Trade Costs and
A Gravity Model of Risk Sharing

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Abstract

This paper presents new evidence that trade costs impede cross-country consumption risk sharing. Our analysis exploits cross-sectional and time-series variations in trade costs across country pairs. Using the data for a large panel of countries over the period 1970-2014, we find that bilateral risk sharing improves once a pair of countries become partners under a regional trade agreement. Moreover, we establish a gravity model of consumption risk sharing by finding that countries that are more geographically distant from each other exhibit weaker bilateral risk sharing. The effect is more pronounced in the absence of RTAs, which suggests that trade-promoting policies mitigate the impact of geographic distance on risk sharing. Furthermore, we build a causal relationship between trade and risk sharing by using instrumental variables. These results point to the importance of the trade channel for international consumption risk sharing. Based on these findings, lifting trade barriers will benefit countries by reducing consumption fluctuations.

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1 Introduction

Classic economic theory identifies frictions in the goods market as an explanation for the lack of consumption risk sharing among countries. For instance, Obstfeld and Rogoff (2001) and Dumas and Uppal (2001) argue that trade costs make it costly for countries to share risks through the exchange of goods and can therefore account for the low cross-country consumption correlations observed in the data. However, there have been few attempts in the literature to provide empirical evidence for these seminal theoretical works.

We revisit the idea theoretically and test the theory empirically by exploiting the variation in trade costs among country pairs. We develop a simple theoretical framework to show higher trade costs weaken bilateral risk sharing. In the data we find that regional trade agreements (RTAs hereafter) facilitate bilateral risk sharing between trade partners for a panel of 178 countries over the 1970-2014 period. This finding based on policy shifts supports the viewpoint that reducing trade costs promotes consumption risk sharing. In addition, we provide cross-sectional evidence by establishing a gravity model of consumption risk sharing. As trade costs increase in geographical distance in general, we hypothesize and then confirm that bilateral risk sharing is weaker for countries which are more distant from each other. The effect is more pronounced in the absence of RTAs, which indicates that trade-promoting policies mitigate the impact of geographic distance on risk sharing. To explore the underlying mechanism of these results, we build the causal relation running from trade to consumption by using RTAs as instrumental variables. These findings provide empirical evidence that trade is an important channel of cross-country consumption risk sharing.

Following the literature, including Sørensen and Yosha (1998) and Kose et al. (2009), we measure a country's consumption risk sharing as the response of its relative consumption growth to its relative output growth. A greater response suggests a lower degree of consumption risk sharing. Consider the extreme case where two countries that face output risk are in complete autarky, each country's consumption is equal to its own output. There is no risk sharing between the two countries since the difference in their consumption growth equals that in output growth. In contrast, when risk sharing is perfect the level of a country's consumption does not fluctuate with its own current output but that of the aggregate economy. As a result, the output difference between countries does not influence their relative consumption to each other.

In this paper we focus on bilateral risk sharing which has received little attention in the literature. In a classical model with complete markets, competitive equilibrium coincides with the allocation of a social planner who makes centralized decisions regardless of bilateral economic exchanges. Nevertheless, in the real world there exist frictions of different magnitudes across country pairs that segment complete markets and make bilateral risk-sharing relations meaningful for analyzing consumption patterns.

To start with, we develop simple analytical frameworks to demonstrate the mechanism. The theory section consists of two parts. First, we build a two-country model to explain how trade costs impede risk sharing by limiting the degree of terms-of-trade adjustments. Second, we develop a three-country model where we show how the variation in trade costs shapes risk-sharing patterns. The model predicts that higher trade costs weaken bilateral risk sharing.

To empirically examine the influence of trade costs on consumption risk sharing, we exploit both cross-sectional and time-series variations in trade costs across country pairs. As discussed earlier, our empirical analysis consists of four parts. First, we examine whether RTAs promote bilateral risk sharing. An RTA is a treaty between two or more countries that aims to foster regional trade partnership. By regulating tariffs and other forms of trade barriers, RTAs reduce the trade costs among member countries. Therefore, we examine consumption patterns around RTA events to uncover the relationship between trade costs and risk sharing. We conduct this analysis for a panel of 178 countries over the 1970-2014 period. We interact a dummy variable that equals 1 when a pair of countries both participate in a specific RTA and 0 otherwise with the two countries' difference in output growth. With the difference in their consumption growth as the dependent variable, the coefficient of the interaction term reveals the influence of RTAs on bilateral risk sharing. After controlling for time fixed effects, we find that co-participating in an RTA lowers the response of relative consumption to output growth by about 0.11 (equivalent to 0.9 standard deviations). The result is robust when we employ both pooled regressions and panel analysis with country-pair fixed effect models.

In addition to exploiting policy changes, we provide cross-sectional evidence that demonstrates the impact of trade costs on consumption risk sharing. Geographical distance is acknowledged to be a vital determinant of trade costs.[1] The more distant countries are from one another, the higher trade costs it incurs to ship goods between them. If consumption risk sharing is hampered by trade costs, we should expect that country pairs with greater geographical distance in between exhibit weaker risk sharing. We conduct a two-step analysis to test this hypothesis. In the first step we calculate the bilateral risk-

[1] See, for instance, Tinbergen (1962) and Anderson and Van Wincoop (2003).

sharing coefficients using the real GDP and consumption data of the 178 countries over the 1970-2014 period in our sample. In the second step we confirm that the risk-sharing coefficients are negatively correlated with geographic distance and positively correlated with the product of GDP per capita for country pairs. We call this finding a gravity model of consumption risk sharing since the signs of these variables are consistent with those in a classic gravity model. The gravity model has emerged as a workhorse in the literature due to its empirical success in predicting bilateral trade flows. More recently, it has been applied in a range of areas to document the importance of geographical variables for explaining economic linkages across countries.[2] This paper contributes to this stand of literature by establishing a gravity model of consumption risk sharing. Based on the regression results, every 1% increase in geographic distance lowers the response of relative consumption to output growth for a country pair by 0.01 (or 0.035 standard deviations). The result remains robust when controlling for other common gravity variables including population, common language, and common legal system.

In the next step we bring the previous analyses together to build the causal link between trade ties and the gravity model. Trade may not be the only channel through which geographic distance shapes risk sharing. Specifically, countries can share risks through financial exchanges and labor mobility. Since the literature has acknowledged the importance of geographic distance for migration and financial flows, additional evidence is needed to attribute the gravity model of risk sharing to the trade channel. To this end, we incorporate RTAs and geographic distance in a single regression. If the trade channel contributes to risk sharing across countries, we should expect that geographic distance becomes less relevant for risk sharing in the presence of RTAs. We confirm the hypothesis in the data by documenting a negative correlation between relative consumption growth and an interaction term of the RTA dummy, distance and output growth. As a result, we conclude that if geographic distance is a proxy for barriers to risk sharing, RTAs overcome these barriers regardless of distance. Besides, trade costs can at least partially explain why risk sharing deteriorates as the geographical distance between countries increases.

Lastly, we explore the causal influence of trade on consumption risk sharing by employing an instrumental variable (IV) method. We collect the bilateral trade data from the Direction of Trade Statistics (DOTS) compiled by IMF. We then use the RTA dummy and its interaction with relative output growth as IVs for bilateral trade and its interac-

[2] For instance, Portes and Rey (2005) show that a gravity model explains international transactions in financial assets. Ramos and Suriñach (2017) use a gravity model to analyze bilateral migration in Europe. Lustig and Richmond (2019) study the gravity effect in the factor structure of exchange rates.

tion with relative output growth. We choose these IVs since RTAs enhance trade flows but are plausibly exogenous for consumption. In our IV estimation we find that the interaction term of trade and relative output growth is negatively correlated with relative consumption growth, which confirms that trade promotes consumption risk sharing across countries. Building the causal link running from trade to consumption sheds light on the mechanism for our previous results: Trade is an essential channel of cross-country consumption risk sharing. Therefore, lifting trade barriers will yield welfare gains by strengthening countries' ability to share risks and smooth consumption.

This paper speaks to a substantial body of literature in international economics. First and foremost, imperfect consumption risk sharing remains to be one of the major puzzles in international macroeconomics (Obstfeld and Rogoff (2001)). On the theoretical front, classic papers including Obstfeld and Rogoff (2001), Dumas and Uppal (2001), and Backus and Smith (1993) study the role of goods market imperfections in explaining the lack of international risk sharing. However, there has been very little empirical work in the literature that will support these theoretical arguments. Therefore, our paper fills the void by exploiting cross-sectional as well as time-series variations in trade costs amongst country pairs. More recently, Fitzgerald (2012) and Eaton et al. (2016) build structural models to quantify the impact of trade frictions on consumption risk sharing and conduct counterfactual exercises. Like in most macroeconomic models the results inevitably vary with modeling and parametric assumptions. Our paper complements their analysis by offering direct empirical evidence using econometric methods. Besides trade costs, financial frictions that prohibit countries from trading state-contingent assets have been acknowledged to impede cross-country risk sharing (e.g. Lewis (1996) and Kollmann (1995)). In an empirical paper that also exploits institutional changes like ours, Kose et al. (2009) examine whether financial liberalizations facilitate risk sharing and find little evidence. In our paper we control for country-pairs' financial liberalization status when studying RTA events that do not coincide with financial integration in order to isolate the effects of the trade channel on risk sharing.

Furthermore, this paper is related to several influential studies that investigate the patterns and consequences of cross-country risk sharing. For instance, Kalemli-Ozcan et al. (2003) find that countries or regions with better risk sharing exhibit higher industrial specialization. We follow their two-step approach in our paper when constructing the measure of risk sharing first and then exploring its correlation with variables of interest. In particular, we establish the gravity model by finding that risk sharing increases in country-pairs' GDP but decreases in geographic distance. Moreover, Corsetti et al. (2008)

argue that negative output shocks may result in terms-of-trade deterioration. They estimate a low elasticity of substitution from an international business cycle model with a redistribution sector. We discuss their analytical results and compare them with ours in the theory section. In addition, Callen et al. (2015) evaluate the degree of risk sharing that can be achieved by small sets of countries given that pooling worldwide risk is costly. In a similar spirit, we examine pairwise risk sharing acknowledging the difficulty of sharing risks among all the countries in the world.

This paper also contributes to the extensive empirical literature on the gravity model. Since being introduced by Isard (1954) and Tinbergen (1962), the model has emerged as a classic framework in the trade literature due to its success in matching bilateral trade flows. More recently, seminal works including Anderson and Van Wincoop (2003) and Eaton and Kortum (2002) refine the theoretical foundations of the framework that rationalize empirical regularities of bilateral trade. In addition to trade, the gravity model has recently been applied to a wide range of topics including financial assets (e.g. Portes and Rey (2005), Martin and Rey (2004), Aviat and Coeurdacier (2007), and Okawa and Van Wincoop (2012)) and labor migration (e.g. Lewer and Van den Berg (2008) and Ramos and Suriñach (2017)). Nevertheless, less is known about the effects of distance on macroeconomic fundamentals. Our paper contributes to this literature by exploring the role of geographic distance in shaping consumption allocations.

The remainder of the paper proceeds as follows: Section 2 describes the data and methods of constructing risk-sharing coefficients. Section 3 presents empirical results as to how trade costs influence consumption risk sharing. Section 4 concludes.

2 Theory

This section consists of two parts. First, we develop a two-country model similar to Obstfeld and Rogoff (2001)'s in order to explain why trade costs impede risk sharing. Second, we build a three-country model where we show how trade costs shape bilateral risk-sharing patterns. The analysis will lay the theoretical foundation for our empirical analysis in the next section.

2.1 A Two-country Model

There are two symmetric countries i, j in an economy. A representative household in country i consumes a CES bundle of goods with elasticity of substitution ϕ:

$$c_i = \left[c_{ii}^{\frac{\phi-1}{\phi}} + c_{ji}^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}, \tag{1}$$

where c_{ii} is the consumption of home-produced goods and c_{ji} is the consumption of goods imported from country j.

Exports from country j to i are subject to iceberg shipping costs τ_{ji}. In the symmetric case, we assume $\tau_{ij} = \tau_{ji} = \tau \geq 1$. It implies that τ units must be shipped from the origin in order for one unit of goods to arrive in the destination.

Let y_i and p_i be the quantity and price of goods produced in country i. The market clearing condition is

$$y_i = c_{ii} + \tau c_{ij}. \tag{2}$$

The share of i's goods in j's expenditure is denoted as π_{ij}. Based on the first order condition for optimal consumption,

$$\pi_{ij} = (\frac{\tau p_i}{P_j})^{-\phi}, \tag{3}$$

where the price index in country j under the CES assumption is given by

$$P_j = \left[p_j^{1-\phi} + (\tau p_i)^{1-\phi} \right]^{\frac{1}{1-\phi}}. \tag{4}$$

Moreover, combining equation 2 and 3 yields the demand for i's goods as:

$$y_i = \pi_{ii} c_i + \pi_{ij} c_j = (\frac{p_i}{P_i})^{-\phi} c_i + (\frac{\tau p_i}{P_j})^{-\phi} c_j. \tag{5}$$

We also assume balanced trade to isolate the role of the trade channel in cross-country risk sharing. We impose this assumption not only because it simplifies our analysis, but also because Heathcote and Perri (2002) show that the financial autarky model performs better than models with alternative financial market specifications in matching business cycle features. Under this assumption of balanced trade, a country's expenditure is solely funded by its income:

$$P_i c_i = p_i y_i \tag{6}$$

In the next step we loglinearize the model around its steady state in order to examine how the variables covary under output shocks. We introduce several notations for brevity here. A variable x without a country subscript represents the ratio of x_i to x_j. $\hat{x} = log\frac{x-\bar{x}}{\bar{x}}$ denotes the deviation of x from its steady state. Based on equation 4, the real exchange rate (RER hereafter) $\hat{P}$ is linked to the terms-of-trade (TOT hereafter) $\hat{p}$ through

$$\hat{P} = \frac{1-\tau^{1-\phi}}{1+\tau^{1-\phi}}\,\hat{p}. \tag{7}$$

Let $A = \frac{1-\tau^{1-\phi}}{1+\tau^{1-\phi}}$. Note that $0 < A < 1$ if τ and $\phi > 1$, indicating that the RER appreciates ($\hat{P} > 0$) as the TOT improves ($\hat{p} > 0$) if goods are sufficiently substitutable and trade is costly.

Furthermore, equation 5 and its counterpart for country j requires that relative output satisfies

$$\hat{y} = -\phi\hat{p} + A(\hat{c} + \phi\hat{P}). \tag{8}$$

Besides, it follows from the balanced trade condition (equation 6) that

$$\hat{P} + \hat{c} = \hat{p} + \hat{y}. \tag{9}$$

Combining equations 7-9 allows us to derive the TOT adjustment in response to an output shock:

$$\hat{p} = \frac{1}{A - \phi(A+1)}\hat{y}, \tag{10}$$

From equation 10, TOT moves in the opposite direction to relative output growth if

$$\phi > \frac{A}{A+1}, \tag{11}$$

which implies that exports become more expensive when there is a negative output shock as long as goods are sufficiently substitutable. To elucidate this result, we analyze two effects given any TOT change. When country i experiences a TOT improvement, the higher price cuts the demand for i's goods under the substitution effect. Meanwhile, the TOT change increases the income of country i, which raises i's demand for domestic goods under the income effect. This occurs because trade costs tilt the consumption bundle towards domestic goods. When the elasticity of substitution ϕ is sufficiently high, the substitution effect dominates the income effect. Under this assumption, the country experiencing the negative output shock exhibits a TOT improvement as a result of lower demand for its goods in the equilibrium. The TOT improvement, by raising the nominal value of output, will alleviate the impact of its output loss on consumption.

Corsetti et al. (2008) analyze the other scenario where the elasticity of substitution ϕ is low:[3] A negative supply shock results in a deterioration of TOT, since the substitution effect is dominated by the income effect. Therefore, the value of ϕ is essential for analyzing the effect of trade on risk sharing. The parameter value remains to be debated in the literature. On one hand, estimates based on macro data are lower in value. For instance, Backus et al. (1992), Stockman and Tesar (1995), and Heathcote and Perri (2002) set the parameter to 1.5, 1, and 0.9 respectively. Corsetti et al. (2008) lower the estimate further by introducing a distributive sector in the calibrated model. On the other hand, estimates based on trade data are typically above 3 so that condition 11 is easily satisfied. Examples include Baier and Bergstrand (2001), Imbs and Mejean (2015), and Simonovska and Waugh (2014). As the macro estimates are more sensitive to modeling specifications, we follow the trade literature by assuming the elasticity of substitution is above unity in this paper. Under this assumption, a negative output shock leads to a TOT improvement.

Next we analyze the consumption pattern:

$$\hat{c} = \frac{1 - \phi - \phi A}{(1 - \phi)A - \phi}\hat{y} \equiv \beta\hat{y}. \tag{12}$$

β in equation 12 captures the the response of relative consumption to output growth. The higher the β the weaker the consumption risk sharing. In the situation where

$$\phi(A + 1) = 1, \tag{13}$$

$\beta = 0$ which suggests that consumption risk sharing is perfect. A special case of this occurs when utility is Cobb-Douglas ($\phi = 1$) and trade cost does not exist ($\tau = 1$). This case is discussed in Cole and Obstfeld (1991) who argue that TOT adjustments achieve the same allocation as complete markets. The reason is that an increase in relative output is completely offset by a decrease in TOT under the assumptions. Therefore, trade in goods provides perfect risks sharing across countries in financial autarky.

It is straightforward to show from equation 12 that $\frac{\partial\beta}{\partial\tau} > 0$ as long as $\phi > 1$. This implies that if goods from different countries are sufficiently substitutable, higher trade costs weaken cross-country risk sharing. The reason is that the substitution effect domi-

[3] Instead of trade costs, they introduce preference for domestic goods to generate consumption home bias. The two modeling assumptions yield isomorphic results.

nates the income effect when $\phi > 1$. Therefore, TOT improves when output drops since inequality 11 always holds. As a result, consumption does not fall as much as output thanks to the TOT movement in the opposite direction. But this mechanism is muted when there exist high trade costs that prevent TOT from moving against output. This happens because trade costs induce consumers to bias their consumption towards home goods and to avoid shifting their demand in response to relative prices. Consequently, trade costs strengthen the income effect and weaken the substitution effect, making TOT less likely to decrease with output. Since they limit TOT adjustments that mitigate the impact of output loss on consumption, trade costs pose an obstacle to consumption risk sharing across countries.

2.2 A Three-country Model

After illustrating the mechanism through which trade costs impede risk sharing with a two-country model, we develop a three-country model to explain how the variation in trade costs shapes bilateral consumption risk-sharing patterns. The model predicts that country pairs with higher trade costs exhibit weaker risk sharing.

The setup of the model is similar to that in the two-country scenario. There are three countries i, j, and k. The consumption bundle in country i is

$$c_i = \left[c_{ii}^{\frac{\phi-1}{\phi}} + c_{ji}^{\frac{\phi-1}{\phi}} + c_{ki}^{\frac{\phi}{\phi-1}} \right]^{\frac{\phi-1}{\phi}}. \tag{14}$$

We assume bilateral trade costs are symmetric but not the same across country pairs. Without loss of generality, trade costs between i and j are higher than between j and k:

$$\tau_{ij} = \tau_{ji} > \tau_{jk} = \tau_{kj} > 1. \tag{15}$$

We do not impose additional assumptions on the trade costs between i and k besides they being greater than 1:

$$\tau_{ik} = \tau_{ki} > 1. \tag{16}$$

Given the trade costs, the price level and market clearing condition of country i follow

$$P_i = \left[p_i^{1-\phi} + (\tau_{ji} p_j)^{1-\phi} + (\tau_{ki} p_k)^{1-\phi} \right]^{\frac{1}{1-\phi}}, \tag{17}$$

$$y_i = c_{ii} + \tau_{ij} c_{ij} + \tau_{ik} c_{ik}. \tag{18}$$

Moreover, we still impose the balanced-trade assumption like before:

$$p_i y_i = P_i c_i. \tag{19}$$

We now proceed to analyze the dynamics of variables around the steady state of the economy. We denote the steady state of any variable x as $\bar{x}$ and its deviation from the steady state as $\hat{x} = log\frac{x-\bar{x}}{x}$. Besides, cross-country relative terms are expressed as $x_{i/j} = \frac{x_i}{x_j}$.

First, we characterize the steady state of the economy. We normalize the prices $\bar{p}_i = \bar{p}_j = \bar{p}_k = 1$ and assume the quantity of output are the same across countries. Therefore,

$$\bar{p}_{i/j} = \bar{p}_{k/j} = 1, \qquad \bar{y}_{i/j} = \bar{y}_{k/j} = 1. \tag{20}$$

Since $\tau_{ij} > \tau_{kj}$, country i's price level and consumption on domestic goods are higher than country k's:

$$\bar{P}_i > \bar{P}_k, \qquad \bar{\pi}_{ii} > \bar{\pi}_{kk}. \tag{21}$$

Now we examine the comovement of variables in response to a positive output shock to country j. The output shock makes j's goods more affordable in the international market under the assumption that goods are sufficiently substitutable. As a result, j's TOT deteriorates:

$$\hat{p}_{i/j} > 0, \qquad \hat{p}_{k/j} > 0. \tag{22}$$

Nevertheless, the magnitude of bilateral TOT adjustments varies with bilateral trade costs. To illustrate why this is the case, we first derive the relation between bilateral TOT and RER from equation 17 and its counterpart for country j:

$$\hat{P}_{i/j} - \hat{P}_{k/j} = (\bar{P}_i^{\phi-1} - \bar{P}_k^{\phi-1}\tau_{ik}^{1-\phi})\hat{p}_{i/j} + (\bar{P}_i^{\phi-1}\tau_{ik}^{1-\phi} - \bar{P}_k^{\phi-1})\hat{p}_{k/j}. \tag{23}$$

We then derive the expressions for relative output changes from the market clearing and balanced trade conditions (equation 18 and 19):

$$\begin{aligned}\hat{y}_{i/j} = -\phi\hat{p}_{i/j} + &\frac{1}{1+\tau_{ij}^{1-\phi}\bar{P}_{i/j}^{\phi-1}+\tau_{jk}^{1-\phi}\bar{P}_{k/j}^{\phi-1}} \\ &\times[(1-\tau_{ij}^{1-\phi})\phi\bar{P}_{i/j}^{\phi-1}((\phi-1)\hat{P}_{i/j}+\hat{p}_{i/j}+\hat{y}_{i/j}) \\ &+(\tau_{ik}^{1-\phi}-\tau_{jk}^{1-\phi})\phi\bar{P}_{k/j}^{\phi-1}((\phi-1)\hat{P}_{k/j}+\hat{p}_{k/j}+\hat{y}_{k/j})].\end{aligned} \tag{24}$$

$$\begin{aligned}\hat{y}_{k/j} = -\phi\hat{p}_{k/j} + &\frac{1}{1+\tau_{ij}^{1-\phi}\bar{P}_{i/j}^{\phi-1}+\tau_{jk}^{1-\phi}\bar{P}_{k/j}^{\phi-1}} \\ &\times[(\tau_{ik}^{1-\phi}-\tau_{ij}^{1-\phi})\phi\bar{P}_{i/j}^{\phi-1}((\phi-1)\hat{P}_{i/j}+\hat{p}_{i/j}+\hat{y}_{i/j}) \\ &+(1-\tau_{kj})^{1-\phi}\phi\bar{P}_{k/j}^{\phi-1}((\phi-1)\hat{P}_{k/j}+\hat{p}_{k/j}+\hat{y}_{k/j})].\end{aligned} \tag{25}$$

After that, we take the difference between equation 24 and 25 when imposing $\hat{y}_{i/j} = \hat{y}_{k/j}$, since j is the only country experiencing an output shock in this example:

$$\begin{aligned}\phi(\hat{p}_{i/j}-\hat{p}_{k/j}) = &\frac{\phi(1-\tau_{ik}^{1-\phi})}{1+\tau_{ij}^{1-\phi}\bar{P}_{i/j}^{\phi-1}+\tau_{jk}^{1-\phi}\bar{P}_{k/j}^{\phi-1}} \\ &\times[\bar{P}_{i/j}^{\phi-1}((\phi-1)\hat{P}_{i/j}+\hat{p}_{i/j}+\hat{y}_{i/j})-\bar{P}_{k/j}^{\phi-1}((\phi-1)\hat{P}_{k/j}+\hat{p}_{k/j}+\hat{y}_{k/j})].\end{aligned} \tag{26}$$

Note that $0 < \tau_{ik}^{1-\phi} < 1$ when τ_{ik} and $\phi > 1$. We then combine equation 23 and 26 to find:

$$\hat{p}_{i/j} < \hat{p}_{k/j}, \tag{27}$$

which implies that j experiences a greater TOT deterioration relative to k with which the trade cost is lower. To understand the intuition, recall that TOT movements are governed by two effects which are simultaneously affected by trade costs. On one hand, trade costs weaken the substitution effect. In our example where country j experiences a positive output shock and its goods become cheaper, country i is less likely to raise its demand for j's goods since it faces higher trade costs than k when trading with j. On the other hand, trade costs strengthen the income effect since they tilt the consumption bundle toward domestic goods. In our example here, $\pi_{ii} > \pi_{kk}$ given $\tau_{ij} > \tau_{kj}$, ceteris paribus. Since the substitution effect is stronger and income effect is weaker, the TOT adjustment in response to the output shock is greater for country pairs with lower trade costs.

The TOT movements described in 27 predict bilateral consumption risk-sharing patterns. As we discuss in the two-country model that when TOT moves in the opposite direction to relative output, the trade channel yields risk-sharing benefits by reducing the response of relative consumption to output shocks. Since higher trade costs restrict the degree of TOT adjustments, consumption risk sharing between country i and j is weaker than between k and j. In other words, country pairs with higher costs exhibit weaker risk sharing.

To conclude, our model predicts that trade costs affect bilateral consumption risk sharing. In the next section we test this prediction empirically by exploiting cross-sectional and time-series variations in trade costs amongst country pairs.

3 Data

To examine the influence of trade ties on consumption risk sharing we combine data on regional trade agreements, GDP, consumption, and geographical distance among countries. In this section we describe how we collect and analyze the data.

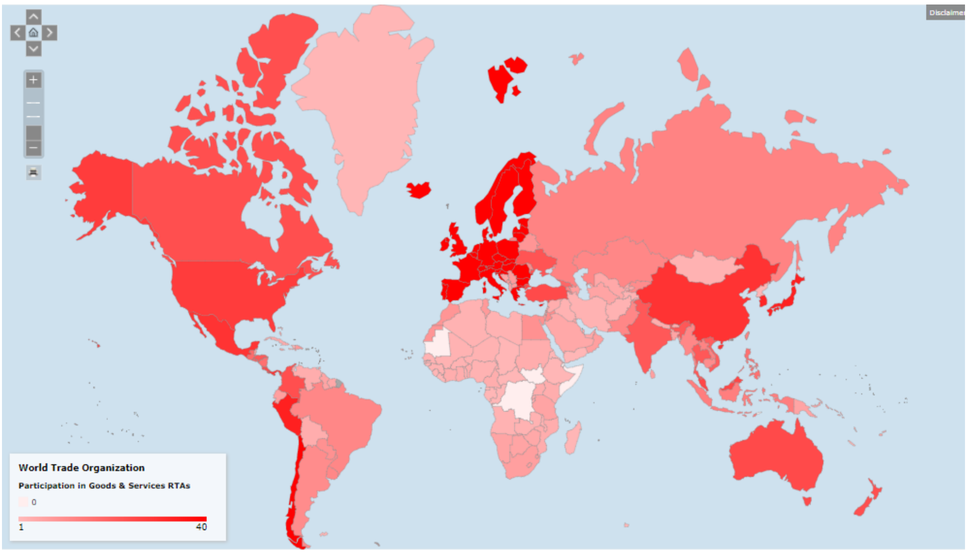
3.1 Regional Trade Agreements

We obtain the information on regional trade agreements from the World Trade Organization (WTO) and the Centre d'tudes Prospectives et d'Informations Internationales (CEPII). The dummy for regional trade agreements (RTA) is 1 for the period where a pair of countries both participate in a specific RTA. The WTO classifies RTAs into four groups: customs unions, economic integration agreements, free trade agreements, and partial scope agreements. We do not consider the last group as RTAs in our analysis since they only cover specific goods and services. Meanwhile we exclude the events where economic integration agreements coincide with policies that promote financial integration to isolate the effect of trade ties on consumption risk sharing.

Figure 1 displays the global map of RTAs as of July 2019. There are close to 300 RTAs signed bilaterally or multilaterally by groups of countries. Figure 2 tracks the historical occurrence of RTAs. It illustrates that the coverage of RTAs has been remarkably expanded over the decades.

Table A.1 provides the list of countries in our sample. In the table we list the number of RTAs a country has been a member of as well as the number of countries that have ever been their partners in any RTA from 1970 to 2014. Among the 178 countries in our sample only three of them have not joined in any full-scope RTA.[4] For the remaining ones, the average number of RTAs a country has participated in is 17.7 over the sample period. A country's average number of RTA partners — whether one-time or serial co-participants — is 18. The average duration of RTAs in the sample is 13.3 years. Lastly, 4778 country pairs (or 15.1% of the sample) have ever become RTA partners.

Figure 1: Current RTAs



Source: WTO

3.2 GDP, consumption, and risk sharing

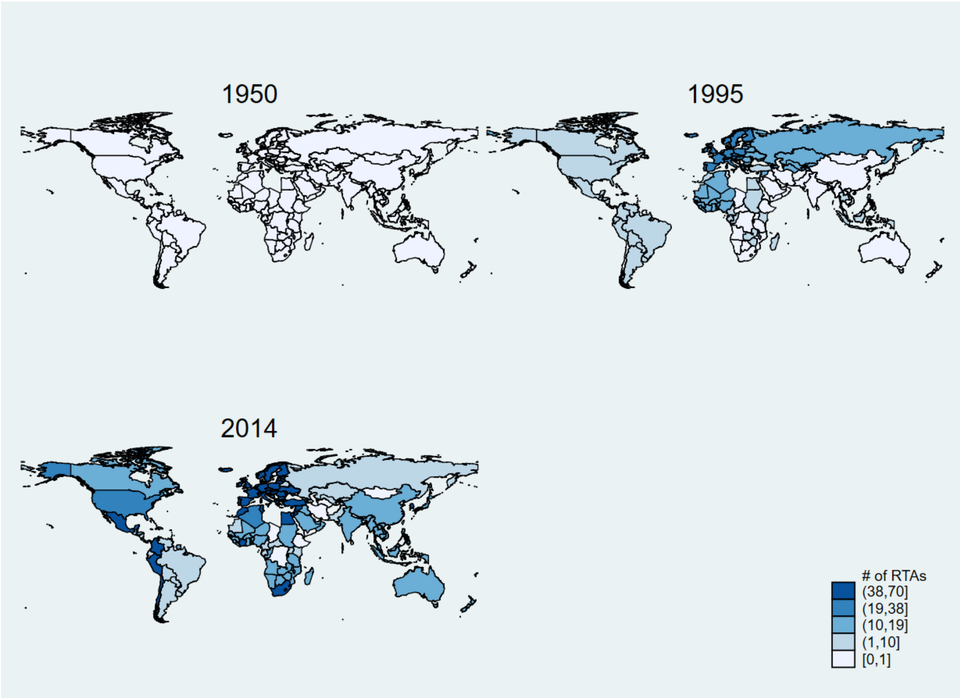
We collect the real GDP, real consumption, and population data from the Penn World Table (PWT) version 9.0. Our sample covers 178 countries over the 1970-2014 period.

Following the literature including Sørensen and Yosha (1998) and Kose et al. (2009), we measure a country's consumption risk sharing as the response of its relative consumption growth to its relative output growth. Specifically, we are interested in bilateral risk sharing so that we can exploit pair-specific factors including RTAs and geographic distance in order to provide a more robust understanding of the factors that shape risk-sharing patterns. We evaluate risk sharing between country i and j from

$$\Delta log\ c_{it} - \Delta log\ c_{jt} = \alpha_{ij} + \beta_{ijt}(\Delta log\ y_{it} - \Delta log\ y_{jt}) + \epsilon_{ijt}, \tag{28}$$

[4]Namely Iran, Mongolia, and Sao Tome.

Figure 2: Historical RTAs



Source: WTO and CEPII

where $\Delta log\ c_{it}$ ($\Delta log\ c_{jt}$) denotes the growth of log real per-capita consumption of country $i(j)$ at time t, and $\Delta log\ y_{it}$ ($\Delta log\ y_{jt}$) denotes the growth of log real per-capita output.

A higher coefficient β_{ijt} suggests a lower degree of consumption risk sharing. In the case with perfect risk sharing, relative consumption growth should not vary with relative output growth, which yields a coefficient of 0. In the opposite case where there is no risk sharing, a country's consumption is solely determined by its own output. In this scenario relative consumption growth should equal relative output growth across countries such that $\beta_{ijt} = 1$. Therefore, the better a country is able to share its risks with another, the smaller will be the influence of its relative output on consumption (measured by a lower value for β_{ijt}). For simplicity, we define the bilateral risk-sharing coefficient as $RS_{ijt} \equiv 1 - \beta_{ijt}$. A higher RS_{ijt} stands for better risk sharing.

Table 1 shows the summary statistics of RS_{ijt} estimated with the annual data from 1970 to 2014. Panel A presents the coefficients of all the country pairs in our sample, while Panel B focuses on the country pairs that have ever co-participated in any RTA. Each cell reports the average value in the relevant subsample and the median value is in parenthesis. Column (1) reports the coefficients for the years when two countries are RTA partners, and column (2) reports the coefficients for the years when they are not bound by an RTA. Column (3) reports the difference between column (1) and (2). All the estimates across the three columns are significantly different from zero at the 1% level. In Panel B when country pairs are regional trade partners, the mean (median) value of risk-sharing coefficients is 0.567 (0.529), which is much higher than its counterpart 0.371 (0.333) when countries are not partners under RTAs. If we split countries into different groups, we find the RTAs benefit risk-sharing between industrial and developing countries to a greater extent compared to risk-sharing between countries in the same income group. Across all types of country pairs, there is a robust pattern that risk sharing improves under RTAs.

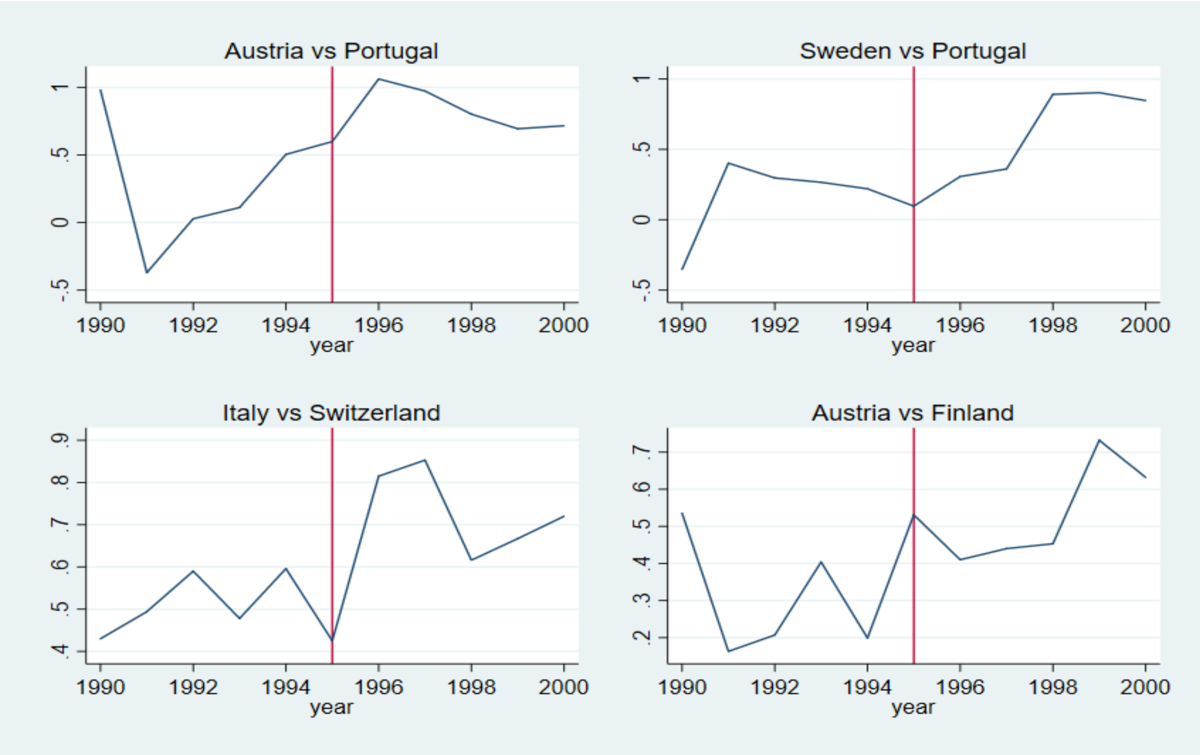
Table 1: Summary Statistics of Risk-sharing Coefficients

	(1) w/ RTA	(2) w/o RTA	(3) Difference
A. Full Sample			
All types of countries	0.572 (0.538)	0.418 (0.396)	0.154 (0.142)
Industrial and industrial	0.426 (0.403)	0.344 (0.347)	0.082 (0.056)
Industrial and developing	0.708 (0.668)	0.402 (0.366)	0.306 (0.302)
Developing and developing	0.477 (0.511)	0.438 (0.422)	0.039 (0.089)
B. RTA Sample			
All types of countries	0.567 (0.529)	0.371 (0.333)	0.196 (0.196)
Industrial and industrial	0.426 (0.403)	0.271 (0.323)	0.155 (0.080)
Industrial and developing	0.703 (0.659)	0.426 (0.342)	0.277 (0.317)
Developing and developing	0.474 (0.509)	0.378 (0.323)	0.096 (0.186)

This table reports bilateral risk sharing coefficients $RS_{ijt} \equiv 1 - \beta_{ijt}$, where β_{ijt} is estimated from equation 28. Panel A presents the coefficients of all the country pairs in our sample, while Panel B focuses on the country pairs that have ever participated in the same RTA. Column (1) reports the coefficients for the years when two countries are RTA partners, and column (2) reports the coefficients for the years when they are not bound by an RTA. Each cell reports the average value in the relevant subsample and the median value is in parenthesis. All the estimates in the table are significantly different from zero at the 1% level. The designation of "industrial" and "developing" countries is based on the Statistics Division of the United Nations.

To exemplify the pattern, we estimate the risk-sharing coefficients RS_{ijt} over six-year rolling windows to capture the median-term trend and show them graphically for a group of European countries. As is illustrated in Figure 3, bilateral risk sharing remarkably improves after the Single Market was established in the mid 1990's. [5]

Figure 3: Bilateral Risk Sharing before and after RTAs



Evolution of risk sharing measured as $RS_{ijt} = 1 - \beta_{ijt}$ for selected pairs of countries. Vertical lines indicate the implementation dates of regional trade agreements.

3.3 Geographic Distance

We add spatial features to our analysis by examining how geographic distances influence bilateral risk sharing. The benchmark measure of geographic distance between two countries comes from the CEPII, which calculates the population-weighted distance between the biggest cities of those two countries. For robustness, we also consider simple distance calculated with the geographical coordinates (latitudes and longitudes) of the capital cities.

[5]Austria, Sweden, and Finland became the new member states of the treaty in 1995. Switzerland was not an official member, but it signed a separate treaty with the members under EFTA.

4 Empirical Analysis

In this section we employ econometric methods to examine the influence of trade ties on risk sharing. First we test whether regional trade agreements promote bilateral risk sharing. Second we empirically establish a gravity model of risk sharing. Third we combine the two pieces and find that RTAs reduce the obstacles posed by geographical distance for risk sharing. Last we build causality from trade to consumption risk sharing by using RTAs as instrumental variables.

4.1 Cross-country Risk Sharing and RTAs

In this section we study consumption patterns around RTA events to provide evidence for the influence of trade costs on consumption risk sharing. We follow two approaches to evaluate the impact of RTAs: pooled panel regressions and fixed-effects models. The former approach allows us to exploit both cross-sectional and time-series variations in country pairs' exposure to RTAs. The second approach focuses on within-country-pair variations over time.

We use annual data for a panel of 178 countries over the 1970-2014 period. Our pooled panel regression has the following specification

$$\begin{aligned} \Delta log\ c_{it} - \Delta log\ c_{jt} &= \alpha + \beta_1(\Delta log\ y_{it} - \Delta log\ y_{jt}) + \beta_2 RTA_{ijt} \\ &+\beta_3 RTA_{ijt} \times (\Delta log\ y_{it} - \Delta log\ y_{jt}) + \eta_t + \eta_i + \eta_j + \epsilon_{ijt}, \end{aligned} \tag{29}$$

where $\Delta c_{it}(c_{jt})$ denotes the change in real consumption per capita of country $i(j)$ at time t and $\Delta y_{it}(y_{jt})$ denotes that of the real output per capita. As discussed earlier, the response of the relative consumption growth to the relative output growth measures the two countries' ability to share risks. Moreover, RTA_{ijt} is a dummy variable that equals 1 for the periods where the country pair participates in a regional trade agreement and 0 otherwise. A negative β_3 suggests that bilateral risk sharing improves in the presence of RTAs. η_t represents time fixed effects, which captures the world aggregate output shock at time t. η_i, η_j represent country fixed effects that capture time-invariant country-specific characteristics. The standard errors ϵ_{ijt} are clustered at country pairs to control for potential heteroskedasticity and autocorrelation. In addition to the baseline specification, we consider other variables that could potentially influence bilateral consumption risk sharing as controls, including the product of the two countries' population and GDP per capita in logs at time t, as well as the two countries' product of GDP volatility over the sample period.

Table 2 reports the estimation results. Panel A presents the results for the full sample of country pairs formed by 178 countries. The coefficient estimate for the relative output growth is around 0.3 in all the regressions. The fact that it is between 0 and 1 in value suggests imperfect risk sharing. More importantly, the coefficient of the interaction term with RTA and relative output growth is significantly negative, which implies that participating in a regional trade agreement facilitates bilateral risk sharing. Based on the estimates, being RTA partners lowers the response of a country pair's relative consumption growth to output growth by 0.11 (or 0.9 standard deviations). The result holds when we control for population, GDP per capita, and GDP volatility of the country pair. These variables do not appear to exhibit correlations with relative consumption growth.

We then focus on the sub-sample of country pairs who have ever co-participated in any RTAs over the sample period. As is shown in Panel B, the absolute value of the coefficient estimate for the interaction term increases, which implies that RTAs play a more vital role in consumption risk sharing for countries that have a history of regional trade partnership.

Next we employ the panel approach with a fixed effects model to quantify the impact of RTAs. By including country-pair fixed effects, this approach controls for unobserved systematic differences across country pairs around RTA events, including factors that induce countries to select into RTAs. Table 2 Panel C reports the results. It demonstrates that the response of relative consumption growth to output growth decreases by 0.112 once a country pair joins an RTA. The coefficient estimate in this fixed-effect model is similar in magnitude to that in the pooled regressions for the full sample of country pairs.

In addition to these baseline findings, we conduct a robustness check. Since having access to broader goods and capital markets may change bilateral risk-sharing patterns, we control for country-pairs' ties with the rest of the world. To this end, we introduce the number of the GATT/WTO members from CEPII and financially-liberalized economies based on Bekaert et al. (2004) in the country pair as regressors. As is shown in Table A.2, financial liberalization promotes risk sharing, while the GATT/WTO membership does not. It could be driven by the fact that being participants of world trade agreements leaves countries less reliant on bilateral risk sharing. Meanwhile, the coefficient estimate for the interaction term with RTA and relative output growth stays significant. The fact that our finding is robust to controlling for countries' financial liberalization status indicates that barriers in the trade channel remain to impede consumption risk sharing when asset market frictions are taken into consideration.

Some may worry about the endogeneity issue associated with the timing of RTAs which may bias our baseline and robustness results. For instance, countries may adjust consumption in anticipation of RTAs. We argue that this possibility is low. First, the average time lag between the notification and effective dates in our RTA sample is as short as 1.2 years, making it harder to respond to the announcement of RTAs in advance. Second, the average number of member states in an RTA is 7.8. The small number casts doubt on the probability that a country's residents will proactively change their overall consumption patterns in expectation of future RTAs. It might pose a bigger concern though if we instead examine the influence of global trade agreements.

To sum up, the coefficient estimate for the interaction term of RTA and relative output growth remains statistically and economically significant across alternative specifications. The finding supports the assertion that lifting trade barriers promotes cross-country risk sharing.

Table 2: Bilateral Risk Sharing and RTA

Dep Var:	Pooled Regression						Panel Approach	
Δ Consumption	*A. Full Sample*			*B. RTA Sample*			*C. FE Model*	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Δ Output	0.302***	0.308***	0.308***	0.327***	0.455***	0.455***	0.302***	0.307***
	(0.005)	(0.005)	(0.005)	(0.012)	(0.013)	(0.013)	(0.005)	(0.005)
RTA		9.16e-17	8.02e-17		6.81e-18	2.17e-17		1.11e-16
		(0.000)	(0.000)		(0.001)	(0.001)		(0.001)
RTA × Δ Output		-0.111***	-0.111***		-0.259***	-0.259***		-0.112***
		(0.014)	(0.014)		(0.018)	(0.018)		(0.014)
GDP			1.11e-15			7.12e-15		
			(0.000)			(0.001)		
Population			-2.52e-15			-1.68e-14		
			(0.001)			(0.003)		
GDP volatility			-6.59e-16			1.03e-15		
			(0.000)			(0.001)		
Country Pair FE							Y	Y
Country FE	Y	Y	Y	Y	Y	Y		
Time FE	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,420,421	1,419,887	1,419,887	217,616	217,616	217,616	1,420,421	1,419,887
R-squared	0.208	0.209	0.209	0.224	0.255	0.255	0.183	0.185

The dependent variable is country i's relative per-capita consumption growth to that of country j. Δ Output is country i's relative per-capita output growth to that of country j. RTA is a dummy variable which is 1 when country i and j both participate in a regional trade agreement at t. Population is the product of the country pair's population at t in logs. GDP is the product of the country pair's GDP per capita at t in logs. GDP volatility is the product of the standard deviation of the two countries' per-capita GDP over time. The regressions include time fixed effects. In addition, pooled regressions include country fixed effects and the panel approach includes country-pair fixed effects. Clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

4.2 A Gravity Model of Risk-sharing

After establishing the importance of trade costs for risk sharing by exploiting policy shifts, we derive a cross-sectional prediction for cross-country consumption allocations. In particular, we explore the implications of geographic distance for bilateral risk sharing.

The international economics literature has a long tradition of empirically studying how geographical distance influences economic linkages across countries. For instance, since being developed by Isard (1954) and Tinbergen (1962), the gravity model in international trade remains to be a workhorse due to its empirical success in predicting bilateral trade patterns. More recently, the gravity model has been applied to a growing range of areas to document that economic ties between two countries — including financial and migration flows — are inversely proportional to the geographic distance between them (e.g. Portes and Rey (2005) and Ramos and Suriñach (2017)). Nevertheless, little is known about the impact of distance on macroeconomic fundamentals. Our paper fills the gap in the literature by focusing on consumption patterns.

The economic reasoning behind our hypothesis is straightforward. Trade costs typically increase with geographic distance: the farther away countries are located from one another, the higher trade costs it incurs to ship goods between them. If trade costs impede risk sharing, we should expect that country pairs with greater geographical distance in between exhibit weaker consumption risk sharing. Therefore, we hypothesize that there is a gravity model of consumption risk-sharing.

We test this hypothesis using a two-stage regression. In the first stage we compute the bilateral risk-sharing coefficients for all the country pairs using annual data over the sample period by estimating the equation:

$$\Delta log\ c_{it} - \Delta log\ c_{jt} = \alpha_{ij} + \beta_{ij}(\Delta log\ y_{it} - \Delta log\ y_{jt}) + \epsilon_{ijt}. \tag{30}$$

In the second stage we regress the estimated β_{ij} on geographic distance $dist_{ij}$ and other country-pair control variables X_{ij}:

$$\beta_{ij} = \alpha + \gamma\,(\ln dist_{ij}) + X_{ij} + \epsilon_{ij}. \tag{31}$$

We will confirm the hypothesis if γ is positive, which implies that countries which are more distant from each other tend to exhibit a lower degree of consumption risk sharing. In addition to the baseline specification with distance only, we augment the analysis with standard gravity regressors including dummies for contiguity, common language, common legal system, and time-averaged product of population in logs and GDP per capita in logs. The values of these variables are sourced from the CEPII gravity database.

Table 3 reports the results of the second-stage regression. The coefficients for geographic distance are significantly positive across all the specifications. The estimates indicate that bilateral risk sharing decreases by about 0.01 (or 0.035 standard deviations) for a 1% increase in geographic distance. The results obtain when other gravity variables are controlled for. Moreover, we find that bilateral risk sharing increases in a country pair's level of economic development. From Column (4), a 1% increase in the product of GDP per capita raises bilateral risk sharing by 0.051. This result indicates that more economically developed countries are more likely to share risks with each other. Meanwhile, bilateral risk sharing decreases by 0.034 for a 1% increase in the product of populations. One potential explanation is that there is a higher level of intra-national risk sharing in a more populous economy which dampens the need for inter-national risk sharing. In terms of other gravity variables in Table 3, we find that sharing a common language promotes bilateral risk sharing, while having a common legal system yields less consistent results. When we control for countries' economic sizes, commonality of legal systems appears to facilitate risk sharing as shown in column (4). In the same column the coefficient estimate for contiguity is positive, which contradicts our expectation that country pairs that share borders should exhibit stronger risk sharing. However, contiguity does promote risk sharing when geographic distance is controlled for (see Table A.3).

To conclude the main baseline findings in Table 3, we confirm that bilateral risk sharing decreases in geographic distance but increases in GDP per capita. The signs of these two variables are reminiscent of those in the existing gravity models including trade, finance, and migration.

Table 3: A Gravity Model of Risk-sharing

Dep Var: β_{ij}	(1)	(2)	(3)	(4)
Distance	0.011***	0.014***	0.009***	0.007***
	(0.002)	(0.003)	(0.002)	(0.002)
Contiguity		0.142***		0.033***
		(0.012)		(0.012)
Language		-0.063***		-0.016***
		(0.005)		(0.005)
Legal		0.008*		-0.033***
		(0.004)		(0.004)
GDP			-0.050***	-0.051***
			(0.001)	(0.001)
Population			0.035***	0.034***
			(0.001)	(0.001)
Constant	0.481***	0.458***	0.319***	0.384***
	(0.021)	(0.022)	(0.032)	(0.033)
Observations	31,684	31,659	31,684	31,659
R-squared	0.001	0.008	0.224	0.226

The dependent variable is the estimated coefficient β from the first stage regression. Higher β suggests weaker consumption risk sharing. Independent variables include the log of geographic distance between two countries in kms, dummies for common language, legal system, contiguity, and time-averaged product of population in logs, and GDP per capita in logs. Standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

In the next step we conduct two sensitivity analyses to verify the robustness of the gravity model. Specifically, we consider an alternative measure of distance and a more robust measure of risk sharing.

The benchmark measure of geographic distance between two countries comes from the CEPII, which calculates the population-weighted distance between the biggest cities of those two countries. For robustness, we also consider simple distance calculated with the geographical coordinates of the capital cities. Results reported in Table A.3 suggest that the results remain unchanged.

Furthermore, we address a potential concern with our measure of risk sharing. In equation 30 where we define and estimate the risk-sharing coefficients, we use the difference in output growth between a pair of countries (denoted as $\Delta log\ y_{it} - \Delta log\ y_{jt}$) to reflect the countries' idiosyncratic risks. By doing so, we implicitly assume that the two countries have the same degree of exposure to global shocks. In other words, when loadings of aggregate shocks (denoted as β_i, β_j) are the same, the difference in idiosyncratic risks can be written as

$$(\Delta log\ y_{it} - \beta_i \Delta log\ y_{wt}) - (\Delta log\ y_{jt} - \beta_j \Delta log\ y_{wt}) = \Delta log\ y_{it} - \Delta log\ y_{jt}, \quad (32)$$

where y_{wt} is the world output per capita at time t. However, this assumption is not valid in some cases so that the difference in output growth is also driven by the countries' distinct degrees of exposure to world aggregate risks. To address this concern, we conduct a robustness check where we adjust for countries' exposure to aggregate risks. First, we estimate β_i, β_j from

$$\Delta log\ y_{it} = \alpha_i + \beta_i \Delta log\ y_{wt} + \epsilon_{it}, \qquad \Delta log\ y_{jt} = \alpha_j + \beta_j \Delta log\ y_{wt} + \epsilon_{jt}. \quad (33)$$

Second, we calculate bilateral risk-sharing coefficients from the response of consumption to this more robust measure of idiosyncratic output shocks:

$$\Delta log\ c_{it} - \Delta log\ c_{jt} = \alpha_{ij} + \beta_{ij}[(\Delta log\ y_{it} - \beta_i \Delta log\ y_{wt}) - (\Delta log\ y_{jt} - \beta_j \Delta log\ y_{wt})] + \epsilon_{ijt}. \quad (34)$$

Lastly, we regress the estimated β_{ij} on geographic distance.

$$\beta_{ij} = \alpha + \gamma\, (\ln dist_{ij}) + X_{ij} + \epsilon_{ij}. \quad (35)$$

Table A.4 presents the result for this robustness check. Compared to Table 3, the coefficient estimates have identical signs and similar values. The magnitude of the coefficient for distance is greater, indicating that geographic distance plays a more crucial role in shaping risk sharing patterns when we control for countries' different degrees of exposure to world aggregate risks. The gravity model of risk sharing remains robust.

4.3 Gravity Model and RTA

In this section we bring the previous pieces together and study the relationship between the gravity model of risk sharing and regional trade agreements. The finding will allow us to examine the impact of policies on the frictions that impede efficient risk sharing across countries.

Theoretically in a frictionless world where geographical distance does not incur costs, bilateral risk sharing should not be correlated with distance among countries. All the countries share risks perfectly regardless of the physical distance among them. Nevertheless, there exist frictions that positively comove with distance in the channels of risk sharing. For example, shipping costs in trade, informational asymmetries in finance, migration cost in labor mobility are factors that prohibit the channels from working efficiently to ensure perfect risk sharing. These frictions typically rise as geographic distance increases, making risk-sharing across country pairs that are physically distant from each other increasingly difficult. These frictions can justify the gravity model established in the previous section.

This paper focuses on trade in the goods market as a channel for risk sharing, but frictions increase with geographic distance in various channels. Therefore, we need additional empirical evidence to establish the causal link between the gravity model and trade in goods and services. To this end, we exploit variations in RTAs as in Section 3.1 in order to attribute the gravity model of risk sharing to the trade channel.

Besides the lower shipping costs due to the shorter traveling distance, countries that are physically closer to each other obtain better risk sharing through trade since they typically face fewer trade policy distortions under RTAs. RTAs are usually signed to reduce trade barriers including tariffs and quotas in order to protect the common economic interest of a geographic region. If the trade channel contributes to risk sharing across countries, we should expect that geographic distance poses a smaller obstacle for risk sharing in the presence of RTAs.

To test this hypothesis we estimate the following specification:

$$\begin{aligned}\Delta log\ c_{it} - \Delta log\ c_{jt} &= \alpha + \beta_1(\Delta log\ y_{it} - \Delta log\ y_{jt}) + \beta_2(ln\ dist_{ij}) \\ &+\beta_3(RTA_{ijt}) + \beta_4(RTA_{ijt} \times ln\ dist_{ij}) \\ &+\beta_5[RTA_{ijt} \times ln\ dist_{ij} \times (\Delta log\ y_{it} - \Delta log\ y_{jt})] \\ &+\eta_t + \eta_i + \eta_j + \epsilon_{ijt}.\end{aligned} \tag{36}$$

In this specification we are particularly interested in β_5. A negative β_5 implies that geographic distance impedes risk sharing to a less extent for a pair of countries when they participate in a regional trade agreement.

The results presented in Table 4 confirm this hypothesis. The coefficients for the three-way interaction term are significantly negative across all the regression specifications. Based on the coefficient estimates, a 1% increase in geographic distance lowers consumption risk sharing by 0.016 (or 0.13 standard deviations) more in the absence of RTAs. The interpretation of the finding is that, if geographic distance is a proxy for barriers to risk sharing, RTAs overcome these barriers regardless of distance. This finding remains robust when I add dummies for contiguity, common language, common legal system, and time-averaged product of population in logs, GDP in logs, and GDP volatility in the regressions. These standard gravity controls do not show significant correlations with cross-country relative consumption growth.

Based on these results, we confirm our hypothesis that one important channel through which we justify the gravity model established earlier is trade in goods. Geographic distance affects risk sharing because they covary with trade costs. Trade policies help to mitigate the impact and facilitate consumption comovement.

4.4 Causality between Trade and Risk Sharing

Lastly, to further investigate the underlying mechanism for our previous results, we explore the causal influence of trade in goods on consumption risk sharing by using an instrumental variable (IV) method. To do so we collect the bilateral trade data, which are the sum of exports and imports, from the Direction of Trade Statistics (DOTS) compiled by IMF. After that we examine the implications of trade for bilateral risk sharing.

Table 5 presents regression results from the panel approach with country-pair fixed effects to analyze the determinants of relative consumption growth across two countries. According to the OLS results reported in column (1), greater geographic distance hampers risk sharing as the coefficient estimate for the interaction term of distance and relative output growth is significantly positive. This finding is consistent with our previous results in the gravity model. Meanwhile, bilateral trade facilities risk sharing between a pair of countries, as is shown by the negative coefficient for the interaction term of trade and output. Nevertheless, this result may suffer from potential endogeneity and reverse causality. For instance, consumption can determine trade flows across countries.

Therefore, we use the RTA dummy and its interaction with relative output growth as the IVs for trade and its interaction with relative output growth. We argue these are valid instruments since they are correlated with trade but are likely to be exogenous for real consumption. Therefore, the influence of RTAs on consumption risk sharing should only be driven by their implications for trade. We also verify that our IVs pass the Sargan

Table 4: Gravity Model with RTA

Dep Var: Δ Consumption	Pooled Regression			Panel Approach
	(1)	(2)	(3)	(4)
Δ Output	0.309***	0.310***	0.310***	0.308***
	(0.005)	(0.005)	(0.005)	(0.005)
RTA	-1.90e-11	-2.11e-11	-2.12e-11	-3.28e-11
	(0.002)	(0.002)	(0.002)	(0.005)
RTA $\times$ Distance	2.61e-12	2.86e-12	2.86e-12	4.33e-12
	(0.000)	(0.000)	(0.000)	(0.001)
RTA $\times$ Distance $\times$ Δ Output	-0.016***	-0.016***	-0.016***	-0.016***
	(0.001)	(0.001)	(0.001)	(0.002)
Contiguity		1.66e-12	1.67e-12	
		(0.000)	(0.000)	
Language		5.12e-14	5.28e-14	
		(0.000)	(0.000)	
Legal		1.25e-13	1.32e-13	
		(0.000)	(0.000)	
GDP			-3.90e-13	
			(0.000)	
Population			4.24e-13	
			(0.001)	
GDP volatility			9.04e-14	
			(0.000)	
Country Pair FE				Y
Country FE	Y	Y	Y	
Time FE	Y	Y	Y	Y
Observations	1,419,887	1,418,802	1,418,802	1,419,887
R-squared	0.210	0.211	0.211	0.195

The dependent variable is country i's relative per-capita consumption growth to that of country j. ΔOutput is country i's relative per-capita output growth to that of country j. Independent variables include the log of geographic distance between two countries in kms, a dummy for RTA which is 1 when country i and j both participate in a regional trade agreement at t, dummies for contiguity, common language, legal system, and time-averaged product of population in logs, GDP p.c. (per capita) in logs, and GDP p.c. volatility. The regressions include time fixed effects. In addition, pooled regressions include country fixed effects and the panel approach includes country-pair fixed effects. Clustered standard errors are reported in parentheses. ***, **, and * indicate significance at the 1% level.

test and the Stock-Yogo weak IV test.[6]

Column (2) through (4) in Table 5 report the IV results. In column (2), the magnitude of the coefficient estimate for the interaction term of trade and relative output growth increases by 10 times once IVs are added. Every 1% increase in bilateral trade lowers the response of relative consumption growth by about 0.01 (or .008 standard deviations). The coefficient is significantly negative, which confirms the causal effects of trade on risk sharing. In column (3) we find the influence of geographic distance on risk sharing diminishes. Hence, distance shapes bilateral risk-sharing patterns mostly through the trade channel — When instrumented trade is controlled for, distance plays an insignificant role. Lastly we verify the robustness of our results in column (4) where we add time-varying products of GDP per capita and population as control variables.

Establishing the causal link from trade to risk sharing sheds light on the mechanism of our previous analysis: As trade is an essential channel of cross-country risk sharing, country-pairs farther apart face greater impediments since trade costs typically rise with geographic distance. Furthermore, efforts to lift trade barriers including signing RTAs will strengthen countries' abilities to share risks and smooth consumption.

[6]Since the number of instrumented variables is equal to the number of instruments, there is no over-identification issue detected by the Sargan test. In the weak IV test, the Cragg-Donald Wald F statistic is 4407 which exceeds the critical values.

Table 5: Trade and Risk Sharing

Dep Var: Δ Consumption	(1) OLS	(2) IV	(3) IV	(4) IV
Δ Output	0.518 ***	0.727 ***	0.726 ***	0.756 ***
	(0.011)	(0.031)	(0.080)	(0.085)
Trade	9.53e-05	6.17e-05	6.17e-05	-9.51e-05
	(6.32e-05)	(3.27e-04)	(3.27e-04)	(2.70e-03)
Trade $\times$ Δ Output	-0.001 ***	-0.011 ***	-0.011 ***	-0.012 ***
	(0.000)	(0.002)	(0.004)	(0.004)
Distance $\times$ Δ Output	7.45e-03 ***		4.35e-05	-1.79e-03
	(1.17e-03)		(3.05e-03)	(3.22e-03)
GDP				3.51e-04
				(1.63e-03)
Population				-9.29e-04
				(1.80e-03)
Country Pair FE	Y	Y	Y	Y
Observations	671,247	671,247	671,247	662,173
R-squared	0.393	0.391	0.391	0.393

The dependent variable is country i's relative per-capita consumption growth to that of country j. Δ Output is country i's relative per-capita output growth to that of country j. 'Trade' stands for bilateral trade values sourced from IMF's DOTS in logs. Other variables include the product of GDP per capita and population at time t in logs. Instrumental Variables (IVs) are RTA and RTA $\times \Delta$ Output. All the regressions include country-pair fixed effects. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

5 Conclusion

This paper theoretically and empirically examines the influence of trade costs on bilateral risk sharing across countries. By exploiting cross-sectional and time-series variations in trade costs among country pairs, we obtain four major findings from a large panel of countries over the period 1970-2014. First, bilateral risk sharing improves once a pair of countries become partners under a regional trade agreement. Moreover, a gravity model of consumption risk sharing obtains as bilateral risk sharing decreases in geographical distance between countries. This effect is more pronounced in the absence of regional trade agreements. Lastly, trade causally influences consumption risk sharing based on the IV approach. The evidence supports the viewpoint that trade costs impede cross-country risk sharing.

This paper contributes to the growing literature that extends the gravity model of trade to other topics including migration, financial flows, and exchange rate determination among others. Since these cross-country economic linkages also play an essential role in international risk sharing, disentangling the influence of each channel, in the spirit of Fitzgerald (2012), can help us better understand the global consumption pattern. Counterfactual analysis based on such structural frameworks will allow us to measure the contribution of each channel to cross-country risk sharing and examine the interactions across channels.

In terms of policy implications, these papers call for the need for policies that eliminate the frictions in the channels of risk sharing. As this paper suggests, policy makers should take into consideration the impact of trade barriers on consumption comovement. Reducing tariffs and other regulatory barriers will allow the global community to yield greater welfare gains by reducing consumption volatility.

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Appendices

A Tables and Charts

Table A.1: List of Countries

Country	Number of RTAs	Number of partners	Average co-participants	Average duration
Albania	12	39	4.4	4
Algeria	4	32	19.1	12.5
Angola	2	22	17.2	14.5
Anguilla	1	47	44	46
Antigua n Barbuda	3	43	17.6	21.7
Argentina	3	8	15.6	4.3
Armenia	8	9	15.7	1.8
Aruba	1	47	44	46
Australia	10	15	13.1	2
Austria	53	109	14.2	24.2
Azerbaijan	5	6	18	1.8
Bahamas	5	85	12.6	43.2
Bahrain	4	18	9.7	6.8
Bangladesh	3	11	17	6.3
Barbados	6	86	11.4	37.7
Belarus	6	8	12.5	3
Belgium	102	160	12.8	18.4
Belize	2	44	23.7	27.5
Benin	6	58	9.5	33.8
Bermuda	1	46	44	46
Bhutan	3	8	6.9	5
Bolivia	1	4	26.6	4
Bosnia	10	36	5	4.2
Botswana	6	65	7.8	30.8
Brazil	3	9	15.6	4.3
Brunei Darussalam	8	18	8.5	8
Bulgaria	58	117	11.7	20.5
Burkina Faso	7	59	8.9	32.1

Burundi	9	65	9.5	27.6
Côte d'Ivoire	7	59	8.9	32.1
Cambodia	6	17	8.8	10
Cameroon	7	76	6.2	34
Canada	11	14	8.4	1.4
Cape Verde	1	14	19.4	14
Cayman Islands	1	47	44	46
Central African	6	58	7.2	35
Chad	6	58	7.2	35
Chile	23	59	8.3	2.6
China	15	27	7.7	2.1
Colombia	8	44	8.6	5.6
Comoros	3	36	14.2	16
Congo	8	67	9.9	30.6
Congo, D.R.	5	65	10.3	39.2
Costa Rica	14	46	9.8	5.1
Croatia	48	116	13.3	23.9
Cyprus	42	110	15.1	28.3
Czech Republic	60	114	12.2	20.9
Denmark	89	159	13.6	19.8
Djibouti	1	19	15.9	18
Dominica	5	50	15	15.2
Dominican Republic	3	48	9.4	17.3
Ecuador	2	34	14.2	17
Egypt	11	73	13.7	10.5
El Salvador	11	40	11.7	6.1
Equatorial Guinea	4	57	7.7	41.5
Estonia	56	116	12.2	21.5
Ethiopia	5	65	10.3	39.2
Fiji	5	84	6.4	40.2
Finland	60	114	13.9	21.4
France	103	162	12.8	18.7
Gabon	6	58	7.2	35
Gambia	4	57	8.7	43.8
Georgia	11	57	16.9	7.9

Germany	104	163	12.8	18.6
Ghana	5	59	14.1	35.8
Greece	64	111	13	22.6
Grenada	6	86	11.4	37.7
Guatemala	11	40	10.7	6
Guinea	9	90	15.6	25
Guinea-Bissau	4	57	8.7	43.8
Haiti	1	15	41.4	14
Honduras	12	41	9.8	5.7
Hong Kong	4	8	4.5	1.8
Hungary	56	117	12.7	22.2
Iceland	43	66	11.9	5.4
India	11	71	13.1	7.4
Indonesia	7	18	8.5	8.7
Iran	.	.	.	.
Iraq	2	17	25.5	10.5
Ireland	90	160	13.3	20.1
Israel	16	45	12.1	3.9
Italy	103	162	12.8	18.7
Jamaica	6	86	11.4	37.7
Japan	13	18	6.7	1.7
Jordan	11	55	12.8	7.1
Kazakhstan	9	10	14.5	2.3
Kenya	8	66	9.8	26.5
Kuwait	3	18	10.1	8.7
Kyrgyzstan	8	11	16.3	2.1
Lao	7	22	13.1	9.3
Latvia	55	116	12.3	21.9
Lebanon	6	49	11	11.8
Lesotho	7	69	9.6	28.9
Liberia	4	57	8.7	43.8
Lithuania	55	116	12.4	21.9
Luxembourg	103	162	12.8	18.7
Macao	1	2	11.2	1
Macedonia	12	47	8.4	3.9

Madagascar	7	84	6.6	36.3
Malawi	6	67	11	34.7
Malaysia	12	19	6.8	5.5
Maldives	2	8	6.2	7
Mali	8	61	12.2	28.6
Malta	42	110	15.1	28.2
Mauritania	6	63	10.3	35.2
Mauritius	9	89	8.4	29.1
Mexico	16	53	13.2	3.5
Moldova	15	48	7.7	3.6
Mongolia	.	.	.	.
Montserrat	3	61	30.2	23.3
Morocco	11	56	13.7	7.4
Mozambique	2	59	9.9	32.5
Myanmar	6	17	8.8	10
Namibia	3	18	10.5	8
Nepal	2	8	6.2	7
Netherlands	103	162	12.8	18.7
New Zealand	10	18	10.2	2.2
Nicaragua	10	40	11	6.3
Niger	7	59	8.9	32.1
Nigeria	4	57	8.7	43.8
Norway	44	68	12.3	5.5
Oman	58	135	12.2	20.9
Pakistan	5	11	7.3	3.4
Palestine	3	33	14.2	11
Panama	15	48	8.3	3.9
Paraguay	3	9	15.6	4.3
Peru	14	54	6.5	3.9
Philippines	7	17	8.5	8.7
Poland	55	117	12.9	22.6
Portugal	65	112	12.5	22.4
Qatar	3	18	10.1	8.7
Romania	54	115	12.4	22
Russia	16	17	17.4	1.8

Rwanda	9	66	9.5	27.6
Saint Lucia	3	44	17.6	21.7
Sao Tome	.	.	.	.
Saudi Arabia	3	18	10.1	8.7
Senegal	7	59	8.9	32.1
Seychelles	3	55	11	20.3
Sierra Leone	4	57	8.7	43.8
Singapore	21	35	8.3	4
Slovakia	58	118	12.4	21.4
Slovenia	61	120	11.7	20.5
South Africa	4	46	11.6	13
South Korea	11	53	8	4.9
Spain	63	112	12.6	22.8
Sri Lanka	5	12	15.1	4.2
St. Kitts	3	44	17.6	21.7
St. Vincent n Grenadines	3	44	17.6	21.7
Sudan	6	78	11.4	35.2
Suriname	3	52	18	22.7
Swaziland	8	72	10.4	27.5
Sweden	56	114	13.6	23
Switzerland	45	71	11.6	4.7
Syria	4	47	24.1	12.5
Taiwan	6	7	5.9	1.2
Tajikistan	4	10	12.9	3.3
Tanzania	8	66	9.6	25.8
Thailand	9	18	8.9	7
Togo	7	59	8.9	32.1
Trinidad n Tobago	6	86	11.4	37.7
Tunisia	8	51	11.2	9.4
Turkey	32	61	8.3	2.5
Turkmenistan	5	8	18.9	1.4
Turks n Caicos	1	47	44	46
U.A.E.	4	19	10.5	6.8
Uganda	8	66	9.8	26.5
Ukraine	19	54	11.9	3.1

United Kingdom	83	161	12.3	20.2
United States	15	21	9.7	1.4
Uruguay	4	10	14.3	3.5
Uzbekistan	4	7	19.4	1.5
Venezuela	1	5	26.6	4
Viet Nam	8	18	7.4	7.8
Virgin Islands	1	47	44	46
Yemen	2	18	25.5	10.5
Zambia	6	67	11	34.7
Zimbabwe	4	56	13.2	19.5

This table reports the list of countries in our sample. We consider active and inactive RTAs over the 1970-2014 period. For each country, we list the number of RTAs it has been a member of, the number of countries that have ever been its partner in any RTA, the average number of co-participants in RTAs it has been a part of, and the average duration of RTAs it has joined in (in the unit of years). Source: CEPII and WTO.

Table A.2: Bilateral Risk Sharing and RTA — Robustness

Dep Var:	Pooled Regression		Panel Approach
Δ Consumption	*A. Full Sample*	*B. RTA Sample*	*C. FE Model*
	(1)	(2)	(3)
Δ Output	0.285***	0.412***	0.284***
	(0.007)	(0.020)	(0.007)
RTA	-2.78e-17	7.51e-18	-3.81e-17
	(0.000)	(0.001)	(0.001)
RTA × Δ output	-0.100***	-0.258***	-0.101***
	(0.012)	(0.017)	(0.012)
WTO	-8.55e-17	-1.49e-17	1.47e-17
	(0.000)	(0.001)	(0.000)
WTO × Δ output	0.118***	0.056***	0.120***
	(0.004)	(0.012)	(0.004)
BHL	-2.38e-17	-9.66e-18	4.74e-17
	(0.000)	(0.001)	(0.000)
BHL × Δ output	-0.138***	-0.026*	-0.140***
	(0.005)	(0.014)	(0.005)
Country-pair FE			Y
Country FE	Y	Y	
Year FE	Y	Y	Y
Observations	1,419,887	217,616	1,419,887
R-squared	0.234	0.257	0.236

The dependent variable is country i's relative consumption growth to that of country j. Δ Output is country i's relative output growth to that of country j. RTA is a dummy variable which is 1 when country i and j both participate in a regional trade agreement at t. WTO and BHL denote the number of the GATT/WTO members and financially-liberalized economies based on Bekaert et al. (2004) in the country-pair. The regressions include time fixed effects. Clustered standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

Table A.3: Gravity Model - Robustness Check with Alternative Distance

Dep Var: β_{ij}	(1)	(2)	(3)	(4)
Distance	0.012***	0.009***	0.015***	0.008***
	(0.002)	(0.002)	(0.003)	(0.002)
GDP		-0.050***		-0.051***
		(0.001)		(0.001)
Population		0.035***		0.034***
		(0.001)		(0.001)
Language			-0.063***	-0.016***
			(0.005)	(0.005)
Legal			0.008*	-0.033***
			(0.004)	(0.004)
Contiguity			0.114	0.487***
			(0.106)	(0.115)
Contg $\times$ Dist			0.005	-0.067***
			(0.016)	(0.017)
Constant	0.475***	0.320***	0.451***	0.371***
	(0.021)	(0.031)	(0.022)	(0.033)
Observations	31,684	31,684	31,659	31,659
R-squared	0.001	0.224	0.008	0.227

The dependent variable is the estimated coefficient β from the first stage regression. Higher β suggests weaker consumption risk sharing. Independent variables include the log of geographic distance between two countries in kms, dummies for common language, legal system, contiguity, and time-averaged product of population in logs, and GDP per capita in logs. Standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level.

Table A.4: Gravity Model - Robustness Check with Alternative β_{ij}

Dep Var: β_{ij}	(1)	(2)	(3)	(4)
Distance	0.014***	0.019***	0.012***	0.011***
	(0.002)	(0.002)	(0.002)	(0.002)
Contiguity		0.145***		0.039***
		(0.012)		(0.012)
Language		-0.059***		-0.014***
		(0.005)		(0.005)
Legal		0.020***		-0.021***
		(0.004)		(0.004)
GDP			-0.051***	-0.052***
			(0.001)	(0.001)
Population			0.033***	0.033***
			(0.001)	(0.001)
Constant	0.453***	0.415***	0.369***	0.411***
	(0.020)	(0.022)	(0.031)	(0.033)
Observations	31,684	31,659	31,684	31,659
R-squared	0.001	0.008	0.225	0.226

The dependent variable is the estimated coefficient β from the first stage regression. Independent variables include the log of geographic distance between two countries in kms, dummies for colony, common language, legal system, and time-averaged product of population in logs, GDP per capita in logs, and GDP p.c. volatility. Standard errors reported in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level.