide sample.

**Variance Decomposition**

To illustrate the sources of risk diversification gains, it is useful to decompose the variance of the growth rate of poolwide GDP into a weighted average of the variances of individual countries’ growth rates and a weighted sum of all bilateral covariances:

\[
\text{Var}(g_p) = \text{Var} \left( \sum_{i=1}^{p} w_i g_i \right) = \sum_{i=1}^{p} w_i^2 \text{Var}(g_i) + \sum_{i=1}^{p} \sum_{j=1, j \neq i}^{p} w_i w_j \text{Cov}(g_i, g_j) \quad \text{for } i \neq j; i = 1,...,p
\]

where \( w_i \) denotes the share of country \( i \) in the pool’s production, \( g_p \) is the growth of aggregate GDP for a pool of \( p \) countries, and individual countries’ growth rates are denoted by \( g_i \). Countries are attractive partners to the extent that they have low variances and low (or, even better, negative) covariances with other members of the pool.
Decomposing poolwide variance for the “best” pool of each pool size, it is possible to show (as we do in Imbs and Mauro, 2007) that diversification gains for pool sizes up to about seven countries stem from both the addition of countries with lower volatility than Chile’s and low (or negative) covariances. The first few countries have both low individual variances and negative covariances with Chile (as well as, importantly, with each other). However, the covariance gains diminish rapidly, as the sum of all bilateral covariances starts increasing again. From pool size of about seven onwards, the remaining diversification gains are accounted for almost exclusively by the addition of countries with lower variance than Chile, but not with negative average covariances with the rest of the membership.

The results presented in this section are confirmed and generalized in the next. On the basis of risk diversification alone, there is little need for arrangements including many countries, as long as partners are chosen carefully. Welfare gains can in principle be sizeable even in small pools formed on a regional basis or where membership is constrained to countries with relatively low economic development. However, pools that deliver the greatest diversification benefits tend to consist of heterogeneous countries with respect to geography, as well as economic and financial development.

C. Global Diversification

We now generalize our results in an exercise that no longer restricts optimal pools to include any given country: Figure 2 reports the envelope of minimal volatility for all pool sizes \( p \) up to 74. As in the previous section, the bulk of possible diversification gains is attained with relatively small pools. The global best using the pure volatility criterion is a pool of 17 countries, which delivers a standard deviation equal to 0.50 percentage points.\(^7\) However, the standard

deviation is already as low as 0.62 percentage points for the best pool of size 7. The property that diversification gains are achieved within groups consisting of a small number of countries continues to prevail in this general setup.

The value reported for \( p=1 \) corresponds to the standard deviation of the individual growth rate for the least volatile country during the sample period, namely France. Diversification gains for specific countries cannot be easily read off the figure, because the identities of countries involved in the various optimal pools of different sizes may change. But we know the identities of the relevant groupings, and can thus assess the gains that optimal pooling would provide to member countries. For example, in the case of the optimal group of size 7, the standard deviations of individual countries’ growth rates range from 1.44 percentage points for Sweden to 8.97 percentage points for Nicaragua. The diversification gains are distributed unequally, with far larger gains accruing to countries with more volatile individual growth rates. This asymmetry has implications for entry transfers.

The list of countries involved in optimal pools confirms that heterogeneity is key. Interestingly, the list overlaps quite substantially with that obtained for the case of Chile. Several of the same countries come up as members of the best pools of smaller sizes (where we run a search over all possible pools, without any approximation) and continue to be present throughout all optimal pools for \( p>7 \). Again, this is unlikely to be an artifact of our approximation method, despite the recursive structure it imposes onto the search, because the procedure leaves plenty of opportunities for countries to drop out of the best pool as size increases. Rather, the evidence suggests that the sample of countries providing the best mutual hedging properties within a universe of 74 economies is relatively small and robust. For example, the country with lowest individual volatility, France, does not enter any of the “best” groupings, likely because its growth

---

8 Austria, Colombia, Costa Rica, Dominican Republic, New Zealand, Nicaragua, and Sweden.
cycle is highly correlated with many other economies in the sample. This reinforces the
empirical relevance of low (or negative) covariances.

Figure 2 also reports the minimum standard deviation of the poolwide growth rate for
sub-samples constrained to the advanced countries, emerging markets, and developing countries. While risk diversification gains are substantial within each sub-sample, they are not as large as in the full universe of countries. The envelopes for emerging and developing economies are roughly one percentage point above the global envelope, for all \( p \). For \( p<3 \), the global envelope and that corresponding to advanced economies coincide, but for larger pool sizes even advanced countries are considerably better off in pools that allow them to share risk with emerging or developing countries. Advanced economies achieve somewhat smaller gains, which is consistent with their lower volatility and internationally correlated business cycles. The rapid exhaustion of diversification opportunities continues to hold in all three sub-samples.

**Welfare Gains**

We now turn to welfare, and allow \( C_0^{i} \neq C_0 \). We still constrain the expected growth rate to be the same for all countries—an assumption we relax in Section V. Figure 3 reports the highest (total income-weighted) welfare gains \( \sum_{j=1}^{N} \omega_j \delta_j \) for any pool size \( N \). The total gains are monotonically increasing with pool size, and attain a maximum when the entire (sub-)universe of countries under consideration are pooling together. Just as volatility decreased rapidly in the number of member countries, welfare gains are large for small-sized groupings. Marginal gains peter out for pools beyond seven or eight members. Again, the rapid decline in marginal welfare gains holds when the exercise is conducted for sub-samples of countries consisting of only advanced, emerging, or developing countries.
The pool formed by the entire 74-country sample for which we have data delivers total gains amounting to 1.9 percent of initial worldwide income (Table 1). Even allowing for entry transfers, the gains are far larger for those groups of countries that start out with higher volatility prior to pooling. As a share of initial income for the group under consideration, total (income-weighted) welfare gains amount to 0.7 percent for advanced countries, 4.4 percent for emerging markets and up to 7.4 percent for developing countries. Welfare gains are relatively small in rich countries simply because they are less volatile. Table 1 shows the size of these gains differs considerably, depending on the country’s individual volatility under the status quo. In the full sample, the minimum (United States) annual gains amount to 0.5 percent of initial country income, and the median gain (Dominican Republic) is 4.1 percent.

To construct Figure 3, we chose $\beta=0.95$, consistent with a 5% annual discount rate, $\theta=2$ and $\gamma=5$. We experimented extensively with alternative values for these parameters. Unsurprisingly, higher values for $\gamma$ or $\beta$ shifted upwards the magnitude of the welfare gains we computed for all poolsizes. But the overall shape of Figure 3 never altered. In particular, the fact that most welfare gains accrue within very small groups of countries always obtained.

### IV. POOLING RISK WITHIN SUB-SAMPLES

In this section we quantify the foregone diversification and welfare gains implied by the need to choose one’s pooling partners within specific sub-samples. In particular, we seek to assess the importance of choosing partner countries for whom contract enforcement and monitoring may be relatively easy. We approximate the concept in a variety of ways, splitting our sample according to: (a) the level of development and country size; (b) institutional quality and past repayment record on international debt obligations; (c) the degree of international financial integration; (d) geographical region; and (e) bilateral trade intensity. In all these cases, we present the results based on simple volatility criteria, as well as welfare computed with and
without entry transfers. We report the main results in Table 2, for the best possible pool of any size. We also consider existing risk-sharing schemes such as the Chiang-Mai Initiative or FLAR, or other types of existing arrangements whereby participants have long established cooperation—for example, in the context of a currency union or a trade agreement. We estimate the extent to which participant countries would be able to obtain larger welfare gains in pools of the same size if they were to choose their partners in an unconstrained manner.

In undertaking these exercises, we assume that the variance-covariance matrix of international output growth rates would not be affected by entering international risk-sharing arrangements. This is consistent with findings by Doyle and Faust (2005). They show that, despite claims that rising integration among the G-7 economies has increased cycles synchronization, there is no evidence of a significant increase in the correlation of output growth rates or other macroeconomic aggregates. Moreover, a large empirical literature has documented the cross-sectional properties of international business cycles, which appear to have extremely persistent determinants, such as trade linkages or patterns of production (see Frankel and Rose, 1998 or Baxter and Kouparitsas, 2005). These results are consistent with our assumption that the international covariances in output growth rates are largely time-invariant.

A. Level of Development and Country Size

The degree of volatility reduction and welfare gains that can be attained by pooling countries within categories defined on the basis of the level of economic development is informative in two respects. First, it helps gauge the potential interest in pooling risk on the part of countries belonging to different income groups. Second, countries may be more likely to engage in risk sharing agreements with members of a similar income group.

In Table 2, we first report for each sub-sample the median value of the standard deviation of individual countries’ growth rates across the countries within the sub-universe. Then, for each
country we search over all possible pools of any size that it can form together with others chosen within the sub-sample. We note the lowest achievable standard deviation of poolwide growth, and report in the second column the median value of that standard deviation across all countries in the sub-sample. We then compute for each country the welfare gain obtained by joining its best pool, assuming that all countries have the same expected growth rate and that there are no entry transfers, following Obstfeld (1994). Again, we impose $\gamma = 5$, $\theta = 2$, and $\beta = 0.95$. Our main conclusions hold for alternative values. We report in the third column the median value of these gains across countries in the sub-universe. Finally, we allow entry transfers and report the sum of the income-weighted welfare gains that would obtain if all countries in the sub-universe were to join together to form a pool.

For the typical advanced country, the standard deviation of consumption growth rate can potentially be cut from 2.0 percentage points under autarky to 0.6 percentage points when moving into the lowest-volatility pool drawn from the entire universe of countries, and 0.9 percentage points when pooling with other advanced countries only. The corresponding welfare gains can be as high as 1.1 percentage point of annual consumption when pooling within the universe of all countries, and 0.8 percentage points when pooling among advanced countries only. Allowing for entry transfers, total welfare gains to the advanced countries (as a share of initial income of all advanced countries) are 0.8 percent when all countries in the universe for which we have data are pooling together, and 0.7 percent when all advanced countries are pooling together. The gains are much larger for emerging markets, and larger still for developing countries. Total gains as a share of initial income are 4.4 percent when all emerging markets pool together; the same figure amounts to 7.4 percent for developing countries.
Country Size

Interest in the risk-sharing gains provided by pooling is likely to be higher for small countries, which are on average prone to greater volatility. The estimates confirm that small countries (defined as those with a population below 5.2 million in 1970) would attain substantial volatility reduction through pooling, and the ensuing welfare benefits would be similarly large. Interestingly, small countries pooling among themselves attain almost as high risk-sharing gains as they would if they were to pool within the whole universe of countries in our sample, an indication that small countries as a group are essentially as diverse as the entire sample.

V. Institutional Quality and Past Repayment Record

We explore the effects of restricting the sample on the basis of whether countries have defaulted in the recent past or whether they receive high scores on measures of institutional quality, and in particular contract enforcement. We consider two definitions. The first, labeled “excellent enforceability” includes all countries that were in the top half of the distribution of the institutional quality index compiled by Kaufmann and others (2005), and that never experienced severe international repayment difficulties during 1970–2004.\(^9\) The second, “above-average institutional quality” is based on the institutional quality index only. In addition to advanced countries, the former sample includes four emerging market and developing countries, whereas the latter includes eight emerging markets and three developing countries.

The median country with excellent enforceability experiences volatility of 2.1 percentage points. When pooling with other excellent enforceability countries only, volatility can decline to 0.9 percentage points, and further down to 0.6 percentage points when pooling in an unconstrained universe. Similarly, the median country with above-average institutional quality has volatility of 2.6 percentage points, which falls to 0.8 percentage point in the best pool within

\(^9\) Default history is drawn from Reinhart, Rogoff and Savastano (2003) and Detragiache and Spilimbergo (2001).
the same sample, but even further, to 0.6 percentage point, when pooling within the whole sample. Available income-weighted welfare gains are equivalent to 0.8 percentage points of annual consumption within the universe of countries with a reputation for “excellent enforceability”, and 1.0 percentage points within the universe of countries with above-average institutional quality. In contrast, the gains are much larger in the complementary samples: 5.1 percentage points of annual consumption for “below-excellent enforceability” countries, and 5.4 percentage points for “below-average institutional quality” countries. Potential risk-sharing gains are smaller within sub-samples consisting of countries with better perceived enforceability. In other words, where enforcement is not perceived to be an issue, risk sharing gains are small; it is where enforcement problems would seem to be serious that risk sharing gains are large.

On a more optimistic note, however, consider the risk-sharing opportunities available to those few emerging market and developing countries that are perceived to have excellent enforceability, but have high volatility (Botswana, Hungary, Malaysia, and South Africa). Their median volatility declines from 4.1 percentage points of GDP to 2.2 percentage points if they can pool together, and to 0.9 percentage points if they draw their pooling partners from the excellent enforceability countries. A similar result holds for emerging market and developing countries with “above-average institutional quality”. Welfare gains for these countries when they pool with the rest of the world are 3 percent of initial income. The magnitudes of these effects illustrate the large welfare potential that could be drawn from improved institutions, especially as regards contract enforcement. The quality of institutions may therefore reduce the volatility of consumption through two channels. First, as suggested by Acemoglu and others (2003), better institutional quality may directly lower output volatility and enable smoother consumption, holding international financial arrangements constant. Second, stronger institutions can facilitate access to international contracts and help countries share risk internationally, enabling smoother
consumption for a given degree of output volatility. The results presented in this section suggest that this second channel has the potential to improve welfare substantially.

A. International Financial Integration

To some extent, many countries are already integrated in global financial markets, though the evidence is overwhelming that markets are still far from complete. A country’s current degree of international financial integration may provide an indication of its ability to be a credible participant in pooling arrangements such as those considered in this paper. We verify in this section that it is indeed amongst isolated economies (from a financial standpoint) that international risk sharing would have maximal welfare effects.

We divide the sample into high-integration and low-integration countries based on whether they are in the top or bottom half of the sample when ranked by total foreign assets to GDP, using the Lane and Milesi-Ferretti (2006) data set. As might be expected, we find that the countries whose international financial integration is already relatively high have lower interest in further international risk sharing. The total income-weighted sum of welfare gains (as a share of the group’s initial income) is 4.2 percent for low-integration countries, and 1.3 percent for high-integration countries.

Could this difference simply reflect the impact of financial integration on the international covariance in output growth rates, which we have assumed fixed and exogenous? Evidence in Kalemli-Ozcan and others (2003) suggests otherwise: financial integration is found to foster specialization in production, as consumption plans become increasingly decoupled from local production. If anything, specialization would thus increase the potential gains from international diversification.
B. Regional Constraints

In practice, existing or prospective pools are often formed on a regional basis. We analyze the implications of geographical constraints through a few examples. We estimate the gains that the advanced European countries would obtain if they were only allowed to pool with other advanced European countries, and compare them to the gains that would obtain if they were allowed to pool with all other advanced countries without geographic restrictions. Similarly, we compare the gains available to emerging Asia or, separately, Latin America, with the gains obtained within the sample of all emerging markets.

Geographical constraints do not turn out to be very important for advanced European countries, presumably because they constitute a high proportion of advanced countries, and because the advanced country cycle has a large worldwide common component. The median advanced European country can cut its volatility from 1.8 percentage points to 1.0 percentage point in a pool of advanced European countries, and to a rather similar 0.9 percentage point in a pool of advanced countries chosen worldwide. The same message holds for welfare gains.

In contrast, geographical constraints are more relevant for emerging markets’ ability to diversify risk. For instance, median volatility for individual Latin American emerging markets equals 4.4 percentage points and can be lowered to 1.9 percentage point by pooling with five well chosen Latin American emerging markets, but to as low as 1.3 (1.1) percentage point by pooling with five (ten) emerging markets in the absence of geographical constraints. Similarly, the median Asian emerging market can reduce its volatility from 3.6 percentage points to 1.8 percentage points in a pool of seven Asian emerging markets, and to 1.1 percentage points in a pool of ten emerging markets chosen also from outside the region. The impact of geographical constraints remains substantial, although it becomes smaller, when measured in terms of welfare. For Latin American emerging markets, welfare gains can amount to 5.4 percentage points of
initial income when pooling within the whole universe of emerging markets, but also gains of 4.1 percentage points when pooling within emerging Latin America. Asian emerging markets can obtain welfare gains equivalent to 3.6 percentage points of initial income when pooling within the whole universe of emerging markets, but also gains of up to 3.0 percentage points when pooling within emerging Asia.

In Imbs and Mauro (2007), we show that the costs of regional constraints are even greater when measured using the number of instances in which countries in a group are simultaneously affected by pressures on the exchange rate. This is consistent with studies that find a substantial regional element in currency crises and in international contagion more generally (Glick and Rose, 1999).

C. Trade Integration

In this sub-section, we explore further the theme of contract enforceability, which we relate to trade patterns and the associated regional element often observed in actual pooling arrangements. On the one hand, trade linkages imply higher output correlations and thus reduced diversification possibilities. But on the other hand, they presumably induce a greater ability to enforce risk-sharing contracts, because defaulting partners can be sanctioned via exclusion from goods trade (see, for example, Rose and Spiegel, 2004). This may explain the regional element observed in actual pooling arrangements, which suggests that the positive impact on contract enforceability may in some cases prevail over the negative impact on diversification opportunities.

To measure trade integration within a pool, we sum exports across all pool members as a ratio to poolwide GDP. We then consider all possible pools and analyze the correlation between this measure of trade integration with the minimal volatility of poolwide output. As is well known, trade is substantially lower among emerging markets than it is among advanced
countries, and it is even lower among developing countries. We analyze separately the relationship between trade integration and poolwide output volatility for all possible pools of (i) advanced economies, (ii) emerging markets, and (iii) developing countries. The relationship is depicted in Figure 4 for pool sizes 5 and 10. The results suggest that greater trade integration is clearly associated with larger minimal poolwide volatility within the universe of emerging markets and, separately, developing countries. In other words, fewer diversification opportunities are available among trade partners. The relationship is weaker among advanced economies, where risk-sharing gains are smaller to begin with.

The few instances of effective risk sharing arrangements we observe have tended to involve regional trade partners. This limits substantially the potential diversification gains, as shown above. Trade relations must then present an offsetting advantage: we conjecture that trade helps leverage the enforcement of international commitments, because of the dynamic threat of exclusion.

D. Existing Arrangements

Finally, we consider the potential welfare gains arising from existing risk-sharing arrangements such as the Chiang-Mai Initiative or FLAR. We also discuss other types of international agreements, whereby participants have long-established cooperation, for example, in the context of a currency union or a trade agreement. We then compare such gains to those that the participant countries would be able to obtain in pools of the same size, drawing their partners from the whole, unconstrained sample. The objective here is not to assess the desirability of existing arrangements, but rather to assess the value of well-established relations of trust, which make it possible to sustain risk-sharing arrangements. Of course, some welfare gains may already have accrued to participating countries because of the existing arrangements. In that regard, our estimates refer to the further gains that would be drawn by moving to full
financial integration within an existing group, compared with full integration in an alternative grouping with an unconstrained membership of the same size.

Table 3 notes the median (first row) and minimum (second row) standard deviation of individual growth rates across participants in the agreements indicated. The third row compares these with the standard deviation of poolwide growth obtained by pooling with other members of the existing arrangement. The last row reports volatility in the best possible pool of the same size as the considered arrangement, but chosen within the whole universe of countries. Substantial gains appear to be available even for the least volatile countries in each arrangement. For the existing groups considered (with the exception of FLAR), poolwide volatility is lower than in autarky. Interestingly, keeping size constant, the lowest possible volatility in a group with unconstrained membership is more than twice smaller than in an existing agreement. While existing arrangements have the potential to yield substantial welfare gains, diversification outside of existing membership may yield considerably greater gains. The last two rows may be interpreted as suggesting that enforcement considerations play a major role because they appear to outweigh potentially large diversification gains.

VI. POOLING GROWTH RATES

In our baseline approach, we have assumed that expected growth rates are the same for all countries. In principle, countries with relatively high expected growth rates should be able to obtain a higher share of poolwide consumption. In practice however, the challenges involved in predicting growth rates more than a few years ahead make it relatively difficult to incorporate differences in expected growth in the terms of risk-sharing contracts. As shown by Easterly and others (1993), country rankings with respect to growth rates change dramatically from one decade to the next. Similarly, Jones and Olken (2005) document that most countries experience both growth miracles and failures at some point in their history. It is unlikely that the parties
negotiating the terms of a risk-sharing agreement would be able to come to a common view of their countries’ relative future growth performance. And the size of the upfront transfers involved might preclude an agreement. Indeed, this may be a further reason underlying the limited extent to which risk-sharing arrangements occur in practice among sovereign nations. Our main interest in this paper relates to the choice of country groupings rather than the optimal design of the risk-sharing contract. We do not analyze the feasibility and optimality of contracts allowing countries to change the shares of poolwide income they receive, as expected growth rates are updated in the light of new information.

Despite these caveats, we now extend the analysis to the case where expected growth rates can differ across countries. To estimate expected economic growth, we simply consider the naïve averaging of growth over the entire period under consideration, namely 1975–2004. In conducting our analysis, we also assume that individual countries’ growth rates are unaffected by pooling arrangements. Although a possible concern might be that lower volatility in a pool may come at the expense of lower mean growth, this seems unlikely in light of the evidence that lower-volatility countries tend to have relatively high mean growth (Ramey and Ramey, 1995).

Table 4 reports the welfare gains obtained for the case where all 74 countries in our sample pool together and for the cases where advanced economies, emerging markets, and developing countries each pool among themselves. The broad pattern of our results holds. In particular, Figure 5 confirms the existence of high gains at small pool sizes and rapidly declining marginal gains as pool sizes increase. Compared with the setup where expected growth is assumed to be the same for all countries (Table 1 and Figure 3), the welfare gains are somewhat larger in most instances. This is natural, given that there is now scope for trade in an additional dimension. In fact, the relatively high heterogeneity in growth histories among emerging markets
may also be the reason why the welfare gains in developing and emerging economies happen to almost overlap in Figure 5.

VII. CONCLUSION

Although the potential benefits of international risk sharing have long been the subject of debate, existing studies have focused on the benefits that an individual country would derive from greater financial integration into the world economy. Full global financial integration has hitherto proved elusive, presumably owing in part to limited contract enforcement and monitoring costs. Monitoring and enforcement may be easier within smaller groups of countries, and we have shown that risk-sharing pools involving a handful of economies often have the potential to provide substantial welfare gains. The question of which countries to pool with then becomes of the essence. We present a systematic analysis of which pools of countries would provide the greatest risk-sharing benefits, under various possible constraints on membership.

Even though our findings rely on a conventional theoretical framework, they suggest that the potential welfare benefits of international risk sharing can be substantial, and achievable among surprisingly few countries. If these gains can be achieved within pools consisting of only a handful of countries, why are risk-sharing arrangements, in one guise or another, not more widespread? We conjecture that contract enforceability imposes major constraints on the country pools that may emerge in practice. We show that potential welfare gains are relatively small among the universe of countries with relatively strong institutions and unblemished repayment records. Samples where enforceability may be easier also tend to provide smaller diversification opportunities, so that arrangements to pool risk may not be worthwhile. More generally, international risk sharing may be limited not because the gains it affords are too small to matter, but rather because contract enforcement may be difficult exactly where risk-sharing gains would be largest.
APPENDIX A: POOLWIDE WELFARE

From the definition of $\delta^j$, we have:

$$
\sum_j \omega_j \delta^j = \frac{(1-\beta \sigma^2)^{\frac{\kappa}{2}}}{\bar{\sigma}} \sum_j \omega_j \frac{H_j (1-\beta M_j^{1-\theta})^{\frac{1}{2\theta}}}{1-\beta M^{-\theta} H_j} - 1
$$

Now consider

$$
\prod_{j=1}^N H_j = \exp \left[ \sum_{j=1}^N \mu_j + \frac{N}{2} \gamma \sigma^2 - \gamma \sum_{j=1}^N \text{cov} \left( \varepsilon_j, \sum_{j=1}^N \varepsilon_j \right) \right]
$$

Since by definition $\text{cov} \left( \varepsilon_j, \sum_{j=1}^N \varepsilon_j \right) = \sigma^2$, we have

$$
\prod_{j=1}^N H_j = \tilde{M} \exp \left[ \sum_{j=1}^N \mu_j - \mu + \frac{N-1}{2} \gamma \sigma^2 \right] \equiv \tilde{M} \Gamma
$$

By the same token,

$$
\prod_{j=1}^N H_j = \exp \left[ \sum_{j=1}^N \mu_j - \mu_k + \frac{N-1}{2} \gamma \sigma^2 - \gamma \sigma^2 + \gamma \sum_{j=1}^N \text{cov} (\varepsilon_j, \varepsilon_k) \right]
$$

Now in the absence of large outliers in average output growth or volatility, $\mu_k = \mu$ and

$$
\sigma_k^2 + \sum_{j=1}^N \text{cov} (\varepsilon_j, \varepsilon_k) = \sigma^2, \text{ so that } \prod_{j=1}^N H_j = \Gamma. \text{ The expression for poolwide welfare simplifies as a result, into}
$$

$$
\sum_j \omega_j \delta^j = \frac{(1-\beta \sigma^2)^{\frac{\kappa}{2}}}{\bar{\sigma}} \sum_j \omega_j \frac{\tilde{M} \Gamma (1-\beta M_j^{1-\theta})^{\frac{1}{2\theta}}}{\Gamma - \beta M^{-\theta} \tilde{M} \Gamma} - 1
$$

which gives the expression in the text.
### Appendix Table 1. Country Samples

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</table>

**Notes:** Advanced countries are defined as in the International Monetary Fund’s *World Economic Outlook*. The remaining countries are emerging if they are included in either the stock-market based International Financial Corporation’s Major Index (2005) or JPMorgan’s EMBI Global Index (2005), which includes countries that issue bonds on international markets. The remaining countries are classified as developing. Small countries are those with a population below 5.2 million in 1975. Above average institutional quality is according to the index of Kaufmann, Kraay, and Mastruzzi (2005). Excellent enforceability is defined as above average institutional quality and no defaults on international debt in 1970-2004 according to Detragiache and Spilimbergo (2001) and Reinhart, Rogoff and Savastano (2003). High (low) capital integration countries are those in the top (bottom) half of the sample when ranked by total foreign assets to GDP. (Foreign assets are from Lane and Milesi-Ferretti, 2006; GDP data in current U.S. dollars are from the IMF’s World Economic Outlook.) GDP data at PPP are from the World Bank’s World Development Indicators.
REFERENCES


<table>
<thead>
<tr>
<th>Sub-Sample</th>
<th>Minimum Gain</th>
<th>Median Gain</th>
<th>Gains as a Share of Initial GDP for Sub-Sample Indicated</th>
</tr>
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<tbody>
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<td>Advanced Countries</td>
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<td>Emerging Markets</td>
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<td>4.97</td>
<td>4.39</td>
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<tr>
<td>Developing Countries</td>
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<td>7.37</td>
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<tr>
<td>Bangladesh</td>
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<td>Madagascar</td>
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</table>

Notes: Minimum, median, and total welfare gains for sub-samples indicated, computed allowing for the possibility of “entry transfers” but assuming the same expected growth (3 percent) across countries. The results assume $\theta = 2$, $\gamma = 5$, and $\beta = 0.95$. The list of sub-samples is provided in Appendix Table 1. GDP data are from the World Bank’s World Development Indicators.
Table 2. Gains from Risk Pooling Among Countries

<table>
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<th>(2)</th>
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<th>(4)</th>
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<tbody>
<tr>
<td></td>
<td>$\sigma$ Individual Country Alone</td>
<td>$\sigma$ Best Pool of Any Size</td>
<td>$\delta$ Best Pool of Any Size</td>
<td>Total Income-Weighted Sum of Gains</td>
</tr>
<tr>
<td>All Countries (Pooling with any country)</td>
<td>3.62</td>
<td>0.54</td>
<td>3.88</td>
<td>1.87</td>
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<tr>
<td><strong>Interest in Risk Sharing, by Level of Development, Size</strong></td>
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<tr>
<td>Advanced (pooling with any country)</td>
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<td>0.89</td>
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<td>Developing (pooling with any country)</td>
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<td>9.14</td>
<td>8.04</td>
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<tr>
<td>Developing (pooling only with developing)</td>
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<td>1.01</td>
<td>8.16</td>
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<td>Small Countries (pooling with any country)</td>
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<tr>
<td>Small Countries (pooling only with small countries)</td>
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<td>6.13</td>
<td>5.56</td>
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<tr>
<td><strong>Current Degree of International Financial Integration</strong></td>
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<tr>
<td>High Integration Countries (pooling with any country)</td>
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<td>0.61</td>
<td>1.94</td>
<td>1.32</td>
</tr>
<tr>
<td>High Integration Countries (pooling only with high integration countries)</td>
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<td>0.74</td>
<td>1.84</td>
<td>1.30</td>
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<tr>
<td>Low Integration Countries (pooling with any country)</td>
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<td>0.51</td>
<td>5.83</td>
<td>4.58</td>
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<tr>
<td>Low Integration Countries (pooling only with low integration countries)</td>
<td>4.36</td>
<td>0.76</td>
<td>5.55</td>
<td>4.21</td>
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<td><strong>Costs of Weak Enforcement</strong></td>
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<td>Excellent Enforceability Countries (pooling with any country)</td>
<td>2.11</td>
<td>0.61</td>
<td>1.17</td>
<td>0.85</td>
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<td>Below Excellent Enforceability Countries (pooling with any country)</td>
<td>4.41</td>
<td>0.52</td>
<td>5.90</td>
<td>5.12</td>
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<td>Excellent Enforceability Countries (pooling only with excellent enforceability countries)</td>
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<td>1.03</td>
<td>0.76</td>
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<tr>
<td>Emerging and Developing Country Excellent Enforceability (pooling with any excellent enforceability)</td>
<td>4.08</td>
<td>0.87</td>
<td>4.94</td>
<td>2.98</td>
</tr>
<tr>
<td>Emerging and Developing Excellent Enforceability (pooling only with emerging and developing excellent enforceability)</td>
<td>4.08</td>
<td>2.25</td>
<td>n.a.</td>
<td>1.52</td>
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<tr>
<td>Above Average Institutional Quality (pooling with any country)</td>
<td>2.61</td>
<td>0.61</td>
<td>1.94</td>
<td>1.06</td>
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<tr>
<td>Below Average Institutional Quality (pooling with any country)</td>
<td>4.26</td>
<td>0.52</td>
<td>5.32</td>
<td>5.42</td>
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<td>Above Average Institutional Quality (pooling only with above average institutional quality countries)</td>
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<td>0.82</td>
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<td>Above Average Institutional Quality Emerging and Developing (pooling with any above average institutional quality country)</td>
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<td>Above Average Institutional Emerging and Developing (pooling only with above average institutional quality emerging and developing)</td>
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<td><strong>Costs of Regional Constraints</strong></td>
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<td>European Union (pooling only with advanced)</td>
<td>1.84</td>
<td>0.89</td>
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<td>0.77</td>
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<td>European Union (pooling only with EU)</td>
<td>1.84</td>
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<td>0.68</td>
<td>0.55</td>
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<td>Asian Emerging (pooling only with emerging)</td>
<td>3.62</td>
<td>1.09</td>
<td>3.60</td>
<td>3.54</td>
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<td>Asian Emerging (pooling only with Asian emerging)</td>
<td>3.62</td>
<td>1.84</td>
<td>2.98</td>
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<td>Latin American Emerging (pooling only with emerging)</td>
<td>4.41</td>
<td>1.07</td>
<td>5.73</td>
<td>5.39</td>
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<td>Latin American Emerging (pooling only with Latin American emerging)</td>
<td>4.41</td>
<td>1.90</td>
<td>4.96</td>
<td>4.08</td>
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</table>

Notes: Column (1) reports the median (across countries in the indicated sub-sample) standard deviation of individual country growth. Column (2) reports the median (across countries in the indicated sub-sample) of the lowest possible standard deviation of poolwide growth. Column (3) reports the median welfare gain (across countries in the indicated sub-sample) obtained by entering the best possible pool of any size chosen within the indicated sub-sample without the possibility of entry transfers, and with pool and individual country growth rates assumed to be fixed at 3 percent per annum. Column (4) reports the income-weighted sum of welfare gains generated by a pool of all countries in the sub-sample, expressed as a share of total initial income for the indicated sub-sample with the possibility of entry transfers, and with pool and individual country growth assumed to be fixed at three percent per annum.
### Table 3. Poolwide Volatility for Selected Groups

<table>
<thead>
<tr>
<th></th>
<th>APEC</th>
<th>ASEAN</th>
<th>CHIANG MAI</th>
<th>ECOWAS</th>
<th>EMU</th>
<th>EU</th>
<th>FLAR</th>
<th>MERCOSUR</th>
<th>NAFTA</th>
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<tbody>
<tr>
<td>$\sigma_{\text{individual median}}$</td>
<td>3.73</td>
<td>4.36</td>
<td>3.93</td>
<td>4.58</td>
<td>1.78</td>
<td>1.77</td>
<td>4.00</td>
<td>4.33</td>
<td>2.11</td>
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<tr>
<td>$\sigma_{\text{individual min}}$</td>
<td>2.00</td>
<td>3.65</td>
<td>2.01</td>
<td>3.07</td>
<td>1.36</td>
<td>1.36</td>
<td>2.19</td>
<td>3.51</td>
<td>2.00</td>
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<tr>
<td>$\sigma_{\text{pool}}$</td>
<td>1.29</td>
<td>3.47</td>
<td>1.40</td>
<td>2.19</td>
<td>1.19</td>
<td>1.11</td>
<td>2.48</td>
<td>3.09</td>
<td>1.81</td>
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<tr>
<td>$\sigma_{\text{unconstr median}}$</td>
<td>0.68</td>
<td>0.86</td>
<td>0.79</td>
<td>0.72</td>
<td>0.66</td>
<td>0.65</td>
<td>0.71</td>
<td>0.74</td>
<td>1.16</td>
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</table>

Notes: The first (second) row reports the median (minimum) standard deviation of individual country GDP growth across countries in the group indicated. The third row is poolwide volatility for the group. The fourth row is the median across countries in the group of poolwide volatility for the best pool (of the same size as the group indicated). The groups are the Asia-Pacific Economic Cooperation (APEC), the Association of South East Asian Nations (ASEAN), the Chiang Mai Initiative (CHIANG MAI), the Economic Community of West African States (ECOWAS), the European Monetary Union (EMU), the European Union (EU), the Latin American Reserve Fund (FLAR), Mercado Común del Sur (Mercosur), and the North American Free Trade Agreement (NAFTA).
Table 4. Welfare Gains Allowing for “Entry Transfers” and Differences in Expected Growth (percent of annual consumption)

<table>
<thead>
<tr>
<th>Sub-sample</th>
<th>Minimum Gain</th>
<th>Median Gain</th>
<th>Gains as a Share of Initial GDP for Sub-Sample Indicated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Sample</td>
<td>0.37</td>
<td>5.84</td>
<td>5.93</td>
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<tr>
<td>United States</td>
<td></td>
<td>Costa Rica</td>
<td></td>
</tr>
<tr>
<td>Advanced Countries</td>
<td>0.42</td>
<td>1.22</td>
<td>1.18</td>
</tr>
<tr>
<td>Italy</td>
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<td>Denmark</td>
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</tr>
<tr>
<td>Emerging Markets</td>
<td>1.74</td>
<td>6.86</td>
<td>9.82</td>
</tr>
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<td>Tunisia</td>
<td></td>
<td>Malaysia</td>
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<tr>
<td>Developing Countries</td>
<td>1.08</td>
<td>7.41</td>
<td>9.86</td>
</tr>
<tr>
<td>Guatemala</td>
<td></td>
<td>Malawi</td>
<td></td>
</tr>
</tbody>
</table>

Notes: Minimum, median, and total welfare gains for sub-samples indicated, computed allowing for the possibility of “entry transfers”. The results assume $\theta = 2$, $\gamma = 5$, and $\beta = 0.95$. Expected growth rates are assumed to equal their averages over the period 1975-2004. The list of sub-samples is provided in Appendix Table 1. GDP data are drawn from the World Bank’s World Development Indicators.
Figure 1. Chile: Benefits of Diversification Under Various Restrictions

Notes: The figure reports the standard deviation of the growth rate of aggregate (poolwide) GDP for the pool (of each size) that yields the lowest standard deviation (or the highest, in the case of the top line). Each group is constrained to contain Chile. GDP data at purchasing power parity are drawn from the World Bank’s World Development Indicators. The pool yielding the lowest (or highest) standard deviation is found by checking all possible combinations of countries for the sub-samples, and by the approximation procedure described in the text for the full sample.
Figure 2. Lowest Poolwide Volatility Envelopes for Samples Constrained by Level of Development

Notes: The figure reports the standard deviation of the growth rate of poolwide GDP for the pool (of each size) that yields the lowest standard deviation for each indicated sub-sample. The pool yielding the lowest standard deviation is found by checking all possible combinations of countries for the sub-samples, and by the approximation procedure described in the text for the full sample. GDP data are from the World Bank’s World Development Indicators.
Figure 3. Pooling Gains

Notes: For each pool size, the figure reports the highest possible (income-weighted) sum of welfare gains obtained by pool members compared with the status quo ("autarky"), scaled by aggregate GDP of the (sub-)universe of countries in question (as indicated). The welfare gains are computed allowing for "entry transfer" payments as in Lewis (2000). The results assume $\theta=2$, $\gamma=5$, and $\beta=0.95$ and a constant growth rate of three percent for all countries and pools. GDP data are from the World Bank’s World Development Indicators.
Figure 4. Trade and Diversification Benefits

Notes: The scatter plots report poolwide trade integration and the standard deviation of the growth rate of aggregate (poolwide) GDP for all pools of sizes 5 and 10 (as indicated) drawn from the sub-samples indicated. Trade integration is the sum (across pool members) of exports to other pool members, divided by poolwide GDP. To compute trade integration, the data on exports (in US$ at current prices) are from the International Monetary Fund’s Direction of Trade Statistics, and the data on GDP (in US$ at current prices) are from the IMF’s World Economic Outlook database. To compute growth volatility, GDP data (PPP) are from the World Bank’s World Development Indicators.
Figure 5: Pooling Gains Allowing for Differences in Expected Growth

Notes: For each pool size, the figure reports the highest possible (income-weighted) sum of welfare gains obtained by pool members compared with the status quo ("autarky"), scaled by aggregate GDP of the (sub-)universe of countries in question (as indicated). The welfare gains are computed allowing for "entry transfer" payments as in Lewis (2000). The results assume $\theta=2$, $\gamma=5$, and $\beta=0.95$ and a observed average growth rates. GDP data are from the World Bank's World Development Indicator.