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Essays in International Economics

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ESSAYS IN INTERNATIONAL ECONOMICS

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in

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by

Prateek Arora

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Abstract

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This dissertation studies topics of international economics, such as the impact of US monetary policy on trade and finance in emerging market economies, impact of trade, migration and finance in influencing consumption across 50 states in the United States, and healthcare costs and choices in a developing economy (India). Each chapter of the dissertation approaches one of these three topics.

The first chapter investigates the role of US dollar as the dominant currency in world trade and finance and its impact on emerging market economies. In response to a U.S. monetary tightening, I show that exports of emerging market economies (EMEs) fall, contrary to the implications of standard open economy models. To explain this puzzle, I construct a DSGE model that incorporates two important aspects of the global economy; a large share of trade volumes among EMEs are denominated in US dollars and firms in EMEs borrow in US dollars. These key features of the model, along with imported inputs in production and financial frictions (a Bernanke-Gertler-Gilchrist style financial accelerator), lead to inefficient current account imbalances. In this paper, I assess the impact on the external balancing mechanism as propounded by Mundell Fleming model through a three-country general-equilibrium model with nominal rigidities, imperfect competition in production, dominant currency pricing and financing, incomplete and imperfect asset markets.

The second chapter examines 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 economies 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 shed light on the design of macroeconomic policies that aim to reduce cross-region consumption disparity.

In the third and last chapter, we use survey data for 500 individuals from 10 villages distributed around the town of Nabha in Punjab, India, to examine patterns of healthcare choices. In particular, we examine the choice between government and private providers, and between medical professionals and informal practitioners. We also examine the joint choice of provider type and distance traveled, and possible factors influencing reported satisfaction levels with the care received. We construct a measure of anticipated treatment cost, and find that this variable, as well as reported cost-sensitivity, affects the choice between government and private providers. Our results have possible implications for policies with respect to the supply of healthcare options and their funding.

To my parents, Kanta and Shiv Arora,

and to my sister Kanika, for being constant pillars.

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I dedicate this dissertation to the loving memory of my late uncle R.G.Arora.

Chapter 1

Dominant Currency Paradigm: Pricing and Financing

1.1 Introduction

The expansive usage of the dominant currencies in international trade as well as international finance has been at the center of research in international economics in recent times. It has been shown empirically that firms in developing countries invoice their trades with each other in a dominant currency (Dominant Currency Pricing) ([Gopinath, 2016], [Goldberg & Tille, 2008]) as well as borrow internationally in the dominant currency (Dominant Currency Financing) even though neither the creditor nor the debtor country is the issuer of the dominant currency([Bruno & Shin, 2017], [McCauley et al., 2015]). Recent literature on dominant currency pricing (DCP) ([Gopinath et al., 2020], [Mukhin, 2018]) has assessed the effect of DCP on the external trade of a small open economies. However, little is known about the implications of financing in dominant currency (DCF) or of the role of financial frictions in a DCP framework which may further impact countries' external position and adjustment mechanisms. This paper aims at filling this gap in the theoretical literature. To shed light on the impact of US monetary policy on trade volumes of emerging market economies, I incorporate both DCP and DCF into a DSGE New Keynesian model and show that the traditional Mundell-Fleming argument of external adjustment fails to hold.

To explore the spillover effects of U.S. monetary policy on EMEs, I begin by estabilishing empirically that monetary tightening in the United States leads to a decline in export and import volumes in EMEs and the decline in trade volumes is larger for countries having a higher share of dollar invoicing in trade or a higher share of dollar debt. Motivated by this empirical finding, I then develop a DSGE model that combines the two channels of pricing as well as financing in dominant currency with financial frictions. After calibrating the model to Colombian data, I quantify the spillovers of US monetary policy. I confirm that a monetary contraction in US leads to a fall in exports in the small open economy. The model, with frictions, predicts a stronger spillover effects of US monetary policy on investment, imports and output as compared to the case without financial frictions. Further, in this dominant currency paradigm of pricing and financing, I compare flexible exchange rate regime with fixed exchange rate regime and I find that the decline in domestic output and investment is exacerbated under the fixed exchange rate regime.

To begin with, I investigate the relationship between the change in exports of EMEs and change in US interest rates conditional on the share of the trade invoiced in US dollars as well as share of dollar debt liabilities. For this analysis, I use trade data of 66 EMEs as well as US interest rate over the period of 1990-

2019. I document that a monetary contraction by US leads to fall in exports: a 1% increase in US monetary policy is associated with a decline of 1.1% in exports in EMEs. The impact is higher with 1) a higher of share of dollar invoicing of exports and with 2) a higher share of dollar debt liabilities. Following the taper tantrum of 2013, several empirical research studies have found the monetary spillovers in the emerging market economies in every conceivable asset[1]. I contribute to this literature by establishing the existence of an inverse relationship between a a rise in the policy rate in the U.S. and EMEs' exports in the short run. This empirical finding points to the importance of dominant currency pricing and financing channels that act as barriers in the transmission of external adjustment mechanism in the EMEs.

Motivated by the empirical analysis, I develop a small open economy DSGE model to examine the channels of dominant currency pricing and financing in a tractable general equilibrium framework. I build on the New Keynesian open economy model of [Gopinath et al., 2020] and augment it with the following additional features. First, in addition to borrowings in the home currency, firms are allowed to also borrow in the dominant currency as well. Second, rather than perfect financial markets, I introduce imperfect risk sharing through financial frictions. Specifically, I extend to the open economy DCP model the financial accelerator framework developed in [Bernanke et al., 1999] and [Gertler et al., 2007]. This framework is, in turn, based on earlier work by [Bernanke & Gertler, 1989], [Carlstrom & Fuerst, 1997] and [Kiyotaki & Moore, 1997]. A monetary contrac-

[1] The most comprehensive papers include Rey (2015) and Miranda-Agrippino and Rey (2015), which look at the Fed's effects on a wide range of markets. However, there are many papers that examine more specific markets. To mention a handful: Brusa et al. (2017) study equity markets; Fratzscher et al. (2017), Burger et al. (2017), and Chari et al. (2017) study capital flows; Cetorelli and Goldberg (2012) and Morais et al. (2015) study bank liquidity and lending; and Gilchrist et al. (2016) study bond markets

tion in US leads to a depreciation of the home currency vis-a-vis US dollars. On one hand, the introduction of dollar loans coupled with financial frictions, reduces the demand of capital in response to a depreciation of the home currency. And on the other hand, the import of investment goods reduces the supply of capital as imports become dearer. The decline in investments reduces the output as well as exports for the small open economy. To illustrate the mechanism of the two channels, I solve the model numerically to obtain results for a small open economy.

By solving the model, I show that the the traditional relationship between nominal exchange rates and terms of trade can breakdown. Financing in dominant currency indicates that exchange rate fluctuations can also have effects through their impact on domestic firms' balance sheets, a phenomenon widely studied in the literature. A depreciation of country's currency with respect to US dollar increases the value of a firm's liabilities relative to its revenues, thereby weakens its balance sheet and hinders access to new financing, because now firms' capacity to repay has deteriorated. However, this effect depends on the currency in which revenues are earned, that is, whether revenues are in dominant currency or in local currency. A rise in interest rate by the dominant country attacks the flexibility of the nominal exchange rate in two ways. First, the DCP mechanism decreases the impact on increase in exports due to a home currency depreciation and secondly, the presence of currency mismatches in borrowers' balance sheets curbs the impact of flexible exchange rate on trading volumes of the small open economy. This double jeopardy hampers the external adjustment role of flexible exchange rates.

After showing the theoretical predictions, I evaluate the model quantitatively by taking it to the Colombian data. As Colombia has more than 98% of its exports invoiced in dollars as well as more than 80% of its debt in dollars, it serves as a model economy for this dominant currency paradigm. I conduct a quantitative exercise involving parametrization using Colombian data to investigate the impact of a 1% rise in US interest rates. I find that the exports quantities decline by 0.22% with the two channels of DCP and DCF in contrast to an increase of 0.43% as per the traditional view (without the channels). Import quantities decline too and the decline is accentuated by the frictions present in the model.

I then investigate the role of financial frictions in the channel. Here, I compare three scenarios: 1)frictionless asset markets, 2) borrowings in only domestic currency and 3) borrowings in both domestic as well as dominant currency. I find that investment, imports as well as output decline as we move from frictionless world to a scenario with home currency debt only and the decline is exacerbated (by more than twice) with the introduction of dominant currency borrowings.

In the next step, I compare the flexible exchange rate regime (with DCP, DCF and financial frictions) and fixed exchange rate regime. One could argue that since in this paradigm of dominant currency financing and pricing, the flexibility of the nominal exchange rate is attacked and therefore, whether the fixed exchange system is in fact better than the flexible one. However, the results suggest that the decline in home country's output and investment to an increase in dominant country's interest rate is greater in the fixed exchange regime (with financial accelerator) than the model results for the flexible exchange rate regime.

Related Literature: The classic argument for the optimality of floating nominal exchange rates, dating back to Milton Friedman ([Friedman, 1953]), goes along the following lines: When prices are sticky, shocks to the economy generate deviations of output from its potential and consequently inefficient recessions and booms. For example, a positive productivity shock at home should, with flexible prices, lower the price of home goods relative to foreign goods. When prices are sticky in the producers currency this relative price adjustment however does not happen automatically. In this case a depreciation of the exchange rate can bring about the right relative price adjustment. A depreciation raises the price of imports relative to exports generating a depreciation of the terms of trade and therefore a shift in demand towards domestically produced goods and away from foreign goods. This exchange rate flexiblity closes the output gap and leaves the economy at its first best level. On the other hand, if the exchange rate is fixed, then the economy suffers from a negative output gap (output below its potential). A core piece of this argument that favors flexible exchange rates is the strong comovement of the nominal exchange rate and the terms of trade: A depreciation of the nominal exchange rate should be associated with an almost one-to-one depreciation of the terms of trade (of goods with sticky prices). That is a 1% depreciation of the bilateral exchange rate should be associated with a close to 1% depreciation of the terms of trade. However, there is pervasive empirical evidence that this external rebalancing mechanism (with sticky prices in producer's currency and frictionless asset markets), as propounded by the seminal contributions of [Fleming, 1962] and [Mundell, 1961], fails to hold.

This paper belongs to two main strands of literature. First, the literature on currency of pricing. Dominance of the dollar in the international price and asymmetric use of currencies in world trade has been empirically established.

([Gopinath, 2016] and [Boz et al., 2020], see 1.8.2). The first generation of open economy models ([Fleming, 1962], [Mundell, 1961], [Dornbusch, 1976], assumed that prices are rigid in producer's currency or PCP. And in those models, a depreciation in a country's exchange rate (triggered by either monetary policy or commodity prices) would imply a reduction or depreciation of the terms of trade. Because a depreciation in the exchange rate would give rise to expenditure switching, the country's exports increase as they become relatively cheaper in the international markets as compared to imports which decrease because they become relatively expensive. Second generation models ([Betts & Devereux, 2000] and [Devereux & Engel, 2001]) take cognizance of the fact that law of price doesn't hold and in these models, the assumption is that export prices are rigid in the destination currency. This paradigm is referred to as Local Currency Pricing or LCP. So, in LCP, a depreciation of country's exchange rate leads to an increase or appreciation of terms of trade. And if the currency of trade invoicing is in a dominant currency rather than producer's currency for emerging market economies, a nominal depreciation with respect to US dollar leads to an increase in import prices in the short term, inducing the same import compression as in PCP. However, prices faced by non-US trading partners do not move because their exchange rates vis-à-vis the dominant currency have not changed. So, the export quantities don't move much.[2] [Boz et al., 2019] estimates that a 1% depreciation of the bilateral exchange rate is associated with only a 0.1% depreciation of the bilateral terms of trade. Based on these empirical observations, [Gopinath et al., 2020] establish through a DSGE model that if firms set export prices in a dominant currency, face strategic complementarities in pricing, and there is roundabout production using domestic and foreign inputs; a small open economy's currency depreciation leads to a decrease in imports from all countries and the response of export volumes

[2]Please see Appendix 1.8.3

is muted under dominant currency pricing. And this in fact implies a weaker exchange rate mechanism of external rebalancing through trade volumes. This paper belongs to the third and the most recent paradigm where price stickiness in dominant currency makes currency choice relevant for monetary policy in most existing open-economy models and so it is natural to use the same friction as a starting point to think about firms' invoicing decisions.

Similarly, it has been established in the literature that firms in emerging market economies often rely on US dollar finding. Through Dominant Currency Financing (DCF), exchange rate fluctuations can also have effects through their impact on firms' balance sheets, a phenomenon widely studied in the literature. ([Bruno & Shin, 2017], [Bruno & Shin, 2020]). However, standard models do not take into account that a depreciation of the domestic currency can tighten financial constraints of firms that have debt denominated in foreign currency, thus affecting trade balance through a different channel. If firms borrow in foreign currency, a depreciation of the domestic currency increases the debt burden of those firms and tightens their financial constraints, with potentially contractionary effects on both exports and imports ([Casas et al., 2020]). So, the second strand of literature corresponds to the currency of financing and the inclusion of financial frictions in the model. The financial accelerator channel - introduced by [Bernanke et al., 1999] was extended to the open economy New Keynesian literature by [Gertler et al., 2007] where their goal was to explore the interaction between the exchange rate regime and financial crises. [Akinci & Queralto, 2018] explores the role of dominant currency in financing with financial frictions in a PCP model and establishes the case for monetary spillovers.

The contribution of this paper in the literature is to investigate the interaction of dominant currency in pricing as well as financing and to understand its impact on the traditional expenditure switching role of the exchange rates. The model in this paper is richer with a number of features and frictions interacting to bring about the results that we observe in the data. Additionally, it paves a way forward for answering a newer set of policy questions.

The remainder of the paper proceeds as follows: Section 2 establishes the impact of dominant currency pricing as well as financing on spillovers from US to EMEs. Section 3 presents a small open economy DSGE framework that includes the two channels of DCP and DCF with financial frictions. Section 4 details the mechanism for the theoretical model. Section 5 spells out the Model parameterization. Section 6 presents the results of the model and Section 7 concludes with discussion on further research.

1.2 Empirical Analysis

This section describes how I empirically establish the spillovers from US monetary policy to the trade volumes of 62 emerging market economies across the world. The findings point to the inverse relationship between US monetary policy and exports in EMEs. The method employed in this empirical section is similar to that in [Adler et al., 2020] where I examine how the variation in dollar invoicing of trade impacts the trade volumes of EMEs. In this paper, I focus on the spillovers from US monetary policy and I also study the impact of variation of dollar debt liabilities on trade volumes.

First, I estimate the role of dollar invoicing on spillovers in EMEs. In particular, the approach consists in estimating the response of the total export quantities of country i:

$$\Delta X_{i,t} = \alpha_i + \beta^u \Delta i_{u,t-1} + \beta^\lambda \lambda^x_{i,t-1} \Delta i_{u,t-1} + \beta^* \Delta i^*_{t-1} + \beta \lambda^x_{i,t-1} + \beta^\theta \theta_{i,t-1} + \Gamma controls_{i,t} + \epsilon_{i,t} \tag{1.1}$$

where Δ $X_{i,t}(M_{i,t})$ denotes the change in export (import) quantities of country i at time t , Δ $i_{u,t-1}$ denotes the lagged change in US shadow interest rate, $\lambda^{x(m)}_{i,t-1}$ represents the share of dollar invoicing in exports (imports) of country i. Following the Global VAR approach, I consider Δ i^*_{t-1} as control variable to take into account the influence of countries other than the dominant country. i^* is an indicator of the rest of the world (except US) monetary policy. This measure is approximated by the cross sectional average of rest of the world (ROW) countries' central bank policy rate (except US). β_u is the response of exports at time t to the change in US monetary policy at time t-1. The coefficient of the interaction term, β_λ, measures how the spillovers effect of US monetary policy change with the share of exports (imports) invoiced in US dollars. The control variables include domestic GDP growth rate and domestic inflation (PPI inflation for exports and CPI inflation for imports). I also control for dollar debt liabilities denoted as $\theta_{i,t-1}$.

The data used in the empirical evaluation of equation 1.2 are obtained from the following sources. The International Monetary Fund (IMF) reports country level quarterly data on exports, imports, domestic GDP, PPI inflation, CPI inflation, central bank policy rates. The sample spans from 1991-2019. Since US interest rates hit zero lower bound for a significant period under study, I use US shadow interest rates estimated by [Wu & Xia, 2016] as a proxy for US interest rates. I use the data on share of invoicing of US dollars estimated by [Boz et al., 2020].

[Benetrix et al., 2019] provides a dataset on the currency composition of the international investment position for a group of 50 countries for the period 1990-2017. I use their estimates of dollar debt liabilities as a proxy for share of dollar debt on firms' balance sheets.

Table 1.1 provides results for the regression of exports as the dependent variable (Equation 1.2). I find that the estimated coefficient (β_u) in Column (1) is negative and significant, which validates the hypothesis that exports in EMEs decline due to a monetary contraction in US. The coefficient remains significant when I add control variables in Column (2). Columns (3) confirms that the decline in exports is larger with higher share of exports invoiced in dollars as the coefficient on the interaction term (β^{λ}) is negative and significant. The coefficient remains negative and significant when I add time fixed effects (Column (4)) and control for share of dollar debt liabilities, θ (Column (5)).

In order to estimate the spillover impact on imports of EMEs, I run the regression given in equation 1.2 with change in imports as the dependent variable. The results of the regression are shown in table 1.8.1. I find that the impact of US monetary policy on EME imports is similar to that of exports where a monetary contraction by US central bank leads to a fall in imports and the decline is higher with a higher share of imports invoiced in dollars. These results indicate that higher dollar invoicing in trade leads to a fall in exports as well as imports in EMEs as a result of an increase in US interest rates.

In the next step, I run regressions to estimate the role of dollar financing on spillovers in EMEs. I use a similar regression equation as in 1.2. However, in

Table 1.1: US Monetary Policy and EMEs' Exports - Impact of Dollar Invoicing of Exports

Dependent Variable:	Δ X	Δ X	Δ X	Δ X	Δ X
	(1)	(2)	(3)	(4)	(5)
Δ US shadow rate	-0.011***	-0.012***	0.013		
	(0.003)	(0.003)	(0.006)		
λ_x * Δ US shadow rate			-0.022**	-0.021***	-0.017*
			(0.004)	(0.000)	(0.000)
λ_x			-0.006	0.078	0.068
			(0.010)	(0.057)	(0.048)
θ					0.004
					(0.019)
Δ ROW policy rate		-0.377***	-0.310***	0.066	0.463***
		(0.060)	(0.074)	(0.201)	(0.094)
PPI Inflation		0.122***	0.020	-0.007	-0.105
		(0.025)	(0.026)	(0.023)	(0.520)
GDP Growth		0.172	0.438***	0.203*	0.328
		(0.122)	(0.136)	(0.119)	(0.204)
Constant	0.073***	0.037***	0.023***	-0.041	-0.028
	(0.005)	(0.004)	(0.007)	(0.034)	(0.039)
Observations	5,479	5,479	4,907	4,907	1,057
R-squared	0.002	0.009	0.059	0.533	0.618
Country FE	Yes	Yes	Yes	Yes	Yes
Time FE	No	No	No	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

order to estimate the impact of dollar financing, the interaction term is modified to include the share of dollar debt liabilities in country i (θ_i). In particular, I estimate the response of the total export quantities of country i due to a lagged change in US shadow rates. In this specification, I control for the share of dollar invoicing in exports (imports). The specification is as follows:

$$\Delta X_{i,t} = \alpha_i + \beta^u \Delta i_{u,t-1} + \beta^\theta \theta_{i,t-1} \Delta i_{u,t-1} + \beta^* \Delta i^*_{t-1} + \beta \theta_{i,t-1} + \beta^\lambda \lambda^x_{i,t-1} + \Gamma controls_{i,t} + \epsilon_{i,t} \tag{1.2}$$

Table 1.2 shows the result of movement in exports as the dependent variable. In Column (2), I add 'share of dollar invoiced exports' as the control variable to take out the effect of dollar pricing from the equation. I find that the coefficient of interest, β^θ, is negative and significant implying that the decline in exports in EMEs due to a monetary contraction in US is larger with higher share of dollar financing. Similarly, the regression of 'change in imports' as the dependent variable shows us that the decline in imports in EMEs due to a monetary contraction in US is larger with higher share of dollar financing too (1.8.2). These results indicate that higher dollar financing leads to a fall in exports as well as imports in EMEs as a result of an increase in US interest rates.

To conclude the empirical section, I establish that a monetary contraction in US leads to a decline in exports as well as imports in EMEs. I also document that the decline in trade (exports as well as imports) is larger with a higher share of dollar invoicing and with a higher share of dollar debt financing. The finding points to the importance of the two channels of pricing and financing in a dominant currency on the external adjustment mechanism. Unlike, the traditional view, an increase in interest rates by US central bank leads to a decline in exports

Table 1.2: US Monetary Policy and EMEs' Exports - Impact of Dollar Invoicing of Exports

VARIABLES	Δ X (1)	Δ X (2)
θ * Δ US shadow rate	-0.025**	-0.029**
	(0.010))	(0.013)
θ	-0.002	0.002
	(0.016)	(0.019)
λ_x		0.071
		(0.048)
Δ ROW policy rate	0.428***	0.463***
	(0.078)	(0.094)
CPI Inflation	-0.057	-0.104
	(0.163)	(0.163)
GDP Growth	0.390	0.334
	(0.259)	(0.258)
Constant	0.031*	-0.029
	(0.017)	(0.039)
Observations	1,375	1,057
R-squared	0.420	0.421
Country FE	Yes	Yes
Time FE	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

as well as imports in EMEs and the fall is larger if these EMEs have higher share of pricing and financing in dominant currency. To explain this empirical finding, I develop a theoretical model in the next section to explore the qualitative and quantitative impact of these channels.

1.3 Theoretical Framework

In this section, I develop a theoretical model to examine the two channels of DCP and DCF with financial frictions. A small open economy H (Home) trades goods and assets with the rest of the world. I divide the rest of the world into two regions: U for the dominant currency country and R for the non-dominant rest of the world. Households (in H) work, save and consume tradable goods produced at home and abroad. Firms in H produce goods and sell to domestic households in domestic currency and export to U and R in the dominant currency. As the trade of final goods is invoiced in dollars, the nominal dollar exchange rate between Home and rest of the world (both U and R included) is denoted as $\epsilon^{\$}_{H,t}$, expressed as Home currency per unit of dollar, so that an increase in $\epsilon^{\$}_{H,t}$ represents a depreciation of the Home currency against dollars. Firms in Home borrow domestically in Home currency and from outside (either U or R) in dollars.

Households

Home is populated by a continuum of symmetric households of measure one. In each period household h consumes a bundle of traded goods $C_{H,t}(h)$. Each household also sets a wage rate $W_{H,t}(h)$ and supplies an individual variety of labor $N_{H,t}(h)$ in order to satisfy demand at this wage rate. Households own all domestic firms. The per-period utility function is separable in consumption and labor and given by

$$\left(\frac{1}{1-\sigma}C_{H,t}^{1-\sigma} - \frac{\kappa}{1+\varphi}N_{H,t}^{1+\varphi}\right), \tag{1.3}$$

where $\sigma > 0$ is the household's coefficient of relative risk aversion, $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply and κ scales the disutility of labor. A representative household in country H has the following preferences

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_{H,t}, N_{H,t}), \tag{1.4}$$

where $C_{H,t}$ denotes consumption at home and $N_{H,t}$ denotes household labor supplied in country H, at time t[3]. So, Household's Consumption bundle $C_{H,t}$ comprises of domestically produced goods ($C_{HH,t}$) and imported goods from U ($C_{UH,t}$) and R ($C_{RH,t}$). $\alpha < 1$ and $\zeta < 1$ are the weights of country U and country R's good in H's consumption bundle and $1 - \alpha - \zeta$ is the home bias. η represents elasticity of substitution between goods produced in different countries.

$$C_{H,t} = \left[(1-\alpha-\zeta)^{\frac{1}{\eta}} C_{HH,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{UH,t}^{\frac{\eta-1}{\eta}} + \zeta^{\frac{1}{\eta}} C_{RH,t}^{\frac{\eta-1}{\eta}}\right]. \tag{1.5}$$

Any bundle $C_{ij}(\omega)$ is a combination of different varieties of the differentiated good by the firm ω which is then aggregated using a CES – Dixit Stiglitz aggregator with elasticity of substitution among these different varieties as ϵ. Henceforth, C_{ij} denotes goods produced in country i and consumed in country j, $i \in \{H, U, R\}$,

$$C_{ij,t} \equiv \left(\int_0^1 C_{ij,t}(\omega)^{\frac{\epsilon-1}{\epsilon}} d\omega\right)^{\frac{\epsilon}{\epsilon-1}}.$$

The demand for good produced by firm ω in country j and consumed in country

[3] To simplify exposition, I omit the indexation of households when possible

i (where $i, j \in \{H, U, R\}$can be written as

$$C_{ji,t}(\omega) = \left(\frac{P_{ji,t}(\omega)}{P_{ji,t}}\right)^{-\epsilon} C_{ji,t}, \tag{1.6}$$

where $P_{ji,t}$ represents the producer price index,

$$P_{ji,t} = (\int_0^1 P_{ji,t}(\omega)^{1-\epsilon} d\omega)^{\frac{1}{\epsilon-1}}. \tag{1.7}$$

For example, the demand for domestically produced good consumed in country H can be written as

$$C_{HH,t}(\omega) = \left(\frac{P_{HH,t}(\omega)}{P_{HH,t}}\right)^{-\epsilon} C_{HH,t}, \tag{1.8}$$

where $P_{HH,t}$ is the Producer Price index for home good.

$$P_{HH,t} = (\int_0^1 P_{HH,t}(\omega)^{1-\epsilon} d\omega)^{\frac{1}{\epsilon-1}} \tag{1.9}$$

Similarly, the price index for product imported from country j $\epsilon\{U, R\}$ to country H is as follows:

$$P_{jH,t} = (\int_0^1 P_{jH,t}(\omega)^{1-\epsilon} d\omega)^{\frac{1}{\epsilon-1}} \tag{1.10}$$

Optimal allocation of expenditures between domestic and imported goods is given by

$$C_{HH,t} = (1 - \alpha - \zeta) \left(\frac{P_{HH,t}}{P_{Ht}}\right)^{-\eta} C_{H,t} \quad ; \tag{1.11}$$

$$C_{UH,t} = \alpha \left(\frac{P_{UH,t}}{P_{H,t}}\right)^{-\eta} C_{H,t} \quad ; \tag{1.12}$$

$$C_{RH,t} = \zeta \left(\frac{P_{RH,t}}{P_{H,t}} \right)^{-\eta} C_{H,t} \quad . \tag{1.13}$$

The Consumer Price Index (for the home country) is

$$P_{H,t} = \left[(1 - \alpha - \zeta) P_{HH,t}^{1-\eta} + \alpha P_{UH,t}^{1-\eta} + \zeta P_{RH,t}^{1-\eta} \right]^{\frac{1}{1-\eta}} \quad . \tag{1.14}$$

Given the aggregate price index, the budget constraint for each differentiated labor type(h) the households (in H's currency) is given by

$$C_{H,t} = \frac{W_{H,t}(h)}{P_{H,t}} N_{H,t}(h) + \Pi_{H,t} - \frac{B_{H,t+1} - (1+i_{t-1}) B_{Ht}}{P_{Ht}} - \left(\frac{\xi^{\$}_{H,t+1} B^{\$}_{H,t+1} - (1+i_{U,t-1}) \xi^{\$}_{H,t} \Psi_{U,t-1} B^{\$}_{H,t}}{P_{H,t}} \right); \tag{1.15}$$

where the representative household spends resources in buying consumption $C_{H,t}$ goods as well as domestic bonds (H bonds) $B_{H,t}$ and the dollar bonds $B_{U,t}$ and they earn nominal wage $W_{H,t}$. $\Pi_{H,t}$ represents profits from ownership of retail firms. In addition, they also earn interest payment on home-bonds ($B_{H,t}$) and dollar bonds ($B_{U,t}$) with interest rates denoted as $(1 + i_{t-1})$ and $(1 + i_{U,t-1})$ respectively. Since the budget constraint is in domestic currency, the dollar exchange rate enters into the equation. $\xi^{\$}_{H,t}$ represent the dollar exchange rate (dollars per unit of home currency). An increase in $\xi^{\$}_{H,t}$ would mean appreciation of home currency vis-a-vis dollars.

The non-stationarity of a small open economy around a local point complicates the dynamics. So, in order to close the model, I introduce a small friction in the world capital market, that is, a country borrowing premium 'Ψ_t' which depends on total net foreign indebtedness[4] ([Schmitt-Grohé & Uribe, 2003]). Ψ_t represents a

[4] I set the elasticity of Ψ_t with respect to NF_t very close to zero so that it doesn't alter the dynamics of the model but nonetheless makes the NF_t revert to trend.

gross borrowing premium that domestic residents must pay to obtain funds from abroad.

From the first order conditions, we get the following Uncovered Interest Parity (UIP) condition, which gives us the relation between the two interest rates, i.e., $(1+i_{t-1})$ and $(1+i_{U,t-1})$ and the exchange rates:

$$(1+i_t) = \Psi_{U,t}(1+i_{U,t})\mathbb{E}\left(\frac{\xi^{\$}_{H,t+1}}{\xi^{\$}_{H,t}}\right). \tag{1.16}$$

The UIP condition implies that an increase in the home interest rate would result in an expected appreciation of the home currency vis-a-vis the dollar. Similarly, if US interest rates increase, it would mean that the home currency would depreciate against the dollar.

Households are subject to a Calvo friction when setting wages: in any given period, they may adjust their wage with probability $1-\Gamma_w$; otherwise they maintain the previous-period nominal wage. Households face a downward sloping demand for the specific variety of labor they supply given by

$$N_{H,t}(h) = \left(\frac{W_{H,t}(h)}{W_{H,t}}\right)^{-\nu} N_{H,t}, \tag{1.17}$$

where $\nu > 1$ is the elasticity of labor demand and $W_{H,t}$ is the aggregate nominal wage in country H. Each household provides differentiated labor which is then combined using CES aggregator with elasticity of substitution as ν. The standard optimality condition for wage setting is given by

$$\begin{gathered}\mathbb{E}_t\sum_{s=0}^{\infty}\Gamma_w^s\beta^s\left(\frac{C_{H,t+s}}{C_{H,t}}\right)^{-\sigma}\frac{P_{H,t}}{P_{H,t+s}}N_{H,t+s}W_{H,t+s}^{\nu(1+\varphi)}\\ \left[\frac{\nu}{\nu-1}\kappa P_{H,t+s}C^{\sigma}_{H,t+s}N^{\varphi}_{H,t+s}-\frac{W^o_{H,t}(h)^{1+\nu\varphi}}{W^{\nu\varphi}_{H,t+s}}\right]=0,\end{gathered} \tag{1.18}$$

where $W^o_{H,t}(h)$ is the optimal nominal reset wage in country H and period t. This implies that $W^o_{H,t}(h)$ is preset as a constant markup over the expected weighted-average of future marginal rates of substitution between labor and consumption and aggregate wage rates, during the duration of the wage. The stickiness in wages is representative of the role of trade unions, employment contracts etc. in the developing economies. Sticky wages are useful to match the empirical fact that wage-based real exchange rates move closely with the nominal exchange rates and is common in the dominant currency literature (see [Gopinath et al., 2020] and [Mukhin, 2018]).

Firms

In the home country, there are three types of producers: Entrepreneurs, capital producers and retailers. Entrepreneurs manage production to produce output and also obtain financing for the capital employed in the production process. The job of capital producers is to repair the depreciated capital and construct new capital goods. Retailers are monopolistically competitive. Their job is to purchase wholesale goods from entrepreneurs, differentiate it slightly and sell the final good (CES composite of individual retail goods) to households. They are subject to nominal price stickiness.

Entrepreneurs

As mentioned above, entrepreneurs manage production and they do it through a Cobb-Douglas production function with capital K, labor L and intermediate good X as inputs.

$$Y_{H,t} = A_{H,t} K_{H,t}^{\alpha_K} X_{H,t}^{\alpha_X} L_{H,t}^{1-\alpha_K-\alpha_X}, \tag{1.19}$$

$A_{H,t}$ denotes productivity and α_K, α_X and $1-\alpha_K-\alpha_X$ signify the share of capital, labor and intermediate goods respectively in the total output ($0<\alpha_K,\alpha_X<1$).

The intermediate good used in the production process, $X_{H,t}$ follows the same aggregation structure (aggregation of domestic as well as imported goods) as the consumption goods:

$$X_{H,t}=\left[(1-\alpha-\zeta)^{\frac{1}{\eta}}X_{HH,t}^{\frac{\eta-1}{\eta}}+\alpha^{\frac{1}{\eta}}X_{UH,t}^{\frac{\eta-1}{\eta}}+\zeta^{\frac{1}{\eta}}X_{RH,t}^{\frac{\eta-1}{\eta}}\right]. \tag{1.20}$$

Another important job for entrepreneurs is capital financing. There are two sources of financing: Internal sources, that is firm's Net worth (NW) and external sources or the loans which the firm borrows (ℓ). Q_H represents the price of capital:

$$Q_{H,t}K_{H,t+1}=NW_{H,t+1}+\ell_{H,t+1}. \tag{1.21}$$

For the external financing, I assume here that a fixed proportion of loans ($\theta\in[0,1]$) are sourced in domestic currency and $1-\theta$ in dominant currency.

$$\theta*\ell_{H,t}=\frac{B_{H,t+1}}{P_{H,t}}; \tag{1.22}$$

$$(1-\theta)*\ell_{H,t}=\frac{\xi^{\$}_{H,t+1}B^{\$}_{H,t+1}}{P_{H,t}}. \tag{1.23}$$

The entrepreneur's demand for capital depends on the expected marginal return and the expected marginal financing cost. The marginal return to capital (equal to the expected average return due to constant returns) is next period's ex post output net of labor costs, normalized by the period t market value of capital:

$$1 + r^k_{H,t+1} = \frac{Y_{H,t+1} - \frac{W_{H,t+1}}{P_{H,t+1}} L_{H,t+1}}{Q_{H,t} K_{H,t+1}}$$
$$= \frac{\Upsilon_{H,t+1} \left[(\alpha_K + \alpha_X) \frac{\overline{Y_{H,t+1}}}{K_{H,t+1}} - \frac{P^I_{H,t+1}}{P_{H,t+1}} \delta + Q_{H,t+1} \right]}{Q_{H,t}}, \tag{1.24}$$

where $\overline{Y_{H,t+1}}$ is the average level of output per entrepreneur ($Y_{H,t+1} = \Upsilon_{H,t+1} \overline{Y_{H,t+1}}$), $\Upsilon_{H,t+1}$ represents idiosyncratic shock. Equation (1.24) shows that the marginal return varies proportionately with $\Upsilon_{H,t+1}$ and since $\mathbb{E}_t\{\Upsilon_{H,t+1}\} = 1$, we can express equation (1.24) as follows:

$$\mathbb{E}_t\{1 + r^k_{H,t+1}\} = \frac{\mathbb{E}_t \left\{ (\alpha_K + \alpha_X) \frac{\overline{Y_{H,t+1}}}{K_{H,t+1}} - \frac{P^I_{H,t+1}}{P_{H,t+1}} \delta + Q_{H,t+1} \right\}}{Q_{H,t}}. \tag{1.25}$$

The marginal cost of funds to the entrepreneur depends on financial conditions. Following [Bernanke et al., 1999] and [Gertler et al., 2007], I postulate an agency problem that makes uncollateralized external finance more expensive than internal finance. As in [Carlstrom & Fuerst, 1997], I assume a costly state verification problem. The idiosyncratic shock Υ_t is private information for the entrepreneur, implying that the lender cannot freely observe the project's gross output. To observe this return, the lender pays an auditing cost, interpretable as a bankruptcy cost, that is a fixed proportion μ_b of the project's ex post gross payoff, $\{1 + r^k_{H,t+1}\} Q_{H,t} K_{H,t+1}$. The entrepreneur and the lender negotiate a financial contract that: (i) induces the entrepreneur not to misrepresent his earnings; and (ii) minimizes the expected dead-weight agency costs (in this case the expected auditing costs) associated with this financial transaction.

As per the standard contract between the lender and the borrower, if the entrepreneur defaults, the lender audits and seizes whatever it finds. If the entrepreneur doesn't default, the lender receives a fixed payment independent of $\Upsilon_{H,t}$. The agency problem arising from costly state verification implies that the opportunity cost of external finance is greater than that of internal finance. The lender charges the borrower a premium to cover the expected bankruptcy costs. The external finance premium affects the entrepreneur's demand for capital because it affects the overall cost of finance. Further, the external finance premium varies inversely with the entrepreneur's net worth: the greater the share of capital that the entrepreneur can either self-finance or finance with collateralized debt, the smaller the expected bankruptcy costs and, hence, the smaller the external finance premium. Following [Bernanke et al., 1999] and [Gertler et al., 2007], the external finance premium, $\chi_t(.)$ varies inversely with net worth and is an increasing function of the leverage ratio, $\ell_{H,t+1}/NW_{H,t+1}$. Using equations (1.22) and (1.23),

$$\chi_{H,t}(.) = \chi\left(\frac{\ell_{H,t+1}}{NW_{H,t+1}}\right). \tag{1.26}$$

$\chi^{'}(.) > 0, \chi(0) = 0, \chi(\infty) = \infty$

With capital market frictions, an entrepreneur's overall marginal cost of funds can be written as:

$$\mathbb{E}_t\{1 + r^k_{H,t+1}\} = (1 + \chi_{H,t}(.))\mathbb{E}_t\left\{(1 + i_t)\theta\ell_{H,t} + (1 + i_{U,t})(1 - \theta)\ell_{H,t}\right\}. \tag{1.27}$$

Let $V_{H,t}$ is the value of the entrepreneurial firm net of borrowing costs which is equal to the return on the capital minus any repayment of loans (RoL) taken in the previous period.

$$V_{H,t} = (1 + r^k_{H,t})Q_{H,t-1}K_{H,t} - RoL; \tag{1.28}$$

$$RoL = (1 + \chi_{H,t-1}(.))\mathbb{E}_t \left\{ (1 + i_{t-1}) \frac{B_{H,t}}{P_{H,t-1}} + (1 + i_{U,t-1}) \frac{\xi^{\$}_{H,t} B^{\$}_{H,t}}{P_{H,t-1}} \right\}. \tag{1.29}$$

The repayment of loan comprises of interest repayment of home currency borrowings as well as dollar borrowings. If we suppose that there are no dollar borrowings and only home currency borrowings, any additional home currency debt, raises the leverage ratio thereby increasing the external finance premium and the overall marginal cost of finance. However, if we have dollar borrowings, then there is an additional factor, i.e., dollar exchange rate, entering into the repayment of loan equation and further impacting the leverage. If there is a depreciation of the home currency vis-a-vis the dollar, interest payments in dollars would increase. This would lower the net worth of the firm. Through this financial accelerator channel, external finance premium would rise thereby the demand for capital would be lower as compared to the perfect capital markets case.

To ensure that the entrepreneurs never accumulate enough funds to fully self-finance their capital acquisitions, I assume they have a finite expected horizon. Each entrepreneur survives until the next period with probability ϕ. The entrepreneurs' population is stationary, with new entrepreneurs entering to replace those who exit. This implies that if $V_{H,t}$ represents the value of the entrepreneurial firm in period t, ϕ times $V_{H,t}$ would be the net worth next period. And $1 - \phi$ entrepreneurs consume the rest of the value, C^e_H and die at the end of period t:

$$NW_{H,t+1} = \phi V_{H,t}, \tag{1.30}$$

$$C^e_{H,t+1} = (1-\phi)V_{H,t}. \tag{1.31}$$

Capital Producers

Capital producers have the task of constructing new capital goods. For this purpose, they use the investment good ($I_{H,t}$). Investment good is bundled in a similar fashion as the consumption good ($C_{H,t}$) and intermediate good ($X_{H,t}$). The bundling involves domestically produced goods and imported goods from U and R.

$$I_{H,t} = \left[(1-\alpha-\zeta)^{\frac{1}{\eta_I}} I_{HH,t}^{\frac{\eta_I-1}{\eta_I}} + \alpha^{\frac{1}{\eta_I}} I_{UH,t}^{\frac{\eta_I-1}{\eta_I}} + \zeta^{\frac{1}{\eta_I}} I_{RH,t}^{\frac{\eta_I-1}{\eta_I}}\right]. \tag{1.32}$$

Parameters α and ζ measure the relative weights of inputs produced in Country U and Country R's respectively. Therefore $1-\alpha-\zeta$ represent home bias in investment input. η_I represents elasticity of substitution between investment goods produced in different countries.

Optimal allocation of expenditures between domestic and imported investment goods is given by:

$$I_{HH,t} = (1-\alpha-\zeta)\left(\frac{P^I_{HH,t}}{P^I_{H,t}}\right)^{-\eta_I} I_{H,t}; \tag{1.33}$$

$$I_{UH,t} = \alpha\left(\frac{P^I_{UH,t}}{P^I_{Ht}}\right)^{-\eta_I} I_{H,t}; \tag{1.34}$$

$$I_{RH,t} = \zeta\left(\frac{P^I_{RH,t}}{P^I_{Ht}}\right)^{-\eta_I} I_{H,t}. \tag{1.35}$$

Investment Price Index (for home country) $P_{H,t}^{I}$ is given by:

$$P_{H,t}^{I} = \left[(1-\alpha-\zeta){P_{HH,t}^{I}}^{1-\eta_I} + \alpha {P_{UH,t}^{I}}^{1-\eta_I} + \zeta {P_{RH,t}^{I}}^{1-\eta_I}\right]^{\frac{1}{1-\eta_I}}. \tag{1.36}$$

The next period capital is equal to the non-depreciated capital and new investment which is subject to adjustment costs represented by Φ, following [Lucas Jr, 1967] and [Eisner & Strotz, 1963]. Consistent with the notion of adjustment costs for investment, $\Phi(.)$ is increasing and concave:

$$K_{H,t+1} = (1-\delta)K_{H,t} + \Phi\left(\frac{I_{H,t}}{K_{H,t}}\right)K_{H,t}. \tag{1.37}$$

The objective of the capital producers is to maximize profits from the construction of investment goods which gives us the following optimality condition for investment or the supply side of investment:

$$\mathbb{E}_{t-1}\left\{Q_{H,t}\Phi'\left(\frac{I_{H,t}}{K_{H,t}}\right) - \frac{P_{Ht}^{I}}{P_{Ht}}\right\} = 0. \tag{1.38}$$

Since imports of the investment goods are priced in dollars, any depreciation of home currency with respect to dollars makes the imports of these investment goods expensive, increases the price of investment good, thereby reducing the investments.

Retailers

There are a continuum of monopolistically competitive retailers whose are subject to nominal price stickiness. These retailers buy wholesale goods from entrepreneurs and differentiate it slightly at no cost. Because the product is differentiated, each retailer z has some market power:

$$Y_{Hi,t} = \left[\int_0^1 Y_{Hi,t}(\omega)^{\frac{\epsilon-1}{\epsilon}} dz \right]^{\frac{\epsilon}{\epsilon-1}}. \tag{1.39}$$

I assume a Calvo pricing environment with the probability that the firm resets its price as 1˘Γ. The retailer's pricing decision problem involves choosing optimal prices for domestic goods (in home currency) as well as exports (in dollars) to maximize

$$\begin{aligned} \mathbb{E}_t \sum_{s=0}^{\infty} \Gamma^s \beta^s \left(\frac{C_{H,t+s}}{C_{H,t}} \right)^{-\varsigma} \frac{P_{H,t}}{P_{H,t+s}} [P^o_{HH,t}(z) Y_{HH,t+s}(z) \\ + \xi^{\$}_{Ht} P^{\$o}_{Hj,t}(z) Y_{Hj,t+s}(z)] - MC_{H,t+s} Y_{H,t+s}(z) \end{aligned} \tag{1.40}$$

Equation 1.40 gives the optimal price setting condition (in domestic currency) which involves the retailers probability who could not reset the prices as Γ and the stochastic discount factor ($\beta^s \left(\frac{C_{H,t+s}}{C_{H,t}} \right)^{-\varsigma} \frac{P_{H,t}}{P_{H,t+s}}$). The retailers get their revenue by selling in domestic market (using optimal domestic price $P^o_{HH,t}(z)$ and by exporting (using optimal dollar price of $P^{\$o}_{Hj,t}, j \in \{U, R\}$). $MC_{H,t}$ represents marginal costs.

The first order condition gives us optimal reset prices for domestically sold goods as well as exported goods:

Optimal Home reset prices

$$P^o_{HH,t}(z) = \frac{\epsilon}{\epsilon - 1} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \Gamma^s Q_{Ht,t+s} MC_{H,t+s} Y_{HH,t+s} (P_{HH,t+s})^{\epsilon}}{\mathbb{E}_t \sum_{s=0}^{\infty} \Gamma^s Q_{Ht,t+s} Y_{HH,t+s} (P_{HH,t+s})^{\epsilon}}$$

;

Optimal Export reset prices

$$P^{\$o}_{Hj,t}(z) = \frac{\epsilon}{\epsilon - 1} \frac{\mathbb{E}_t \sum_{s=0}^{\infty} \Gamma^s Q_{Ht,t+s} MC_{H,t+s} Y_{Hj,t+s} (P^{\$}_{Hj,t+s})^{\epsilon}}{\mathbb{E}_t \sum_{s=0}^{\infty} \Gamma^s Q_{Ht,t+s} Y_{Hj,t+s} \xi^{\$}_{H,t+s} (P^{\$}_{Hj,t+s})^{\epsilon}}$$

.

Interest rates

The domestic risk-free interest rate is set by H's monetary authority and follows an inflation targeting Taylor rule with inertia, where ϕ_M captures the sensitivity of the policy rate to domestic price inflation and ρ_M captures the inertia in setting rates. $\bar{i}$ denotes the target nominal interest rate. Shock to the home interest rates, $e_{i,t}$ follows an AR(1) process. Thus, the policy rule takes the form:

$$i_t - \bar{i} = \rho_m (i_{t-1} - \bar{i}) + (1 - \rho_m) \phi_M \pi_t + e_{i,t}. \tag{1.41}$$

The dollar interest rate is exogenously given, equal to the international interest rate i^* plus a shock $\epsilon_{U,t}$ (follows an AR(1) process which captures country U's monetary policy:

$$i_{U,t} = i^* + \epsilon_{U,t}. \tag{1.42}$$

Market Clearing

The resource constraint (goods market clearing) for home tradable goods sector is

$$Y_{H,t} = C_{HH,t} + C_{HU,t} + C_{HR,t} + I_{HH,t} + I_{HU,t} + I_{HR,t} + X_{HH,t} + X_{HR,t} + X_{HU,t} + C^{e}_{H,t}. \tag{1.43}$$

The final good produced in country H is consumed, invested and used as domestic inputs (domestically and exported to U and R). $C^{e}_{H,t}$ represents entrepreneurial consumption of domestic good.

1.4 Mechanism

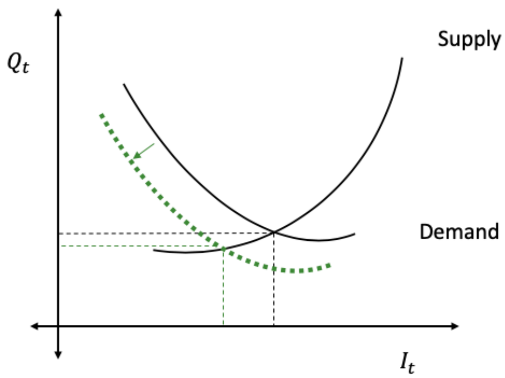
Let us understand the model mechanism through a thought experiment of an increase in country U's interest rates and its impact on investment in the home country. An increase in Country U's interest rates leads to a nominal depreciation of the home exchange rate vis-a-vis the dominant currency (Equation 1.16). Let us see how the supply and demand of capital get affected by the depreciation of home currency vis-a-vis the dollar.

I first consider a case where the two channels, viz DCP and DCF are absent. Here I assume that pricing of tradable goods and financing is done in home currency instead of producer currency. Since the financing is in home currency alone, this implies that $\theta = 1$ and a depreciation of home currency would not have any effect on value of the firm as given by Equation 1.28

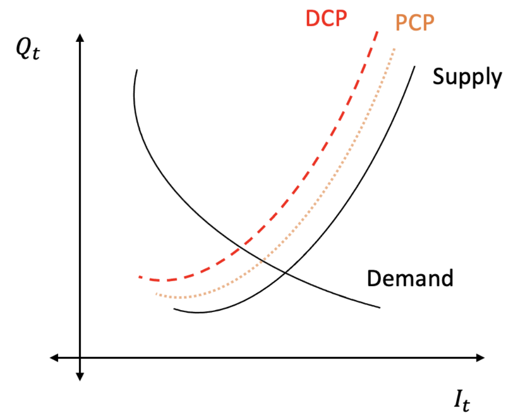
We first consider the impact on demand of investment which comes through the DCF channel. As evident from equation 1.29, a nominal depreciation of the home currency increases the interest payments on loans taken by the entrepreneurs in the dominant currency. An increase in repayment lowers the value of the entrepreneur (Equation 1.28); that reduces the net worth of the firm (Equation 1.30). Since the external finance premium varies inversely with net worth (Equation 1.26), a lowering of net worth increases the external finance premium. This implies that entrepreneur's marginal cost of funds increases and we would expect the investment demand curve to shift to the left. The reduction on the equilibrium level of investment as shown in the figure 1.1a (shown in green color) is due to a combination of financing in dominant currency as well as frictions in the asset market (financial accelerator). However, if the DCF channel is absent and financing is done in the home currency instead of the dominant currency ($\theta = 1$), then there would be no direct impact of home currency depreciation on the demand of capital through 1.29 as net worth of the entrepreneur is not directly affected by exchange rates if financing is sourced in home currency only.

On the supply side of capital, the impact comes through the DCP channel. Since investment good is a composite of domestically produced investment good and investment goods imported from country U and R, a nominal depreciation of home currency leads to a reduction in the import of investment goods (from both U and R) as the price of imported investment good goes up. This implies that the supply of investment goods decreases and we expect the investment supply curve of the capital producers (equation 1.38 to shift to the left as well. The reduction in the equilibrium level of investment as shown in the figure 1.1b (shown in red color) is due to the dominant currency pricing. However, if trade is financed in home currency instead of dominant currency, then the leftward shift in supply curve will be weaker (shown in orange color) as a depreciation of home exchange rates reduces imports from country U only, imports from country R remain the same as exchange rate between H and R does not change.

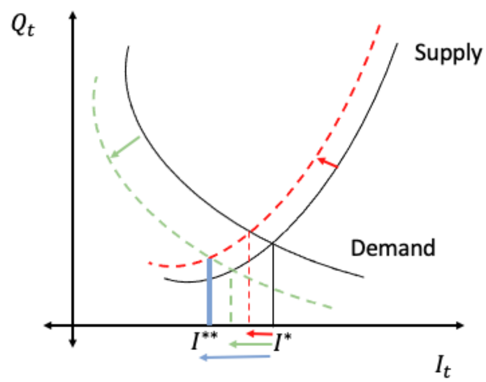
As clear from the figure 1.1c, the combined effect of DCP and DCF on the equilibrium level of investment on impact is greater than each of the individual effects (from I^* to I^{**}). Further, let us extend the argument and see the impact on exports due to a positive monetary policy shock in country U.



(a) Impact through Financing



(b) Impact through Pricing



(c) Combined Effect through DCP and DCF

Figure 1.1: Model Mechanism: An illustration

Through DCP, a depreciation of home currency implies an increase in price of imported inputs which increases the marginal costs of the firms and dampens the incentive for the firms to reduce the prices of their exports. And therefore, we would expect the effect of a currency depreciation on exports would be muted. Additionally, through DCF, a depreciation of home currency would imply the interest payments on the loans borrowed by the entrepreneur go up, thereby lowering net worth and increasing the external finance premium, which further increases the price of imported investment good. We expect the investments, output as well as exports to go down. The export volumes are in double jeopardy and depending on the relative elasticity of exports, we may observe that the effect on exports due to a depreciation of home currency may be further muted, no effect or even dampening of exports, thereby indicating that the Mundell-Fleming external rebalancing mechanism does not hold in this Dominant Currency Paradigm of pricing and financing.

1.5 Model Parameterization

The quantitative analysis in the next section is meant to capture the broad features of an emerging market economy such as Colombia with its heavy reliance on dollar invoicing and financing. Table 1.3 lists parameter values employed in the simulation for quarter as the time period. A number of parameters are set to values standard in the literature [5] . I fix the quarterly discount factor β, at 0.99. The disutility of labor supply (κ) is set as 1 and the Frisch elasticity (η) is set as .5. The value falls in the normal range in the macroeconomic literature.[6] I set the elasticity of inter-temporal substitution, $1/\sigma$, equal to 0.2. consistent with the evidence of low sensitivity of expected consumption growth to real interest rates. Following [Gali & Monacelli, 2008], I set the intra-temporal elasticity of substitution for the consumption composite (same as investment or intermediate goods composite), η, at 0.5 and elasticity of substitution between differentiated goods at 6. Following [Christiano et al., 2011], I set the wage stickiness parameter

[5] see [Gali & Monacelli, 2008], [Galí, 2010], [Gopinath et al., 2020]

[6] For instance, [Reichling & Whalen, 2012a] suggest that the estimates of the Frisch elasticity most relevant for fiscal policy analysis range from 0.27 to 0.53, with a central estimate of 0.40.

$\Gamma_w = 0.85$.

On the production side, depreciation is assigned the conventional value of 0.025. Through the following methodology adopted by [Daudey & García-Peñalosa, 2007] and [Jayadev, 2007], [Guerriero, 2019] estimates the share of labor compensation in GDP of Colombia from the period 1970-2015 to be 0.39.

$$\text{Labor Share} = \frac{\text{compensation of employees}}{\text{value added - indirect taxes- fixed capital}}$$

As per the world bank estimates, the average of gross fixed capital formation to GDP ratio for Colombia for the period 1960-2020 is 0.19. Accordingly, the remainder 0.55 share is attributed to the share of intermediate inputs in the production function. [7] Following [Gertler et al., 2007] and [Gopinath et al., 2020], I set the price stickiness parameter $\Gamma = 0.75$.

For the monetary rule, as is standard in the literature, I set inertia parameter, ρ_m, equal to 0.5, inflation sensitivity, ϕ_M as 1.5 and steady state interest rate, $\bar{i} = 1/\beta - 1$.

As per Colombian's recent thin capitalisation rule, the debt to equity ratio is now 2:1, which is almost twice that of US. I set the steady state leverage ratio equal to 2. Following [Gertler et al., 2007], I set the steady-state external finance premium at 3.5%, roughly 200 basis points higher than U.S. historical data. To obtain these steady-state values, I need to set the non-standard parameters of

[7] [Gopinath et al., 2020] uses labor share as 1/3 and intermediate inputs share as 2/3 (There is no capital in their production function). In the literature, with only capital and labor in the production function, normally labor share is between 0.55-0.65 and rest is attributed to capital.

the model that affect the relation between real and financial variables such as the entrepreneurs' death rate, (1 - ϕ), equal to 0.0272. Further, I assume that the idiosyncratic productivity variable ω_t is log-normally distributed with variance equal to 0.29. Finally, I fix the fraction of realized payoffs lost in bankruptcy, μ_b, to 0.15.

Table 1.3: Parameter values for calibrated model

Description	**Parameter**	**Value**
Household Sector		
Discount Factor	β	0.99
Risk Aversion	σ	5
Frisch elasticity of N	φ	0.5
Disutility of labor	κ	1
Elasticity of substitution	ϵ	6
Wage rigidity	Γ_w	0.85
U-bias	α	0.2
R-bias	ζ	0.2
Home bias	$1 - \alpha - \zeta$	0.6
Production Sector		
Capital depreciation rate	δ	0.025
Price rigidity	Γ_p	0.75
Entrepreneur's death rate	ϕ	0.028
Labor Share	α_l	0.39
Capital share	α_k	0.19
Intermediate share	$1 - \alpha_k - \alpha_l$	0.42
Share of dollar loans	θ	0.8
(log) Productivity	A	1
Fraction of payoff lost in bankruptcy	μ_b	0.15
Variance of log normal productivity	σ_ω	0.29
Monetary Policy		
Inertia Parameter	ρ_m	0.5
Inflation Sensitivity	ϕ_M	1.5

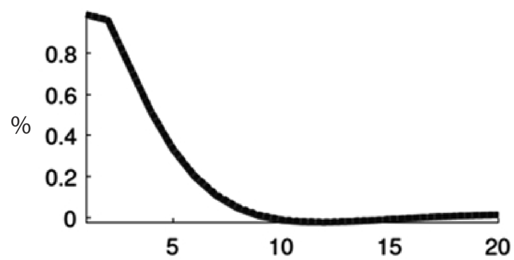
1.6 Qualitative Analysis

1.6.1 Monetary Tightening by Dominant Country

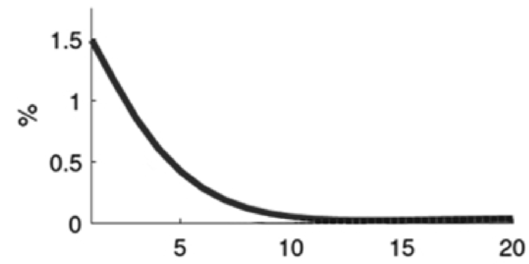
As the previous discussion reveals, the implications for DCP and DCF are deeper than each of the channels considered separately. In this section, I present numerical impulse responses to a monetary policy shock in the dominant country to tease out the effect of each of the channels separately and when combined together.

Figure 1.2 plots the impulse response to a 1 percent increase in country U's interest rates or monetary tightening by the dominant country. In each subfigure, I show the response in the baseline case (that is, with producer currency pricing and financing with no frictions) and add each of the channels subsequently to show the effect of each of the channels separately as well as together. The solid black line represents the case without DCP and DCF (baseline case, hereafter). The dashed red line represents the case where instead of PCP, I introduce DCP and there are no dominant currency loans and the financial accelerator channel is shut off. Similarly, represented by green dashed line, we see the impact of DCF with the financial accelerator but with PCP. Finally, the solid blue line indicates the combination of both the channels together - DCP and DCF - with financial frictions.

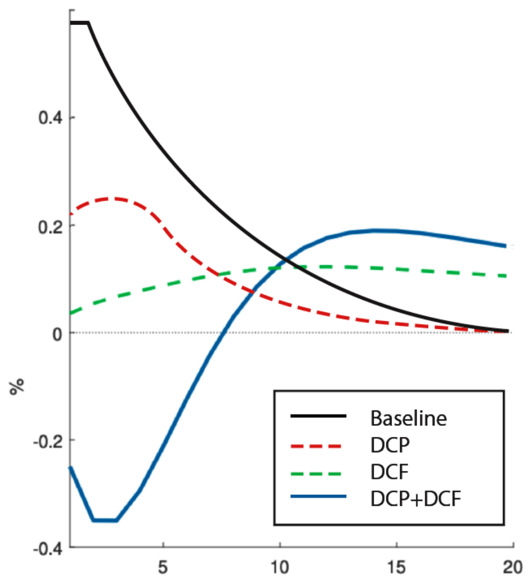
Due to a monetary tightening in the dominant country (country U), Equation 1.16 tells us that the home currency depreciates against the dominant currency as shown in Figure 1.2b. If we look at Figure 1.2c, we notice that due to a depreciation of the home currency, exports are muted in case of DCP with no DCF and no



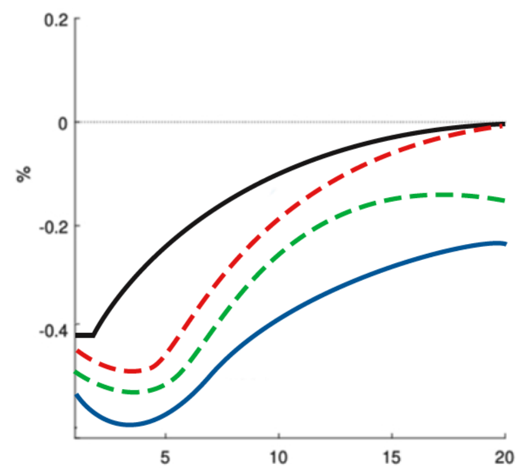
(a) Interest rate - Dominant Country



(b) Nominal Exchange Rate



(c) Exports



(d) Imports

Figure 1.2: Impact of monetary tightening by dominant country on Home country

financial frictions as compared to the baseline case despite the expansionary effect of monetary policy [8]. This is because due to the currency depreciation, imported inputs become expensive for the domestic producers and their marginal costs rise. An increase in marginal costs dampens their incentive to reduce prices of their exported product and therefore, exports do not increase as much with DCP as

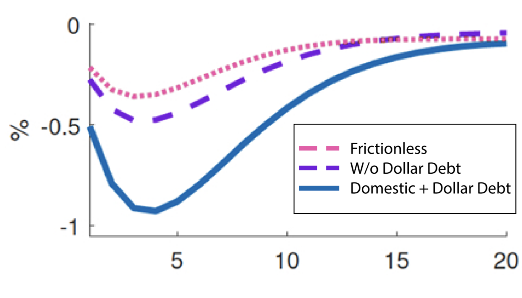
[8]My results concur with [Gopinath et al., 2020] where they too find that export quantities are muted in DCP as compared to PCP

they would with PCP. Similarly, if we shut the DCP channel and allow for DCF with financial frictions, we see a similar impact on the export quantity where the exports do not increase as much as they do in baseline case due to a home currency depreciation. The reason for the same is that due to a home currency depreciation, the interest payments on the dollar borrowings increase which leads to a fall in net worth as well as investment by the firms. A reduction in investments leads to a reduced output and dampened exports. The most interesting and novel result is the case represented in the solid blue line where both the channels DCP and DCF with financial frictions act together and we observe that exports go down as a result of a depreciation of home currency where the combination . And this is in congruence with the empirical results in Figure 1.8.3 where in short run exports decrease due to a depreciation of the currency. Further, this signifies a major blow to the external rebalancing mechanism as mentioned in the traditional literature.

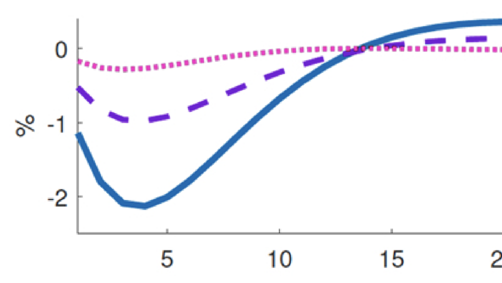
Similarly, if we compare the baseline case where a depreciation of home currency leads to a reduction in imports (Figure 1.2d) with the cases where the new channels are added, we observe that the decline of imports in the case of DCP is bigger than that of DCP because of export contraction under DCP and use of imported inputs. Similarly, DCF (with financial frictions) implies that imported investment goods become expensive and we see a larger decline as compared to the baseline case. And if we combine the two channels together, we see a bigger decline than the decline from the individual channels respectively.

1.6.2 Role of Financial Frictions

In order to understand the role of financial frictions in this model, I compare three cases - 1) DCP without financial frictions, 2) DCP with frictions and home currency borrowing only and 3) DCP and DCF with financial frictions. In the third scenario, we consider a mix of home currency and dominant currency loans with the ratio of home currency loans to domestic currency loans as 1:1. As discussed previously, due to the introduction of financial frictions, a depreciation of the home currency is expected to lead to a decline in the investment quantity. Figure 1.3a clearly shows the decline in the investment if we move from frictionless case to the home currency debt case and they fall further if the debt is financed in dominant currency too. Further, we observe the impact of financial frictions on imports (Figure 1.3b) as well where dominant currency financing coupled with financial frictions leads to a larger decline in imports as compared to the frictionless case. With foreign currency debt, the depreciation of the exchange rate reduces entrepreneurial net worth, thus enhancing the financial accelerator mechanism.



(a) Investment



(b) Imports

Figure 1.3: Role of financial frictions due to monetary tightening by dominant country on Home country

1.6.3 Fixed v/s Flexible Exchange rates

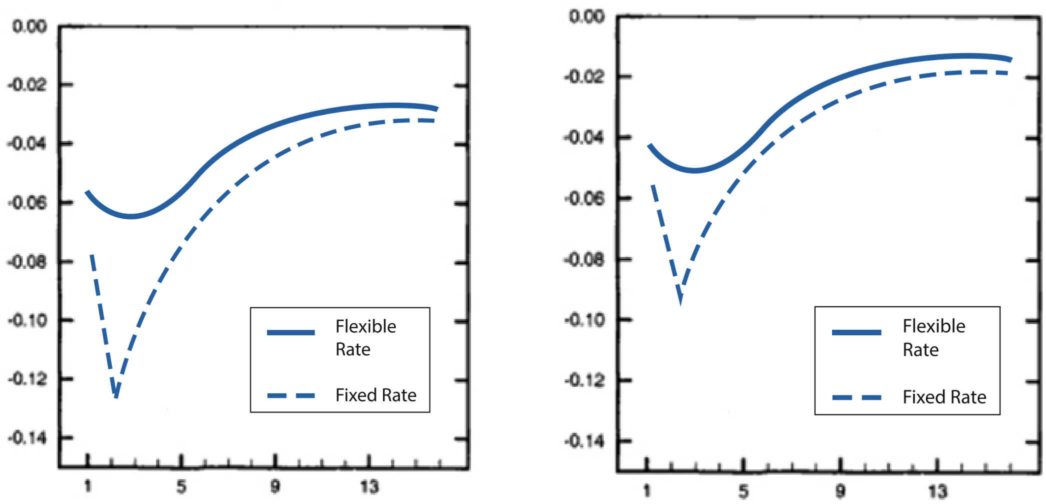
In this section, we consider shocks to the home economy under three different scenarios (i) a fixed exchange rate regime and (ii) a floating exchange rate regime where the central bank manages the nominal interest rate according to a Taylor rule.

Under the fixed exchange rate regime, the central bank keeps the nominal exchange rate pegged at a predetermined level, i.e.,

$$S_t = \bar{S}, \forall t \tag{1.44}$$

Under the fixed exchange rate regime, the domestic nominal interest rate rises to match the increase in dominant country's monetary tightening as per equation 1.16. Due to nominal price rigidities, there is also a significant increase in the real interest rate which, in turn, induces a contraction in output. The financial accelerator magnifies the output drop — the rise in the real interest rate induces a contraction in asset prices, which raises the leverage ratio and the external finance premium. The increase in the latter further dampens investment and output.

Under the flexible exchange rate regime, the policy instrument becomes the nominal interest rate. As per equation 1.41, the central bank adopts a feedback rule that ha the nominal rate adjust to deviations of CPI inflation from the target value. So, the domestic nominal interest rate is no longer tied to country U's interest rate, rather governed by the feedback rule. The rise in the country risk premium produces an immediate depreciation of the domestic currency, but due to the dominant currency framework, we observe a decrease in exports and a drop in CPI inflation. The central bank reduces the nominal interest rate, according to the feedback rule. With the current parameterization, this implies only a modest increase in the real interest rate however, and a moderate drop in investment. Because the fall in domestic inflation is due to the currency depreciation, it is short-lived. Output falls slightly on net, due to offsetting effects of a reduction in investment demand and increasing exports. Overall, output is significantly more stable under the flexible exchange rate regime.



(a) Output (b) Investment

Figure 1.4: Fixed versus Flexible Exchange Rates

1.7 Concluding Remarks and Further Research

This paper presents a unique paradigm for small open economies involving the pricing and financing in dominant currency - the dominant currency paradigm. In this paper, I developed a small open economy general equilibrium framework that incorporated nominal price and wage rigidities, financial frictions, imported inputs into production and pricing and borrowing in dominant currencies. The objective was to explore the interaction between pricing and financing in a dominant currency to explain the failure of external readjustment mechanism of exchange rates which has been explored in the empirical literature extensively. I found that the model's mechanism is quite successful in explaining the impact on trade volumes due to (say) a monetary tightening in the dominant country. The findings imply that a weakening of emerging market currencies relative to the dominant (dollar) currency following, say, a monetary policy tightening in the latter, will be associated with a decline in world trade (exports plus imports) relative to the situation when pricing and financing is in the producer's currency.

In the paper, I first empirically establish the spillovers from US moentary policy to the trade volumes in 66 EMEs across the world. An increase in US interest rate is associated with a decrease in fall in exports as well as imports of the EMEs. To explain this fact, I develop a theoretical model to explore the impact of dollar pricing in trade and dollar financing on trade of these EMEs. I extend the three economy framework of [Gopinath et al., 2020] that combines the two channels of pricing as well as financing in dominant currency with [Bernanke et al., 1999] style financial frictions. The framework, using Colombian data, quantifies the spillovers of US monetary policy on export and import volumes.

One important extension of this New Keynesian DSGE framework is to endogenize the choice of currency of debt. This would lead to an interesting question of optimal portfolio of debt for the small open economy. The dynamics of the ratio of domestic debt to foreign debt may affect the net worth and external finance premium. And it is a pertinent question for a small open economy to determine the optimal level of dominant currency debt on its balance sheet. In this direction, [Eren & Malamud, 2021] provides an international general equilibrium framework in which firms optimally choose the currency composition of their nominal debt but their model does not venture into the intersection where dominance of the currency is applicable in pricing and financing. The framework in this paper has the potential of taking that discussion forward.

Further this paper makes the case for optimal monetary policy in open economy framework. As is pointed out by [Corsetti et al., 2010] that gains from coordination are theoretically possible, however they are quantitatively small due to assumptions such as law of one price and complete international financial markets. This paper provides a framework in which both the assumptions are relaxed. In particular, this framework is useful to be employed in the optimal monetary policy context where bith the assumptions are relaxed. Other papers pursuing this research direction include [Corsetti et al., 2018] and [Casas et al., 2017], where either or both of the assumptions are relaxed. As per the results of this paper, standard monetary policy and exchange rate flexibility would not be able to fully insulate a small open economy from shock as it does in the Mundell-Fleming Framework. And therefore, it seems that the introduction of imperfect asset market in this paper along with dominant currency pricing and financing may provide directions for future research.

1.8 Appendix

1.8.1 Tables

Table 1.8.1: US Monetary Policy and EMEs' Imports - Impact of Dollar Invoicing of Imports

Dependent Variable	Δ M (1)	Δ M (2)	Δ M (3)	Δ M (4)	Δ M (5)
Δ US shadow rate	-0.005	-0.011***	-0.009		
	(0.008)	(0.003)	(0.008)		
λ_m * Δ US shadow rate			-0.034*	-0.030*	-0.017**
			(0.012)	(0.012)	(0.009)
λ_m			-0.041*	-0.005	0.200**
			(0.022)	(0.084)	(0.085)
θ					-0.060
					(0.037)
Δ ROW policy rate		-0.317***	-0.337***	0.169	-0.142
		(0.069)	(0.079)	(0.279)	(0.207)
GDP Growth		0.193	0.180	0.078	0.328
		(0.146)	(0.151)	(0.147)	(0.258)
CPI Inflation		0.017	0.016	-0.010	-0.105
		(0.027)	(0.028)	(0.027)	(0.164)
Constant	0.069***	0.029***	0.054***	-0.028	-0.039
	(0.009)	(0.006)	(0.014)	(0.059)	(0.052)
Observations	5,479	5,479	4,907	4,907	1,057
R-squared	0.0001	00025	0.0031	0.355	0.618
Country FE	Yes	Yes	Yes	Yes	Yes
Time FE	No	No	No	Yes	Yes

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

1.8.2 Figures

Table 1.8.2: US Monetary Policy and EMEs' Imports - Impact of Dollar Financing

Dependent Variable	Δ M (1)	Δ M (2)
θ * Δ	-0.038***	-0.046***
	(0.011)	(0.013)
θ	-0.017	-0.021
	(0.017)	(0.019)
λ_m		-0.023
		(0.028)
Δ ROW policy rate	0.082	0.062
	(0.081)	(0.099)
CPI Inflation	1.111***	0.912**
	(0.322)	(0.375)
GDP Growth	0.091	0.056
	(0.729)	(0.840)
Constant	0.048***	0.060**
	(0.018)	(0.029)
Observations	1,375	1,004
R-squared	0.269	0.280
Number of countryid	26	19

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

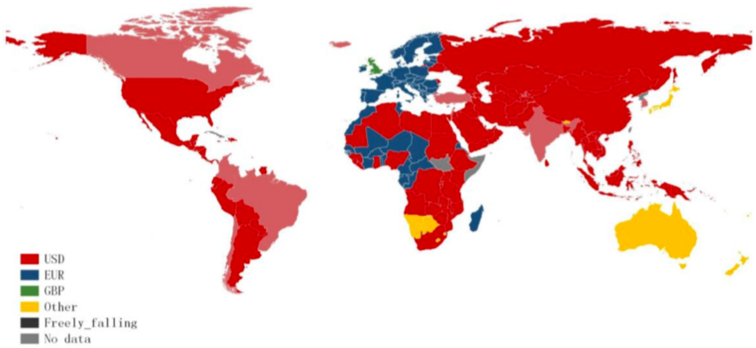


Figure 1.8.1: Dollar as an Anchor Currency

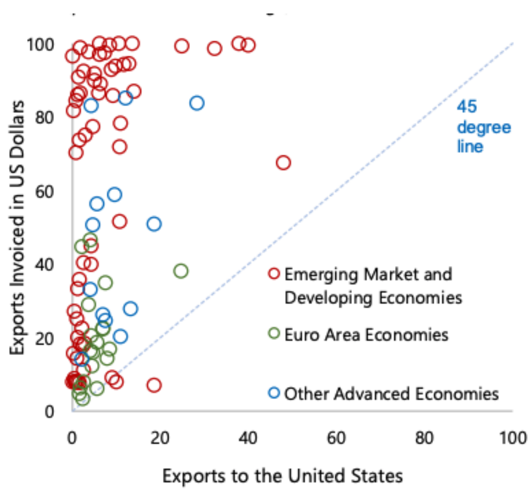


Figure 1.8.2: Dominant Currency: Pricing)

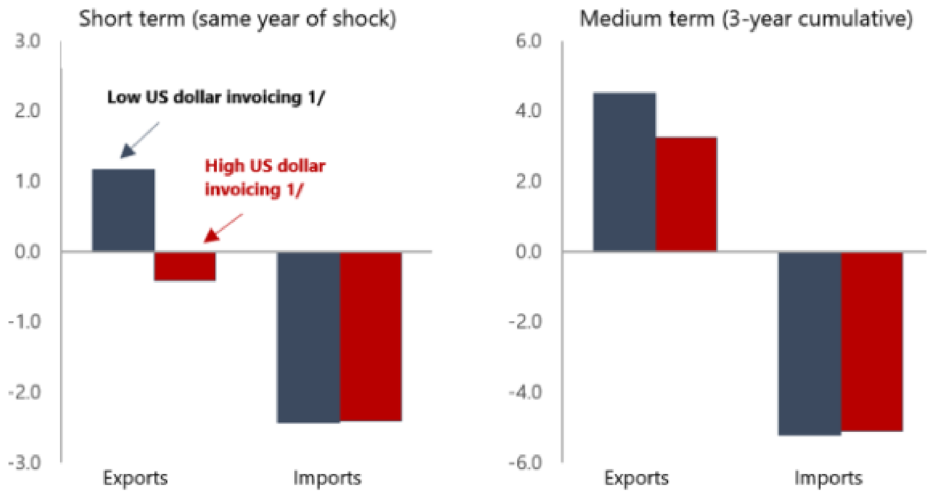


Figure 1.8.3: Currency Depreciation and Trade Volumes

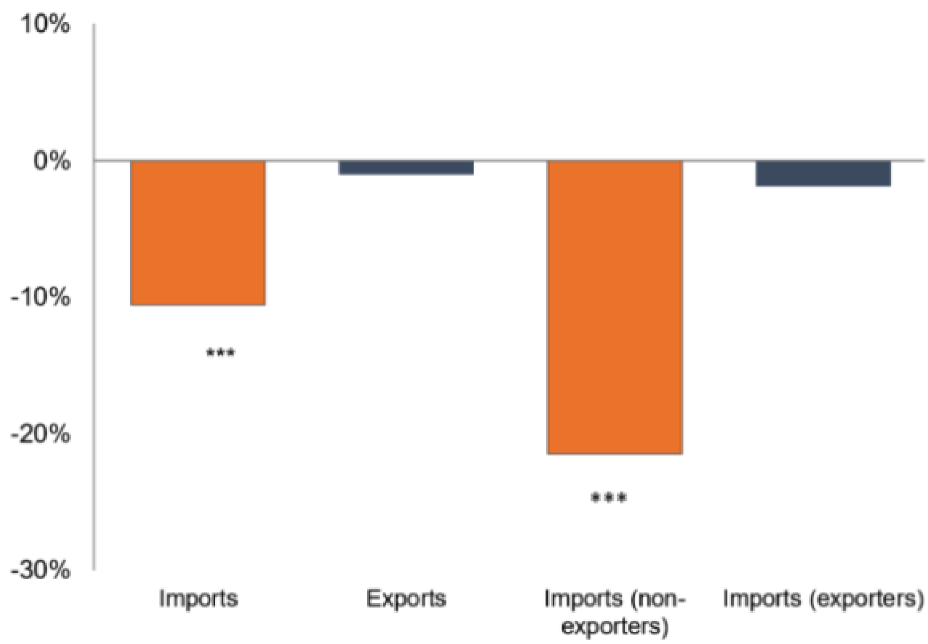


Figure 1.8.4: Dominant Currency: Financing

Chapter 2

Spatial Consumption Risk Sharing

2.1 Introduction

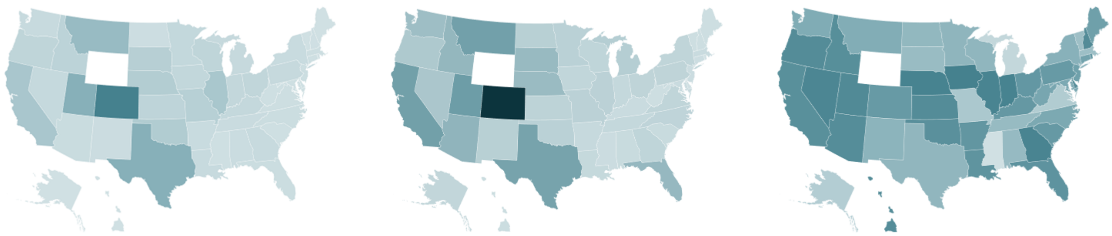
Consumption risk sharing allows different agents to experience welfare gains by reducing consumption fluctuations caused by idiosyncratic income shocks. However, there exist frictions in economic exchanges across regions that impede consumption from being smoothed across space and time. This paper[1] explores the patterns and determinants of consumption risk sharing by exploiting the variations in bilateral economic linkages shaped by geography.

In the macroeconomic literature, what drives imperfect consumption correlations across economies remains a central question of interest since the phenomenon attests to the failure of complete markets. For example, [Obstfeld & Rogoff, 2000b] consider the low cross-country consumption comovement as one of the major puzzles in international macroeconomics. Besides trade costs in the goods market discussed by these authors, migration costs in the labor market, as well as asset transaction costs in the financial market, potentially affect risk sharing since they pose barriers for economic resources to be freely mobile across economies in the presence of local shocks. Contrary to most existing literature that examines the influence of one friction, this paper extends the workhorse open economy real business cycle (RBC) model developed by [Backus et al., 1992] (BKK hereafter) into a unified theoretical framework with trade, migration, and finance as channels of risk sharing. This framework enables us to quantify the magnitude and disentangle the effects of frictions in different channels.

Another distinct feature of this paper is that we add a geographic dimension to our macroeconomic analysis. One similarity of the three channels of risk sharing lies in the fact that economic linkages in these channels covary with geo-

[1] This is a joint work with Dongwan Choo (UC Santa Cruz) and Chenyue Hu (UC Santa Cruz)

Figure 2.1.1: Wyoming's Bilateral Ties with Other States



(a) Bilateral Trade **(b)** Bilateral Migration **(c)** Consumption Corr.

This figure plots the economic linkages between Wyoming (in white) and other states in the U.S. averaged over the sample period of 1997-2017. A darker color suggests a higher value of trade and migration flows (the sum of inflows and outflows) as well as a greater correlation coefficient of real consumption per capita. Data sources are listed in Appendix 2.6.2.

graphic distance between a pair of economies, as is documented in the literature on the gravity model of trade, finance, and migration.[2] Since these channels are important drivers for cross-economy 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 the US in figure 2.1.1 and confirm that ties are generally stronger for neighboring states.[3] To capture these spatial characteristics, we embed bilateral linkages through channels of consumption risk sharing in a multi-region theoretical framework. Compared to a symmetric two-economy model such as BKK, this multi-economy framework allows us to examine the aggregate influences across bilateral exchanges on each economy's consumption. Compared to the quantitative spatial models surveyed by [Redding & Rossi-Hansberg, 2017], this RBC framework has the advantage of examining the second moments (variance and covariance) in addition to the first moment (level) of macroeconomic fundamentals, both of which are essential for welfare analysis.

We focus on state-level analysis within the US in this paper, but the general framework can be easily tailored to another setting of interest.[4] In the empirical section, we explore the relationship between consumption risk sharing and geographic distance. Following the macroeconomic literature such as

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

[3]Detailed data description can be found in Appendix 2.6.2. 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.

[4]For example, the model can be applied to intranational analysis of any other country, or international analysis of the European Union which exhibits a high level of integration in goods, financial, and labor markets.

[Asdrubali et al., 1996] and [Kose et al., 2009a], we measure a region'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, since the region's own income more predominantly drives its consumption fluctuations. We first calculate the degree of bilateral risk sharing using the output and consumption per capita data of the fifty US states over the period 1977-2019. In the next step we document that risk sharing is weaker for state pairs that are more geographically distant: Every 1% increase in distance lowers the response of relative consumption to output growth between a pair of states by 0.151 (or 0.402 standard deviations). This spatial characteristic of bilateral economic linkages echoes the prediction of the classic gravity model. As a novel empirical regularity for consumption, the finding points to the existence of barriers to risk sharing that are influenced by geography in the channels of risk sharing.

Furthermore, we examine the 2006 North Dakota oil boom as an event study to verify the importance of geography in determining the variation of consumption gains for other states. Through panel regressions, we find that due to the positive output shock, bilateral linkages of North Dakota with other states exhibit strong geographic patterns: North Dakota witnessed greater migration and trade inflows from states located in closer proximity. Meanwhile, these states also experienced stronger consumption comovements with North Dakota following the oil shock.

Motivated by the empirical findings, we develop a DSGE model to examine the channels that may shape this geographic pattern of consumption synchronization. Our model is populated by representative households who reside in different states. There are three forms of bilateral economic exchanges among states: trade, migration, and finance. In the trade channel, we follow the classic [Armington, 1969] model and assume each state produces one type of intermediate good which is traded across states subject to iceberg trade costs. In the migration channel, we modify the framework developed by [Artuc et al., 2010], who derive an Euler-type condition to capture dynamic labor adjustments. In our model, we assume households make forward-looking migration decisions in response to consumption differentials across states under migration frictions. Both the trade and migration models mentioned above have been adopted in the recent literature that examines the macroeconomic impacts of economic linkages (see, for example, [Caliendo et al., 2018], [House et al., 2018], and [House et al., 2020]).

What is more unique about our spatial analysis is the modeling of financial flows in a multi-region framework. Due to the difficulty of incorporating a frictional financial channel in a multilateral model, the existing literature has either focused on extreme scenarios (autarky or complete markets) or taken net asset positions directly from the data as exogenous. In contrast to these approaches, we set up a portfolio choice problem and endogenize households' preferences among assets from different states driven by their risk sharing needs. Furthermore, we introduce bilateral financial frictions as iceberg transaction costs on asset returns following [Heathcote & Perri, 2013] and [Tille & Van Wincoop, 2010].[5] To derive portfolios under frictions, we employ and extend [Devereux & Sutherland, 2011]'s solution technique, which combines a second-order approximation of the Euler equation and a first-order approximation of other equations to derive the steady-state portfolio in a DSGE model. 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 interact with each other to jointly shape cross-state consumption correlations, we start with a symmetric two-economy framework à la BKK. The model features key elements of real business cycles including endogenous capital accumulation and labor supply. We enrich the framework by introducing multiple channels of risk sharing subject to frictions. By conducting a set of comparative analyses, we find that the interplay among the three channels of risk sharing may yield non-monotonic predictions of how the various frictions affect consumption correlations across states. For example, higher financial frictions, by tilting portfolios towards domestic assets, reduce bilateral consumption correlations in general, consistent with the argument from the neoclassical model of risk sharing ([Lucas, 1982]). Nevertheless, when financial frictions are so high as to deteriorate wealth accumulation, population moves out of the region which has experienced a positive productivity shock. Meanwhile, the productivity shock leads to a depreciation of the region's terms-of-trade on impact which translates into lower wage rates. Therefore, these migration outflows which raise local wages due to decreased labor supply, will stabilize the cross-region wage disparity and lead to stronger consumption comovement. This analysis, by showing the effects of the channels' interactions on consumption, underscores the importance of examining these channels in an integrated general equilibrium setting.

After discussing how the three channels affect macroeconomic dynamics using the two-economy model, we extend it to a multi-region framework for a quantitative assessment of the theory. In this numerical analysis, we still focus on the bilateral linkages built through the three channels between a pair of states. Meanwhile, we consider the rest of the economy (ROE) which exerts 'multilateral resistance' on the state-pair under examination in the spirit of [Anderson & Van Wincoop, 2003]. Specifically, we develop a trilateral framework that consists of the state-pair and ROE which aggregates all the other states from the state-pair's perspective. This trilateral framework allows us to overcome the computational challenge of solving the portfolio choice problem in a DSGE model

[5] An alternative modeling assumption of the financial friction is information asymmetry. [Okawa & Van Wincoop, 2012] discuss the comparability of information frictions and transaction costs in terms of their prediction for the gravity model of financial flows. Even within a country, there exist such financial frictions that covary with geography. Empirical evidence for this is the 'home bias at home' phenomenon documented by [Coval & Moskowitz, 1999].

with many economies of unequal sizes. In terms of parametrization of the quantitative model, we calibrate trade and migration frictions to match a state-pair's bilateral trade and migration flows. Furthermore, we use the state-pair's coefficient of risk sharing estimated from the empirical section as a targeted moment to solve for the portfolio that supports this consumption comovement, and then recover the bilateral financial frictions from this specific portfolio arrangement. We conduct the estimation for all the state pairs in our sample, after which we confirm that the three types of bilateral frictions all show significantly positive correlations with bilateral geographic distance. For a 1% increase in distance, trade, migration, and financial frictions increase by 0.53%, 0.10%, and 0.23% respectively.

After computing the magnitude of frictions, we proceed to quantify their impacts on consumption. For this purpose, we conduct a series of counterfactual analyses where frictions are turned off. When evaluating the level of consumption in the steady state of the economy, we find that most states benefit from the reduction in trade costs, whereas the reduction in migration costs generates disparate predictions for different states. The most affluent states such as New York and California benefit from population inflows, while other states witness lower wage income under labor market integration. In terms of second moments, eliminating three types of frictions uniformly leads to lower consumption volatility. The mean reduction in consumption volatility across states is 0.7%, 1.0%, and 0.3% respectively when bilateral trade, migration, and financial frictions are turned off. This result supports the argument that reducing barriers to risk sharing yields welfare gains by smoothing consumption fluctuations. These counterfactual analyses not only disentangle the influences of each channel on the level and volatility of consumption, but 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 can be a useful and flexible tool for the design of macroeconomic policies which aim to narrow consumption disparity across space and time.

Relation to Literature

This paper contributes to the macroeconomic literature on consumption risk sharing by adding the geographic dimension, which enriches the understanding of the patterns and determinants of consumption comovement across economies. To explain the failure of consumption risk sharing, the existing international macroeconomic literature examines frictions in the financial market (e.g. [Baxter & Crucini, 1995], [Kollmann, 1995], and [Lewis, 1996]) and dynamics in the goods market (e.g. [Dumas & Uppal, 2001], [Corsetti et al., 2008], and that impair consumption smoothing across countries. Nevertheless, many of these works focus on one channel only and therefore do not provide a comprehensive analysis of the multiple channels for risk sharing that can disentangle their influences on consumption. Furthermore, most papers employ a two-country framework, which is not ideal to study the aggregate influences of bilateral linkages, with potential substitutability and complementarity, on macroeconomic fundamentals. There are two notable exceptions that are closer to our work. First, [Fitzgerald, 2012a] disentangles the impacts of trade costs and financial frictions on cross-country risk sharing. Compared to her paper which captures country-level financial frictions as the departure of countries' relative consumption to a benchmark country (the US) from the consumption predicted by complete markets, our portfolio choice framework makes it possible to quantify the magnitude of financial frictions at the bilateral level for cross-sectional comparison and counterfactual analysis. Second, [House et al., 2018] combine frictional trade and migration channels in a multi-region framework to quantify the benefits of labor mobility in the European Union. They have rich New Keynesian ingredients in the theoretical framework but they do not explicitly model bilateral financial frictions across economies, which are important in shaping the variation in bilateral consumption comovement in our risk-sharing analysis.

In the domestic context, [Asdrubali et al., 1996], [Hess & Shin, 1998b], [Athanasoulis & Van Wincoop, 2001], [Del Negro, 2002], and pioneered the work on consumption risk sharing within the US. These empirical works quantify the level of intranational risk sharing using state-level data. At the micro level, seminal papers including [Storesletten et al., 2004] and explore heterogeneity across the US households in terms of the impacts of income on consumption. Neither these macro nor micro perspectives focus on the effects of bilateral economic linkages across regions or the influences of region-specific conditions on households' consumption and migration decisions. Therefore, our paper extends this literature by considering additional channels for facilitating consumption smoothing within a country.

Our paper is also influenced by recent developments in the spatial economics literature. As is discussed in the comprehensive survey by new quantitative models of economic geography provide powerful yet tractable tools to characterize the distribution of economic activity across a large number of locations of uneven sizes. There are two dimensions along which our work differs from and potentially contributes to that strand of literature. First, we add a financial channel under bilateral frictions by setting up the portfolio choice framework, which complements existing papers that primarily focus on the real side of the economy and linkages in the goods and labor markets. Second, our RBC framework has the advantage of examining the second moments (variance and covariance) in addition to the first moment (level) of macroeconomic variables. For any risk-averse agent, both the level and the volatility of consumption are essential for welfare analysis. But the 'exact hat algebra' method widely used in the existing quantitative trade literature does not excel in analyzing the volatility of variables, especially when one 1) departs from the assumption of time-separable logarithm utility of consumption, 2) deviates from extreme cases for financial allocation including autarky or complete markets. Therefore, our framework fills the gap in the literature by endogenizing financial investment both over time and across space. Admittedly, the local solution method used in this RBC framework is not as flexible as the global method used in the quantitative trade literature, yet it proposes a new technique to incorporate a frictional financial channel in a multi-region framework.

Lastly, this paper 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 & Van Wincoop, 2003] and [Eaton & Kortum, 2002a] refine the theoretical foundations of the framework that rationalize empirical regularities of bilateral trade. In addition to trade, the gravity model has been applied to a wide range of topics including financial assets (e.g. [Portes & Rey, 2005], [Martin & Rey, 2004], [Aviat & Coeurdacier, 2007], and [Okawa & Van Wincoop, 2012]) and population flows (e.g. [Lewer & Van den Berg, 2008] and [Ramos & 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 the consumption pattern.

The remainder of the paper proceeds as follows: Section 2 empirically explores the influence of geographic distance on consumption comovement. Section 3 develops a two-economy framework to examine the three channels of consumption risk sharing influenced by distance. Section 4 conducts a quantitative assessment of a multi-region model to quantify the level and influence of frictions from these channels. Section 5 concludes.

2.2 Empirical Motivation

This section empirically establishes the importance of geographic distance for bilateral consumption risk sharing by using the US data. Our analysis consists of two parts. First, we use the state-level consumption and output data to compute the degree of bilateral consumption risk sharing and find that it weakens with the geographic distance between state pairs. Second, we examine the 2006 North Dakota oil shock as an event study to verify the role of geography in shaping the variation in consumption comovement of other states with North Dakota. The evidence points to the existence of frictions that covary with geography in the channels of risk sharing.

Following the literature including [Asdrubali et al., 1996] and [Kose et al., 2009a], we measure a region's consumption risk sharing as the response of its relative consumption growth to its relative output growth. 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 regions. Specifically, we evaluate risk sharing between state i and j from

$$\Delta \log\ c_{it} - \Delta \log\ c_{jt} = \alpha_{ij} + \beta_{ij}(\Delta \log\ y_{it} - \Delta \log\ y_{jt}) + \epsilon_{ijt}, \qquad (2.2.1)$$

where $\Delta \log\ c_{it}$ ($\Delta \log\ c_{jt}$) denotes the growth of log real per-capita consumption of state $i(j)$ at time t, and $\Delta \log\ y_{it}$ ($\Delta \log\ y_{jt}$) denotes the growth of log real per-capita output. The coefficient β_{ij} measures the degree of bilateral consumption risk sharing. In the case with perfect risk sharing, relative consumption growth should equal zero 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 value for the coefficient β_{ij} suggests a higher degree of bilateral risk sharing.

The data using which we evaluate equation 2.2.1 are obtained from the following sources. The US Bureau of Economic Analysis (BEA) reports state-level output, consumption and price data in the Regional Economic Accounts (REA). Our sample spans from 1977 to 2019 during which period the data for real state gross state product (GSP) are available. State-level consumption and price data from the BEA have shorter coverage (from 1997 and 2008 onwards respectively), which are 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 & Steinsson, 2014]'s state-level inflation series, deflated by which we obtain state-level real consumption. Appendix 2.6.2 provides the details of these datasets and describes the method we use to compile and analyze the data.

Table 2.2.1 provides a first glance at the state-level data of interest. Panel A reports the summary statistics of real output and consumption per capita of the 50 US states averaged from 1977-2019. The mean value of real output per capita across states is \$41,701 with a standard deviation of \$8,409. The median value is \$40,129, representing the mean output of Ohio and Georgia. In terms of consumption, the mean value across states is \$28,944 and the standard deviation is \$2,481. Both values are significantly lower for consumption than for output. The median states are Alaska and California, whose average consumption is \$28,815.

Panel B of table 2.2.1 presents bilateral correlations among all the state pairs over the sample period. The correlations are calculated using HP-filtered consumption and output per capita both in the logarithmic form. From the table, the mean bilateral output correlation is 0.422 and the consumption correlation is 0.340. This finding that bilateral output correlation is higher than consumption correlation across states within the US is consistent with international evidence documented by [Lewis, 1996], [Backus et al., 1992], and [Heathcote & Perri, 2004] among others. Since this empirical regularity contradicts the theoretical prediction in complete markets, it remains a perplexing puzzle in international macroeconomics ([Obstfeld & Rogoff, 2000b]). In this paper we use domestic data to quantify the degree of risk sharing and explore its determinants, which will potentially shed light on this consumption correlation puzzle in the international context as well.

We establish an empirical gravity model of consumption 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 2.2.1 to estimate the bilateral risk-sharing coefficients for all the state pairs over the sample period. Table 2.2.2 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 consumption risk sharing across states.

In the second stage, we regress the estimated $\hat{\beta}_{ij}$ on the log of bilateral geographic distance:

$$\hat{\beta}_{ij} = \alpha + \gamma \log(dist_{ij}) + \Gamma X_{ij} + \nu_{ij}. \tag{2.2.2}$$

We also consider control variables (X_{ij}) including state pairs' products of time-averaged GSP, geographic features, and degree of industrial and political proximity in the regression. Our hypothesis is that state pairs with greater geographic distance exhibit weaker consumption risk sharing, since bilateral economic exchanges which facilitate consumption comovements potentially face frictions that increase with bilateral distance. γ in equation 2.2.2 is therefore expected to be positive under this hypothesis. When constructing the cross-state geographic distance, we apply the Haversine formula to state capitals' longitude and latitude to approximate the distance between two states. In addition, we use the shipment distance from the Commodity Flow Survey (CFS) and verify the robustness of our empirical findings (shown in table A.2).[6]

The results reported in table 2.2.3 confirm our hypothesis that bilateral geographic distance and risk-sharing coefficients are significantly and positively cor-

[6] 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.

Table 2.2.1: Summary Statistics of Real Output and Consumption

	Mean	Std. Dev.	Min	Median	Max	Obs.
A. Level (in Dollars)						
Output	41,701	8,409	28,311	40,129	73,551	50
Consumption	28,944	2,481	24,480	28,815	34,805	50
B. Bilateral Correlation						
Output	.422	.316	-.552	.947	.479	1,225
Consumption	.340	.329	-.511	.949	.388	1,225

Real output and consumption per capita are averaged over 1977-2019 for each state. Bilateral correlation of output (consumption) is calculated as the correlation of HP-filtered real output (consumption) per capita in logarithms among all the state pairs over the sample period.

Table 2.2.2: Summary Statistics of the estimated risk sharing coefficients

	Mean	Std. Dev.	Median	Obs.
$\hat{\beta}_{ij}$	0.515	0.292	0.501	1,225

β_{ij} is estimated as the response of the relative consumption growth to the relative output growth as specified in equation 2.2.1. A higher β_{ij} suggests a lower degree of risk sharing.

related. 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' GSP per capita averaged over the sample period 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 trade flows in the classic gravity model. In column (3) we consider other geographic variables of the state pair including the product of their land sizes in square miles, the number of mainland and coastal states,[7] a contiguity dummy which equals one for adjacent states, and the total number of neighboring states to capture the state pair's multilateral ties with adjacent states. Finally, we have the total number of Metropolitan Statistical Area (MSA) and the number of MSA that geographically spans the two states under examination. The MSA numbers matter for the percentage of commuters whose location of residence differs from that of income. After controlling for these geographic variables, we find the signs of the coefficients for distance and output per-capita to remain the same as in column (2).

Furthermore, we consider measures of political and industrial proximity across

[7] These numbers take values 0,1,or 2 for a pair of states. Mainland states refer to the 48 contiguous states. Coastal states refer to the states that are not landlocked and therefore have a coastline.

Table 2.2.3: 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)
$\log(\bar{y}_1 \cdot \bar{y}_2)$		-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)
# Neighboring States			-0.002	-0.005
			(0.004)	(0.004)
# MSA			0.001	-0.002 *
			(0.001)	(0.001)
# Shared MSA			0.021	0.022
			(0.023)	(0.022)
Industrial Dissimilarity				-5.480 ***
				(0.754)
Political Dissimilarity				0.069 **
				(0.032)
Obs.	1225	1225	1225	1225
R^2	0.161	0.169	0.255	0.288

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.

states which potentially affect risk sharing according to the recent macroeconomic literature. For example, [Parsley & 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. In this spirit, we construct a state's position on the political spectrum based on whether its voter chose a Republican or a Democratic candidate ($Pol_{it} = 0$ or 1) during presidential elections and compute the mean value over the sample period from 1976 to 2020 (denoted as $\bar{P}ol_i$), and then take the squared difference to measure the political remoteness between a pair of states

$$Pol_{ij} = (\bar{P}ol_i - \bar{P}ol_j)^2. \tag{2.2.3}$$

Meanwhile, the degree of similarity of industrial structures across states influence their output synchronization. Besides, industrial profiles potentially covary with consumption synchronization since they are both affected by financial integration ([Kalemli-Ozcan et al., 2003]). Therefore, we consider a measure of industrial remoteness by comparing sectoral composition between states

$$Ind_{ij} = \sum_{s=1}^{S}(b_{i,s} - b_{j,s})^2, \qquad \text{where} \qquad b_{i,s} = \frac{\bar{Y}_{i,s}}{\sum_{s=1}^{S}\bar{Y}_{i,s}}. \tag{2.2.4}$$

$\bar{Y}_{i,s}$ denotes the output of sector s in state i averaged over the sample period sourced from the BEA.[8] Hence, $b_{i,s}$ computes the share of sector s in state i's output. By aggregating its squared difference across sectors, Ind_{ij} measures the overall dissimilarity of industrial profiles between state i and j. Based on the results reported in column (4), state pairs with a greater political similarity and industrial dissimilarity achieve a higher level of risk sharing, while the coefficient of geographic distance remains to be economically and statistically significant.

In addition the baseline estimation detailed above, we perform a series of tests to verify the robustness of our finding. The robustness checks can be divided into two groups. First, we consider alternative data sources for state-level consumption and price levels, as well as for 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 2.6.1 suggest that our finding about the gravity model of consumption risk sharing remains robust.

After exploring the general covariance between bilateral risk sharing and geographic 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

[8] We use the real sectoral output series (SAGDP9N) from the BEA, which reports data based on the 2012 North American Industry Classification System (NAICS) at the 3-digit level.

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

$$X_{ijt} = \alpha_0 + \alpha_1 \text{Oil}_t + \sum_{m=1}^{T} \alpha_{2m} \text{Oil}_{t-m} + \alpha_3 \log(dist_{ij}) + \sum_{n=0}^{T} \alpha_{4n} \text{Oil}_{t-n} \times \log(dist_{ij}) + \alpha_{5t} I_t. \tag{2.2.5}$$

X_{ijt} represents bilateral variables of interest including migration flows ($\log(mig_{ijt})$), trade values ($\log(trd_{ijt})$), and relative per-capita consumption growth between state i as ND and j as any other state. For migration and trade, we focus on ND's population and goods inflows from other states to capture the spillover of the positive shock. For the 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 for the dependent variables. Among the independent variables, we control for time fixed effects (denoted as I_t) which reflect the aggregate shocks that happen at time t. Furthermore, Oil_t is a binary variable which is unity when t denotes 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.

Table 2.2.4 reports the regression results. Based on the coefficient estimates for 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 migration and trade flows from another state to ND by 0.394% and 0.578% respectively due to the oil shock. 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

Table 2.2.4: Bilateral Linkages after the Oil Shock

	(1)	(2)	(3)	(4)
Dep. Var:	$\log(mig)$	$\log(trd)$	Δc	$\Delta \tilde{c}$
Oil_t	0.124		-0.009	0.014
	(0.465)		(0.049)	(0.054)
$\sum_{m=1}^{T} Oil_{t-m}$	-0.974	1.883 *	-0.045	0.098
	(0.599)	(0.967)	(0.077)	(0.063)
$\log(dist)$	0.013	0.012	-0.002	-0.001
	(0.014)	(0.075)	(0.002)	(0.002)
$\sum_{n=0}^{T} Oil_{t-n} \times \log(dist)$	-0.394 ***	-0.578 *	0.049 ***	0.040 **
	(0.146)	(0.325)	(0.017)	(0.017)
Observations	1,360	244	1,372	1,372
R^2	0.645	0.657	0.650	0.676

Robust standard errors in parentheses. *** significant at 1%, ** at 5%, and * at 10%. The dependent variables include North Dakota (ND)'s migration ($\log(mig)$) and trade ($\log(trd)$) inflows 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 column (2) since trade data from the CFS are not available that year.

distant states are constrained from physically moving to or selling products to the booming state. Such barriers can also account for the spatial pattern of consumption. As is reported in columns (3) and (4), ND's per-capita consumption growth is larger in magnitude relative to that of geographically distant states. From column (3), a 1% increase in distance raises ND's relative consumption boost driven by its oil shock by 0.049%. 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 (4) where we adjust consumption for output differentials, which further implies that the degree of consumption risk sharing decreases in distance across economies, consistent with the empirical regularity we documented earlier.

To conclude the empirical section, we first use consumption and output data to compute the degree of bilateral consumption risk sharing over a long horizon across states in the US. Furthermore, we establish a gravity model by documenting that risk-sharing deteriorates as geographic distance rises between a pair of states. In addition to this general pattern, we conduct an event study examining the 2006 North Dakota oil shock to verify that distance plays an essential role in spreading consumption gains, potentially through channels including migration and trade. These findings point to the existence of frictions in the channels of risk sharing that covary with distance. In the next section, we develop a theoretical model in which we examine the interplay among the channels and quantify their impacts on the level and comovement of consumption across economies.

2.3 Theoretical Model

2.3.1 Setup

In this section we develop a theoretical framework to examine the channels of consumption risk sharing across regions. The economy is populated by a continuum of infinitely-lived homogeneous households who reside in different regions indexed $i \in [1, \mathcal{I}]$. Regions are interconnected through trade, migration, and finance channels.

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

$$Y_{is,t} = A_{i,t} K_{is,t}^{\alpha} L_{is,t}^{1-\alpha}. \tag{2.3.1}$$

The region-specific productivity $A_{i,t}$ is subject to shocks $\epsilon_{i,t}$. To capture the comovement of productivity shocks across regions, we specify a joint autoregression for the vector of productivity $A_t \equiv (A_{1,t}, A_{2,t}, ..., A_{\mathcal{I},t})$ subject to shocks $\epsilon_t \equiv (\epsilon_{1,t}, \epsilon_{2,t}, ..., \epsilon_{\mathcal{I},t})$:

$$A_t = \rho A_{t-1} + \epsilon_t, \tag{2.3.2}$$

where ρ is a persistence coefficient matrix for lagged productivity of all the regions. The contemporaneous correlations among regional shocks $\epsilon_{i,t}$ can be captured by a covariance matrix denoted as Σ.

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

$$C_{i,t} = C_{iT,t}^{\nu} C_{iNT,t}^{1-\nu}, \tag{2.3.3}$$

where ν captures the weight of tradables which are composed of intermediate goods supplied by all the regions. The final goods for investment, whose price and quantity are denoted as $I_{i,t}$ and $P_{Ii,t}$, are also a Cobb-Douglas composite:

$$I_{i,t} = I_{iT,t}^{\nu_I} I_{iNT,t}^{1-\nu_I}, \tag{2.3.4}$$

where investment adds to the capital stock in region i net of depreciation δ

$$K_{i,t} = (1-\delta) K_{i,t-1} + I_{i,t}. \tag{2.3.5}$$

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

$$K_{i,t} = K_{iT,t} + K_{iNT,t}, \qquad L_{i,t} = L_{iT,t} + L_{iNT,t}, \tag{2.3.6}$$

$$Y_{iNT,t} = C_{iNT,t} + I_{iNT,t}. \tag{2.3.7}$$

On the other hand, tradable goods for consumption and investment in region i will be a CES bundle of intermediate tradable goods sourced from all the regions:

$$X_{iT,t} = C_{iT,t} + I_{iT,t}, \qquad \text{where} \qquad X_{iT,t} = (\sum_{j=1}^{\mathcal{I}} X_{ji,t}^{\frac{\phi-1}{\phi}})^{\frac{\phi}{\phi-1}}. \tag{2.3.8}$$

However, trade from j to i is subject to an iceberg cost $\tau_{ji} \geq 1$. Therefore, the aggregate price level of tradables in region i is determined by the trade cost, as well as the price of j's output, denoted as $p_{j,t}$ summed across regions of origin:

$$P_{iT,t} = [\sum_{j=1}^{\mathcal{I}} (\tau_{ji} p_{j,t})^{1-\phi}]^{\frac{1}{1-\phi}}. \tag{2.3.9}$$

Bilateral trade flows from j to i at t will therefore be given by

$$X_{ji,t} = \pi_{ji,t} X_{iT,t}, \qquad where \qquad \pi_{ji,t} = (\frac{\tau_{ji} p_{j,t}}{P_{iT,t}})^{-\phi}. \tag{2.3.10}$$

In addition, trade costs also enter the tradable goods' market clearing condition

$$Y_{iT,t} = \sum_{j}^{\mathcal{I}} \tau_{ij} X_{ij,t}. \tag{2.3.11}$$

In addition to trade, regions are integrated in the finance channel by holding each other's assets, whose dividend payout is calculated as capital income net of investment expenditure. Let $p_{i,t}$ be the price and $Y_{i,t} = Y_{iT,t} + Y_{iNT,t}$ be the quantity of output in region i, and α be the capital share from the Cobb-Douglas production function, region i's dividend at time t is given by

$$D_{i,t} = \alpha p_{i,t} Y_{i,t} - P_{Ii,t} I_{i,t}. \tag{2.3.12}$$

The returns to the assets from region i include these dividends and the changes in asset prices denoted as $q_{i,t}$:

$$R_{i,t} = \frac{q_{i,t} + D_{i,t}}{q_{i,t-1}}. \tag{2.3.13}$$

In every region there is a mutual fund that constructs a portfolio of assets from different regions on behalf of the households in that region. A household has the right to an equal share of the fund as long as it resides there. To simplify the portfolio choice problem, we assume households are myopic and do not take their migration probabilities into consideration. Instead, they expect themselves to stay and consume in the region of residence when deciding on investment for the next period.[9] Meanwhile, they incur costs when collecting financial gains earned from other regions. In particular, the literature on the gravity model of financial flows across countries, led by [Portes & Rey, 2005] and [Okawa & Van Wincoop, 2012], suggests that bilateral financial frictions covary with geographic distance. In this spirit, we introduce bilateral financial friction $e^{-f_{ij}}$ as an iceberg trade cost region j incurs when repatriating financial gains from region i. The cost can be regarded as an asset transaction cost or tax, similar to the friction modeled in [Heathcote & Perri, 2004] and [Tille & Van Wincoop, 2010].[10] Moreover, we assume it is second order in magnitude (i.e. proportional to shocks in the model). This assumption allows us to use the perturbation method developed by [Devereux & Sutherland, 2011] to solve the portfolio choice problem. The method combines a second-order approximation of the Euler equations and a first-order approximation of other equations in the model. Specifically, region i's Euler equation follows

$$E_t[\frac{U'(c_{i,t+1})}{P_{i,t+1}}R_{i,t+1}] = E_t[\frac{U'(c_{i,t+1})}{P_{i,t+1}}e^{-f_{ji}}R_{j,t+1}], \qquad \forall j \in [1, \mathcal{I}]. \tag{2.3.14}$$

where $c_{i,t}$ denotes consumption per-capita.

We use the Euler equation to derive the solution to the portfolio choice problem. First, we assume assets from region $\mathcal{I}$ to be a numeraire asset and denote i's holding of j's assets as $\alpha_{j,i,t}$. Region i's external wealth position is therefore given by

$$\mathcal{W}_{i,t+1} = R_{\mathcal{I},t}\mathcal{W}_{i,t}+\sum_{j}^{\mathcal{I}}\alpha_{j,i,t}(e^{-f_{ji}}R_{j,t}-e^{-f_{\mathcal{I}i}}R_{\mathcal{I},t})+p_{i,t}\sum_{s}Y_{is,t}+T_{i,t}-P_{i,t}C_{i,t}-P_{Ii,t}I_{i,t}, \tag{2.3.15}$$

where $T_{i,t}$ denotes the tax transfer region i receives, which is introduced to capture fiscal policies that potentially also play an essential role in risk sharing within a country.

The vector of excess returns to the other assets is introduced as R_x:

$$\hat{R}'_{x,t} = [\hat{R}_{1,t} - \hat{R}_{\mathcal{I},t}, \hat{R}_{2,t} - \hat{R}_{\mathcal{I},t}, ..., \hat{R}_{\mathcal{I}-1,t} - \hat{R}_{\mathcal{I},t}], \tag{2.3.16}$$

[9] A future extension of this baseline scenario is to relax the assumption and allow households to consider migration probabilities which prompt them to reduce saving and raise current consumption when making the investment decisions.

[10] [Okawa & Van Wincoop, 2012] discuss alternative bilateral financial frictions, including information costs, which can also rationalize the gravity model of financial flows.

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 equation 2.3.14 as

$$E_t[\hat{R}_{x,t+1} + \frac{1}{2}\hat{R}^2_{x,t+1} - (\sigma\hat{c}_{i,t+1} + \hat{P}_{i,t+1})\hat{R}_{x,t+1}] = -\frac{1}{2}\mathcal{F}_i + \mathcal{O}(\epsilon^3), \qquad (2.3.17)$$

where $\hat{R}^{2\prime}_{x,t+1}$ denotes the vector of excess squared returns

$$\hat{R}^{2\prime}_{x,t+1} = [\hat{R}^2_{1,t+1} - \hat{R}^2_{\mathcal{I},t+1}, \hat{R}^2_{2,t+1} - \hat{R}^2_{\mathcal{I},t+1}, ..., \hat{R}^2_{\mathcal{I}-1,t+1} - \hat{R}^2_{\mathcal{I},t+1}], \qquad (2.3.18)$$

and $\mathcal{F}_i$ denotes i's vector of financial frictions defined as

$$\mathcal{F}'_i = [f_{\mathcal{I}i} - f_{1i}, f_{\mathcal{I}i} - f_{2i}, ..., f_{\mathcal{I}i} - f_{\mathcal{I}-1i}], \qquad (2.3.19)$$

whose k^{th} element represents the additional financial friction region i incurs when holding $\mathcal{I}$'s asset relative to k's. The last term in equation 2.3.17, $\mathcal{O}(\epsilon^3)$, captures all terms of order higher than two.

In the next step, we take the difference of any pair of regions i and j's expanded Euler equations (2.3.17)

$$E_t[\sigma(\hat{c}_{i,t+1} - \hat{c}_{j,t+1}) + (\hat{P}_{i,t+1} - \hat{P}_{j,t+1})]\hat{R}_{x,t+1} = \frac{1}{2}(\mathcal{F}_i - \mathcal{F}_j). \qquad (2.3.20)$$

The term in the bracket represents the inflation-adjusted consumption differential across regions. We denote it in the vector term for all the region-pairs under examination as $\hat{c}p$ hereafter. Equation 2.3.20 can therefore be written as

$$E_t(\hat{c}p_{t+1}\hat{R}'_{x,t+1}) = \frac{1}{2}\mathcal{F} + \mathcal{O}(\epsilon^3), \qquad (2.3.21)$$

where $\mathcal{F}$ stacks $\mathcal{F}'_i - \mathcal{F}'_j$ vertically in a $\frac{\mathcal{I}(\mathcal{I}-1)}{2} \times (\mathcal{I}-1)$ matrix for the $\frac{\mathcal{I}(\mathcal{I}-1)}{2}$ region-pairs being analyzed. Appendix 2.6.3 outlines the technical details of how we solve the portfolio choice problem by evaluating equation 2.3.21, the portfolio determination condition. From this equation, one can tell that bilateral financial frictions in $\mathcal{F}$ affect cross-region consumption comovement $\hat{c}p$ through asset allocations.

Households' objective is to maximize their expected lifetime utility. At the beginning of every period, a household living in region i supplies labor, collects wage and financial income, and decides on consumption and investment. 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 region of residence:

$$U_{i,t} = \frac{c_{i,t}^{1-\sigma}}{1-\sigma} - \kappa\frac{l_{i,t}^{1+\eta}}{1+\eta}, \qquad (2.3.22)$$

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 region i, the household decides whether and where it wants to migrate. When it makes the decision at time t, it takes into account a non-pecuniary migration cost $d_{ij} > 0$ when moving from region i to j. If it stays, the cost is set to zero ($d_{ii} = 0$). Whether the household stays or moves, it collects an idiosyncratic benefit $\omega_i \sim F(\omega)$ from being located in region i at the end of the period. ω_i can be considered as a non-monetary benefit, such as weather and culture, that adds to the utility of living in region i. Following [Artuc et al., 2010], we assume ω_i is i.i.d across households, time, and space. It is drawn from an extreme-value distribution with zero mean:

$$F(\omega) = \exp[-e^{\omega/\theta-\gamma}]. \tag{2.3.23}$$

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

$$V_{i,t} = U_{i,t} + \beta E(V_{i,t+1}) + \sum_{j}^{\mathcal{I}} \int (\bar{\omega}_{ij,t} + \omega_{jt}) f(\omega_j) \Pi_{k \neq j} F(\bar{\omega}_{ij,t} - \bar{\omega}_{ik,t} + \omega_{jt}) d\omega_j. \tag{2.3.24}$$

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 region, and option value of moving from the region 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:

$$\bar{\omega}_{ij,t} \equiv \beta[E(V_{j,t+1}) - E(V_{i,t+1})] - d_{ij}. \tag{2.3.25}$$

Under the distributional assumption of ω, the share of population moving from i to j at t follows

$$m_{ij,t} = \frac{\exp(\bar{\omega}_{ij,t}/\theta)}{\sum_{k=1}^{\mathcal{I}} \exp(\bar{\omega}_{ik,t}/\theta)}, \tag{2.3.26}$$

where the parameter from the extreme-value distribution θ governs the responsiveness of migration to economic conditions. The law of motion for population in region i given $m_{ij,t}$ follows

$$N_{i,t} = \sum_{j=1}^{\mathcal{I}} m_{ji,t-1} N_{j,t-1}. \tag{2.3.27}$$

With all the ingredients introduced, we now proceed to characterize optimal consumption risk sharing across regions as a benchmark. Suppose there is a benevolent social planner whose objective is to maximize the sum of all the representative households' expected lifetime utility in the economy:

$$\max \sum_{t=0}^{\infty} \sum_{i}^{\mathcal{I}} \beta^t N_{i,t} \lambda_{i,t} \left(\frac{c_{i,t}^{1-\sigma}}{1-\sigma} - \kappa \frac{l_{i,t}^{1+\eta}}{1-\eta} \right) \tag{2.3.28}$$

subject to the resource constraint

$$\sum_{i}^{\mathcal{I}} (N_{i,t} P_{i,t} c_{i,t} + P_{Ii,t} I_{i,t}) = \sum_{i}^{\mathcal{I}} p_{i,t} (Y_{iN,t} + \sum_{j}^{\mathcal{I}} X_{ij,t}) + \sum_{i}^{\mathcal{I}} T_{i,t}. \tag{2.3.29}$$

$\lambda_{i,t}$ is the per capita weight that the social planner assigns to the utility of residents in region i at time t. The social planner's optimal decision rule for a pair of regions i and j should satisfy

$$\frac{\lambda_{i,t}}{\lambda_{j,t}} \left(\frac{c_{i,t}}{c_{j,t}} \right)^{-\sigma} = \frac{P_{i,t}}{P_{j,t}}. \tag{2.3.30}$$

When asset markets are complete, the optimal consumption allocation in the competitive equilibrium coincides with the decision of the planner who assigns time-invariant weights to all the regions regardless of the realization of regional productivity shocks. Therefore, the ratio of $\lambda_{i,t}$ to $\lambda_{j,t}$ denoted as

$$\Lambda_{ij,t} = \frac{\lambda_{i,t}}{\lambda_{j,t}} \tag{2.3.31}$$

should be constant. Based on this analysis, the volatility of $\Lambda_{ij,t}$ over time reflects bilateral financial frictions because it captures the departure of consumption from the allocation under complete markets. As is argued by [Fitzgerald, 2012a], $\Lambda_{ij,t}$ offers great flexibility since it does not depend on the assumption about the asset market structure or about the specific form the financial friction takes. However, it is easier to use the asset transaction cost f_{ij} we introduced earlier as a measure to quantify the magnitude of financial frictions for cross-region comparison and counterfactual exercise. Therefore, we will use $\Lambda_{ij,t}$ in the qualitative analysis and f_{ij} in the quantitative analysis in the next section for the examination of a two-region scenario.

2.3.2 Two-region Analysis

After describing the general setup including $\mathcal{I}$ regions, we analyze a two-region case to explain the mechanism through which different channels affect consumption risk sharing and illustrate how the channels interact with each other.

Before showing the quantitative results from numerical exercises, we conduct qualitative analysis to elucidate the intuition of how consumption risk sharing is achieved in a two-region framework. To keep this qualitative analysis tractable, we impose several simplifying assumptions temporarily: The two regions under examination, indexed 1 and 2, are perfectly symmetric. There is no endogenous labor supply, tax transfer, or capital accumulation. All goods are tradable subject to bilateral trade costs $\tau_{12} = \tau_{21} = \tau > 1$. Under these assumptions we analyze the cross-region ratio of any variable $x \equiv \frac{x_1}{x_2}$ whose deviation from the steady state is denoted as $\hat{x} = \log \frac{x - \bar{x}}{\bar{x}}$. Log-linearizing the goods market clearing condition (equations 2.3.10 and 2.3.11) and the social planner's allocation rule (equations 2.3.30 and 2.3.31) yields

$$\hat{Y} = \Omega(1 - \sigma\phi)\hat{c} - \phi\hat{p} + \Omega\phi\hat{\lambda} + \Omega\hat{L}, \\ where \qquad \Omega = \frac{1 - \tau^{1-\phi}}{1 + \tau^{1-\phi}}. \tag{2.3.32}$$

Based on equation 2.3.32, the response of relative per-capita consumption $\hat{c}$ to relative output $\hat{Y}$ driven by productivity changes, varies with trade costs τ through the coefficient Ω. When domestic and foreign goods are sufficiently substitutable ($\phi > 1$), higher trade costs impede consumption risk sharing because the relative consumption increases with relative output fluctuations:

$$\frac{\partial(\partial c/\partial Y)}{\partial \tau} = \frac{1}{\sigma\phi - 1}\frac{1}{\Omega^2}\frac{\partial \Omega}{\partial \tau} > 0. \tag{2.3.33}$$

Meanwhile, three channels, represented by the other terms on the right hand side of 2.3.32, help absorb the impact of productivity shocks on consumption. In particular, the direction for the dynamics of the variables follows

$$\frac{\partial p}{\partial Y} < 0, \qquad \frac{\partial \lambda}{\partial Y} > 0, \qquad \frac{\partial L}{\partial Y} > 0. \tag{2.3.34}$$

To explain the economic interpretation of how these channels counteract output shocks to insulate consumption, we analyze a scenario where there is a relative negative output shock to region 1 ($\hat{Y} \downarrow$). First, a terms-of-trade appreciation ($\hat{p} \uparrow$) alleviates the shortfall of region 1's income and hence leaves its consumption less affected. Second, more financial resources, represented by $\hat{\lambda} \downarrow$, mitigates region 1's consumption fluctuation. Since λ can be interpreted as the inverse of marginal utility from consumption given price levels, the decline of λ's value represents the situation where the marginal utility of the residents in region 1 which inflicts the output loss is more valued by the social planner when allocating financial resources. Given this financial allocation, region 1's relative consumption does not decline as significantly. Third, migration of population out of region 1 ($\hat{L} \downarrow$) reduces the local population among which resources are allocated and therefore equalizes consumption per-capita across regions.

We now proceed to conduct numerical exercises and analyze the quantitative results of the model. The framework is similar in style to the workhorse model in international macroeconomics developed by [Backus et al., 1992] who examine the real business cycles of two symmetric economies. We enrich the framework by incorporating trade, migration, and asset flows under frictions across economies. In terms of parameterization, the model is calibrated to the U.S. annual data for cross-state analysis. Table 2.3.1 summarizes the parametric assumptions under which the baseline two-region framework is solved. First, we adopt the standard assumptions from macroeconomic literature (listed in panel (I)) including the coefficient of risk aversion and elasticity of labor supply.

In panel (II), we report the parameters estimated from the U.S. aggregate economy. Specifically, 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. In addition, we set the share of consumption expenditure on tradables (ν) as 0.31 following [Johnson, 2017a], who estimates the value based on the US CPI expenditure data from the BEA. Moreover, we set the weight of tradables in investment (ν_I) as 0.4 following [Bems, 2008a]. His analysis uses the input-output table from the OECD. Last but not least, we follow [Simonovska & Waugh, 2014] and [Artuc et al., 2010] when setting elasticities of trade and migration as 4.1 and 4.5 respectively.

In panel (III), we characterize the joint productivity process of 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 region $i \in \{\text{GA, OH}\}$ at time t from

$$\log(A_{i,t}) = \log(Y_{i,t}) - \alpha \log(K_{i,t}) - (1 - \alpha) \log(L_{i,t}), \tag{2.3.35}$$

where $Y_{i,t}$ and $L_{i,t}$ are output and number of employees in state i in year t from the BEA over the sample period. State-level capital stock $K_{i,t}$ is not directly available, so we construct the measure following [Garofalo & Yamarik, 2002]'s method. Specifically, we apportion national capital stock to states based on their industry-level income data (see Appendix 2.6.2 for details). After we calculate the state-level TFP, we detrend the series with the Hodrick-Prescott (HP) filter. Lastly, we estimate a joint AR(1) process (specified in equation 2.3.2) assuming the shocks are serially independent and drawn from a joint normal distribution. Table 2.3.1 reports the persistence and covariance matrices of Georgia and Ohio's productivity.

Panel (IV) of table 2.3.1 lists the values of bilateral frictions calibrated to the pair of states under examination. Trade costs, migration costs, and financial costs are estimated to match three targeted moments: the mean export-to-output ratio (0.392), the mean emigrant-to-population ratio (0.028), and the bilateral consumption correlation (0.824) of Georgia and Ohio over the sample period. When estimating trade and migration frictions simultaneously, we start with an initial guess for the combination of the two frictions, solve for the corresponding wage rates and labor hours given the frictions that satisfy the labor market clearing condition (equation 2.3.6), and update the guess as well as repeat the procedure until the model-predicted export-to-output and emigrant-to-population ratios converge to those in the data. After calibrating these two frictions on the real side of the economy, we estimate model-consistent financial frictions. Unlike trade and migration whose bilateral flows are available in the data, state-to-state financial flows are not directly observable. Therefore, we infer financial frictions indirectly from the consumption pattern. Besides its feasibility given limited data availability, this method is helpful in capturing the influences of the financial channel on consumption comovement. Calibrating financial frictions with this method involves three steps. First, we obtain the coefficient matrices necessary to solve the portfolio choice problem from the first-order conditions of the model.[11] Second, we solve for asset holdings $\tilde{\alpha}$ under which the model-implied bilateral consumption correlation exactly matches that in the data. Third, we plug the calibrated portfolio in equation 2.3.21 to recover financial frictions.

Table 2.3.1: Parametrization

Parameter	Description	Value	Source
	(I)		
β	Annual discount factor	0.95	
σ	Coefficient of relative risk aversion	1	Macroeconomic
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, 2017a]
ν_I	Weight of tradables in investment	0.40	[Bems, 2008a]
α	Capital intensity in production	0.41	BEA
θ-1	Elasticity of trade	4.1	[Simonovska & Waugh, 2014]
ϕ	Elasticity of migration	4.5	[Artuc et al., 2010]
	(III)		
ρ	Persistence matrix of productivity	$\begin{bmatrix} 0.65 & 0.06 \\ 0.04 & 0.53 \end{bmatrix}$	
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
d	Migration cost	19.58	GA and OH's target,
f	Financial cost	3e-5	values.

Under the specified parametrization, table 2.3.2 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 the aggregate and the per capita levels. In either case, output exhibits stronger cross-state synchronization than consumption. This result, which verifies the consumption correlation puzzle in the empirical section, points to the existence of frictions that impair consumption risk sharing. Panel (II) presents the correlation between a state's consumption with its own output per capita. Based on the finding that the correlation is greater

[11] Appendix 2.6.3 provides the technical details. The coefficient matrices include R_1, R_2, D_1, and D_2 in equations A17 and A18, which capture the responses of consumption differentials and excess asset returns to excess portfolio returns.

Table 2.3.2: 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

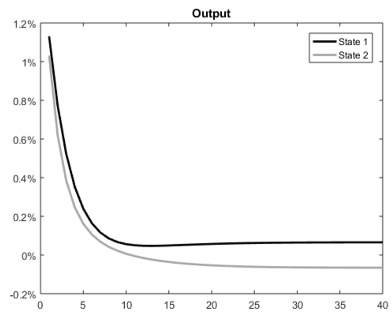
This table reports the contemporaneous correlations of Hodrick-Prescott filtered data and those in the calibrated model. Panel (I) reports the cross-region comovement of output and consumption at the aggregate (denoted as Y_i, C_i) and per capita (denoted as y_i, c_i) levels. Panel (II) reports the comovement of a region'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.

than 0.9 in both the model and the data, consumption is highly procyclical. Furthermore, Panel (II) reports the correlation between a state's scaled net export (NX/Y) and population (N) with its own output (Y). Scaled net exports, measured as the ratio of the differences between exports and imports to output, turn out to be countercyclical. This finding is consistent with the international stylized facts documented by [Mendoza, 1991] and [Backus et al., 1992]. In addition, the contemporaneous correlation between population and output is negative both empirically and theoretically. Nevertheless, this correlation does not reflect the cumulative effects caused by delayed migration decisions under migration costs. To overcome such limitations, we examine the dynamic response of variables by plotting impulse response functions in the next step.

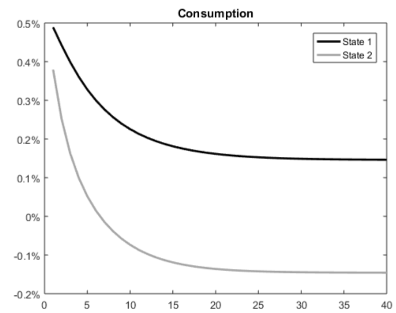
Figure 2.3.1 shows the impulse responses of the two states' output and consumption to a one-standard-deviation innovation in state 1's productivity. The black line shows the dynamics of state 1's variables and the grey line shows state 2's. Both states experience increases in output and consumption right after the productivity shock takes place. Even though the shock happens to state 1, there is positive spillover to state 2 not only due to productivity covariances but also thanks to cross-state goods, financial, and labor flows. Nevertheless, synchronization across states is not perfect and therefore state 1 witnesses greater improvements in its output and consumption.

To further understand the driving forces of synchronization, we examine the key variables of interest in the three channels. Figure 2.3.2 plots the impulse responses of state 1's terms of trade, external wealth position, investment, and population. Following a positive productivity shock to state 1, state 1 experiences

Figure 2.3.1: Cross-state Comparison of Impulse Response Functions



(a) Output



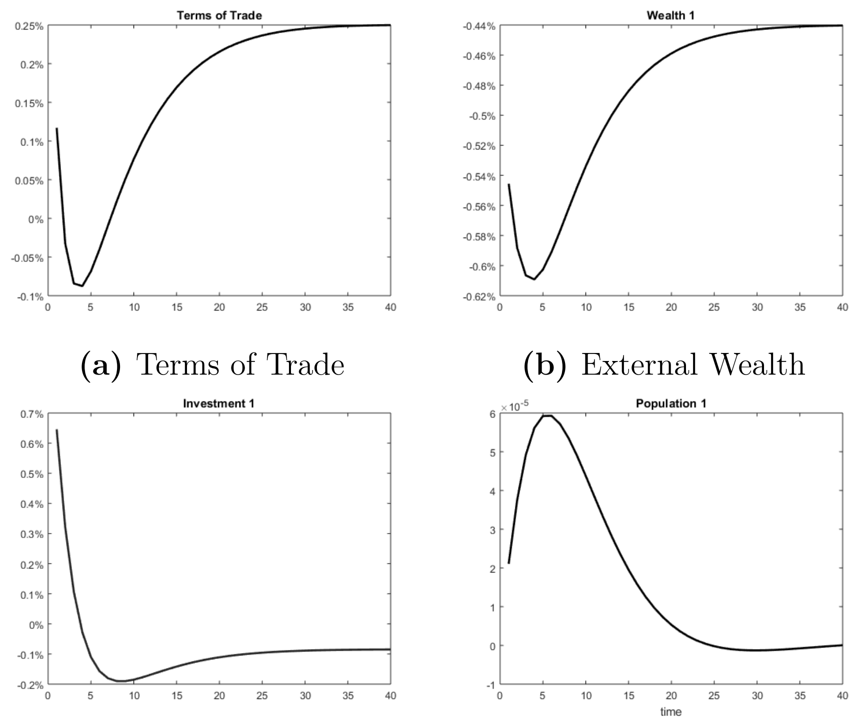
(b) Consumption

Note: This figure plots the dynamic responses of macroeconomic variables, including output and consumption, to a one-standard-deviation innovation in state 1's productivity. The black and grey lines respectively show state 1's and state 2's variables. These variables are measured as a percentage of steady-state output in the plots.

a terms-of-trade depreciation as its exports become cheaper relative to imports to clear the goods market. This depreciation will help increase the consumption of state 2, which does not experience the productivity boost, by raising its relative nominal income. Meanwhile, state 1 has a negative external wealth position, 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 investment are higher, which causes state 1's investment spike shown in figure 2.3.2c. As is argued by [Heathcote & Perri, 2013], this cross-border investment financing facilitates risk sharing. Lastly, population flows into state 1 (figure 2.3.2d), which raises the number of households among whom the increased aggregate consumption is shared and therefore helps to equalize consumption per capita across states. These quantitative results are mostly consistent with the qualitative analysis based on equation 2.3.34, with the exception that endogenous capital accumulation, which is absent from the qualitative analysis, alters the direction of financial flows in the short run, the same prediction as the one from the international RBC framework by [Backus et al., 1992].

In the next step we conduct comparative analyses by varying the magnitude of the frictions to understand the impacts of barriers on the effectiveness of as well as the interactions among the channels of consumption risk sharing. Figures 2.3.3-2.3.5 illustrate the scenarios in which one type of friction doubles its calibrated value while the other parameters remain unchanged as in the baseline case. In the trade channel, state 1's terms-of-trade and exports to state 2 are less volatile when trade costs are high, as is shown in figure 2.3.3. This finding suggests that higher trade costs mute trade adjustments to productivity innovations, which leaves state 2 less benefited from state 1's positive productivity shock. In the financial channel

Figure 2.3.2: Impulse Response of State 1's Macroeconomic Variables



(a) Terms of Trade

(b) External Wealth

(c) Investment

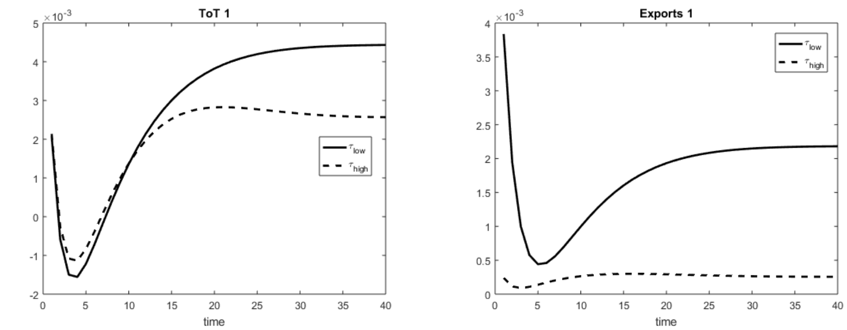
(d) Population

Note: This figure plots the dynamic responses of macroeconomic variables to a one-standard-deviation innovation in state 1's productivity. Variables under examination include state 1's terms of trade, external wealth, investment, and population. They are measured as a percentage of steady-state output in the plots.

(see figure 2.3.4), financial frictions raise state 1's cost of holding state 2's assets and generate asset home bias. However, the current dividends to assets, calculated as the difference between capital income and investment expenditure, are lower for state 1's assets than for state 2's given state 1's investment spike driven by the productivity shock. Therefore, in figure 2.3.4a higher financial frictions lower state 1's wealth accumulation by tilting portfolios toward temporarily lower-yielding domestic assets. Meanwhile, the financial channel has spillover effects on the migration channel by altering households' migration decisions. Lower financial frictions facilitate consumption risk sharing by allowing states to hold each others' assets, which dampens households' incentive to physically move across states in pursuit of higher consumption. Therefore, the dynamics of population are less volatile when financial frictions are lower in figure 2.3.4b.

The response of migration is also smaller when migration costs are higher, as is shown in figure 2.3.5a that raising migration costs flattens the curve of cross-

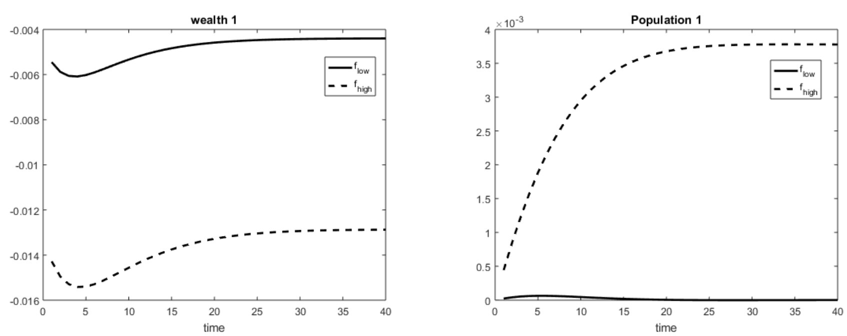
Figure 2.3.3: Comparative Analysis under Different Trade Costs



(a) Terms of Trade **(b)** Exports

Note: This figure plots the dynamic responses of state 1's terms of trade and exports to state 2, to a one-standard-deviation innovation in state 1's productivity. The solid and dashed lines show the situations with low and high trade costs respectively.

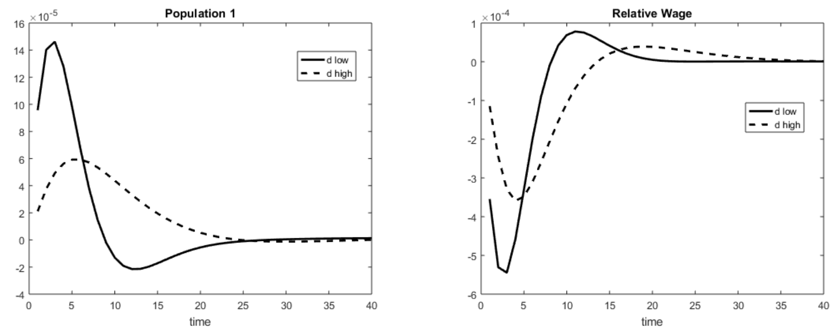
Figure 2.3.4: Comparative Analysis under Different Financial Frictions



(a) Wealth **(b)** Population

Note: This figure plots the dynamic responses of state 1's external wealth and population, to a one-standard-deviation innovation in state 1's productivity. The solid and dashed lines show the situations with low and high financial frictions respectively.

Figure 2.3.5: Comparative Analysis under Different Migration Costs



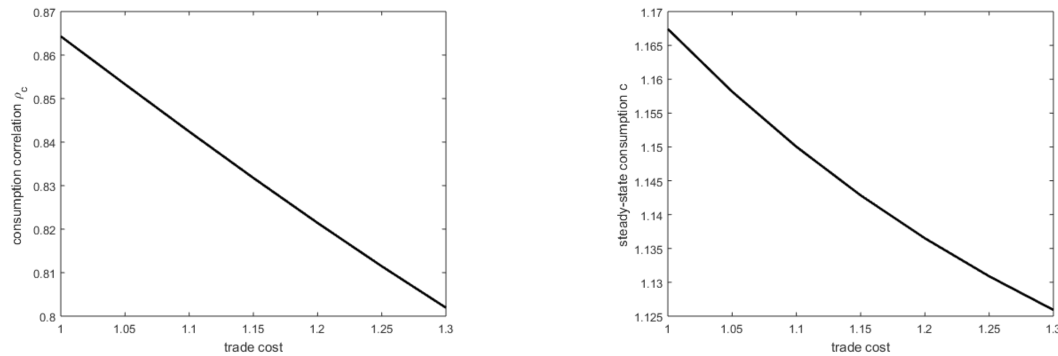
(a) Population **(b)** Relative wage

Note: This figure plots the dynamic responses of state 1's population and relative wage $w = \frac{w_1}{w_2}$, to a one-standard-deviation innovation in state 1's productivity. The solid and dashed lines show the situations with low and high migration costs respectively.

state population flows. Under higher migration costs, not only is the magnitude of migration smaller, but also the duration of population flows is longer before reaching the new steady state. The hump-shaped migration pattern is driven by the forward-looking migration decisions subject to migration frictions. Moreover, the dynamics of the relative wage rate across states denoted as $w = \frac{w_1}{w_2}$ is depicted in figure 2.3.5b, which appears almost as a mirror image of figure 2.3.5a given the labor market clearing condition. The figure shows that higher migration costs cause smoother fluctuations in the relative wage. For example, the plunge of the relative wage right after state 1's positive productivity shock is larger when migration costs are lower. To understand this result, w_1 falls more relative to w_2 due to the terms-of-trade depreciation that reduces state 1's nominal marginal product of labor. If migration were to take place that drew more population to state 1 in response to its higher consumption growth, w_1 would decline even further to clear the labor market. Therefore, higher migration costs avoid a greater plummet in the relative wage and therefore increase wage synchronization across states.

Based on these discussions, bilateral economic linkages through trade, migration, and finance, affect consumption risk sharing across regions. As a result, frictions in these channels have important implications for cross-state consumption comovement. We conduct another set of comparative analyses to test this hypothesis. Specifically, we calculate the model-predicted consumption correlation when changing the counterfactual value of one friction at a time. This exercise involves 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 evaluat-

Figure 2.3.6: Consumption under Different Trade Costs



(a) $\rho(c_1, c_2)$ **(b)** $\bar{c}_i$

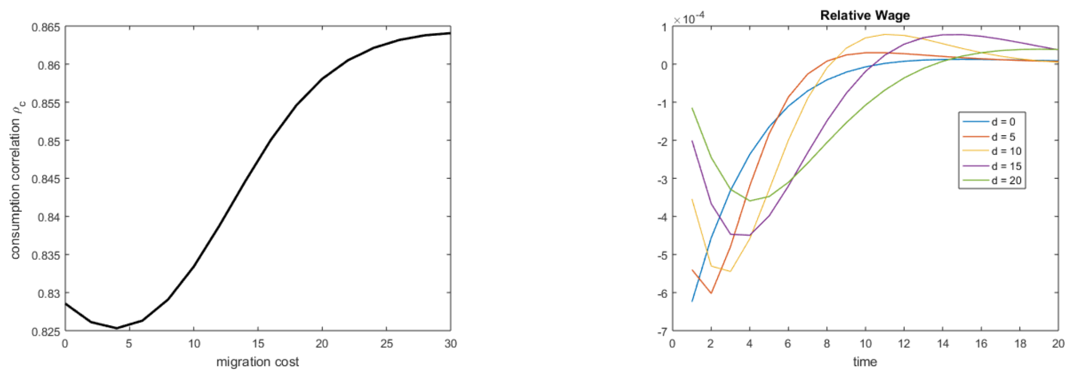
Note: This figure plots the pattern of consumption per capita under different trade costs. Figure 2.3.6a plots the correlation coefficient of consumption per capita across states given different trade costs. Figure 2.3.6b plots the state-level consumption per capita in the steady state of the economy.

ing the first- and second-order dynamics of the model. Step 3, we simulate the model that encompasses both real and financial allocations of the two-state economy and compute the resulting bilateral consumption comovement in all these counterfactual scenarios.

Figure 2.3.6 shows the pattern of consumption per capita under different trade costs. Figure 2.3.6a plots the correlation coefficient of consumption per capita across states $\rho(c_1, c_2)$. The figure suggests that higher trade costs hinder cross-state consumption comovement. For example, when the trade cost is 1.3 consumption correlation is 0.802, which rises to 0.864 when there is no trade cost ($t = 1$). Besides raising the correlation coefficient as a second-moment variable, lowering trade costs also raises the level of consumption as a first-moment variable. Figure 2.3.6b illustrates the state-level consumption per capita in the steady state of the economy. The level of consumption increases from 1.13 to 1.17 when the trade cost decreases from 1.3 to 1, which is caused by the smaller loss of tradable goods during transportation under lower iceberg trade costs. Based on these findings, eliminating trade costs raises state-level consumption and facilitates cross-state risk sharing.

Figure 2.3.7 shows the pattern of consumption per capita under different migration costs. The cross-state consumption correlation shown in figure 2.3.7a does not change monotonically with migration costs as with trade costs. When the costs first emerge around the neighborhood of zero, consumption comovement decreases, which suggests that higher migration costs impair consumption risk sharing. After that, consumption correlation increases with migration costs, although the concave curve suggests diminishing marginal effects of the migration

Figure 2.3.7: Consumption under Different Migration Costs



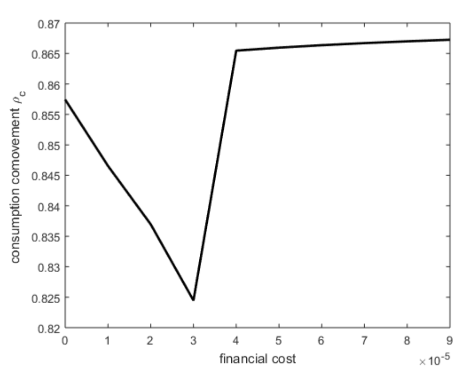
(a) $\rho(c_1, c_2)$ **(b)** Impulse response of w

Note: Figure 2.3.7a plots the correlation coefficient of consumption per capita across states given different migration costs. Figure 2.3.7b plots the impulse response of the cross-state wage ratio $w = \frac{w_1}{w_2}$ to a one-standard-deviation innovation in state 1's productivity.

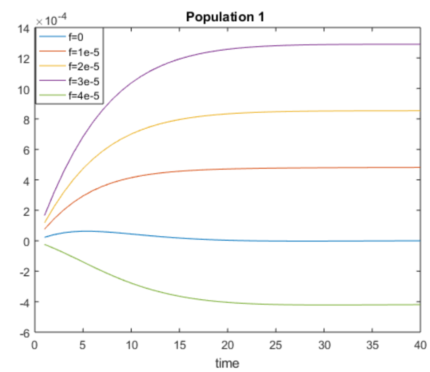
costs. The shape of the curve is largely driven by the impact of the migration costs on the relative wage across states (denoted as $w = \frac{w_1}{w_2}$), whose impulse responses are plotted in figure 2.3.7b. Consistent with the earlier analysis for figure 2.3.5b, higher migration costs reduce the dynamics of the wage ratio through flattening population flows over time. A smoother relative wage pattern suggests a greater correlation of wage rates across states, which leads to a higher degree of consumption comovement since labor income is an important funding source for households' consumption expenditure. This explains the reason that higher migration costs raise the correlation coefficient of consumption in general (figure 2.3.5a). The exception to this general pattern happens when migration costs are too low to generate a smooth cross-state wage convergence (shown as the kink of the red line in figure 2.3.5b). Under this circumstance, consumption comovement deteriorates under higher migration costs.

Figure 2.3.8 explores the patterns and determinants of consumption comovement under different financial frictions. As is shown in 2.3.8a, consumption correlation does not vary monotonically or smoothly with financial costs. Around the neighborhood of the calibrated financial friction $[0, 3]e^{-5}$, higher financial frictions lead to weaker consumption comovement. This is consistent with our analysis earlier: financial frictions raise the cost of holding foreign assets and tilt portfolios more toward domestic assets. Consequently, each state's consumption, driven more by its own output performance, is less synchronized with each other. What causes the discontinuity in figure 2.3.8a is the drastic change in the migration pattern shown in 2.3.8b. To understand this result, recall from the analysis for figure 2.3.4 that higher financial costs reduce state 1's wealth accumulation in response to its positive productivity shock (figure 2.3.8c). When financial frictions are

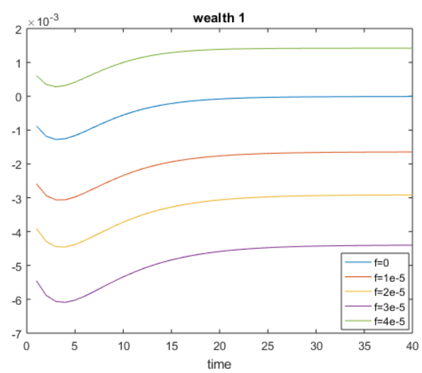
Figure 2.3.8: Consumption under Different Financial Frictions



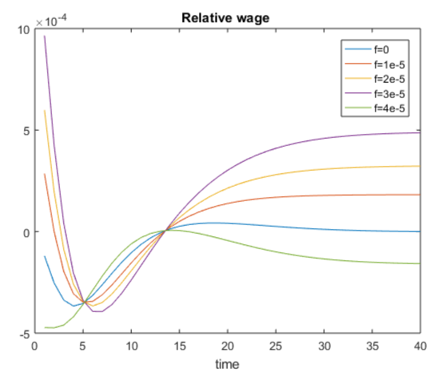
(a) $\rho(c_1, c_2)$



(b) population 1



(c) wealth 1



(d) relative w

Note: Figure 2.3.8a plots the correlation coefficient of consumption per capita across states given different financial frictions. Figures 2.3.8b-2.3.8d plot the impulse responses of state 1's population, wealth, and cross-state wage ratio $w = \frac{w_1}{w_2}$ to a one-standard-deviation innovation in state 1's productivity.

sufficiently large ($\geq 4e^{-5}$), the deterioration of state 1's wealth position starts to negatively affect its consumption and hence alters the direction of population flows so that population moves from state 1 to 2 instead. Based on the same analysis as for figure 2.3.5b, this migration from state 1 to 2, by raising the relative wage of state 1, counteracts the impact of terms-of-trade depreciation after state 1's productivity shock. Therefore, the wage ratio across states is less volatile (figure 2.3.8d), which suggests that cross-state wage comovement is stronger. Given the importance of labor income for consumption expenditure, consumption correlation is stronger when financial costs are high enough to shift migration. Therefore, the three channels of consumption risk sharing are all manifested in figure 2.3.8a where they jointly shape the pattern of consumption correlation under financial frictions. This analysis underscores the importance of examining the interaction of these channels in the general equilibrium.

To conclude this section, we develop a theoretical model in which cross-region consumption synchronization is shaped by three channels: migration, trade, and finance. We use a two-region example calibrated to the US data to elucidate the interplay among the three channels and their joint effects on the consumption pattern. In the next section we extend the two-region case to a multi-region scenario to conduct a more comprehensive and realistic quantitative analysis of the theoretical model.

2.4 Quantitative Assessment

This section evaluates the theoretical model quantitatively in a multi-region DSGE framework, which allows us to quantify and disentangle the impacts of various frictions on spatial consumption comovement through counterfactual analyses. Furthermore, we use this general equilibrium model to deliver implications for macroeconomic policies that aim to improve welfare by raising consumption levels and reducing consumption fluctuations.

2.4.1 Extended Model

We enrich the framework for quantitative analysis in section 2.3.2 by relaxing the symmetric two-region assumption. First, the equilibrium population size is different across states and taken from their values from the data averaged over the sample period (1997-2017). Second, we extend the two-region to a multi-region case so that multilateral economic exchanges clear the goods, labor, and financial markets in aggregate. This extension allows us to examine the total effects of bilateral economic linkages on each region's macroeconomic variables.

Calibrated to the U.S. state-level data, the model encompasses $\mathcal{I} = 50$ regions. Ideally, a household in region i considers all the $\mathcal{I}$ regions when making economic decisions. One computational challenge we face when solving the multi-region

DSGE model is that the large matrix that covers the bilateral ties for all the regions is badly scaled given the uneven distribution of economic sizes. Therefore, using this matrix to derive portfolio choice with the perturbation method yields inaccurate results. To overcome this challenge, we propose a trilateral framework when analyzing any region-pair formed by regions $i, j \in \mathcal{I}$. The framework consists of i and j, as well as the rest of the economy from i and j's perspective (ROE for simplicity). This trilateral framework not only enables the examination of bilateral frictions between i and j, but also considers the impacts of multilateral resistance of all the other regions affecting the region-pair. The latter echoes the extended gravity model in the trade literature developed by [Anderson & Van Wincoop, 2003] to capture the substitutability across trade partners.

In terms of parametrization, many parameters take the same values from the existing literature as in the two-economy framework summarized in table 2.3.1. For state-specific parameters, we follow the same strategy as in section 2.3.2 with modifications tailored to the trilateral framework. For example, we follow the literature including [Backus et al., 1992] and [Corsetti et al., 2008] to characterize productivity as the Solow residual. The variables of ROE, denoted with asterisks below, will be the sum of all the $\mathcal{I}$ regions' variables minus i and j's. Therefore, ROE's productivity at time t is computed from

$$\begin{aligned}\log(A_t^{ij*}) &= \log(Y_t^{ij*}) - \alpha\log(K_t^{ij*}) - (1-\alpha)\log(L_t^{ij*}) \\ &\equiv \log(\sum_i^{\mathcal{I}} Y_{i,t} - Y_{i,t} - Y_{j,t}) - \alpha\log(\sum_i^{\mathcal{I}} K_{i,t} - K_{i,t} - K_{j,t}) \\ &- (1-\alpha)\log(\sum_i^{\mathcal{I}} L_{i,t} - L_{i,t} - L_{j,t}).\end{aligned} \tag{2.4.1}$$

After that we obtain the variance-covariance matrix of these three regions' productivity assuming the annual persistence of productivity is 0.72, which is estimated from the U.S. national-level macro data. This assumption allows a state to have consistent productivity persistence among all the state pairs it forms. We estimate the variance-covariance matrix for all the $\frac{1}{2}\frac{\mathcal{I}}{\mathcal{I}-1} = 1225$ state pairs in the sample.

Another distinct feature of this asymmetric framework is that each region 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 net asset position of the economy. ROE's asset position will be the sum of all the states' positions minus the positions of the state-pair under examination. The time-averaged asset positions will be reflected in portfolio choice.

We now proceed to discuss the calibration strategies for bilateral frictions in the trilateral framework. There are three economies numbered $1, 2, 3$ with 1 and

2 representing the pair of states under examination and 3 representing ROE. The three economies encounter a set of six bilateral frictions in each of the trade, migration, and finance channels

$$\{x_{12}, x_{13}, x_{23}, x_{21}, x_{31}, x_{32}\}, \qquad x \in \{\tau, d, f\}. \tag{2.4.2}$$

In terms of trade and migration costs, we estimate them simultaneously to ensure that the model-predicted bilateral migration and trade ties match those from the IRS and CFS data (see Appendix 2.6.2 for a data description). 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 (equation 2.3.6). Step 3, we calculate the corresponding bilateral trade shares ($\pi_{ij,t}$ in equation 2.3.26) and migration shares ($m_{ij,t}$ in equation 2.3.10) 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 estimate frictions in the financial channel. Due to the lack of state-to-state financial data, we estimate bilateral financial frictions indirectly from the pattern of consumption comovement across economies. For this purpose, we estimate the coefficients of consumption risk sharing with the same data and method as in the empirical section

$$\beta = [\beta_{12}, \beta_{13}, \beta_{23}], \tag{2.4.3}$$

and use the coefficients as targeted moments to estimate bilateral frictions. Appendix 2.6.3 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 A17-A18, 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 2.3.21) to compute financial frictions.

Our benchmark calibration is based on the data over the sample time 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, total asset positions, trade, and migration data over the sample period as the steady-state values of those variables when estimating and solving the model. We evaluate the model fit by comparing empirical and model-predicted moments of bilateral variables. Figure A.2 presents the performance of the model in matching targeted moments including bilateral trade shares, bilateral migration shares, and coefficients of consumption risk sharing. From the figures, the model does a good job matching these empirical moments since most of the observations fall on the 45-degree line. In terms of untargeted moments, the key variable of interest is bilateral consumption correlation. To obtain its predicted value from the quantitative model, first we compute the steady-state values of all the endogenous variables in this DSGE model after calibrating the productivity shocks and bilateral frictions that generate consistent moments with the data. Then we simulate the model with productivity shocks and examine the impulse responses of consumption per capita in different states. Lastly, we compute bilateral consumption correlation, averaged over the simulated shocks, and compare it to the counterpart from the empirical section. Figure A.3 suggests that the model does modestly well in predicting consumption comovement across all the state pairs. In Wyoming's case, the model successfully predicts that Wyoming exhibits a notably stronger consumption correlation with Texas and West Virginia than Massachusetts and Minnesota.

After evaluating the model performance in matching targeted and untargeted moments, we now proceed to discuss numerical predictions from the quantitative model.

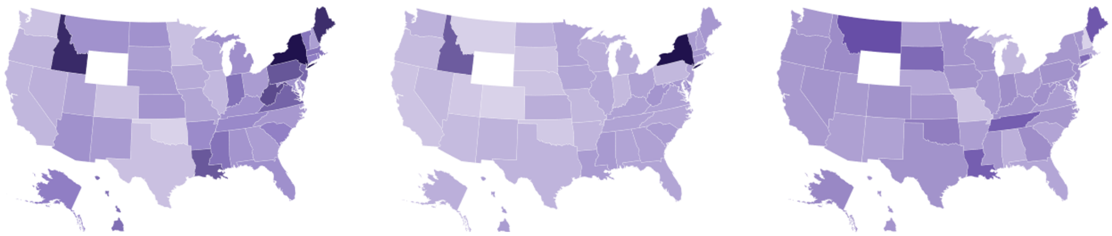
2.4.2 Numerical Results

This section presents the predictions of the quantitative model. First, we estimate the magnitude of frictions estimated from the model. Second, we conduct a set of counterfactual analyses to quantify the effects of each friction. Lastly, we solve for optimal macroeconomic policies which, by offsetting the impacts of frictions on consumption, could improve social welfare.

To provide a first glance of the frictions in the three channels of risk sharing, we use Wyoming (WY) as an example by showing the heatmaps of its estimated bilateral frictions with other states in figure 2.4.1. 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 2.1.1 that Wyoming shows stronger economic ties with states which are geographically closer. However, there are exceptions to the pattern. Idaho, another neighboring state of Wyoming, is estimated to inflict high trade costs due to its low trade volume with Wyoming unexplained by the size of its aggregate expenditure.

To explore the geographic characteristics of frictions in general, we run bivari-

Figure 2.4.1: Wyoming's Estimated Frictions with Other States



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

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.

Table 2.4.1: 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

This table reports the regression results of equation 2.4.4. Robust standard errors in parentheses, standardized coefficients in brackets. *** significant at 1%, ** significant at 5%. Estimated frictions are missing for some 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.

ate regressions with the estimated bidirectional frictions as dependent variables and geographic distance as the independent variable for all the $\frac{\mathcal{I}(\mathcal{I}-1)}{2}$ state pairs:

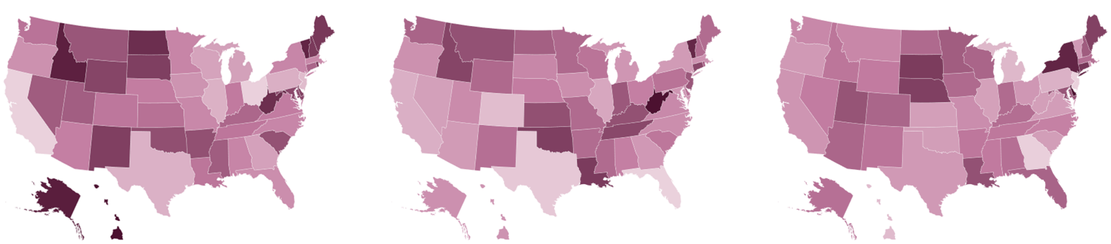
$$\log(\hat{x}_{ij}) = \alpha_x + \gamma_x \log(dist_{ij}) + \epsilon_{ij}, \qquad x \in \{\tau, d, f\}. \tag{2.4.4}$$

As reported in table 2.4.1, 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. By comparing these values, we infer that trade costs are most sensitive to distance. All the coefficient estimates ($\hat{\gamma_x}$ in regression 2.4.4) are significantly positive. This numerical result confirms one of the key hypotheses of this paper that frictions that impair risk sharing covary with geographic distance between states, which potentially shapes the spatial pattern of consumption.

To evaluate and compare frictions at the state level, we compute the median frictions across all the state pairs each state forms and present them in figure 2.4.2 and table A.4. Based on the estimation results, the trade costs of Hawaii and Alaska, the two non-contiguous states, are among the highest. For example, the median outbound trade cost of Alaska is 3.14 times the cost of Georgia and Ohio, the median states in terms of output per capita. In the migration channel, Florida and Texas are estimated to face the lowest inbound migration costs. This finding coincides with the observation that these two states are popular destinations of migration inflows in recent decades. In the financial channel, states whose estimated financial frictions are the highest include Delaware, Alaska, and Nebraska. This result is largely driven by the relatively low degree of consumption risk sharing unexplained by trade and migration channels between these states and others.

After discussing the magnitude of estimated frictions, we proceed to quantify their impacts by conducting counterfactual analyses where we turn off one friction at a time. To focus on the impacts of bilateral frictions, we will first shut down the frictions between a pair of states denoted as economies 1 and 2 ($x_{12}, x_{21}, x \in \{\tau, d, f\}$) but not the frictions between either state with ROE denoted as economy 3 ($x_{i3}, x_{3i}, i \in \{1, 2\}, x \in \{\tau, d, f\}$). This set of counterfactual analyses consists of three parts. First, we examine the influences of bilateral frictions on bilateral ties in the three channels of risk sharing. Second, we evaluate the effects of frictions on bilateral consumption comovement. Third, we compute the state-level consumption level and volatility averaged across pairs to study the overall effects of these frictions.

Figure 2.4.2: Average Friction by State



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

This figure plots the estimated frictions averaged across all the state pairs each state forms. A darker color suggests a higher value of frictions. Frictions are calculated as the geometric average of bidirectional frictions in logarithms.

Table 2.4.2 reports the key statistics of bilateral trade, migration, and asset shares across all the state pairs in the sample. If we use our earlier notations by denoting the three economies when analyzing a state pair as 1,2, and 3 with 3 representing the rest of the economy (ROE), and denoting exports from i to j as X_{ij}, average bilateral trade shares between 1 and 2 equal

$$\frac{1}{2}(\pi_{12} + \pi_{21}) = \frac{1}{2}(\frac{X_{12}}{\sum_{i=1,2,3} X_{1i}} + \frac{X_{21}}{\sum_{i=1,2,3} X_{2i}}). \quad (2.4.5)$$

Table 2.4.2: Counterfactual Bilateral Ties

	(I). With Friction		(II). Without Friction	
	Mean	Median	Mean	Median
Trade	0.0060	0.0029	0.4440	0.4548
Migration	0.0007	0.0004	0.4914	0.4918
Finance	0.1636	0.1557	0.2764	0.2466

This table reports the counterfactual bilateral exchanges when corresponding bilateral frictions are set to zero. Variables reported include the mean and median values of bilateral trade, migration, and asset shares across all the state pairs in the sample.

Similarly, with population flows from i to j denoted as N_{ij}, we calculate bilateral migration shares (m) as

$$\frac{1}{2}(m_{12} + m_{21}) = \frac{1}{2}\left(\frac{N_{12}}{\sum_{i=1,2,3} N_{1i}} + \frac{N_{21}}{\sum_{i=1,2,3} N_{2i}}\right). \tag{2.4.6}$$

With j's holding of asset from i denoted as α_{ij}, bilateral financial shares ($\hat{\alpha}$) can be computed as

$$\frac{1}{2}(\hat{\alpha}_{12} + \hat{\alpha}_{21}) = \frac{1}{2}\left(\frac{\alpha_{12}}{\sum_{i=1,2,3} \alpha_{i2}} + \frac{\alpha_{21}}{\sum_{i=1,2,3} \alpha_{i1}}\right). \tag{2.4.7}$$

Following these formulas, we calculate these bilateral shares in the original case under the calibrated frictions and in the counterfactual case where corresponding bilateral frictions $x_{12}, x_{21}, x \in \{\tau, d, f\}$ are turned off. As is reported in table 2.4.2, bilateral economic ties in all the three channels strengthen remarkably under counterfactual scenarios absent bilateral frictions. For example, bilateral trade shares rise from 0.006 to 0.444 on average across state pairs when bilateral trade costs are assumed to be 1. Moreover, the elimination of migration costs raises average bilateral migration shares from 0.0007 to 0.4914, while the elimination of financial frictions raises bilateral asset holdings from 0.1636 to 0.2764. What is common about these counterfactual scenarios is that, these bilateral shares turn out to be close in value to each state's own shares for trade, migration, and finance:

$$z_{12} \approx z_{11}, \qquad z \in \{\pi, m, \alpha\}. \tag{2.4.8}$$

The reasoning behind this result is that when a pair of states form an economic zone without barriers, they treat each other like themselves when exchanging goods, labor, and assets. Meanwhile, they drastically cut economic linkages from the rest of the economy with which frictions are considerably higher.

After evaluating the impacts of bilateral frictions on each channel of economic

Table 2.4.3: Counterfactual Bilateral Consumption Comovement

	Org	No τ	No d	No f
ρ_c	0.4177	0.7451	0.4141	0.4064
β_c	0.5324	0.7396	0.8181	0.7097

This table reports the median bilateral consumption correlation (ρ_c) and degree of risk sharing (β_c) across all the state pairs in the original case and when trade costs (τ), migration costs (d), and financial frictions (f) are turned off.

exchanges, we examine the counterfactual pattern of bilateral consumption comovement. Specifically, we focus on two measures: first, the bilateral correlation coefficient of consumption per capita (ρ_c) and second, the degree of consumption risk sharing ($\beta_c = 1 - \beta$), measured as the difference between unity and the response of relative consumption growth to output growth between a pair of states. Table 2.4.3 reports the median values of these two variables across the state pairs in the sample. The median correlation of consumption increases from 0.4177 in the benchmark case with calibrated frictions to 0.7451 when there is no trade cost. Meanwhile, the correlation slightly drops to 0.4141 and 0.4064 when there is no migration cost and no financial friction respectively. These findings are largely consistent with the two-region analysis from the theory section (see figures 2.3.6-2.3.8). While the decrease in trade costs inarguably raises consumption correlations, the reduction in migration or financial frictions yields nonmonotonic predictions. In the situation where migration exacerbates cross-region wage inequality following terms-of-trade adjustments, a decline in the migration costs leads to lower consumption correlation. Moreover, when financial frictions are so low as to encourage migration in the direction that worsens wage disparity, raising the financial frictions helps improve consumption comovement across economies. It is worth noting that a decrease in consumption correlation may not necessarily mean a deterioration in consumption risk sharing, because cross-region output correlation may also vary with the reduction of bilateral frictions. To this end, we examine the degree of consumption risk sharing β_c. From table 2.4.3, the median value of β_c increases remarkably from 0.5324 in the original case to 0.7396, 0.8181, and 0.7097 in the counterfactual scenarios where trade, migration, and financial frictions are turned off respectively. This numerical result suggests that eliminating the frictions in these channels will reduce the impacts of local output shocks on consumption fluctuations by allowing economies to share risks with each other.

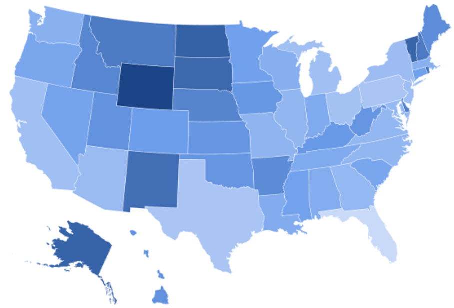
Furthermore, we examine the overall impacts of bilateral frictions on state-level consumption. For this purpose, we first compute the steady-state level as well as the volatility of consumption per capita of the two states forming each of the $\frac{\mathcal{I}(\mathcal{I}-1)}{2} = 1225$ state pairs. After that, we take the median value across the

$\mathcal{I} - 1 = 49$ state pairs involving a specific state as that state's consumption level and volatility. Table A.5 presents the ratio of counterfactual consumption to that in the original case. Based on the reported values, figures 2.4.3-2.4.4a visualize the counterfactual consumption level compared to that in the original case.[12] Most states witness improvements to their consumption levels when there is no trade cost. In general, states that are subject to the highest trade costs experience the greatest boost in consumption under the counterfactual circumstance. For example, Alaska's consumption rises by 29.8% with the reduction of trade costs. Across the states, the median increase in consumption under the elimination of trade costs is 7.3%.

The reduction in migration costs, on the other hand, generates a more disparate pattern across states. While the most affluent states including Florida and California benefit from labor mobility, most other states expect lower consumption per capita when the restriction on population is lifted. Across the states, the median change in consumption per capita is -3.2% when migration costs are removed. To explain this pattern, we show the change of each state's population size in figure 2.4.4b whose geographic pattern is almost the opposite to figure 2.4.4a's: a larger population is associated with a lower consumption per capita. What happens is that the elimination of bilateral migration costs causes drastic population inflows for most states from the rest of the economy (ROE). This is not driven by the change in the migration cost between a state-pair and ROE (i.e. $d_{i3}, d_{3i}, i = 1, 2$) which is assumed to be fixed in this counterfactual analysis, but driven by the change in the migration costs between the pair of states (i.e. d_{12}, d_{21}). Based on the rule of migration decisions (equation 2.3.24), households move to a state with a high "option value," which captures the expected future payoff from moving from that state to other states. Therefore, states like Wyoming with the darkest color in figure 2.4.4b attract large migration inflows because people find it easier to move from those states to California due to the reduction in their bilateral migration costs with California. Nevertheless, unlike California whose TFP is high enough to benefit from the rise in labor supply, Wyoming does not have enough jobs to meet the needs of the increased population. As a result, wage declines under the labor market clearing condition, which translates to a lower consumption level. This reasoning explains the disparate pattern of consumption across states generated by the reduction in migration costs in figure 2.4.4a. Nevertheless, it is worth noting that our current theoretical framework assumes that consumption is the main driver for migration and therefore neglects other factors including residential land and amenities which also play an important role in migration decisions (see, for example, [Saiz, 2010], [Albouy & Lue, 2015], [Monte et al., 2018]). Once considered, these factors will

[12]Since financial frictions are second-order in magnitude and will therefore not affect the level of consumption in the steady state of the model, we focus our analysis here on the situations with no trade and migration costs.

Figure 2.4.3: Counterfactual Consumption without Trade Costs



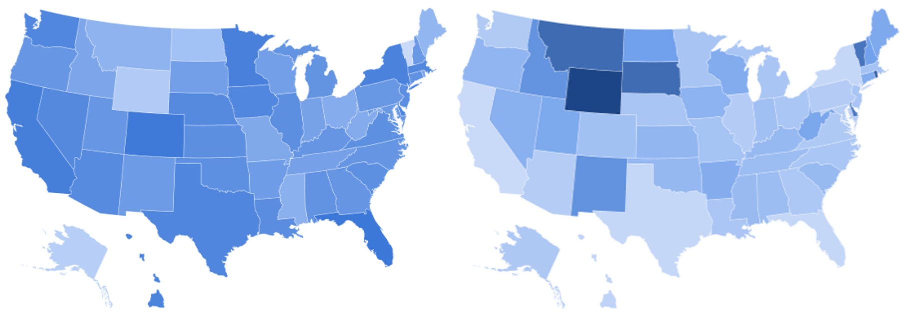
Note: This figure plots the ratio of counterfactual to original level of consumption per capita in the steady state of the economy when bilateral trade cost is shut down. A darker color in the map suggests a higher ratio. Data are reported in table A.5.

dampen households' motives to migrate to states with less elastic housing supply and lower quality of amenities, and reshape the counterfactual population pattern in figure 2.4.4b. Despite these considerations, the elimination of migration costs still generates consumption gains for some states and losses for others, largely due to the zero-sum redistribution of population across states it causes.

After examining the level of consumption per capita, we continue to investigate its volatility measured as the standard deviation. Figure 2.4.5 illustrates the ratio of consumption volatility in the counterfactual case to that in the original case. As is reported in table A.5, the volatility of consumption is lower on average under all the three counterfactual scenarios. The mean reduction in consumption volatility across states is 0.7%, 1.0%, and 0.3% respectively when bilateral trade, migration, and financial frictions are turned off. The magnitude of change is relatively small since it is driven by the elimination of bilateral frictions but not the overall frictions with respect to the rest of the economy. The three plots in figure 2.4.5 exhibit geographic resemblance, which implies the substitutability among the channels of risk sharing in lowering consumption volatility of the states most subject to frictions. For a risk-averse agent, lower consumption volatility indicates higher lifetime utility. Therefore, the finding that shutting down the frictions reduces consumption fluctuations reiterates the significance of the three channels of risk sharing for improving welfare.

Last but not least, we use the counterfactual exercises conducted above to deliver policy implications. Our earlier analysis about the spatial characteristics of frictions indicates that eliminating the barriers in the channels of risk sharing can be challenging due to geographic constraints. Nevertheless, we can design macroeconomic policies 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

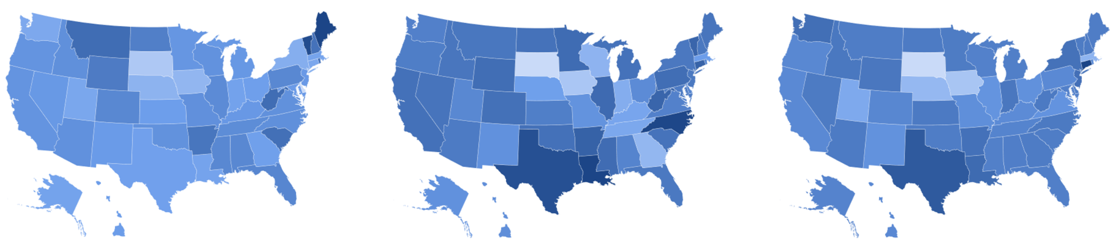
Figure 2.4.4: Counterfactual Consumption and Population without Migration Costs



(a) Consumption p.c. **(b)** Population

Note: This figure plots the ratio of counterfactual to original level of consumption per capita and population in the steady state of the economy when bilateral migration cost is shut down. A darker color in the map suggests a higher ratio. Data are reported in table A.5.

Figure 2.4.5: Counterfactual Volatility of Consumption



(a) No τ **(b)** No d **(c)** No f

Note: This figure plots the ratio of counterfactual to original volatility of consumption per capita. A darker color suggests a higher ratio. Data are reported in table A.5.

frictions can potentially undo the influences of frictions on the level and volatility of consumption. On the modeling side, introducing optimal fiscal transfers T_i^* rewrites the wealth constraint of state i

$$\mathcal{W}_{i,t+1} = R_{\mathcal{I},t}\mathcal{W}_{i,t} + \sum_{j}^{\mathcal{I}} \alpha_{j,i,t}(e^{-f_{ji}}R_{j,t} - e^{-f_{\mathcal{I}i}}R_{\mathcal{I},t}) + p_{i,t}\sum_{s} Y_{is,t} + T_{i,t}^* - P_{i,t}C_{i,t} - P_{Ii,t}I_{i,t}, \tag{2.4.9}$$

Under the new constraint, households in state i can adjust their expenditure on consumption and make necessary migration decisions based on the new cross-state consumption differentials. Meanwhile, the portfolio of state i can be reconstructed according to the risk-sharing needs under the new wealth constraint. Therefore, the design of fiscal policies requires taking into consideration the endogenous changes of variables in the existing channels of risk sharing and the interplay among these channels.

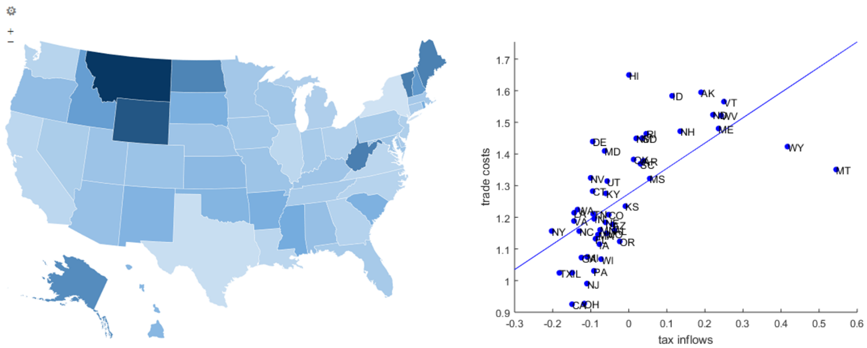
To exemplify such policy analysis, we examine the fiscal transfer that mitigates the reduction of consumption caused by bilateral trade costs. To keep this example simple, we don't impose an aggregate budget constraint for the federal government or restrict the amount of transfers it distributes to any state. The analysis involves the following steps. Step 1, we calculate the policy's targeted moment which is the counterfactual level of consumption when there is no bilateral trade cost. Step 2, we use the state-level wages in the original case as the initial guess, and solve for the supply and demand of labor in each state given the counterfactual trade and migration pattern under the new trade costs. After that, we update the value of wages that clear the labor market. We repeat this procedure until the difference between the old and new wages is small enough which pins down the equilibrium wages under the counterfactual scenario. Step 3, we solve for the values of all the endogenous variables in the model based on the wages from step 2 and calculate the corresponding level of consumption. Step 4, we repeat steps 2 and 3 until the model-predicted consumption converges to the targeted moment from step 1. We conduct this 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 2.4.6. It illustrates that regions that are estimated to be confronted with higher trade costs, such as Wyoming, Montana, and Alaska, should receive more tax transfers to mitigate 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.

This example shows that the quantitative model we propose in this paper 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. Meanwhile, the framework is flexible enough to be adapted to any other country under the specific budget constraint its government is subject to. These policies, if well designed and implemented, facilitate risk sharing and hence reduce both consumption volatility over time and consumption disparity across regions.

2.5 Conclusion

This paper explores the role of bilateral economic exchanges influenced by geography in shaping the pattern of consumption comovement across 50 states in the US. Failure of consumption risk sharing has been recognized as a major puzzle in the macroeconomic literature. To explain this puzzle, our research exploits variations among state pairs and analyzes frictions that dampen bilateral consumption comovement. For this purpose, we propose a comprehensive and unified approach that encompasses trade, migration, and finance as channels of consumption risk

Figure 2.4.6: Tax Transfers under Trade Costs



(a) Predicted Transfer Inflows

(b) Estimated τ and Transfers

Note: This figure 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. The scatter plot shows the positive relationship between the transfer and estimated trade costs (reported in table A.4).

sharing.

In the paper we first empirically establish a gravity model of consumption risk sharing by documenting that bilateral risk sharing decreases in geographic distance among the US states. To explain this fact, we develop a theoretical model to explore the impacts of frictions in the channels of risk sharing that potentially covary with distance. We start with a two-economy framework following [Backus et al., 1992] to examine the mechanism of different channels affect consumption as well as how they interact with each other. After that, we extend the model to a multi-region framework calibrated to the US data for a quantitative assessment. The framework enables us to quantify not only the magnitude but also the influence of each friction through counterfactual analysis. The quantitative framework also serves as a useful tool for the design of macroeconomic policies which aim to reduce consumption disparity across time and space.

One important extension of our real business cycle (RBC) framework is to introduce the New Keynesian ingredients including nominal rigidity. As is pointed out by [Hazell et al., 2022] that even within a monetary union, cross-region heterogeneity generates different slopes of the Phillips Curve under a uniform national monetary policy, which consequently creates welfare disparity across economies. Therefore, extensions of our model can incorporate monetary factors into the analysis when explaining cross-state consumption comovement. Meanwhile, the frictional economic linkages examined by our model, in particular through the channels of finance and migration, are absent in their analysis. Hence, our paper complements that literature by accounting for the transmission and prorogation of economic shocks through disaggregate cross-region economic ties. Other papers pursuing this research direction include [House et al., 2018] and [House et al., 2020], which quantify the welfare outcome of micro-founded economic ties under monetary policies.

Our paper focuses on cross-state risk sharing within the US as an example, but our theoretical framework is general and flexible enough to be tailored to another context of interest to examine bilateral linkages across economies through various channels. Therefore, we can apply the framework to explain consumption synchronization not only within but also across countries, or even both simultaneously. In particular, our framework is useful to be employed in such a context as the European Union and NAFTA where bilateral exchanges in different channels are commonplace. For example, one application of the model is to compare intra- versus inter-national linkages to diagnose the border effects of risk sharing proposed by [Devereux & Hnatkovska, 2020], who document a sharp decrease of consumption comovement at the US-Canada border as opposed to the prediction made by [Backus & Smith, 1993]. By quantifying the magnitudes and impacts of frictions in channels of risk sharing in this setting, our framework can provide guidance for trade and exchange rate policies with a target to reduce consumption disparity and raise social welfare both within and across country borders.

2.6 Appendix

2.6.1 Figures and Tables

Figure A.1: U.S. Map

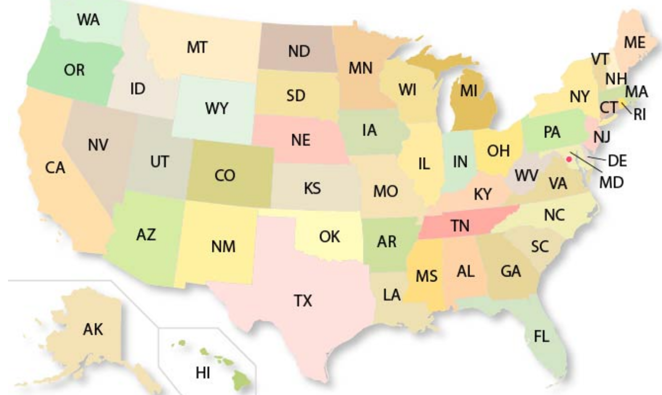


Table A.1: List of US States with Abbreviations

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 A.2 and A.3 report the results of robustness checks for the gravity model of risk sharing. Each table reports a set of robustness checks. First, we consider alternative data sources for state-level consumption and price levels, 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 results reported in the table 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

$$\Delta \log\ c_{it} - \Delta \log\ c_{jt} = \alpha_{ij} + \beta_{ij}(\Delta \log\ y_{it} - \Delta \log\ y_{jt}) + \mu_i X_{i,t} + \mu_j X_{j,t} + \epsilon_{ijt}. \quad \text{(A1)}$$

Table A.2: Gravity Model 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

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 at the state-level. $\log(d_{ij})$ denotes the geographic distance between state i and j in logarithms. Compared to the baseline estimation reported in 2.2.3, 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 A.3: Gravity Model 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 Var	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

Robust standard errors in parentheses. *** significant at 1%. The dependent variable in panel A (B) is the risk sharing coefficient estimated based on equation A1 (A3). d_{ij} denotes the geographic distance between state i and j. Geographic variables and political/industrial dissimilarity measures remain the same as in the baseline estimation (table 2.2.3).

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 2.2.1 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

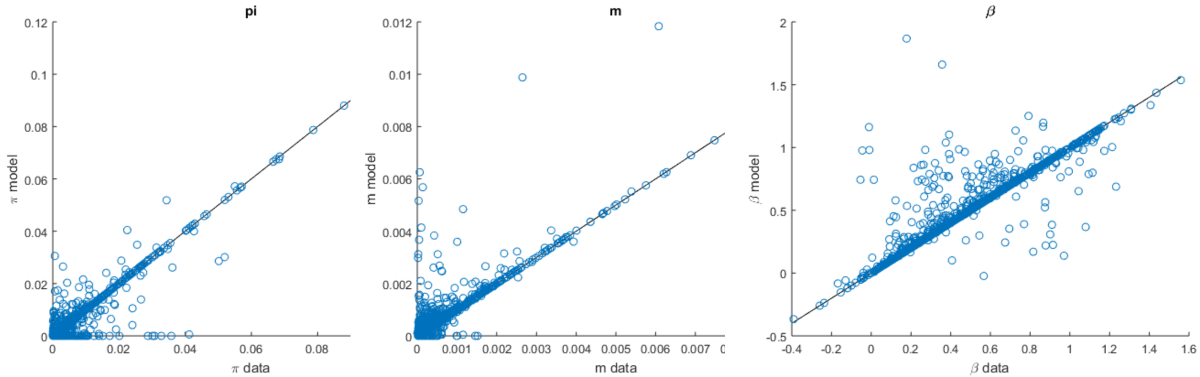
$$\Delta \log\ y_{it} = \alpha_i + \beta_i \Delta \log\ y_{USt} + \epsilon_{it}, \qquad \Delta \log\ y_{jt} = \alpha_j + \beta_j \Delta \log\ y_{USt} + \epsilon_{jt}, \quad \text{(A2)}$$

where $\Delta \log\ y_{USt}$ denotes the growth of log real per-capita output of the United States, and hence β_i captures the impact of aggregate shocks on state i's output. After that, we calculate bilateral risk-sharing coefficients from

$$\Delta \log\ c_{it} - \Delta \log\ c_{jt} = \alpha_{ij} + \beta_{ij}[(\Delta \log\ y_{it} - \beta_i \Delta \log\ y_{USt}) - (\Delta \log\ y_{jt} - \beta_j \Delta \log\ y_{USt})]. \quad \text{(A3)}$$

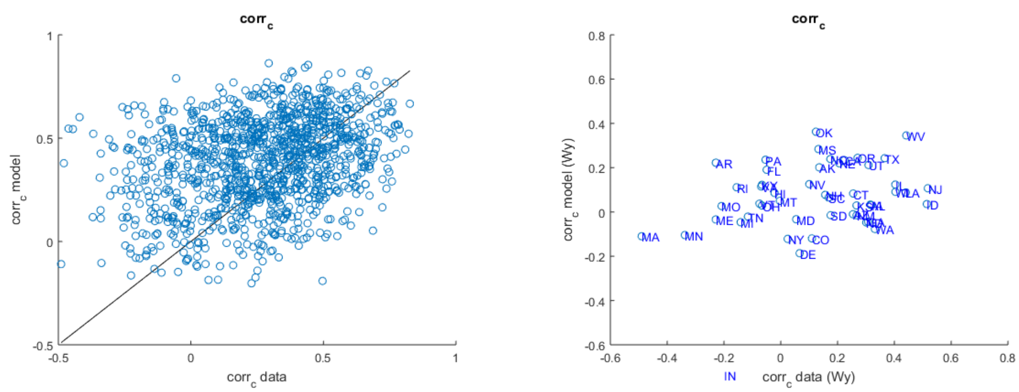
Panel B in table A.2 reports the results.

Figure A.2: Model Fit (I)



Note: This figure plots the relationship between model-implied and actual bilateral ties including bilateral trade shares, bilateral migration shares, and coefficients of consumption risk sharing. Empirical moments are on the horizontal axis, and theoretical moments are on the vertical axis. The plots show the model performs well in matching these empirical moments.

Figure A.3: Model Fit (II)



Note: This figure plots the relationship between model-implied and actual bilateral consumption correlations. Empirical moments are on the horizontal axis, and theoretical moments are on the vertical axis. The left diagram covers all the state pairs, the right covers the pairs formed by Wyoming as an example.

Table A.4: Estimated Frictions by State

	Trade Cost		Migration Cost		Financial Cost	
State	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound
AL	0.975	1.476	1.035	1.117	0.493	0.592
AK	3.136	3.643	0.888	1.146	30.850	54.888
AZ	1.561	1.410	0.996	0.974	1.403	1.281
AR	1.007	2.296	1.002	1.115	1.562	0.754
CA	1.845	0.452	1.018	0.858	0.930	0.568
CO	1.406	1.520	0.934	0.966	1.379	1.864

CT	1.478	1.513	1.033	1.165	5.474	3.356
DE	1.536	2.822	1.069	1.175	80.416	72.842
FL	1.731	0.994	1.007	0.821	1.277	7.177
GA	1.057	1.113	0.970	0.973	1.292	1.393
HI	2.710	4.099	0.980	1.086	6.792	9.723
ID	1.045	2.719	1.019	1.159	3.249	5.006
IL	1.111	0.719	0.988	0.983	0.750	0.672
IN	0.917	1.042	0.999	1.044	3.381	2.784
IA	0.646	1.952	1.005	1.080	7.757	4.730
KS	0.702	2.099	0.978	1.060	3.390	2.600
KY	0.884	1.483	1.000	1.074	7.201	6.939
LA	1.151	1.729	1.030	1.105	2.384	3.223
ME	1.128	2.384	1.019	1.181	0.002	2.119
MD	1.766	1.660	1.029	1.058	9.218	3.651
MA	1.374	1.200	1.005	1.064	3.732	3.272
MI	0.938	1.189	1.030	1.038	2.645	4.517
MN	1.150	1.555	1.025	1.076	1.414	0.780
MS	0.865	2.047	1.014	1.153	2.014	6.122
MO	0.921	1.101	1.008	1.032	1.119	0.827
MT	1.291	2.440	0.975	1.152	0.022	0.201
NE	1.082	1.695	1.025	1.167	14.183	14.576
NV	1.319	2.052	0.980	1.086	1.060	1.493
NH	1.522	2.535	1.013	1.193	1.580	3.732
NJ	1.012	1.104	1.018	1.068	0.899	0.883
NM	2.197	2.103	0.998	1.128	8.109	14.685
NY	2.122	0.673	1.074	0.977	8.658	7.305
NC	0.901	1.339	1.018	0.957	0.646	0.924
ND	0.910	3.245	0.984	1.177	0.735	5.364
OH	0.943	0.887	1.030	1.027	0.708	0.607
OK	1.077	1.913	1.036	1.113	1.754	0.808
OR	1.083	1.585	1.027	1.128	3.052	3.060
PA	1.070	0.762	1.021	1.032	0.216	0.308
RI	1.081	3.156	1.068	1.213	0.690	1.087
SC	0.983	1.334	1.003	1.034	0.283	0.633
SD	0.909	3.413	0.997	1.162	11.196	11.012
TN	0.884	0.942	0.978	0.995	1.836	2.071
TX	1.236	0.690	0.999	0.849	1.249	1.208
UT	0.951	1.873	1.013	1.125	2.752	3.114
VT	1.082	4.098	1.035	1.214	0.023	0.374
VA	1.252	1.335	0.997	0.976	2.416	2.006
WA	0.954	1.330	1.018	1.006	1.188	1.222
WV	1.070	2.900	1.084	1.201	0.308	14.961
WI	1.166	0.957	1.037	1.082	0.926	0.692
WY	1.490	3.177	0.932	1.157	0.018	0.566

This table presents the normalized trade, migration, and financial costs averaged across state pairs for each state. Step 1, we calculate both inbound and outbound frictions averaged across $\mathcal{I}-1$ pairs a state i forms: ($x_i^{ex} = \text{mean}(x_{ij}),\ x_i^{in} = \text{mean}(x_{ji}), j \in [1, \mathcal{I}-1], x \in \{\tau, d, f\}$). Step 2, we normalize the average friction of Georgia and Ohio, the median states in terms of output per capita, to 1 in each channel: $x^{ex}_{\text{GA,OH}} = x^{in}_{\text{GA,OH}} = 1$. We report the ratio of state-level frictions from step 2 to the median states' in the table for cross-state comparison.

Table A.5: Counterfactual Consumption Relative to Benchmark

State	Equilibrium Level $\bar{c}$ No τ	Equilibrium Level $\bar{c}$ No d	Volatility σ_c No τ	Volatility σ_c No d	Volatility σ_c No f
Alabama	1.058	0.958	1.015	0.974	1.007
Alaska	1.298	0.955	0.908	0.969	0.981
Arizona	1.072	0.985	0.999	0.993	1.000
Arkansas	1.161	0.981	1.068	1.015	1.000
California	1.033	1.044	0.987	1.047	1.018
Colorado	1.067	0.978	1.036	1.009	1.049
Connecticut	1.092	0.998	0.939	1.006	0.993
Delaware	1.202	0.967	0.816	0.970	0.998
Florida	0.979	1.032	0.998	0.995	1.003
Georgia	1.026	0.983	0.966	0.971	1.003
Hawaii	1.094	0.977	0.953	0.979	1.000
Idaho	1.200	0.931	1.036	0.987	1.002
Illinois	1.009	0.978	0.972	0.994	1.002
Indiana	1.050	0.943	0.970	0.982	0.958
Iowa	1.064	0.947	0.879	0.967	1.010
Kansas	1.059	0.962	0.959	0.963	0.986
Kentucky	1.051	0.948	0.966	0.983	0.998
Louisiana	1.075	0.968	0.897	1.002	0.991
Maine	1.165	0.939	1.156	0.971	1.000
Maryland	1.070	0.974	1.003	0.990	1.001
Massachusetts	1.036	0.980	0.958	0.988	1.004
Michigan	1.021	0.993	0.958	0.999	1.005
Minnesota	1.082	0.972	0.997	0.966	1.006
Mississippi	1.127	0.954	1.033	0.990	0.991
Missouri	1.071	0.974	1.022	0.992	0.990
Montana	1.213	0.906	1.112	0.985	1.000
Nebraska	1.136	0.957	0.910	1.017	0.965
Nevada	1.097	0.968	0.979	0.985	1.000
New Hampshire	1.250	0.983	1.106	0.992	1.000
New Jersey	1.002	0.976	0.946	0.990	1.001
New Mexico	1.221	0.988	0.969	1.018	0.996
New York	1.027	1.018	0.956	1.038	1.000
North Carolina	1.024	0.989	0.975	1.004	0.969
North Dakota	1.263	0.919	1.041	1.032	1.000
Ohio	1.014	0.965	0.957	1.010	1.010
Oklahoma	1.080	0.964	0.997	0.984	0.981
Oregon	1.070	0.952	0.982	0.977	0.959
Pennsylvania	1.001	0.974	1.012	0.987	1.000
Rhode Island	1.197	0.946	1.117	0.984	1.007
South Carolina	1.091	0.959	1.080	0.965	1.003
South Dakota	1.245	0.903	0.901	0.928	0.951
Tennessee	1.075	0.955	0.999	0.981	1.000
Texas	0.964	0.993	0.932	1.031	1.032
Utah	1.135	0.962	0.971	0.979	0.995
Vermont	1.329	0.909	1.193	0.985	1.000
Virginia	1.001	0.979	0.999	0.994	1.000
Washington	1.033	0.989	0.923	1.005	1.001

West Virginia	1.093	0.941	1.070	1.001	1.004
Wisconsin	1.072	0.959	1.030	0.983	0.998
Wyoming	1.356	0.927	1.018	0.962	1.000
Mean	1.103	0.966	0.993	0.990	0.997
Median	1.073	0.968	0.984	0.988	0.999

This table 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).

2.6.2 Data

State-level output, consumption, and price

The US Bureau of Economic Analysis (BEA) reports state-level output, consumption, and price data in the Regional Economic Accounts (REA). Real GDP by state (GSP) data are available 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 in coding, 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 value of 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 & Steinsson, 2014] over the period from 1966 to 2008. They obtain the inflation series from 1966 to 1995 from [Del Negro, 1998], who constructs the series using a combination of 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 two series 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 conduct sensitivity analyses using alternative data sources to verify the robustness of the gravity model. Table A.2 Panel A uses the state-level inflation rates 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. The gravity model of consumption risk sharing remains robust under these alternative data sources.

Bilateral trade and migration flows

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

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 patterns across states. The data are available for filing years 1991 through 2019.

State-level productivity

In this multi-region framework, we estimate the total factor productivity (TFP) for 50 states in the US. In particular, we examine the Solow residual from

$$\log(A_{i,t}) = \log(Y_{i,t}) - \alpha \log(K_{i,t}) - (1-\alpha)\log(L_{i,t}), \tag{A4}$$

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 use the Bureau of Economic Analysis (BEA) data over the period 1977-2019 for the estimation. The BEA reports state-level gross domestic product and employment in the Regional Economic Accounts. It also provides the national and sectoral capital data in the Fixed Assets Accounts.

We construct the estimates for state-level capital stock using the methodology developed by [Garofalo & Yamarik, 2002]. Namely, we apportion the national capital stock, measured as the net stock of total private fixed assets net of residential fixed assets, to the states using sector-level income data. For each two-digit NAICS industry s, we apportion the national capital stock based on the relative income generated within each state as follows:

$$K^s_{i,t} = \left(\frac{Y^s_{i,t}}{Y^s_{US,t}}\right) K^s_{US,t}, \tag{A5}$$

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

$$K_{i,t} = \sum_{s=1}^{K} K_{i,t}^{s}. \tag{A6}$$

Lastly, We estimate $1-\alpha$ in equation A4 to be 0.59 by dividing the labor earnings by the economic output based on the BEA data over the sample period.[13] After obtaining the values of all the elements that appear in equation A4, we calculate the state-level TFP with which we subsequently estimate the joint productivity process across states.

2.6.3 Portfolio Choice in Trilateral Framework

In this section I describe and solve the portfolio choice problem introduced in the theory section within a framework with three economies numbered $i = 1, 2, 3$. In particular, region 3 can be regarded as the rest of the economy from the perspective of the region-pair formed by regions 1 and 2. Each economy's financial asset, which can be traded in an integrated financial market, is its claims to capital income net of investment expenditure. Nevertheless, there are bilateral financial frictions modeled as capital gain taxes 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 respectively given by

$$\begin{aligned}
E_t[\tfrac{U'(c_{1,t+1})}{P_{1,t+1}} R_{1,t+1}] &= E_t[\tfrac{U'(c_{1,t+1})}{P_{1,t+1}} e^{-f_{21}} R_{2,t+1}] &&= E_t[\tfrac{U'(c_{1,t+1})}{P_{1,t+1}} e^{-f_{31}} R_{3,t+1}],\\
E_t[\tfrac{U'(c_{2,t+1})}{P_{2,t+1}} R_{2,t+1}] &= E_t[\tfrac{U'(c_{2,t+1})}{P_{2,t+1}} e^{-f_{12}} R_{1,t+1}] &&= E_t[\tfrac{U'(c_{2,t+1})}{P_{2,t+1}} e^{-f_{32}} R_{3,t+1}],\\
E_t[\tfrac{U'(c_{3,t+1})}{P_{3,t+1}} R_{3,t+1}] &= E_t[\tfrac{U'(c_{3,t+1})}{P_{3,t+1}} e^{-f_{13}} R_{1,t+1}] &&= E_t[\tfrac{U'(c_{3,t+1})}{P_{3,t+1}} e^{-f_{23}} R_{2,t+1}].
\end{aligned} \tag{A7}$$

In the next step we derive portfolios with [Devereux & Sutherland, 2011]'s method by evaluating the second-order approximation of 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:

$$\hat{R}'_{x,t} = [\hat{R}_{1,t} - \hat{R}_{3,t}, \hat{R}_{2,t} - \hat{R}_{3,t}], \tag{A8}$$

where $\hat{y}_t$ represents the log-deviation of any variable y from its steady state at t.

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

Next we evaluate the second-order Taylor expansion of the Euler equations as

$$\begin{aligned} E_t[\hat{R}_{x,t+1} + \tfrac{1}{2}\hat{R}^2_{x,t+1} - (\sigma\hat{c}_{1,t+1} + \hat{P}_{1,t+1})\hat{R}_{x,t+1}] &= -\tfrac{1}{2}\begin{bmatrix} f_{31} \\ f_{31} - f_{21} \end{bmatrix} + \mathcal{O}(\epsilon^3), \\ E_t[\hat{R}_{x,t+1} + \tfrac{1}{2}\hat{R}^2_{x,t+1} - (\sigma\hat{c}_{2,t+1} + \hat{P}_{2,t+1})\hat{R}_{x,t+1}] &= -\tfrac{1}{2}\begin{bmatrix} f_{32} - f_{12} \\ f_{32} \end{bmatrix} + \mathcal{O}(\epsilon^3), \\ E_t[\hat{R}_{x,t+1} + \tfrac{1}{2}\hat{R}^2_{x,t+1} - (\sigma\hat{c}_{3,t+1} + \hat{P}_{3,t+1})\hat{R}_{x,t+1}] &= -\tfrac{1}{2}\begin{bmatrix} -f_{13} \\ -f_{23} \end{bmatrix} + \mathcal{O}(\epsilon^3). \end{aligned} \tag{A9}$$

where $\hat{R}^{2\prime}_{x,t+1}$ denotes differences in squared changes of returns

$$\hat{R}^{2\prime}_{x,t+1} = [\hat{R}^2_{1,t+1} - \hat{R}^2_{3,t+1}, \hat{R}^2_{2,t+1} - \hat{R}^2_{3,t+1}]. \tag{A10}$$

On the right-hand side of equations A9 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 A9 yields

$$\begin{aligned} E_t[(\hat{c}_{12,t+1} + \tfrac{\hat{P}_{12,t+1}}{\sigma})\hat{R}_{x,t+1}] &= \tfrac{1}{2\sigma}\begin{bmatrix} f_{31} - f_{32} + f_{12} \\ f_{31} - f_{21} - f_{32} \end{bmatrix} + \mathcal{O}(\epsilon^3), \\ E_t[(\hat{c}_{13,t+1} + \tfrac{\hat{P}_{13,t+1}}{\sigma})\hat{R}_{x,t+1}] &= \tfrac{1}{2\sigma}\begin{bmatrix} f_{13} + f_{31} \\ f_{31} - f_{21} + f_{23} \end{bmatrix} + \mathcal{O}(\epsilon^3), \\ E_t[(\hat{c}_{23,t+1} + \tfrac{\hat{P}_{23,t+1}}{\sigma})\hat{R}_{x,t+1}] &= \tfrac{1}{2\sigma}\begin{bmatrix} f_{32} - f_{12} + f_{13} \\ f_{23} + f_{32} \end{bmatrix} + \mathcal{O}(\epsilon^3), \end{aligned} \tag{A11}$$

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

$$\frac{\hat{cp}'_t}{\sigma} = [\hat{c}_{12,t} + \frac{\hat{P}_{12,t}}{\sigma}, \hat{c}_{13,t} + \frac{\hat{P}_{13,t}}{\sigma}, \hat{c}_{23,t} + \frac{\hat{P}_{23,t}}{\sigma}]. \tag{A12}$$

Equations A11 can therefore be re-written in the vector form as

$$E_t[\hat{cp}_t \hat{R}'_{x,t+1}] = \frac{\mathcal{F}}{2} \equiv \frac{1}{2}\begin{bmatrix} f_{31} - f_{32} + f_{12} & f_{31} - f_{21} - f_{32} \\ f_{13} + f_{31} & f_{31} - f_{21} + f_{23} \\ f_{32} - f_{12} + f_{13} & f_{23} + f_{32} \end{bmatrix} + \mathcal{O}(\epsilon^3). \tag{A13}$$

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

$$\epsilon'_t = [\epsilon_{1,t}, \epsilon_{2,t}, \epsilon_{3,t}], \tag{A14}$$

whose coefficients, as a function of portfolio choice, need to satisfy equation A13 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

$$\tilde{\alpha} = \frac{1}{\beta \bar{Y}} \begin{bmatrix} \alpha_{1,1} & \alpha_{1,2} \\ \alpha_{2,1} & \alpha_{2,2} \end{bmatrix}, \tag{A15}$$

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

$$\xi_t = \tilde{\alpha}' \hat{R}_{x,t}. \tag{A16}$$

Region-specific productivity shocks ϵ_t affect the two components in equation A13 both directly and indirectly through ξ_t:

$$\hat{c}p_{t+1} = D_1 \xi_{t+1} + D_2 \epsilon_{t+1} + D_3 z_{t+1} + \mathcal{O}(\epsilon^2), \tag{A17}$$

$$\hat{R}_{x,t+1} = R_1 \xi_{t+1} + R_2 \epsilon_{t+1} + \mathcal{O}(\epsilon^2), \tag{A18}$$

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}, $\hat{c}p_{t+1}$, and $\hat{R}_{x,t+1}$ in terms of ϵ_{t+1} only:

$$\xi_{t+1} = \tilde{H} \epsilon_{t+1}, \qquad where \qquad \tilde{H} = \frac{\tilde{\alpha}' R_2}{1 - \tilde{\alpha}' R_1}; \tag{A19}$$

$$\hat{c}p_{t+1} = \tilde{D} \epsilon_{t+1} + D_3 z_{t+1} + \mathcal{O}(\epsilon^2), \qquad where \qquad \tilde{D} = D_1 \tilde{H} + D_2. \tag{A20}$$

$$\hat{R}_{x,t+1} = \tilde{R} \epsilon_{t+1} + \mathcal{O}(\epsilon^2), \qquad where \qquad \tilde{R} = R_1 \tilde{H} + R_2. \tag{A21}$$

Now that we have examined the two components in equation A13 separately as functions of innovations ϵ_{t+1}, we can multiply them to evaluate the portfolio determination condition:

$$E_t[\hat{c}p_t \hat{R}'_{x,t+1}] = \tilde{D} \Sigma \tilde{R}' = \frac{\mathcal{F}}{2}. \tag{A22}$$

In terms of computation, 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

$$Dy = \frac{\partial y_{ij}}{\partial \epsilon}, \tag{A23}$$

where ϵ is the vector of productivity shocks defined in A14. 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

$$Dc = \frac{\partial c_{ij}}{\partial \epsilon}, \tag{A24}$$

which based on equation A20 is influenced by portfolio choice $\tilde{\alpha}$ from A15 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

$$\hat{\beta}_{ij} = \frac{\partial c_{ij}}{\partial y_{ij}} = \frac{Dc}{Dy}. \tag{A25}$$

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 from the empirical section which serves as a targeted moment for the state-pair under examination. 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 A22 to find matrix $\mathcal{F}$. Lastly, we recover bilateral financial frictions from this matrix of financial frictions based on equation A13.

Chapter 3

Healthcare Costs, Choice of Providers and Patient Satisfaction: Survey Evidence from India

3.1 Introduction

A key aspect of understanding health care provision is the process by which individuals seek care[1]. In many developed countries, national or private insurance schemes are mostly determinative of these choices, with some scope for choice within the constraints of the insurance scheme. For non-emergency cases, individuals can make choices of where and from whom to seek care based on available knowledge and information related to the providers' reputation, prior experience, anticipated out-of-pocket monetary costs, and convenience, including travel and wait times.[2] Typically, the institutional structures associated with insurance schemes limit choice to a preassigned provider or facility, so that going outside this structure greatly increases costs.

The situation in developing countries is much more variable, with a wide array of institutional arrangements. China appears to have a relatively strong government-provided and funded health care system (e.g., [Li et al., 2017]). More typically, citizens of developing countries incur substantial out-of-pocket costs for health care, because of lack of access or adequacy of government-provided and government-funded options (e.g., [Han, 2012], which discusses Mexico and Viet-

[1] This paper is a joint work with Nirvikar Singh (UC Santa Cruz) and Abhijit Visaria (Duke-NUS Medical School)

[2] [Dupas, 2011] surveys studies of many aspects of health behavior in developing countries, including information problems, financial constraints, and behavioral factors such as time preferences.

nam, and compares them to China). India is very much in this latter category, though it has consistently sought to increase access to government-provided health care, with a system of health sub-centers largely in rural areas, primary health centers, larger community health centers in towns, and urban hospitals. These efforts were expanded in 2005, with the launch of a National Rural Health Mission. In 2013, this was expanded to a National Health Mission, with rural and urban "submissions." However, government-provided health care is plagued by problems of absence of personnel ([Chaudhury et al., 2006]; [Muralidharan et al., 2011]), poor quality ([Das et al., 2020]) and corruption ([Kumar, 2003]).

Problems of government-provided health care in India lead to individuals often choosing private providers, even if the monetary cost is greater. In some cases, the private providers are low cost and local, offering affordability and convenience, but they lack proper medical qualifications. For example, a 2016 WHO report estimated that over 57 percent of India's practitioners of Western medicine (as opposed to indigenous systems such as Ayurveda, which are formally recognized by the Indian government) lacked proper qualifications,[3], and this estimate was accepted by the government in 2019, after initial resistance. Similar issues have been documented in local studies, in Madhya Pradesh, which is a state in central India ([Das & Mohpal, 2016]), and most notably in Udaipur district in Rajasthan, which is a state in northern India ([Banerjee et al., 2004]; [Banerjee & Duflo, 2009]).

The research presented here focuses on health care choices in another Indian state, Punjab, which borders Rajasthan. Punjab is where India's "green revolution" in agriculture began, leading to a period of having one of the highest per capita outputs among India's major states. More recently, it has been beset by political, social and environmental problems, and its income ranking has fallen substantially.[4] Nevertheless, Punjab's income levels and geography make it an area where substantive health care choices are possible. Furthermore, its road network and other infrastructure are relatively good, supporting access to multiple healthcare options.

In our analysis, we seek to understand the factors – particularly anticipated costs – that shape where individuals seek treatment, what the treatment costs are, and how these individuals perceive the results of their choices. Particular choices that we examine are the decision whether to go to a government or private provider, and the level of qualification of chosen providers. These kinds of choices relate to prior work on the quality of provision and how it relates to the type of provider (e.g., [Das et al., 2020]). This kind of detailed empirical analysis of health care choices from the demand side is relatively uncommon, as far as we are aware. Some examples for developing countries include stud-

[3]See also [Anand & Fan, 2016]. [Das et al., 2020], based on a 2009 survey, document the status of rural healthcare across much of India, including issues of quality, cost and access.

[4]See [Singh & Singh, 2002] and [Singh & Singh, 2016], especially Chapter 11

ies of health care choices in Mumbai slums ([Naydenova et al., 2017]),[5] female sex workers in individual cities in India, Kenya, Mozambique, and South Africa ([Lafort et al., 2016]), health care choices in India ([Jana & Basu, 2017]), malaria patients' choices in rural Kenya ([Nyamongo, 2002]), and maternal health care choices in India ([Shariff et al., 2002]).[6]

Our focus on the cost of healthcare, and its possible impacts on effective access, also makes our analysis relevant for two specific issues. First, in 2008, the national government introduced a publicly-funded health insurance scheme specifically for those officially below the poverty line, that would allow enrolled individuals to obtain care from private providers. Individual states implemented this scheme in different ways, and coverage has varied across states, with heterogeneous results. National government programs for health insurance have continued to evolve, and how to achieve universal health coverage in India remains a hotly debated topic.[7] Second, the novel coronavirus pandemic of 2020-21 focused attention on access to healthcare, including the supply of care along with its cost: during spikes in cases, poor people were shut out of receiving care because of the overall supply shortage combined with high costs of privately provided care.[8]

The empirical analysis in this paper is based on a survey of 500 individuals, distributed evenly across 10 villages within similar distances of a major second-tier town in Punjab, Nabha. We collected basic demographic information, healthcare utilization, information on type of health condition, type of provider, various components of the cost of treatment, as well as reasons for making a choice of provider and satisfaction with the treatment. The data are described and summarized in more detail in the next section. The detailed cost data we collected is of interest in itself, aside from its use in the regression analysis, since it sheds light on the systemic features of the situation in which people seek treatment, beyond whether

[5][Naydenova et al., 2017] references several other previous studies of health care choices in urban slums in India.

[6]Examples of recent studies of health care choices in developed countries include [Liu & Liu, 2010] for Taiwan, [Aalto et al., 2018] for Finland, and [Chan et al., 2018] for Singapore.

[7]The initial national health insurance scheme was called Rashtriya Swasthya Bhima Yojana (RSBY). Several states, most notably Andhra Pradesh in the south, introduced their own versions of health insurance schemes. After some evolution and expansion, in 2018 RSBY was folded into a larger national effort, called Ayushman Bharat. [Palacios et al., 2011] provide several early studies of the impacts of RSBY. [Prinja et al., 2017] summarize several dozen studies of the impacts of publicly funded health insurance schemes (PHFIS's) in India, finding mixed results. [Karan et al., 2017] specifically estimated the impact of RSBY on out-of-pocket health spending. [Khetrapal et al., 2019] examined data for two locations in Punjab and Haryana, and found more positive effects of RSBY. However, [Hooda, 2020] found that the coverage of PHFIS's has been considerably overstated in official statistics. On a different note, [Selvaraj & Karan, 2012] argue that PHFIS's risk undercutting public provision by allowing private providers to cherry pick patients. [Asfaw et al., 2014] provide some analysis of the implementation of the RSBY in Punjab, including problems and possible solutions.

[8]For example, see [Rukmini, 2020] and [Raman et al., 2021].

or not the care provider is a government employee. The data are analyzed using various discrete choice models.

Among the factors that affect individuals' choice of type of provider in our data are distance, type of health condition, familiarity with the provider, and reputation through referral. At least in our data, demographic variables such as age, gender and economic status are mostly not significant determinants of health care choices.[9] We also examine two dimensions of satisfaction with the care experience, namely, quality and convenience. Here, cost-sensitivity and type of condition seem to matter, and , in some cases, the type of provider is significant: there is somewhat less satisfaction with private providers.

While several of the studies referenced earlier in this section use multinomial logit analysis, they often focus on specific populations, such as young couples with children, or healthcare utilization for particular reasons, such as maternal health care. The most relevant study to compare with ours is that of [Jana & Basu, 2017] who use multinomial logit regressions to analyze National Sample Survey data for 2014, comparing two very different states, Kerala and Bihar. Their results emphasize the impact of distance and transportation costs. By contrast, we do not find these to be important in the same way for the particular geography of our sample.[10] Our contribution is in how we analyze the role of anticipated costs in health care choices. In particular, [Jana & Basu, 2017] do not allow for the endogeneity of medical expenditures, and they do not have information on the preferences of those seeking treatment, cost-sensitivity in particular. Specifically, we consider three different aspects of healthcare choices. First, we analyze the factors affecting the binary choice between a government and a private provider. Second, we consider the binary choice between a professionally qualified provider and informal alternatives. Finally, we examine the factors influencing the level of satisfaction of respondents with the quality of care.

The remainder of the paper is structured as follows. In the next section, we provide some background on Punjab, and describe our data and some of its basic patterns. This is followed by the formal empirical analysis and discussion of the results. The final section is a summary conclusion. In our conclusion, we also discuss possible implications of our analysis for the kinds of issues with respect to healthcare that have arisen as a result of the novel coronavirus pandemic.

[9] Our demographic data is limited, so our failure to find impacts here is not conclusive. Other studies do establish effects such as age, marital status, income status, and literacy ([Jana & Basu, 2017]).

[10] Kerala is more densely populated than Punjab, and has stronger public services, but Punjab has better rural roads. Since our sample is focused on a small area, one cannot make too much of state level comparisons.

3.2 Background and Data

3.2.1 Health Indicators in Punjab

Demographically, Punjab, by 2006, was one of the earliest states to reach replacement level total fertility ([SRS, 2016]). At the same time life expectancy at birth in Punjab has also been one of the highest in India since the mid-2000s ([SRS, 2016]). In 2016, Punjab was fourth among all Indian states in terms of the epidemiological transition (after Kerala, Goa, and Tamil Nadu), indicating that a relatively greater contribution to disability-adjusted life years was made by non-communicable diseases and injuries, versus communicable, maternal, neonatal, and nutritional diseases ([ICMR, 2017]). Indeed, results of the National Family Health Survey 2015-16 (NFHS-4), presented in Table A.1, indicate that maternal and child health status and healthcare utilization indicators in Punjab compare favorably to all-India averages ([IIPS, 2017]).[11]

Both infant mortality and under-5 mortality rates in Punjab are well below the national levels. Maternal healthcare utilization rates in Punjab are high, with about 3 in 4 women surveyed in the NFHS-4 having received antenatal care within the first trimester, and nearly 88% receiving postnatal care within 2 days. Nearly 9 in 10 births in the last five years occurred at an institution. However, only a little over half of these were in public facilities, lower than all-India averages in urban areas and higher in rural areas. Immunization rates among children were considerably higher than all-India averages, with marginally lower rates of immunization received in public facilities in urban areas.

On a less positive note, Punjab (along with the neighboring state of Haryana, and the National Capital Territory of Delhi) is characterized by an extremely biased sex ratio at birth (Table A.1), the result of son preference and consequent female-specific abortions. Sex-selective abortions, while banned, have become more common as sex-determination technologies have become cheaper and more pervasive. This issue, in stark form, illustrates that the boundaries of health care are not well-defined: behavior that determines health outcomes is a function of a complex interplay of individual, family and social motives.

3.3 Data Description

In collaboration with a local NGO, the Nabha Foundation, and the Center for Advanced Study of India at the University of Pennsylvania, a Health Care Experience Survey was conducted in May-June 2010 among 500 households, spread evenly across 10 villages ringing the town of Nabha, in the Indian state of Punjab.

[11]NFHS-5, 2020 fieldwork was delayed in Punjab because of the Covid-19 pandemic and the findings not released at the time of writing this paper. An excellent survey of the status of healthcare services and outcomes in Punjab, using slightly earlier data, is [Asfaw et al., 2014].

Table A.1: Select indicators of health status and healthcare utilization in Punjab and all-India, 2015-16

	Punjab			India		
	Overall	*Urban*	*Rural*	*Overall*	*Urban*	*Rural*
Life expectancy at birth *(in years)*	71.6	69.7	73.9	67.9	66.4	69.6
Total fertility rate	1.6	1.6	1.6	2.2	1.8	2.4
Infant mortality rate *(per 1000 live births)*	29	22	34	41	29	46
Under-5 mortality rate *(per 1000 live births)*	33	25	39	50	34	56
Sex ratio at birth for births in the last five years *(females per 1000 males)*	860	792	909	919	899	927
Antenatal check-up in first trimester, for last birth among births in 5 years (*prior to survey*) (%)	75.6	76	75.3	58.6	69.1	54.2
At least 4 antenatal care visits, for last birth among births in five years (*prior to survey*) (%)	68.5	69.4	67.8	51.2	66.4	44.8
Mothers who received postnatal care from a health personnel within 2 days of last delivery* (%)	87.2	86.6	87.7	62.4	71.1	58.5
Children who received a health check after birth from a health personnel within 2 days of birth* (%)	47.2	46.7	47.6	24.3	27.2	23
Institutional births, among all births in five years prior to survey (%)	90.5	89	91.5	78.9	88.7	75.1
Institutional births in a public facility, among all births in five years prior to survey (%)	51.7	41.3	58.5	52.1	46.2	54.4
Children aged 12-23 fully immunized[@] (%)	89.1	88.7	89.3	62	63.9	61.3
Children aged 12-23 months who received most of the vaccinations in a public health facility (%)	89	80.4	94.3	90.7	82.1	94.2

* Health personnel refers to a doctor, nurse, auxiliary nurse midwife, lady health visitor, or other.
@ Full immunization refers to having received the BCG, measles, and 3 doses each of polio and diptheria-pertussis-tetanus vaccines.
Data are from the National Family Health Survey 2015-16 (NFHS-4), except for life expectancy at birth estimates which pertain to 2010-14 and are from the NITI Aayog, Government of India website (http://niti.gov.in/content/life-expectancy). Retrieved on 1 June 2021

The town of Nabha and its environs constitute the subdistrict (tehsil) of Nabha, in the district of Patiala. Nabha has a population of about 200,000, and the city of Patiala has a population three or four times that. Both Nabha and Patiala were princely states in British India, and partly as a result, have somewhat better than average health care facilities: in particular, Nabha has a sizable government hospital, originally built by the princely ruler. Nabha is about 100 km away from the state capital of Chandigarh, which is generally acknowledged to have very high-quality specialized medical facilities.

Households were chosen at random in each of the 10 villages, by local employees of the Nabha foundation. Individual respondents were determined by availability within each household. The villages were all within 5 to 30 km. of Nabha, in varying directions. The villages were chosen to provide some variation in terms of distance from Nabha, population size, social composition (percentage of scheduled castes), and type of neighborhood health facilities. The village characteristics are displayed in Table A.1, and their approximate locations are shown in Figure A.1.

Table A.1: Village Characteristics

Name	Population, 2011	Scheduled Caste Percentage	Government Health Facility	Distance from Nabha town (km)
Alhoran Kalan (Al)	4250	40.0	None	6
Ajnauda Kalan (Aj)	2144	23.1	PHC	15
Bhadson (B)	3774	31.2	CHC	20
Dhingi (D)	1563	24.6	None	8
Gurditpura (Gu)	2078	29.3	SHC	17
Malkon (M)	782	76.2	None	15
Chhintanwala (C)	2563	48.7	SHC	18
Galwati (Ga)	1545	48.2	SHC	13
Sahouli (S)	1869	25.4	None	12
Rampur Sahiewal (R)	808	37.0	None	28

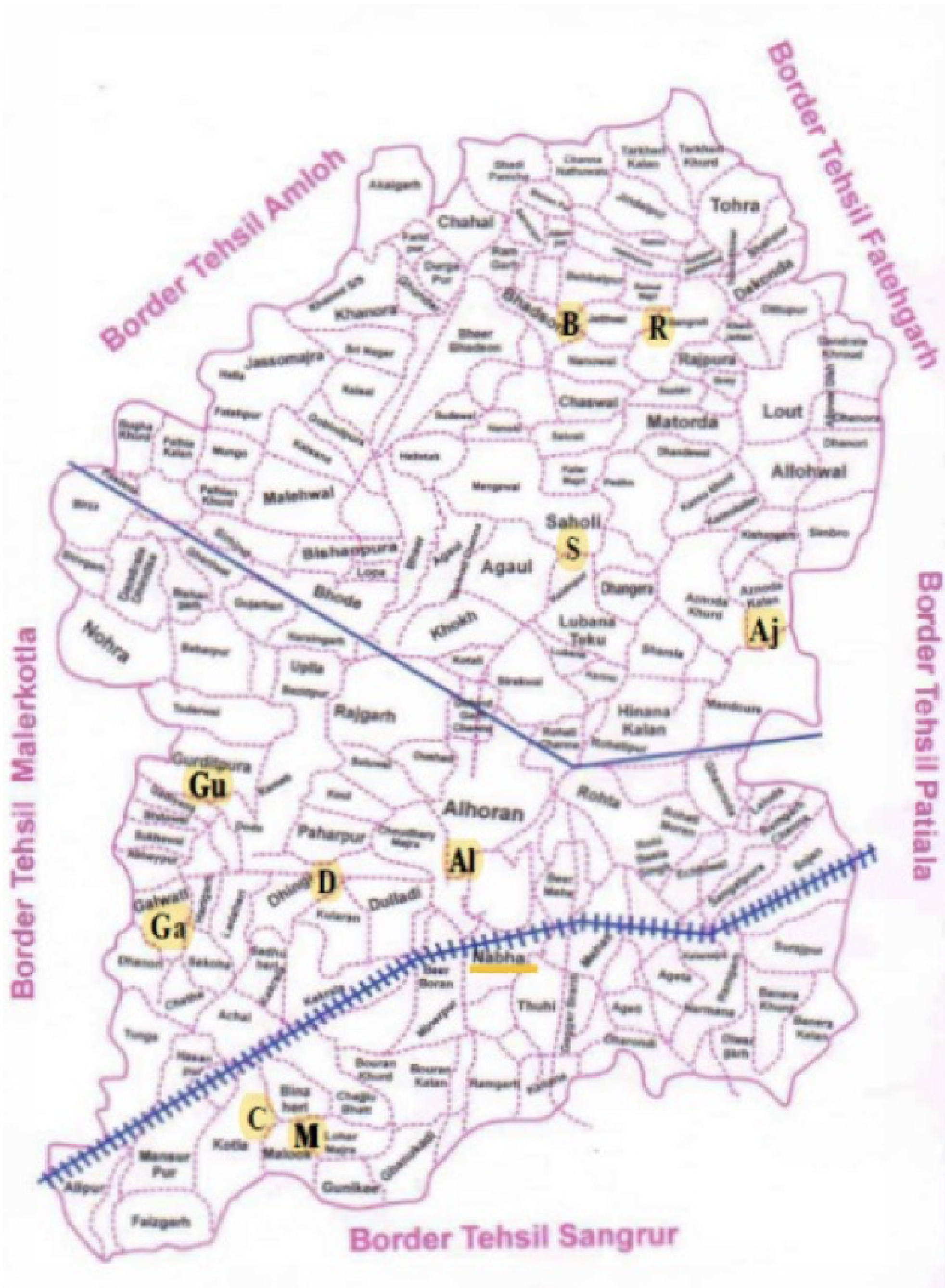
Note: CHC: Community Health Center; PHC: Primary health Centre; SHC: Sub-health centre.
Source: Government of Punjab and Nabha Foundation

Nine of the survey responses had significant missing data, or outlier values, and are omitted from all the analysis. Therefore, the summary statistics we report are based on 491 observations. There was, in some cases, significant variation across the villages in sample characteristics or other reported data. But, in our formal empirical analysis, we did not find that village-level fixed effects were significant, and we report summary statistics for the sample as a whole. We report rounded values in general.

Individual respondents were aged 16-90 years; the median age of the respondents was 40. 46 percent of the respondents were male. Almost all (96 percent) were married. 29 percent of respondents satisfied the government classification of being below the poverty line (BPL), which entitles BPL card holders to certain kinds of welfare benefits. Respondents were asked about having sought medical care since the beginning of the year, i.e. in the previous 5-6 months. Of the respondents, 73 percent had sought medical care for themselves, and the remainder reported seeking it for a family member. In the latter cases, the objective characteristics of the care were those of the patient, but the opinions on subjective characteristics such as quality were those of the respondent. Care had been sought a mean of 3.6 times in the period covered by the questions. The distribution of frequency of care was quite skewed: 16 percent of the cases involved a single visit, 25 percent reported 2 visits, another 43 percent involved 3-5 visits, and the remainder of the sample reported from 6 to as many as 20 visits in the period.[12]

[12] About one in six of those who made more than one visit went to multiple providers: subsequent answers regarding the provider were asked in context of the "main visit for medical treatment."

Figure A.1: Map of Nabha Tehsil



Source: Nabha Foundation

The different kinds of conditions for which care was sought are reported in Table A.2, with percentage frequencies of occurrence within the sample. In cases of multiple visits, the data on detailed visit characteristics was specifically collected for what the respondent considered to be the main visit for medical treatment.

Table A.2: Medical Conditions

Condition Category	Percentage
Cough, Cold, Fever, Joint Pains, Similar Temporary Illness	55.0
Stomach or other Gastro Problems	13.7
TB, Diabetes, High BP, Other Chronic Conditions	18.4
Injury	3.8
Mother or Child-related	7.1
Other	2.0

Source: Calculated from survey data

Table A.3: Healthcare Provider Type

Provider Type	Percentage
Government MBBS Doctor or Specialist	30.7
Government Nurse or Auxiliary Nurse-midwife	3.4
Private MBBS Doctor or Specialist	26.5
Government AYUSH	0.6
Private AYUSH	2.4
Pharmacist/Shopkeeper/RMP	35.3
Other Traditional Healers	1.0
Government	34.7
Private	64.3

Source: Calculated from survey data

The survey also collected details on the type of provider visited, as presented in Table A.3. Consistent with other data for India, well over a majority of the cases involved choosing a private provider, and over half of those were simply a pharmacist, shopkeeper or rural medical practitioner (RMP). The latter designation is used for those practicing Western medicine with qualifications, which is distinct from the AYUSH category, which has government recognition and various kinds of formal qualifications. However, it is a very heterogeneous category, the acronym standing for Ayurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy.[13] The last two rows report the detailed percentages aggregated into two categories: government and private providers.

[13] Recently, the government has decided to treat the acronym as a new word, meaning "traditional and non-conventional systems of healthcare and healing, which include Ayurveda, Yoga, Naturopathy, Unani, Siddha, Homeopathy, etc." This expanded definition would then encompass the cases we have classified as "other traditional healers."

The survey also collected information on the type of facility where care was sought. In the case of government providers, there is a multilevel hierarchy of facilities, and five tiers are listed in Table A.4, from the most basic (and typically the closest), i.e., the rural dispensary, to the most complete facility, the district hospital.[14] There is apparently a slight discrepancy in comparing Tables A.2 and A.3, since the latter has a higher percentage of private locations (67%) versus the percentage of private providers (64.3%). This is likely due to government providers on occasion practicing in their own private clinics. The use of the lowest two government tiers is low, consistent with various evidence that these facilities are not staffed when they are supposed to be, or that they lack medicines or equipment.[15] It is also the case for the geography of our sample villages that the higher tiers of government facilities are not much harder to travel to than the two lowest ones.

Table A.4: Type of Healthcare Facility

Facility Type	**Percentage**
Government Rural Dispensary	4.2
Government Sub-Health Center	1.4
Government Primary Health Center	5.3
Government Community Health Center	4.4
Government District Hospital	17.2
Private Clinic/Shop	43.4
Private Hospital	23.6
Other	0.4

Source: Calculated from survey data

The mean distance travelled by the respondents was 11.5 kilometers, while the median was lower, at 8 kilometers. The maximum reported distance travelled was 110 kms, and several respondents reported travelling 50-70 kms. Average transportation costs were relatively low, at Rs. 45. In 46 percent of cases, respondents reported that another provider was available closer or at a similar distance, which suggests that, at least in such cases, distance was not a determining factor in their choice. Responses regarding reasons for their choices are discussed below.

[14] Comparing choices with availability of local government health facilities (Table A.1), it is apparent that individual choices were not particularly constrained by what facility was available in their own village. Factors that are not captured in the data are absence of personnel through absenteeism or unfilled positions, and lack of medicines or equipment. [Sharma, 2017] reports on a state government audit that documented these problems.

[15] One of the authors visited several of the survey sites shortly before the survey was conducted, and observed the absence of personnel during regular hours, as well as the poor state of the facilities. In one case, one of the rooms of the sub-center, meant for treatment of patients, was being used as a permanent kitchen by the facility caretaker. Such anecdotal evidence for India is common.

The survey collected data on various kinds of costs incurred by the respondents. To provide a reference point for the cost figures, our estimate of average monthly household income at the time of the survey is approximately Rs. 24,000.[16] For government providers, the average fee paid was Rs. 13, with a median of only Rs. 2, and a maximum of Rs. 400. For private providers, the average fee paid was Rs. 118, with a median of Rs. 50, and a maximum of Rs. 10,000. Almost every patient was prescribed some medicine, but only 382 reported expenditure on medicines, with an average for this set of Rs. 692, and a median of Rs. 200. Thus, medicine costs were substantially higher than provider fees. Similarly, about 30 percent of patients incurred costs for diagnostic services such as lab tests and x-rays: the average for this subset was Rs. 519, with a median of Rs. 200.

Combining costs of transportation, provider fees, medicines and additional services, the average expenditure for the respondents was Rs. 821, but the median was considerably lower, at Rs. 232. These cost figures do not include hospitalization costs, which affected 14 percent of patients in the survey. There was one extreme outlier for hospitalization costs, and omitting that observation, the average cost of hospitalization was Rs. 7,861. For hospitalized patients, hospital costs were typically a large percentage of total costs of care, mostly in the range of 60 to 95 percent of the total.[17]

In addition to explicit costs associated with healthcare, 30 percent of respondents reported loss of wages due to the time spent on the visit to the healthcare provider. The mean wage loss reported was Rs. 155, and the median was Rs. 150. The highest reported frequencies were for Rs. 100, 150 and Rs. 200, but a handful of reports were much higher, Rs. 400 to Rs. 1,000. Therefore, for some respondents, the loss of wages was more significant than the provider fees. Almost one-sixth of the respondents reported having had to take out a loan to cover costs of the visit and any treatment prescribed thereafter. About 85 percent of those reported the loan amount: the median of these reports was Rs. 500, and the mean was Rs. 1871.

When asked about the reason for their choice of healthcare provider, 446 responses were obtained, as summarized in Table A.5. If we consider familiarity with the provider and recommendation as related reasons, and similarly treat cost and convenience as similar, then the responses are almost equally split between these two groups of determinative factors, as reported by the respondents. All those in

[16] This number is calculated using Punjab state government figures of per capita income for Patiala district, converted to household level by using Census data on average household size, and adjusted for an estimated state-level rural-urban per capita income differential.

[17] Averages of total costs and of various components of healthcare costs are reported in Appendix B, Table B.1. In addition to the averages for the entire sample, the table also reports the averages for government vs. private providers, and professionals vs. informal providers. Note that the averages are calculated across the entire sample or subsample, so in the case of hospitalization, the higher average for government hospitals reflects the higher proportion of hospital stays in that subsample.

the "other" category reported "satisfaction" as their reason, which would imply prior familiarity. We did not allow for multiple responses, so it is possible that more than one reason entered the decision-making calculus. Nevertheless, the responses are informative with respect to how individuals make such choices.

Respondents were asked about their satisfaction with the convenience of the healthcare facility, and with the quality of care that they received, with response options on a five-level likert scale, ranging from very satisfied, somewhat satisfied, neutral, to somewhat satisfied or not satisfied. The results are reported in Table A.6. There was a very high correlation of 0.94 between the two responses, suggesting a concomitance in the assessments of the two dimensions of the respondents' experience. Given what we know about the quality of healthcare services in India, even in better-off urban settings ([Das & Hammer, 2007]; [Das et al., 2008]), the self-reported levels of satisfaction are somewhat surprising in their positive nature. One can conjecture that they might reflect lack of knowledge, ex post justification of choices, or reporting bias,[18] but investigating these possibilities would require both objective and subjective data, and is beyond the scope of this paper.

Table A.5: Reasons for Choice of Healthcare Provider

Reason	**Percentage**
Known Healthcare Provider	35.7
Cost	28.5
Convenience	20.8
Recommended by someone	13.6
Other	1.3

Source: Calculated from survey data

Table A.6: Satisfaction with Quality and Convenience

Satisfaction Level	**Quality of Care** (Percentage)	**Convenience** (Percentage)
Very Satisfied	56.3	54.7
Somewhat Satisfied	35.9	37.3
Neutral	5.2	4.6
Somewhat Dissatisfied	1.6	2.4
Very Dissatisfied	1.0	1.0

Source: Calculated from survey data

[18]Healthcare is an example of a credence good, for which quality is not reliably ascertainable even after consumption. See, for example, [Dulleck et al., 2011] for a general framework, as well as Dupas (2011) in the context of healthcare.

3.4 Empirical Strategy

Our empirical strategy was to estimate discrete choice regressions, to understand the factors influencing respondent choices with respect to type of healthcare provider. In particular, we were interested in the choice between government and private providers, and that between providers with formal medical qualifications and those without. These choices are a key focus of discussions of healthcare access in India, but the methodology of our empirical analysis is novel.

The impact of costs on healthcare choices is of particular interest, and is captured in two distinct ways in our explanatory variables. First, we included a dummy variable indicating whether the respondent indicated that cost was the primary factor in their choice of where they went for care. Second, we created a variable representing the anticipated cost of the treatment. This variable was constructed by instrumenting for the actual treatment cost, which would be endogenous, to proxy for the (unobserved) anticipated treatment cost.

We used the Stata GSEM package for handling endogeneity in estimating discrete choice logit models. The nonlinearity of the logit model implies that a standard IV or 2SLS estimation does not yield correct standard errors. GSEM handles endogeneity by including common, unobserved components into the equations for the different variables; in our case, a discrete choice variable of interest, plus the treatment cost. The actual treatment cost is regressed on a set of explanatory variables, including what would be analogous to instruments in a conventional 2SLS approach, to generate what we interpret as the anticipated treatment cost.[19] The estimation is implemented through a maximum likelihood procedure.

From the responses to the question on reasons for the choice of provider, we also included a dummy variable indicating whether or not knowing the provider was the main reason for the choice made. We had data on whether the household was classified as below poverty line (BPL), and we also included this dummy variable as a possible measure of cost sensitivity.

Since the type of condition would be likely to affect anticipated treatment costs, and hence provider choices, we classified all the responses with respect to health conditions into what we term "major," and a residual category comprising, implicitly, less serious conditions.[20] We also included a variable measuring the number of times the healthcare provider was visited, as a proxy for the seriousness of the condition. Missing values for this variable led to the omission of two more responses, so our regressions are based on 489 observations.

We did not have complete data on the age and sex of family members who

[19] The regressors include the explanatory variables in the primary regressions, as well as "ration" and "age squared." The equation is presented in Appendix A.

[20] The category includes chronic conditions, injuries, and a few specific cases in the "other" category that we could rank as serious conditions. The total in this category was just over 20 percent of the sample.

were treated for a health condition, in cases where the respondent themselves did not seek treatment. Hence, we included age and sex only in regressions for the subset of respondents who had sought treatment for themselves.

Individual village dummies were not generally significant in our regressions, and including them did not materially alter our estimates or effective conclusions, so are omitted in the results presented here.[21]

The model was applied to the binary choice between government and private providers, as well as to the binary choice between going to a medical professional, versus someone without those formal credentials. In order to allow for the possibility that the factors determining health care choices were different when the patient was the respondent, versus where the patient was a family member of the survey respondent, we also separately estimated each of these binary choices for these two subsets of the sample. This approach is more general than, say, including a dummy variable for whether the treatment was for the respondent or for a family member. We adopted a similar strategy to explore possible differences between the factors affecting healthcare choices that involved hospital stays, versus those that did not.

In practice, choices of provider are not made independently – a government provider within a reasonable distance might necessarily be a medical professional, whereas a nearby private provider might be an unqualified chemist or pharmacist. The type of facility is also correlated with the type of provider or nature of the treatment or condition. There are several possible methods for analyzing such choices that have been used in the literature on transport decisions, such as cross-nested logit. However, these methods are not always well suited to handle endogeneity of RHS variables. Therefore, we explored some of these complications of bundles of choice characteristics in the case of the government versus private provider decision, by combining this characteristic with a measure of distance traveled, which would be a proxy for some of the other characteristics such as professional qualifications and type of facility. We created a binary variable for distance, up to 10 km and above 10 km, so that we had four choice combinations, which we analyzed with a multinomial logit regression.

Finally, we considered the determinants of level of satisfaction of the respondents with the care they received. The survey asked questions about satisfaction with quality of care and convenience, and the answers were highly correlated. This was also true of our regression results, and we report the results for satisfaction with quality of care, estimated using an ordered logit regression. Again, we used the GSEM procedure to deal with the endogeneity of the treatment cost.

[21] We also tried using dummies to capture some geographic clustering in the data – five villages mostly to the west of Nabha, and four roughly to the north, with the omitted village being effectively on the outskirts of the town – but this specification also did not alter our main results.

3.5 Results and Discussion

As noted in the introduction, we analyze three different aspects of healthcare choices. First, we examine the factors affecting the binary choice between a government and a private provider. We expand on this choice by also considering distance traveled to the provider. Next, we consider the binary choice between a professionally qualified provider and informal alternatives. Finally, we examine the factors influencing the level of satisfaction of respondents with the quality of care. The results for these three issues are presented sequentially.

3.5.1 Government vs Private Providers

The results for the choice between a government and a private provider are in Table A.1. All the regressions involve bivariate logit estimation. Aside from the first column, the remaining five columns include the anticipated treatment cost variable.[22] From the first column, we see that respondents who identified cost as a primary consideration in their provider choice were more likely to choose a government provider. None of the other variables capturing income status (BPL) or seriousness of condition are statistically significant, and neither is whether the provider was familiar to the respondent or not. When the estimated treatment cost is added to the regression (column 2), these results do not change. The anticipated treatment cost variable has the anticipated positive sign (indicating greater likelihood of choosing a government provider), and is marginally statistically significant.

Almost three quarters of the respondents sought treatment for themselves, and for this subsample (column 3), the estimated treatment cost variable is statistically significant and has the expected positive sign, implying a preference for a government provider. For this regression, we are able to include age and sex of the patient, but neither is a statistically significant factor in the choice between a government and private provider. For cases where the identified care was for the respondent's family member (column 4), the anticipated treatment cost variable is no longer significant. Finally, when the sample is split into cases that did or did not require hospital stays, the anticipated treatment cost does not significantly affect the choice, while reported cost sensitivity continues to be significant in both subsamples (columns 5 and 6). The choice between government and private providers for cases involving hospital stays was the only one significantly affected by the number of times that treatment was needed. This is plausible in that a need for frequent visits might favor choosing a less-costly government provider.

We also calculated marginal effects from Table A.1. We focus on the cost sensitivity and anticipated treatment cost variables. For the sample as a whole, a cost-sensitive respondent was almost 20 percentage points more likely to choose

[22]This variable is included in units of Rs. 100.

Table A.1: Government vs Private Provider

GOVT. PROVIDER	(1) *FullSample*	(2) *FullSample*	(3) *Self*	(4) *Fam*	(5) *Non − Hospital*	(6) *Hospital*
cost_sensitive	0.8461***	0.9266***	0.9118***	1.2313**	0.8799***	1.5630*
	(0.2357)	(0.2415)	(0.2879)	(0.4842)	(0.2584)	(0.8265)
major_condition	0.3625	0.2996	0.3985	-0.3967	0.4060	-0.1101
	(0.2282)	(0.2320)	(0.2665)	(0.5959)	(0.2556)	(0.6164)
known_provider	-0.1436	-0.0774	-0.1319	0.0519	-0.2001	0.8956
	(0.2409)	(0.2451)	(0.2929)	(0.4775)	(0.2686)	(0.6794)
bpl	-0.2258	-0.2012	-0.1301	-0.4934	-0.2093	0.0345
	(0.2197)	(0.2208)	(0.2585)	(0.4489)	(0.2454)	(0.6283)
times	0.0168	0.0117	0.0491	-0.1240	-0.0456	0.2442**
	(0.0389)	(0.0393)	(0.0456)	(0.0863)	(0.0480)	(0.1074)
treatment_cost		0.0043*	0.0067**	0.0011	0.0015	0.0043
		(0.0025)	(0.0033)	(0.0039)	(0.0082)	(0.0044)
age			-0.0011			
			(0.0083)			
sex			-0.0933			
			(0.2350)			
Observations	489	489	359	130	423	66

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

a government provider over a private one. Cost-sensitivity has a similar impact in the subsample of respondents who were patients themselves. For the other subsamples, the marginal effect of being cost-sensitive was higher, ranging from a 25 to 35 percentage point higher probability.

On the other hand, the marginal impact of the anticipated treatment cost was small. In the two cases where the anticipated treatment cost variable was significant, a Rs. 1000 increase in the estimated cost was associated with only about a 1 percentage point increase in the probability of choosing a government provider.

Next, we incorporate distance as a factor in the choice between government and private providers. We do this through multinomial regressions based on a bundle of characteristics – whether the provider was private or not, and the distance (near, i.e. 10 kilometers or closer to the patient's village, versus far) of the provider.[23] The results are reported in Table A.2, and give a good picture of some of the factors influencing healthcare decisions. The coefficients represent effects relative to the baseline of choosing a government provider that was near the patient's village. Cost sensitive respondents were less likely to choose private providers, especially distant private providers for whom the effect was stronger. The impact of cost-sensitivity between near and distant government providers was not different. A higher anticipated treatment cost made it less likely that a private provider within 10 km would be chosen, versus a government option close by. However, a higher anticipated treatment cost was associated with a greater chance of going to a

[23]The latter characteristic is correlated with whether the provider was a medical professional, so that aspect of choice is captured in the regression to some extent.

provider further away, whether government or private. This result suggests a joint determination of going to a more distant provider and treatment cost, rather than a causal linkage. Those who indicated that familiarity with a provider was their primary reason for who they visited, were less likely to travel more than 10 km. On the other hand, a greater number of visits was associated with a greater likelihood of seeing a private provider, or going further to see a government provider. Finally, being a BPL household was associated with being more likely to go to a more distant private provider versus other options – this may possibly be because of insurance arrangements, or because certain private facilities provide discounts on treatment costs for BPL patients. In fact, the average cost for BPL patients going to a distant private hospital was Rs. 1752, versus Rs. 2342 for a distant government hospital, which is consistent with the conjecture.[24]

Table A.2: Government vs Private Provider and Distance

VARIABLES	(1) *Pvt_Near*	(2) *Govt_Distant*	(3) *Pvt_Distant*
cost_sensitive	-0.62587*	-0.17713	-2.04778***
	(0.34727)	(0.39120)	(0.43500)
major_condition	-0.27346	0.46555	0.34299
	(0.34819)	(0.37820)	(0.37788)
known_provider	0.02973	-0.95053**	-0.99960***
	(0.34409)	(0.43611)	(0.38043)
bpl	0.05806	0.23296	0.83443**
	(0.31768)	(0.36746)	(0.35031)
times	0.23387***	0.37497***	0.30228***
	(0.08372)	(0.08799)	(0.08711)
treatment_cost	-0.03981***	0.01132**	0.01119**
	(0.01343)	(0.00524)	(0.00518)
Constant	0.68255*	-1.15931***	-0.33417
	(0.36773)	(0.43639)	(0.40089)
Observations	489	489	489

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

The coefficients represent effects relative to the baseline of choosing a government provider that was near the patient's village. (Govt_Near = baseline)

[24]Note that overall, costs were lower for private providers versus government providers (Appendix Table B.1), but this comparison includes a variety of providers, including a large proportion of informal private providers, so one cannot draw any clear inference in the general sample. We also estimated binary logit regressions separately for close and distant providers. The results were consistent with those for the multinomial logit: see Appendix Table 3.7.2.

3.5.2 Professional vs Informal Providers

The results for the binary choice between going to a medical professional versus an alternative such as a rural practitioner or pharmacist, are presented in Table A.3. In this choice, cost-sensitivity is no longer a significant factor, except when the anticipated treatment cost is omitted (column 1), where it has the expected negative sign.[25] Those who had based their choice of provider on the provider being known or familiar to them were also less likely to go to a medical professional – most likely reflecting the fact that familiar providers would be local pharmacists or informal practitioners. In particular, this result holds in the overall sample as well as sub-samples where the effect was statistically significant. As one might expect, those that we classify as having major conditions were in general more likely to go to a medical professional. Across the different samples or subsamples, the anticipated treatment cost is a significant factor in the choice, being associated with a greater likelihood of choosing a medical professional versus non-professional provider. For the regression involving respondents who were patients themselves, age and sex were not significant factors in the decision, paralleling the previous result for the government-private provider choice. Since a hospital stay would normally be associated with being treated by a medical professional, the results of cases that did and did not require hospital stays are also reported, but are not particularly informative.

Table A.3: Professional vs Informal Providers

	(1)	(2)	(3)	(4)	(5)	(6)
PROF PROVIDER	*FullSample*	*FullSample*	*Self*	*Fam*	*Non − Hospital*	*Hospital*
cost_sensitive	-0.5092**	-0.1603	-0.3099	0.3156	0.0106	-0.5023
	(0.2408)	(0.2541)	(0.2975)	(0.5869)	(0.2661)	(1.2004)
major_condition	0.8650***	0.6698**	0.7246**	-0.0076	0.7173**	-1.2009
	(0.2512)	(0.2658)	(0.2971)	(0.7776)	(0.2821)	(1.1962)
known_provider	-0.7970***	-0.6402***	-0.9944***	0.5523	-0.6555**	0.5068
	(0.2301)	(0.2442)	(0.2889)	(0.5520)	(0.2574)	(1.4189)
bpl	0.0089	0.0462	0.3702	-0.8428*	0.1322	-0.0566
	(0.2137)	(0.2242)	(0.2634)	(0.4978)	(0.2378)	(1.1580)
times	0.0345	-0.0214	-0.0348	0.0248	-0.0630	0.3424
	(0.0404)	(0.0433)	(0.0505)	(0.1033)	(0.0473)	(0.2995)
treatment_cost		0.0889***	0.0666***	0.3028***	0.1998***	0.0263*
		(0.0212)	(0.0205)	(0.1139)	(0.0433)	(0.0159)
age			0.0055			
			(0.0087)			
sex			-0.3753			
			(0.2405)			
Constant	0.5713**	0.1512	0.5021	-0.2830	-0.0487	0.2398
	(0.2376)	(0.2519)	(0.5602)	(0.5355)	(0.2686)	(1.6038)
Observations	489	489	359	130	423	66

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

[25] The importance of cost sensitivity is confirmed when anticipated treatment cost is omitted from the regression, as can be observed in Appendix Table 3.7.3.

The marginal effects of the anticipated treatment cost in the case of the choice between professional and non-professional provider are quite large, a Rs. 1000 increase being associated from a 14 to 46 percentage point increase in the probability of choosing a professional provider. In the case of individuals who stated that their choice was based on familiarity with the provider, this was associated with a 13 to 20 percent reduction in the probability of going to a professional, for the sample or subsets where the impact was statistically significant.

3.5.3 Satisfaction with Quality of Care

Finally, we examined how reported satisfaction, along the dimension of perceived quality of care, was explained by some of the characteristics of the care and the patients. These results are reported in Table A.4, for ordered logit estimation. Self-reported cost sensitivity always had a positive impact on satisfaction, and was statistically significant in most cases. Also, for most of the regression cases, those with what we classify as a major condition had higher levels of satisfaction. Interestingly, respondents who reported choosing a known provider as their criterion did not have higher levels of satisfaction. Anticipated treatment cost mostly had a negative impact on reported satisfaction, though it was not statistically significant in most cases. As in previous regressions, age and sex did not matter for satisfaction levels. It should be noted that the average levels of satisfaction were quite high (Table A.5), so these results on the determinants of satisfaction with the care received may somewhat reflect that limited range of reported outcomes. As noted earlier, these reported levels of satisfaction may not be accurate or unbiased indicators of the actual quality of care, but they are nevertheless informative of the perceptions of those receiving healthcare, or their family members.

3.6 Conclusion

Our survey and empirical analysis provide some insight into how rural households make healthcare decisions in the context of a developing country. India has government provided healthcare, but its availability and quality may not be conducive to effective provision of care. In our sample, households more often than not went to private providers. However, they did take account of costs, and those who identified themselves as cost-sensitive were more likely to choose government providers. In addition, anticipated treatment costs also seemed to affect this decision by households. The choice between medical professionals and informal providers was affected by the anticipated treatment cost but not reported cost sensitivity. Higher anticipated treatment costs were associated with a greater likelihood of choosing a medical professional versus non-professional provider. Those who chose a provider on the basis of familiarity were more likely to choose an informal provider.

Table A.4: Satisfaction with quality of care

VARIABLES	(1) *FullSample*	(2) *FullSample*	(3) *Self*	(4) *Fam*	(5) *Non − Hospital*	(6) *Hospital*
cost_sensitive	0.5703**	0.4933**	0.1957	1.3623***	0.3502	2.0126***
	(0.2230)	(0.2265)	(0.2638)	(0.4797)	(0.2407)	(0.7513)
major_condition	0.3886*	0.4644**	0.0953	1.4235***	0.4304*	0.4189
	(0.2160)	(0.2203)	(0.2516)	(0.5475)	(0.2376)	(0.6473)
known_provider	-0.0940	-0.1616	-0.2912	-0.2422	-0.1120	-1.0104
	(0.2203)	(0.2232)	(0.2580)	(0.4937)	(0.2363)	(0.8732)
bpl	0.0806	0.0502	0.2294	-0.2333	-0.0044	0.1283
	(0.2007)	(0.2015)	(0.2307)	(0.4512)	(0.2180)	(0.6751)
times	0.0348	0.0408	0.0329	-0.0150	0.0307	0.0866
	(0.0349)	(0.0353)	(0.0406)	(0.0804)	(0.0399)	(0.0885)
treatment_cost		-0.0050*	-0.0024	-0.0081	0.0004	-0.0041
		(0.0027)	(0.0033)	(0.0050)	(0.0071)	(0.0049)
age			0.0123			
			(0.0077)			
sex			-0.1466			
			(0.2131)			
Observations	489	489	359	130	423	66

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Individuals in the survey reported high levels of satisfaction with the care they received, though it is possible that there is response bias or over optimism in this respect. Patient perceptions of care as captured in reported satisfaction highlight a particular problem with asymmetric information in healthcare provision ([Dupas, 2011]), since objective measures suggest that quality is of care is unsatisfactory ([Das et al., 2020]). In our sample, distances and transport costs were not major factors in affecting access, and households had clear alternatives from which to choose. In general, they seemed to make decisions based on the information they had access to, as well as available alternatives. Understanding patient behavior at this micro level may be useful in guiding policies with respect to building new rural healthcare facilities or strengthening existing facilities, as well as financial support for healthcare costs.

The survey data come from a time when India's national publicly funded health insurance scheme was relatively new, and other evidence ([Hooda, 2020]) suggests that effective coverage was low in states like Punjab. The situation at the time of our data collection was consistent with households being able to manage their choices of where to seek healthcare, while taking into account the anticipated costs of treatment. However, individual health emergencies or catastrophes, or events such as the Covid-19 pandemic, are precisely the kinds of cases where those seeking treatment cannot make the kinds of decisions modeled in this paper.[26] A

[26] For example, see the report by [Kumar, 2020], on how the pandemic led to redeployment of healthcare personnel away from rural areas that already were underserved ([Sharma, 2017]). More broadly, there are many institutional complexities with respect to government provision of public health services, as well as individual healthcare: [Khemani et al., 2020] provide a theoretical discussion, as well as empirical evidence from Bihar, another Indian state, but much

study of various public-private healthcare combinations in Punjab ([Singh, 2011]) included suggestions for greater flexibility and efficiency in resource allocation, such as more effective mobile medical units serving a catchment area around each town instead of the current model centred around rural facilities. Such a model is feasible in Punjab because of its excellent network of rural roads. This potential benefit of rural roads might counter some of the less positive conclusions of studies that examine the developmental impact of rural roads ([Aggarwal, 2018]; [Asher & Novosad, 2020]).

Although our data is from 2010, we do not believe that individual- or household-level decision-making on availing curative healthcare has changed fundamentally in the ensuing years. The National Health Insurance Scheme (RSBY, referenced earlier) included coverage for day-surgeries and hospitalizations, but outpatient care was covered for a short duration only when it preceded or followed hospitalization. Hence, although there may be some effect of having insurance coverage on individual cost-sensitivity at the time of an acute health event or chronic illness that an individual perceives as being likely to lead to hospitalization, having coverage under the RSBY is unlikely to influence decision-making for the vast majority of the medical conditions for which care was sought in this study. To the best of our knowledge, this study is unique in formally modeling the relationship between anticipated treatment costs and the choice of healthcare provider. It would be worthwhile for future studies to further examine and update our understanding of this relationship in order to account for different contexts and the difference in anticipated costs over time.

Our analysis also reinforces what is known about costs of treatment beyond doctor fees: these are very substantial in general, even for non-hospital treatment. Therefore, our survey data and empirical analysis can be useful in designing policies for improving affordable access to healthcare in India.

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poorer than Punjab.

3.7 Appendix

3.7.1 A: Treatment Cost

Anticipated treatment cost equation

$$\begin{aligned} TC_i = \beta_0 + \beta_1 age_i + \beta_2 cost\_sensitive_i + \beta_3 major\_condition_i + \\ \beta_4 known\_provider_i + \beta_5 bpl_i + \beta_6 times_i + \beta_7 ration_i + \beta_8 age_i^2 \end{aligned} \tag{3.7.1}$$

3.7.2 B: Figures and Tables

Table 3.7.1: Costs

	Total Cost	Treatment Cost	Hospital Cost	Medicine Cost	Fees	Extra Costs
Full Sample	1597.63	1565.02	874.75	455.62	61.39	173.27
Private	1389.74	1359.22	667.72	443.29	87.7	160.52
Government	1983.2	1946.72	1258.72	478.5	12.6	196.91
Professional	2435.74	2389.85	1401	655.8	72.38	260.67
Informal	269.88	258.31	41.05	138.5	43.97	34.79

Source: Calculated from survey data

Table 3.7.2: Government vs Private Providers; Close vs. Distant

	(1)	(2)
VARIABLES	*Near*	*Distant*
cost_sensitive	0.6571*	2.0289***
	(0.3502)	(0.4199)
major_condition	0.3302	0.1024
	(0.3650)	(0.3350)
known_provider	-0.0974	0.0653
	(0.3488)	(0.3856)
bpl	0.0092	-0.6785**
	(0.3235)	(0.3385)
times	-0.2133**	0.1219**
	(0.0843)	(0.0583)
treatment_cost	0.0143**	-0.0002
	(0.0069)	(0.0030)
Constant	-0.6415*	-1.0378***
	(0.3557)	(0.4022)
Observations	283	206

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3.7.3: Professional vs Informal Provider (Omitting Treatment Cost)

PROF PROVIDER	(1) *FullSample*	(2) *Self*	(3) *Family*	(4) *Non − Hospital*	(5) *Hospital*
cost_sensitive	-0.5092**	-0.5989**	-0.1832	-0.3370	-1.1054
	(0.2408)	(0.2844)	(0.5040)	(0.2529)	(1.0882)
major_condition	0.8650***	1.0260***	0.5189	0.9404***	-0.6874
	(0.2512)	(0.2772)	(0.6866)	(0.2656)	(1.0297)
known_provider	-0.7970***	-1.0598***	0.1675	-0.7458***	-0.3242
	(0.2301)	(0.2738)	(0.4990)	(0.2436)	(1.3284)
bpl	0.0089	0.2694	-0.6587	0.0243	-0.8633
	(0.2137)	(0.2529)	(0.4333)	(0.2287)	(1.0557)
times	0.0345	0.0102	0.1411	0.0008	0.3802
	(0.0404)	(0.0458)	(0.0958)	(0.0431)	(0.3089)
Constant	0.5713**	0.4881*	0.6479	0.4246*	2.1792
	(0.2376)	(0.2841)	(0.4829)	(0.2471)	(1.3355)
Observations	489	359	130	423	66

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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