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ESSAYS IN INTERNATIONAL ECONOMICS

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in

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by

Dongwan Choo

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Abstract

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This dissertation studies topics of international economics, such as the long-run relationship between international capital flows and economic growth, the gravity of consumption risk sharing between countries, and the spacial consumption risk sharing across 50 states in the United States. Each chapter of the dissertation approaches one of these three topics.

The first chapter examines the long-run patterns of net private and public capital inflows empirically and theoretically. Using data for 83 developing countries over the sample period 1980–2019, the empirical results show a robust positive correlation between net private capital inflows and GDP per capita growth and a robust negative correlation between net public capital inflows and economic growth. Further, this paper finds that the patterns of private and public capital flows remain when human capital is controlled in the regression model. Based on these findings, I provide a theoretical framework that explains the long-run joint behavior of private and public capital flows in a small open economy. In the balanced growth model, the benevolent government spends money on human capital investment, which is the key source of growth. The government increases its expenditure to sustain a higher balanced growth rate, which leads to an increase in public savings in the international reserve accumulation.

The second chapter studies how frictions in bilateral economic linkages shape the consumption pattern across economies. Using state-level data from the US, we find that the degree of bilateral consumption risk sharing across states decreases in geographic distance. To explain this novel fact, we develop a DSGE model that incorporates trade, migration, and finance as channels of risk sharing which are subject to frictions that covary with distance. Calibrated to the US data, the model not only enables us to quantify the magnitude of the frictions in each channel, but also allows us to examine the interplay among the channels and disentangle their effects on the level, volatility, and comovement of consumption across states. Counterfactual analyses based on the model provide guidance for the design of macroeconomic policies that aim to reduce cross-region consumption disparity.

The third chapter 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.

To my wife, my son, my father, my brother.

And mostly, to my dearest mother.

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Finally, this dissertation is dedicated to my mother in heaven, Youngsook Na.

Chapter 1

Growth and International Capital Flows: Private versus Public

1.1 Introduction

The standard neoclassical growth model predicts that capital should be directed toward countries that experience faster productivity growth among developing countries. However, the data tells a different story. Prasad et al. (2007) and Gourinchas and Jeanne (2013) find that faster-growing emerging economies are associated with lower net capital inflows. Gourinchas and Jeanne (2013) calls this the allocation puzzle because capital does not flow more to countries that invest and grow more, which contradicts the prediction of the standard economic theory.

Figure 1.1 plots the average total factor productivity (TFP) growth rate against the average net total capital inflows over the period 1980–2019. Net total capital inflows

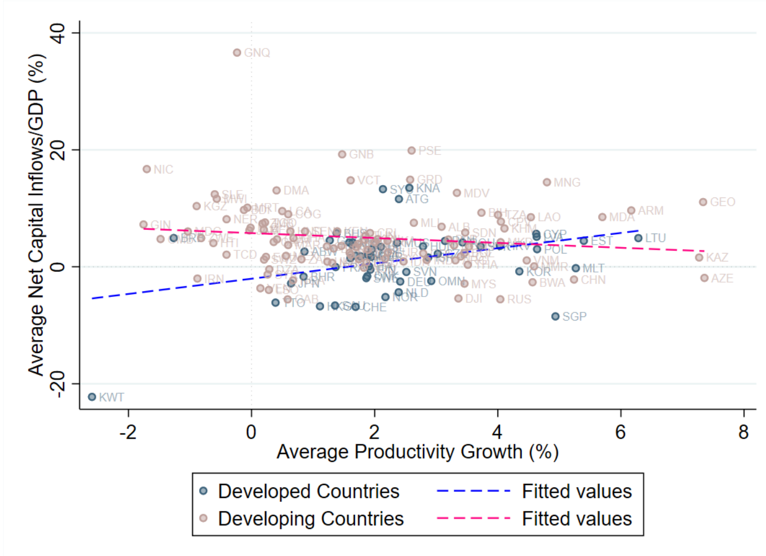


Figure 1.1: Average productivity growth and average net capital inflows

are measured as the ratio of a country's current account deficit over its GDP, averaged over the sample period. The blue circles represent developed countries, and the red circles are for developing countries. There is a difference in the relationship between growth and net total capital inflows across the two country groups. The blue dashed line represents the positive correlation between the TFP growth rate and net total capital inflows in developed countries. The faster-growing developed countries experience more significant capital inflows. On the other hand, the red dashed line illustrates the allocation puzzle. Net total capital inflows are negatively correlated with productivity growth in emerging countries. Alfaro et al. (2014) and Kim and Zhang (2022) show that public capital flows account for this negative correlation between net total international capital inflows and growth in developing countries. In contrast, private flows conform with the predictions of the neoclassical growth model.

The main objective of this paper is to build a model that explains the long-run behavior of private and public capital flows shown in the data. First, I examine the long-run patterns of two types of net international capital inflows, private and public, in emerging economies. Private and public capital flows show different signs in the long-run correlations with economic growth. And these results suggest that both private and public capital flows should be considered when constructing a model under an open economy setup. To explore the long-run relationship between public capital flows and economic growth, introducing a government into the model is necessary. In this paper, I assume that a benevolent government plays a crucial role in accumulating human capital by spending money on human capital accumulation. To justify the addition of human capital accumulation into the model, I check that the patterns of both capital flows hold out when the human capital index is controlled in the regression.

I first empirically examine the long-run patterns of net private and public capital flows. It starts with carefully constructing measures of the two types of flows for developing countries. Net private capital inflows consist of net inflows of foreign direct investment (FDI), portfolio equity investment, and private debt. Private debt includes both the private sector's borrowing on net and also debt investment by foreign private investors. Net public capital inflows include any government-guaranteed debt net of the change in foreign reserves.

The empirical result shows that net private capital inflows are positively correlated with the GDP per capita growth rate in the long run, using data for 83 developing countries over 1980 - 2019. This result is consistent with the prediction of the neoclassic growth model. Meanwhile, net public capital inflows are negatively correlated with the GDP per capita growth rate in the long run. These results are robust when control variables are added, including human capital. Moreover, human capital is statistically significant in both capital flows. It is positively correlated with net private capital inflows and negatively correlated with net public capital inflows.

To explain the long-run patterns of private and public capital flows, I present a balanced growth model of a small open economy. Human capital investment is the key source of growth in this model. Human capital investment depends on publicly provided inputs. The government taxes consumption and has access to the international financial market. Unlike the previous literature, the model doesn't involve friction in the foreign financial market.

Investors from the rest of the world purchase the bonds of the firms. And foreign investors increase their purchase of private bonds in countries with a faster growth rate. Therefore, net private capital inflows are positively correlated with economic growth in the long run. On the other hand, public capital flows show a different pattern from private capital flows. The government needs funds to finance the government expenditure on human capital, and the tax revenue is not enough to cover the expense. Therefore, the government saves money in the international financial market by taking advantage of the high interest rate in the world market. The amount of government expenditure depends on the balanced growth rate. Sustaining the high growth rate is associated with enormous government spending, which requires the government to save more money. As a result, this implies a negative correlation between public capital flows and economic growth in the long run. The fact that government saves money in the international financial market aligns with Gourinchas and Jeanne (2013) and Alfaro et al. (2014), which find that the current account surpluses observed in fast growing developing economies are driven by their policy of reserve accumulation.

One other prediction of the model is that net public capital inflows decrease when government spending increases. I empirically examine the relationship between net public capital inflows and government spending. Government spending is measured using data on government expenditure on education and health from the World Bank. The data confirms the prediction of the model showing a negative correlation between government spending and net public capital inflows.

The rest of this paper is structured as follows. I start by discussing the related literature. Section 1.3 presents the empirical findings on the long-run relationship between private and public capital inflows and economic growth. Then, I introduce the framework in section 1.4 and conduct a quantitative analysis in section 1.5. Section 1.6 concludes.

1.2 Literature Review

This paper is related to the literature on the relationship between growth and international capital inflows in developing countries. Prasad, Rajan, and Subramanian (2007) show that the correlation between per capita GDP growth and the average current account to GDP ratio is positive and significant among nonindustrial countries.

Gourinchas and Jeanne (2013) find that the negative correlation between long-run productivity growth and net capital flows and identify that the pattern of capital flows is driven by national savings. They further decompose net capital flows into net private capital inflows and net public capital inflows, and point out that the negative correlation between productivity catch-up and net capital flows is present for public capital flows. Alfaro et al. (2014) have carefully constructed measures of net private and public capital flows for a broad cross-section of developing countries, considering both the creditor and debtor side of the international debt transactions. They demonstrate that sovereign-to-sovereign transactions, the case when the borrowing by the government is from another government, account for upstream capital inflows and global imbalances. This paper examines long-run patterns of net private and public capital inflows using data for 83 developing countries over the sample period of 1980–2019.

This article belongs to the strands of literature providing a theoretical framework that reproduce the negative correlation between growth and capital inflows characterizing developing countries. Early theoretical work has focused on total, public, or private flows alone. Angeletos and Panousi (2011), Benhima (2013), Sandri (2014), and Buera and Shin (2017) introduce uninsurable investment or entrepreneur risk to focus on private capital outflows. Aguiar and Amador (2011) develop a tractable growth model that highlights the interaction of political economy frictions, political frictions and contracting friction, and public capital flows in a small open economy. In their model, small open economies have a dramatic difference in growth outcomes, and the ones that grow fast do so while increasing their net foreign asset position.

Benigno, Fornaro, and Wolf (2022) and Kim and Zhang (2022) provide a framework that explains the joint behavior of private and public capital flows in fast-growing emerging economies. In Benigno, Fornaro, and Wolf (2022), the government uses foreign exchange reserves to internalize the growth externalities present in the tradable sector and to provide liquidity to private agents during periods of financial stress. And it creates a positive link between reserve accumulation and growth. Kim and Zhang (2022) introduce a benevolent government that saves in reserve assets and finances its budget and spending with consumption taxes. This government saves when growth is strong, resulting in smaller aggregate debt, making the economy less vulnerable to future adverse shocks than the case without public saving. This article presents a balanced growth model of a small open economy. The government plays a role in human capital accumulation by spending on education. Unlike the previous literature, the government can participate in the international financial market without friction. In the balanced growth path, the government in a faster-growing country spends more money on human capital investment. Therefore, the government saves more money to finance government expenditures by taking advantage of the interest payment.

While this paper studies the behavior of public capital inflows, which have hardly been addressed in the literature on human capital, it shares many features with previous work in education economics. A number of papers have formalized the link between government education spending and growth by building endogenous growth models where public education expenditures directly influence the human capital accumulation and consequently affect long-run growth. Examples include Glomm and

Ravikumar (1997, 1998) and Blankenau and Simpson (2004). Blankenau, Simpson, and Tomljanovich (2007) find a positive relationship between public education expenditures and long-term growth for developed countries after controlling for the government budget constraint. Barro (2013) study the effect of education on economic growth in 100 countries. The author used two different measures of education: the quantity of education measured by years of attainment at various levels, and the quality gauged by scores on internationally comparable examinations. Both measures of education have a positive relation with economic growth. Dissou, Didic, and Yakautsava (2016) assess the growth implications of alternative methods of financing public spending on education in a small open economy. Their simulation results suggest that all forms of funding public expenditures on education considered in the paper positively impact the long-run economic growth rate with different transitional impacts. This paper first empirically documents that human capital is positively correlated with net private capital inflows and negatively correlated with net public capital inflows. Then, I study the impact of human capital on growth under a small open economy setup, where the firms and government can lend or borrow in the international capital market. The model shows a negative relationship between net public capital inflows and government spending on human capital in the long run.

1.3 Empirical Analysis

The neoclassical growth model predicts that countries with faster productivity growth should invest more and attract more foreign capital.[1] This section studies the relationship between net capital inflows and economic growth, using 83 developing countries over 1980–2019. Economic growth is measured as the average annual GDP per capita growth rate. I decompose the net total capital inflows into net private and public capital inflows, following Alfaro et al. (2014), and examine how each type of capital inflow comoves with GDP per capita growth in developing countries. Later, I add human capital into the regression model, and show that human capital is a statistically significant variable while the pattern of the net private and public capital inflows to the GDP growth survives.

1.3.1 Regression Model: Allocation Puzzle

Following Gourinchas and Jeanne (2013), I regress net capital inflows on economic growth:

$$\left(\overline{\frac{\Delta D_i}{Y_i}}\right) = \alpha + \beta \bar{g}_i + \Gamma controls_i + u_i.$$

The dependent variable $\overline{\Delta D_i / Y_i}$ is the average of the annual net capital inflows normalized by the annual nominal GDP in country i.[2] $\bar{g}$ denotes the average real GDP

[1] Gourinchas and Jeanne (2013) identify an allocation puzzle where fast-growing developing countries experience capital outflows instead of inflows.

[2] Gourinchas and Jeanne (2013) measure capital inflows as the change in external debt normalized by initial GDP. And they show that the predictions of the model are qualitatively the same for the

per capita growth rate. The control variables include the average of the human capital index, $\bar{h}$, the initial capital stock normalized by the initial GDP, K_0/Y_0, the initial debt normalized by the initial GDP, D_0/Y_0, the average growth rate of the population over the sample period, $\bar{n}$, and the average of the financial openness, $\overline{open}$.

The standard neoclassical growth model expects β to be positive, which implies that net capital inflows are increasing in the productivity growth, according to Gourinchas and Jeanne (2013). Further details of the data and the measures are described below.

1.3.2 Data

1.3.2.1 Net Private Capital Inflows and Net Public Capital Inflows

A country's Balance of Payments (BOP) is the set of accounts that measures all the economic transactions between the country and the rest of thes world. Theoretically, the main accounts are the current and the financial accounts, with the sum of the balances on the two accounts equal to zero. The current account balance is the sum of the country's exports minus imports in goods and services, net factor income, and transfer payments. The financial account shows the net acquisition and disposal of financial assets and liabilities. A country with a financial account deficit (or current account surplus) is a net lender, sending its surplus to the rest of the world, thereby increasing its net holdings of foreign assets or reducing its net liabilities. On the other hand, a country with a financial account surplus (or current account deficit) is a net

measures of capital flows I use in this empirical study.

borrower from the rest of the world, attracting surplus savings from overseas, thereby increasing net liabilities or reducing net assets abroad. The *International Financial Statistics* (IFS) data by the International Monetary Fund (IMF) is the standard data source for the balance of payments.

Net total capital flows are further decomposed into net public capital inflows and net private capital inflows. I assume that net private capital inflows, ΔD^{priv}, do not offset net public capital inflows, ΔD^{pub}. With this assumption, net capital inflows are disintegrated as follows:

$$\Delta D = \Delta D^{priv} + \Delta D^{pub}.$$

Public capital flows are defined as the capital flows from transactions by officials. Officials include international financial institutions, bilateral government flows, all forms of government (including federal or central, state, and municipal), public enterprises, central banks, sovereign wealth funds, and related intermediaries and publicly guaranteed activities. Private capital flows include both transactions by private.

Following Lane and Milesi-Ferretti (2001) and Alfaro et al. (2014), I use the flows recorded in the financial account of the BOP and decompose the total capital flows into public and private flows as follows:

$$\begin{aligned}
\text{Net Total Capital Flows} &= \text{Net Private Capital Flows} + \text{Net Public Capital Flows} + \text{Errors} \\
&= (\Delta FDIL - \Delta FDIA + \Delta EQL - \Delta EQA + \Delta PVDL - \Delta PVDA) \\
&\quad + (\Delta PBDL - \Delta PBDA + IMF - \Delta RES) + (EF - EO).
\end{aligned}$$

$\Delta FDIA$ and $\Delta FDIL$ denote, respectively, flows of foreign direct investment on equity assets and liabilities. ΔEQA and ΔEQL are portfolio equity assets and liabilities flows. $\Delta PVDA$ and $\Delta PVDL$ denote private debt flows (portfolio debt, loans, and other instruments, including financial derivatives, currency and deposits, financial leases, and trade credits). $\Delta PBDA$ and $\Delta PBDL$ are flows of public debt assets and liabilities, IMF is the IMF credit, ΔRES denotes changes in reserve assets controlled by the country authorities. EO is net errors and omissions and EF is exceptional financing.

Net private capital inflows include net inflows of foreign direct investment (FDI) on equity, portfolio equity investment, and private debt. The measure of net FDI and portfolio equity inflows is the annual flows of direct investment and portfolio equity liabilities minus the annual flows of direct investment and portfolio equity assets in current U.S. dollars from the IFS database. The IFS data does not provide information on whether a debt is held by private and public agents. The data on private debt flows are available in the external debt data from the *International Debt Statistics* (IDS) database issued by the World Bank.

The IDS database provides detailed external debt data based on official and private borrowers. However, the data is only available for countries classified as developing by the World Bank. Total external debt is decomposed into short-term external debt, long-term external debt, and the use of IMF credits. The long-term debt consists of private nonguaranteed (PNG) debt and public and publicly guaranteed (PPG) debt. PPG debt can be further divided into PPG debt from official creditors (multilateral and bilateral lenders) and PPG debt from private creditors (commercial banks, bonds, and others). Short-term debt[3] and PNG debt are considered private debt. The net private debt inflows measure the annual changes in total debt stocks held by private borrowers.

The measure of net public capital inflows includes net PPG debt flows and the IMF credit, net of international reserves. The reserve accumulation data is available from the IFS database. One concern for developing countries is whether aid flows drive the pattern of public inflows. To address this concern, I subtract net aid flows from net public capital inflows using the *official development assistance* (ODA) data from the OECD Development Assistance Committee database (DAC). The net public capital inflows used in the main empirical analysis exclude aid flows. I ran robustness checks using the net public capital with aid flows included, and the results are broadly similar to the main results. Both net private and public capital flows are normalized by annual GDP in current U.S. dollars and averaged out over the sample period.

1.3.2.2 Explanatory Variables

The main focus of the empirical analysis is to study the long run relationship between net capital inflows and economic growth. Economic growth is measured as the average of the annual GDP per capita growth rate. The control variables include human capital, the initial capital abundance, the initial net external debt, population growth, and financial openness. Human capital ($\bar{h}$) is the average of the annual human

[3] Unfortunately, the source does not permit the distinction between public and private short-term debt. I assign the short-term debt to private flows as it shows the most conservative result among different assumptions, following Alfaro et al. (2014).

capital index from the PWT. Initial capital abundance (K_0/Y_0) is the level of the total capital stock of the first sample period normalized by the nominal GDP in the first sample period. Initial net external debt ratio (D_0/Y_0) is the negative of net foreign asset position (NFA) of the first sample period over initial GDP from Lane and Milesi-Ferretti (2007)'s *External Wealth of Nations Mark* database. Population growth ($\bar{n}$) is the average annual population growth rate over the sample period from World Bank. Financial openness ($\bar{o}$) is estimated by using the average of Chinn-Ito financial openness index over the sample period.

1.3.2.3 Sample

The sample period is from 1980 to 2019. This choice of the period is motivated by two considerations. First, countries started to open financially in the 1980s sharply, according to the Chinn and Ito (2008) index. For example, the Chinn-Ito index indicates an average increase in financial openness from -0.63 in 1980 to -0.15 in 2000 for the sample countries. Second, the sample period has to be as long as possible, since this paper focuses on the long-run patterns of net private and public capital inflows. Results over shorter periods may be disproportionately affected by a financial crisis in some countries or fluctuations in the world business cycle. The sample countries have at least ten years of capital flows and GDP growth data over the sample period.

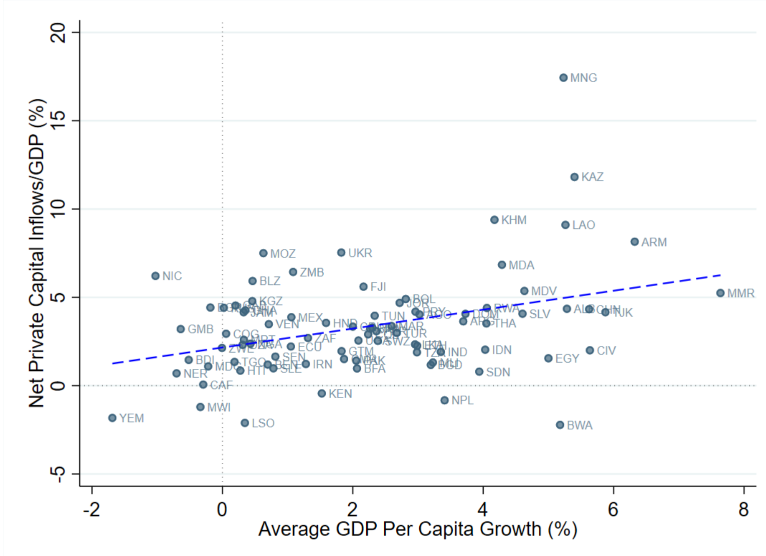
This paper examines data for 83 developing countries, which are currently classified either as a low-income country, a lower middle-income country, or an upper middle-income country. IDS database covers data only for the countries which are

Table 1.1: Capital flows and economic growth across income groups and regions

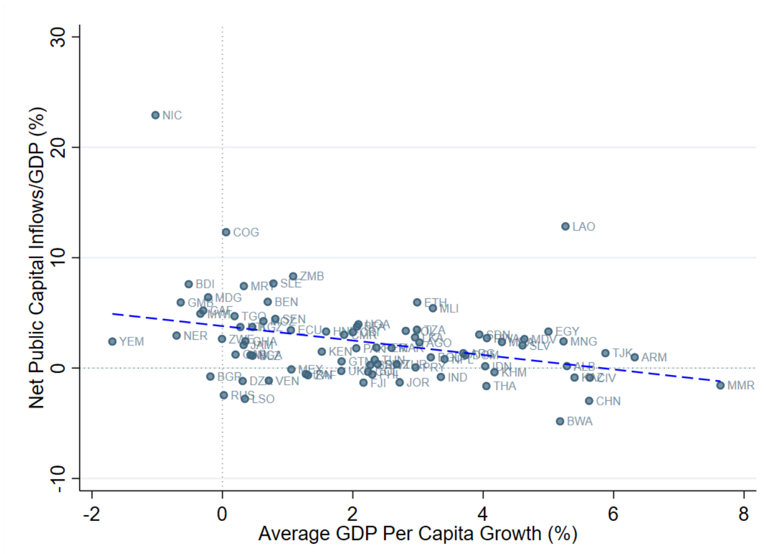
	Net Private capital flows/ GDP	Net public capital flows/ GDP	$\bar{g}$	Years of schooling	Obs.
Total	3.40	2.36	2.20	5.58	83
Income Group					
Upper Middle	3.93	0.06	2.60	7.18	29
Lower Middle	3.68	3.12	2.39	5.25	36
Low Income	1.70	4.56	1.21	3.23	18
Region					
Africa	2.02	3.18	1.45	4.21	40
Asia	4.75	1.01	4.00	5.47	15
Europe & Central Asia	5.95	0.46	3.20	9.56	10
Latin America & Caribbean	3.65	2.72	1.83	6.37	18

considered developing by the World Bank at the moment of release. If a country is reclassified as a "high-income country", then the country is no longer included in the database. Therefore, the IDS data is not available for countries such as Hong Kong, Israel, Korea, Singapore, Taiwan Province of China, and Uruguay.

Table 1.1 presents the average of net private and public capital inflows normalized by annual GDP, the annual GDP per capita growth rate, and years of schooling for the whole sample, as well as income and regional group. The average economic growth rate ($\bar{g}$) indicates that the upper-middle income group (2.6%) grew faster than the lower income group (1.21%) on average. Thus the neoclassic growth model expects a lot of



(a) Net private capital inflows



(b) Net public capital inflows

Figure 1.2: Average GDP per capita growth and net capital inflows over 1980 – 2019

capital to flow to the countries in the upper-middle income group.

There is more support for the standard model when looking at private capital flows. Private capital flows more toward the upper middle income countries (3.93% of the GDP) than the low income countries (1.7% of the GDP). Net private capital inflows are positively correlated with economic growth, while the behavior of public flows is at odds with that of private flows. Net public capital inflows are much more significant in low income countries (4.56% of the GDP) than in upper middle income countries (0.06% of the GDP). These patterns are also shown across regions. Asia and Europe grew faster than Latin America and Africa. Private capital flew more toward Asia and Europe, while public capital flew more toward Latin America and Africa.

Figures 1.2a and 1.2b show the different behavior between private capital flows and public capital flows. Figure 1.2a depicts the positive correlation between the average annual GDP per capita growth rate and the average of net private capital inflows relative to output. And figure 1.2b presents the negative correlation between net public capital inflows and economic growth.

Table 1.7 in Appendix A shows the summary of the data for the sample countries. It reports the sample period, the average of net private capital inflows, the average of net public capital inflows, the average growth rate of GDP per capita, the average population growth rate, the average financial openness, and the average years of schooling for each country.

1.3.3 Results

Table 1.2 presents the regression results. The results of private capital flows are reported in the first three columns. Column (1) shows the bivariate OLS regression of net private capital inflows on GDP per capita growth, and there is a significant positive correlation between private capital flows and economic growth. The results when including the predictors identified by Gourinchas and Jeanne (2013) are reports in column (2). Observed private capital inflows are still significantly positively correlated with economic growth. Column (3) reports the results of the same regression when the human capital index is added as a regressor. The coefficient on the GDP per capita growth rate remains significantly positive.

This is consistent with the prediction of the neoclassical growth model, where countries that enjoy higher productivity growth receive more net capital inflows. These results are also documented by Gourinchas and Jeanne (2013) and Alfaro et al. (2014), who report a statistically significant positive relationship between net private capital inflows and productivity growth. Besides, column (2) indicates that net private capital inflows increase when the degree of financial openness is higher but decreases when the population growth rate is larger.

The last three columns focus on the net public capital inflows. The relationship between public flows and output growth is at odds with that of private flows and the coefficient is always larger in magnitude. The coefficient of GDP per capita growth in column (4) is statistically significantly negative, and it is consistent with the results of

Table 1.2: Net capital flows and GDP per capita growth

	(1)	(2)	(3)	(4)	(5)	(6)
Dependent variable	Net private capital inflows/GDP			Net public capital inflows/GDP		
GDP per capita growth ($\bar{g}_y$)	0.536***	0.387*	0.356*	-0.655**	-0.560*	-0.540*
	(0.193)	(0.197)	(0.189)	(0.260)	(0.300)	(0.298)
Human capital ($\bar{h}$)			2.122***			-1.382*
			(0.732)			(0.763)
Initial capital (K_0/Y_0)		0.002	0.000		-0.002	-0.001
		(0.001)	(0.001)		(0.001)	(0.001)
Initial debt (D_0/Y_0)		1.036	0.916		2.294**	2.372**
		(0.850)	(0.836)		(0.887)	(0.939)
Population growth ($\bar{n}$)		-0.719***	0.013		0.861**	0.384
		(0.260)	(0.406)		(0.386)	(0.545)
Financial openness ($\bar{o}$)		0.742*	0.266		0.329	0.525
		(0.377)	(0.353)		(0.449)	(0.485)
Constant	2.158***	3.358***	-1.906	3.806***	1.848	5.276*
	(0.394)	(0.880)	(2.394)	(0.815)	(1.568)	(2.983)
Observations	83	83	83	83	83	83
R-squared	0.133	0.261	0.328	0.116	0.231	0.248

Note: Robust standard errors in parentheses. *, **, and *** significant at 10, 5, and 1% respectively.

Aguiar and Amador (2011), Gourinchas and Jeanne (2013), and Alfaro et al. (2014). This result is robust to controlling for other determinants. In addition, public inflows increase with initial debt and population growth, as shown in column (5).

Column (3) and (6) shows the results when human capital is added to the regression. One interesting fact is that the human capital index is a statistically significant variable for both measures of capital flows, while the correlations of private and public capital flows with economic growth remain the same. Moreover, human capital also shows different behavior between private and public capital flows. The countries with higher human capital experience more private capital inflows but fewer public capital inflows.

1.3.4 Robustness Check

In this subsection, I conduct various robustness checks using the regression analysis. I controlled for years of school as an alternative measure of the human capital index. I also examine the pattern of net public capital inflows when aid flows are added. The main regression results shown above are based on the assumption that private and public capital flows are not offset by other types of capital flows. I relax this assumption and run a regression of economic growth on the two types of capital flows.

1.3.4.1 Years of Schooling

I use the PWT as the main data source for the human capital index because it provides comparable data of human capital across countries.[4] It is difficult to precisely and quantitatively measure human capital since it is multifaceted and includes a complex set of human attributes. Many have used educational attainment as a proxy. The most widely used of these measures is the number of years that citizens spend in school (Lee and Lee (2016)). Therefore, I use the *education attainment* (BL) data from Barro and Lee (2013) to check the robustness of the regression results.

[4] The human capital index in the Penn World Table is based on the average years of schooling from Barro and Lee (BL, 2013) with an assumed rate of return to education, based on Mincer equation estimates around the world (Psacharopoulos, 1994), following a common approach in the literature (e.g., Caselli, 2005).

Table 1.3: Years of schooling

Dependent variable	(1) Net private capital inflows/GDP	(2) Net public capital inflows/GDP
GDP per capita growth ($\bar{g}_y$)	0.360*	-0.557*
	(0.200)	(0.309)
Years of schooling	0.404**	-0.394**
	(0.161)	(0.171)
Initial capital (K_0/Y_0)	0.000	-0.001
	(0.001)	(0.001)
Initial debt (D_0/Y_0)	0.911	2.548***
	(0.916)	(0.947)
Population growth ($\bar{n}$)	-0.143	0.382
	(0.392)	(0.536)
Financial openness ($\bar{o}$)	0.377	0.588
	(0.373)	(0.490)
Constant	0.407	4.554*
	(1.789)	(2.477)
Observations	77	77
R-squared	0.289	0.270

In table 1.3, I report the results using the BL data. There are less sample countries due to the data availability on years of schooling. However, the results are similar to those in table 1.2. Private capital flows are postively correlated with both GDP per capita growth and years of schooling. On the contrary, public capital flows are negatively correlated with economic growth and education attainment.

1.3.4.2 Aid Flows

One concern for developing countries is whether aid flows drive the pattern of public inflows. The main results shown above subtracted aid flows from public capital

Table 1.4: Net public capital inflows including aid flows

	(1)	(2)	(3)
Dependent variable	Net public capital inflows/GDP		
GDP per capita growth ($\bar{g}_y$)	-1.287***	-0.959**	-0.893*
	(0.450)	(0.466)	(0.464)
Human capital ($\bar{h}$)			-4.587***
			(1.694)
Initial capital (K_0/Y_0)		-0.002	0.001
		(0.003)	(0.004)
Initial debt (D_0/Y_0)		4.056**	4.315**
		(1.735)	(1.782)
Population growth ($\bar{n}$)		2.737***	1.155
		(0.642)	(0.875)
Financial openness ($\bar{o}$)		0.576	1.225
		(0.902)	(0.968)
Constant	10.581***	3.926	15.302***
	(1.510)	(2.380)	(5.342)
Observations	83	83	83
R-squared	0.108	0.267	0.311

Note: Robust standard errors in parentheses. *, **, and *** significant at 10, 5, and 1% respectively.

flows. In this exercise, I include net aid flows in net public capital inflows. Aid flows consist of total grants and concessional development loans for the objective of economic development and welfare, and the data is available from the OECD Development Assistance Committee database (DAC). The results are reported in table 1.4. The public capital flows with aid flows are negatively correlated with growth, and the degree of correlation is stronger than it of public capital without aid flows shown in table 1.2. The negative relationship is still significant when human capital is added to the regression.

Table 1.5: Net capital flows and GDP per capita growth rate: robustness check

Dependent variable: $\bar{g}$	(1) Public capital without ODA	(2) Public capital with ODA
Net private capital flows	0.261***	0.242***
	(0.062)	(0.061)
Net public capital flows	-0.188***	-0.082***
	(0.049)	(0.024)
Constant	1.777***	2.028***
	(0.324)	(0.382)
Observations	83	83
R-squared	0.124	0.106

Note: Robust standard errors in parentheses. *, **, and *** significant at 10, 5, and 1% respectively.

1.3.4.3 Relaxing the Assumption of the Decomposition of Total Capital Flows

The results shown in table 1.2 are based on an assumption where net private capital inflows do not offset net public capital inflows. However, this is an extreme assumption since a change in public flows could be offset by a countervailing change in private flows (Gourinchas and Jeanne (2013)). In this subsection, I regress the output growth rate on net private capital inflows and net public capital inflows, allowing the fact that the private flows could offset public flows.

Column (1) in table 1.5 presents the results when aid flows are excluded from public capital flows, and column(2) reports the results when aid flows are added. The patterns shown in the main results survive. But, the coefficient of public capital flows is smaller than that of private capital flows in magnitude. Also, the magnitudes of coefficients of both types of capital flows are smaller than those when running the regression separately, reported 1.2 and 1.4. One thing to point out is that the magnitude of the coefficient of public capital flows is smaller when aid flows are included.

To sum up, net private capital inflows are positively correlated with growth, which is consistent with the prediction of the basic neoclassical model. Net public capital inflows are negatively correlated with economic growth, which implies that public flows account for the allocation puzzle. These empirical findings provide guidelines for developing theories of international capital flows.

1.4 Model

I consider a small open economy. The economy consists of a large number of households and firms, and a benevolent government. Firms are owned by households and produce tradable consumption goods. The benevolent government collects consumption taxes and spends on education. The firms and the government can borrow or save abroad in terms of one-period non-contingent bonds denominated in units of tradable goods. Time is discrete, and there is no uncertainty.

1.4.1 Households

The representative household derives utility from consumption and supplies one unit of labor inelastically each period. The household's lifetime expected utility is given by

$$\sum_{t=0}^{\infty} \beta^t U(C_t). \tag{1.1}$$

$\beta < 1$ denotes the subjective discount factor, and C_t indicates consumption.

Each period the household faces the following budget constraint

$$(1 + \tau_c)C_t = w_t + \Pi_t, \tag{1.2}$$

where τ_c denote the consumption tax rates. The left-hand side represents the household's expenditure. On the right-hand side, the household receives labor income w_t and dividends Π_t from the firms it owns. For simplicity, I assume that domestic household do not trade directly with foreign investors. However, household can indirectly access international financial markets through their firms' ownership.

The representative household chooses consumption C_t to maximize its utility (1.1) subject to the budget constraint (1.2). The household's first order condition is given by

$$U'(C_t) = (1 + \tau_c)\lambda_t, \tag{1.3}$$

where $U'(C_t)$ is the marginal utility of consumption and λ_t denotes the Lagrangian multiplier on the budget constraint, or the household's marginal utility of wealth.

1.4.2 Firms

The representative firm produces a single homogeneous good using capital and labor, according to a Cobb-Douglas production function

$$Y_t = K_t^{\alpha}(H_t L_t)^{1-\alpha}, \tag{1.4}$$

where Y_t denotes the amount of final goods produced, K_t is the stock of domestic physical capital, H_t indicates the stock of human capital, L_t is the labor supply. α is the labor share in gross output. Human capital is non-rival and can be used by firms within the country.

The firm distributes dividends to the households at the end of each period

$$\Pi_t = Y_t - w_t L_t - I_t + D_{t+1} - (1+r)D_t. \tag{1.5}$$

I_t denotes investment, where $I_t = K_{t+1} - (1-\delta)K_t$. Firms can trade in a non-contingent risk-free bond denominated in units of tradable goods that pays a fixed world interest rate r. D_t is the firm's external debt holding at the start of time t. When $D_t < 0$, the firm holds foreign bonds.

Firms working in the production of the final good chooses K_t, L_t, D_{t+1} to maximizes its present value of dividends discounted by the households' marginal utility of wealth

$$\sum_{t=0}^{\infty} \beta^t \lambda_t \Pi_t. \tag{1.6}$$

The firm's first order conditions are given by

$$\lambda_t = \beta\lambda_{t+1}\left(\alpha K_{t+1}^{\alpha-1} H_{t+1}^{1-\alpha} L_{t+1}^{1-\alpha} + 1 - \delta\right), \tag{1.7}$$

$$(1-\alpha) K_t^{\alpha} H_t^{1-\alpha} L_t^{-\alpha} = w_t, \tag{1.8}$$

$$\lambda_t = \beta\lambda_{t+1}\left(1 + r\right). \tag{1.9}$$

Equation (1.8) represents the optimal demand for labor, which implies equality between the marginal product of labor and the wage. Equation (1.9) is the intertemporal Euler that equates the marginal benefit of one additional unit of borrowing today to the marginal cost next period. By combining equation (1.7) and (1.9), we derive the optimal demand for capital

$$\alpha K_t^{\alpha-1} H_t^{1-\alpha} L_t^{1-\alpha} = r + \delta, \tag{1.10}$$

which implies equality between the marginal product of capital and the cost.

1.4.3 Human Capital

Following Glomm and Ravikumar (1998) and Blankenau and Simpson (2004), I assume that human capital is formed by the combination of public inputs the human capital of the previous period. For analytical tractability, the stock of human capital evolves according to

$$H_{t+1} = z H_t^{1-\gamma} G_t^{\gamma}. \tag{1.11}$$

H_t is the human capital at the beginning of period t, G_t is the public education spending, $0 < \gamma < 1$ is the elasticity of human capital to public education expenditure, and z

denotes the learning technology. The inclusion of the previous level of human capital as an argument has two motivations. First, it is well documented that educational achievement is positively influenced by the educational achievement in the past. Also, private investment in human capital can be interpreted as the current agent hiring the prior agent to serve as tutors. I assume that human capital is a non-rival and non-excludable good. This implies that firms do not internalize the impact of their actions on the evolution of the economy's stock of human capital.

1.4.4 Government

The government spends on G_t units of the commodity on education each period. To finance these expenditures, the government levies taxes on consumption and labor income, and can borrow or lend in the international capital market at an exgenously given interest rate r.

The government's budget constraint is

$$G_t = \tau_c C_t + B_{t+1} - (1+r)B_t, \tag{1.12}$$

with B_t being the stock of public debt outstanding at time t. Public debts were issued and purchased by the rest of the world at time $t-1$. When $B_t < 0$, accumulate foreign bonds.

The economy's aggregate resource constraint can be obtained by combining the household's budget constraint (1.2), the definition of dividends (1.5), and the government's budget constraint (1.12)

$$Y_t + D_{t+1} + B_{t+1} = C_t + I_t + G_t + (1+r)D_t + (1+r)B_t. \tag{1.13}$$

The benevolent government chooses G_t, H_{t+1}, and B_{t+1} to maximize the household's utility subject to the resource constraint (1.13) and human capital accumulation (1.11). The first order condition of the government's problem are given by

$$\nu_t = \gamma z H_t^{1-\gamma} G_t^{\gamma-1} \mu_t, \tag{1.14}$$

$$\mu_t = \beta(1-\alpha) K_{t+1}^{\alpha} H_{t+1}^{-\alpha} L_{t+1}^{1-\alpha} \nu_{t+1} + \beta(1-\gamma) z H_{t+1}^{-\gamma} G_{t+1}^{\gamma} \mu_{t+1}, \tag{1.15}$$

$$\nu_t = \beta \nu_{t+1} (1+r). \tag{1.16}$$

where μ_t and ν_t denote respectively the multipliers on the equation human capital accumulation (1.11) and the resource constriant (1.13).

1.4.5 Market Clearing and Competitive Equilibrium

The resource constraint (1.13) implies the market clearing condition of the good. The labor supply is exogenous and equal to the population, and the number of population is normalized to 1. The small open economy borrows and lend at an exogenously given world real interest rate r_w. The equilibrium can be defined as a set of processes $\{C_t, w_t, \lambda_t, Y_t, H_{t+1}, K_{t+1}, G_t, B_{t+1}, D_{t+1}, \mu_t, \nu_t\}_{t=0}^{\infty}$ satisfying (1.3), (1.4), (1.8) – (1.11), and (1.12) – (1.16), given the government policy τ_c, the world interest rate r_w, and the initial conditions K_0, H_0, D_0, and B_0.

The model has a balanced growth path in which $C_t, G_t, Y_t, K_{t+1}, B_{t+1}, D_{t+1}$, and w_t all grow at the same rate as H_t.

Along the balanced growth path,

$$1+g=C_{t+1}/C_t=K_{t+1}/K_t=H_{t+1}/H_t=G_{t+1}/G_t=Y_{t+1}/Y_t=B_{t+1}/B_t=D_{t+1}/D_t,$$

where g is the balanced growth rate. For simplicity, I assume log preferences $U(C) = log(C)$. The balanced growth path is completely determined by a system of four equations:

$$1+g=\beta(1+r_w), \tag{1.17}$$

$$\frac{K_t}{H_t}=\left(\frac{r_w+\delta}{\alpha}\right)^{\frac{1}{\alpha-1}}, \tag{1.18}$$

$$1+g=z\left(\frac{G_t}{H_t}\right)^{\gamma}, \tag{1.19}$$

$$\frac{1}{\gamma z}\left(\frac{G_t}{H_t}\right)^{1-\gamma}=\beta(1-\alpha)\left(\frac{K_t}{H_t}\right)^{\alpha}\frac{C_t}{C_{t+1}}+(1-\beta)\frac{1-\gamma}{\gamma}\frac{G_{t+1}}{H_{t+1}}\frac{C_t}{C_{t+1}}. \tag{1.20}$$

Equation (1.17) is the balanced growth version of the Euler equation (1.9). Equation (1.18) follows from equations (1.7) and (1.9) since the world real interest rate is constant along the balanced growth path. Equation (1.19) is derived directly from the human capital accumulation. Equation (1.20) comes from the government's optimal conditions on human capital and government spending. After pinning down the parameters of the model we need to solve for two unknowns: g and β.

Two remarks are in order here. First, the consumption tax rate plays no role in determining the balanced growth path in this economy. Second, the growth rate of the economy is bounded from above by the world interest rate 4% because the subjective discount factor cannot exceed 1.

1.5 Quantitative Analysis

In this section, I use the theoretical framework to describe the long-run patterns of private and public capital flows. First, I calibrate the model and study the relationship between the balanced growth rate and the two types of net capital inflows. Then, I examine the impact of the consumption tax rate on the net public capital inflows.

1.5.1 Baseline Calibration

The model cannot be solved analytically, so we must resort to numerical simulations. Since the goal is to examine the model's quantitative implications for the long-run relationship of growth and capital flows, we will study a parameterized version and restrict attention to balanced growth paths. The model period corresponds to one year.

Some parameters are chosen as it is standard in the literature. The interest rate at which domestic firms and government can borrow from foreign investors is equal to $r_w = 0.04$, assuming that the United States determines the world interest rate. I set the labor shares $1 - \alpha = 0.6$, and the depreciation rate of physical capital δ to 0.06. The appropriate value for $1 - \gamma$ is debatable; estimates range from 0 (Coleman (1966)) to 0.12 (Card and Krueger (1992)). Following Glomm and Ravikumar (1998), I concentrate on the case $1 - \gamma = 0.05$. I also explore three other different values: $1 - \gamma = 0.01$, 0.1, and 0.12. However, the choice of value doesn't affect the main results.

Table 1.6: Baseline parameters

Parameter	Value	Description	Source
$1-\alpha$	0.6	Labor share in output	
δ	0.06	Annual depreciation of physical capital	
$1-\gamma$	0.95	Elasticity of human capital	Glomm and Ravikumar (1998)
τ_c	0.1	Consumption tax rate	
r_w	0.04	World real interest rate	

1.5.2 Growth and International Capital Flows: Private versus Public

I begin by examining how net private capital inflows and net public capital inflows vary across different growth rates. I assume that the only difference across countries occurs in education technology, $0.98 \leq z \leq 1.02$. Then, we obtain β from equations (1.17) – (1.20). This results in the discount factor ranging from 0.9129 to 0.9909 and the balanced growth rate from -5% to 3%. That is, countries with better productivity in human accumulation experience higher growth rates.

Foreign investors from the rest of the world purchase private firms' bonds. And foreign investors increase their purchase of private bonds in countries with a faster growth rate. This generates a positive correlation between net private capital inflows and economic growth in the long run.

Figure 1.4a plots the positive relationship between net private capital inflows and the balanced growth rate. The net private debt flows are measured relative to output. The firms in a country with a faster growth rate borrow more. The country with a -2% growth rate experiences net private capital outflows of about 24% of its GDP.

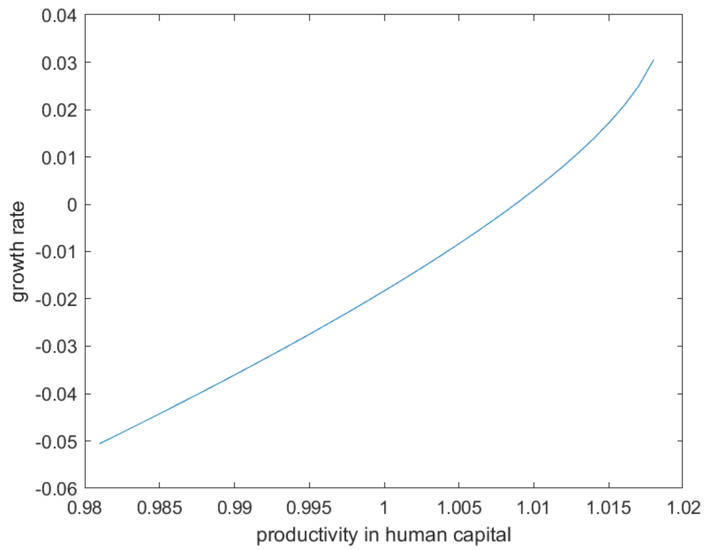
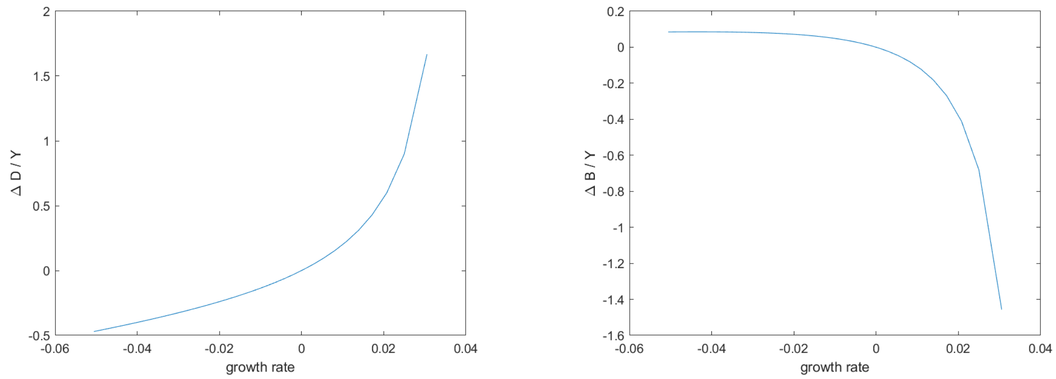


Figure 1.3: The balanced growth rate and productivity on human capital

On the other hand, net private capital flows toward a country with a 1.7% growth rate by 42% of its GDP.

On the other hand, public capital flows show a different pattern from private capital flows. The government needs funds to finance the government expenditure on education, and the tax revenue is insufficient. Therefore, the government saves money in the international financial market and takes advantage of the high interest rate. The government expenditure increases to sustain the high growth rate, which requires the government to save more money. As a result, public capital flows are negatively correlated with the balanced growth rate.

Figure 1.4b shows the negative relationship between net public capital inflows and the balanced growth rate. A higher growth rate is associated with an increase in the net public outflows relative to output. The country with a -2% growth rate experiences



(a) Net private capital inflows (b) Net public capital inflows

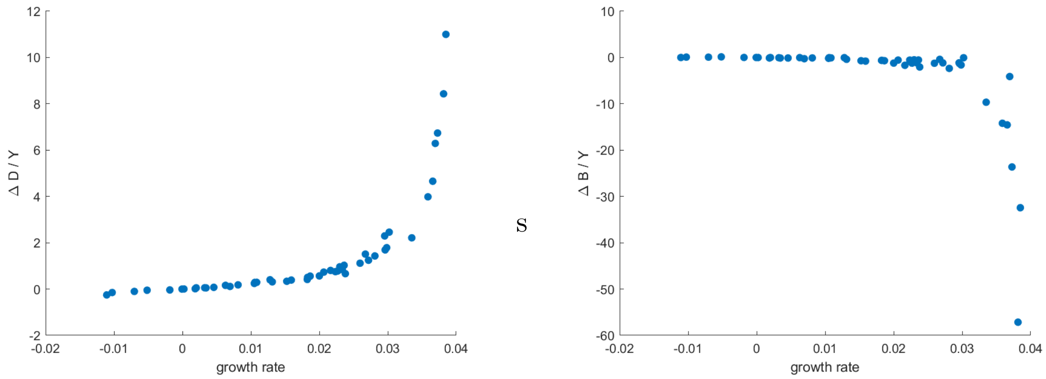
Figure 1.4: Balanced growth and international capital flows

net public capital inflows of about 7% of its GDP. On the other hand, net public capital flows out of a country with a 2% growth rate by 41% of its GDP.

Figures 1.9, 1.10, and 1.11 in the appendix presents the results when γ equals 0.01, 0.1, and 0.12, respectively. Those figures imply that the value of γ does not affect the main results. In the long run, countries with a higher growth rate experience more net private capital inflows and more net public capital outflows.

1.5.3 Quantitative Predictions

In the main exercise described above, I assume that the growth difference comes from the distinct productivity levels in human capital accumulation z across countries. All the countries are assumed to have the same labor share, depreciation rate, and tax rate. Therefore, the countries with higher productivity levels in the education sector are associated with a higher balanced growth rate.



(a) Net private capital inflows

(b) Net public capital inflows

Figure 1.5: Balanced growth and international capital flows

However, the countries may differ in the other parameter values, which also affects the growth rate. In this experiment, I set the parameter values differently for each country based on the country data. The country-specific β is obtained from equation (1.17) using the average growth rate of GDP per capita. Since β must be less than 1, countries with a growth rate higher than 4% are excluded. The depreciation rate δ and the labor share $1-\alpha$ are available in the Penn World Table data. The data of taxes on goods and services relative to the value added of industry and services from the World Bank is used for the consumption tax. z is calculated by solving equations (1.17) – (1.20) using the parameter values for each country. The parameter values are listed in the table 1.8 in the appendix.

The two graphs in figure 1.5 present the relationship between economic growth and net private and public capital inflows. And they display similar patterns shown in the main exercise. The model predicts that fast-growing countries experience more net

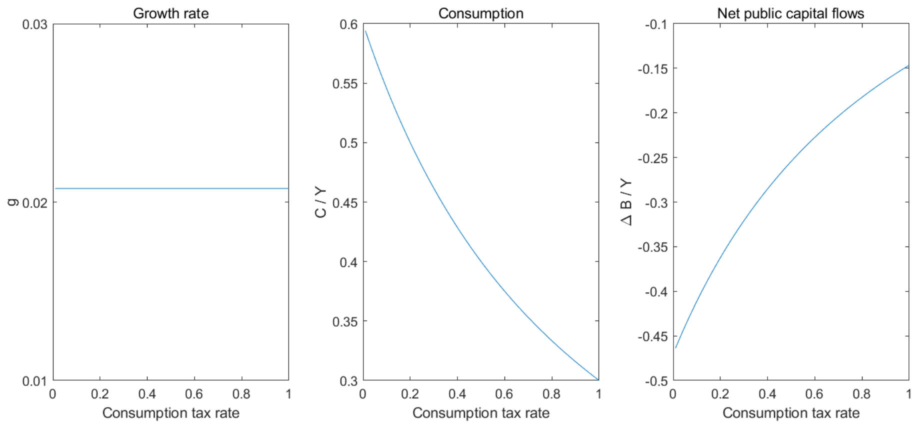


Figure 1.6: Impact of consumption tax

private capital inflows, as shown in figure 1.5a. And public capital flows out more from the small open economy when the growth is strong, as depicted in figure 1.5b.

1.5.4 Tax Rate and International Capital Flows

In this subsection, I explore the impact of increasing the consumption tax rate. Changes in the tax rate affect the optimal consumption choice through equation (1.3). The growth rate does not change at all in response to an increase in the consumption tax rate in this model. And the consumption tax rate has no effect on private external debt relative to the output. On the other hand, changes in the consumption tax rate have a significant impact on the government's saving decision. As the overall tax revenue increases, the government decreases its reserve accumulation.

Figure 1.6 presents the impact of consumption tax. In this exercise, I use the average growth rate $g = 0.022$ from our sample of 83 developing countries and set the productivity level of the human accumulation as $z = 1.016$. The figure on the left displays that the consumption tax rate doesn't affect the growth rate. However, the consumption tax rate has a negative impact on the consumption-to-output ratio, as illustrated in the middle figure. The equilibrium consumption is about 60% of the GDP when the government doesn't impose any tax on consumption. The consumption-to-output ratio decreases to 55% when the government raises the consumption tax rate to 10%. The figure on the right-hand side depicts that net public capital outflows decrease as the consumption tax rate increases. In this example, an increase in the consumption tax rate from 0% to 10% increases net public capital flows relative to the GDP by 4 percentage points.

1.5.5 Public Human Capital Investment and Net Capital Inflows

One of the predictions of the model is that the government has to spend money on human capital investment to sustain the growth rate. A rise in the growth rate is associated with an increase in government expenditure. As a result, government spending relative to the output is positively correlated with net private capital inflows and negatively correlated with net public capital inflows. These patterns are shown in figure 1.8 in the appendix.

To check this prediction, I collect the government spending data. I use the government spending on education and health from the World Bank dataset. Figure 1.7 shows the relationship between the average government spending on education and health relative to GDP and the average net foreign capital inflows. The government spending on human capital relative to the output are positively correlated with net

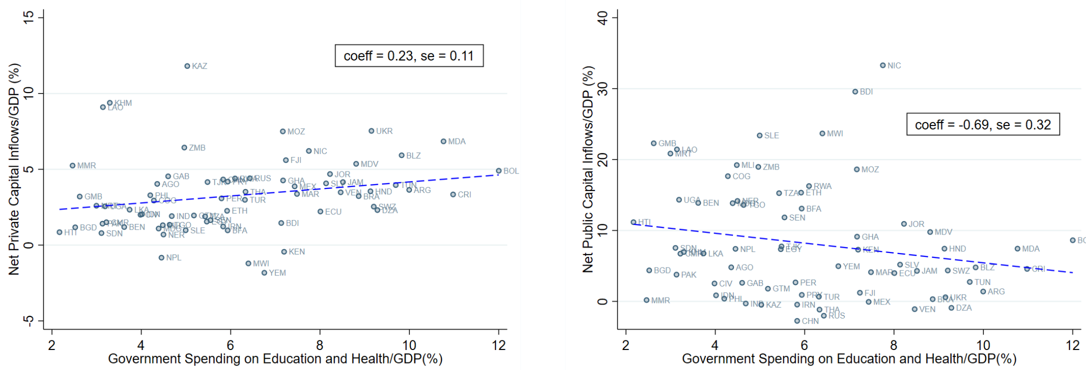


Figure 1.7: Government spending on human capital and international capital flows

private capital inflows. When I regress net private capital inflows on the government spending-to-output ratio, the coefficient of government spending is 0.23 with the standard error of 0.11. The public human capital investment relative to the output is negatively correlated with public capital inflows. The coefficient of government spending is -0.69 with the standard error of 0.32.

1.6 Conclusion

This paper examines the long-run relationship between economic growth and international capital flows. While the literature has focused on total, public, or private flows alone, I study both private and public capital flows in emerging markets. I first empirically explore the patterns of net private and public capital inflows across 83 developing countries. Net private capital inflows are positively correlated with GDP per capita growth, and net public capital inflows are negatively correlated. That is, fast-growing emerging countries receive more net private inflows but less net public capital inflows. And these patterns remain statistically significant when human capital is controlled.

Then, I present a framework that can reproduce the long-run patterns shown in the data. In the model, a small open economy consists of a large number of households and firms and a government. The benevolent government plays an essential role in forming human capital by spending money on education. Both firms and the government can access the international financial market and trade international bonds in tradable units. I assume there is no friction in the international financial market, unlike the models of the previous literature.

Foreign investors purchase private bonds. The amount of private capital inflows rise when the balanced growth rate is larger. As a result, The net private capital inflows are positively correlated with economic growth. On the other hand, the government takes advantage of the world interest rate and saves money in the international capital market to finance its public human capital investment. The government in a fast-growing country has to increase its spending on human capital to sustain its high economic growth. As a result, government saving increases as the balanced growth rate rises, and public capital inflows are negatively correlated with the growth rate.

These findings have both theoretical and practical implications. This paper suggests that it is essential to study both private and public capital flows when examining the behavior of international capital flows, especially for developing countries. And the fact that public capital flows are negatively correlated with economic growth, which contradicts the prediction of the standard neoclassical model, sheds light on the role of the government. Therefore, the government sector should be considered in the model when we study developing countries.

1.A Appendices

1.A.1 Summary of Data

Table 1.7: Data summary

ISO	Country	Start	End	$\overline{\Delta D^{priv}/Y}$	$\overline{\Delta D^{pub}/Y}$	$\bar{g}$	$\bar{n}$	$\bar{open}$	$\bar{h}$
ALB	Albania	1993	2019	4.35	5.75	5.28	-0.44	-0.33	2.82
DZA	Algeria	1977	2019	2.31	-0.91	0.31	2.15	-1.40	1.76
AGO	Angola	1989	2019	4.04	4.81	3.02	3.41	-1.62	1.33
ARG	Argentina	1976	2019	3.64	1.40	3.69	1.25	-0.41	2.64
ARM	Armenia	1997	2019	8.15	6.49	6.32	-0.30	2.17	3.11
BGD	Bangladesh	1976	2019	1.17	4.38	3.20	1.92	-1.43	1.62
BLZ	Belize	1984	2019	5.93	4.79	0.46	2.55	-0.82	2.99
BEN	Benin	1974	2019	1.19	13.9	0.70	2.90	-0.76	1.38
BOL	Bolivia	1976	2019	4.91	8.62	2.81	1.89	0.42	2.38
BWA	Botswana	1975	2019	-2.22	-0.69	5.18	2.60	0.59	2.21
BRA	Brazil	1975	2019	3.23	0.32	2.27	1.56	-1.21	2.05
BGR	Bulgaria	1991	2004	4.42	1.07	-0.18	-0.95	-1.03	2.86
BFA	Burkina Faso	2005	2019	0.97	13.1	2.06	2.96	-1.22	1.20
BDI	Burundi	1985	2018	1.46	29.6	-0.52	2.60	-1.51	1.23
KHM	Cambodia	1993	2019	9.39	6.97	4.17	1.99	0.39	1.66
CMR	Cameroon	1977	2019	1.51	6.73	1.87	2.83	-0.89	1.65
CAF	Central African Republic	1977	1994	0.061	19.1	-0.29	2.51	-0.86	1.19
CHN	China	1982	2019	4.33	-2.75	5.62	0.91	-1.34	2.25
COL	Colombia	1970	2019	2.90	0.055	2.23	1.76	-1.20	2.07
COG	Congo, Rep.	1978	2016	2.94	17.7	0.056	2.87	-1.19	1.83
CRI	Costa Rica	1977	2019	3.34	4.58	2.00	1.99	0.24	2.35
CIV	Côte d'Ivoire	2005	2018	2.00	2.53	5.64	2.38	-1.22	1.57
DOM	Dominican Republic	1970	2019	4.07	1.91	3.73	1.80	-0.61	2.05
ECU	Ecuador	1976	2019	2.22	3.99	1.05	2.07	0.25	2.38
EGY	Egypt, Arab Rep.	1977	2019	1.55	7.36	5.00	2.17	-0.25	1.93
SLV	El Salvador	1976	2019	4.07	5.19	4.60	1.00	0.28	1.80
SWZ	Eswatini	1974	2019	2.54	4.36	2.38	1.94	-0.74	1.71
ETH	Ethiopia	1981	2018	2.26	15.3	2.99	2.98	-1.26	1.19
FJI	Fiji	1979	2019	5.60	1.22	2.16	0.92	-0.87	2.37
GAB	Gabon	1978	2015	4.54	2.62	0.20	2.78	-0.71	1.99
GMB	Gambia, The	1978	2018	3.20	22.3	-0.64	3.35	1.14	1.31
GHA	Ghana	1975	2019	4.26	9.13	0.35	2.53	-1.55	1.99
GTM	Guatemala	1977	2019	1.95	1.79	1.83	2.28	1.09	1.61
HTI	Haiti	1971	2019	0.85	11.2	0.28	1.79	1.09	1.42
HND	Honduras	1974	2019	3.55	7.44	1.59	2.58	-0.33	1.88
IND	India	1975	2019	1.91	-0.30	3.35	1.80	-1.22	1.67
IDN	Indonesia	1981	2019	2.04	0.86	4.03	1.55	1.32	2.10
IRN	Iran, Islamic Rep.	1980	2000	1.23	-0.45	1.28	2.70	-1.65	1.43
JAM	Jamaica	1976	2019	4.16	4.30	0.33	0.85	0.35	2.42
JOR	Jordan	1972	2019	4.69	10.9	2.72	3.58	0.62	2.19
KAZ	Kazakhstan	1995	2019	11.8	-0.48	5.40	0.59	-1.22	3.13
KEN	Kenya	1975	2019	-0.44	7.29	1.52	3.09	-0.093	1.86
KGZ	Kyrgyz Republic	1994	2019	4.79	12.8	0.46	1.38	0.86	3.08
LAO	Lao PDR	1984	2019	9.10	21.4	5.26	2.00	-1.35	1.69
LSO	Lesotho	1995	2019	-2.11	4.52	0.34	0.53	-1.20	1.99
MDG	Madagascar	1974	2019	1.09	13.9	-0.22	2.89	-0.81	1.47
MWI	Malawi	1977	2019	-1.21	23.7	-0.34	2.82	-1.31	1.56
MDV	Maldives	1980	2019	5.36	9.78	4.63	3.11	1.53	1.78

Continued on next page

ISO	Country	Start	End	$\overline{\Delta D^{priv}/Y}$	$\overline{\Delta D^{pub}/Y}$	$\bar{g}$	$\bar{n}$	$\overline{open}$	$\bar{h}$
MLI	Mali	1975	2018	1.31	19.2	3.23	2.49	-0.71	1.15
MRT	Mauritania	1975	2019	2.60	20.8	0.33	2.79	-1.23	1.48
MEX	Mexico	1979	2019	3.87	-0.065	1.06	1.66	0.54	2.37
MDA	Moldova	1995	2019	6.84	7.44	4.29	-0.30	-1.19	3.01
MNG	Mongolia	1992	2019	17.4	11.0	5.23	1.34	1.15	2.72
MAR	Morocco	1975	2019	3.38	4.12	2.59	1.64	-1.32	1.49
MOZ	Mozambique	2005	2019	7.50	18.6	0.63	2.81	-1.22	1.19
MMR	Myanmar	2000	2019	5.25	0.19	7.64	0.79	-1.92	1.69
NPL	Nepal	1976	2019	-0.83	7.41	3.41	1.72	-1.19	1.39
NIC	Nicaragua	1977	2019	6.21	33.3	-1.03	1.90	0.69	1.87
NER	Niger	1974	2019	0.70	14.2	-0.70	3.39	-0.88	1.10
NGA	Nigeria	1977	2019	2.38	1.75	0.43	2.62	-1.08	1.48
PAK	Pakistan	1976	2019	1.41	3.78	2.05	2.67	-1.23	1.54
PRY	Paraguay	1975	2019	4.19	0.92	2.96	2.11	-0.24	2.14
PER	Peru	1977	2019	3.08	2.68	2.36	1.67	1.05	2.43
PHL	Philippines	1977	2019	3.29	0.39	2.30	2.17	-0.51	2.36
RUS	Russian Federation	1994	2004	4.41	-2.02	0.022	-0.27	-0.70	3.07
RWA	Rwanda	2010	2019	4.40	16.3	4.06	2.55	0.71	1.75
SEN	Senegal	1974	2018	1.64	11.8	0.81	2.72	-0.70	1.28
SLE	Sierra Leone	1977	2019	0.98	23.4	0.78	2.15	-1.25	1.35
ZAF	South Africa	1999	2019	2.70	-0.31	1.31	1.40	-1.22	2.47
LKA	Sri Lanka	1975	2019	2.34	6.77	2.95	1.02	-0.53	2.61
SDN	Sudan	1977	2019	0.79	7.55	3.94	2.85	-1.16	1.35
TJK	Tajikistan	2002	2019	4.16	7.75	5.87	2.16	-1.22	3.11
TZA	Tanzania	1988	2019	1.89	15.3	2.98	2.81	-1.19	1.52
THA	Thailand	1975	2019	3.52	-1.16	4.05	1.16	-0.42	2.16
TGO	Togo	1974	2018	1.34	13.6	0.19	2.74	-1.10	1.56
TUN	Tunisia	1976	2019	3.96	2.74	2.34	1.65	-1.12	1.85
TUR	Turkey	1974	2019	2.99	0.67	2.67	1.74	-0.86	1.91
UGA	Uganda	1980	2019	2.56	14.3	2.09	3.25	0.70	1.72
UKR	Ukraine	1994	2019	7.54	0.59	1.82	-0.59	-1.55	3.15
VEN	Venezuela, RB	1970	2014	3.48	-1.09	0.71	2.23	-0.0067	2.00
YEM	Yemen, Rep.	2005	2016	-1.83	4.96	-1.69	2.75	2.33	1.45
ZMB	Zambia	1978	2019	6.44	19.0	1.08	2.90	0.56	2.05
ZWE	Zimbabwe	1981	2017	2.14	7.41	-0.0062	1.77	-1.36	2.08

Note: The table reports the sample period for each country (Start and End), the average of net private capital flows ($\overline{\Delta D^{priv}/Y}$), net private capital flows ($\overline{\Delta D^{pub}/Y}$), GDP per capita growth rate ($\bar{g}$), population growth rate ($\bar{n}$), the financial openness index ($\overline{open}$), and the human capital index ($\bar{h}$).

1.A.2 Results Based on the Baseline Parameters

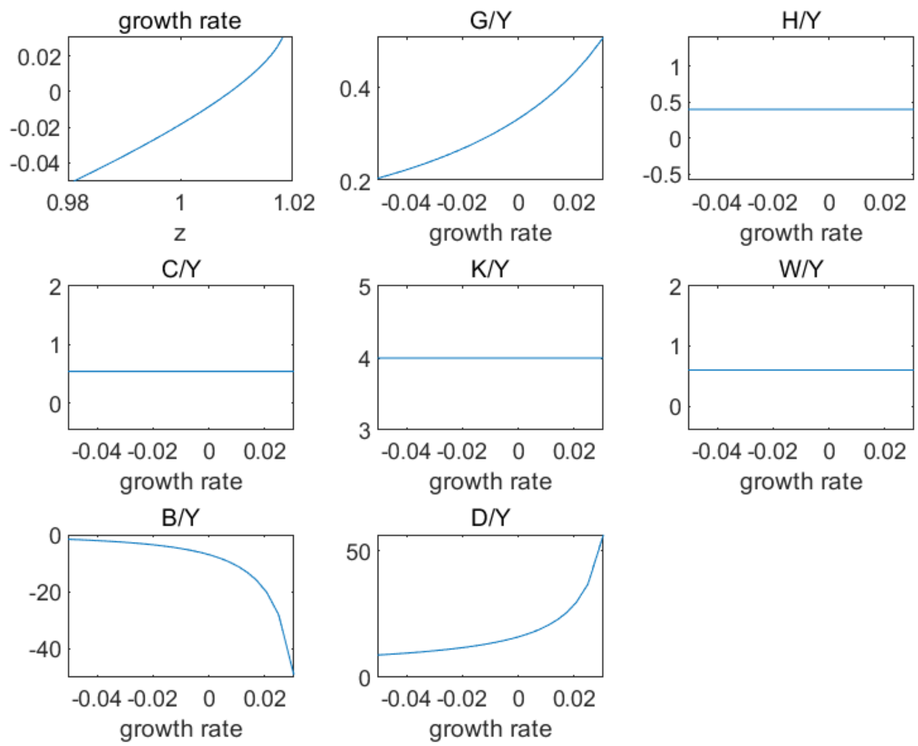
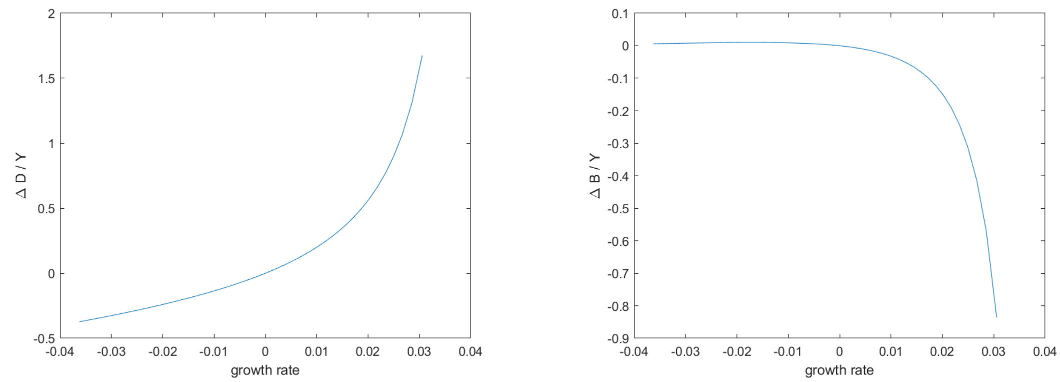


Figure 1.8: The results using the baseline parameters

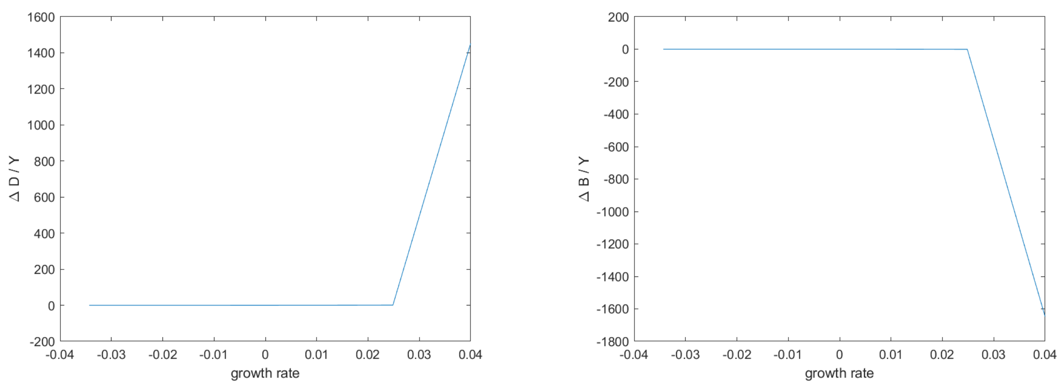
1.A.3 Balanced Growth Rate and International Capital Flows



(a) Net private capital inflows

(b) Net public capital inflows

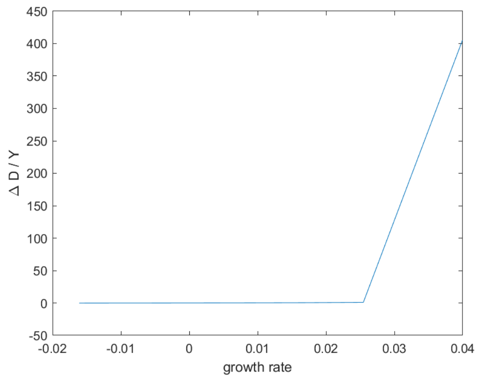
Figure 1.9: Balanced growth and international capital flows ($\gamma = 0.01$)



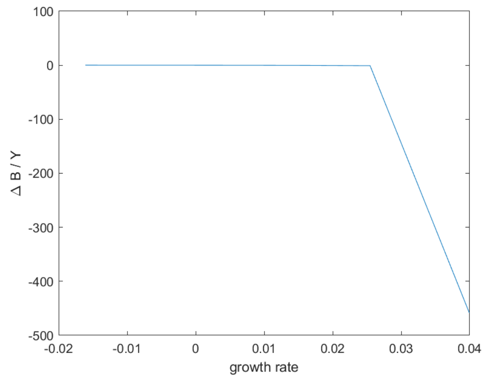
(a) Net private capital inflows

(b) Net public capital inflows

Figure 1.10: Balanced growth and international capital flows ($\gamma = 0.1$)



(a) Net private capital inflows



(b) Net public capital inflows

Figure 1.11: Balanced growth and international capital flows ($\gamma = 0.12$)

1.A.4 Country Specific Parameters

Table 1.8: Country specific parameters

ISO	Country	$\bar{g}$	$\bar{\delta}$	$1-\bar{\alpha}$	$\bar{\tau}$
AGO	Angola	0.030	0.040	0.291	0.022
ARG	Argentina	0.037	0.031	0.435	0.068
BDI	Burundi	-0.005	0.033	0.707	0.153
BEN	Benin	0.007	0.043	0.628	0.027
BFA	Burkina Faso	0.021	0.048	0.478	0.103
BGR	Bulgaria	-0.002	0.047	0.450	0.125
BIH	Bosnia and Herzegovina	0.038	0.057	0.659	0.216
BLR	Belarus	0.037	0.037	0.566	0.134
BOL	Bolivia	0.028	0.054	0.525	0.112
BRA	Brazil	0.023	0.047	0.537	0.075
CMR	Cameroon	0.019	0.049	0.524	0.054
COL	Colombia	0.022	0.034	0.479	0.075
CPV	Cabo Verde	0.036	0.045	0.584	0.120
CRI	Costa Rica	0.020	0.051	0.577	0.086
DOM	Dominican Republic	0.037	0.052	0.576	0.063
ECU	Ecuador	0.011	0.039	0.498	0.073
FJI	Fiji	0.022	0.091	0.554	0.136
GAB	Gabon	0.002	0.047	0.346	0.032
GIN	Guinea	-0.011	0.050	0.303	0.038
GTM	Guatemala	0.018	0.040	0.528	0.071
HND	Honduras	0.016	0.055	0.582	0.088
IND	India	0.034	0.043	0.613	0.060
IRN	Iran, Islamic Rep.	0.013	0.039	0.358	0.016
JAM	Jamaica	0.003	0.033	0.561	0.129
JOR	Jordan	0.027	0.038	0.485	0.117
KEN	Kenya	0.015	0.044	0.591	0.083
KGZ	Kyrgyz Republic	0.005	0.036	0.595	0.140
LKA	Sri Lanka	0.030	0.073	0.413	0.101
LSO	Lesotho	0.003	0.047	0.643	0.167
MAR	Morocco	0.026	0.044	0.501	0.143
MEX	Mexico	0.011	0.035	0.397	0.077
MKD	North Macedonia	0.039	0.036	0.555	0.157
MOZ	Mozambique	0.006	0.049	0.415	0.138
NER	Niger	-0.007	0.031	0.557	0.052
NIC	Nicaragua	-0.010	0.037	0.544	0.112
PER	Peru	0.024	0.048	0.442	0.088
PHL	Philippines	0.023	0.047	0.441	0.045

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ISO	Country	$\bar{g}$	$\bar{\delta}$	$1-\bar{\alpha}$	$\bar{\tau}$
PRY	Paraguay	0.030	0.038	0.462	0.074
RUS	Russian Federation	0.001	0.030	0.517	0.098
SEN	Senegal	0.008	0.038	0.487	0.114
SRB	Serbia	0.024	0.037	0.612	0.206
TGO	Togo	0.002	0.038	0.806	0.133
TUN	Tunisia	0.023	0.045	0.523	0.108
TUR	Turkey	0.027	0.048	0.395	0.092
TZA	Tanzania	0.030	0.042	0.471	0.086
UKR	Ukraine	0.018	0.026	0.555	0.142
ZAF	South Africa	0.013	0.048	0.542	0.100
ZMB	Zambia	0.011	0.041	0.431	0.082
ZWE	Zimbabwe	-0.001	0.039	0.555	0.085

Note: The table reports the average GDP per capita growth rate ($\bar{g}$), the average depreciation rate ($\bar{\delta}$), the average labor share ($1-\bar{\alpha}$), and the average consumption tax rate ($\bar{\tau}$).

Chapter 2

Spatial Consumption Risk Sharing

2.1 Introduction

Consumption risk sharing allows agents to yield welfare gains by reducing consumption fluctuations caused by idiosyncratic income shocks. However, frictions in economic exchanges impede consumption from being smoothed across space and time. This paper explores the patterns and determinants of risk sharing by exploiting the variation in bilateral economic linkages shaped by geography.

What drives imperfect consumption correlations across economies remains a central question of interest as the phenomenon attests to the failure of complete markets. Obstfeld and Rogoff (2000) consider the low cross-country consumption comovement as a major puzzle in international macroeconomics. Besides trade costs in the commodity market discussed by these authors, migration costs in the labor market and financial frictions in the asset market affect risk sharing since they pose barriers for resources to be freely mobile in the presence of local shocks. While most existing literature studies one channel, this paper extends the workhorse open economy real business cycle model developed by Backus et al. (1992b) (BKK) into a unified framework with trade, migration, and finance. This comprehensive framework enables us to examine the interaction of these channels as they jointly influence consumption.

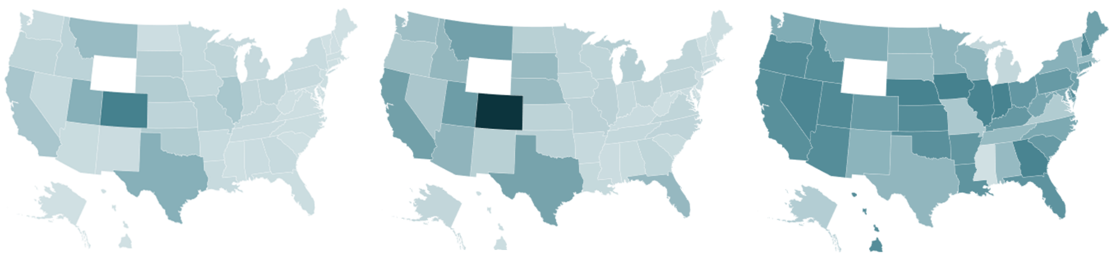
We add a geographic dimension to macro analysis, since bilateral linkages in these channels covary with geographic distance as documented by the gravity model of trade, finance, and migration.[1] Since these channels are important drivers for synchronization, bilateral consumption comovement is also expected to exhibit similar geographic characteristics. To exemplify such patterns, we plot the bilateral economic ties between Wyoming and other states in figure 2.1 and confirm that ties are generally stronger for neighboring states.[2] To capture such spatial features, we embed bilateral linkages through channels of risk sharing in a multi-economy DSGE framework that enables us to examine the aggregate influences of different channels in general equilibrium. This RBC framework also contributes to quantitative spatial models surveyed by Redding and Rossi-Hansberg (2017) by evaluating the second moments (variance and

[1] For example, Anderson and Van Wincoop (2003) develop a theory-grounded econometric framework to revive the gravity model of trade flows across countries. Portes and Rey (2005) document that bilateral equity flows decrease with distance between country pairs. Lewer and Van den Berg (2008) develop and test a gravity model of immigration among OECD countries.

[2] Detailed data description can be found in Appendix 2.A.2. Cross-state trade data are sourced from the CFS, migration data are from the IRS, and consumption data are from the BEA. Comprehensive data for state-to-state financial flows are not available to our knowledge.

covariance) and first moments (level) of macroeconomic fundamentals, both of which are essential for welfare analysis.

Figure 2.1: Wyoming's bilateral linkages with other states



(a) Bilateral trade (b) Bilateral migration (c) Consumption correlation

Note: This figure plots bilateral ties between Wyoming (in white) and other states in the U.S. averaged over the period of 1997-2017. A darker color suggests a greater value of bidirectional flows (sum of inflows and outflows) for trade and migration as well as a higher correlation coefficient of real consumption per capita.

This paper focuses on the US state-level analysis, but the general framework can be tailored to other contexts of interest.[3] The empirical section consists of two parts. The first establishes a gravity model of consumption risk sharing using output and consumption data from 1977 to 2019. We measure a state's consumption risk sharing as the response of its relative consumption growth to its relative output growth following the macro literature including Asdrubali et al. (1996). Specifically, we compute bilateral risk sharing for all the state pairs and find it is weaker for pairs that are

[3]For example, the model can be applied to intranational analysis of another country, or international analysis of the European Union which exhibits a high degree of integration for goods, financial, and labor markets. Given that frictions are relatively low across states in the US, our estimates provide a lower bound on the importance of frictions for consumption.

more geographically distant: Every 1% increase in distance deteriorates consumption risk sharing by 0.151 (or 0.402 standard deviations). This spatial characteristic of consumption synchronization points to the existence of barriers to risk sharing influenced by geography. The second empirical analysis examines the 2006 North Dakota (ND) oil boom as an event study to verify the importance of geography in spreading consumption gains. Through panel regressions, we find that bilateral linkages of ND with other states exhibit strong geographic patterns after ND's output boost: ND witnessed greater migration and trade inflows from states located in closer proximity. These states also experienced stronger consumption comovement with ND following the oil shock.

Motivated by the empirical findings, we develop a DSGE model to examine the drivers for this geographic pattern of consumption synchronization. Our model is populated by representative households who reside in different states connected by three channels. In the trade channel, we follow the classic Armington (1969) model to assume that states exchange intermediate goods subject to iceberg trade costs. In the migration channel, we adopt Artuc et al. (2010)'s analysis with modifications by assuming that households make forward-looking migration decisions in response to consumption differentials across states. In the financial channel, we set up a portfolio choice problem and endogenize agents' preference among assets issued by different states. To capture asset market incompleteness, we introduce bilateral financial frictions as transaction costs on asset returns.[4] When deriving portfolios under frictions, we employ the solution

[4] This modeling assumption follows Heathcote and Perri (2013) and Tille and Van Wincoop (2010), but financial frictions can take alternative forms to asset transaction costs. For example, Okawa and

technique developed by Devereux and Sutherland (2011) and Tille and Van Wincoop (2010). The portfolio choice will in turn affect consumption correlations, which allows us to quantify both the magnitude of bilateral financial frictions and the distortion of consumption caused by them.

To illustrate the mechanism of how the three channels of risk sharing jointly shape consumption synchronization, we start with a symmetric two-economy analysis à la BKK. By conducting comparative static analyses, we find that the interaction of the channels yields non-monotonic predictions for the impacts of various frictions on consumption correlations. For example, higher financial frictions, by tilting portfolios towards domestic assets and lowering the reliance of consumption on foreign output, reduce bilateral consumption correlations in general, consistent with the neoclassical model of cross-economy risk sharing (Lucas (1982)). Nevertheless, when financial frictions are so high as to encourage saving that crowds out consumption, population moves out of the state which has experienced a positive productivity shock. These migration outflows equalize consumption per capita across states and hence generate a stronger consumption comovement. This analysis underscores the importance of considering multiple channels of risk sharing in an integrated general equilibrium setting.

To conduct policy analysis with the model, we extend the bilateral to a trilat-

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Van Wincoop (2012) discuss the comparability of information frictions and transaction costs in predicting the gravity model of financial flows. Even within a country, there exist such financial frictions that vary at the bilateral level. Empirical evidence for this includes the 'home bias at home' phenomenon documented by Coval and Moskowitz (1999).

eral framework where we consider the rest of the economy (ROE) which exerts 'multilateral resistance' on a state-pair in the spirit of Anderson and Van Wincoop (2003). To calibrate frictions in the three channels, we use trade and migration shares as well as coefficients of risk sharing as targeted moments. We conduct the estimation for all the state pairs and confirm the geographic feature of bilateral frictions: For a 1% increase in distance, bilateral trade, migration, and financial frictions increase by 0.53%, 0.10%, and 0.23% respectively. Furthermore, we quantify the impacts of frictions on consumption through counterfactual analyses. Eliminating three types of bilateral frictions leads to lower consumption volatility, with a reduction of 0.7%, 1.0%, and 0.3% averaged across states when bilateral trade, migration, and financial frictions are turned off respectively. This result supports the argument that reducing barriers to risk sharing yields welfare gains by smoothing consumption fluctuations. These counterfactual analyses also provide guidance for fiscal policies which, by mitigating the impacts of the frictions, reduce consumption inequality. Using an example that studies the direction and magnitude of transfers across states to alleviate the effects of trade costs on the level of consumption, we show that our framework offers a useful tool for the design of macro policies which aim to narrow consumption disparity across space and time.

This paper contributes to the macroeconomics literature on consumption risk sharing by exploiting the bilateral variation across economies influenced by geography. To explain the failure of cross-country risk sharing, international macro literature has examined frictions in the financial channel (e.g. Baxter and Crucini (1995), Kollmann (1995), and Lewis (1996)) or the trade channel (e.g. Dumas and Uppal (2001), Corsetti et al. (2008), and Eaton et al. (2016)). Nevertheless, many works focus on one channel in a two-country framework, which is not ideal to fully characterize the general equilibrium effects. Therefore, this paper is closer to House et al. (2018), Fitzgerald (2012a), and Caliendo et al. (2018), who consider multiple channels in a multi-economy framework. Compared to these papers, our portfolio choice framework makes it possible to quantify financial frictions at the pair level for cross-sectional comparison and counterfactual analysis. These bilateral financial frictions are important for the spatial pattern of consumption comovement.

In the domestic context, Asdrubali et al. (1996), Hess and Shin (1998b), Crucini (1999), Athanasoulis and Van Wincoop (2001), Del Negro (2002), and Kalemli-Ozcan et al. (2010) pioneered the work on risk sharing using the US state-level data. At the micro level, seminal papers including Storesletten et al. (2004) and Heathcote et al. (2014) explore heterogeneous impacts of income on consumption across households. Neither these macro nor micro perspectives focus on the influences of bilateral frictions across states on households' consumption and migration decisions. Therefore, our paper complements this literature by considering additional channels of intranational risk sharing.

Lastly, this paper contributes to empirical gravity models. Since being introduced by Isard (1954) and Tinbergen (1962), the model has emerged as a classic framework in the trade literature. In addition to trade, the gravity model has 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 population flows (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, together with Chertman et al. (2020) for cross-country analysis, adds to this literature by exploring the role of geographic distance in shaping consumption patterns.

The remainder of this chapter proceeds as follows: Section 2.2 empirically explores the influence of geographic distance on consumption comovement. Section 2.3 develops a theoretical framework to examine the magnitude and impact of frictions that covary with geography in the channels of consumption risk sharing. Section 2.4 concludes.

2.2 Empirical Motivation

This section empirically establishes the importance of geography for consumption risk sharing. First, we use the US state-level consumption and output data to compute the degree of bilateral risk sharing and explore its sources of variation including distance. Second, we conduct an event study of the 2006 North Dakota oil discovery to verify the role of geography in spreading consumption gains from a local shock.

We measure consumption risk sharing as the response of an economy's relative consumption growth to its relative output growth following the macro literature such as Asdrubali et al. (1996) and Kose et al. (2009a). In particular, we focus on bilateral risk sharing so that we can exploit pair-specific factors including geographic distance in order to examine the patterns and determinants of consumption comvement across economies. Specifically, we evaluate risk sharing between state i and j from

$$\Delta \log\ c_{it} - \Delta \log\ c_{jt} = \alpha_{ij} + \beta_{ij}(\Delta \log\ y_{it} - \Delta \log\ y_{jt}) + \epsilon_{ijt}, \tag{2.1}$$

where $\Delta \log\ c_{it}$ ($\Delta \log\ c_{jt}$) and $\Delta \log\ y_{it}$ ($\Delta \log\ y_{jt}$) denote the growth of log real per-capita consumption and output of state $i(j)$ at time t. The coefficient β_{ij} measures the degree of bilateral consumption risk sharing. In the case with perfect risk sharing, consumption is equalized regardless of relative output growth, which yields a coefficient of 0. In the opposite case with complete autarky, a state's consumption is solely determined by its own output, which implies a coefficient of 1. Therefore, a lower β_{ij} suggests a higher degree of bilateral risk sharing.

The data using which we evaluate equation 2.1 are obtained from the following sources (see Appendix 2.A.2 for details). The US Bureau of Economic Analysis (BEA) reports real gross state product (GSP) since 1977 and state-level consumption but only since 1997, which is not ideal for our analysis of risk sharing that requires long-horizon data. Therefore, we follow Asdrubali et al. (1996)'s method of constructing state-level consumption by rescaling state-level retail sales by the country-level ratio of private consumption to retail sales, both of which are available from the BEA. Moreover, we use Nakamura and Steinsson (2014)'s state-level inflation series to convert nominal to real consumption.

Panel A of table 2.1 presents the summary statistics of bilateral correlations of HP-filtered real consumption and output per capita (in logs). The mean bilateral

Table 2.1: Summary statistics of output, consumption, and risk sharing coefficients

	Mean	Median	Std. Dev.	Observations
A. Bilateral Correlation				
Output	0.422	0.479	0.316	1225
Consumption	0.340	0.388	0.329	1225
B. Risk Sharing Coefficient				
$\hat{\beta}_{ij}$	0.515	0.501	0.292	1225

Note: Bilateral correlation of output (consumption) is calculated as the correlation of HP-filtered real output (consumption) per capita in logarithms across all the state pairs over the sample period from 1977-2019. $\hat{\beta}_{ij}$ is estimated as the response of the relative consumption growth to the relative output growth as specified in equation 2.1.

output correlation is 0.422 which is higher than the consumption correlation 0.340. This stylized fact across states is consistent with that across countries, which is listed as a puzzle in international macroeconomics (Obstfeld and Rogoff (2000)) since the empirical fact contradicts the theoretical prediction in complete markets. This paper uses domestic data to understand the drivers for consumption synchronization, which also potentially sheds light on the puzzle in the international context.

We establish an empirical gravity model of risk sharing by deriving a cross-sectional prediction for consumption comovement across states. In particular, we explore the implications of geographic distance for bilateral consumption risk sharing by conducting a two-stage regression. In the first stage, we follow equation 2.1 to estimate the bilateral risk-sharing coefficients for all the state pairs over the sample period. Panel B of table 2.1 summarizes the statistics of the estimated coefficients $\hat{\beta}_{ij}$. The mean and median values are 0.515 and 0.501 respectively. The fact that $\hat{\beta}_{ij}$ is between 0 and 1 implies imperfect cross-state consumption risk sharing. In the second stage, we regress the estimated $\hat{\beta}_{ij}$ on the log of geographic distance:

$$\hat{\beta}_{ij} = \alpha + \gamma \log(dist_{ij}) + \Gamma X_{ij} + \nu_{ij}. \tag{2.2}$$

Our hypothesis is that state pairs with greater geographic distance exhibit weaker consumption risk sharing, since bilateral economic exchanges which facilitate consumption comovement potentially face frictions that increase with bilateral distance. γ in equation 2.2 is therefore expected to be positive.

To test the hypothesis with regression 2.2, we compile the following variables. We measure cross-state geographic distance by applying the Haversine formula to state capitals' longitude and latitude. In addition, we consider the distance based on the Commodity Flow Survey (CFS) to verify the robustness of our empirical findings.[5] The results reported in table 2.2 confirm our hypothesis that bilateral geographic distance and risk-sharing coefficients are significantly and positively correlated. In column (1), when distance rises by 1%, bilateral risk sharing weakens by 0.151 (or 0.402 standard deviations). In column (2) we control for state pairs' time-averaged GSP per capita and find that risk sharing is stronger for states with higher income levels. Therefore, bilateral risk sharing covaries with distance and income per capita in the same direction as in the classic gravity model of international trade. In column (3) we consider other geographic variables of the state pair including the product of their land sizes in square

[5]The CFS reports the shipment mileage between origin and destination ZIP code points for commodity flows used for domestic expenditure within the US. We use the average mileage of shipments between two states to calculate this CFS-based bilateral distance. See table 2.9 for this robustness check.

Table 2.2: Spatial pattern of risk sharing

Dep. Var: $\hat{\beta}_{ij}$	(1)	(2)	(3)	(4)
$\log(d_{ij})$	0.151***	0.156***	0.220***	0.211***
	(0.010)	(0.010)	(0.012)	(0.012)
$\log(\bar{y}_i \cdot \bar{y}_j)$		-0.099***	-0.061*	0.052
		(0.032)	(0.035)	(0.038)
Land Area			-0.038***	-0.022***
			(0.006)	(0.006)
Mainland			0.117***	0.079***
			(0.025)	(0.024)
Coastal			0.018	0.023*
			(0.014)	(0.014)
Contiguity			0.128***	0.102***
			(0.033)	(0.033)
Number of Neighboring States			-0.002	-0.005
			(0.004)	(0.004)
Number of MSA			0.001	-0.002*
			(0.001)	(0.001)
Number of Shared MSA			0.021	0.022
			(0.023)	(0.022)
Industrial Dissimilarity (Ind_{ij})				-5.480***
				(0.754)
Political Dissimilarity (Pol_{ij})				0.069**
				(0.032)
Observations	1225	1225	1225	1225
R^2	0.161	0.169	0.255	0.288

Note: Robust standard errors in parentheses. *** significant at 1%. The dependent variable is the risk sharing coefficient $\hat{\beta}_{ij}$, which is estimated using the real consumption and output data over 1977-2019. d_{ij} denotes the geographic distance between state i and j. $\bar{y}_i$ denotes the time-averaged output per capita of state i. Other control variables include a state-pair's geographic characteristics as well as political and industrial dissimilarity.

miles (in logs), the number of mainland and coastal states, a contiguity dummy which equals one for state pairs sharing borders, and the total number of neighboring states to capture the state pair's multilateral ties with adjacent states.[6] Besides, we have the

[6] The number of mainland and coastal states takes values 0, 1, or 2 for a pair of states. Mainland

total number of Metropolitan Statistical Area (MSA) and the number of MSA that geographically spans the state pair. MSA matters for the percentage of commuters whose location of residence and consumption differs from location of income.

Furthermore, we consider political and industrial proximity as potential factors for risk sharing based on the macro literature.[7] We measure a state's position on the political spectrum based on whether its voters chose a Republican or a Democratic candidate ($Pol_{it} = 0$ or 1) during presidential elections from 1976 to 2020, and take a state-pair's squared difference in the time-averaged values ($\bar{P}ol_i$) to measure political remoteness

$$Pol_{ij} = (\bar{P}ol_i - \bar{P}ol_j)^2. \tag{2.3}$$

For the dissimilarity of industrial profiles, we compute a state-pair's sectoral composition of output and aggregate the squared difference over sectors

$$Ind_{ij} = \sum_{s=1}^{S}(b_{i,s} - b_{j,s})^2, \qquad \text{where} \qquad b_{i,s} = \frac{\bar{Y}_{i,s}}{\sum_{s=1}^{S} \bar{Y}_{i,s}}. \tag{2.4}$$

$\bar{Y}_{i,s}$ denotes the output of sector s in state i averaged over the sample period sourced from the BEA.[8] As suggested by table 2.2 column (4), state pairs with greater political

states refer to the 48 contiguous states. Coastal states refer to the states that are not landlocked and instead have a coastline.

[7]For example, Parsley and Popper (2021) document stark business cycle asynchronicity among blue versus red states in the US, and reason that differences in fiscal policies potentially explain how political division shapes this pattern of risk sharing. Meanwhile, the complementarity of industrial structures influences and is influenced by economies' output and consumption synchronization, according to the empirical findings of Kalemli-Ozcan et al. (2003).

[8]To calculate sectoral shares in state-level output ($b_{i,s}$), we use the real sectoral output series

similarity and industrial dissimilarity exhibit a higher level of risk sharing, consistent with the results documented by Parsley and Popper (2021) and Kalemli-Ozcan et al. (2003). Meanwhile, the coefficient of distance remains economically and statistically significant.

In addition to the baseline estimation described above, we perform two sets of tests to verify the robustness of the gravity model. First, we consider alternative data sources for state-level consumption, price, and bilateral geographic distance. Second, we reconstruct measures of bilateral risk sharing after controlling for 1) state-level demographic variables which potentially shift aggregate demand over time including age, gender ratio, and education level, and 2) states' distinct exposure to aggregate country-level shocks. The results reported in Appendix 2.A.1 suggest that our finding remains robust.

The gravity model of risk sharing established above suggests the existence of frictions in the channels of risk sharing that covary with distance. We test for the underlying mechanism by examining the joint influences of distance and potential channels including trade, migration, and finance on consumption. Specifically, we compute bilateral linkages in these channels as the state-pair's mean value of bidirectional flows averaged over time. For example, bilateral trade linkages (Z_{ij}) are calculated with trade flows in logarithm

$$Z_{ij} = \sum_{t=1}^{T} \frac{\log(trd_{ijt}) + \log(trd_{jit})}{2T}. \tag{2.5}$$

(SAGDP9N) from the BEA, which reports data based on the 2012 North American Industry Classification System (NAICS) at the 3-digit level.

Bilateral trade and migration flows are obtained from the CFS and IRS respectively (see Appendix 2.A.2 for details). Financial flows are based on FDIC's deposit amount collected by financial institutions headquartered in one state and located in another.[9] Table 2.3 reports the regression results with estimated $\hat{\beta}_{ij}$ as the dependent variable and all the gravity variables from table 2.2 plus the three bilateral linkages as independent variables. The results show that $\hat{\beta}_{ij}$ still increases in distance but decreases in its interaction terms with bilateral trade, migration, and finance. The negative coefficients of the interaction terms suggest that these three channels alleviate the negative impacts of geography on cross-state consumption risk sharing.

After exploring the general covariance between risk sharing and distance using long-term data, we conduct an event study to verify the importance of geography for bilateral economic linkages including consumption comovement. Specifically, we focus on the North Dakota oil supply shock that started from the surprising discovery of oil by a petroleum geologist in 2006. The discovery provides a natural experiment for us to evaluate the impacts of a local output boost. The rapid oil extraction since the

[9] Comprehensive data for state-to-state financial flows are not existent to our knowledge, but the Federal Deposit Insurance Corporation (FDIC) bank statistics lists branch locations and deposits of its insured financial institutions. States i and j are hereby deemed to exhibit stronger financial ties when banks headquartered in i collect more deposits from branches located in j. It is the among the most comprehensive public data to document financial linkages across states. However, given the geographic concentration of the US banking industry and under-representation of bank deposits in total financial exchanges, it is not sufficient to empirically reflect bilateral financial flows or to structurally estimate the theoretical model with in the next section.

Table 2.3: Interaction of distance with different channels of risk sharing

Dep. Var: $\hat{\beta}_{ij}$	(1)	(2)	(3)	(4)
Indep. Var Z_{ij}	–	Trade	Migration	Finance
$\log(d_{ij})$	0.211***	0.423***	0.429***	0.218***
	(0.012)	(0.044)	(0.054)	(0.012)
Z_{ij}		0.206***	0.268***	5.4e-08***
		(0.042)	(0.053)	(1.8e-08)
$\log(d_{ij}) \times Z_{ij}$		-0.022***	-0.023***	-7.4e-09***
		(0.006)	(0.008)	(2.5e-09)
Other Gravity Var	Y	Y	Y	Y
Observations	1225	1225	1225	1225
R^2	0.288	0.307	0.360	0.293

Note: Robust standard errors in parentheses. *** significant at 1%. The dependent variable is the estimated risk sharing coefficient $\hat{\beta}_{ij}$. d_{ij} denotes the geographic distance between state i and j. Z_{ij} is the state-pair's mean value of bidirectional trade, migration, and financial flows averaged over time. Trade data are from the CFS, migration data are from the IRS, finance data here are based on FDIC's amount of deposit collected by financial institutions with a branch in one state and headquarter in another. Trade and migration flows are in logarithm and financial flows are in levels to keep the full sample of state pairs (given 700 out of 1225 observations as zeros). Other gravity variables include all the independent variables listed in table 2.2.

discovery has not only fueled the economic boom of North Dakota (ND hereafter) but also positively affected other states through their economic exchanges with ND.

To establish the spatial feature of economic linkages in the wake of the oil shock, we run a panel regression with all the state pairs formed by ND over the period from 1991 to 2019 where migration and trade data are available. The regression is specified as follows

$$X_{ijt} = \alpha_0 + \alpha_1 Oil_t + \sum_{m=1}^{T} \alpha_{2m} Oil_{t-m} + \alpha_3 \log(dist_{ij}) + \sum_{n=0}^{T} \alpha_{4n} Oil_{t-n} \times \log(dist_{ij})$$
$$+ \alpha_{5t} I_t + \alpha_{6j} I_j + \zeta_{ijt}. \qquad (2.6)$$

X_{ijt} represents bilateral variables of interest including migration flows (mig_{ijt}), trade values (trd_{ijt}), and relative per-capita consumption growth between state i as ND and j as any other state.[10] For migration and trade, we focus on the log of ND's population and goods inflows from other states to capture the spillover of the positive shock. For the relative consumption growth, we consider both $\Delta c_{ijt} \equiv \Delta \log c_{it} - \Delta \log c_{jt}$ and $\Delta \tilde{c}_{ijt} \equiv (\Delta \log c_{it} - \Delta \log c_{jt}) - (\Delta \log y_{it} - \Delta \log y_{jt})$. The latter can be regarded as the consumption growth unexplained by the output growth of ND relative to other states, which provides a more robust measure of consumption risk sharing. To isolate the responses of these variables to the oil shock as deviations from their long-term trend, we take the difference between the realization of these bilateral variables at time t and their mean values over the sample period, and use these demeaned values as dependent variables. In addition, we control for time fixed effects (denoted as I_t) which reflect the aggregate shocks that happen at time t and state fixed effects (I_j) to control for cross-state differences independent of the oil shock. Oil_t is a binary variable which is unity when t represents year 2006 and zero otherwise. We also consider medium-run effects of the shock by including lagged dummies Oil_{t-m} which equal one when the oil shock happens m years ago. In the baseline case, we set the maximum number of lags as three years for migration and consumption, and as eleven years for trade to get sufficient observations under its five-year data frequency. The key variable of interest to verify the importance of geography for economic linkages is $\sum_{n=0}^{T} \alpha_{4n}$, the linear combination of coefficient estimates for the interaction terms of the oil shock and bilateral distance.

[10] We do not include finance in this event analysis due to the lack of financial data. Even with FDIC's banking data, ND's observations are very scarce since it is not a major hub for the banking industry.

Table 2.4: Bilateral linkages after the oil shock

	(1)	(2)	(3)	(4)	(5)	(6)
Dep. Var:	log(trd)	log(mig)	log(trd)	log(mig)	Δc	$\Delta \tilde{c}$
Oil_t		0.124		0.123	-0.010	0.014
		(0.465)		(0.473)	(0.051)	(0.055)
$\sum_{m=1}^{T} Oil_{t-m}$	1.883*	-0.974	1.836*	-0.974	-0.045	0.098
	(0.967)	(0.599)	(0.992)	(0.608)	(0.079)	(0.064)
log($dist$)	0.012	0.013	0.006	0.014	-0.002	-0.001
	(0.075)	(0.014)	(0.352)	(0.057)	(0.008)	(0.009)
$\sum_{n=0}^{T} Oil_{t-n} \times \log(dist)$	-0.578*	-0.394***	-0.339	-0.393***	0.049***	0.040**
	(0.325)	(0.146)	(0.363)	(0.149)	(0.017)	(0.017)
State FE	N	N	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y	Y
Observations	244	1,360	244	1,360	1,372	1,372
R^2	0.657	0.645	0.688	0.645	0.650	0.676

Note: Robust standard errors in parentheses. *** significant at 1%, ** at 5%, and * at 10%. The dependent variables include North Dakota (ND)'s demeaned migration and trade inflows in logs from other states, as well as ND's per-capita consumption growth relative to other states (Δc), and the relative consumption adjusted for output growth ($\Delta \tilde{c}$). log($dist$) denotes the geographic distance between ND and other states. Oil_t is a dummy variable for the oil shock to ND in 2006. Its coefficient is missing in columns (1) (3) since the CFS trade data are not available that year.

Table 2.4 reports the regression results. Based on the interaction terms, bilateral economic linkages exhibit strong spatial patterns. As is shown in columns (1) and (2), a 1% increase in bilateral geographic distance lowers trade and migration flows from another state to ND by 0.578% and 0.394% respectively due to the oil shock.[11] This finding points to the barriers in these two channels that covary with geography which limit the scope of positive influences brought forth by ND's economic success. Consequently, residents from distant states are constrained from physically moving to or exporting goods to the booming state. Such barriers can also account for the spatial

[11]These results from columns (1) and (2) become weaker in columns (3) and (4) where state fixed effects are added, particularly given the limitation of trade data with low frequency and high sparsity.

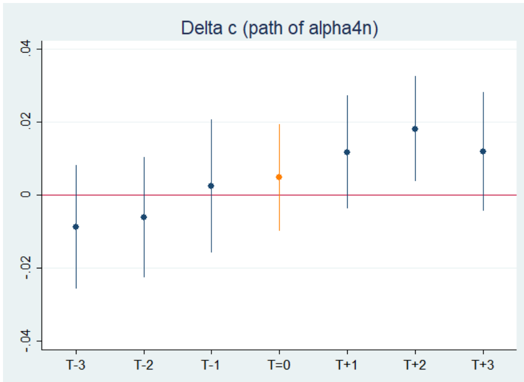
pattern of consumption. As is reported in columns (5) and (6), ND's per-capita consumption growth is larger in magnitude relative to that of more distant states. From column (5), a 1% increase in distance raises ND's relative consumption growth driven by its oil shock by 0.049%. Figure 2.2 plots the time path of α_{4n} and its cumulative change, which shows a noticeable slope increase after the oil shock. For example, the cumulative consumption growth three years after the shock in Nebraska is 8.7% higher than in Florida. This result, which suggests that ND's consumption is more synchronized with neighboring states', indicates that geography plays an essential role in shaping the variation in consumption comovement. The result remains robust in column (6) where we adjust consumption for output differentials, which further implies that consumption risk sharing deteriorates when distance rises.

To conclude this empirical section, both the gravity model analysis and the ND event study verify that geographic distance is important for consumption synchronization. We build a structural model in the next section to explain this spatial pattern of consumption.

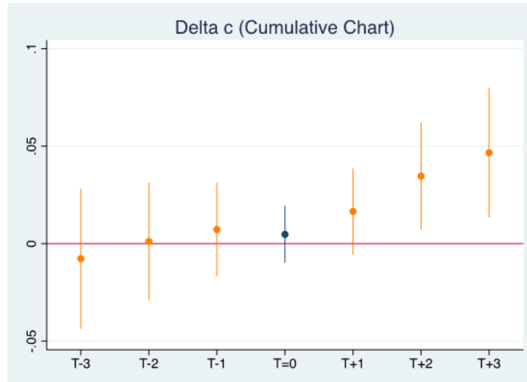
2.3 Theoretical Model

This section develops a model to explain the potential influences of geography on consumption through trade, migration, and financial channels. Section 2.3.1 describes the model setup. Section 2.3.2 discusses mechanism of how different channels interact to jointly influence consumption in a symmetric two-state scenario. Section

Figure 2.2: Time series path of α_{4n} for relative consumption growth



(a) α_{4n}



(b) $\sum_{n=0} \alpha_{4n}$

Note: This figure plots the time series pattern of the coefficient estimate α_{4n} when the relative consumption growth Δc is the dependent variable and the interaction term for the oil shock and distance is the independent variable (column (5) in table 2.4). (a) shows α_{4n}'s estimate and confidence interval at each time point, where $T = 0$ represents year 2006 where the oil shock happened. (b) shows cumulative changes $\sum_{n=0} \alpha_{4n}$ over time.

2.3.3 provides quantitative analyses to deliver fiscal policy implications in a multi-state setting.

2.3.1 Setup

The economy is populated by a continuum of infinitely-lived homogeneous households which reside in different states indexed $i \in \{1, 2, ..., \mathcal{I}\}$. States are interconnected through trade, migration, and finance channels.

Each state produces two intermediate goods: tradables (T) and nontradables (NT). The production of intermediate goods in state i sector $s \in \{T, NT\}$ combines capital $K_{is,t}$ and labor $L_{is,t}$ with a Cobb-Douglas technology:

$$Y_{is,t} = A_{i,t} K_{is,t}^{\alpha} L_{is,t}^{1-\alpha}. \tag{2.7}$$

The state-level productivity $A_{i,t}$ which constitutes a vector $A_t = [A_{1,t}, A_{2,t}, ..., A_{\mathcal{I},t}]$ follows a joint AR(1) process subject to shocks $\epsilon_t = [\epsilon_{1,t}, \epsilon_{2,t}, ..., \epsilon_{\mathcal{I},t}]$ with a persistence coefficient matrix ρ and a contemporaneous covariance matrix Σ:

$$A_t = \rho A_{t-1} + \epsilon_t. \tag{2.8}$$

The final goods for consumption consist of tradables $C_{iT,t}$ and nontradables $C_{iNT,t}$:

$$C_{i,t} = C_{iT,t}^{\nu} C_{iNT,t}^{1-\nu}, \tag{2.9}$$

where ν is the weight of tradables. Similarly, the final goods for investment, with price denoted as $P_{Ii,t}$, tradables' weight as ν_I, and quantity $I_{i,t}$ specified as

$$I_{i,t} = I_{iT,t}^{\nu_I} I_{iNT,t}^{1-\nu_I}, \tag{2.10}$$

add to the capital stock in state i subject to depreciation δ

$$K_{i,t} = (1-\delta) K_{i,t-1} + I_{i,t}. \tag{2.11}$$

The market clearing conditions for factors of production and for nontradable goods in state i are respectively given by

$$K_{i,t} = K_{iT,t} + K_{iNT,t}, \qquad L_{i,t} = L_{iT,t} + L_{iNT,t}, \tag{2.12}$$

$$Y_{iNT,t} = C_{iNT,t} + I_{iNT,t}. \tag{2.13}$$

Meanwhile, tradable goods for consumption and investment will be a CES bundle of intermediate goods sourced from all the states:

$$X_{iT,t} = C_{iT,t} + I_{iT,t}, \qquad \text{where} \qquad X_{iT,t} = (\sum_{j=1}^{\mathcal{I}} X_{ji,t}^{\frac{\phi-1}{\phi}})^{\frac{\phi}{\phi-1}}. \tag{2.14}$$

However, trade from j to i is subject to an iceberg cost $\tau_{ji} \geq 1$, which together with the price of j's output $p_{j,t}$, appears in the aggregate price of tradables in state i:

$$P_{iT,t} = [\sum_{j=1}^{\mathcal{I}} (\tau_{ji} p_{j,t})^{1-\phi}]^{\frac{1}{1-\phi}}. \tag{2.15}$$

Based on the price, bilateral trade flows from j to i at t follow

$$X_{ji,t} = \pi_{ji,t} X_{iT,t}, \qquad \text{where} \qquad \pi_{ji,t} = (\frac{\tau_{ji} p_{j,t}}{P_{iT,t}})^{-\phi}. \tag{2.16}$$

In addition to trade, states are connected through finance. In modeling the asset market, we develop and solve a portfolio choice problem following the asset home bias literature. The main purpose of setting up the portfolio choice problem is to capture the variation of bilateral asset positions in a multi-economy setting.[12] The bilateral variation requires modeling asset holdings and financial frictions at state-pair instead of state-specific levels. Therefore, we introduce bilateral financial friction $e^{-f_{ij}}$ as an iceberg transaction cost when state j repatriates financial returns from state i.[13]

[12]Empirical evidence for this bilateral variation includes the gravity model of cross-country financial flows (Portes and Rey (2005)), the 'home bias at home' phenomenon in the domestic context (Coval and Moskowitz (1999)), and the FDIC banking statistics including the results from table 2.3 in this paper.

[13]Modeling transaction costs is not the only way to introduce frictions in the financial channel. In particular, Okawa and Van Wincoop (2012) discuss alternative bilateral financial frictions, including information costs, which can also rationalize the geographic patterns of financial flows.

Following Coeurdacier and Rey (2013) and Heathcote and Perri (2013), we assume that each state issues equities, whose dividend payout is capital income net of investment expenditure

$$D_{i,t} = \alpha p_{i,t} Y_{i,t} - P_{Ii,t} I_{i,t}, \tag{2.17}$$

where $Y_{i,t} = Y_{iT,t} + Y_{iNT,t}$ is the aggregate output in state i. The returns to i's assets include these dividends and the changes in asset prices denoted as $q_{i,t}$:

$$R_{i,t} = \frac{q_{i,t} + D_{i,t}}{q_{i,t-1}}. \tag{2.18}$$

We assume there is a mutual fund in every state which makes investment decisions on behalf of its households. The mutual fund constructs a portfolio of assets to maximize the expected lifetime utility from consumption of a household living in the state. In particular, its objective function is

$$\max \sum_{t=0}^{\infty} \beta^t \frac{c_{i,t}^{1-\sigma}}{1-\sigma}, \tag{2.19}$$

where $c_{i,t}$ denotes consumption per-capita of state i at time t. A household has the right to an equal share of the fund as long as it resides there.[14] To solve the portfolio choice problem, we use the Devereux and Sutherland (2011) and Tille and Van Wincoop (2010)

[14] To simplify the portfolio choice problem, we assume households are myopic and expect themselves to stay in the state when deciding on saving for the next period. Under this assumption, households only care about the expected consumption per-capita in their state of residence during the next period, based on which the local mutual fund makes investment decisions (2.19). A future extension of this baseline scenario is to relax the assumption and allow households to consider their own migration probabilities which prompt them to reduce saving and raise current consumption when making investment decisions.

solution method which combines a second-order approximation of the Euler equations and a first-order approximation of other model equations. Specifically, we evaluate state i's Euler equation

$$E_t[\frac{U'(c_{i,t+1})}{P_{i,t+1}}R_{i,t+1}] = E_t[\frac{U'(c_{i,t+1})}{P_{i,t+1}}e^{-f_{ji}}R_{j,t+1}], \qquad \forall j \in [1, \mathcal{I}], \tag{2.20}$$

and take its difference from state j's Euler equation to derive a portfolio determination equation (see Appendix 2.A.3.2 for the derivation in an example with three states):

$$E_t[\sigma(\hat{c}_{i,t+1} - \hat{c}_{j,t+1}) + (\hat{P}_{i,t+1} - \hat{P}_{j,t+1})]\hat{R}_{x,t+1} = \frac{1}{2}\mathcal{F}, \tag{2.21}$$

where a hat above a variable denotes its log-deviation from the steady state of the economy. $P_{i,t}$ denotes i's price level, $R_{x,t+1}$ is the vector of excess financial returns, and $\mathcal{F}$ is a matrix of financial frictions. If markets are complete such that the Backus-Smith condition holds:

$$E_t[\sigma(\hat{c}_{i,t+1} - \hat{c}_{j,t+1}) + (\hat{P}_{i,t+1} - \hat{P}_{j,t+1})] = 0, \tag{2.22}$$

the implied financial frictions in matrix $\mathcal{F}$ should equal zero. Therefore, we infer the magnitude of bilateral financial frictions from equation 2.21 based on consumption patterns. Since these financial frictions are estimated as the wedge that generates the deviation of consumption from the prediction derived under complete markets, they can be interpreted as all the barriers to financial arrangements that cause market incompleteness impairing consumption risk sharing.[15]

[15]This estimation strategy based on consumption data allows us not to take a strong stand on the exact form these financial frictions take in the real world, which may include borrowing constraints

If $\alpha_{j,i,t}$ denotes i's holding of j's assets derived from the portfolio choice problem, and state $\mathcal{I}$'s asset is a numeraire asset whose return is $R_{\mathcal{I},t}$, state i's wealth position follows

$$\mathcal{W}_{i,t+1} = e^{-f_{\mathcal{I}i}} R_{\mathcal{I},t} \mathcal{W}_{i,t} + \sum_{j}^{\mathcal{I}} \alpha_{j,i,t} (e^{-f_{ji}} R_{j,t} - e^{-f_{\mathcal{I}i}} R_{\mathcal{I},t}) + w_{i,t} L_{i,t} + T_{i,t} - P_{i,t} C_{i,t} - P_{Ii,t} I_{i,t}. \tag{2.23}$$

$T_{i,t}$ denotes the tax transfer state i receives, which is introduced to capture fiscal policies that also play an essential role in intranational risk sharing.

Households' objective is to maximize their expected lifetime utility. At the beginning of every period, a household living in state i supplies labor, collects labor and financial income, and decides on consumption. It derives utility from consumption $c_{i,t} = \frac{C_{i,t}}{N_{i,t}}$ and disutility from labor hours $l_{i,t} = \frac{L_{i,t}}{N_{i,t}}$ in its state of residence with population $N_{i,t}$:

$$U_{i,t} = \frac{c_{i,t}^{1-\sigma}}{1-\sigma} - \kappa \frac{l_{i,t}^{1+\eta}}{1+\eta}, \tag{2.24}$$

where σ captures the degree of risk aversion and $\frac{1}{\eta}$ is the elasticity of labor supply.

After earning and spending its income in state i, the household decides whether and where it wants to migrate. When it makes the decision, it takes into account a non-pecuniary migration cost $d_{ij} \geq 0$ when moving from state i to j. The household collects an idiosyncratic benefit $\omega_j \sim F(\omega)$ from being located in state j at the end of the period.

states face when raising funds, informational frictions that prohibit bilateral capital flows, and asset transaction costs that cause market inefficiency. It would be difficult to identify and quantify all of these barriers to financial investment, especially given the lack of comprehensive state-to-state financial data. In a similar spirit, Fitzgerald (2012a) also infers asset market frictions from consumption data.

ω_j can be considered as a non-monetary benefit, such as weather and culture, that adds to the utility of living in j. Following Artuc et al. (2010), we assume ω_j is i.i.d across households and drawn from an extreme-value distribution with zero mean:

$$F(\omega) = \exp[-e^{\omega/\theta-\gamma}]. \tag{2.25}$$

Therefore, a household's expected value of being in state i at time t is

$$V_{i,t} = U_{i,t} + \beta E(V_{i,t+1}) + \sum_{j}^{\mathcal{I}} \int (\bar{\omega}_{ij,t} + \omega_{jt}) f(\omega_j) \Pi_{k\neq j} F(\bar{\omega}_{ij,t} - \bar{\omega}_{ik,t} + \omega_{jt}) d\omega_j. \tag{2.26}$$

From the three components on the right side of the equation, the expected value consists of the current utility the household obtains, the base value of staying in the state, and option value of moving from the state to others in the future. $\bar{\omega}_{ij,t}$ denotes the cutoff benefit that makes the household indifferent between staying in i and moving to j at t:

$$\bar{\omega}_{ij,t} \equiv \beta[E(V_{j,t+1}) - E(V_{i,t+1})] - d_{ij}. \tag{2.27}$$

Under the distributional assumption of ω, the share of migrants from i to j is

$$m_{ij,t} = \frac{\exp(\bar{\omega}_{ij,t}/\theta)}{\sum_{k=1}^{\mathcal{I}} \exp(\bar{\omega}_{ik,t}/\theta)}, \tag{2.28}$$

The law of motion for population in state i hence follows

$$N_{i,t} = \sum_{j=1}^{\mathcal{I}} m_{ji,t-1} N_{j,t-1}. \tag{2.29}$$

To summarize the description of the model, the general equilibrium consists of prices and quantities such that 1) firms set output and price to maximize profit, 2) households choose consumption and migration, mutual funds construct portfolios, to maximize households' expected lifetime utility, and 3) commodity, factor, and asset markets clear.

2.3.2 Two-state Analysis

This section quantitatively explores the mechanism through which different channels interact with each other and affect consumption risk sharing. We extend the workhorse BKK model by incorporating trade, migration, and financial linkages subject to frictions across two symmetric economies.

In terms of parameterization, the model is calibrated to the US annual data for cross-state analysis. Table 2.5 summarizes the parametric assumptions under which the baseline two-state framework is solved. Panels (I) and (II) list the parameters whose values are either standard in the macro literature or estimated from the US aggregate economy. For example, we estimate labor share in production $1-\alpha$ to be 0.59 by dividing the labor earnings by the output data, both from the BEA, over the period of 1977-2019. We set the share of consumption expenditure on tradables (ν) as 0.31 following Johnson (2017b), who estimates the value based on the US CPI expenditure data from the BEA. We set the weight of tradables in investment (ν_I) as 0.4 following Bems (2008b) based on the OECD input-output table. Moreover, we follow Simonovska and Waugh (2014) and Artuc et al. (2010) when setting elasticities of trade and migration respectively.

Panel (III) of table 2.5 characterizes the joint productivity process for a pair of states. We choose Georgia and Ohio (GA and OH for brevity), the median states in terms of output per capita, as our sample of analysis. We first calculate the total factor productivity (TFP) proxied by the Solow residual in each state $i \in \{\text{GA, OH}\}$ at time

t from

$$\log(A_{i,t}) = \log(Y_{i,t}) - \alpha \log(K_{i,t}) - (1-\alpha)\log(L_{i,t}), \tag{2.30}$$

where $Y_{i,t}$ and $L_{i,t}$ are output and number of employees in state i in year t from the BEA. State-level capital stock $K_{i,t}$ is not directly available, so we construct the measure following Garofalo and Yamarik (2002)'s method. Specifically, we apportion national capital stock to states based on their industry-level income data (see Appendix 2.A.2 for details). After we calculate state-level TFP, we detrend the series with the HP filter and estimate a joint AR(1) process, with estimated persistence and covariance matrices of GA and OH's productivity reported in table 2.5.

Panel (IV) of table 2.5 lists the values of bilateral frictions calibrated to the state pair. Trade, migration, and financial costs are estimated to match three targeted moments: the mean export-to-output ratio (0.392) and emigrant-to-population ratio (0.028), and the coefficient of risk sharing (0.541) of GA and OH over the sample period. When estimating trade and migration frictions simultaneously, we start with an initial guess for the combination of the two frictions, and solve for the corresponding wage rates and labor hours given the frictions that satisfy the labor market clearing condition. Then we update the guess and repeat the procedure until the model-predicted export-to-output and emigrant-to-population ratios converge to those in the data. In the asset market, we infer financial frictions from consumption based on the Euler equation 2.21, to capture any barriers in the financial channel that may cause market incompleteness. Calibrating financial frictions with this method involves three steps. First, we obtain the coefficient matrices necessary for portfolio choice from the first-order dynamics of the model (see Appendix 2.A.3.2 for technical details). Second, we solve for asset holdings under which the model-implied bilateral risk sharing matches that estimated from the data. Third, we use the asset holdings to recover financial frictions from portfolio determination equations.

Table 2.5: Parametrization

Parameter	Description	Value	Source
		(I)	
β	Annual discount factor	0.95	
σ	Coefficient of relative risk aversion	1	Macro
δ	Capital depreciation	0.06	Literature
η	Inverse of elasticity of labor supply	0.5	
		(II)	
ν	Weight of tradables in consumption	0.31	Johnson (2017b)
ν_I	Weight of tradables in investment	0.40	Bems (2008b)
α	Capital intensity in production	0.41	BEA
θ-1	Elasticity of trade	4.1	Simonovska and Waugh (2014)
ϕ	Elasticity of migration	4.5	Artuc et al. (2010)
		(III)	
ρ	Persistence matrix of productivity	$\begin{bmatrix} 0.65 & 0.06 \\ 0.04 & 0.53 \end{bmatrix}$	Estimated from GA and OH's TFP
Σ	Covariance matrix of shocks	$\begin{bmatrix} 1.21 & 1.25 \\ 1.25 & 2.56 \end{bmatrix} e^{-4}$	
		(IV)	
τ	Trade cost	1.031	Calibrated to match GA and OH's mean
d	Migration cost	19.58	export-to-output, emigrant-to-population,
f	Financial cost	3e-5	and consumption comovement

Given the specified parametrization, table 2.6 compares the contemporaneous correlations of variables in the calibrated model with those in the data. Panel (I) reports the cross-state comovement of output and consumption. The model performs well in matching empirical moments at both aggregate and per-capita levels. In either case, output exhibits stronger cross-state synchronization than consumption, consistent with empirical facts. Panel (II) presents the correlation between a state's own variables with its output per capita. Consumption per capita is highly procyclical while scaled net export (NX/Y) is countercyclical.[16] In addition, the contemporaneous correlation

[16]These findings are also consistent with the international stylized facts documented by Mendoza

Table 2.6: Contemporaneous correlations of variables

	Model	Data
	(I) *Cross-state Correlation*	
Output $\rho(Y_1, Y_2)$	0.85	0.84
Consumption $\rho(C_1, C_2)$	0.79	0.78
Output per capita $\rho(y_1, y_2)$	0.84	0.88
Consumption per capita $\rho(c_1, c_2)$	0.82	0.82
	(II) *Correlation with Self Output*	
Consumption per capita $\rho(c, y)$	0.95	0.91
Net exports $\rho(NX/Y, Y)$	-0.04	-0.03
Population $\rho(N, Y)$	-0.01	-0.02

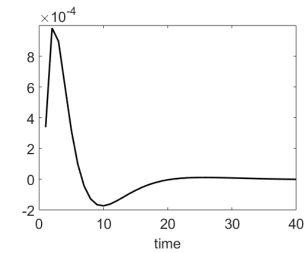
Note: This table reports the contemporaneous correlations of HP filtered data and those in the calibrated model. Panel (I) reports the cross-state comovement of output and consumption at the aggregate (denoted as Y_i, C_i) and per capita (denoted as y_i, c_i) levels. Panel (II) reports the comovement of a state's scaled net exports (NX/Y) and population (N) with its own output, as well as the correlation between its consumption and output per capita.

between population and output is negative in both the model and data. Nevertheless, this correlation does not reflect the cumulative effects caused by delayed migration decisions under frictions. To overcome such limitations, we examine the dynamics of variables by plotting impulse response functions (IRFs).

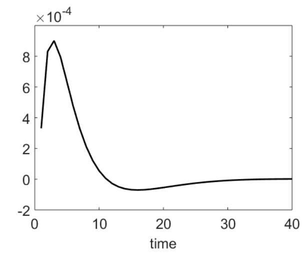
Figure 2.3 shows the IRFs following a one-standard-deviation innovation to state 1's productivity. State 1 experiences a stronger output boost in response to its local productivity shock than state 2, as shown in the spike of relative output per capita ($\frac{y_1}{y_2}$) in figure 2.3a. In comparison, the response of relative consumption per capita ($\frac{c_1}{c_2}$) in figure 2.3b is not as volatile, which provides evidence for consumption risk sharing through the following channels. In the trade channel (2.3c), state 1 witnesses a terms-of-trade (TOT) depreciation as its exports become relatively cheaper under increased

(1991) and Backus et al. (1992b).

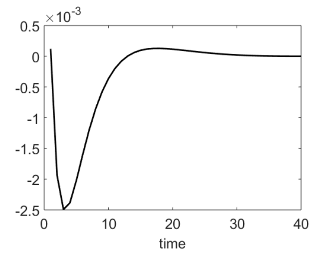
Figure 2.3: Impulse response functions after state 1's positive productivity shock



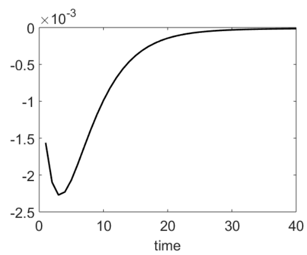
(a) Output $\frac{y_1}{y_2}$



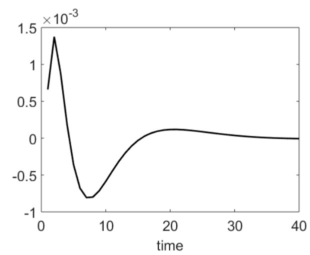
(b) Consumption $\frac{c_1}{c_2}$



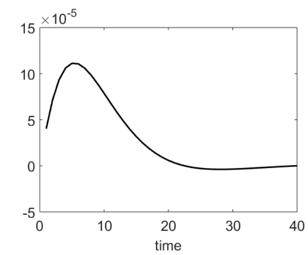
(c) TOT $\frac{p_1}{p_2}$



(d) Wealth 1



(e) Investment $\frac{I_1}{I_2}$

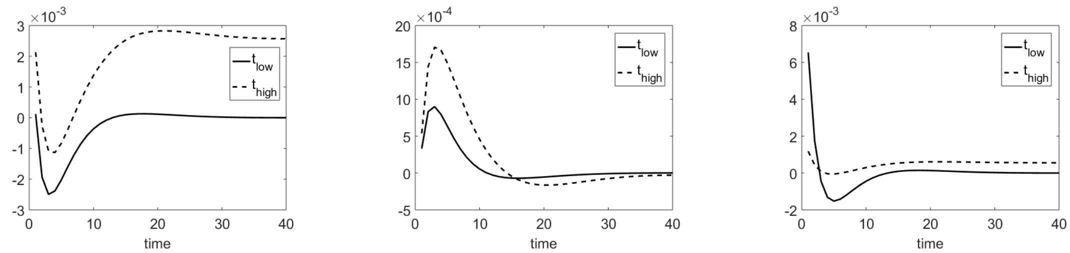


(f) Population N_1

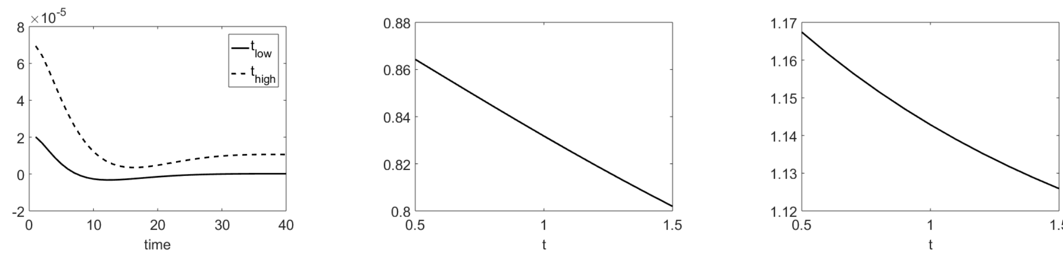
Note: This figure plots the impulse response functions to a one-standard-deviation innovation in state 1's productivity. Variables under examination include the cross-state ratio of output per capita (2.3a), consumption per capita (2.3b), price of output or terms-of-trade (2.3c), and investment expenditure (2.3e), as well as state 1's external wealth (2.3d) and population (2.3f).

supply to clear the goods market. This depreciation helps increase the consumption of state 2 by raising its relative nominal income and making its imports more affordable. Meanwhile, state 1 has a negative external wealth position (2.3d) which suggests that it borrows from state 2. This could be understood from the fact that capital resources are allocated to the more productive economy where returns to capital are higher, which contributes to state 1's relative investment spike shown in figure 2.3e. This cross-economy investment financing facilitates risk sharing, as is argued by Heathcote and Perri (2013). Lastly, population flows into state 1 (2.3f), which raises the number of households among which the increased aggregate consumption is shared and hence helps to equalize consumption per capita across states.

Figure 2.4: IRFs and consumption moments under different trade costs



(a) IRF of TOT $\frac{p_1}{p_2}$ (b) IRF of consumption $\frac{c_1}{c_2}$ (c) IRF of export$_{2\to1}$



(d) IRF of migration$_{2\to1}$ (e) $\rho(c_1, c_2)$ and trade cost (f) $\bar{c}_i$ and trade cost

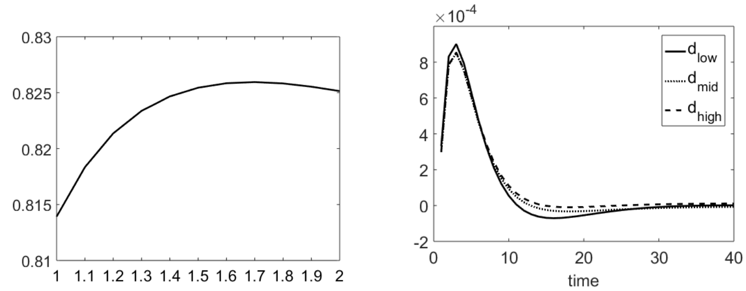
Note: Figures 2.4a–2.4d plot the impulse response functions to a one-standard-deviation innovation in state 1's productivity. Variables include state 1's terms of trade TOT (2.4a) and consumption ratio to state 2's (2.4b), state 2's export (2.4c) and migration (2.4d) to state 1. Solid lines are IRFs under calibrated trade cost (t_{low}), while dashed lines are IRFs under counterfactual trade cost whose value is twice as large as the calibrated value (t_{high}). Figure 2.4e plots the correlation coefficient across states and figure 2.4f plots the steady-state value for consumption per capita under different multipliers for the calibrated trade cost.

We conduct comparative static analyses by varying frictions in different channels to see how they interact to influence consumption. Figure 2.4 plots the IRFs when trade cost is 1 (t_{low}) and 2 (t_{high}) times the calibrated value while other parameters remain unchanged. Under a higher trade cost, state 1's TOT depreciation in 2.4a is diminished. Turning off this price adjustment in the trade channel limits the consumption gain of state 2, which is reflected in 2.4b where relative consumption of state 1 becomes more volatile. For bilateral economic exchanges, a higher trade cost not only poses barriers for commodity to move across states in 2.4c, but also pushes more population to migrate from state 2 to 1 in 2.4d due to the worsening consumption inequality caused by the trade friction. In this process, households switch from trade to migration as means of consumption risk sharing. Yet, this is not sufficient to leave consumption unaffected as figure 2.4e suggests that a higher trade cost reduces consumption correlation across states.[17] Besides, the steady-state level of consumption in 2.4f decreases in trade costs that cause loss of tradable goods during transportation. Based on these results, eliminating trade costs will both raise consumption and facilitate cross-state risk sharing.

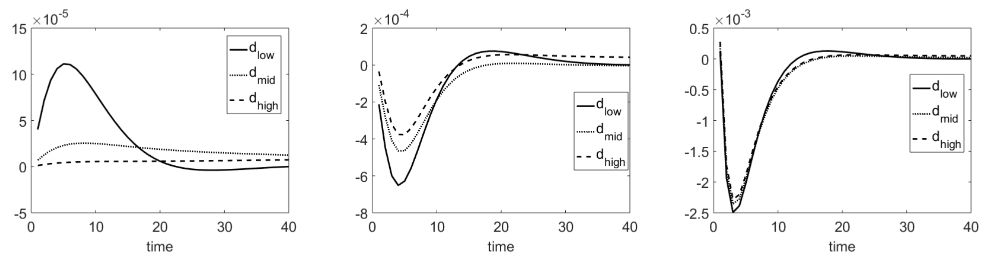
We proceed to conduct analysis in the migration channel. Figure 2.5a suggests a non-monotonic pattern between consumption correlation and migration cost. To understand this pattern, we plot the IRFs when migration cost is 1 (d_{low}), 1.5 (d_{mid}), and 2 (d_{high}) times the calibrated value. When the migration cost decreases from mid

[17]We calculate the model-predicted consumption correlation under counterfactual frictions by following three steps. Step 1, we calculate the equilibrium values of all the variables on the real side of the economy under specific trade and migration frictions. Step 2, we solve the portfolio choice problem under financial frictions by evaluating the first-order dynamics of the real-side of the economy and then the second-order expansion of the portfolio equation (see appendix 2.A.3.2 for details). Step 3, we simulate productivity shocks to the economy that encompasses both real and financial allocations and compute the resulting bilateral consumption comovement.

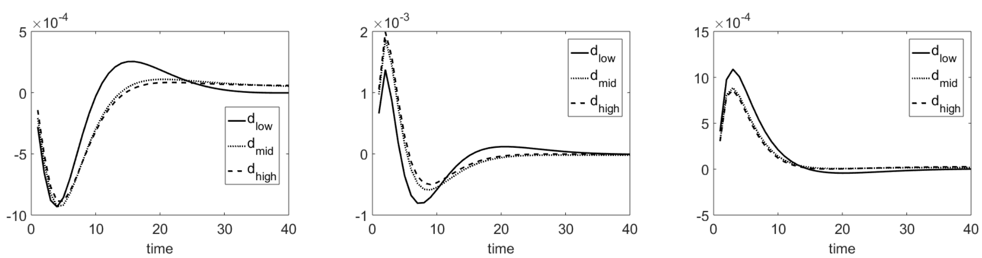
Figure 2.5: Consumption comovement and IRFs under different migration costs



(a) $\rho(c_1, c_2)$ and migration cost (b) IRF of consumption p.c. $\frac{c_1}{c_2}$



(c) IRF of population 1 (d) IRF of wage $\frac{w_1}{w_2}$ (e) IRF of TOT $\frac{p_1}{p_2}$



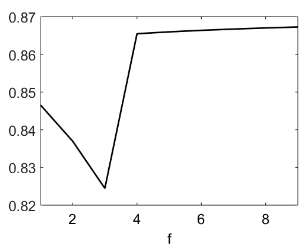
(f) IRF of capital return $\frac{r_1}{r_2}$ (g) IRF of investment $\frac{I_1}{I_2}$ (h) IRF of consumption $\frac{C_1}{C_2}$

Note: Figure 2.5a plots the bilateral correlation of consumption per capita under different multipliers for the calibrated migration cost. Figures 2.5b–2.5h plot the impulse response functions (IRFs) to a one-standard-deviation innovation in state 1's productivity. Variables include cross-state ratio of consumption per capita (2.5b), wage (2.5d), output price (2.5e), capital return (2.5f), investment (2.5g), aggregate consumption (2.5h), and state 1's population (2.5c). Solid, dotted, and dashed lines represent IRFs when the migration cost is 1 (d_{low}), 1.5 (d_{mid}), and 2 (d_{high}) times the calibrated value respectively.

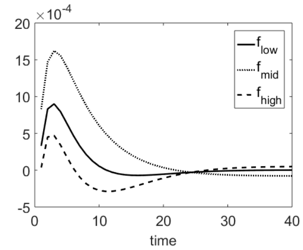
to low, more population flows into state 1 after its productivity shock (2.5c), which causes a larger drop in relative wage (2.5d). This decline of wage as a production cost exacerbates the TOT depreciation of state 1 (2.5e), which also reduces state 1's relative nominal marginal product of capital during the initial periods (2.5f). This lower capital return discourages physical capital investment (2.5g) and encourages households in state 1 to raise their consumption (2.5b, 2.5h) which becomes even larger than state 2's right after the productivity shock. This explains why consumption correlation declines when migration cost decreases if the cost is in a low range. If the migration cost is in a high range, it no longer significantly affects factor prices or consumption-investment decisions (2.5f-2.5h). Consumption synchronization is impaired if the migration cost changes from mid to high, because a higher cost deters population from moving, while migration would help narrow the difference in consumption per capita across states. Hence based on the non-monotonic pattern in figure 2.5a, lowering migration costs will facilitate consumption risk sharing for states faced with high costs, but not for states that start with low migration costs.

Lastly, we explore the pattern of consumption comovement under different financial frictions. Figure 2.6a suggests that consumption correlation does not vary monotonically or smoothly with financial frictions. To understand this pattern, we plot the IRFs when the financial friction is 1 (f_{low}), 3 (f_{mid}), and 9 (f_{high}) times the calibrated value. When the financial friction increases from low to mid, consumption comovement becomes weaker. This is because a higher cost of holding foreign assets tilts portfolios more toward domestic assets. Each state's consumption, driven more by

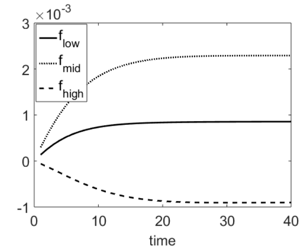
Figure 2.6: Consumption comovement and IRFs under different financial frictions



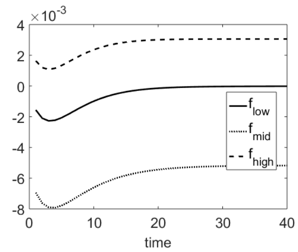
(a) $\rho(c_1, c_2)$ and f



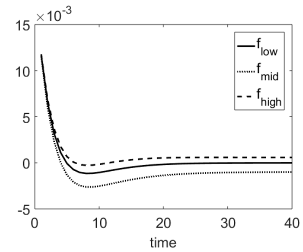
(b) IRF of consumption $\frac{c_1}{c_2}$



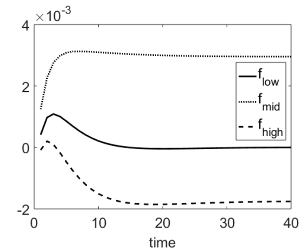
(c) IRF of population 1



(d) IRF of wealth 1



(e) IRF of investment 1



(f) IRF of consumption $\frac{C_1}{C_2}$

Note: Figure 2.6a plots the bilateral correlation of consumption per capita under different multipliers for the calibrated financial friction. Figures 2.6b–2.6f plot the impulse response functions (IRFs) to a one-standard-deviation innovation in state 1's productivity. Variables include state 1's population (2.6c), wealth (2.6d), physical investment (2.6e), and cross-state ratio of aggregate consumption (2.6f) and consumption per capita (2.6b). Solid, dotted, and dashed lines represent IRFs when the financial friction is 1 (f_{low}), 3 (f_{mid}), and 9 (d_{high}) times the calibrated value respectively.

its own output performance, is hence less synchronized with each other. Therefore, a higher financial friction strengthens the relative consumption growth of state 1 after its productivity boost (2.6b), which attracts more population inflows (2.6c). What causes the discontinuity in figure 2.6a is the drastic change in the migration pattern when financial friction is even higher. When the friction further increases from mid to high, state 1 has to start saving for its own expenditure, shown as a positive wealth position in (2.6d). This saving raises investment (2.6e) but crowds out consumption (2.6f).

Lower aggregate consumption induces population to move out of state 1 (2.6c), which equalizes consumption per capita across states and generates a higher consumption comovement in figure 2.6a. In this process, migration replaces finance as a major channel for consumption synchronization when the latter faces greater barriers.

From these comparative static analyses, different channels of risk sharing interact to jointly shape consumption comovement. Examining them in isolation without considering their interplay may yield incorrect policy predictions. The next section builds on these mechanisms to design macro policy that addresses consumption disparity.

2.3.3 Multi-state Analysis

This section evaluates the quantitative predictions in an asymmetric multi-state setting to deliver policy implications. Compared to the symmetric two-state case in section 2.3.2, states have different economic sizes and wealth positions calibrated to the data. A state's change in its net wealth position, which equals the difference between its aggregate expenditure and income especially tax transfers, also reflects other means of risk sharing including fiscal federalism beyond the three channels. Meanwhile, the multilateral framework ensures the clearing of goods, labor, and financial markets in aggregate.

Ideally, a household in state i considers $\mathcal{I} = 50$ states when making economic decisions in the three channels. One computational challenge we face when solving the large-scale DSGE model is that the coefficient matrices that cover all the $\mathcal{I}$ states are badly scaled given states' uneven sizes and sparse bilateral linkages. Therefore, using these matrices to derive portfolio choice with higher-order perturbation yields unreliable numerical predictions.[18] To overcome this challenge, we propose a trilateral framework that consists of a state-pair and the rest of the economy (ROE) that sums up all the states except for the pair under examination. This trilateral framework, which is applied to all the $\frac{1}{2}\frac{\mathcal{I}}{\mathcal{I}-1} = 1225$ state pairs, enables the analysis of both bilateral linkages between the pair and multilateral resistance exerted on the pair from all the other states in the spirit of Anderson and Van Wincoop (2003). Appendix 2.A.3 provides more details of the quantitative model, including the calibration strategy for different frictions in 2.A.3.1.[19]

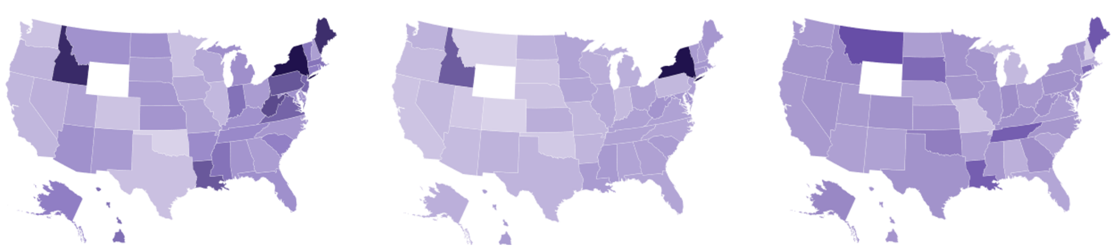
To provide a first glance of the estimated frictions in the three channels of risk sharing, we use Wyoming as an example by showing the heatmaps of its estimated

[18] The badly-scaled coefficient matrices both make the Blanchard-Kahn condition hard to be satisfied and generate extreme values for numerical results even when the condition holds. This issue worsens as solving for portfolio choice requires 2nd-order approximations, which are likely to generate explosive paths even when corresponding linear approximations are stable (Fernández-Villaverde et al. (2016)).

[19] In particular, financial frictions are estimated from the consumption data to capture barriers that cause the deviation of consumption from the allocation in complete markets. Table 2.12 compares these model-predicted frictions with bilateral banking linkages based on the FDIC data, and find states with stronger banking linkages are predicted to face lower frictions. Although this evidence provides some external validity, financial frictions take many other forms beyond the banking sector, including transaction costs, financial liquidity, and informational frictions in different asset markets. Given the scarcity of state-to-state financial data, estimating bilateral financial friction from consumption which reflects market incompleteness offers much theoretical appeal and flexibility.

bilateral frictions with others in figure 2.7. Each type of bilateral friction is calculated as the geometric mean of outbound and inbound frictions ($x_{WY,i},\ x_{i,WY},\ i \in [1, \mathcal{I}], x \in \{\tau, d, f\}$) between Wyoming (in white) and any other state. In general, states located within a smaller radius from Wyoming exhibit lower frictions with the state. For example, the migration cost between Wyoming and a neighboring state Colorado is the lowest, whose value is approximately 1/3 of that between Wyoming and Hawaii. This spatial pattern is consistent with the observation in figure 2.1 that Wyoming shows stronger economic linkages with states in closer proximity. However, there are exceptions to the pattern. Idaho, another neighboring state of Wyoming, is estimated to inflict relatively high trade cost under its low trade volume with Wyoming unexplained by the size of its expenditure.

Figure 2.7: Wyoming's estimated frictions with other states



(a) Trade (b) Migration (c) Finance

Note: This figure plots the estimated bilateral frictions between Wyoming (in white) and other states in the U.S. A darker color suggests a higher value of friction. Frictions are calculated as the geometric average of bidirectional frictions (inbound friction to and outbound friction from Wyoming) in each of the channels.

To explore the general spatial pattern of the three frictions, we run bivariate regressions with the estimated frictions as the dependent variables and geographic distance as the independent variable for all the $\frac{\mathcal{I}(\mathcal{I}-1)}{2}$ state pairs:

$$\log(\hat{x}_{ij}) = \alpha_x + \gamma_x \log(dist_{ij}) + \epsilon_{ij}, \qquad x \in \{\tau, d, f\}. \tag{2.31}$$

As reported in table 2.7, a 1% rise in distance is associated with a 0.525% increase in trade costs, a 0.100% increase in migration costs, and a 0.232% increase in financial frictions. These values suggest that trade costs are most sensitive to geography. As the coefficient estimates of distances are all significantly positive, we confirm a key hypothesis of this paper that frictions which impair risk sharing covary with geographic distance between states, which potentially shapes the spatial pattern of consumption synchronization.

Table 2.7: Bilateral frictions and geographic distance

Dep. Var: Est. Frictions	$\log(\hat{\tau_{ij}})$	$\log(\hat{d}_{ij})$	$\log(\hat{f}_{ij})$
$\log(dist_{ij})$	0.525 ***	0.100 ***	0.232 **
	(0.047)	(0.01)	0.097
Observations	2442	2442	2442
R^2	0.041	0.023	0.003

Note: This table reports the regression results of equation 2.31. Robust standard errors in parentheses, standardized coefficients in brackets. *** significant at 1%, ** significant at 5%. Estimated frictions are missing for few pairs because the eigenvalues computed at the steady state of the model for those pairs do not satisfy the Blanchard and Kahn condition to establish the existence of a unique solution.

We proceed to quantify the impacts of frictions by conducting counterfactual analyses where we turn off one friction at a time. The median bilateral correlation coefficient of consumption per capita across state pairs in the sample is 0.401 in the data, and changes to 0.735, 0.395, and 0.429 respectively without bilateral frictions in trade, migration, and finance. The direction of changes is consistent with the two-state analysis in section 2.3.2 (figures 2.4-2.6): while the decrease in trade costs inarguably raises consumption correlation, the reduction in migration or financial frictions yields non-monotonic predictions. Around the calibrated migration cost for the median state-pair (d_{low} in figure 2.5), migration exacerbates cross-state consumption inequality following the terms-of-trade adjustment. Therefore, a decline in migration cost leads to a lower consumption correlation in that range of parameter values. In the financial channel, the magnitude of the calibrated friction (f_{low} in figure 2.6) is not large enough to redirect migration. The financial friction only skews portfolios towards domestic assets and hence reduces the reliance of consumption on foreign economies. For this reason, eliminating financial frictions facilitates cross-state consumption risk sharing.

Turning off these frictions also affects the level and volatility of consumption. Table 2.11 reports these median counterfactual consumption moments across the state pairs formed by each state. For example, Alaska's consumption rises most by 29.8% with the reduction of trade costs across all the states whose mean increase in consumption is 10.3%. Meanwhile, the mean reduction in consumption volatility across states is 0.7%, 1.0%, and 0.3% respectively absent bilateral trade, migration, and financial frictions. For a risk-averse agent, lower consumption volatility implies higher lifetime utility. Therefore, the finding that eliminating the frictions reduces consumption fluctuations reiterates the significance of the three channels of risk sharing for improving welfare.

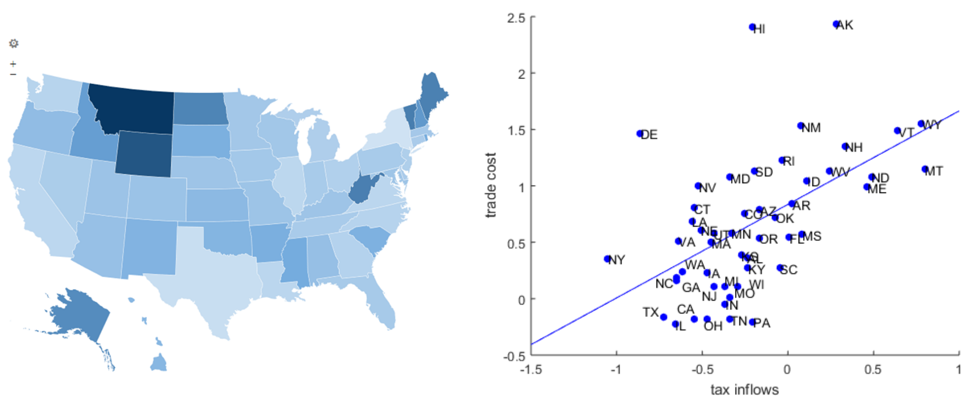
We use these counterfactual results to deliver policy implications. The spatial characteristics of frictions imply that lifting barriers in the channels of risk sharing is challenging due to geographic constraints. Nevertheless, macro policies can be introduced to alleviate the negative impacts of the frictions. In particular, fiscal transfers have been acknowledged as an important channel of risk sharing within a country. Redistribution of wealth from beneficiaries to victims of frictions can potentially undo the influences of frictions on the level and synchronization of consumption. On the modeling side, introducing optimal fiscal transfers T_i^* rewrites state i's wealth constraint

$$\mathcal{W}_{i,t+1} = e^{-f_{\mathcal{I}i}} R_{\mathcal{I},t} \mathcal{W}_{i,t} + \sum_{j}^{\mathcal{I}} \alpha_{j,i,t} (e^{-f_{ji}} R_{j,t} - e^{-f_{\mathcal{I}i}} R_{\mathcal{I},t}) + p_{i,t} \sum_{s \in \{T,NT\}} Y_{is,t} + T_{i,t}^* - P_{i,t} C_{i,t} - P_{Ii,t} I_{i,t}. \tag{2.32}$$

It is noteworthy that T_i^* is a supplementary transfer added to the existing transfers already reflected in state i's calibrated wealth position. Under the new constraint with the additional T_i^*, households in state i choose their expenditure and make migration decisions based on the updated cross-state consumption differentials. Meanwhile, the portfolio of state i is re-constructed according to the risk-sharing needs given the new wealth position. Therefore, the design of fiscal policies considers all the endogenous changes of variables including their interactions in different channels of risk sharing.

To exemplify such policy analysis, we evaluate the optimal fiscal transfers that mitigate the impacts of trade cost on the level of consumption. The targeted moment for the policy design is consumption per capita absent bilateral trade cost. For a state pair consisting of i and j, we solve for T_i^* and T_j^* as their transfer inflows. To keep the aggregate budget constraint of the federal government intact, the rest of the economy (ROE)'s transfer outflows will be the sum of T_i^* and T_j^*. We conduct the policy analysis for all the state pairs and, for cross-state comparison plot the median tax transfers across the state pairs formed by each state in figure 2.8. The model predicts that, states confronted with higher trade costs, such as Wyoming, Montana, and Alaska, should receive more tax transfers to alleviate the impacts of trade frictions on their consumption. In contrast, states that face lower trade costs, including New York, Texas, and California, should be net tax payers to achieve the counterfactual outcome. The general relationship between the predicted transfers and the estimated trade costs is positive.

Figure 2.8: Tax transfers under trade costs



(a) Predicted transfer inflows (b) Estimated τ and transfers

Note: Figure (a) plots the tax transfers as shares of a state's GSP to achieve its level of consumption in the counterfactual situation absent trade costs. A darker color in the heatmap suggests more tax inflows. Figure (b) shows the positive relationship between the transfer and estimated trade costs, calculated as the geometric mean of inbound and outbound trade costs reported in table 2.11, relative to Georgia and Ohio the median states in terms of output per capita.

This example shows that the quantitative model provides a useful framework for policy analyses. The framework is general enough to accommodate a rich set of targeted moments including the level, volatility, and covariance of macroeconomic variables. These policies that facilitate consumption risk sharing reduce both consumption volatility over time and consumption disparity across space.

2.4 Conclusion

This paper empirically and theoretically examines how bilateral economic exchanges shape the geographic pattern of consumption. In particular, we exploit the variation across US state pairs and evaluate the channels of consumption risk sharing including trade, migration, and finance. Quantitative assessment of the model provides both economic insights on how the channels interact to influence consumption and implications for macro policy aiming to reduce consumption inequality.

One extension of our real business cycle framework is to introduce the New Keynesian ingredients, as Hazell et al. (2022) reason that cross-state heterogeneity generates different slopes of the Phillips Curve and consequently creates welfare disparity in a monetary union. Incorporating nominal rigidity into the model allows for examining the influences of monetary policy on the transmission and propagation of economic shocks through disaggregate cross-state economic linkages studied in this paper.

Our framework focuses on the US cross-state analysis but it is general enough to be tailored to another setting such as the European Union with a high degree of bilateral exchanges in multiple channels. Moreover, it can be used to compare intra- and inter-national linkages to diagnose the border effects of risk sharing proposed by

Devereux and Hnatkovska (2020), so as to provide guidance for tariffs and exchange rate policies. Such policies which help to reduce consumption disparity both within and across country borders will yield important welfare implications for the world economy.

2.A Appendices

2.A.1 Figures and Tables

Figure 2.9: U.S. Map

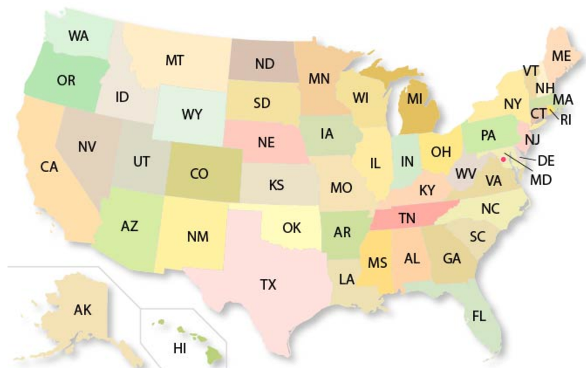


Table 2.8: List of US states with abbreviations

Name	Abbreviation	Name	Abbreviation	Name	Abbreviation	Name	Abbreviation	Name	Abbreviation
Alabama	AL	Hawaii	HI	Massachusetts	MA	New Mexico	NM	South Dakota	SD
Alaska	AK	Idaho	ID	Michigan	MI	New York	NY	Tennessee	TN
Arizona	AZ	Illinois	IL	Minnesota	MN	North Carolina	NC	Texas	TX
Arkansas	AR	Indiana	IN	Mississippi	MS	North Dakota	ND	Utah	UT
California	CA	Iowa	IA	Missouri	MO	Ohio	OH	Vermont	VT
Colorado	CO	Kansas	KS	Montana	MT	Oklahoma	OK	Virginia	VA
Connecticut	CT	Kentucky	KY	Nebraska	NE	Oregon	OR	Washington	WA
Delaware	DE	Louisiana	LA	Nevada	NV	Pennsylvania	PA	West Virginia	WV
Florida	FL	Maine	ME	New Hampshire	NH	Rhode Island	RI	Wisconsin	WI
Georgia	GA	Maryland	MD	New Jersey	NJ	South Carolina	SC	Wyoming	WY

Tables 2.9 and 2.10 report the results of two sets of robustness checks for the gravity model of risk sharing. First, we consider alternative data sources for state-level consumption and inflation, and for bilateral geographic distance. Second, we reconstruct measures of bilateral risk sharing after adjusting for additional time-series and cross-section variations (see the detailed description in the next paragraph). The re-

Table 2.9: Spatial pattern of risk sharing – alternative data sources

Dep. Var.: $\hat{\beta}_{ij}$	A. Alternative Price		B. Alternative Consumption		C. Alternative Distance	
	(1)	(2)	(3)	(4)	(5)	(6)
$\log(d_{ij})$	0.119***	0.176***	0.041***	0.050***	0.151***	0.211***
	(0.017)	(0.024)	(0.005)	(0.007)	(0.010)	(0.012)
Geographic Variables	N	Y	N	Y	N	Y
Political Dissimilarity	N	Y	N	Y	N	Y
Industrial Dissimilarity	N	Y	N	Y	N	Y
Observations	528	528	1225	1225	1225	1225
R^2	0.077	0.183	0.056	0.148	0.161	0.288

Note: Robust standard errors in parentheses. *** significant at 1%. The dependent variable is the estimated risk sharing coefficient $\hat{\beta}_{ij}$. d_{ij} denotes the geographic distance between state i and j. Panel A uses the state-level CPI data by Hazell et. al. (2020), Panel B uses the BEA consumption data, and Panel C uses the shipment distance from the CFS. Geographic variables and political/industrial dissimilarity measures remain the same as in the baseline estimation (table 2.2).

sults reported in the tables suggest that our finding about the comovement between geographic distance and consumption risk sharing remains robust.

When constructing alternative measures of bilateral risk sharing, first we consider demographic variables whose dynamics potentially shift consumption demand over time. These state-level variables (denoted as $X_{i,t}$) include average age, gender ratio, and education levels, whose data are obtained from the American Community Survey conducted by the Census Bureau. The estimation of risk sharing coefficients becomes

$$\Delta \log\ c_{it} - \Delta \log\ c_{jt} = \alpha_{ij} + \beta_{ij}(\Delta \log\ y_{it} - \Delta \log\ y_{jt}) + \mu_i X_{i,t} + \mu_j X_{j,t} + \epsilon_{ijt}. \quad (2.33)$$

Second, we adjust for states' distinct exposure to aggregate risks when measuring bilateral risk sharing, as the difference in output growth between a pair of states in equation 2.1 may reflect the two states' heterogeneous exposure to national shocks. To address this potential mismeasurement of local output shocks, we first estimate β_i and β_j from

$$\Delta \log\ y_{it} = \alpha_i + \beta_i \Delta \log\ y_{USt} + \epsilon_{it}, \qquad \Delta \log\ y_{jt} = \alpha_j + \beta_j \Delta \log\ y_{USt} + \epsilon_{jt}, \quad (2.34)$$

where $\Delta \log\ y_{USt}$ denotes the growth of log real per-capita output of the US, and hence β_i captures the impact of aggregate shocks on state i's output. We then estimate β_{ij} from

$$\Delta \log\ c_{it} - \Delta \log\ c_{jt} = \alpha_{ij} + \beta_{ij}[(\Delta \log\ y_{it} - \beta_i \Delta \log\ y_{USt}) - (\Delta \log\ y_{jt} - \beta_j \Delta \log\ y_{USt})] + \epsilon_{ijt}. \quad (2.35)$$

We also consider the bootstrap method for the potential finite sample bias from equation 2.34. Specifically, we draw a random sample with replacement (30 out of 43 years of sample) when running regression 2.35 to generate β_{ij}. When we regress the obtained β_{ij} on distance 1000 times for its estimate γ, we find the result to remain significant given the confidence interval as the 2.5% and 97.5% quantiles of the $\hat{\gamma}$ distribution.

Table 2.10: Spatial pattern of risk sharing – alternative β

Dep. Var.: $\hat{\beta}_{ij}$	A. β_{ij} adjusted for demand shifters		B. β_{ij} adjusted for aggregate shocks	
	(1)	(2)	(3)	(4)
$\log(d_{ij})$	0.128***	0.143***	0.147***	0.214***
	(0.013)	(0.017)	(0.010)	(0.012)
Geographic Variables	N	Y	N	Y
Political Dissimilarity	N	Y	N	Y
Industrial Dissimilarity	N	Y	N	Y
Observations	1225	1225	1225	1225
R^2	0.067	0.205	0.148	0.315

Note: Robust standard errors in parentheses. *** significant at 1%. The dependent variable in panel A (B) is the estimated β_{ij} based on equation 2.33 (2.35). d_{ij} denotes distance between i and j. Geographic variables and political/industrial dissimilarity measures remain the same as in the baseline estimation (table 2.2).

Table 2.11: Estimated frictions and counterfactual predictions by state

	Panel (I). Estimated Frictions						Panel (II). Counterfactual Predictions				
	Trade Cost τ		Migration Cost d		Financial Cost f		Equilibrium Level $\bar{c}$		Volatility σ_c		
State	Out(bound)	In(bound)	Out	In	Out	In	No τ	No d	No τ	No d	No f
AL	0.975	1.476	1.035	1.117	0.493	0.592	1.058	0.958	1.015	0.974	1.007
AK	3.136	3.643	0.888	1.146	30.850	54.888	1.298	0.955	0.908	0.969	0.981
AZ	1.561	1.410	0.996	0.974	1.403	1.281	1.072	0.985	0.999	0.993	1.000
AR	1.007	2.296	1.002	1.115	1.562	0.754	1.161	0.981	1.068	1.015	1.000
CA	1.845	0.452	1.018	0.858	0.930	0.568	1.033	1.044	0.987	1.047	1.018
CO	1.406	1.520	0.934	0.966	1.379	1.864	1.067	0.978	1.036	1.009	1.049
CT	1.478	1.513	1.033	1.165	5.474	3.356	1.092	0.998	0.939	1.006	0.993
DE	1.536	2.822	1.069	1.175	80.416	72.842	1.202	0.967	0.816	0.970	0.998
FL	1.731	0.994	1.007	0.821	1.277	7.177	0.979	1.032	0.998	0.995	1.003
GA	1.057	1.113	0.970	0.973	1.292	1.393	1.026	0.983	0.966	0.971	1.003
HI	2.710	4.099	0.980	1.086	6.792	9.723	1.094	0.977	0.953	0.979	1.000
ID	1.045	2.719	1.019	1.159	3.249	5.006	1.200	0.931	1.036	0.987	1.002
IL	1.111	0.719	0.988	0.983	0.750	0.672	1.009	0.978	0.972	0.994	1.002
IN	0.917	1.042	0.999	1.044	3.381	2.784	1.050	0.943	0.970	0.982	0.958
IA	0.646	1.952	1.005	1.080	7.757	4.730	1.064	0.947	0.879	0.967	1.010
KS	0.702	2.099	0.978	1.060	3.390	2.600	1.059	0.962	0.959	0.963	0.986
KY	0.884	1.483	1.000	1.074	7.201	6.939	1.051	0.948	0.966	0.983	0.998
LA	1.151	1.729	1.030	1.105	2.384	3.223	1.075	0.968	0.897	1.002	0.991
ME	1.128	2.384	1.019	1.181	0.002	2.119	1.165	0.939	1.156	0.971	1.000
MD	1.766	1.660	1.029	1.058	9.218	3.651	1.070	0.974	1.003	0.990	1.001
MA	1.374	1.200	1.005	1.064	3.732	3.272	1.036	0.980	0.958	0.988	1.004
MI	0.938	1.189	1.030	1.038	2.645	4.517	1.021	0.993	0.958	0.999	1.005
MN	1.150	1.555	1.025	1.076	1.414	0.780	1.082	0.972	0.997	0.966	1.006
MS	0.865	2.047	1.014	1.153	2.014	6.122	1.127	0.954	1.033	0.990	0.991
MO	0.921	1.101	1.008	1.032	1.119	0.827	1.071	0.974	1.022	0.992	0.990
MT	1.291	2.440	0.975	1.152	0.022	0.201	1.213	0.906	1.112	0.985	1.000
NE	1.082	1.695	1.025	1.167	14.183	14.576	1.136	0.957	0.910	1.017	0.965
NV	1.319	2.052	0.980	1.086	1.060	1.493	1.097	0.968	0.979	0.985	1.000
NH	1.522	2.535	1.013	1.193	1.580	3.732	1.250	0.983	1.106	0.992	1.000
NJ	1.012	1.104	1.018	1.068	0.899	0.883	1.002	0.976	0.946	0.990	1.001
NM	2.197	2.103	0.998	1.128	8.109	14.685	1.221	0.988	0.969	1.018	0.996
NY	2.122	0.673	1.074	0.977	8.658	7.305	1.027	1.018	0.956	1.038	1.000
NC	0.901	1.339	1.018	0.957	0.646	0.924	1.024	0.989	0.975	1.004	0.969
ND	0.910	3.245	0.984	1.177	0.735	5.364	1.263	0.919	1.041	1.032	1.000
OH	0.943	0.887	1.030	1.027	0.708	0.607	1.014	0.965	0.957	1.010	1.010
OK	1.077	1.913	1.036	1.113	1.754	0.808	1.080	0.964	0.997	0.984	0.981
OR	1.083	1.585	1.027	1.128	3.052	3.060	1.070	0.952	0.982	0.977	0.959
PA	1.070	0.762	1.021	1.032	0.216	0.308	1.001	0.974	1.012	0.987	1.000
RI	1.081	3.156	1.068	1.213	0.690	1.087	1.197	0.946	1.117	0.984	1.007
SC	0.983	1.334	1.003	1.034	0.283	0.633	1.091	0.959	1.080	0.965	1.003
SD	0.909	3.413	0.997	1.162	11.196	11.012	1.245	0.903	0.901	0.928	0.951
TN	0.884	0.942	0.978	0.995	1.836	2.071	1.075	0.955	0.999	0.981	1.000
TX	1.236	0.690	0.999	0.849	1.249	1.208	0.964	0.993	0.932	1.031	1.032
UT	0.951	1.873	1.013	1.125	2.752	3.114	1.135	0.962	0.971	0.979	0.995
VT	1.082	4.098	1.035	1.214	0.023	0.374	1.329	0.909	1.193	0.985	1.000
VA	1.252	1.335	0.997	0.976	2.416	2.006	1.001	0.979	0.999	0.994	1.000
WA	0.954	1.330	1.018	1.006	1.188	1.222	1.033	0.989	0.923	1.005	1.001
WV	1.070	2.900	1.084	1.201	0.308	14.961	1.093	0.941	1.070	1.001	1.004
WI	1.166	0.957	1.037	1.082	0.926	0.692	1.072	0.959	1.030	0.983	0.998
WY	1.490	3.177	0.932	1.157	0.018	0.566	1.356	0.927	1.018	0.962	1.000
Mean	1.253	1.835	1.009	1.074	4.893	5.891	1.103	0.966	0.993	0.990	0.997
Median	1.082	1.570	1.013	1.081	1.488	2.095	1.073	0.968	0.984	0.988	0.999

Note: Panel (I) presents the normalized trade, migration, and financial costs averaged across state pairs for each state. We first calculate both inbound and outbound frictions averaged across $\mathcal{I} - 1$ pairs a state i forms: ($x_i^{ex} = \text{mean}(x_{ij}),\ x_i^{in} = \text{mean}(x_{ji}), j \neq i \in [1, \mathcal{I}], x \in \{\tau, d, f\}$). We then normalize the average friction of Georgia and Ohio, the median states in terms of output per capita, to 1 in each channel: $x_{\text{GA,OH}}^{ex} = x_{\text{GA,OH}}^{in} = 1$, and report the ratio of state-level frictions relative to the median states' in the table for cross-state comparison. Panel (II) presents each state's median counterfactual steady-state level and volatility of consumption across its state pairs, as a ratio to the values in original case with frictions calibrated to the data. Counterfactual scenarios include the cases absent bilateral trade costs (τ), migration costs (d), and financial frictions (f).

2.A.2 Data

2.A.2.1 State-level output, consumption, and price

The US Bureau of Economic Analysis (BEA) reports the real GDP by state (GSP) since 1977, with data from 1977-1997 reported in the Standard Industrial Classification (SIC) and those from 1997-2019 in the North American Industry Classification (NAICS). To address this discontinuity, we first calculate the annual growth rate based on the SIC-based real GSP, and then reconstruct the time series of real GSP from 1977 to 1997 using this annual growth rate and the NAICS-based real GSP in 1997.

The nominal consumption data from the BEA are only available after 1997, which is not ideal for our risk-sharing analysis over a long horizon. Therefore, we follow Asdrubali et al. (1996)'s method of constructing state-level private consumption by rescaling state-level retail sales by the country-level ratio of private consumption to retail sales, both obtained from the BEA. To convert nominal to real consumption, we use the state-level inflation series constructed by Nakamura and Steinsson (2014) over the period from 1966 to 2008. They obtain the inflation series from 1966 to 1995 from Del Negro (1998), who combines the BLS regional inflation data and cost-of-living estimates from the American Chamber of Commerce Realtors Association (ACCRA). For the estimates between 1995 and 2008, they multiply a population-weighted average of cost-of-living indices from the ACCRA across states with the US aggregate CPI. After 2008, we use the Regional Price Parities (RPP) from the BEA that measure price differences within the United States. RPP is a weighted average of the price level of goods and services for the average consumer in one geographic region compared to all other regions in the US. We merge these data to construct a state-level CPI index for 1966-2019, using which we deflate the nominal consumption data to calculate real consumption at the state level.

We also use alternative data sources to verify the robustness of the gravity model. Table 2.9 Panel A uses state-level inflation from Hazell et al. (2022) who construct CPI with micro data gathered by the BLS from 1978 to 2017. Panel B uses only the recent BEA data of consumption expenditure and real GSP between 1997 and 2018.

2.A.2.2 Bilateral trade and migration flows

The Commodity Flow Survey (CFS) is conducted every five years by the Census Bureau in partnership with the Department of Transportation. The survey provides detailed information on commodity flows within the US, including the type of commodities shipped, origin and destination, value and weight, and mode of transport. There are six waves of surveys so far (1993, 1997, 2002, 2007, 2012, 2017).

State-to-state migration data are based on year-to-year address changes reported on individual income tax returns filed with the Internal Revenue Service (IRS). Specifically, we use the reported number of returns filed every year to track migration across states. The data are available for filing years 1991 through 2019.

2.A.2.3 State-level productivity

We estimate the state-level total factor productivity (TFP) as the Solow residual from

$$\log(A_{i,t}) = \log(Y_{i,t}) - \alpha \log(K_{i,t}) - (1-\alpha)\log(L_{i,t}), \tag{2.36}$$

where $Y_{i,t}$, $K_{i,t}$, and $L_{i,t}$ are output, capital, and labor in state i at time t respectively, while α denotes capital share in production. We estimate $1-\alpha$ to be 0.59 by dividing the labor earnings by the economic output based on the BEA data.[20] Moreover, we use the GSP and employment data reported by the BEA for $Y_{i,t}$ and $K_{i,t}$ over the period 1977-2019 for the estimation.

We construct the estimates for state-level capital stock following Garofalo and Yamarik (2002). Namely, we apportion the national private capital stock, to states using sectoral income data from the BEA: For each two-digit NAICS industry

$$K_{i,t}^{s} = \left(\frac{Y_{i,t}^{s}}{Y_{US,t}^{s}}\right) K_{US,t}^{s}, \tag{2.37}$$

where $K_{i,t}^{s}$ ($Y_{i,t}^{s}$) refers to capital (output) of industry s in state i at time t, while $K_{US,t}^{s}$ ($Y_{US,t}^{s}$) represents country-level capital (output). Each state's capital stock estimate, $K_{i,t}$, is then the sum of sectoral-level capital stock:

$$K_{i,t} = \sum_{s=1}^{S} K_{i,t}^{s}. \tag{2.38}$$

After obtaining the values of all the variables in equation 2.36, we calculate TFP with which we subsequently estimate the joint productivity process across states.

[20] The BEA reports the data of labor earning(SAINC5), which consists of compensation of employees and proprietors' income with inventory valuation adjustment and capital consumption adjustment.

2.A.3 Details of the Quantitative Model

This section provides details of the quantitative model for three-state analysis. Section 2.A.3.1 discusses the calibration strategy. Section 2.A.3.2 explains the solution to the portfolio choice problem in a trilateral framework.

2.A.3.1 Calibration

Many common parameters and state-specific variables are calibrated in the same way as in the two-economy model from section 2.3.2. The variables of the rest of the economy (ROE) from a state-pair's perspective, denoted with asterisks below, will be the sum of all the $\mathcal{I}$ states' variables minus the state-pair's. Therefore, ROE's productivity for i and j at time t is computed from

$$\begin{aligned}\log(A_t^{ij*}) &= \log(Y_t^{ij*}) - \alpha\log(K_t^{ij*}) - (1-\alpha)\log(L_t^{ij*}) \\ &\equiv \log(\sum_i^{\mathcal{I}} Y_{i,t} - Y_{i,t} - Y_{j,t}) - \alpha\log(\sum_i^{\mathcal{I}} K_{i,t} - K_{i,t} - K_{j,t}) \\ &- (1-\alpha)\log(\sum_i^{\mathcal{I}} L_{i,t} - L_{i,t} - L_{j,t}).\end{aligned} \tag{2.39}$$

We then obtain the variance-covariance matrix (Σ) of these three states' productivity assuming the annual persistence of productivity is 0.72, which is estimated from the U.S. country-level Solow residual.

Another distinct feature of this asymmetric framework is that each state may not run a balanced budget in the equilibrium. To this end, we collect the data on state-level output and expenditure (defined as the sum of consumption and investment), whose difference represents the wealth position of the economy that also includes any fiscal transfer received by it. ROE's wealth position will be the sum of all the states' positions minus the positions of the state-pair under examination.

We now proceed to discuss the calibration strategies for bilateral frictions in the trilateral framework. Our calibration is based on the sample period from 1997 to 2017. The sample selection is largely driven by the availability of the CFS trade data. We use the time-averaged state-level population, net asset positions, trade and migration flows as the steady-state values of those variables when estimating and solving the model. There are three economies numbered $1, 2, 3$ with 1 and 2 representing the pair of states being studied and 3 representing ROE. The three economies encounter a set of six bilateral frictions in each of the trade, migration, and finance channels

$$\{x_{12}, x_{13}, x_{23}, x_{21}, x_{31}, x_{32}\}, \qquad x \in \{\tau, d, f\}. \tag{2.40}$$

In terms of trade and migration costs, we estimate them simultaneously to ensure that the model-predicted bilateral migration and trade linkages match those from the IRS and CFS data. The estimation procedure is similar to that in section 2.3.2: Step 1, we start with an initial guess for the combination of migration and trade costs. Step 2, we solve for wage rates and labor hours given the frictions that satisfy the labor market clearing condition. Step 3, we calculate the corresponding trade and migration shares to the wages solved earlier. Step 4, we repeat the previous steps until the trade and migration shares converge to the empirical moments.

After characterizing the real side of the model, we calibrate frictions in the financial channel to the pattern of consumption comovement across economies. Specifically, we estimate the coefficients of consumption risk sharing among the three economies with the same data and method as in the empirical section

$$\beta = [\beta_{12}, \beta_{13}, \beta_{23}], \tag{2.41}$$

and use the coefficients as targeted moments to estimate bilateral frictions. Appendix 2.A.3.2 outlines the technical details of the portfolio choice problem in this trilateral framework. The algorithm is slightly modified from that in section 2.3.2: First, we obtain the coefficient matrices, including R_1, R_2, D_1, D_2 in equations 2.52-2.53 necessary to solve the portfolio choice problem from the first-order dynamics of the model. Second, we solve for asset holdings under which the model-implied risk-sharing coefficients β match those estimated from the data. To simplify our computation in this step, we assume a state's holding of ROE's assets is the same whose baseline weight in the portfolio is one-half but the state can choose the remaining composition between its own and pair partner's assets under risk-sharing motives. Third, we plug the calibrated asset positions in the portfolio determination equation (equation 2.48) to compute financial frictions.

Among the three frictions, we are particularly interested in testing whether our estimated financial frictions are reasonable. To this end, we collect the Federal Deposit Insurance Corporation (FDIC) bank statistics, which list branch locations and their reported deposits. States i and j are deemed to exhibit stronger financial ties when banks headquartered in i open more local branches in j or collect more deposits from branches located in j. Therefore, we compile this information of all the FDIC-

Table 2.12: Estimated financial frictions and banking linkage

Dep. Var: Est. Frictions $\log(\hat{f}_{ij})$	(1)	(2)
Branches	-5.7e-04***	
	(1.1e-04)	
Deposits		-6.8e-09***
		(1.6e-09)
Observations	2442	2442
R^2	0.001	0.001

Note: Robust standard errors in parentheses, *** significant at 1%. The independent variable is the estimated bilateral financial friction between states i and j. Dependent variables include the number of bank branches, and the dollar amount of deposits collected by financial institutions, located in i and headquartered in j. Estimated frictions are missing for few pairs because the eigenvalues computed at the steady state of the model for those pairs do not satisfy the Blanchard and Kahn (1980) condition to guarantee the existence of a unique solution.

insured institutions and explore its consistency with financial frictions $\hat{f}_{ij}$. Based on the results presented in table 2.12, an increase of one thousand branches or one billion deposits collected by institutions, located in i and headquartered in j, is associated with a decrease of .57% or 6.8% estimated financial frictions ($\hat{f}_{ij}$) respectively. This analysis provides external validity for our estimates: Financial frictions estimated from the consumption data are consistent with empirical evidence from the banking sector. That said, as discussed in the main text, the estimated financial frictions reflect the deviation of allocation from complete markets and therefore take many other forms beyond the banking sector.

2.A.3.2 Portfolio Choice in Trilateral Framework

This section describes the portfolio choice problem in a framework with three economies numbered $i = 1, 2, 3$. Each economy's financial asset, which is its claims to capital income net of investment expenditure, can be traded in an integrated financial market. Nevertheless, there are bilateral financial frictions modeled as transaction costs f_{ij} on returns R_i when j holds assets from i. These second-order frictions appear in the Euler equations of the three economies

$$\begin{aligned} E_t[\tfrac{U'(c_{1,t+1})}{P_{1,t+1}}R_{1,t+1}] &= E_t[\tfrac{U'(c_{1,t+1})}{P_{1,t+1}}e^{-f_{21}}R_{2,t+1}] &&= E_t[\tfrac{U'(c_{1,t+1})}{P_{1,t+1}}e^{-f_{31}}R_{3,t+1}], \\ E_t[\tfrac{U'(c_{2,t+1})}{P_{2,t+1}}R_{2,t+1}] &= E_t[\tfrac{U'(c_{2,t+1})}{P_{2,t+1}}e^{-f_{12}}R_{1,t+1}] &&= E_t[\tfrac{U'(c_{2,t+1})}{P_{2,t+1}}e^{-f_{32}}R_{3,t+1}], \\ E_t[\tfrac{U'(c_{3,t+1})}{P_{3,t+1}}R_{3,t+1}] &= E_t[\tfrac{U'(c_{3,t+1})}{P_{3,t+1}}e^{-f_{13}}R_{1,t+1}] &&= E_t[\tfrac{U'(c_{3,t+1})}{P_{3,t+1}}e^{-f_{23}}R_{2,t+1}]. \end{aligned} \tag{2.42}$$

We derive portfolios with Devereux and Sutherland (2011)'s method by evaluating these Euler equations. First we assume assets from economy 3 to be a numeraire asset and denote the vector of excess returns to the other assets as R_x:

$$\hat{R}'_{x,t} = [\hat{R}_{1,t} - \hat{R}_{3,t}, \hat{R}_{2,t} - \hat{R}_{3,t}], \tag{2.43}$$

where $\hat{y}_t$ represents the log-deviation of any variable y from its steady state at t. Next we evaluate the second-order Taylor expansion of the Euler equations as

$$\begin{aligned} E_t[\hat{R}_{x,t+1} + \tfrac{1}{2}\hat{R}^2_{x,t+1} - (\sigma\hat{c}_{1,t+1} + \hat{P}_{1,t+1})\hat{R}_{x,t+1}] &= -\tfrac{1}{2}\begin{bmatrix} f_{31} \\ f_{31} - f_{21} \end{bmatrix} + \mathcal{O}(\epsilon^3), \\ E_t[\hat{R}_{x,t+1} + \tfrac{1}{2}\hat{R}^2_{x,t+1} - (\sigma\hat{c}_{2,t+1} + \hat{P}_{2,t+1})\hat{R}_{x,t+1}] &= -\tfrac{1}{2}\begin{bmatrix} f_{32} - f_{12} \\ f_{32} \end{bmatrix} + \mathcal{O}(\epsilon^3), \\ E_t[\hat{R}_{x,t+1} + \tfrac{1}{2}\hat{R}^2_{x,t+1} - (\sigma\hat{c}_{3,t+1} + \hat{P}_{3,t+1})\hat{R}_{x,t+1}] &= -\tfrac{1}{2}\begin{bmatrix} -f_{13} \\ -f_{23} \end{bmatrix} + \mathcal{O}(\epsilon^3). \end{aligned} \tag{2.44}$$

where $\hat{R}^{2'}_{x,t+1}$ denotes differences in squared changes of returns

$$\hat{R}^{2'}_{x,t+1} = [\hat{R}^2_{1,t+1} - \hat{R}^2_{3,t+1}, \hat{R}^2_{2,t+1} - \hat{R}^2_{3,t+1}]. \tag{2.45}$$

On the right-hand side of equations 2.44 are vectors of financial frictions each country incurs when holding assets from economies 1 and 2 relative to the frictions associated with its holding assets from economy 3. Plus, the last term $\mathcal{O}(\epsilon^3)$ captures all terms of order higher than two. Taking the difference among equations 2.44 yields

$$\begin{aligned}
E_t[(\hat{c}_{12,t+1} + \tfrac{\hat{P}_{12,t+1}}{\sigma})\hat{R}_{x,t+1}] &= \tfrac{1}{2\sigma}\begin{bmatrix} f_{31} - f_{32} + f_{12} \\ f_{31} - f_{21} - f_{32} \end{bmatrix} + \mathcal{O}(\epsilon^3), \\
E_t[(\hat{c}_{13,t+1} + \tfrac{\hat{P}_{13,t+1}}{\sigma})\hat{R}_{x,t+1}] &= \tfrac{1}{2\sigma}\begin{bmatrix} f_{13} + f_{31} \\ f_{31} - f_{21} + f_{23} \end{bmatrix} + \mathcal{O}(\epsilon^3), \\
E_t[(\hat{c}_{23,t+1} + \tfrac{\hat{P}_{23,t+1}}{\sigma})\hat{R}_{x,t+1}] &= \tfrac{1}{2\sigma}\begin{bmatrix} f_{32} - f_{12} + f_{13} \\ f_{23} + f_{32} \end{bmatrix} + \mathcal{O}(\epsilon^3),
\end{aligned} \tag{2.46}$$

where $c_{ij,t} = \frac{c_{i,t}}{c_{j,t}}$ and $P_{ij,t} = \frac{P_{i,t}}{P_{j,t}}$ denote cross-region consumption and price ratios of i to j, which constitute a vector of price-adjusted consumption differential defined as

$$\frac{\hat{cp}'_t}{\sigma} = [\hat{c}_{12,t} + \frac{\hat{P}_{12,t}}{\sigma}, \hat{c}_{13,t} + \frac{\hat{P}_{13,t}}{\sigma}, \hat{c}_{23,t} + \frac{\hat{P}_{23,t}}{\sigma}]. \tag{2.47}$$

Equations 2.46 can therefore be re-written in the vector form as

$$E_t[\hat{cp}_t \hat{R}'_{x,t+1}] = \frac{\mathcal{F}}{2} \equiv \frac{1}{2}\begin{bmatrix} f_{31} - f_{32} + f_{12} & f_{31} - f_{21} - f_{32} \\ f_{13} + f_{31} & f_{31} - f_{21} + f_{23} \\ f_{32} - f_{12} + f_{13} & f_{23} + f_{32} \end{bmatrix} + \mathcal{O}(\epsilon^3). \tag{2.48}$$

On the left hand side of this portfolio determination equation are two components: inflation-adjusted consumption differential $\hat{cp}$ and excess financial returns $\hat{R}_x$. Both components can be expressed in terms of region-specific innovations

$$\epsilon'_t = [\epsilon_{1,t}, \epsilon_{2,t}, \epsilon_{3,t}], \tag{2.49}$$

whose coefficients, as a function of portfolio choice, need to satisfy equation 2.48 in the equilibrium of the model. Let $\alpha_{i,j}$ represent j's holding of asset i, then the unknown portfolio matrix scaled by the discount factor β and the region's steady-state output $\bar{Y}$ to be solved in this three-economy framework is

$$\tilde{\alpha} = \frac{1}{\beta\bar{Y}} \begin{bmatrix} \alpha_{1,1} & \alpha_{1,2} \\ \alpha_{2,1} & \alpha_{2,2} \end{bmatrix}, \tag{2.50}$$

while the remaining holdings $\alpha_{3,j}$ and $\alpha_{i,3}$ can be recovered from each region's budget constraint and asset market clearing condition respectively. Given the portfolio arrangement, excess portfolio return is defined as

$$\xi_t = \tilde{\alpha}' \hat{R}_{x,t}. \tag{2.51}$$

Region-specific productivity shocks ϵ_t affect the two components in equation 2.48 both directly and indirectly through ξ_t:

$$\hat{cp}_{t+1} = D_1\xi_{t+1} + D_2\epsilon_{t+1} + D_3 z_{t+1} + \mathcal{O}(\epsilon^2), \tag{2.52}$$

$$\hat{R}_{x,t+1} = R_1\xi_{t+1} + R_2\epsilon_{t+1} + \mathcal{O}(\epsilon^2), \tag{2.53}$$

where R_1, R_2, D_1, D_2, D_3 are the coefficient matrices extracted from the first-order conditions of the model. R_1 and D_1 capture the response of the two components (consumption differential and excess asset returns) to excess portfolio returns; R_2 and D_2 capture their response to productivity shocks; and D_3 are their response to other state variables in the model summarized by z. In addition, using $\xi_{t+1} = \tilde{\alpha}' \hat{R}_{x,t+1}$ allows us to express ξ_{t+1}, $\hat{cp}_{t+1}$, and $\hat{R}_{x,t+1}$ in terms of ϵ_{t+1} only:

$$\xi_{t+1} = \tilde{H}\epsilon_{t+1}, \qquad \textit{where} \qquad \tilde{H} = \frac{\tilde{\alpha}' R_2}{1 - \tilde{\alpha}' R_1}; \tag{2.54}$$

$$\hat{cp}_{t+1} = \tilde{D}\epsilon_{t+1} + D_3 z_{t+1} + \mathcal{O}(\epsilon^2), \qquad \textit{where} \qquad \tilde{D} = D_1\tilde{H} + D_2. \tag{2.55}$$

$$\hat{R}_{x,t+1} = \tilde{R}\epsilon_{t+1} + \mathcal{O}(\epsilon^2), \qquad \textit{where} \qquad \tilde{R} = R_1\tilde{H} + R_2. \tag{2.56}$$

Now that we have examined the two components in equation 2.48 separately as functions of innovations ϵ_{t+1}, we can multiply them to evaluate the portfolio determination condition:

$$E_t[\hat{c}p_{t+1}\hat{R}'_{x,t+1}] = \tilde{D}\Sigma\tilde{R}' = \frac{\mathcal{F}}{2}. \tag{2.57}$$

In terms of calibration, we follow the steps below to numerically estimate bilateral financial frictions f_{ij}. First, we extract coefficient matrices R_1, R_2, D_1, D_2, and the response of the relative output differential $\hat{y}_{ij} = \hat{y}_i - \hat{y}_j$ to shocks from the first order conditions in the model. In particular, we take the first order derivative of output differential to productivity shocks

$$Dy = \frac{\partial y_{ij}}{\partial \epsilon}, \tag{2.58}$$

where ϵ is the vector of productivity shocks defined in 2.49. We use the same method to capture the response of the relative consumption differential $\hat{c}_{ij} = \hat{c}_i - \hat{c}_j$ to shocks

$$Dc = \frac{\partial c_{ij}}{\partial \epsilon}, \tag{2.59}$$

which based on equation 2.55 is influenced by portfolio choice $\tilde{\alpha}$ from 2.50 together with coefficient matrices R_1, R_2, D_1, D_2 calculated earlier. The coefficient of consumption risk sharing $\hat{\beta}_{ij}$ can therefore be approximated as the differential between Dc and Dy in response to productivity shocks. After we compute $\hat{\beta}_{ij}$ for each productivity shock following the steps above using the first-order dynamics of the model, we take the mean value of $\hat{\beta}_{ij}$ across shocks to get a state-pair's overall consumption risk sharing and compare it with the coefficient estimated with the method from the empirical section which serves as a targeted moment. We loop over different portfolios $\tilde{\alpha}$ until the model-predicted coefficient of risk sharing matches its empirical moment. After that, we plug the calibrated portfolio $\tilde{\alpha}$ in $\tilde{D}$ and $\tilde{R}$ of equation 2.57 to find matrix $\mathcal{F}$. Lastly, we recover bilateral financial frictions from this matrix of financial frictions based on equation 2.48.

Chapter 3

Trade Costs and a Gravity Model of Risk Sharing

3.1 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. (2009b), 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-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

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

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 rel-

[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.

ative 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 interaction 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 (2012a) 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. (2009b) 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 (2002a) 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 this chapter proceeds as follows: Section 3.2 describes the data and methods of constructing risk-sharing coefficients. Section 3.3 presents empirical results as to how trade costs influence consumption risk sharing. Section 3.4 concludes.

3.2 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.

3.2.1 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:

$$c_i = \left[c_{ii}^{\frac{\phi-1}{\phi}} + c_{ji}^{\frac{\phi-1}{\phi}} \right]^{\frac{\phi}{\phi-1}}, \tag{3.1}$$

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

$$y_i = c_{ii} + \tau c_{ij}. \tag{3.2}$$

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

$$\pi_{ij} = (\frac{\tau p_i}{P_j})^{-\phi}, \tag{3.3}$$

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

$$P_j = \left[p_j^{1-\phi} + (\tau p_i)^{1-\phi}\right]^{\frac{1}{1-\phi}}. \tag{3.4}$$

Moreover, combining equation 3.2 and 3.3 yields the demand for i's goods as:

$$y_i = \pi_{ii} c_i + \pi_{ij} c_j = (\frac{p_i}{P_i})^{-\phi} c_i + (\frac{\tau p_i}{P_j})^{-\phi} c_j. \tag{3.5}$$

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:

$$P_i c_i = p_i y_i \tag{3.6}$$

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 3.4, the real exchange rate (RER hereafter) $\hat{P}$ is linked to the terms-of-trade (TOT hereafter) $\hat{p}$ through

$$\hat{P} = \frac{1-\tau^{1-\phi}}{1+\tau^{1-\phi}}\,\hat{p}. \tag{3.7}$$

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 3.5 and its counterpart for country j requires that relative output satisfies

$$\hat{y} = -\phi\hat{p} + A(\hat{c} + \phi\hat{P}). \tag{3.8}$$

Besides, it follows from the balanced trade condition (equation 3.6) that

$$\hat{P} + \hat{c} = \hat{p} + \hat{y}. \tag{3.9}$$

Combining equations 3.7-3.9 allows us to derive the TOT adjustment in response to an output shock:

$$\hat{p} = \frac{1}{A - \phi(A+1)}\hat{y}, \tag{3.10}$$

From equation 3.10, TOT moves in the opposite direction to relative output growth if

$$\phi > \frac{A}{A+1}, \tag{3.11}$$

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. (1992a), 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 3.11 is easily satisfied. Examples include Baier and Bergstrand (2001), Imbs and Mejean (2015), and Simonovska and Waugh (2014). As the macro estimates are

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

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:

$$\hat{c} = \frac{1 - \phi - \phi A}{(1 - \phi)A - \phi}\hat{y} \equiv \beta\hat{y}. \tag{3.12}$$

β in equation 3.12 captures the the response of relative consumption to output growth. The higher the β the weaker the consumption risk sharing. In the situation where

$$\phi(A + 1) = 1, \tag{3.13}$$

$\beta = 0$ 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 3.12 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 dominates the income effect when $\phi > 1$. Therefore, TOT improves when output drops since inequality 3.11 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.

3.2.2 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

$$c_i = \left[c_{ii}^{\frac{\phi-1}{\phi}} + c_{ji}^{\frac{\phi-1}{\phi}} + c_{ki}^{\frac{\phi}{\phi-1}} \right]^{\frac{\phi-1}{\phi}}. \tag{3.14}$$

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:

$$\tau_{ij} = \tau_{ji} > \tau_{jk} = \tau_{kj} > 1. \tag{3.15}$$

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

$$\tau_{ik} = \tau_{ki} > 1. \tag{3.16}$$

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

$$P_i = \left[p_i^{1-\phi} + (\tau_{ji}p_j)^{1-\phi} + (\tau_{ki}p_k)^{1-\phi}\right]^{\frac{1}{1-\phi}}, \tag{3.17}$$

$$y_i = c_{ii} + \tau_{ij}c_{ij} + \tau_{ik}c_{ik}. \tag{3.18}$$

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

$$p_i y_i = P_i c_i. \tag{3.19}$$

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,

$$\bar{p}_{i/j} = \bar{p}_{k/j} = 1, \qquad \bar{y}_{i/j} = \bar{y}_{k/j} = 1. \tag{3.20}$$

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

$$\bar{P}_i > \bar{P}_k, \qquad \bar{\pi}_{ii} > \bar{\pi}_{kk}. \tag{3.21}$$

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:

$$\hat{p}_{i/j} > 0, \qquad \hat{p}_{k/j} > 0. \tag{3.22}$$

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 3.17 and its counterpart for country j:

$$\hat{P}_{i/j} - \hat{P}_{k/j} = (\bar{P}_i^{\phi-1} - \bar{P}_k^{\phi-1}\tau_{ik}^{1-\phi})\hat{p}_{i/j} + (\bar{P}_i^{\phi-1}\tau_{ik}^{1-\phi} - \bar{P}_k^{\phi-1})\hat{p}_{k/j}. \tag{3.23}$$

We then derive the expressions for relative output changes from the market clearing and balanced trade conditions (equation 3.18 and 3.19):

$$\begin{aligned}\hat{y}_{i/j} = -\phi\hat{p}_{i/j} + &\frac{1}{1+\tau_{ij}^{1-\phi}\bar{P}_{i/j}^{\phi-1}+\tau_{jk}^{1-\phi}\bar{P}_{k/j}^{\phi-1}} \\ &\times[(1-\tau_{ij}^{1-\phi})\phi\bar{P}_{i/j}^{\phi-1}((\phi-1)\hat{P}_{i/j}+\hat{p}_{i/j}+\hat{y}_{i/j}) \\ &+(\tau_{ik}^{1-\phi}-\tau_{jk}^{1-\phi})\phi\bar{P}_{k/j}^{\phi-1}((\phi-1)\hat{P}_{k/j}+\hat{p}_{k/j}+\hat{y}_{k/j})].\end{aligned} \tag{3.24}$$

$$\begin{aligned}\hat{y}_{k/j} = -\phi\hat{p}_{k/j} + &\frac{1}{1+\tau_{ij}^{1-\phi}\bar{P}_{i/j}^{\phi-1}+\tau_{jk}^{1-\phi}\bar{P}_{k/j}^{\phi-1}} \\ &\times[(\tau_{ik}^{1-\phi}-\tau_{ij}^{1-\phi})\phi\bar{P}_{i/j}^{\phi-1}((\phi-1)\hat{P}_{i/j}+\hat{p}_{i/j}+\hat{y}_{i/j}) \\ &+(1-\tau_{kj})^{1-\phi}\phi\bar{P}_{k/j}^{\phi-1}((\phi-1)\hat{P}_{k/j}+\hat{p}_{k/j}+\hat{y}_{k/j})].\end{aligned} \tag{3.25}$$

After that, we take the difference between equation 3.24 and 3.25 when imposing $\hat{y}_{i/j} =$

$\hat{y}_{k/j}$, since j is the only country experiencing an output shock in this example:

$$\phi(\hat{p}_{i/j} - \hat{p}_{k/j}) = \frac{\phi(1 - \tau_{ik}^{1-\phi})}{1 + \tau_{ij}^{1-\phi}\bar{P}_{i/j}^{\phi-1} + \tau_{jk}^{1-\phi}\bar{P}_{k/j}^{\phi-1}} \times [\bar{P}_{i/j}^{\phi-1}((\phi-1)\hat{P}_{i/j} + \hat{p}_{i/j} + \hat{y}_{i/j}) - \bar{P}_{k/j}^{\phi-1}((\phi-1)\hat{P}_{k/j} + \hat{p}_{k/j} + \hat{y}_{k/j})]. \tag{3.26}$$

Note that $0 < \tau_{ik}^{1-\phi} < 1$ when τ_{ik} and $\phi > 1$. We then combine equation 3.23 and 3.26 to find:

$$\hat{p}_{i/j} < \hat{p}_{k/j}, \tag{3.27}$$

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 3.27 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.

3.3 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.

3.3.1 Regional Trade Agreements

We obtain the information on regional trade agreements from the World Trade Organization (WTO) and the Centre d'Études 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 3.1 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 3.2 tracks the historical occurrence of RTAs. It illustrates that the coverage of RTAs has been remarkably expanded over the decades.

Table 3.6 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.

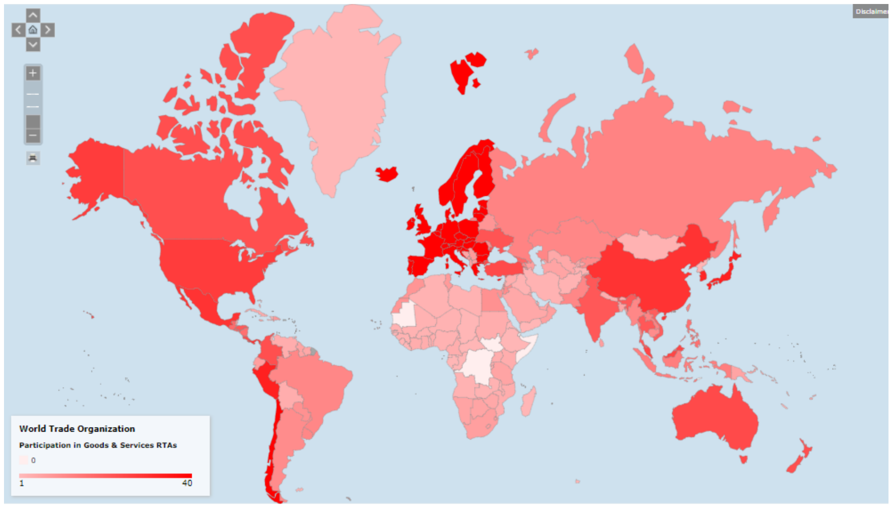
3.3.2 GDP, consumption, and risk sharing

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. (2009b), we measure a country's consumption risk sharing as the response of its relative

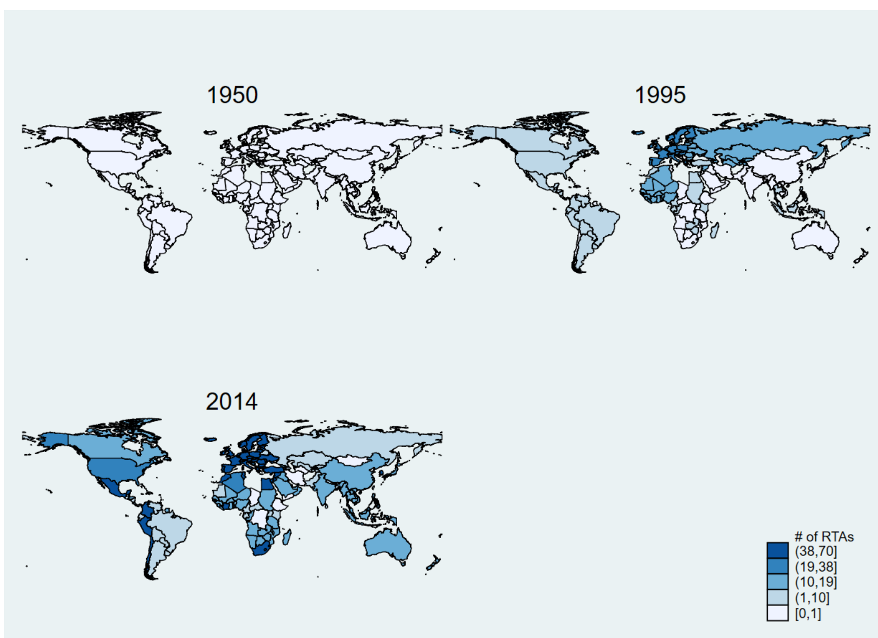
[4] Namely Iran, Mongolia, and Sao Tome.

Figure 3.1: Current RTAs



Source: WTO

Figure 3.2: Historical RTAs



Source: WTO and CEPII

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

$$\Delta log\ c_{it} - \Delta log\ c_{jt} = \alpha_{ij} + \beta_{ijt}(\Delta log\ y_{it} - \Delta log\ y_{jt}) + \epsilon_{ijt}, \tag{3.28}$$

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 3.1 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 3.1: Summary statistics of risk-sharing coefficients

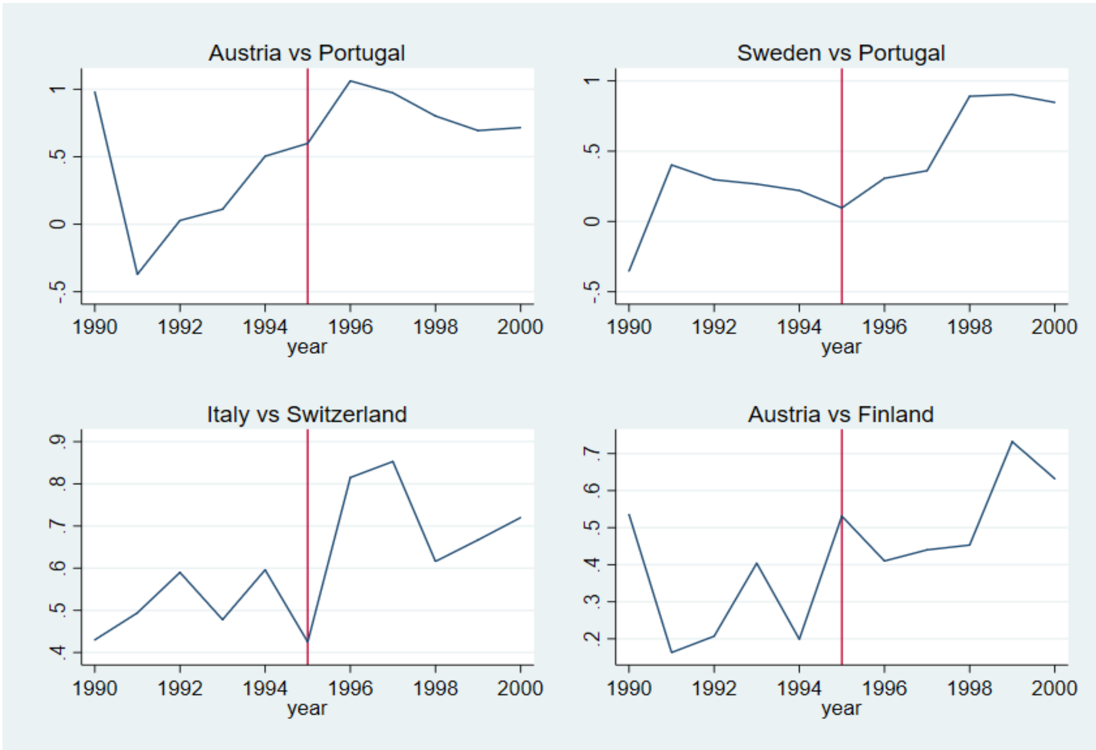
	(1) w/ RTA	(2) w/o RTA	(3) Difference
A. Full Sample			
All types of countries	0.572 (0.538)	0.418 (0.396)	0.154 (0.142)
Industrial and industrial	0.426 (0.403)	0.344 (0.347)	0.082 (0.056)
Industrial and developing	0.708 (0.668)	0.402 (0.366)	0.306 (0.302)
Developing and developing	0.477 (0.511)	0.438 (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)

Note: This table reports bilateral risk sharing coefficients $RS_{ijt} \equiv 1 - \beta_{ijt}$, where β_{ijt} is estimated from equation 3.28. 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 3.3, bilateral risk sharing remarkably improves after the Single Market was established in the mid 1990's. [5]

[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.

Figure 3.3: 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.

3.3.3 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.

3.4 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.

3.4.1 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

$$\begin{aligned} \Delta log\ c_{it} - \Delta log\ c_{jt} &= \alpha + \beta_1(\Delta log\ y_{it} - \Delta log\ y_{jt}) + \beta_2 RTA_{ijt} \\ &+\beta_3 RTA_{ijt} \times (\Delta log\ y_{it} - \Delta log\ y_{jt}) + \eta_t + \eta_i + \eta_j + \epsilon_{ijt}, \end{aligned} \tag{3.29}$$

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 3.2 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 3.2 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 3.7, 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 3.2: 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

Note: 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.

3.4.2 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:

$$\Delta log\ c_{it} - \Delta log\ c_{jt} = \alpha_{ij} + \beta_{ij}(\Delta log\ y_{it} - \Delta log\ y_{jt}) + \epsilon_{ijt}. \tag{3.30}$$

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

$$\beta_{ij} = \alpha + \gamma\,(\ln dist_{ij}) + X_{ij} + \epsilon_{ij}. \tag{3.31}$$

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 3.3 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 3.3, 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 3.8).

To conclude the main baseline findings in Table 3.3, 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 3.3: 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

Note: 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 3.8 suggest that the results remain unchanged.

Furthermore, we address a potential concern with our measure of risk sharing. In equation 3.30 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

$$(\Delta log\ y_{it} - \beta_i \Delta log\ y_{wt}) - (\Delta log\ y_{jt} - \beta_j \Delta log\ y_{wt}) = \Delta log\ y_{it} - \Delta log\ y_{jt}, \qquad (3.32)$$

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

$$\Delta log\ y_{it} = \alpha_i + \beta_i \Delta log\ y_{wt} + \epsilon_{it}, \qquad \Delta log\ y_{jt} = \alpha_j + \beta_j \Delta log\ y_{wt} + \epsilon_{jt}. \qquad (3.33)$$

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

$$\Delta log\ c_{it} - \Delta log\ c_{jt} = \alpha_{ij} + \beta_{ij}[(\Delta log\ y_{it} - \beta_i \Delta log\ y_{wt}) - (\Delta log\ y_{jt} - \beta_j \Delta log\ y_{wt})] + \epsilon_{ijt}. \tag{3.34}$$

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

$$\beta_{ij} = \alpha + \gamma\,(\ln dist_{ij}) + X_{ij} + \epsilon_{ij}. \tag{3.35}$$

Table 3.9 presents the result for this robustness check. Compared to Table 3.3, 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.

3.4.3 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 3.3.1 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:

$$\begin{aligned}\Delta log\ c_{it} - \Delta log\ c_{jt} \quad &= \alpha + \beta_1(\Delta log\ y_{it} - \Delta log\ y_{jt}) + \beta_2(ln\ dist_{ij}) \\ &+\beta_3(RTA_{ijt}) + \beta_4(RTA_{ijt} \times ln\ dist_{ij}) \\ &+\beta_5[RTA_{ijt} \times ln\ dist_{ij} \times (\Delta log\ y_{it} - \Delta log\ y_{jt})] \\ &+\eta_t + \eta_i + \eta_j + \epsilon_{ijt}.\end{aligned} \tag{3.36}$$

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 3.4 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.

Table 3.4: 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 × Distance	2.61e-12	2.86e-12	2.86e-12	4.33e-12
	(0.000)	(0.000)	(0.000)	(0.001)
RTA × Distance × 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

Note: 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.

3.4.4 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 3.5 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 test and the Stock-Yogo weak IV test.[6]

Column (2) through (4) in Table 3.5 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 3.5: Trade and risk sharing

Dep Var: Δ Consumption	OLS (1)	IV (2)	IV (3)	IV (4)
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 × Δ Output	-0.001***	-0.011***	-0.011***	-0.012***
	(0.0001)	(0.002)	(0.004)	(0.004)
Distance × 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

Note: 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.

3.5 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 (2012a), 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.

3.A Appendices

Table 3.6: 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

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Country	Number of RTAs	Number of partners	Average co-participants	Average duration
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

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Country	Number of RTAs	Number of partners	Average co-participants	Average duration
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

Continued on next page

Country	Number of RTAs	Number of partners	Average co-participants	Average duration
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

Continued on next page

Country	Number of RTAs	Number of partners	Average co-participants	Average duration
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

Note: 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 3.7: 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

Note: 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 3.8: 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 × 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

Note: 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 3.9: 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

Note: 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.

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