Trade Costs, Limited Enforcement and Risk Sharing: A Joint Test*

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Abstract

This paper addresses the question of whether both goods and asset market frictions are necessary to explain the failure of consumption risk sharing across countries. I present a multi-country DSGE model with Armington specialization. There are iceberg costs of shipping goods across countries. In asset markets, contracts are imperfectly enforceable. Both frictions separately limit the extent to which countries can pool risk. The model suggests a test for the presence of each of the two types of friction that exploits data on bilateral imports. I implement this test using a sample of developed and developing countries. I find that both trade costs and asset market imperfections are necessary in order to explain the failure of perfect consumption risk sharing. The rejection of complete markets is weaker for developed than developing countries. At the same time, financial autarky is also rejected, indicating that some risk sharing is possible through asset markets.

Keywords: Risk sharing, trade costs, asset market frictions

1 Introduction

In a world where there are no frictions in goods markets, and a full set of contingent claims can be traded, consumption growth will be perfectly correlated across countries [Lucas (1982)].

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However this prediction is strongly rejected by the data [see Backus, Kehoe and Kydland (1992)]. Considerable progress has been made in understanding how different types of goods market frictions and different types of asset market frictions can help resolve this puzzle. This paper contributes to this literature by providing a new type of test for the role of goods and asset market frictions in explaining failures of risk sharing. I present a multi-country DSGE model with Armington specialization and iceberg costs of shipping goods across countries. This is a dynamic stochastic "gravity" model of trade both within and across states and periods. In asset markets, contracts are imperfectly enforceable. Both frictions separately limit the extent to which countries can pool risk. But to the extent that there is risk sharing, this paper shows it must show up in bilateral imports. With sufficiently rich data on bilateral imports, it is possible to distinguish between the role of trade costs and asset market frictions in limiting risk sharing. I implement this test for a sample of developed and developing countries from 1970-2000. Both trade costs and asset market imperfections are necessary in order to explain the failure of perfect consumption risk sharing. However asset market frictions appear to be relatively less important for developed than developing countries, and the null hypothesis of financial autarky is also rejected.

The intuition for the results presented here can be understood by thinking of each country as being endowed with a tree that produces a stochastic amount of a particular type of fruit (this abstracts from investment, which is included in the formal model). Consumers in these countries wish to smooth consumption along several dimensions. They prefer to consume a variety rather than one single type of fruit. They also wish to smooth their consumption across states of the world and over time. However some of the fruit spoils during shipping, so the quantity received by the importer is less than the quantity sent by the exporter. The fraction that spoils varies with the bilateral distance between the countries. This resource cost of smoothing implies first, that the composition of each country's consumption basket is tilted towards the fruits produced in countries that are "close." Second, even if the full set of Arrow-Debreu securities is traded, and all contracts are perfectly enforced, consumption growth rates will differ across countries.

Now suppose that in addition, contracts (other than spot trades) cannot be perfectly enforced. Even though the full set of Arrow-Debreu securities can be traded, countries cannot commit ex-ante to make transfers that are not ex-post optimal. Unless they are very patient, the extent of possible risk sharing across countries will be further reduced. In the extreme case of financial autarky, countries will engage only in spot trades, and the value of a country's exports must equal the value of its imports. Even in this case, however, there will be *some* risk sharing, through movements in the terms of trade.

Clearly, in order for any degree of consumption smoothing to take place, there must be bilateral flows of fruits. This is the insight that motivates the empirical part of the paper. In particular, the value of bilateral imports is given by a "gravity equation." Once trade costs (if present) have been controlled for, the value of bilateral imports always moves one-for-one with the value of output of the exporting country. However the response of imports to the value of output of the importing country varies depending on whether or not there are frictions in asset markets. This allows the hypotheses of trade costs and frictions in asset markets to be tested against the alternative of a frictionless world using a panel of data on bilateral imports.

As already noted, this paper contributes to a very large literature that tries to explain the failure of international consumption risk sharing. There are two strands of the literature that focus primarily on goods market frictions: those that examine the role of non-traded goods, and those that examine the role of transactions costs on goods trade. This paper falls into the second category, which includes Backus, Kehoe and Kydland (1992, 1995), Heathcote and Perri (2004a, b), Kose and Yi (2005), Mazzenga and Ravn (2004), and Obstfeld and Rogoff (2000). This paper advances this literature by integrating costs of trading goods into a multi-country DSGE model in a way that is consistent with a gravity model of bilateral trade. The gravity equation is one of the outstanding successes of the empirical trade literature, and it has recently received rigorous theoretical foundations in both Eaton and Kortum (2002) and Anderson and van Wincoop (2003, 2004). The assumption of specialization gives the model a chance to match facts about intra-state trade as well as inter-state and intertemporal trade, while simultaneously nesting risk sharing through the terms of trade as described in Cole and Obstfeld (1991). This treatment of trade costs paves the way for the new test for the presence of frictions presented in the paper.

The enormous literature on international asset market frictions initially focused on exogenously restricting the set of assets traded, but has recently explored the role of transactions costs, asymmetric information and sovereign risk. This paper follows the latter approach, in particular that of Kehoe and Perri (2002) who assume that contracts can only be enforced by the threat of future exclusion from asset markets. This is convenient in the context of theoretical framework used here, but the empirical results should not be thought of as distinguishing between different types of asset market imperfection. In this, the paper is similar to Choi (2005) who looks at the effect of non-traded goods and asset market frictions on the relationship between real exchange rates and relative consumption. I also follow Heathcote and Perri (2002) in considering the case of perfect financial autarky.

The first section describes the theoretical framework. The second section outlines the empirical strategy. The third section describes the data and results. The final section concludes.

2 Theoretical framework

I first lay out the frictionless model, and develop its implications for international risk sharing. I then introduce in turn costs of trading goods and an enforcement friction in asset markets. Again, I focus on the implications of these frictions for risk sharing. I also consider the case of perfect financial autarky as an extreme alternative to complete financial markets. Throughout, the emphasis is on consumption allocations and the form of trade flows required to support those allocations, rather than on asset holdings. The section concludes with an illustrative special case which develops the intuition for the empirical tests outlined in the next section.

2.1 Frictionless model

Summary

There are N countries in the world, indexed $i = 1, \ldots, N$. Each country produces a distinct intermediate good, (also indexed i) using capital and labor. Capital is accumulable, while labor is fixed in supply. Productivity in the production of intermediates differs across countries, and is stochastic. The intermediate goods are tradeable. They are combined using a CES production function, identical in all countries, to produce an aggregate non-traded good used for consumption and investment.

Uncertainty

The structure of uncertainty is as follows. In each period t, the economy experiences one event, $s_t \in S$. Denote by s^t the history of events from date 0 to date t. The probability of history s^t at date t is given by $\pi(s^t)$.

Utility and production

Across periods, utility is isoelatic. Expected utility in country i is given by

$$U_i = \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi\left(s^t\right) u\left(s^t\right)_i = \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi\left(s^t\right) \frac{\left[C\left(s^t\right)_i\right]^{1-\rho}}{1-\rho} \tag{1}$$

The production function for the agregate non-traded good, X, used for consumption and investment is:

$$X\left(s^t\right)_i = \left(\sum_{k=1}^{N} Z\left(k, s^t\right)_i^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} \tag{2}$$

where $Z\left(k, s^t\right)_i$ is absorption in country i of intermediate good k at time t after history s^t. The aggregate good resource constraints are given by

$$X\left(s^t\right)_i = C\left(s^t\right)_i + I\left(s^t\right)_i = C\left(s^t\right)_i + K\left(s^t\right)_i - K\left(s^{t-1}\right)_i \tag{3}$$

where $K\left(s^{t-1}\right)_i$ is the capital available for use in production in country i at time t (predetermined) and $I\left(s^t\right)_i$ is investment in country i at time t after history s^t. Investment need not be positive (capital can be eaten). The world intermediate goods resource constraints are given by:

$$Y\left(s^t\right)_i = A\left(s^t\right)_i K\left(s^{t-1}\right)_i^{\alpha} L_i^{1-\alpha} = \sum_{k=1}^{N} Z\left(i, s^t\right)_k \tag{4}$$

where $A\left(s^t\right)_i$ is the realization of productivity in country i at time t after history s^t.

Planner's problem

I study the social planning problem where the planner chooses sequences $\{C\left(s^t\right)_i\}$, $\{K\left(s^t\right)_i\}$ and $\{Z\left(k, s^t\right)_i\}$ to maximize a weighted sum of country utilities:

$$\sum_{i=1}^{N} \lambda_i U_i = \sum_{i=1}^{N} \sum_{t=0}^{\infty} \sum_{s^t} \lambda_i \beta^t \pi\left(s^t\right) u\left(s^t\right)_i \tag{5}$$

subject to $2N$ resource constraints for every period t and history s^t. Let the Lagrange multipliers on the aggregate good resource constraints be denoted

$$\sigma\left(s^t\right)_i = \beta^t \pi\left(s^t\right) P\left(s^t\right)_i \tag{6}$$

and let the Lagrange multipliers on the intermediate good resource constraints be denoted:

$$\mu\left(i,s^t\right)=\beta^t\pi\left(s^t\right)Q\left(i,s^t\right) \tag{7}$$

The multiplier $\sigma\left(s^t\right)_i$ is the date-0 price of a unit of the final good in country i at time t following history s^t. $P\left(s^t\right)_i$ is its date-t price. The multiplier $\mu\left(i,s^t\right)$ is the date-0 price of a unit of good i in country i at time t following history s^t. $Q\left(i,s^t\right)$ is then its date-t price.

I focus on the first order conditions of the planner's problem with respect to consumption, C and absorption of intermediates, Z (the first order condition with respect to capital is not necessary for what follows). They are ($C\left(s^t\right)_i$):

$$\lambda_i C\left(s^t\right)_i^{-\rho}=P\left(s^t\right)_i \tag{8}$$

and ($Z\left(k,s^t\right)_i$):

$$Q\left(k,s^t\right)=P\left(s^t\right)_i X\left(s^t\right)_i^{\frac{1}{\eta}} Z\left(k,s^t\right)_i^{-\frac{1}{\eta}} \tag{9}$$

Equilibrium

Together with the two sets of resource constraints, the first order conditions (including the first order condition with respect to capital) determine absorption of each intermediate good and consumption of the final good by each country in every period and state. The appropriate values of λ_i in the decentralized equilibrium without transfers can in principle be recovered by combining the first order conditions with the resource constraints and the individual country budget constraints.

Consumption correlations

Using the production function for the aggregate good X combined with the first order conditions with respect to absorption of individual intermediate goods, the date-t state-s^t aggregate price level in country i can be written:

$$P\left(s^t\right)_i=\left[\sum_{k=1}^{N}Q\left(k,s^t\right)^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{10}$$

The real exchange rate between i and j is given by the ratio of the price levels. In the absence of frictions, the real exchange rate between any pair of countries is always equal to 1.

The first order condition for consumption implies a monotonic relationship between the real exchange rate and relative consumption, given by

$$RER\left(s^t\right)_{ij} = \frac{P\left(s^t\right)_j}{P\left(s^t\right)_i} = \frac{\lambda_j}{\lambda_i}\left[\frac{C\left(s^t\right)_i}{C\left(s^t\right)_j}\right]^{\rho} \tag{11}$$

Since the real exchange rate between any pair of countries is always equal to 1, this implies that relative consumption is constant, given by:

$$\frac{C\left(s^t\right)_i}{C\left(s^t\right)_j} = \left[\frac{\lambda_i}{\lambda_j}\right]^{1/\rho}$$

In order for this to be the case, the growth rate of consumption must be the same in all countries. This is the expression from which standard tests of consumption risk sharing are derived.

Bilateral imports

Risk sharing across countries takes place through bilateral trade flows The first order conditions with respect to consumption and absorption of intermediates can be combined with the resource constraints to yield the following expression for the value of country i's absorption of k's output in period t following history s^t:

$$\begin{aligned} & Q\left(k, s^t\right) Z\left(k, s^t\right)_i \\ = \; & \left[P\left(s^t\right)_i X\left(s^t\right)_i\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right] \frac{1}{\sum_{j=1}^{N} P\left(s^t\right)_j X\left(s^t\right)_j} \end{aligned} \tag{12}$$

This expression is the standard gravity relationship between the value of bilateral imports and the size of the exporting and importing countries in the absence of trade costs.

2.2 Trade costs

Resource cost of trade

The setup is exactly as before, except that intermediate goods trade is costly: in order for one unit of j's good to arrive in i, $t\left(s^t\right)_{ij}$ units must be shipped, with $t\left(s^t\right)_{ii} = 1$, $t\left(s^t\right)_{ij} \geq 1$ and $t\left(s^t\right)_{ij} t\left(s^t\right)_{jk} \geq t\left(s^t\right)_{ik}$. The intermediate goods resource constraints must be modified to take account of this fact:

$$Y\left(s^{t}\right)_{i}=A\left(s^{t}\right)_{i}K\left(s^{t-1}\right)_{i}^{\alpha}L_{i}^{1-\alpha}=\sum_{k=1}^{N}t\left(s^{t}\right)_{ki}Z\left(i,s^{t}\right)_{k} \tag{13}$$

where $t\left(s^{t}\right)_{ki}$ is the quantity of good i that must be shipped from i to k in order for one unit to arrive in k.

Planner's problem and equilibrium

The planner's problem is modified from the zero trade cost case in that the weighted sum of country utilities is maximized subject to the modified resource constraints. The first order conditions with respect to consumption is unchanged. The first order condition with respect to absorption of intermediates is modified:

$$Q\left(k,s^{t}\right)t\left(s^{t}\right)_{ik}=P\left(s^{t}\right)_{i}X\left(s^{t}\right)_{i}^{\frac{1}{\eta}}Z\left(k,s^{t}\right)_{i}^{-\frac{1}{\eta}} \tag{14}$$

As in the zero trade cost case, the two sets of resource constraints and the first order conditions (including the first order condition with respect to capital) determine absorption of each intermediate good and consumption of the final good by each country in every period and state.[1] The appropriate values of λ_i in the decentralized equilibrium without transfers can in principle be recovered by combining the first order conditions with the resource constraints and the individual country budget constraints. Allowing for specialized endowments and costly trade modifies several of the predictions of the standard frictionless model. These modifications are now summarized:

Consumption correlations

Marginal utilities are not equalized across countries because relative prices differ due to trade costs. Using the production function for the aggregate good X combined with the first order conditions with respect to absorption of individual intermediate goods, the date-t state-s^t aggregate price level in country i can be written:

$$P\left(s^{t}\right)_{i}=\left[\sum_{k=1}^{N}\left(t\left(s^{t}\right)_{ik}Q\left(k,s^{t}\right)\right)^{1-\eta}\right]^{\frac{1}{1-\eta}} \tag{15}$$

[1] Alvarez and Lucas (2006) give conditions for existence and uniqueness of equilibrium in this model with balanced trade (financial autarky).

Purchasing power parity fails. The real exchange rate between i and j can differ from 1. However the first order condition for consumption still implies a monotonic relationship between the real exchange rate and relative consumption, given by:

$$RER\left(s^t\right)_{ij} = \frac{P\left(s^t\right)_j}{P\left(s^t\right)_i} = \frac{\lambda_j}{\lambda_i}\left[\frac{C\left(s^t\right)_i}{C\left(s^t\right)_j}\right]^{\rho} \tag{16}$$

But since price levels differ across countries in a way that varies over time, this implies that relative consumption is not constant.

Relative consumption can be rewritten:

$$\frac{C\left(s^t\right)_i}{C\left(s^t\right)_j} = \left[\frac{\lambda_i}{\lambda_j}\right]^{1/\rho}\left[\frac{\sum_{k=1}^{N}\frac{t\left(s^t\right)_{ik}^{1-\eta}}{\phi\left(s^t\right)_k}Y\left(s^t\right)_k^{\frac{\eta-1}{\eta}}}{\sum_{k=1}^{N}\frac{t\left(s^t\right)_{jk}^{1-\eta}}{\phi\left(s^t\right)_k}Y\left(s^t\right)_k^{\frac{\eta-1}{\eta}}}\right]^{\frac{1}{(\eta-1)\rho}} \tag{17}$$

with

$$\phi\left(s^t\right)_k = \left[\sum_{h=1}^{N}\lambda_h^{\eta}t\left(s^t\right)_{hk}^{1-\eta}C\left(s^t\right)_h^{-\rho\eta}X\left(s^t\right)_h\right]^{\frac{\eta-1}{\eta}} \tag{18}$$

The response of relative consumption between i and j to a shock to productivity in country k clearly depends on the trade cost between i and k relative to the trade cost between j and k. In order for consumption risk sharing to take place, goods must be shipped internationally, and since it is costly to do so, agents will optimally choose not to smooth consumption perfectly. In contrast to models with separable preferences over traded and non-traded goods, this trade cost model predicts less than perfect correlation of the growth of traded goods consumption across countries. In a world with trade costs, there is no "world consumption growth rate," or "world output growth rate," as world consumption and output are different depending on where they are measured.

Bilateral imports

The risk sharing that takes place across countries must still be reflected in trade flows. The value of country i's absorption of k's output in period t following history s^t is given by the expression:

$$
\begin{aligned}
& t\left(s^t\right)_{ik} Q\left(k, s^t\right) Z\left(k, s^t\right)_i \\
= \quad & \frac{\left[P\left(s^t\right)_i X\left(s^t\right)_i\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]}{t\left(s^t\right)_{ik}^{\eta-1}} \frac{\lambda_i^{\eta-1} C\left(s^t\right)_i^{\rho(1-\eta)}}{\sum_{j=1}^N \lambda_j^\eta C\left(s^t\right)_j^{-\rho\eta} X\left(s^t\right)_j t\left(s^t\right)_{kj}^{1-\eta}}
\end{aligned} \tag{19}
$$

This is a slightly unorthodox formulation of the standard gravity relationship in the presence of trade costs, where bilateral imports depend on the size of the two countries, bilateral trade costs, and "multilateral resistance" terms [see Anderson and van Wincoop (2003), 2004)]. Appropriate substitution yields the more standard form of the relationship:

$$
t\left(s^t\right)_{ik} Q\left(k, s^t\right) Z\left(k, s^t\right)_i = \left[P\left(s^t\right)_i X\left(s^t\right)_i\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]\left(\frac{P\left(s^t\right)_i \Pi\left(s^t\right)_k}{t\left(s^t\right)_{ik}}\right)^{\eta-1} \tag{20}
$$

where

$$
\Pi\left(s^t\right)_k^{1-\eta} = \sum_{j=1}^N P\left(s^t\right)_j X\left(s^t\right)_j \left(t\left(s^t\right)_{kj} / P\left(s^t\right)_j\right)^{1-\eta} \tag{21}
$$

As will become clear presently, the former expression has the advantage over the latter that it allows us to distinguish whether or not there are frictions in asset markets.

2.3 Enforcement constraint

Suppose now that output is perfectly observable, but countries cannot commit ex ante to make payments that are not ex post optimal. Intertemporal and interstate trade across countries is then feasible only to the extent to which payment can be enforced by the threat of exclusion from future intertemporal, interstate and possibly intratemporal trade. This will limit the degree of risk-sharing that can be supported. There are various possible equilibria of this game. The degree of risk sharing that can be sustained is depends on the discount factor and the severity of the punishment. I assume that there exists a subgame perfect equilibrium of this game where a country that defaults on its obligations to another country is excluded from participating in all future markets by all countries, forever. "Cheat the cheater" punishments are necessary to sustain this SPE when $N > 2$ [see Kletzer and Wright (2000)].

Planner's problem

The planner maximizes a weighted sum of country utilities subject to the standard resource constraints and the incentive compatibility constraints:

$$\sum_{r=t}^{\infty}\sum_{s^r}\beta^{r-t}\pi\left(s^r|s^t\right)u\left(s^r\right)_i \geq V\left(K\left(s^{t-1}\right)_i, s^t\right)_i \tag{22}$$

where

$$V\left(K\left(s^{t-1}\right)_i, s^t\right)_i = \max\sum_{r=t}^{\infty}\sum_{s^r}\beta^{r-t}\pi\left(s^r|s^t\right)u\left(s^r\right)_i \tag{23}$$

subject to[2]

$$C\left(s^t\right)_i + I\left(s^t\right)_i = A\left(s^t\right)_i K\left(s^{t-1}\right)_i^{\alpha} L_i^{1-\alpha}$$

The Lagrange multipliers on the resource constraints are as before. Let the Lagrange multipliers on the IC constraints be denoted

$$\gamma\left(s^t\right)_i = \beta^t\pi\left(s^t\right)\delta\left(s^t\right)_i \tag{24}$$

Following Marcet and Marimon (1998), solutions to the following problem are also solutions to the planner's problem:

$$\mathcal{L} = \sum_{i=1}^{N}\sum_{t=0}^{\infty}\sum_{s^t}\beta^t\pi\left(s^t\right)\left[\begin{array}{l} M\left(s^{t-1}\right)_i u\left(s^t\right)_i + \delta\left(s^t\right)_i\left[u\left(s^t\right)_i - V\left(K\left(s^{t-1}\right)_i, s^t\right)_i\right] + \\ Q\left(i, s^t\right)\left[A\left(s^t\right)_i K\left(s^{t-1}\right)_i^{\alpha} L_i^{1-\alpha} - \sum_{k=1}^{N} t\left(s^t\right)_{ki} Z\left(i, s^t\right)_k\right] + \\ P\left(s^t\right)_i\left[\left(\sum_{j=1}^{N} Z\left(j, s^t\right)_i^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}} - C\left(s^t\right)i - K\left(s^t\right)_i + K\left(s^{t-1}\right)_i\right] \end{array}\right]$$

with

$$M\left(s^t\right)_i = M\left(s^{t-1}\right)_i + \delta\left(s^t\right)_i \tag{25}$$

and $M\left(s^{-1}\right)_i = \lambda_i$. $M\left(s^t\right)_i$ is country i's weight in the planner's welfare.

The first order condition for this problem with respect to $C\left(s^t\right)_i$ is:

$$M\left(s^t\right)_i C\left(s^t\right)_i^{-\rho} = P\left(s^t\right)_i \tag{26}$$

[2] The assumption that the punishment is autarky (rather than financial autarky) means it that V does not depend on the capital stock of all countries.

and with respect to $Z(k, s^t)_i$is:

$$Q\left(k, s^t\right) t\left(s^t\right)_{ik} = P\left(s^t\right)_i X\left(s^t\right)_i^{\frac{1}{\eta}} Z\left(k, s^t\right)_i^{-\frac{1}{\eta}} \tag{27}$$

Equilibrium

The two sets of resource constraints, the IC constraints, the dynamic game which determines $V\left(K\left(s^{t-1}\right)_i, s^t\right)_i$ and the first order conditions (including the first order condition with respect to capital) together determine equilibrium absorption of each intermediate and consumption of the final good by each country in every period and state. It is not necessary to characterize fully the equilibrium allocation in order to derive a number of results on consumption correlations and the reflection of consumption risk sharing in bilateral imports. The results that follow are based only on the resource constraints and the first order conditions described by (25), (26) and (27)

Consumption correlations

The relationship between the domestic price levels, trade costs and the price of intermediates in the country of production is exactly as in the case with no asset market friction. If trade costs are non-zero, purchasing power parity fails. The relationship between the real exchange rate and relative consumption implied by the first order condition with respect to consumption is:

$$RER\left(s^t\right)_{ij} = \frac{P\left(s^t\right)_i}{P\left(s^t\right)_j} = \frac{M\left(s^t\right)_i}{M\left(s^t\right)_j}\left[\frac{C\left(s^t\right)_j}{C\left(s^t\right)_i}\right]^{\rho} \tag{28}$$

The relative sum of multipliers $M\left(s^t\right)_i / M\left(s^t\right)_j$ will in general depend on the consumption allocation, so the relationship between the real exchange rate and relative consumption need not be monotonic.[3]

Relative consumption can be written:

$$\frac{C\left(s^t\right)_i}{C\left(s^t\right)_j} = \left[\frac{M\left(s^t\right)_i}{M\left(s^t\right)_j}\right]^{1/\rho}\left[\frac{\sum_{k=1}^{N}\frac{t\left(s^t\right)_{ik}^{1-\eta}}{\phi\left(s^t\right)_k}Y\left(s^t\right)_k^{\frac{\eta-1}{\eta}}}{\sum_{k=1}^{N}\frac{t\left(s^t\right)_{jk}^{1-\eta}}{\phi\left(s^t\right)_k}Y\left(s^t\right)_k^{\frac{\eta-1}{\eta}}}\right]^{\frac{1}{(\eta-1)\rho}} \tag{29}$$

[3]This implication of financial frictions for the Backus-Smith puzzle is pointed out by Choi (2005).

with

$$\phi\left(s^t\right)_k = \left[\sum_{h=1}^{N} M\left(s^t\right)_h^{\eta} t\left(s^t\right)_{hk}^{1-\eta} C\left(s^t\right)_h^{-\rho\eta} X\left(s^t\right)_h\right]^{\frac{\eta-1}{\eta}} \quad (30)$$

Clearly, even if there are no trade costs, relative consumption is not constant, and consumption growth rates are not perfectly correlated, due to the friction in asset markets.

Bilateral imports

In the presence of both types of friction, the risk sharing that takes place across countries must still be reflected in trade flows. The first order conditions together with the resource constraints yield the following expression for the value of country i's consumption of k's endowment in period t following history s^t:

$$\begin{aligned} & t\left(s^t\right)_{ik} Q\left(k, s^t\right) Z\left(k, s^t\right)_i \qquad (31) \\ = \ & \frac{\left[P\left(s^t\right)_i X\left(s^t\right)_i\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]}{t\left(s^t\right)_{ik}^{\eta-1}} \frac{M\left(s^t\right)_i^{\eta-1} C\left(s^t\right)_i^{\rho(1-\eta)}}{\sum_{j=1}^{N} M\left(s^t\right)_j^{\eta} C\left(s^t\right)_j^{-\rho\eta} X\left(s^t\right)_j t\left(s^t\right)_{jk}^{1-\eta}} \end{aligned}$$

Again, this is a slightly unorthodox formulation of the standard gravity relationship. Appropriate substitution yields the more standard form of the relationship:

$$t\left(s^t\right)_{ik} Q\left(k, s^t\right) Z\left(k, s^t\right)_i = \left[P\left(s^t\right)_i X\left(s^t\right)_i\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]\left(\frac{P\left(s^t\right)_i \Pi\left(s^t\right)_k}{t\left(s^t\right)_{ik}}\right)^{\eta-1} \quad (32)$$

with

$$\Pi\left(s^t\right)_k^{1-\eta} = \sum_{j=1}^{N} P\left(s^t\right)_j X\left(s^t\right)_j \left(t\left(s^t\right)_{kj} / P\left(s^t\right)_j\right)^{1-\eta} \quad (33)$$

Notice that the former expression has the advantage over the latter that it differs depending on whether or not there are asset market frictions.[4]

2.4 Financial autarky

Under financial autarky, trade must be balanced in all periods and states of the world, but spot trades are not restricted. At each point in time and for every realized history, the representative agent in each country maximizes utility $u\left(s^t\right)_i$ subject to the i-country

[4] However from (31) it is not possible to distinguish enforcement frictions of the type presented here from other types of asset market friction.

aggregate good resource constraint and the balanced trade condition:

$$\sum_{k=1}^{N} t\left(s^{t}\right)_{ik} Q\left(k, s^{t}\right) Z\left(k, s^{t}\right)_{i} = Q\left(i, s^{t}\right) A\left(s^{t}\right)_{i} K\left(s^{t-1}\right)_{i}^{\alpha} L_{i}^{1-\alpha} \tag{34}$$

where $Q\left(k, s^{t}\right)$ is the spot price in country k of good k. Denote the multipliers on the aggregate good resource constraint

$$\sigma\left(s^{t}\right)_{i} = \beta^{t} \pi\left(s^{t}\right) \tilde{P}\left(s^{t}\right)_{i} \tag{35}$$

and the multipliers on the balanced trade condition

$$\varphi\left(s^{t}\right)_{i} = \beta^{t} \pi\left(s^{t}\right) R\left(s^{t}\right)_{i} \tag{36}$$

The first order conditions with respect to $C\left(s^{t}\right)_{i}$ are given by:

$$C\left(s^{t}\right)_{i}^{-\rho} = \tilde{P}\left(s^{t}\right)_{i} \tag{37}$$

and with respect to $Z\left(k, s^{t}\right)_{i}$ are given by:

$$\tilde{P}\left(s^{t}\right)_{i} X\left(s^{t}\right)_{i}^{1/\eta} Z\left(k, s^{t}\right)_{i}^{-1/\eta} = R\left(s^{t}\right)_{i} t\left(s^{t}\right)_{ik} Q\left(k, s^{t}\right) \tag{38}$$

For the purpose of comparing the financial autarky case with the cases previously considered, define

$$P\left(s^{t}\right)_{i} = \tilde{P}\left(s^{t}\right)_{i} R\left(s^{t}\right)_{i} \tag{39}$$

Equilibrium

The two sets of resource constraints, the budget constraints and the first order conditions (including the first order condition with respect to capital) together determine consumption of each good by each country in every period and state. Again, it is not necessary to characterize the equilibrium allocation in order to derive results on consumption correlations and the reflection of consumption risk sharing in bilateral imports.

Consumption correlations

The relationship between the domestic price levels, trade costs and the spot price of intermediates in the country of production is exactly as in the case of no asset market frictions. If trade costs are non-zero, purchasing power parity fails. The relationship between the real exchange rate and relative consumption is:

$$RER\left(s^t\right)_{ij} = \frac{P\left(s^t\right)_i}{P\left(s^t\right)_j} = \frac{R\left(s^t\right)_i}{R\left(s^t\right)_j}\left[\frac{C\left(s^t\right)_j}{C\left(s^t\right)_i}\right]^{\rho} \tag{40}$$

The relative multipliers $R\left(s^t\right)_i / R\left(s^t\right)_j$ will in general depend on the consumption allocation, so as in the enforcement friction case, the relationship between the real exchange rate and relative consumption need not be monotonic.

Relative consumption can be written

$$\frac{C\left(s^t\right)_i}{C\left(s^t\right)_j} = \left[\frac{R\left(s^t\right)_i}{R\left(s^t\right)_j}\right]^{1/\rho}\left[\frac{\sum_{k=1}^N \frac{t\left(s^t\right)_{ik}^{1-\eta}}{\phi\left(s^t\right)_k} Y\left(s^t\right)_k^{\frac{\eta-1}{\eta}}}{\sum_{k=1}^N \frac{t\left(s^t\right)_{jk}^{1-\eta}}{\phi\left(s^t\right)_k} Y\left(s^t\right)_k^{\frac{\eta-1}{\eta}}}\right]^{\frac{1}{(\eta-1)\rho}} \tag{41}$$

with

$$\phi\left(s^t\right)_k = \left[\sum_{h=1}^N R\left(s^t\right)_h^{\eta} t\left(s^t\right)_{hk}^{1-\eta} C\left(s^t\right)_h^{-\rho\eta} X\left(s^t\right)_h\right]^{\frac{\eta-1}{\eta}} \tag{42}$$

Even if there are no trade costs, relative consumption is not constant, and consumption growth rates are not perfectly correlated. However, as in Cole and Obstfeld (1991), there is some risk sharing through movements in the terms of trade, as long as trade costs and the elasticity of substitution between different goods are less than infinite.

Bilateral imports

The first order conditions together with the resource constraints yield the following expression for the value of country i's consumption of k's endowment in period t following history s^t:

$$\begin{aligned} & t\left(s^t\right)_{ik} Q\left(k, s^t\right) Z\left(k, s^t\right)_i \\ = \; & \frac{\left[P\left(s^t\right)_i X\left(s^t\right)_i\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]}{t\left(s^t\right)_{ik}^{\eta-1}} \frac{R\left(s^t\right)_i^{\eta-1} C\left(s^t\right)_i^{\rho(1-\eta)}}{\sum_{j=1}^N R\left(s^t\right)_j^{\eta} C\left(s^t\right)_j^{-\rho\eta} X\left(s^t\right)_j t\left(s^t\right)_{jk}^{1-\eta}} \end{aligned} \tag{43}$$

Making use of the fact that under financial autarky, the value of a country's output is equal to the value of its expenditure , this can be rewritten:

$$\begin{aligned} & t\left(s^t\right)_{ik} Q\left(k, s^t\right) X\left(k, s^t\right)_i \\ = & \frac{\left[P\left(s^t\right)_i X\left(s^t\right)_i\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]}{t\left(s^t\right)_{ik}^{\eta-1}}\left(R\left(s^t\right)_i C\left(s^t\right)_i^{-\rho} R\left(s^t\right)_k C\left(s^t\right)_k^{-\rho}\right)^{\eta-1} \end{aligned} \tag{44}$$

or

$$t\left(s^t\right)_{ik} Q\left(k, s^t\right) X\left(k, s^t\right)_i = \frac{\left[P\left(s^t\right)_i X\left(s^t\right)_i\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]}{t\left(s^t\right)_{ik}^{\eta-1}}\left(P\left(s^t\right)_i P\left(s^t\right)_k\right)^{\eta-1} \tag{45}$$

which closely resembles the form of the gravity equation derived by Anderson and van Wincoop (2003).

2.5 A special case

For the purpose of building intuition, it is worth considering a special case of the above model. Suppose that each of the N countries in the world is *endowed* with a distinct tradeable intermediate. These intermediates are combined to produce a non-tradeable final consumption good using the same Dixit-Stiglitz aggregator as before. There is no production or investment. Suppose that preferences are such that $\rho = 1/\eta$.[5] In this case, when there are no frictions in asset markets, bilateral imports are given by:

$$t\left(s^t\right)_{ik} P\left(k, s^t\right) C\left(k, s^t\right)_i = \frac{\left[\lambda_i^\eta\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]}{t\left(s^t\right)_{ik}^{\eta-1}} \frac{1}{\sum_{j=1}^N \lambda_j^\eta t\left(s^t\right)_{kj}^{1-\eta}} \tag{46}$$

With the enforcement friction in asset markets, bilateral imports are given by:

$$t\left(s^t\right)_{ik} P\left(k, s^t\right) C\left(k, s^t\right)_i = \frac{\left[M\left(s^t\right)_i^\eta\right]\left[Q\left(k, s^t\right) Y\left(s^t\right)_k\right]}{t\left(s^t\right)_{ik}^{\eta-1}} \frac{1}{\sum_{j=1}^N M\left(s^t\right)_j^\eta t\left(s^t\right)_{kj}^{1-\eta}} \tag{47}$$

Under financial autarky, bilateral imports are given by:

$$t\left(s^t\right)_{ik} P\left(k, s^t\right) C\left(k, s^t\right)_i = \frac{\left[Q\left(i, s^t\right) Y\left(s^t\right)_i\right]\left[Q\left(k, s^t\right)_t Y\left(s^t\right)_k\right]}{t\left(s^t\right)_{ik}^{\eta-1}}\left(P\left(s^t\right)_i P\left(s^t\right)_k\right)^{\eta-1} \tag{48}$$

When there are no frictions in asset markets, bilateral imports do not respond to shocks

[5] This is the special case of preferences consdered in Obstfeld and Rogoff (1996), Chapter 5.

to the value of importer GDP. Country i's consumption of good k does not depend on i's current income. Under financial autarky, bilateral imports move one-for-one with the value of importer GDP. Country i's consumption of good k moves one-for-one with i's current income. When there is a friction in asset markets, but some cross-state and cross-period trade is possible, bilateral imports move with the value of importer GDP to the extent that $M\left(s^t\right)_i^\eta$, the multiplier on i's IC constraint, depends on i's current GDP. It is tempting to hypothesize that i's consumption of good k moves with i's current income, but less than one-for-one.

3 Empirical strategy

The predictions of the models outlined above with respect to the relationship between bilateral imports, output, consumption and trade costs can be conveniently summarized. Let IM_{ikt} denote the value of country i's imports from country k in period t. Let EXP_{it} denote the value of i's absorption $(P\left(C+I\right))$ in period t. Let GDP_{kt} denote the value of k's output in period t. Then:

$$\frac{IM_{ikt}}{EXP_{it}GDP_{kt}} = \Theta_{it}\Phi_{kt}t_{ikt}^{1-\eta} \tag{49}$$

where the implications of the different assumptions are given by:

Assumption	Θ_{it}	Φ_{kt}	$t_{ikt}^{1-\eta}$
(1) Enforcement friction, trade costs	$M_{it}^{\eta-1}C_{it}^{-\rho(\eta-1)}$	$1/\sum_{j=1}^{N}\Theta_{jt}EXP_{jt}t_{kjt}^{1-\eta}$	$t_{ikt}^{1-\eta}$
(2) Financial autarky, trade costs	$R_{it}^{\eta-1}C_{it}^{-\rho(\eta-1)}$	$R_{kt}^{\eta-1}C_{kt}^{-\rho(\eta-1)}$	$t_{ikt}^{1-\eta}$
(3) Complete financial markets, trade costs	$\lambda_i^{\eta-1}C_{it}^{-\rho(\eta-1)}$	$1/\sum_{j=1}^{N}\Theta_{jt}EXP_{jt}t_{kjt}^{1-\eta}$	$t_{ikt}^{1-\eta}$
(4) No trade costs	1	$1/\sum_{j=1}^{N}EXP_{jt}$	1

Note that it is only in the presence of trade costs that it is possible to distinguish between the different configurations of asset market frictions.

Given data on bilateral imports and the other relevant variables, it is possible to test which of these alternatives fits the data best. Taking logs of (49) and substituting in the standard assumption about the form of trade costs,[6]

$$t_{ikt}^{1-\eta} = \prod_{m=1}^{M} (Z_{ik}^{m})^{\gamma_t^m}\ ,\ Z_{ik}^{m} = 1 \text{ if } i = k,\ z_{ik}^{m} \geq 1 \text{ otherwise} \tag{50}$$

the six different assumptions about the configuration of frictions can be implemented by estimating six different linear models. Let $w_{ikt} = \ln\left(IM_{ikt}/EXP_{it}GDP_{kt}\right)$, $c_{it} = \ln C_{it}$ and $z_{ikt}^{m} = \ln Z_{ikt}^{m}$. Let θ_{it} be an importer-year fixed effect, ϕ_{kt} an exporter-year fixed effect and ψ_i an importer fixed effect. Then the four empirical models are given by:

Assumption	Estimating equation
(1) Enforcement friction, trade costs	$w_{ikt} = \theta_{it} + \phi_{kt} + \sum_{m=1}^{M} \gamma_t^m z_{ik}^m + \varepsilon_{ikt}$
(2) Financial autarky, trade costs	$w_{ikt} = \theta_{it} + \theta_{kt} + \sum_{m=1}^{M} \gamma_t^m z_{ik}^m + \varepsilon_{ikt}$
(3) Complete financial markets, trade costs	$w_{ikt} = \theta_{i} + \phi_{kt} + \beta_c c_{it} + \sum_{m=1}^{M} \gamma_t^m z_{ik}^m + \varepsilon_{ikt}$
(4) No trade costs	$w_{ikt} = \phi_{t} + \varepsilon_{ikt}$

It is appropriate to impose the restrictions on the relationship between ϕ_{kt} and the other variables in models (1), (2), and (3) only if they are estimated using data on the universe bilateral pairs (including imports from self). However, because of data availability constraints, these restrictions will not be imposed.

The enforcement friction, trade cost model nests all the other possible configurations of frictions. Hence, a likelihood ratio test can be used to test null hypotheses against the alternative of frictions in both markets. The data used to implement this strategy is described below. For many bilateral pairs in the sample used, bilateral imports are recorded as zero. In order to avoid dropping these observations, one is added to all bilateral imports, so w_{ikt} is constructed as $\ln\left[\left(1 + IM_{ikt}\right)/EXP_{it}GDP_{kt}\right]$. All cases are estimated as two-way fixed effect models, as the number of dummy variables would otherwise be very large. Time-varying trade costs can be allowed for by letting the coefficients on the gravity variables vary over time.

Given assumptions about the values of η and ρ, it is possible to use the estimates of the unrestricted model to recover the implied bilateral trade costs for all country-pairs, and a time-series for the implied weight of each country in the planner's problem. These exercises provide a useful test of the reasonableness of the underlying model. The bilateral trade costs

[6] See Anderson and van Wincoop (2004).

are recovered by calculating:

$$t_{ikt} = \left[\exp\left(\sum_{m=1}^{M} \hat{\gamma}_t^m z_{ikt}^m\right)\right]^{\frac{1}{1-\eta}}$$

The implied weights in the planner's problem are recovered by calculating:

$$weight_{it} = \frac{\left[\exp\left(\hat{\theta}_{it}\right)\right]^{\frac{1}{\eta-1}} C_{it}^{\rho}}{\sum_{h=1}^{N}\left[\exp\left(\hat{\theta}_{ht}\right)\right]^{\frac{1}{\eta-1}} C_{ht}^{\rho}}$$

4 Data and results

Annual bilateral merchandise imports in current dollars from 1970 to 2000 are taken from the *NBER-United Nations Trade Data* prepared by Feenstra and Lipsey. The current dollar value of GDP, the current dollar value of total expenditure and the current dollar value of total imports are taken from the World Bank's *World Development Indicators* (WDI). The dependent variable is constructed using this data as follows:

$$\frac{IM_{ikt}}{EXP_{it}GDP_{kt}} = \left[IM_{ikt}^{UN}.\frac{IM_{it}^{WDI}}{\sum_{h=1}^{N} IM_{iht}^{UN}}\right]\left[\frac{1}{[GDP_{it}^{WDI} - EX_{it}^{WDI} + IM_{it}^{WDI}].[GDP_{kt}^{WDI}]}\right]$$

where IM_{it} and EX_{it} denote the value of i's total imports and exports in period t, and the subscripts UN and WDI indicate the source of the data.

Real private consumption and real government consumption are taken from the *Penn World Tables*, version 6.1. The baseline measure of real consumption is the sum of both private and government consumption.

For the purposes of estimating the gravity equation, data on variables that are correlated with trade costs are required. In choosing which variables to include, attention is restricted to the subset of standard gravity variables that is least likely to be endogenously determined. Bilateral distance in miles is calculated using the great circle distance algorithm provided by Gray (2001). Dummy variables indicating common language, contiguity, a colonial relationship post-1945 and a common colonizer post-1945 are constructed based on the *CIA World Factbook*. A dummy variable indicating common legal origin (British, French, German, Scandinavian or Socialist) is constructed based on the categorization provided by la

Porta et al (1999).

One issue in mapping the model into the data is that we have data on the value of bilateral *merchandise* imports, not bilateral imports. Data on bilateral service trade are not available. It is implicitly assumed that bilateral service flows follow the same pattern as bilateral merchandise flows.

The largest possible sample given the requirement that all of these variables be available for all sample years consists of 80 developed and developing countries. The list of countries is in the Appendix.

4.1 Results

Baseline results

Table 1 reports the results from estimating the four models described above using all bilateral pairs in the 80-country sample. The coefficients on the gravity variables are allowed to vary by 5-year period. Standard errors are clustered by country-pair. The estimated coefficients on the gravity variables in the models with trade costs are fairly standard and relatively stable across specifications. They strongly suggest that trade costs are falling over time, most rapidly in the first half of the sample period.

Table 2 reports the likelihood ratio test statistics and p-values for the three hypothesis tests, taking the trade cost-enforcement friction model as the alternative hypothesis in each case. The null of no frictions in asset markets is rejected at all significance levels. The null of financial autarky is rejected at all significance levels. The null of no trade costs is also rejected at all significance levels.

The estimated coefficients on the gravity variables from the unrestricted model (column 1) can be used to construct fitted values of bilateral trade costs between all country pairs for the 6 five-year intervals covered by the sample. This requires an estimate of the elasticity of substitution, η. Following Anderson and van Wincoop (2004), a baseline elasticity of 6 is used. Table 3 reports summary statistics of the implied trade costs. Using this elasticity, the predicted trade costs are very high, much higher than the measured costs of trade for goods that are actually traded. This is typical of the fitted trade costs estimated using gravity models of this type. One way to understand it is to think of the costs constructed here as a weighted average applying to all of output, including the large fraction that is non-traded. Another explanation is that there are both fixed and per unit costs of trade. The failure of the empirical model used here to take account of fixed costs may lead to upward-biased estimates of per unit trade costs [see Helpman, Melitz and Rubinstein (2004)]. At any rate, the evidence presented here strongly suggests a much greater macroeconomic role for trade costs than usually presumed in the international real business cycle literature.

The estimated coefficients of the unrestricted model are used to recover the implied weight of each country in the planner's problem given values of $\eta = 6$ and $\rho = 1$ (log utility). At these values, the time-series average of the implied weight of the US in the planner's problem (32%) matches the time-series average of its share in within-sample world GDP (also 32%).[7] Meanwhile, the cross-sectional correlation of these two averages for the full sample of 80 countries is 0.97. The time-series properties of the weights are explored by dividing the sample into 21 OECD countries and the 59 remaining countries (see the Appendix for details). The predicted planning weight for developing countries is much more volatile than that of developed countries. Table 4 reports summary statistics for the coefficient of variation of the implied weights for these two groups (i.e. the standard deviation divided by the mean). The corresponding statistics for the coefficient of variation of shares in within-sample world GDP are also reported.

Results by level of development

The same four empirical models are estimated on two subsamples of the data, one containing only observations on bilateral imports between 21 OECD countries, and the other containing only observations on bilateral imports between the remaining 49 countries. The estimation results are reported in Table 5 and Table 8. The coefficients on the gravity variables in the models with trade costs are quite different in the two samples. The implied trade costs are substantially larger in the non-OECD sample than in the OECD sample (see Tables 7 and 10).

Tables 6 and 9 report the likelihood ratio test statistics and associated p-values for the two samples. In both samples, the null of no asset market frictions and costly trade is rejected against the alternative of frictions in both goods and asset markets. For the non-OECD sample, the rejection is at all significance levels. For the OECD sample, the null is rejected at all conventional levels of significance, but the p-value is 0.89. The null of financial autarky is also rejected in favor of some degree of risk sharing through intertemporal trade.

[7] Higher values for ρ produce a much more skewed distribution of planning weights, with the weight on the US being much higher and that on all other countries much lower.

For developing countries, the likelihood ratio statistic for the null of financial autarky is lower than the likelihood ratio statistic for the null of complete financial markets, while for the 21 OECD countries, the ordering is reversed. In both samples, the null of no trade costs is rejected against the alternative of frictions in both goods and asset markets at all levels of significance.

Results by period

The same models are estimated separately on the first half of the time-period (1970-1984) and the second half of the time period (1985-2000), and the likelihood ratio tests performed. Tables 11 and 12 report the likelihood ratio test statistics and associated p-values for the two samples. In both the earlier period and the later period, the null of no asset market frictions but costly trade is rejected against the alternative of frictions in both goods and asset markets, though the likelihood ratio statistic is much lower in the later period. Similarly, the null of financial autarky is rejected in favor of the alternative of some risk sharing through financial markets, and the null of no trade costs is strongly rejected in both periods.

4.2 Robustness

The results are robust along a number of different dimensions.

Time variation in trade costs

The baseline specification allows trade costs to vary over time by 5-year period. The results are unchanged if the full 31 year interactions with trade costs are allowed for. The estimated evolution of trade costs (high and falling 1970-1984, constant thereafter) is similar whether the full 31 year interactions are allowed for or only the baseline 5-year interactions. The results are also robust to the elimination of time variation in trade costs.

5-year aggregation of the data

The model does not specify what is the length of a period. It is customary to use annual data to estimate gravity equations, but there is no reason why longer frequencies should not be used (shorter frequencies exacerbate the problem of zeros in the dependent variable). The data is aggregated over 5-year periods, deflating nominal variables by the US consumer price index (from WDI). The results obtained using this shorter panel of data are very similar to the baseline results. The only difference is that the implied trade costs are considerably more reasonable. This may be attributed partly to the attenuation of the problem of the zeros.

Inclusion of estimates of trade with self

The model presented above suggests that domestic absorption of domestic output can be treated exactly like absorption of foreign output. In principle, one would like to include observations on absorption of domestic output in the sample, but data on this variable is not available. It is possible to contruct an estimate along the lines described in Fitzgerald (2005). This estimate assumes that the ratio of gross output to value added is constant, and equal to 2. Domestic absorption of domestic output is then given by:

$$IM_{iit} = 2.GDP_{it} - EX_{it}$$

To be consistent, total expenditure is calculated as

$$EXP_{it} = 2.GDP_{it} - EX_{it} + IM_{it}$$

The results of the likelihood ratio tests estimated using the modified data set are unchanged from the baseline, though the estimated trade costs differ somewhat in magnitude.

5 Conclusion

This paper presents a multi-country model with frictions in goods and asset markets. The goods market friction takes the form of costs of trading goods, while the friction in asset markets takes the form of limited enforcement. Both of these frictions separately reduce the extent to which countries can pool risk. The model suggests a test for the presence of each of the two types of friction that can be implemented using data on bilateral imports. I implement this test using a sample of developed and developing countries. The results suggest that both trade costs and asset market imperfections are necessary in order to explain the failure of perfect consumption risk sharing. However there is some risk sharing through intertemporal trade, and asset market frictions are less important for developed than for developing countries. In addition, I find that trade costs, though falling over time, are of much greater economic importance than is usually assumed in the international real business cycle literature.

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Table 1: Regression results for full sample of 80 countries, 1970-2000

		(1)			(2)			(3)			(4)	
Asset market		Enforcement			Autarky			No friction			.	
Goods market		Trade costs			Trade costs			Trade costs			No trade costs	
variable	interaction	coeff.	s.e.		coeff.	s.e.		coeff.	s.e.		coeff.	s.e.
ln(consumption)	none	.	.		.	.		0.00	0.00		.	.
ln(1+dist)	1970-1974	-1.69	0.09	**	-1.69	0.09	**	-1.68	0.09	**	.	.
ln(1+dist)	1975-1979	-1.50	0.08	**	-1.50	0.08	**	-1.54	0.08	**	.	.
ln(1+dist)	1980-1984	-1.08	0.08	**	-1.08	0.08	**	-1.26	0.08	**	.	.
ln(1+dist)	1985-1989	-0.81	0.10	**	-0.81	0.10	**	-0.98	0.09	**	.	.
ln(1+dist)	1990-1994	-0.88	0.09	**	-0.88	0.09	**	-0.78	0.09	**	.	.
ln(1+dist)	1995-2000	-0.89	0.09	**	-0.89	0.09	**	-0.67	0.09	**	.	.
not contiguous	1970-1974	-0.22	0.44		-0.22	0.44		-0.11	0.48		.	.
not contiguous	1975-1979	0.55	0.42		0.55	0.42		0.80	0.43	*	.	.
not contiguous	1980-1984	0.41	0.36		0.41	0.36		0.80	0.35	**	.	.
not contiguous	1985-1989	0.25	0.41		0.25	0.41		0.43	0.41		.	.
not contiguous	1990-1994	0.58	0.39		0.58	0.38		0.29	0.40		.	.
not contiguous	1995-2000	0.67	0.38	*	0.67	0.38	*	0.16	0.40		.	.
no common lang.	1970-1974	-2.22	0.15	**	-2.22	0.16	**	-2.70	0.16	**	.	.
no common lang.	1975-1979	-1.66	0.15	**	-1.66	0.15	**	-1.87	0.15	**	.	.
no common lang.	1980-1984	-1.48	0.15	**	-1.48	0.16	**	-1.36	0.15	**	.	.
no common lang.	1985-1989	-1.38	0.19	**	-1.38	0.20	**	-1.09	0.19	**	.	.
no common lang.	1990-1994	-1.67	0.19	**	-1.67	0.20	**	-1.52	0.19	**	.	.
no common lang.	1995-2000	-1.69	0.18	**	-1.69	0.19	**	-1.59	0.19	**	.	.
no colonial rel.	1970-1974	-2.56	0.31	**	-2.56	0.29	**	-1.86	0.32	**	.	.
no colonial rel.	1975-1979	-2.71	0.34	**	-2.71	0.33	**	-2.53	0.33	**	.	.
no colonial rel.	1980-1984	-2.93	0.34	**	-2.93	0.33	**	-3.27	0.34	**	.	.
no colonial rel.	1985-1989	-2.98	0.38	**	-2.98	0.37	**	-3.52	0.37	**	.	.
no colonial rel.	1990-1994	-2.70	0.38	**	-2.70	0.38	**	-2.88	0.36	**	.	.
no colonial rel.	1995-2000	-2.48	0.39	**	-2.48	0.38	**	-2.32	0.36	**	.	.
no com. col. rel.	1970-1974	-2.56	0.23	**	-2.56	0.24	**	-2.43	0.21	**	.	.
no com. col. rel.	1975-1979	-1.77	0.23	**	-1.77	0.23	**	-1.88	0.21	**	.	.
no com. col. rel.	1980-1984	-0.56	0.21	**	-0.56	0.21	**	-0.67	0.20	**	.	.
no com. col. rel.	1985-1989	0.33	0.27		0.33	0.28		0.46	0.25	*	.	.
no com. col. rel.	1990-1994	0.41	0.26		0.41	0.27		0.35	0.25		.	.
no com. col. rel.	1995-2000	0.48	0.26	*	0.48	0.27	*	0.51	0.24	**	.	.
no com. legal hist.	1970-1974	0.31	0.12	**	0.31	0.13	**	0.11	0.12		.	.
no com. legal hist.	1975-1979	0.14	0.12		0.14	0.12		0.13	0.12		.	.
no com. legal hist.	1980-1984	-0.06	0.12		-0.06	0.12		0.02	0.12		.	.
no com. legal hist.	1985-1989	-0.44	0.14	**	-0.44	0.15	**	-0.31	0.14	**	.	.
no com. legal hist.	1990-1994	-0.18	0.14		-0.18	0.14		-0.12	0.14		.	.
no com. legal hist.	1995-2000	-0.08	0.13		-0.08	0.14		-0.13	0.13		.	.
importer fixed effects		no			no			yes			no	
importer-year fixed effects		yes			no			no			no	
exporter-year fixed effects		yes			no			yes			no	
symmetric-year fixed effects		no			yes			no			no	
year fixed effects		no			no			no			yes	
R^2		0.54			0.51			0.51			0.03	
N		195920			195920			195920			195920	

Dependent variable is $\log(1+IM_{ij}/EXP_iGDP_j)$. * significant at 10%; ** significant at 5%

Table 2: Likelihood ratio test results for full sample of 80 countries, 1970-2000

Null	Alternative	LR	d.f.	N	p-value
Trade costs, no asset market friction	trade, asset friction	13625	2399	195920	1
Trade costs, financial autarky	trade, asset friction	12898	2480	195920	1
No trade costs	trade, asset friction	145273	4965	195920	1

LR test statistic is asymptotically distributed as chi-squared with d.f. as given
A p-value greater than 0.05 indicates rejection of the null at the 5% significance level

Table 3: Fitted trade costs for full sample of 80 countries
Allowing trade costs to vary every 5 years

	elasticity of substitution = 6			elasticity of substitution = 9		
Period	Mean	Min	Max	Mean	Min	Max
1970-1974	6615	706	10859	1266	269	1783
1975-1979	3316	594	5043	799	236	1074
1980-1984	1350	393	1841	429	171	538
1985-1989	737	205	974	276	101	341
1990-1994	739	213	1001	276	104	348
1995-2000	685	207	960	261	102	337

Trade costs are expressed as a percentage of the home country price

Table 4: Summary statistics of coefficient of variation
of implied planning weights and shares in world GDP

	OECD countries			Non-OECD countries		
	Mean	Min	Max	Mean	Min	Max
Planning weights	0.17	0.06	0.38	0.36	0.15	0.79
GDP shares	0.13	0.08	0.25	0.29	0.13	0.65

Planning weights are calculated as described in the text
GDP shares are calculated relative to total in-sample GDP
The coefficient of variation is sd/mean over period 1970-2000

Table 5: Regression results for non-OECD countries only, 1970-2000

		(1)			(2)			(3)			(4)	
Asset market		General friction			Autarky			No friction			.	
Goods market		Trade costs			Trade costs			Trade costs			No trade costs	
variable	interaction	coeff.	s.e.		coeff.	s.e.		coeff.	s.e.		coeff.	s.e.
ln(consumption)	none	.	.		.	.		0.00	0.00		.	.
ln(1+dist)	1970-1974	-2.91	0.12	**	-2.91	0.13	**	-3.27	0.13	**	.	.
ln(1+dist)	1975-1979	-2.83	0.11	**	-2.83	0.11	**	-3.01	0.11	**	.	.
ln(1+dist)	1980-1984	-2.18	0.10	**	-2.18	0.10	**	-2.30	0.10	**	.	.
ln(1+dist)	1985-1989	-1.66	0.13	**	-1.66	0.14	**	-1.63	0.13	**	.	.
ln(1+dist)	1990-1994	-1.59	0.13	**	-1.59	0.13	**	-1.33	0.13	**	.	.
ln(1+dist)	1995-2000	-1.59	0.14	**	-1.59	0.14	**	-1.29	0.14	**	.	.
not contiguous	1970-1974	-0.33	0.52		-0.33	0.52		0.27	0.56		.	.
not contiguous	1975-1979	0.82	0.51		0.82	0.50		1.26	0.51	**	.	.
not contiguous	1980-1984	0.38	0.37		0.38	0.37		0.72	0.39	*	.	.
not contiguous	1985-1989	0.07	0.47		0.07	0.47		0.02	0.49		.	.
not contiguous	1990-1994	0.54	0.46		0.54	0.46		0.04	0.48		.	.
not contiguous	1995-2000	0.90	0.48	*	0.90	0.47	*	0.21	0.50		.	.
no common lang.	1970-1974	-1.90	0.22	**	-1.90	0.23	**	-2.29	0.23	**	.	.
no common lang.	1975-1979	-1.08	0.21	**	-1.08	0.22	**	-1.20	0.22	**	.	.
no common lang.	1980-1984	-1.03	0.19	**	-1.03	0.20	**	-0.83	0.20	**	.	.
no common lang.	1985-1989	-0.87	0.26	**	-0.87	0.27	**	-0.66	0.26	**	.	.
no common lang.	1990-1994	-1.49	0.27	**	-1.49	0.28	**	-1.46	0.27	**	.	.
no common lang.	1995-2000	-1.62	0.26	**	-1.62	0.27	**	-1.56	0.27	**	.	.
no com. col. rel.	1970-1974	-2.80	0.30	**	-2.80	0.31	**	-2.63	0.26	**		
no com. col. rel.	1975-1979	-2.34	0.29	**	-2.34	0.30	**	-2.51	0.26	**		
no com. col. rel.	1980-1984	-1.51	0.24	**	-1.51	0.26	**	-1.84	0.23	**		
no com. col. rel.	1985-1989	-1.03	0.33	**	-1.03	0.34	**	-0.93	0.29	**		
no com. col. rel.	1990-1994	-0.66	0.33	*	-0.66	0.34	*	-0.61	0.29	**		
no com. col. rel.	1995-2000	-0.44	0.33		-0.44	0.33		-0.28	0.30			
no com. legal hist.	1970-1974	0.47	0.20	**	0.47	0.21	**	0.23	0.19		.	.
no com. legal hist.	1975-1979	0.29	0.19		0.29	0.20		0.29	0.18		.	.
no com. legal hist.	1980-1984	0.32	0.17	*	0.32	0.18	*	0.23	0.17		.	.
no com. legal hist.	1985-1989	0.08	0.22		0.08	0.23		0.02	0.20		.	.
no com. legal hist.	1990-1994	0.20	0.21		0.20	0.21		0.39	0.20	*	.	.
no com. legal hist.	1995-2000	0.28	0.20		0.28	0.21		0.45	0.20	**	.	.
importer fixed effects		no			no			yes			no	
importer-year fixed effects		yes			no			no			no	
exporter-year fixed effects		yes			no			yes			no	
symmetric-year fixed effects		no			yes			no			no	
year fixed effects		no			no			no			yes	
R^2		0.50			0.45			0.44			0.06	
N		106082			106082			106082			106082	

Dependent variable is $\log(1+IM_{ij}/EXP_iGDP_j)$. * significant at 10%; ** significant at 5%

Table 6: Likelihood ratio test results for 59 non-OECD countries, 1970-2000

Null	Alternative	LR	d.f.	N	p-value
Trade costs, no asset market friction	trade, asset friction	11357	1769	106082	1
Trade costs, financial autarky	trade, asset friction	9472	1829	106082	1
No trade costs	trade, asset friction	65971	3657	106082	1

LR test statistic is asymptotically distributed as chi-squared with d.f. as given

A p-value greater than 0.05 indicates rejection of the null at the 5% significance level

Table 7: Fitted trade costs for 59 non-OECD countries
Allowing trade costs to vary every 5 years

	elasticity of substitution = 6			elasticity of substitution = 9		
	Mean	Min	Max	Mean	Min	Max
1970-1974	31595	1402	65345	3440	444	5653
1975-1979	17725	1296	34664	2386	419	3774
1980-1984	5342	662	9252	1096	256	1605
1985-1989	2076	368	3164	578	162	783
1990-1994	1719	337	2627	507	151	689
1995-2000	1565	335	2403	474	151	648

Trade costs are expressed as a percentage of the home country price

Table 8: Regression results for OECD countries only, 1970-2000

		(1)			(2)			(3)			(4)	
Asset market		General friction			Autarky			No friction			.	
Goods market		Trade costs			Trade costs			Trade costs			No trade costs	
variable	interaction	coeff.	s.e.		coeff.	s.e.		coeff.	s.e.		coeff.	s.e.
ln(consumption)	none	.	.		.	.		0.00	0.00		.	.
ln(1+dist)	1970-1974	-0.90	0.08	**	-0.90	0.08	**	-0.98	0.07	**	.	.
ln(1+dist)	1975-1979	-0.98	0.08	**	-0.98	0.07	**	-0.99	0.07	**	.	.
ln(1+dist)	1980-1984	-1.06	0.07	**	-1.06	0.07	**	-1.04	0.07	**	.	.
ln(1+dist)	1985-1989	-1.02	0.07	**	-1.02	0.06	**	-1.02	0.07	**	.	.
ln(1+dist)	1990-1994	-1.06	0.07	**	-1.06	0.06	**	-1.02	0.07	**	.	.
ln(1+dist)	1995-2000	-1.04	0.07	**	-1.04	0.06	**	-1.01	0.07	**	.	.
not contiguous	1970-1974	-0.06	0.13		-0.06	0.13		0.05	0.13		.	.
not contiguous	1975-1979	-0.02	0.12		-0.02	0.12		0.03	0.12		.	.
not contiguous	1980-1984	0.10	0.10		0.10	0.10		0.07	0.11		.	.
not contiguous	1985-1989	0.10	0.10		0.10	0.10		0.09	0.10		.	.
not contiguous	1990-1994	0.16	0.11		0.16	0.10		0.10	0.10		.	.
not contiguous	1995-2000	0.16	0.11		0.16	0.11		0.11	0.11		.	.
no common lang.	1970-1974	-0.28	0.13	**	-0.28	0.13	**	-0.24	0.12	*	.	.
no common lang.	1975-1979	-0.21	0.12	*	-0.21	0.12	*	-0.23	0.11	**	.	.
no common lang.	1980-1984	-0.16	0.10		-0.16	0.11		-0.15	0.10		.	.
no common lang.	1985-1989	-0.13	0.09		-0.13	0.10		-0.11	0.09		.	.
no common lang.	1990-1994	-0.06	0.09		-0.06	0.10		-0.07	0.09		.	.
no common lang.	1995-2000	-0.04	0.10		-0.04	0.11		-0.08	0.09		.	.
no com. legal hist.	1970-1974	-0.39	0.08	**	-0.39	0.08	**	-0.38	0.08	**	.	.
no com. legal hist.	1975-1979	-0.34	0.07	**	-0.34	0.08	**	-0.33	0.07	**	.	.
no com. legal hist.	1980-1984	-0.36	0.07	**	-0.36	0.08	**	-0.37	0.07	**	.	.
no com. legal hist.	1985-1989	-0.40	0.06	**	-0.40	0.07	**	-0.40	0.06	**	.	.
no com. legal hist.	1990-1994	-0.46	0.06	**	-0.46	0.07	**	-0.46	0.06	**	.	.
no com. legal hist.	1995-2000	-0.48	0.06	**	-0.48	0.07	**	-0.48	0.06	**	.	.
importer fixed effects		no			no			yes			no	
importer-year fixed effects		yes			no			no			no	
exporter-year fixed effects		yes			no			yes			no	
symmetric-year fixed effects		no			yes			no			no	
year fixed effects		no			no			no			yes	
R^2		0.89			0.86			0.88			0.18	
N		13020			13020			13020			13020	

Dependent variable is $\log(1+IM_{ij}/EXP_iGDP_j)$. * significant at 10%; ** significant at 5%

Table 9: Likelihood ratio test results for 21 OECD countries, 1970-2000

Null	Alternative	LR	d.f.	N	p-value
Trade costs, no asset market friction	trade, asset friction	672	629	13020	0.89
Trade costs, financial autarky	trade, asset friction	3388	651	13020	1
No trade costs	trade, asset friction	26109	1295	13020	1

LR test statistic is asymptotically distributed as chi-squared with d.f. as given
A p-value greater than 0.05 indicates rejection of the null at the 5% significance level

Table 10: Fitted trade costs for 21 OECD countries
Allowing trade costs to vary every 5 years

	elasticity of substitution = 6			elasticity of substitution = 9		
	Mean	Min	Max	Mean	Min	Max
1970-1974	349	143	532	154	74	216
1975-1979	395	163	611	170	83	241
1980-1984	444	184	700	186	92	267
1985-1989	411	173	642	175	87	250
1990-1994	439	185	694	184	92	265
1995-2000	421	179	663	179	90	256

Trade costs are expressed as a percentage of the home country price

Table 11: Likelihood ratio test results for full sample of countries, 1970-1984

Null	Alternative	LR	d.f.	N	p-value
Trade costs, no asset market friction	trade, asset friction	6249	1119	94800	1
Trade costs, financial autarky	trade, asset friction	7149	1200	94800	1
No trade costs	trade, asset friction	69926	2403	94800	1

LR test statistic is asymptotically distributed as chi-squared with d.f. as given
A p-value greater than 0.05 indicates rejection of the null at the 5% significance level

Table 12: Likelihood ratio test results for full sample of countries, 1985-2000

Null	Alternative	LR	d.f.	N	p-value
Trade costs, no asset market friction	trade, asset friction	1676	1199	101120	1
Trade costs, financial autarky	trade, asset friction	5888	1280	101120	1
No trade costs	trade, asset friction	75287	2562	101120	1

LR test statistic is asymptotically distributed as chi-squared with d.f. as given
A p-value greater than 0.05 indicates rejection of the null at the 5% significance level

OECD countries

Australia	Germany	Norway
Austria	Greece	Portugal
Belgium	Ireland	Spain
Canada	Italy	Sweden
Denmark	Japan	Switzerland
Finland	Netherlands	UK
France	New Zealand	USA

Non-OECD countries

Algeria	Gabon	Niger
Argentina	Gambia	Nigeria
Barbados	Ghana	Pakistan
Benin	Guatemala	Paraguay
Bolivia	Honduras	Peru
Brazil	Hong Kong	Philippines
Burkina Faso	Hungary	Rwanda
Burundi	Iceland	Senegal
Cameroon	Indonesia	South Africa
Chad	Israel	Sri Lanka
Chile	Jamaica	Syria
China	Kenya	Thailand
Colombia	Korea	Togo
Congo	Madagascar	Trinidad and Tobago
Costa Rica	Malawi	Tunisia
Cote d'Ivoire	Malaysia	Turkey
Dominican Republic	Mali	Uruguay
Ecuador	Mexico	Venezuela
Egypt	Morocco	Zambia
El Salvador	Nepal	