Essays on Globalization

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Dedication

To the loving memory of my mother.

Abstract

This dissertation consists of two essays.

The first essay analyzes the labor market effects of import competition in the U.S. Recent empirical research indicates, in contrast to standard trade theory, that trade and foreign competition negatively impact some locations by worsening labor market outcomes such as unemployment. I extend and confirm this work using unique data on the U.S. Trade Adjustment Assistance (TAA) programs since 1983. I find that locations that face more foreign competition have higher job destruction rates, lower job creation rates, and thereby higher unemployment rates. I introduce a simple trade model with unemployment and segmented local labor markets facing different degrees of foreign competition. Import competition has a correlated effect on job destruction and job creation because the most vulnerable locations to foreign competition have lower productivity. Despite large reductions in employment rate in the worse hit local labor markets and in contrast to an exogenous increase in foreign productivity, an unexpected trade liberalization yields aggregate welfare gains in the model calibrated to the U.S.

In the second essay, Sewon Hur and I study the foreign reserves accumulation of emerging economies. Emerging economies, unlike advanced economies, have accumulated large foreign reserve holdings. We argue that this policy is an optimal response to an increase in foreign debt rollover risk. In our model, reserves play a crucial role in reducing debt rollover crises ("sudden stops"), akin to the role of bank reserves in preventing bank runs. An unexpected increase in rollover risk leads to a global rise in sudden stops, prompting emerging economies to update their priors about the risk they face. We show that a global increase in the rollover risk faced by emerging economies

explains the outburst of sudden stops in the late 1990s, the subsequent increase in foreign reserves holdings, and the salient resilience of these countries to sudden stops ever since.

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Chapter 1

Trade Reforms, Foreign Competition, and Labor Market Adjustments in the U.S.

1.1 Introduction

In standard models of international trade, the reallocation of production factors is at the heart of the gains from trade. The effects of trade reforms therefore depend crucially on how these factors are reallocated. While cross-country mobility of labor and capital has been extensively investigated in the trade literature, the differences in reallocation within countries have been less studied. In particular, in standard trade models, labor markets are centralized and typically frictionless. Standard trade theory also does not consider geographic variations in the unemployment effects of trade reforms. However, recent evidence such as Autor, Dorn, and Hanson (2011) indicates that the labor market effects of trade are uneven across locations. This paper makes empirical and theoretical contributions to the literature on international trade and labor markets.

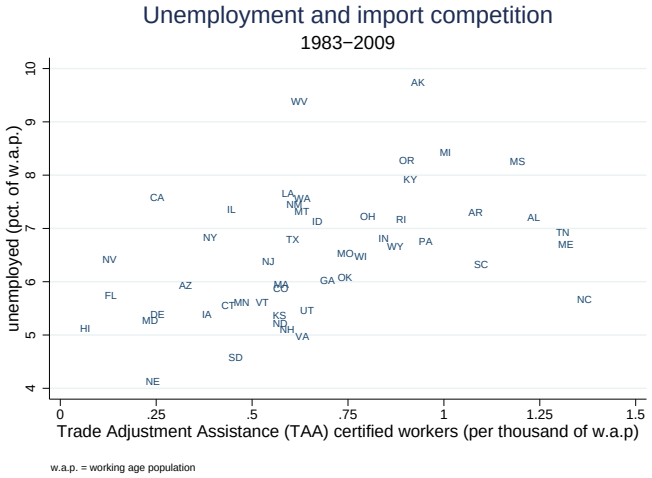
First, this paper establishes new facts on the impact of foreign competition on non-employment and job flows using variations in import competition across locations in the U.S. Second, this paper introduces a new trade model with unemployment and local labor markets that face varying degrees of foreign competition (head-to-head versus monopolistic competition). This model is used to rationalize the observed effects of trade-induced foreign competition across locations and to evaluate the welfare effects from trade liberalization.

In practice, it is hard to measure job losses caused by import competition. Consider, for instance, a shipment of electronic parts imported from China arriving at the port of Savannah in Georgia. It is not obvious to determine which American workers and which plants are displaced because of these Chinese imports. In this paper, I create a novel state-level panel dataset on job losses due to foreign competition since 1983 based on data from the U.S. Department of Labor Trade Adjustment Assistance (TAA) programs. These programs investigate all the establishment-level petitions submitted on behalf of workers that were deemed displaced due to import competition. Figure 1 illustrates the average import competition and the average unemployment rate across states from 1983 to 2009 using the Trade Adjustment Assistance (TAA) data and the Current Population Survey (CPS).

I find that, across locations, import competition is associated with reduced employment. Import competition has a correlated impact on the job destruction rate and the job creation rate: locations that face more foreign competition not only have a higher job destruction rate but also a lower job creation rate. Import competition therefore has a large differential impact on unemployment across locations. In fact, one extra worker displaced due to import competition is associated with an overall unemployment differential of three workers, across these differently exposed locations. The effects documented are robust to state fixed effects, time fixed effects, panel-level autocorrelation

and heteroskedasticity.

Figure 1.1: Unemployment and import competition in the U.S.



Most importantly, the measured unemployment effects of trade across locations imply that models capturing these empirical effects are needed to evaluate the welfare effects of trade and to provide an explanation for the documented facts. This paper extends a model of international trade with imperfect competition to incorporate unemployment and local labor markets facing different levels of foreign competition. The model is then used to evaluatethe labor markets effects and the welfare effects of an unexpected trade reform while workers have not switched away from potentially depressed labor markets.

At the heart of the model with unemployment, there is a new hybrid model of trade which combines monopolistic competition and direct head-to-head competition. The model is hybrid in the sense that some firms monopolistically produce differentiated varieties that have no perfect substitute (see Dixit and Stiglitz (1977)) while other firms produce differentiated varieties that have a perfect foreign substitute (see Dornbusch, Fischer, and Samuelson (1977) and Bernard, Eaton, Jensen, and Kortum

(2003)). Hence, some firms do not face direct foreign competition while others face direct foreign competition making them vulnerable to shutdowns when trade barriers fall.

On top of this hybrid trade model, I introduce a continuum of locations and local unemployment. In adding locations to the model, the main goal is to have differences across locations in their vulnerability to foreign competition. This is accomplished via exogenous productivity differences across locations in the Ricardian tradition. Local unemployment is obtained using random Leontieff matching and collective Nash bargaining within labor markets. Across labor markets, workers are allocated, ex ante, so that they are indifferent among these locations.

The heterogeneity in the level of foreign competition across these segmented labor markets is a key ingredient to explain the association between import competition and unemployment as well as the correlated effect of import competition on job creation and job destruction. In fact, an unexpected reduction in trade frictions unevenly increases the extent of unanticipated foreign competition that domestic firms face. Fierce foreign competition in the least productive areas therefore causes job losses as many local firms shut down. These job losses contribute to differences in unemployment across locations since these locations differ in degree of foreign competition. The model delivers the dual effect of import competition on job creation across locations because the most vulnerable locations to foreign competition also have lower productivity and thereby create fewer new jobs.

Overall, the welfare effects of a trade reform are therefore a quantitative question. I perform an unexpected trade liberalization experiment using the model calibrated to the U.S. economy. The main calibration target is the total number of workers certified to be displaced because of import competition in the parameterized model. The trade liberalization yields aggregate welfare gains along with large reductions in employment

rate and earnings in the badly hit local labor markets: some locations gain while other locations hurt a lot. However, aggregate welfare gains disappear in the case of an unexpected rise in foreign productivity.

This paper is structured as follows. Section 2 discusses this paper's relation to the existing literature. Section 3 empirically analyzes import competition and labor market outcomes and job flows across states in the U.S.. Section 4 provides a simple static model showing the uneven impact of trade competition on unemployment across segmented labor markets that differ in foreign competition. Section 5 considers the effects of an unexpected trade liberalization on unemployment and welfare in this model when workers are tied to their initial (pre-liberalization) labor markets. Section 6 concludes.

1.2 Related Literature

This paper contributes to a growing literature that bridges international trade and labor economics. Following the contributions of Topalova (2007) and Kovak (2010) on the impact of trade liberalization on migration and wages in India and Brazil respectively, Autor, Dorn, and Hanson (2011) made an influential contribution by conducting a thorough empirical analysis of the impact of increased in trade with China on local U.S. labor market outcomes. They document the "China syndrome": the worsening of labor market outcomes in localities that are more exposed to growing imports from China due to their local industrial mix. In this paper, I introduce the first direct measure of local job displacements due to foreign competition in the trade and labor literature. This measure uses local displacements attributed to foreign competition in contrast with the standard local import penetration proxies that are inferred from aggregate national data. Margalit (2011) recently constructed a similar local measure for a novel use in the political science literature: the effects of job losses due to foreign competition on anti-incumbent voting behavior during the elections cycles. Yotov (2007) and Uysal and

Yotov (2011) first used the underlying petition data in the trade literature to measure trade-induced job losses by industry and firm. This paper instead introduces a location-specific measure to study the labor markets effects of trade across locations.

Moreover, the models used to motivate the existing empirical studies do not feature local unemployment. In this paper, I introduce a new model trade and local unemployment. The novelty of both the dataset and the theory also differentiates this paper from past studies on the effects of foreign competition on job flows. Following the work of Goldberg and Tracy (2000) on exchange rates and local labor markets, studies such as Klein et al. (2003) and Moser et al. (2010) empirically document the effects of foreign competition on job creation and job destruction using real exchange fluctuations as exogenous shifters of foreign competition. In this paper, I find that foreign competition has correlated effects on both job destruction rates and job creation rates.

This paper is also related to the theoretical models of trade and unemployment. In particular, Davidson et al. (1999) showed that labor market institutions are an important determinant of international comparative advantage. Helpman and Itskhoki (2010) extended this approach to the Melitz (2003) model of international trade with monopolistic competition and heterogeneous firms. Janiak (2006), Egger and Kreickemeier (2009a), Mitra and Ranjan (2010), and Felbermayr et al. (2010) also introduce unemployment in the baseline models of international trade. Recently, Dutt et al. (2009) and Felbermayr et al. (2011) studied the effects of trade openness on labor market outcomes across countries using model of trade and unemployment. None of these papers features local unemployment and local labor markets. Also, Kambourov (2009), Cosar (2010), and Dix-Carneiro (2010) recently studied transition paths in dynamic models of trade and unemployment with a rich notion of sectoral and human capital heterogeneity within a country.

In this paper, I complement these studies by introducing unemployment across heterogenous labor markets varying in the degree of import competition they face. Furthermore, this paper introduces a novel baseline model of international trade combining the Chamberlinian monopolistic competition model with head-to-head competition akin to Bernard, Eaton, Jensen, and Kortum (2003). Finally, this paper most closely builds on Helpman and Itskhoki (2010) by introducing, within an economy, segmented local labor markets subject to different degrees of head-to-head foreign competition. This feature allows the model to be consistent with the differential unemployment effect of import competition across locations. In fact, this paper introduces the first model of unemployment with variable markups in the trade literature. This paper also shares with Helpman and Itskhoki (2010), an important ex-ante indifference condition across labor markets reminiscent of Harris and Todaro (1970) and Lewis (1954).

1.3 Evidence

In this section, after describing the state-level panel dataset I create using the petitions data from the U.S. Trade Adjustment Assistance (TAA) programs, I present my main empirical findings: import competition is associated with higher unemployment, lower labor force participation, higher job destruction rates, lower job creation rates, and longer unemployment spells. Furthermore, the labor market effects of import competition magnify the displacements directly due to foreign competition.

1.3.1 Data Description

The March CPS

I use public data from the Current Population Survey (CPS). In particular, I use data from the Annual Social and Economic Supplement (ASEC) applied to the sample surveyed in March and assembled into the Integrated Public Use Microdata Series by King et al. (2010). I construct, for every year $t = 1983 ... 2009$ and for every state, the following labor market outcomes: unemployed per working age population, not in the labor force per working age population, and average unemployment duration.

The Business Dynamics Statistics

I also use public data from the Business Dynamics Statistics (BDS) that contains annual series describing establishment-level business dynamics. The BDS are created from the Longitudinal Business Database (LBD) by the Census Bureau. Using this data, I obtain, for every year $t = 1983 ... 2009$ and for every state, the following labor market outcome counterparts: jobs destruction rate, job creation rate, and net job creation rate. These measures are computed following Davis, Haltiwanger, and Schuh (1998).

The Trade Adjustment Assistance (TAA) programs for workers

To measure import competition at the state-level, I construct a novel state-level panel dataset based on the Trade Adjustment Assistance (TAA) programs for workers. The international trade literature had not previously used the direct and local measure of foreign competition introduced in this paper[1] . Instated in its current form as part of

[1] The only exception I am aware of is Margalit (2011) who constructs a similar measure in the political science literature. Yotov (2007) and Uysal and Yotov (2011) are precursors in the use of the petitions data from the Trade Adjustment Assistance (TAA). Decker and Corson (1994) uses survey data on the characteristics and the outcomes individual workers receiving Trade Adjustment Assistance (TAA) benefits in 1988 to study the impact of a reform emphasizing training. Numerous reports and studies such as Magee (2001) and Park (2011) use similar survey data on worker characteristics and

the pivotal Trade Act of 1974, the Trade Adjustment Assistance (TAA) for workers is a federal program that aims to support the professional transition of workers displaced due to foreign trade. Rosen (2006) and Rosen (2008) provide a detailed history of the program. I use data on the number of workers certified under this program by the Department of Labor (DoL) to have been displaced due to foreign trade from 1983 to 2009.

Firms, unions, state unemployment agencies, or groups of workers can file a petition on behalf of a group of workers at a given establishment to be eligible for Trade Adjustment Assistance (TAA) benefits. These benefits include: Trade Readjustment Assistance (TRA) for up to two years as long as the workers are enrolled in training, income support for the workers who are find full employment following the trade-induced separations, job search allowances, relocation allowances, and healthcare assistance.

To establish the eligibility of the petitioning workers, federal investigators at the Department of Labor (DoL) seek evidence that these workers were separated because of (a) import competition that led to decline in sales or production, (b) a shift in production to another country with which the United States has a trade agreement, or (c) due to loss of business as an upstream supplier or downstream producer for another producer that is TAA-certified. For each petition, investigators make a "confidential data request" (CDR) for data such as sales history, sales of import-competing products, major declining customers and unsuccessful bids. The Trade Adjustment Assistance (TAA) investigators also have legal power to subpoena if the company does not comply to the data request. All the workers covered by an approved petition become eligible for the Trade Adjustment Assistance (TAA) benefits.

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the design of the Trade Adjustment Assistance (TAA) to assess the effectiveness of the program itself. These studies and reports do not use the establishement-level certification data used in this paper and do not consider the aggregate labor markets effects of international trade.

I construct measures of trade-induced foreign competition using data on all establishment-level petitions filed under the program up to 2009. I exclude data prior to 1983 due to the lack of reliability of these data as a measure of import competition (see Rosen (2006)). Each petition includes information on the location of the establishment, the numbers of workers affected, the certification decision, and the date of impact[2] .

1.3.2 Measuring Import Competition

Using the Trade Adjustment Assistance (TAA) petitions data, for every year $t = 1983 \ldots 2009$ and for every state[3] i in the U.S., I measure the degree of import competition at a given location and at a given time as the ratio of all workers newly certified for Trade Adjustment Assistance (TAA) relative to the working age population:

$$\text{TAA import pressure}_t^i \equiv \frac{\sum_{\text{plants } j \in i} \text{Trade Adjustment Assistance (TAA) certified workers}_{j,t}^i}{\text{working age population}_t^i}$$

In 2009, a record 330,906 workers were certified for Trade Adjustment Assistance (TAA) across all states. Figure 9 shows an overview of the total number of TAA certified workers in the U.S. over time. Table 1 and Figure 1 show the typical order of magnitude of this TAA-based import pressure across states between 1983 and 2009. Table 3 in the appendix shows detailed descriptive statistics by state.

Table 1.1: Summary statistics (1983-2009)

Variable	p10	p25	p50	p75	p90
TAA certified workers (per thousand w.a.p.)	0.03	0.17	0.43	0.88	1.64
TAA petitioning workers (per thousand w.a.p.)	0.11	0.39	0.80	1.43	2.38
Unemployed minus US average (percent w.a.p)	-2.24	-1.33	-0.35	0.79	1.99

[2] Individual petitions are publicly available at http://www.doleta.gov/tradeact/taa/taa_search_form.cfm

[3] I choose to aggregate the petition data at the state level because of the greater reliability of other economic series at the state level. In a companion project, I conduct empirical investigations on the labor market effects of trade at the commuting zone level.

It is important to note that this measure is expressed in workers displaced and therefore is different from the standard import penetration proxies used in the literature. Typically, the import penetration proxies are expressed in dollars per worker by taking a weighted average of U.S.-wide imports by industrial classification. In fact, it is not obvious to map U.S.-level imports to the plants that are most directly affected. It is not clear which plants in the U.S. are directly affected by a shipment of toys coming through the port of Savannah. Import penetration proxies are widely used in economics and rely on the local industrial mix to infer the local import competition by accordingly averaging national imports by industry. These proxies assume that two plants producing toys are equally in the U.S. are equally impacted by the Chinese imports, thereby ignoring differences in productivity between these plants. In other words, the standard proxy would wrongly suggest that the more productive plant is shrinking in size as much the less productive plant.

For instance, the "China syndrome" measure used in Autor, Dorn, and Hanson (2011) - henceforth ADH - is an import penetration measure obtained as a weighted average of U.S. imports across more than four hundred industries using the local labor force shares by industry as weights:

$$\text{ADH import penetration}_t^i \equiv \sum_{\text{industries } k} \underbrace{\frac{\text{employment}_{i,t}^k}{\text{employment}_{i,t}}}_{\text{local industrial mix}} * \underbrace{\frac{\Delta\text{imports}_{US,t}^k}{\text{employment}_{US,t}^k}}_{\text{national imports}}$$

Table 2 shows the typical order of magnitude of this TAA-based import pressure across states between 1988 and 2005[4] .

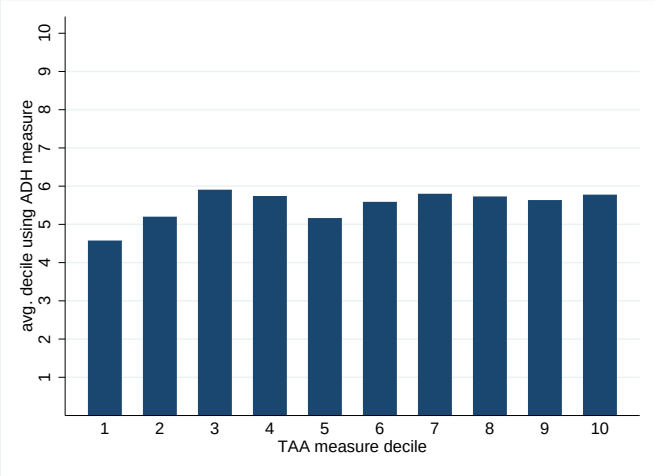
By using a more direct measure of import competition, I circumvent the inference implicit in the import penetration proxy as well as the non-obvious price effects. For example, this measure exhibits variations at very aggregate levels (state, region) that

[4] The China exposure is computed following Autor, Dorn, and Hanson (2011) for 1988-1997 and 1999-2005 only due to data limitations.

Table 1.2: Summary statistics (1988-2005)

Variable	p10	p25	p50	p75	p90
Change in China import exposure ($000s per worker)	0.12	0.25	0.56	1.38	2.70

Figure 1.2: Import penetration proxy and import competition at the state-level



are not captured by Autor, Dorn, and Hanson (2011) as shown in Figure 2.

In fact, this limited variation across states is one of the practical reasons why Autor, Dorn, and Hanson (2011) investigate the impact of trade openness at a more granular level using commuting zones. This limitation is not surprising given the fine granularity of the imports data: more than four hundred industry specific imports are collapsed in the import penetration index constructed by Autor, Dorn, and Hanson (2011). Figure 16 in the appendix shows the detailed state-level time series.

1.3.3 Impact of Import Competition on Labor Market Outcomes

Unemployment

The relationship between import competition and unemployment is not obviously positive. The magnitude of this relationship is even less obvious.

To assess the impact of import competition on unemployment, I first estimate the simple regression specified below:

$$\text{not employed}_t^i = \alpha + \beta \times \text{import pressure}_t^i + \gamma \cdot \text{controls}_t^i + \text{error}_t^i$$

where i denotes a state, t denotes a year between 1983 and 2009. I also separately estimate each of the simple linear regressions specified below to distinguish the unemployment effect from the non labor force participation margin:

$$\text{unemployment}_t^i = \alpha + \beta \times \text{import pressure}_t^i + \gamma \cdot \text{controls}_t^i + \text{error}_t^i$$

$$\text{not in labor force}_t^i = \alpha + \beta \times \text{import pressure}_t^i + \gamma \cdot \text{controls}_t^i + \text{error}_t^i$$

where i denotes a state, t denotes a year between 1983 and 2009.

The variable import pressure_t^i is the number of workers certified by the Trade Adjustment Assistance (TAA) in state i *during* year t relative to that state's working age population. The dependent variable not employed_t^i is the number of workers who are not employed in state i *as of* the March CPS in t+1 relative to that state's working age population. The dependent variable unemployment_t^i is the number of unemployed in state i *as of* the March CPS in t+1 relative to that state's working age population. Similarly, the variable $\text{not in labor force}_t^i$ is the number of people not in the labor force in state i *as of* the March CPS in t+1 relative to that state's working age population.

At the state level, I assume there is first-order autocorrelation AR(1) in the error

terms and that the coefficient of the AR(1) process is common across states. Furthermore, the errors are assumed to be panel-level heteroskedastic. Hence, the standard errors reported here are robust to panel-level heteroskedasticity. The controls include: state fixed effects, year fixed effects, the state log income per working age population, and the state share of U.S. working age population. Other controls such as the state unionization rate, the state-specific Trade Adjustment Assistance (TAA) approval rate, and the standard import penetration proxies are included in the subsequent robustness checks. The findings below are robust to alternative specifications with lagged variables or changes in non-employment instead of auto-correlated errors.

The first specification yields the following estimate using a Prais-Winsten regression to generate robust standard errors:

$$\text{not employed}^{i}_{t} = \alpha + \underset{(0.780)}{3.349 \times \text{import pressure}^{i}_{t}} + \gamma \cdot \text{controls}^{i}_{t} + \text{error}^{i}_{t}$$

$$R^2 = 0.8633 \qquad N = 1350$$

The related regressions on unemployment and non labor force participation yield the following estimates[5] :

$$\text{unemployment}^{i}_{t} = \alpha + \underset{(0.553)}{1.409 \times \text{import pressure}^{i}_{t}} + \gamma \cdot \text{controls}^{i}_{t} + \text{error}^{i}_{t}$$

$$R^2 = 0.6345 \qquad N = 1350$$

[5] The coefficients do not add up to the coefficient in the non-employment regression. This is simply because the errors are assumed to be autocorrelated and the persistence parameters estimated are not exactly the same across these regressions.

$$\text{not in labor force}_t^i = \alpha + \underset{(0.617)}{2.187 \times \text{import pressure}_t^i} + \gamma \cdot \text{controls}_t^i + \text{error}_t^i$$

$$R^2 = 0.8588 \qquad N = 1350$$

The coefficients estimated indicate a large differential effect of foreign competition on labor markets: across locations, an extra worker separated due to import competition is associated with an additional difference in the overall non-employment of two to three extra workers. A world with frictionless reallocation would imply that the import pressure should have no effect on the unemployment level. A world in which these workers stay unemployed for four months[6] would imply a coefficient less than one if most of these workers permanently transition back into employment. The coefficient estimated is therefore very large. These findings indicate that the workers certified by the Trade Adjustment Assistance (TAA) are only a symptom of foreign competition: differences in unemployment magnify differences in job losses due to foreign competition across locations.

While these results confirm and extend our interpretation of the findings reported in Autor, Dorn, and Hanson (2011), it is worth noting that the findings of Autor, Dorn, and Hanson (2011) do not hold at the state-level. The standard import penetration proxy has limitations when it is used at an aggregate level, in addition to some of the conceptual limitations discussed in the previous subsection. On the other hand, the estimates reported in this paper using the new measure of import competition are robust to the inclusion of the standard import penetration as an additional control.

[6] The average unemployment spell is 16 to 17 weeks.

Job Destruction Rate and Job Creation Rate

To further document the labor market effects of trade across locations, I study the effects of import competition on job flows. First, the effects of import competition displacements on non-employment using the March Current Population Survey (CPS) mirror the effects of import competition on the net job creation rate constructed from the Business Dynamics Statistics (BDS). Most importantly, the Business Dynamics Statistics (BDS) allows to distinguish between job destruction and job creation following the definition of Davis, Haltiwanger, and Schuh (1998). Davis, Haltiwanger, and Schuh (1998) nicely explain the importance of using plant-level data to decompose change in unemployment into two separate margins: the destruction of existing jobs and the creation of new jobs. I find that the unemployment effects of import competition are explained by both higher job destruction and lower job creations as shown below:

$$\text{job destruction rate}^{\text{i}}_{\text{t}} = \alpha + \underset{(0.724)}{1.819} \times \text{import pressure}^{i}_{\text{t}} + \gamma \cdot \text{controls}^{i}_{\text{t}} + \text{error}^{i}_{\text{t}}$$

$$R^2 = 0.7955 \qquad N = 1350$$

$$\text{job creation rate}^{\text{i}}_{\text{t}} = \alpha - \underset{(0.630)}{1.276} \times \text{import pressure}^{i}_{\text{t}} + \gamma \cdot \text{controls}^{i}_{\text{t}} + \text{error}^{i}_{\text{t}}$$

$$R^2 = 0.7717 \qquad N = 1350$$

These findings on job flows bridge two strands of the literature on trade and jobs: the first one studies the unemployment effects of trade using import penetration proxies while the other studies the effects of real exchange rate fluctuations on job flows. The existing papers do not agree that real exchange rate fluctuations affect both job creation

and job destruction as shown in Klein et al. (2003) and Moser et al. (2010). This paper documents, empirically and theoretically, the correlated effects of import competition on both job destruction and job creation in the U.S. in agreement with the net effect on unemployment.

Unemployment Duration

Finally, average unemployment durations are also longer when import competition is higher as shown below:

$$\underset{}{\text{weeks unemployed}_t^i} = \underset{}{\alpha} + \underset{(0.149)}{0.507 \times \text{import pressure}_t^i} + \gamma \cdot \text{controls}_t^i + \text{error}_t^i$$

$$R^2 = 0.5351 \qquad N = 1350$$

In the unemployment spell regression above, the import pressure was rescaled by 1,000 and therefore expressed in numbers of Trade Adjustment Assistance (TAA) certified workers displaced per thousand w.a.p. The regression specification already included several controls (in particular time, location, income).

Summary

Using the novel state-level panel dataset I created to directly measure foreign competition, I document a large differential effect of foreign competition across locations. Across locations, increased foreign competition is associated with increased unemployment. This difference in unemployment across locations is driven by the dual effects of import competition on both job destruction and job creation. Overall, the effects documented above are robust to the inclusion of more controls, in particular the state level unionization rate, the state level contemporaneous Trade Adjustment Assistance

(TAA) approval rate, and the widely use import penetration proxy[7] . Other labor market outcomes such as hourly wages, hours worked and the skill premium do not appear to be significantly impacted by this measure of import competition. The non significant effects of import competition on population dynamics are also shown in the appendix.

These findings provide a new understanding on the uneven impact of trade across locations. However, these empirical findings also trigger questions that warrant a model: why does foreign competition have a correlated effect of both job destruction and job creation? what are the welfare effects of the uneven effect of foreign competition across locations? what are the consequences of the limited geographical mobility of workers in response to trade shocks? Unfortunately, standard trade theory is not equipped to address some of these questions. In this next section, I propose a new model to tackle these questions.

1.4 A Trade Model with Heterogeneous Labor Markets

In the following section, I build a model of international trade and local unemployment to address the questions motivated by the empirical findings and to ultimately evaluate the effects of trade reforms. Specifically, I introduce head-to-head competition, segmented local labor markets in a hybrid trade model. The hybrid trade model combines some firms monopolistically producing differentiated varieties with no perfect substitute (see Dixit and Stiglitz (1977)) and other firms producing differentiated varieties with a perfect foreign substitute (see Dornbusch, Fischer, and Samuelson (1977) and Bernard,

[7] To deal with potential measurement errors, I instrument for the TAA-based import competition measure using the import exposure used by Autor, Dorn, and Hanson (2011) in a companion project. Given the limited variation of the standard import penetration measure at the state-level (see Figure 2 and Figure 13), this has to be done at commuting zone level instead. The commuting zones are obtained by clustering counties using the U.S. Census Commuting ("Journey-to-Work") data following Autor and Dorn (2010) and Tolbert and Sizer (1996).

Eaton, Jensen, and Kortum (2003)). The economy features a continuum of locations or islands that vary in the exogenous productivity of their local firms, thereby inducing differences in the degree of foreign competition. Local unemployment is obtained using random matching of workers to firms and collective Nash bargaining while the distribution of population across locations is determined by the uncoordinated search for work across locations. This structure therefore has similarities with Alvarez and Shimer (2010) who consider a competitive equilibrium setup with directed search across many islands and random matching within each island.

In this section, I layout the model in detail and characterize the equilibrium allocation. I use this model to study the effects of an unexpected trade reform in the next section.

1.4.1 Environment

The environment in consists of two symmetric countries $j = 0, 1$ populated a unit measure of families and firms. Each family[8] is composed of L (potential) workers allocated across the towns of their home country.

Preferences

Each family has quasi-linear preferences over its homogeneous good consumption q_0 and its composite good consumption Q:

$$\mathsf{U} = q_0 + \frac{1}{\eta}\mathsf{Q}^{\eta}$$

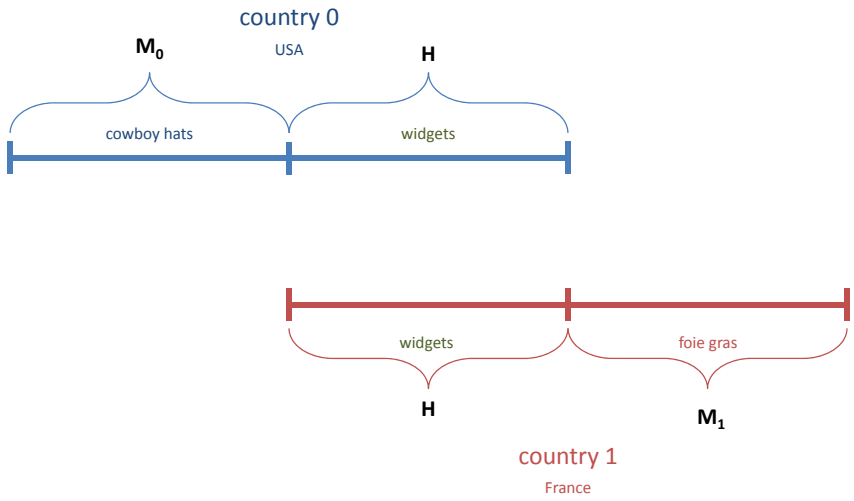
where Q is the Spence-Dixit-Stiglitz aggregator over differentiated goods $\nu \in \mathsf{M}_0 \cup \mathsf{H} \cup \mathsf{M}_1$:

$$\mathsf{Q} \equiv \left(\int_{\mathsf{M}_0 \cup \mathsf{H} \cup \mathsf{M}_1} q(\nu)^{\frac{\sigma-1}{\sigma}} \, \mathrm{d}\nu \right)^{\frac{\sigma}{\sigma-1}}$$

[8] As in Helpman and Itskhoki (2010), the family interpretation is essential in the case of quasi-linear preferences but not when preferences are homothetic.

and $0 < \eta < \frac{\sigma-1}{\sigma} < 1$.

Figure 1.3: A simple overview of the model



The differentiated goods have two possible types as illustrated in Figure 3:

- the monopolistic M−goods have no foreign counterpart and the producers of these goods are monopolistic competitors (e.g. cowboy hats and foie gras respectively), or
- the head-to-head H−goods have a perfect substitute produced by a foreign competitor and the domestic producer of these goods competes head-to-head for domestic and foreign markets (e.g. widgets).

For simplicity, one can think of Texas towns and Pennsylvania towns making cowboy hats and widgets respectively. I elaborate later on locations and labor markets in each country.

Taking the homogeneous as the numeraire ($p_0 = 1$), the household faces a price

index P for the differentiated good defined as:

$$\mathsf{P} = \left(\int_{\mathsf{M}_0 \cup \mathsf{H} \cup \mathsf{M}_1} p(\nu)^{1-\sigma} \, \mathrm{d}\nu \right)^{\frac{1}{1-\sigma}}$$

A household with total income R therefore chooses:

$$\begin{aligned} q_0 = &\quad \mathsf{R} - \mathsf{P}^{-\frac{\eta}{1-\eta}} = \mathsf{R} - \mathsf{Q}^{\eta} \\ \mathsf{Q} = &\quad \mathsf{P}^{-\frac{1}{1-\eta}} \\ q(\nu) = &\quad \mathsf{Q}^{-\frac{\rho-\eta}{1-\rho}} \, p(\nu)^{-\sigma} \end{aligned}$$

where $\rho \equiv \frac{\sigma-1}{\sigma} \equiv \frac{1}{\mu}$ and the household income R is the sum of total earnings from its working members and the dividends it receives from domestic firms.

Technology and Competition

Each $\mathsf{M}-$type producer is a monopolistic competitor while each $\mathsf{H}-$type producer faces head-to-head competition from its unique foreign counterpart. An $\mathsf{H}-$type (head-to-head) producer competes with its competitor via simultaneous price setting given the productivity of their rival. This form of head-to-head competition is similar Bernard, Eaton, Jensen, and Kortum (2003) with the distinction that there is no domestic head-to-head competitor in this model.

The total measure of varieties (and firms) is fixed (and normalized to 1 to shutdown the effect of the total number of varieties on the price index[9]). There is a measure H of $\mathsf{H}-$type (head-to-head) firms and a measure M of $\mathsf{M}-$type firms. Given this structure, the model is effectively a hybrid setup combining the Chamberlinian monopolistic competition with head-to-head imperfection competition. These two modes of international competition emerge as special cases of the setup ($\mathsf{H} = 0$ and $\mathsf{H} = 1$ respectively)[10] . A

[9] This however does not shutdown the effect of the relative number of varieties of each type. See Blanchard and Giavazzi (2003) and Benassy (1996) for related discussions.

[10] The combination of both monopolistic competition and head-to-head competition resembles the model of *mass production plants* and *boutique shops* used by Holmes and Stevens (2010) in their study

model that includes only monopolistic competitors without direct foreign competition will fail to match the data: it cannot generate job losses due to foreign competition. A model without monopolistic competitors, on the other hand, may overstate the effects foreign competition on job losses. Moreover, the hybrid model features general equilibrium effects between these two types of goods as their price indices differ.

There are no fixed costs of entry or operation. Each firm φ is exogenously assigned its type $\nu(\varphi) \in \{\mathsf{H}, \mathsf{M}\}$ and its productivity $z(\varphi) \in Z$. Each differentiated good firm operates a linear production technology that uses labor as the only input:

$$y(\varphi) = z(\varphi) \cdot \ell$$

where ℓ is the labor input. The productivity $z(\varphi)$ is drawn randomly and follows a Pareto distribution with lower bound $\mathsf{A}_\mathsf{K} \equiv 1$ and shape parameter s where K denotes the type (H or M). Finally, each $\mathsf{H}-$type (head-to-head) producer has a head-to-head competitor randomly drawn by nature.

The firms in the homogeneous good sector are homogeneous, compete perfectly and have a simple linear technology:

$$y_0 = \ell$$

I assume there are symmetric international iceberg transportation costs $\tau \geq 1$.

Segmented Local Labor Markets

The economy is composed of a continuum of local labor markets across which families assign their workers. Within each local labor market, workers are randomly matched with vacancies based on a Leontieff matching function: firms fill all their vacancies if there are more workers looking for jobs than vacancies. This aspect of the model's

of plant size distribution with an application the trade in wood furniture. In this paper, I do not assume monopolistic firms are smaller or that they do not export.

labor market structure is similar to Alvarez and Shimer (2010) in the sense that there is directed search across labor markets markets and random search within local labor markets.

I assume that, in each country, there are many $\mathsf{H}-$type (head-to-head) towns and many $\mathsf{M}-$type (monopolist) towns, in addition to the homogeneous towns. The main goal in defining locations in this model is to have variations in the extent of foreign competition. I define a local labor market as a collection of towns with the same productivity level (z) and the same type (M or H). In other words, firms do not choose the locations where they operate. Within each local labor market, firms differ in the productivity of the foreign firms they face. The common productivity assumption is key to get varying degrees of foreign competition across local labor markets[11] . Figure 4 provides an illustration of differences across and within locations.

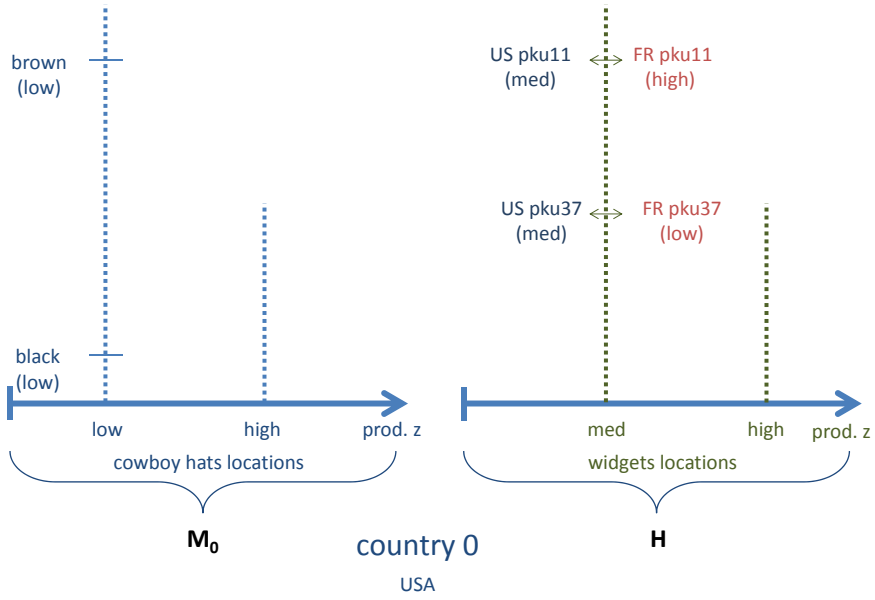
At each plant[12] , the workers bargain collectively with the firm over wages and production decisions. The workers collectively have bargaining power λ. Unlike Felbermayr et al. (2010) and Helpman and Itskhoki (2010), I simply assume Nash-bargaining and not the multilateral bargaining approach proposed by Stole and Zwiebel (1996). This obviously alters the surplus sharing rule between the firm and the workers and the size of the firm but it is not essential for the distribution of unemployment across labor markets. Firms have to pay a hiring cost γ per hire[13] . The union's threat point is defined by a home production technology yielding $b \geq 1$ units of the numeraire good. The homogeneous sector is not subject any hiring and matching frictions.

[11] The stark assumption on common productivity within a location is simply made to highlight the channel of foreign competition I introduce. At the opposite extreme, if all locations did not vary in productivity, the model would be unable to address the unemployment effects of trade across locations.

[12] Given the export decisions of the firms, in each town, there could be one or two plants: the domestic production plant if the local firm produces for the domestic market and the foreign production plant if the local firm exports. This distinction is a useful simplification because the productivity of the firm is effectively reduced by iceberg transportation costs when it produces for the export market: it takes more labor to produce one unit of output sellable abroad since the product "melts" on the way.

[13] Since the matching of workers with jobs follows a Leontieff function, there are no congestion externalities in this model.

Figure 1.4: A simple illustration of locations



1.4.2 Characterization

M−type (Monopolist) Firm Problem

Consider the decision of a monopolist firm in country j with productivity z that is supplying country j'. With $\ell_{j'}^{j}$ workers, the firm-union match generates the following surplus:

$$S_{j'}^{j}\left(z,\ell_{j'}^{j}\right)=\underbrace{\mathsf{Q}_{j'}^{-(\rho-\eta)}\left(\frac{1}{\tau_{j'}^{j}}\,z\,\ell_{j'}^{j}\right)^{\frac{1}{\mu}}}_{R_{j'}^{j}\left(z,\ell_{j'}^{j}\right)}-b\,\ell_{j'}^{j}-\gamma\,\ell_{j'}^{j}$$

since the price implied from the demand function is:

$$p_{j'}^{j}\left(z,\ell_{j'}^{j}\right)=\mathsf{Q}_{j'}^{-(\rho-\eta)}\left(\frac{1}{\tau_{j'}^{j}}\,z\,\ell_{j'}^{j}\right)^{-\frac{1}{\sigma}}$$

The firm's profit from this plant is:

$$\pi^j_{j'}\left(z,\ell^j_{j'}\right)=R^j_{j'}\left(z,\ell^j_{j'}\right)-\gamma\,\ell^j_{j'}-\omega^j_{j'}\left(z\right)\,\ell^j_{j'}$$

where $\omega^j_{j'}\left(z\right)$ is the wage paid to the workers.

The wages $\omega^j_{j'}\left(z\right)$ and the plant size $\ell^j_{j'}$ are determined through Nash-bargaining with the workers' union:

$$\max_{\omega,\ell}\left[\mathsf{Q}^{-(\rho-\eta)}_{j'}\left(\frac{1}{\tau^j_{j'}}\,z\,\ell\right)^{\frac{1}{\mu}}-\gamma\,\ell-\omega\left(z\right)\,\ell\right]^{1-\lambda}\cdot\left[\left(\omega-b\right)\,\ell\right]^{\lambda}$$

The problem of the monopolist is cast in terms of size (ℓ) and not prices but the two formulations are equivalent given the bijection between price and quantities. Since all costs are variables, the firm and the union choose to share revenues according to their bargaining power and set:

$$p^j_{j'}\left(c\right) \qquad =\mu\,\tau^j_{j'}\,c \qquad \text{price}$$

$$\omega^j_{j'}\left(c\right)-b \quad =\lambda\left(\mu-1\right)\left(\gamma+b\right)\equiv\omega_{\mathsf{M}}-b \qquad \text{wage}$$

$$\ell^j_{j'}\left(c\right) \qquad =\mathsf{Q}^{-\frac{\rho-\eta}{1-\rho}}_{j'}\left[\mu\,\left(\gamma+b\right)\right]^{-\sigma}\left[\frac{\left(\gamma+b\right)}{\tau^j_{j'}\,c}\right]^{\sigma-1}\equiv\mu^{-\sigma}\,\overline{\ell}^j_{j'}\left(c\right) \qquad \text{size}$$

where $\tau^j_{j'}\,c\equiv\tau^j_{j'}\,\dfrac{\left(\gamma+b\right)}{z}$ is the firm's unit cost and $\overline{\ell}^j_{j'}\left(c\right)$ is the size corresponding to the marginal cost pricing (zero profits).

The $\mathsf{M}-$type (monopolist) producers therefore choose the standard markup pricing rule that equalizes the marginal revenue and the marginal cost. Although more productive firms are larger, it is important to note that the wages are independent of the firm productivity for the monopolistic firms. This is a standard result in environments with

power revenue functions and linear technology[14] . The surplus extracted by a worker is a fraction of the average gross revenues of the firm: each worker receives a share λ of the net markup $(\mu - 1)$. Also, since there are no fixed cost of exporting, all $\mathsf{M}-$type producers export.

Therefore, given the random Leontieff matching assumed, the local labor market of an $\mathsf{M}-$type producer with productivity z has an employment rate $\mathsf{e}_{\mathsf{M}}(z)$:

$$\mathsf{e}_{\mathsf{M}}(z) = \frac{\sum_{j'=0,1} \ell^{j}_{j'}(z)}{\mathsf{L}_{\mathsf{M}}(z)}$$

where $\mathsf{L}_{\mathsf{M}}(z)$ is the population of workers in that town. The expected earnings per worker $\mathrm{W}_{\mathsf{M}}(z)$ in the town of an $\mathsf{M}-$type producer with productivity z therefore satisfy:

$$\mathrm{W}_{\mathsf{M}}(z) - b = (\omega_{\mathsf{M}} - b) \cdot \mathsf{e}_{\mathsf{M}}(z)$$

$\mathsf{H}-$type (Head-to-head) Firm Problem

The problem of the $\mathsf{H}-$type (head-to-head) producers can be similarly characterized. Each type producer makes its production decision knowing its productivity and the productivity of its head-to-head foreign competitor. The problem faced by the $\mathsf{H}-$type firm is a constrained version of the $\mathsf{M}-$type firm's problem. The constraint here is that its price has to be above the price that makes the competitor's profits equal zero. This is effectively a constraint on the firm's ability to reduce output by charging the unconstrained monopolistic price.

The constrained problem faced by the $\mathsf{H}-$type (head-to-head) producers can therefore be written as a problem similar to the $\mathsf{M}-$type (monopolistic) producer problem with an an upper bound on the price set by the firm:

[14] This property that wages do not depend on firm productivity is the main reason why $\mathsf{M}-$type (monopolist) towns have a degenerate distribution of wages and unemployment rate. Felbermayr et al. (2010) and Helpman and Itskhoki (2010) also have the same result. In the next subsection, I show how variable markups induced by head-to-head competition change these results.

$$\max_{\omega,\ell} \qquad \left[\mathsf{Q}_{j'}^{-(\rho-\eta)}\left(\frac{1}{\tau_{j'}^{j}}\,z\,\ell\right)^{\frac{1}{\mu}} - \gamma\,\ell - \omega\,(z)\;\ell\right]^{1-\lambda} \cdot\; [(\omega-b)\;\ell]^{\lambda}$$

s.t.

$$p_{j'}^{j}\,(z,\ell) \leq \overline{p}_{j'}^{1-j}\,(\tilde{z})$$
$$\pi_{j'}^{j}\,(z,\ell) \geq 0$$

where $\overline{p}_{j'}^{1-j}\,(\tilde{z})$ is the marginal cost to supply country j for the foreign competitor whose productivity is $\tilde{z}$.

The upper bound on the price is precisely the constraint on a firm's ability to restrict output. This bound only depends on the competitor's productivity. More specifically, when an $\mathsf{H}-$type (head-to-head) producer from country j with productivity z is matched with a foreign competitor with productivity $\tilde{z}$, the $\mathsf{H}-$type producer from country j supplies a country j' in its variety if and only if:

$$\tau_{j'}^{j}\;\frac{(\gamma+b)}{z} < \tau_{j'}^{j}\;\frac{(\gamma+b)}{\tilde{z}}$$

since the unit cost of for the firm-union entity is $\tau_{j'}^{j}\;\dfrac{(\gamma+b)}{z} \equiv \tau_{j'}^{j}\;c$.

It is convenient to interchangeably and without loss of generality identify a firm z by its unit cost: $c \equiv \dfrac{(\gamma+b)}{z}$. Conditional on supplying the market j', the producer may either be at the corner (constrained) or choose the unconstrained monopolistic pricing:

$$p_{j'}^{j}(c\,,\,\tilde{c}) \quad = \underbrace{\min\left\{\tau_{j'}^{1-j}\,\tilde{c}\;\;,\;\;\mu\,\tau_{j'}^{j}\,c\right\}}_{\mu_{j'}^{j}(c,\tilde{c})\;\times\;\tau_{j'}^{j}\,c} \qquad\qquad \text{price}$$

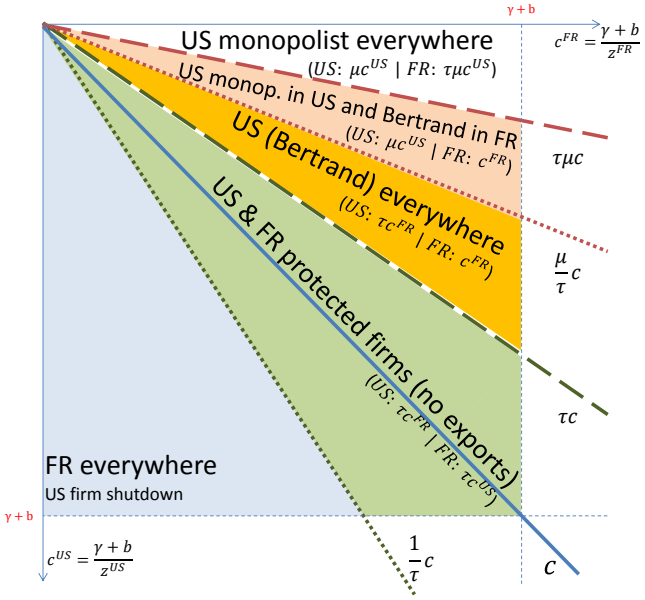
which implies that:

$$\omega_{j'}^{j}\left(c\,,\,\tilde{c}\right)-b \;=\lambda\left(\mu_{j'}^{j}\left(c,\tilde{c}\right)-1\right)\left(\gamma+b\right) \qquad \text{wage}$$

$$\begin{aligned}\ell_{j'}^{j}\left(c\,,\,\tilde{c}\right) &= \mathsf{Q}_{j'}^{-\frac{\rho-\eta}{1-\rho}}\left[\mu_{j'}^{j}\left(c,\tilde{c}\right)\left(\gamma+b\right)\right]^{-\sigma}\left(\frac{1}{\tau_{j'}^{j}}\frac{\gamma+b}{c}\right)^{\sigma-1} \qquad \text{size}\\ &= \left[\mu_{j'}^{j}\left(c,\tilde{c}\right)\right]^{-\sigma}\overline{\ell}_{j'}^{j}\left(c\right)\end{aligned}$$

Therefore, the profit margin of the $\mathsf{H}-$type (head-to-head) producer is more squeezed the more productive its competitor is. This is associated with lower wages for those workers as well because of the surplus sharing rule. The effect of the head-to-head competition on the firm behavior also depends on the level of frictions to international trade. In fact, as the tariff τ goes to infinity (autarky), the $\mathsf{H}-$type producers are all in operation and they all charge the unconstrained monopolistic price: $\lim_{\tau\to\infty}\mu_{j}^{j}\left(c\,,\,\tilde{c}\right)=\mu$. On the other hand, when trade is frictionless, only some firms charge the monopolistic price. The model generates rich pricing dynamics as shown in the illustration in Figure 5.

Figure 1.5: Variable markups illustrated



These variable markups are also the reason why productivity differences yield differences in foreign competition across locations: in the more productive locations, more firms outcompete their foreign competitors relative to the less productive locations. Also, the relative size of trade tariffs and markups are also important to predict the elasticity of trade. For instance, a careful inspection of Figure 5 shows that when $\mu < \tau^2$, some tariff-protected firms price as monopolists even if they do not export. The model also generates a region of international dumping that only disappears in the limit of frictionless trade when $\tau = 1$.

Based on these results, a town of $\mathsf{H}-$type (head-to-head) producers with productivity z has an unemployment rate $\mathsf{e}_{\mathsf{H}}(z)$ satisfying:

$$\mathsf{e}_{\mathsf{H}}(z) = \frac{\int \sum_{j'=0,1} \ell^{j}_{j'}(z,\tilde{z})\, \mathrm{d}F_{\mathsf{H}}(\tilde{z})}{\mathsf{L}_{\mathsf{H}}(z)}$$

where $\mathsf{L}_\mathsf{H}(z)$ is the population of workers in that town and $\ell^j_{j'}(z\,,\,\tilde{z}) = 0$ if a local producer does not supply country j' due to the competition. The expected earnings per worker $\mathrm{W}_\mathsf{H}(z)$ in that town therefore satisfy:

$$\mathrm{W}_\mathsf{H}(z) - b = \frac{\int \sum_{j'=0,1} \left(\omega^j_{j'}(z,\tilde{z}) - b\right) \cdot \ell^j_{j'}(z,\tilde{z})\, \mathrm{d}F_\mathsf{H}(\tilde{z})}{\mathsf{L}_\mathsf{H}(z)}$$

Labor Allocation

Each family[15] allocating its workers across locations is indifferent among these locations since the workers are *ex ante* mobile. Workers are allocated knowing the tariff, the town's competition type (monopolistic or head-to-head competition), and the productivity of the firms in these locations. Therefore, each worker knows the distribution of wages and unemployment rates across towns. Each family therefore chooses $\{\,\mathsf{L}_0,\,\mathsf{L}_\mathsf{M}(z)\,,\,\mathsf{L}_\mathsf{H}(z)\;:\;z\in Z\,\}$ such that:

$$\mathsf{L} \;\; = \mathsf{L}_0 + \int \mathsf{L}_\mathsf{M}(z)\;\mathrm{d}F_\mathsf{M}(z) + \int \mathsf{L}_\mathsf{H}(z)\;\mathrm{d}F_\mathsf{H}(z)$$

In a symmetric equilibrium, the allocation of labor is an interior point if and only if they are indifferent across the towns. In other words, expected earnings are equalized across towns:

$$\omega_0 \;\; = \mathrm{W}_\mathsf{M}(z) = \mathrm{W}_\mathsf{H}(z) \qquad \forall\; z \;\; \mid \mathsf{L}_\mathsf{K}(z) > 0$$

where $\omega_0 = p_0 = 1$ is the wage in the frictionless homogeneous region. The indifference condition simplifies to an equality in expected earnings because the preferences are quasi-linear.

[15] As in Helpman and Itskhoki (2010), the family interpretation is essential in the case of quasi-linear preferences but not when preferences are homothetic.

Market Clearing

The market clearing condition for the homogeneous good is:

$$\mathsf{L_0} = q_0 + \gamma \cdot \left(\int \sum_{j'=0,1} \ell^j_{j'}(z)\, \mathrm{d}F_{\mathsf{M}}(z) + \iint \sum_{j'=0,1} \ell^j_{j'}(z,\tilde{z})\, \mathrm{dF}_{\mathsf{H}}(\tilde{\mathrm{z}})\, \mathrm{d}F_{\mathsf{H}}(z) \right)$$

since the hiring costs are paid in units of the homogeneous good.

1.4.3 Equilibrium

Having characterized the problem and the optimal decision of the agents in the economy, a symmetric equilibrium is:

- a price P,
- quantities q_0 and Q,
- population allocations $\{\, \mathsf{L_0},\, \mathsf{L_M}(z),\, \mathsf{L_H}(z) \;:\; z \in Z \,\}$,
- earnings W, and
- aggregate profits π

such that:

- households solve their utility maximization given prices and profits and earnings.
- the indifference condition across towns for labor allocation holds,
- firms producing the differentiated goods solve their profit maximization problem given their productivity, their competition, and the aggregate consumption indexes.
- aggregate profits, aggregate earnings, and the price index are consistent with the firm decisions.
- all goods markets clear.

1.4.4 Wages, Unemployment, and Geographic Inequality

This model is quite simple and tractable. Most importantly, the model incorporates standard gains from trade in addition to unemployment in segmented labor markets facing different levels of foreign competition. The following important properties hold in equilibrium:

Proposition 1.1. *Equal expected earnings.*
Expected earnings are equalized across all labor markets. When all workers have an equal share in all the firms within an economy, average income is also equalized across labor markets.

Proof. The proof trivially follows from the labor allocation rule characterized. Given the quasi-linear preferences, in equilibrium, expected earnings (job finding rate multiplied by wages) are equalized across labor markets. □

In light of this proposition, greater vulnerability to foreign competition does not mean labor market outcomes are necessarily worse in those locations. Unemployment is actually lower in the most vulnerable towns because they pay lower wages and attract fewer workers. However, unexpected trade reforms unevenly change the expected level of foreign competition faced by different labor markets. The most vulnerable labor markets can be wiped out following a trade reform and the distribution of expected earnings is no longer degenerate. This is shown and discussed in the next section.

Proposition 1.2. *Constant unemployment across location with no foreign competition. Across the labor markets where the firms are all monopolistic competitors, the more productive labor markets have higher employment but they pay the same wage and have the same unemployment rate as less productive labor markets.*

Proof. The proof trivially follows from the fact that markups are constant across all

$\mathsf{M}-$type (monopolist) firms and that expected earnings are equalized because of the directed search. □

This proposition is important because it shows why head-to-head competition is key for a non-degenerate distribution of unemployment across labor markets. In the absence of head-to-head competition, the distribution of unemployment rate is degenerate because wages would be independent of firm productivity. Consequently, the wage determination rule assumed in this model is not an innocuous assumption. However, the abstraction from multilateral bargaining is not problematic since the constant wage result also holds in Helpman and Itskhoki (2010) and Felbermayr et al. (2010).

Proposition 1.3. *Unemployment profile across locations facing foreign competition. Across the labor markets where the firms face foreign competitors, when there are no trade barriers, the more productive labor markets have higher employment, pay higher wages and have higher unemployment rate than less productive labor markets.*

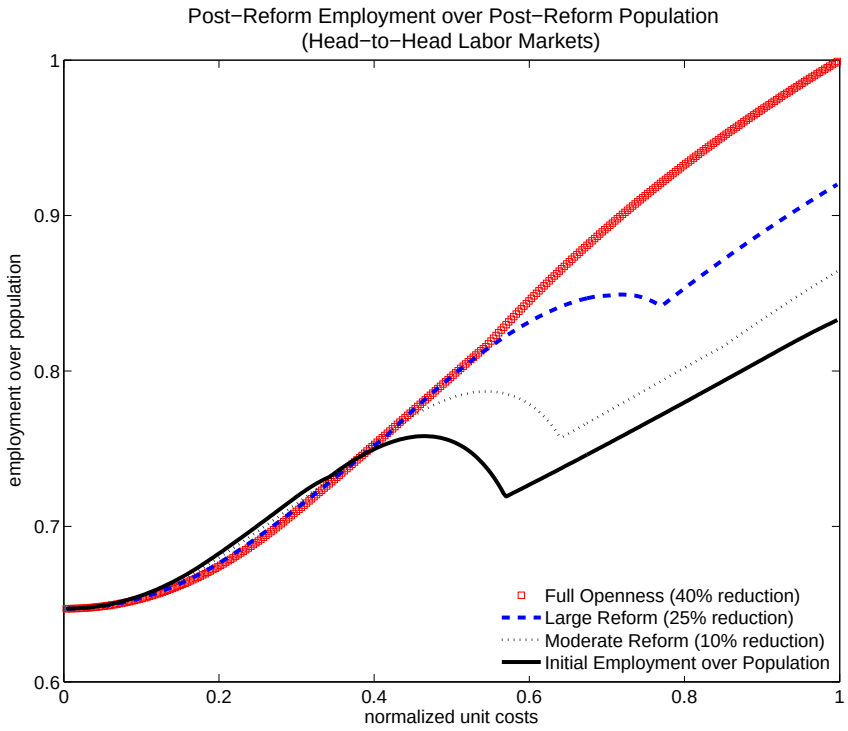
Proof. The proof is follows from the fact the expected markups and wages of $\mathsf{H}-$type (head-to-head) firms increase with their productivity. □

This proposition only holds in the absence of trade barriers because trade barriers alter the distribution of markups as illustrated in Figure 5. For instance, if trade barriers are high enough, non exporters charge the same markup as the most productive firms while some exporters charge a lower markup because of foreign competition. In that case, the unemployment rate is not decreasing with productivity. In general, the non monotonicity of unemployment rate holds as illustrated in Figure 6, except in the extreme cases of autarky and frictionless trade.

1.4.5 Equilibrium Labor Allocations

To illustrate the distribution of unemployment, Figure 6 shows the equilibrium[16] employment-to-population in head-to-head labor markets ordered by the unit cost of their local firms (inversely proportional to productivity) for different levels of iceberg transportation trade costs. The initial level of iceberg transportation costs used in this illustration is arbitrarily set to $\tau = 1.75$.

Figure 1.6: Trade Barriers and Labor Allocation



The hump in the unemployment profile that occurs around medium size locations

[16] While the model is quite simple and tractable in terms of individual optimization, the equilibrium has to be numerically computed because the double integrals involved do not yield nice closed form solutions.

only disappears in the limit of frictionless trade. Also, there is a kink at the productivity level where firms produce but not export. This is a result of the distribution of variable markups illustrated in Figure 5. Higher markups mean higher wages which typically more employment levels but also lower employment rates. At the kink, the inframarginal that exports has higher employment rate because markups and therefore wages fall slightly due to iceberg transportation costs. The effect of the iceberg transportation costs on exporting firms explains the observed kink. The observed hump is therefore a normal artifact since the markups are bounded. Also, in autarky, the employment-to-population ratio is constant at the employment rate of the most productive labor market: in the most productive labor markets, firms almost surely outcompete their foreign rivals and behave as monopolists.

In the remainder of the paper, I discuss the unemployment effects of an unexpected trade liberalization. Following, Helpman and Itskhoki (2010), I assume the workers are *ex ante* identical and mobile across labor markets but *ex post* immobile across labor markets. Specifically, the *ex post* mobility assumption means workers do not move across local labor market following an unexpected trade reform. This assumption is made to simply capture the very slow adjustments of the total population to adverse trade shocks documented in Autor, Dorn, and Hanson (2011) and in this paper. Topalova (2007) also has similar findings using data on districts in India following a trade liberalization.

1.5 Effects of an Unexpected Trade Liberalization

The model incorporated new ingredients to deliver a simple theory of local unemployment and import competition. I now use this model to perform an analysis of the effects of an unexpected trade liberalization. I also compare these medium run outcomes when workers do not move across labor markets to the long-run equilibrium when workers have been reallocated in response to new trade regime. I evaluate welfare effects using

the model parameterized to match job losses due to import competition in the U.S. I also constrast the welfare effects of trade liberalization with the welfare effects of an exogenous productivity growth in the foreign country.

First, the model can replicate the correlated effects of increased import competition both job losses and job gains. In other words, layoffs and plant shutdowns are only one symptom of foreign competition. The locations that face tougher foreign competition and lay off more workers are precisely less productive. This also implications for the new jobs they create relative to other locations: less productive locations create fewer new export-driven jobs. Second, the model predicts aggregate welfare gains following an unexpected trade liberalization despite the large job losses and the high unemployment in the worse hits locations. Third, an unexpected foreign productivity increase can, in constrast, yield aggregate welfare losses.

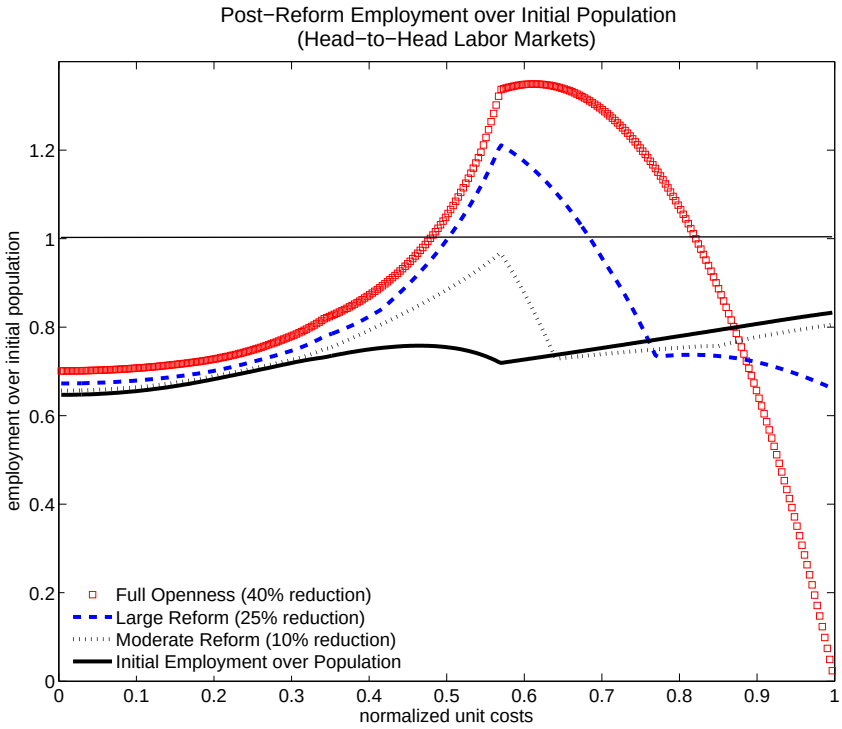
Below, I motivate and define the concept of medium run equilibrium before discussing the model calibration and the welfare gains from an unexpected trade liberalization and the effects of an exogenous productivity growth in the foreign country.

1.5.1 Medium Run Equilibrium

When trade barriers unexpectedly fall, it asymmetrically affects firms and labor markets: some labor markets expand as their firms newly gain access to foreign markets, some labor markets are wiped out as most of their firms are outcompeted, and some labor markets expand as their pressured firms slash domestic prices while workers can only move within but not across local labor markets.

With large reductions in trade barriers, the size adjustments induced by lower prices required can be very large, and even exhaust the pre-reform population (see an example in Figure 7). On the other hand, modest tariffs reforms require modest size adjustments (see an example in Figure 7).

Figure 1.7: Limits to Long Run Reallocation of Labor



Therefore, the equilibrium allocation of an economy following a trade reform depend on the pre-existing unemployment rates in the local labor markets where firms need to expand. In this model, the largest (proportional) firm expansions typically occur in the medium-sized firms that are new exporters. This is reflected in the kink at the export cutoff level shown in Figure 7: the largest expansion occur in the inframarginal exporting location.

Given the employment capacity constraints that firms may face in the wake of trade reforms, the aggregate firm behavior needs to be consistent with the population bounds in each location. This is a problem that does not exist in the long-run equilibrium in which all labor markets have a positive unemployment rate.

A notion of equilibrium coherent with the limited mobility is needed. I define the *medium-run equilibrium* as an equilibrium concept similar to the long-run equilibrium, except that families do not have a labor allocation problem. In other words, the population levels in the segmented local labor markets are fixed to the levels prior to the unexpected fall in trade barriers. These constraints effectively reduce the quantity of differentiated good supplied in the *medium-run* compared to the long run[17] .

To compute the *medium-run equilibrium* outcome, I define and characterize the workforce-constrained firm problems. For simplicity, I assume that firms that operate in labor markets that are constrained simply produce as much as they can[18] . Given an initial population allocation $\{ \mathsf{L_0}, \mathsf{L_M}(z), \mathsf{L_H}(z) \ : \ z \in Z \}$, a symmetric *medium run equilibrium* is:

- a price index $\widehat{\mathsf{P}}$,
- quantities $\widehat{q}_0$ and $\widehat{\mathsf{Q}}$,
- earnings $\widehat{\mathrm{W}}$, and
- aggregate profits $\widehat{\pi}$

such that:

- households solve their utility maximization given prices and profits and earnings.
- firms solve their profit maximization problem given their productivity, their competition, the aggregate consumption indexes, and the local population

[17] However, it does not mean that welfare gains are necessarily lower compared to the long run. This is because there is an allocative inefficiency when workers are mobile across locations.

[18] In earlier version of the paper, I considered the case when the firms seek to equalize the marginal surplus across domestic and foreign production when they are capacity constrained. It does not fundamentally alter the results but introduces more discontinuities in the employment rate without adding any important insight. This is the main reason behind the simplification made here.

- aggregate profits, aggregate earnings, and the price index are consistent with the firm decisions.

- all goods markets clear.

1.5.2 Medium Run Labor Market Outcomes

To illustrate the effect of trade reforms on labor market adjustments, I show in Figure 8 the medium run distribution of labor in head-to-head labor markets compared the initial allocations and the long run distribution when workers move across labor markets[19] .

Figure 1.8: Medium Run Reallocation of Labor

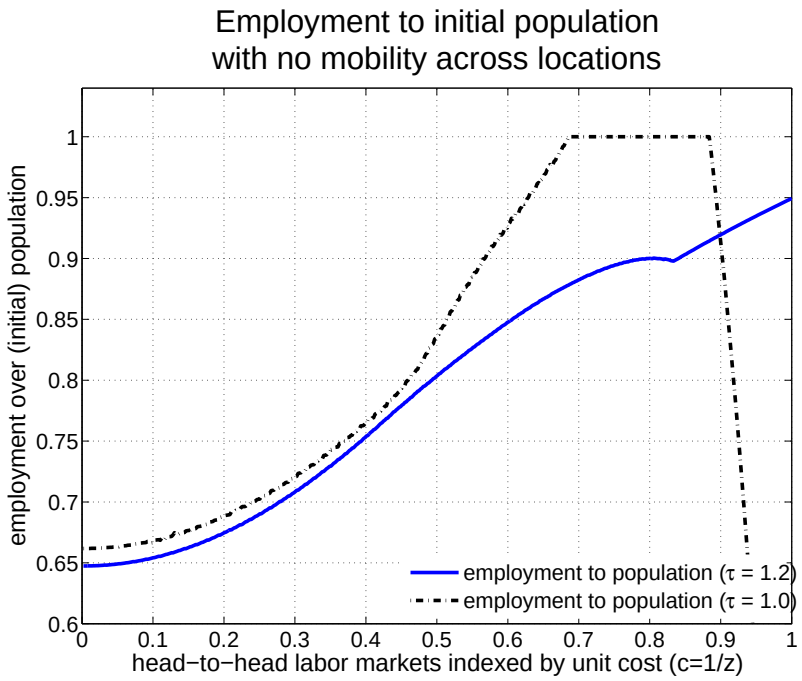


Figure 8 shows the uneven labor market adjustments that occur across head-to-head

[19] Obviously, worker immobility following the trade reform is also a crucial assumption because it ensures local job losses induce local unemployment. Otherwise, workers would move to towns with better prospects leaving ghost towns behind. The assumption made on worker relocation is however consistent with empirical findings on the lack of population response to trade shocks.

local labor markets ordered by unit costs (inversely proportional to productivity). As before, the monopolist labor markets have a degenerate distribution at the level of the best head-to-head labor markets. The equilibrium concept defined above ensures that the aggregate demand in consistent with the decisions of the firms operating in the labor markets that are population constrained.

Figure 8 also illustrates that some labor markets do not expand as much as they would if labor were fully mobile. These firms however still expand a lot while the least productive labor markets shrink. In fact, the least productive labor markets lose all their firms since all of them are outcompeted in the absence of trade barriers.

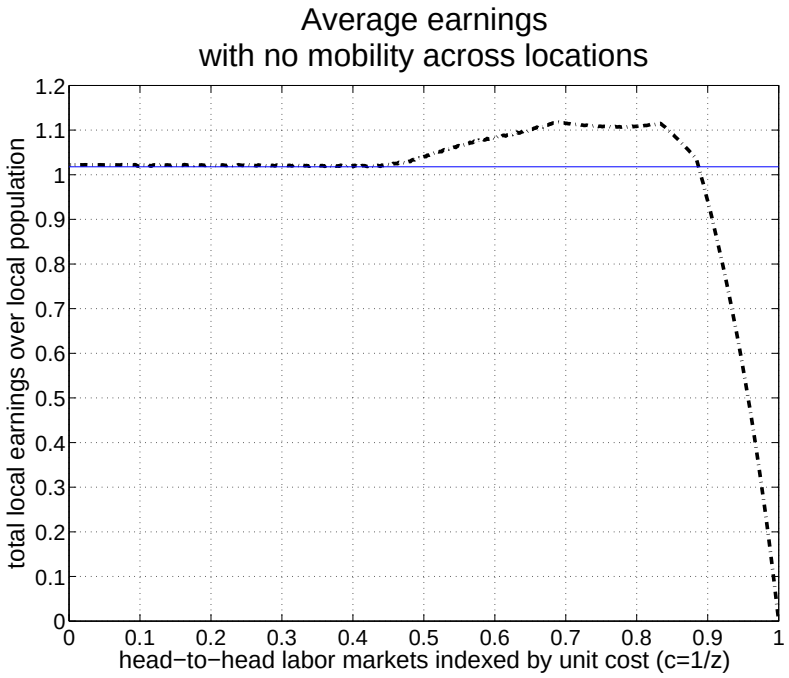
As trade barriers fall, the firms in the inframarginal exporting labor markets are able to outcompete their foreign rivals in foreign markets, and thereby expand a lot. This extensive margin explains the largest expansions. In comparison, some less productive head-to-head labor markets lose most of their firms because they are outcompeted. At the other extreme, the most productive head-to-head labor markets are hardly affected by the fall in trade barriers as they behave as monopolists and have almost no new exporters.

Overall employment changes depend on both job losses due to increased foreign competition and job creation. The correlation is driven in the model by the fact that local labor markets differ in productivity.

The combined effects of changes in employment and changes in wages are reflected in Figure 9 which shows the expected earnings in each head-to-head labor market in the medium run. While full labor mobility ensured wages were equalized across labor markets, limited mobility induces a non-degenerate distribution of expected earnings. This earnings inequality is a source of income redistribution across labor markets if consumption is equalized across labor markets. It is important to note that no redistribution across labor markets is needed under full worker mobility because of the indifference

condition across locations.

Figure 1.9: Medium Run Earnings Differentials



1.5.3 Calibration

In this section, I calibrate the model to measure the effects of a trade liberalization in the U.S. across labor markets. The overall parameters used in the unexpected trade liberalization exercise are summarized in Table 3.

The Armington elasticity is also crucial for the differential effects across labor markets since the labor markets vary in productivity and threfore average producer prices. The Armington elasticity choice follows the Armington elasticity of substitution found by Ruhl (2004). The iceberg transportation cost is set below the trade costs including observed tariffs and non-tariff barriers in rich countries documented in Anderson and van Wincoop (2004). The Pareto distribution shape parameter is set to be greater than

2.05 to guarantee finite mean and finite variance. The bargaining power is set to 0.5 so the union and the firm have equal bargaining power.

The fraction of firms subject to head-to-head foreign competition is chosen so that the total number of trade-induced displacements in the U.S. matches the level we see in the data.

The outside option parameter is chosen so that all local labor markets receive attract workers under full worker mobility. The parameters are set to have a non-employment rate around 30 percent.

Table 1.3: Parameterization

Parameter	Description	Value
H	Fraction of head-to-head firms	0.03
M	Fraction of monopolist firms	0.97
σ	Armington elasticity	2.01
η	Elasticity of substitution of differentiated good	0.50
s	Pareto distribution shape	2.05
λ	Union bargaining power	0.50
b	Outside option	1.00
γ	Hiring cost	0.15
L	Population	1.00
τ_0	Iceberg transportation costs pre-liberalization	1.20
τ_1	Iceberg transportation costs post-liberalization	1.00

1.5.4 Job Losses due to Foreign Competition and Unemployment

To relate the model to the empirical findings, I now measure the import competition faced by a labor market using a statistic akin to Trade Adjustment Assistance (TAA) certifications observed in the data: the number of workers in a given labor market that are displaced because of foreign competition. In particular, I measure local import competition in the model as the fraction of local workers who lost their jobs after their

plant shut down due to head-to-head competition. This measure is equal to zero in non head-to-head labor markets. It is also equal to zero in the absence of trade reforms since workers are not employed at outcompeted firms in the first place[20] .

Figure 10 illustrates the relationship between the measure of TAA-certified workers and unemployment changes in the model. First, net changes in unemployment maybe positive or negative depending on the productivity of the head-to-head labor markets. As indicated earlier, the non head-to-head labor markets correspond to a degenerate distribution at the point where trade-induced job losses are zero. Second, the job creation margin explains the increased steepness of the curve in thelocations experiencing the largest job losses due to import competition. Third, it is easy to observe that the elasticity of local nonemployment to local job losses due to import competition is close to three in the worst hit locations. This differential effect is explained by the correlation between lower productivity and vulnerability to import competition.

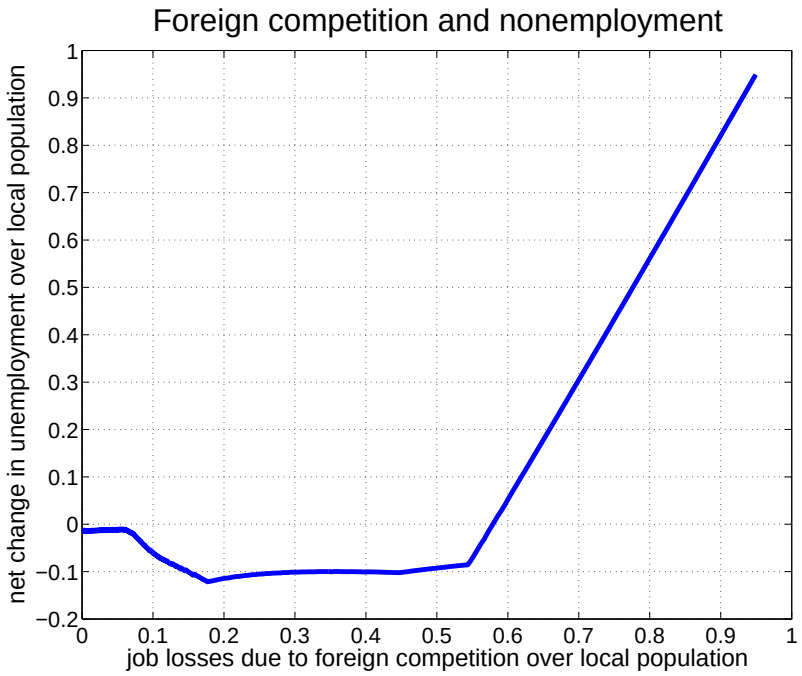
However, this relationship is non monotonic. This is due to the heterogeneity in markups discussed in the previous section. This last feature does not show in the data although a Pareto distribution of firm productivity skews the unit cost distribution to the right.

It is also important to note that, in a given labor market, the overall job losses are equal to job losses to foreign competition since the model does not have any local input-output linkage mechanism such as the local burger stand closing down[21] . However, such local amplification or linkage would not deliver deliver the additional job creation margin documented in this paper.

[20] It is important to note that without head-to-head competition, this measure would not be meaningful. In the standard Melitz (2003) model and similar models with no direct competition, a TAA-measure of import competition would always be zero because the firms do not shut down because of direct foreign competition. TAA investigators would not find evidence for the foreign competition as a cause of the layoffs.

[21] Using data on housing starts by state, I did not find any significant empirical effect of these related local linkages.

Figure 1.10: Job Losses due to Foreign Competition and Unemployment



1.5.5 Welfare Gains and Limited Worker Mobility

Both the model and the data indicate that import competition has large uneven effects on labor markets through job losses but also job gains: there are large differential of foreign competition on earnings across locations. Clearly, without transfers, some locations are worse off as they see their employment and earnings drop.

However, the model predicts overall aggregate welfare gains and increased aggregate employment in the medium run despite with the large differential impact of import competition on unemployment and earnings across the few local labor markets subject to head-to-head foreign competition. The aggregate welfare effects are summarized in Table 4.

Table 1.4: Effects of Limited Mobility

	Trade job losses (per 1,000 w.a.p.)	Not employed (percent)	$\%\Delta Q$ (diff. goods)	$\%\Delta q_0$ (hom. good)	$\%\Delta U$ (utility)
Pre-reform	0.00	27.86	-	-	-
Medium run	1.4	27.32	+5.20	-0.33	+0.99
Long run	0.00	28.14	+5.21	-5.89	+0.85

These welfare gains are actually not smaller than the gains when labor is fully mobile. While the differentiated good demand is indeed however lower, the limited mobility reduces the inefficiencies from search frictions by increasing the overall employment level. This finding is in contrast with the results found in models of unemployment and trade such as Cosar (2010),Dix-Carneiro (2010) and Kambourov (2009) where limited sectoral mobility necessarily reduces the overall gains from trade. In this model, the main source of unemployment of the inefficiency from the directed search as opposed to matching frictions. Limited mobility can partially undo that inefficiency.

1.5.6 Trade Reforms and Exogenous Growth : Similar Effects?

The sustained and balanced growth in U.S. imports as a share of its gross domestic product may indicate a fall in trade barriers or a growth in foreign foreign productivity. For instance, Autor et al. (2011) argue that the adverse labor market effects of import competition from China are due to an exogenous growth in China. In this subsection, I compare the effects an unexpected trade reform and an exogenous foreign productivity growth.

In contrast to the aggregate welfare gains obtained in the wake of a trade reform, the aggregate welfare effects are negative in the advanced economy in the case of an

asymmetric setup with foreign exogenous growth instead of the current case of an exogenous fall in trade barriers. The intuition is that all domestic labor markets would be losing jobs due to the surge foreign competition (see Figure 11).

Figure 1.11: Foreign Competition and Unemployment with Exogenous Growth

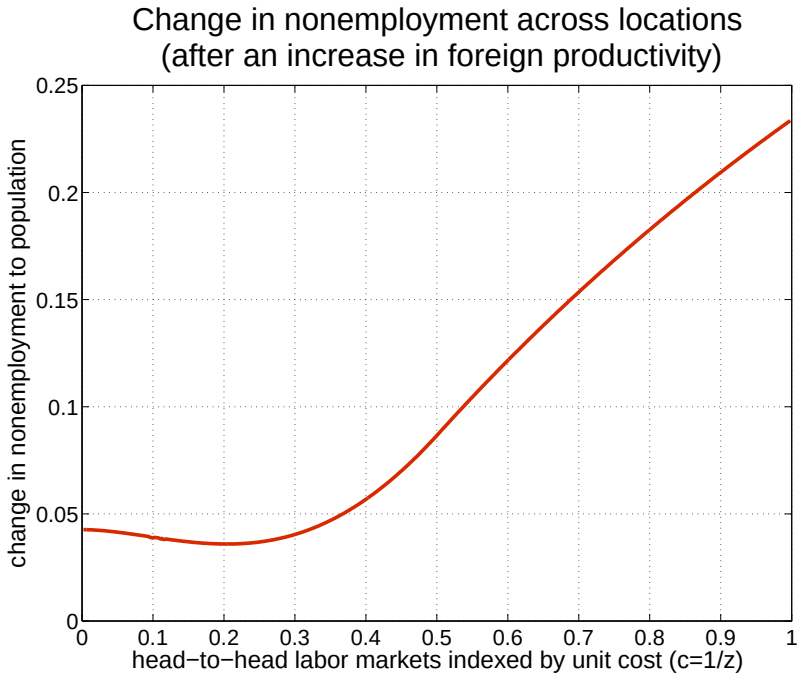


Figure 11 illustrates the net changes in unemployment across head-to-head labor markets when the foreign country experiences an exogenous growth in productivity[22] in the absence of trade barriers. However, it is worth noting that this exogenous growth case cannot easily match the empirical evidence of the joint effects of foreign competition on both job creation and job destruction. Therefore, this exogenous growth scenario could only deliver a smaller differential effect of import competition on nonemployment across locations. In the case of an exogenous growth, all labor markets would lose jobs

[22] Specifically, this change is done while preserving the support of the Pareto distribution of productivity. In the example used in the text, I reduce the shape (or tail) parameter in the foreign country and then randomly assign productivities to foreign producers according to the new distribution.

with no differences in job creation rate. Overall, these effects yield negative aggregate welfare effects due to the fall in income. Therefore, a naive application of the welfare effects formula in Arkolakis, Costinot, and Rodriguez-Clare (2010) would also wrongly predict welfare gains instead of welfare losses in this case.

1.6 Conclusion

In this paper, I study both empirically and theoretically the labor market effects on increased trade openness in the U.S. I document the impact of foreign competition on labor market outcomes and job flows across a panel of U.S. states using a novel dataset on all the establishment-level petitions filed for Trade Adjustment Assistance in the U.S. over the last three decades. I find a large differential effect of import competition on unemployment across locations. This effect is driven by both increased job destruction and reduced job creation. These findings are robust to controlling for location fixed effects, time fixed effects, income, industrial composition, heteroskedasticity and serial correlation at the panel-level. The results therefore confirm and extend the recent findings in Autor, Dorn, and Hanson (2011).

This paper also extends a model of international trade to incorporate unemployment and segmented labor markets facing different degrees of foreign competition. This novel model is built to be consistent with the empirical findings on the uneven impact of trade on unemployment across locations. The model can rationalize the correlated effect of import competition on job destruction and job creation because the locations that are more vulnerable to foreign competition are precisely the less productive ones. The model is used to estimate the welfare effects associated with the uneven effects of trade across locations. Some locations are severely affected or wiped out while other locations gain from the reduction in trade barriers. However, aggregate welfare gains from trade reforms are not lower as a result of reduced relocation across labor markets. In contrast,

aggregate welfare effects can be negative in the case of an exogenous productivity growth in the foreign country since all labor markets workers on net in the domestic economy.

Overall, this paper makes a contribution to the growing literature on the labor market adjustments induced by trade reforms. Much has been left out in this investigation of unemployment, foreign competition and local labor markets. Given the findings in this paper, future work on welfare effects of trade reforms should probably focus on a richer set of labor market frictions and the drivers of technological change in negatively affected locations, firms, and workers.

Chapter 2

A Theory of Sudden Stops, Foreign Reserves, and Rollover Risk in Emerging Economies

2.1 Introduction

Obstfeld, Shambaugh, and Taylor (2010) noted that the sustained accumulation of massive international reserves in emerging economies constitutes a puzzle. Standard models predict that emerging economies should hold very little reserves or none at all, while in the data these economies hold as much as 50 percent of GDP in reserves. Because of this disconnect between theory and practice, the management of international reserves remains one of the main topics in policy debates on global imbalances. Gourinchas and Obstfeld (2012) reiterated the need for research on foreign reserves and financial crises after finding that the emerging economies with more foreign reserves were more resilient during the 2007-2009 global crisis.

In this paper, we ask why emerging economies have massively accumulated foreign

reserves. Using a novel model of sudden stops[1] and rollover risk[2], we show that the buildup in reserves is an optimal response to endogenous sudden stops arising from an increase in foreign debt rollover risk. We argue that the outburst of sudden stops in the late 1990s reflected an unanticipated increase in rollover risk. Sudden stops have since come under control as monetary authorities and governments optimally increased their foreign reserves.

In our model of optimal reserves and rollover risk, the external debt of a small open economy is subject to the rational rollover decision of foreign lenders. Foreign reserves play a crucial role in inducing the foreign lenders to roll over debt. This role is akin to the role of reserves in banks to prevent bank-runs. In fact, consistent with Gourinchas and Obstfeld (2012), we find that foreign reserves are associated with a reduced sudden stop probability in the data.

Following an unexpected increase in the foreign debt rollover risk, our model can quantitatively account for both the increase in reserves and sudden stop occurrences in emerging economies. This is precisely because, given an underlying rollover risk, the model predicts an endogenous relation between sudden stop probabilities and foreign reserves. Therefore, an unexpected increase in rollover risk first causes an outburst in sudden stops. However, these unexpected crises allow governments to rationally update their beliefs and thereby increase their reserves accordingly. Sudden stops subside as reserve levels are appropriate. But did the rollover risk actually increase? Our model indicates that the volatility of gross flows of external liabilities reflects the rollover risk. In fact, we find that flows of gross external liabilities have become more volatile in emerging economies since the mid-1990s.

[1] A sudden stop is a sudden reversal of external capital inflows which is typically associated with a fall in output.

[2] Our rollover risk is similar to the time-preference liquidity shocks la Diamond and Dybvig (1983). However, ours is more akin to a country-preference liquidity shock that prevents some lenders from agreeing to roll over the debt.

This paper is structured as follows. In the following subsection, we briefly relate our work to the existing literature. Section 2.2 empirically analyzes foreign reserves, external debt liabilities, and sudden stops in emerging economies from 1990 to 2007. Section 2.3 provides a simple three-period model of reserves allocation that delivers an optimal reserves-to-debt ratio with endogenous sudden stop probabilities. Section 2.4 presents a multi-country dynamic extension with Bayesian learning and regime change. In the calibrated model, we show it can quantitatively account for the outburst of sudden stops experienced by emerging economies, the subsequent accumulation of reserves, and the resilience of emerging economies to sudden stops since then. Section 2.5 concludes.

2.1.1 Relation to the Literature

This paper builds on a large body of literature on reserves and sudden stops. For a long time, reserves were seen as an integral part of a country's export promotion strategy: they promote export by slowing appreciation. Dooley, Folkerts-Landau and Garger (2004) recently reiterated this explanation to justify the large foreign reserve holdings of emerging economies, in particular China. As documented by Aizenman and Lee (2007), this export promotion view cannot explain the recent increases in reserves of most countries, including China. In fact, reserves mostly increased long after exports started growing. If reserves mainly served to promote exports, they should have grown during the export growth.

Heller (1966) and Frenkel and Jovanovic (1981) model reserves as a buffer against exogenous stochastic balance-of-payments deficits. In Frenkel and Jovanovic (1981), the government seeks to minimize the one-time adjustment costs that are incurred when reserves dry up. Higher reserves increase the distance-to-adjustment because the exogenous adjustment threshold is hit less often. Reserves however have an opportunity cost represented by the forgone interest earnings. This trade-off determines the optimal

reserves held by a government. Numerous papers follow this inventory approach to the role of reserves, e.g. Flood and Marion (2001).

More recently, precautionary motives have been explored as a potential key determinant of reserve allocations (see for example Aizenman and Marion (2003); Durdu, Mendoza, Terrones (2009)). In Jeanne and Ranciere (2008) and Alfaro and Kanczuk (2007), reserves serve as a consumption smoothing mechanism since reserves can be used even after a sudden stop or default. However, these consumption smoothing models of reserves can neither account for the rise in reserve holdings nor the pattern of sudden stop occurrences. In fact, Alfaro and Kanczuk (2007) prescribe that emerging countries should hold no foreign reserves at all.

Our work is closely related to Aizenman and Lee (2007) who use a simple Diamond-Dybvig framework with exogenous interest rate, investment scale, and exogenous sudden stop probability to model reserve hoarding. In Aizenman and Lee (2007), countries face exogenous balance of payments deficits which must be financed with reserves or by liquidating domestic investments. Reserves hence serve as a cushion against the costly liquidation of productive domestic projects. Our work departs from Aizenman and Lee (2007) by crucially endogenizing the probability of sudden stops. These endogenous sudden stops probabilities also relate our work to the large literature on income fluctuations, rollover risk and sovereign default in incomplete markets following Arellano (2008).

Obstfeld, Shambaugh, and Taylor (2010) document the predictive failure of the existing "sudden stop" theories of reserves as they are not able to rationalize the level of reserves accumulated by emerging economies. In contrast to these existing theories, our model generates time series of reserves and sudden stop occurrences that are consistent with the data. The main difference in our work is that reserves serve more than just to smooth consumption; they also play an essential role in preventing sudden stops.

Furthermore, Obstfeld, Shambaugh, and Taylor (2010) show that an empirical specification of reserves with "financial stability" outperforms a specification with traditional motives[3] . However, the large reserves held since the 2000s remain largely unexplained by this empirical "financial stability" specification. Nonetheless, their empirical work indicates the need for better models of reserves and the potential connection between financial crises and reserves. In fact, Gourinchas and Obstfeld (2012) find that, in emerging economies, foreign reserves were associated with greater resilience during the global 2007-2009 crisis.

2.2 Facts on Reserves and Sudden Stops in Emerging Economies

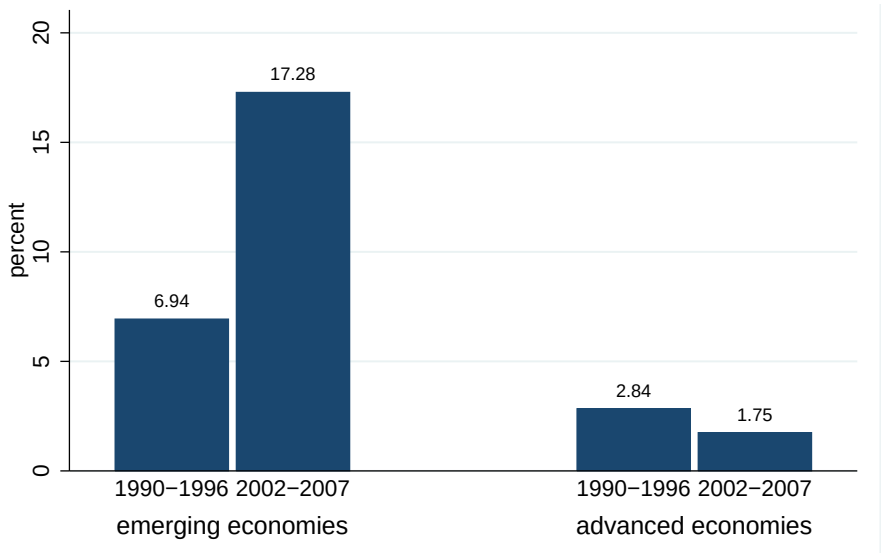
In this section, we document a set of stylized facts regarding foreign reserves, external debt liabilities, and sudden stops in 23 emerging economies during 1990-2007. We use data on international liquidity from the International Monetary Fund dataset on International Financial Statistics (IFS) in conjunction with the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti (2007). The list of emerging economies we consider includes Argentina, Brazil, Chile, China, Colombia, the Czech Republic, Egypt, Hungary, India, Indonesia, Malaysia, Mexico, Morocco, Pakistan, Peru, Philippines, Poland, Romania, Russia, South Africa, South Korea, Thailand, and Turkey. This list includes countries appearing in most classifications of emerging countries with the exception of Taiwan for which the available data is limited.

[3] Their "financial stability" specification entails the inclusion of regressors such as domestic financial liabilities (M2), financial openness, access to foreign currency through debt markets, and exchange rate policy.

2.2.1 Foreign Reserves over GDP

In the IFS dataset, foreign reserves are defined as *all official public sector foreign assets, except Gold, that are readily available to and controlled by the monetary authorities.*[4] We highlight two notable facts regarding foreign reserves holdings. The first fact is that foreign reserves as a percent of GDP in emerging economies are significantly higher than those in advanced economies.[5] The second fact is that these ratios have increased in emerging economies while they have decreased in advanced economies. These facts are summarized in figure 2.1 which shows the cross-country median foreign-to-GDP ratio for emerging and advanced economies respectively.

Figure 2.1: Foreign Reserves over GDP



Note: The value for each period and each group of economies is as derived the median across economies of the period-average of each economy's ratio of reserves-to-GDP.

[4] This definition of foreign reserves includes convertible foreign exchange, SDR holdings, and IMF reserve position.

[5] We use advanced economies to refer to the United States, the United Kingdom, France, and Germany.

It is worth noting that this phenomenon of increasing reserves is not limited to just a few countries or just driven by China as one might think. In fact, foreign reserves are increasing in almost all emerging economies with Chile and Egypt being the exceptions. This robust observation is shown in the detailed table (table B.1) of average foreign reserves by country and by period.

2.2.2 Foreign Reserves and External Debt Liabilities

We document two additional facts on foreign reserves using the external debt liabilities measures.[6] The first fact is that reserves-to-liabilities ratios are also much higher in emerging economies than in advanced economies. For the period 2002-2007, these ratios for emerging economies are almost 40 times higher than that for advanced economies. The second fact is that reserves-to-liabilities ratios have been increasing in emerging economies while they have been decreasing in advanced economies.

These facts are shown succinctly in figure 2.2 which depicts the median reserves-to-liabilities ratio within each group of countries. Again, this observation holds in most emerging economies. Table B.1 details the average reserves-to-liabilities ratios by country and era.

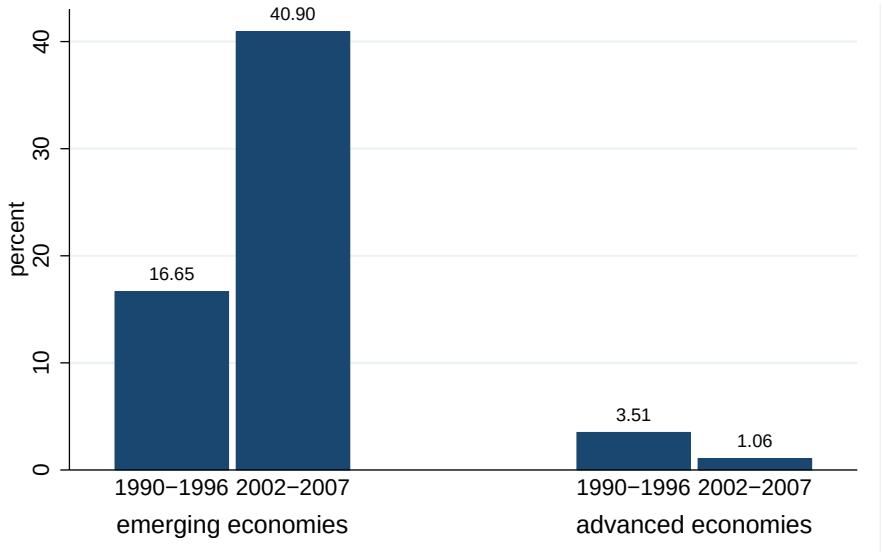
2.2.3 Sudden Stops in Emerging Economies

Following Calvo et al. (2004), we define a sudden stop episode as a spell with exceptionally large current account reversals and a recession. We find 12 sudden stop experiences during 1990-2007 across the 23 emerging economies with an outburst of 10 sudden stops between 1997 and 2001.[7]

[6] The measure of "External Debt Liabilities" include the "Debt Securities" item under "Portfolio Investment Liabilities" as well as "Other Investment Liabilities".

[7] Our sudden stop episodes are: Turkey (1994), Mexico (1995), Thailand (1997), Czech Republic, Indonesia, Philippines, South Korea (1998), Chile, Peru, Russia (1999), Argentina, Turkey (2001). Durdu, Mendoza, Terrones (2009) report other episodes which do not meet the criteria extended from Calvo et al. (2004): Argentina (1994), Malaysia (1997), Brazil, Colombia, Pakistan (1999). Whether

Figure 2.2: Foreign Reserves over External Debt Liabilities



Note: The value for each period and each group of economies is derived as the median across economies of the period-average of each economy's ratio of reserves over external debt liabilities.

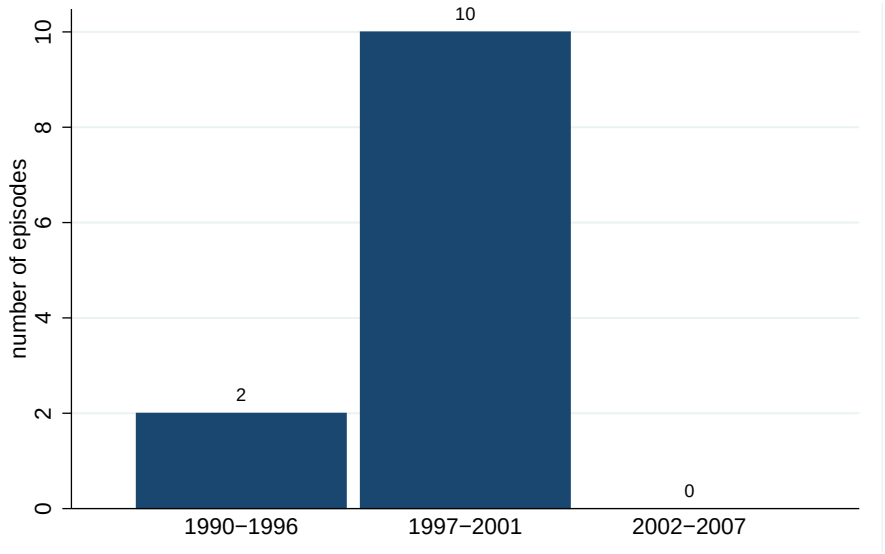
We therefore divide this time frame into three periods as shown in figure 2.3: 1990-1996 is a period of low-frequency sudden stops (with 2 occurrences), 1997-2001 is a period of high-frequency sudden stops (with 10 occurrences), and 2002-2007 is a period of low-frequency sudden stops (with no occurrence).

2.2.4 Reserves and Sudden Stop Probabilities

Following Gourinchas and Obstfeld (2012), we use a panel discrete-choice model to document the effect of foreign reserves on sudden stops. They documented that foreign reserves are associated with reduced banking crisis, currency crisis, or sovereign

we use sudden stops reported by other authors or the ones we measured, there was an outburst in sudden stops between 1997 and 2001. Our methodology for constructing sudden stop episodes is further explained in the data appendix.

Figure 2.3: Sudden Stops in Emerging Economies



default. We find that higher foreign reserves are also associated with reduced sudden stop likelihood.

As in Gourinchas and Obstfeld (2012), we use a panel logit model with country fixed effects:

$$\Pr\left(S_k^i = 1 \,|\, x_i\right) = \frac{\exp\left(\alpha_i + \beta x_i\right)}{1 + \exp\left(\alpha_i + \beta x_i\right)}$$

where S_k^i denotes whether country i is in a sudden stop episode in the next k years and x_i are foreign reserves in country i during a year that is not 0 to 3 years after a sudden stop episode (that is, "tranquil" times using the terminology of Gourinchas and Obstfeld (2012)).

The results of the panel logit estimation across emerging economies are reported in table 2.1. Foreign reserves are significantly associated with resilience to sudden stops. For instance, one standard deviation increase in the ratio of foreign reserves to external debt liabilities (around 26 percent) is associated with a fall of 11.5 percent in the probability of sudden stop in the next three years.

Table 2.1: Panel Logit Estimation across Emerging Economies

		Sudden Stop $\partial p/\partial x$	
x	$s.d.\,(x)$	1 year ahead	1-3 years ahead
Reserves over	26.06	-0.0090***	-0.0044**
External Debt Liabilities		(.0025)	(.0019)
Sudden Stops Mean		0.05	0.26

Note: **, and *** denote significance at 5%, and 1%. $\partial p/\partial x$ is the marginal effect in percentage at "tranquil" sample mean. $s.d.\,(x)$ is the unconditional standard deviation of x over "tranquil" times. Robust standard errors in parentheses are computed using the delta-method. The estimation sample is an unbalanced panel that spans 15 emerging countries between 1973 and 2007.

2.2.5 Volatility of Gross External Liabilities

Finally, we document that the volatility of quarterly gross debt flows in emerging economies has increased over time. Using the series on external liabilities relative to output, we find that gross external liabilities were less volatile prior to the outburst of sudden stops.

Table 2.2: Quarterly Gross Flows of Total External Liabilities

	Period		
	1990-1996	1997-2001	2002-2007
Standard deviation	3.23	4.97	4.83
Mean	7.90	9.75	9.88
Coefficient of variation	0.41	0.51	0.49

Table 2.2 summarizes the increase in the volatility of global liquidity flows. Since the late nineties, there are been an increase in both the standard deviation and the coefficient of variation of gross total external liabilities flows.

2.3 A Three-Period Model of Optimal Reserves Allocation

In this section, we provide a theory of optimal reserves allocation in an environment where governments face rollover risk. The model highlights the endogenous role of reserves in determining sudden stop probabilities. In the next section, we provide a dynamic extension to explain the increase in reserves and the pattern of sudden stops in emerging countries documented in the previous section.

2.3.1 Environment

We consider a small open economy model with three periods: $t = 1$ (initial), 2 (interim), 3 (final). There is a unit measure of risk neutral foreign lenders who can choose to lend to

the domestic country.[8] The domestic country has a representative agent who has linear preferences $u(C) = C$ over the final period consumption C. The government chooses allocations and debt arrangements to maximize the expected utility of the domestic agent.

2.3.2 Technologies

The domestic country has access to two technologies à la Diamond and Dybvig (1983). The first transforms the investment K made in the initial period into AK units in the final period if production is uninterrupted. However, if production is interrupted in the interim through the liquidation of $L \in [0, K]$ units of investment, the technology yields λL in the interim and $A(K - L)$ in the final period. We assume $\lambda < 1$, reflecting the idea that it is costly to divest from the long-term investment in the interim. We also impose that there is no partial interim liquidation, that is: $L \in \{0, K\}$. This assumption of full liquidation is made for analytical tractability and is relaxed in the next section. The second technology transforms a unit of investment into a unit of output in the subsequent period. This technology is referred to as the "reserves" technology.

These technologies are summarized by the following table:

Technologies	$t = 1$	$t = 2$	$t = 3$
Production and liquidation	$-K$ investment	λL liquidation	$A(K - L)$ final output
Reserves	$-R_1$ initial reserves	R_1	
		$-R_2$ interim reserves	R_2

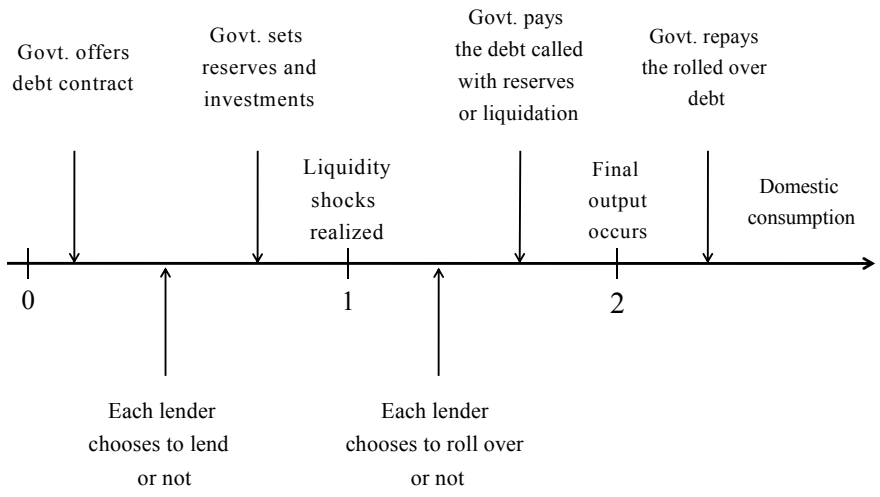
[8] For technical reasons, we assume that the foreigners' capital endowment is finite and large enough.

2.3.3 International Financial Markets: Timeline and Constraints

Timing of actions and shocks

In the initial period, the domestic government borrows D from foreign lenders to finance its initial period investments. An overview of the sequence of actions taken by the government and the lenders is presented in figure 2.4. In the interim, a fraction φ of the foreign lenders receive liquidity shocks, denoted by $\varphi_i = 1$, meaning that they must call the loan and be repaid back. The fraction φ is stochastic and has a cumulative distribution function that follows the bounded Pareto distribution given by $F_\sigma(\varphi) = 1 - (1-\varphi)^{\frac{1}{\sigma}}$. The remaining fraction $(1-\varphi)$ of lenders with $\varphi_i = 0$ can choose to call or roll over their loans.

Figure 2.4: Timeline



We denote $\psi_i = 0$ if lender i chooses to roll over the loan and $\psi_i = 1$ otherwise. We assume that each individual lender i takes the actions $\{\psi_j(\varphi, \varphi_j)\}_{j \neq i}$ of the other lenders $j \in [0,1]$ as given. This implies that once the aggregate liquidity shock is realized, the fraction of lenders calling the loan $\psi(\varphi) \triangleq \int \psi_j(\varphi) dj$ can be inferred by each individual

lender. We call it a *sudden stop* when all lenders refuse to roll over in the interim, that is, when $\psi(\varphi) = 1$.

Payments Schedule

We allow the debt contract to be contingent on whether or not the economy is facing a sudden stop. During normal times, foreign lenders receive $P_1 = D$ if they call the loan in the interim, and $P_2 = (1 + r_N) D$ in the final period if they roll over the loan.[9] During a sudden stop, however, all the lenders call the debt and receive $P_1 = (1 + r_S) D$ in the interim. The debt payment schedule is then summarized given by:

	Interim payment P_1	Final payment P_2
Normal times($\psi(\varphi) < 1$)	D	$(1 + r_N) D$
Sudden stop ($\psi(\varphi) = 1$)	$(1 + r_S) D$	-

Because the interest rate is different when the economy is in sudden stop, the government can choose to partially default during sudden stop episodes by setting $r_S < r_N$. However, there is a limit to the haircut the lenders can suffer because the lenders can collectively bargain and extract a fraction θ of the interim resources available $(R + \lambda K)$.

Feasible Debt Contracts

We now define the feasibility constraints that the debt contract offered by the government must satisfy in this environment. First, we define a debt contract as a list of:

- four scalars: $\{R_1,\ K,\ r_N,\ r_S\}$ representing the initial reserves, the normal interest rate, and the sudden stop interest rate, and

[9] The assumption that lenders receive zero net return on debt called in the interim is not essential; in fact, it can be any arbitrary return that does not exceed the world interest rate.

- four state-contingent functions: $\{C(\varphi),\ R_2(\varphi),\ L(\varphi),\ \psi_i(\varphi,\varphi_i)\}$, which denote the consumption, the interim reserves, the interim liquidation, and the individual rollover policies, respectively.

Resource Feasibility A debt contract is *resource feasible* if it satisfies the following constraints:

$$\begin{aligned} R_1 + K &\leq D && (2.1)\\ R_2(\varphi) + \psi(\varphi) P_1(\psi(\varphi)) &\leq R_1 + \lambda L(\varphi) \quad \forall\varphi && (2.2)\\ C(\varphi) + (1-\psi(\varphi)) P_2(\psi(\varphi)) &\leq R_2(\varphi) + A(K - L(\varphi)) \quad \forall\varphi && (2.3)\\ L(\varphi) &\in \{0, K\} \quad \forall\varphi && (2.4)\\ 0 &\leq R_1,\ R_2(\varphi),\ C(\varphi) \quad \forall\varphi && (2.5) \end{aligned}$$

In other words, initial reserves and invested capital cannot exceed the loan amount; interim reserves and interim payments cannot exceed initial reserves and interim output; and consumption and final payments cannot exceed interim reserves and final output.

Individual Rationality A debt contract is *individually rational* if, in the interim, an individual rolls over the loan if and only if this yields a higher payoff than calling the loan:

$$\psi_i^*(\varphi,\varphi_i) \in \arg\max V(\cdot) \qquad (2.6)$$

$$\text{where} \quad V(\psi_i \mid \varphi,\varphi_i) = \begin{cases} P_1(\psi(\varphi)) & \text{if } \psi_i = 1 \\ \mathbb{1}_{\varphi_{i=0}} \cdot P_2(\psi(\varphi)) & \text{if } \psi_i = 0 \end{cases}$$

Participation Constraint A debt contract satisfies the *participation constraint* if ex ante the debt contract is as profitable as investing at the world interest rate r_W:

$$\mathbf{E}\left[V\left(\psi_i \,|\, \varphi, \varphi_i\right)\right] \quad \geq \quad (1 + r_W)D \tag{2.7}$$

Renegotiation Proofness Finally, a debt contract is *renegotiation-proof* if it satisfies:

$$(1 + r_S)\, D \quad \geq \quad \min\left\{(1 + r_N)\, D, \theta\left(R_1 + \lambda K\right)\right\} \tag{2.8}$$

This condition arises as foreigners bargain over domestic interim output during sudden stops. In this section, we impose $\theta = 1$. This assumption can be relaxed in the next section.

2.3.4 Optimal Debt Contract

An *optimal debt contract* is a tuple $B^* = \{R_1^*,\, K^*,\, r_N^*,\, r_S^*,\, C^*\left(\varphi\right),\, R_2^*\left(\varphi\right),\, L^*\left(\varphi\right),\, \psi_i^*\left(\varphi, \varphi_i\right)\}$ which maximizes the expected utility of the domestic representative agent subject to resource feasibility, individual rationality, the participation constraint, and renegotiation-proofness. In other words, the government solves the following problem:

$$\begin{aligned} \max_B \qquad & \mathbf{E}_\varphi\left[C\left(\varphi\right)\right] \\ \text{subject to} \quad & (2.1) - (2.8). \end{aligned}$$

2.3.5 Optimal Contract Characterization

We now characterize the solution to the optimal debt contract problem.

Proposition 2.1. Optimal Debt Contract

If B^* solves the government's problem then:

(i) Interim payments are paid exclusively with reserves until they are depleted, i.e.,

$$\exists \varphi_R \in [0,1] \text{ s.t. } \begin{cases} R_2(\varphi) > 0 & \iff \varphi \in [0, \varphi_R) \\ L(\varphi) = 0 & \iff \varphi \in [0, \varphi_R) \end{cases}$$

Furthermore,

$$\varphi_R^* = \frac{R_1}{D} = 1 - \left[\frac{A-1}{A-\lambda} \left(\frac{\sigma}{\sigma+1} \right) \right]^{\sigma}$$

(ii) For sufficiently large aggregate shocks, all lenders call their loans in the interim, i.e.,

$$\exists \varphi_S \in [0,1] \text{ s.t. } \begin{cases} \psi(\varphi) = \varphi & \forall \varphi \in [0, \varphi_S) \\ \psi(\varphi) = 1 & \forall \varphi \in [\varphi_S, 1] \end{cases}$$

Furthermore, $\varphi_S = \varphi_R$.

Discussion Proposition 2.1(i) and 2.1(ii) establish that there are cutoff rules for reserves, liquidation, and sudden stops. In Proposition 2.1(i), φ_R is the liquidity shock at which reserves are depleted and the government must start liquidating the invested capital to meet the promised payments. In Proposition 2.1(ii), φ_S is the liquidity shock above which all lenders exit; we identify this phenomena as a *sudden stop*.

Because $\lambda < 1$, the government always uses existing reserves to meet payments before eventually liquidating the invested capital. Proposition 2.1(i) also establishes that the optimal reserves-to-liabilities ratio is φ_R.

Corollary 2.2. Endogenous Sudden Stop Probability

The optimal contract B^* *induces an ex ante endogenous probability that a sudden stop occurs.*

Furthermore, $\Pr(\psi = 1) = 1 - F(\varphi_R^*)$.

Proof. This follows immediately from Proposition 2.1. □

Discussion Together, Proposition 2.1 and Corollary 2.2 highlight the endogenous relation between the reserves-to-liabilities and the probability of sudden stops. In this environment, reserves are set to balance the liquidation costs incurred when reserves are not high enough, the sudden stop risks associated with excessive liquidation and the cost of holding idle reserves.

2.3.6 Comparative Statics

In this subsection, we discuss how reserves and sudden stop probabilities are affected by changes in the underlying rollover risk, that is, changes in σ.

Proposition 2.3. Reserves and Sudden Stop Probability

(i) The optimal reserves-to-debt liabilities is increasing in rollover risk:

$$\frac{\partial \varphi_R^*}{\partial \sigma} > 0$$

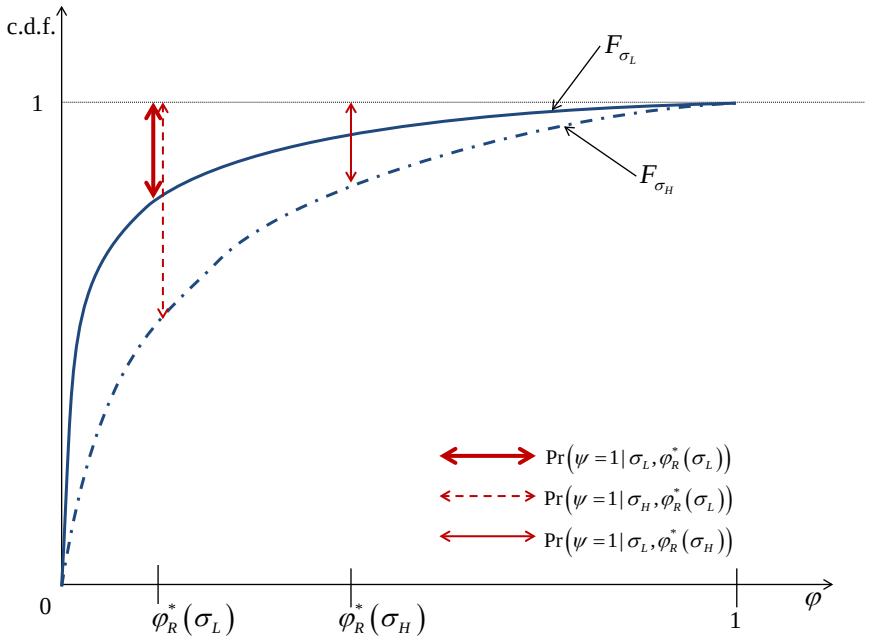
(ii) The sudden stop probability is increasing in rollover risk:

$$\frac{\partial \Pr\left(\psi\left(\varphi\right) = 1 \mid \sigma\right)}{\partial \sigma} > 0$$

Proposition 2.3 establishes that both the reserves-to-liabilities ratio and sudden stop probability are increasing in rollover risk. A larger σ implies larger interim shocks, prompting the domestic government to invest in higher reserves. However, the increase in reserves does not completely offset the higher probability of larger shocks, thus leading to an increase in the sudden stop probability.

A crucial question that we address in this paper is: what happens during an unexpected increase in rollover risk fromσ_L to $\sigma_H > \sigma_L$? It is easy to see that an unexpected increase in σ leads to a large increase in sudden stop probability not only due to the fact that larger shocks are more likely, but also because the government underinvests in

Figure 2.5: Illustration of Sudden Stop Surge



reserves. This relationship between beliefs, reserve-to-debt liabilities, and actual sudden stop probabilities is illustrated in Figure 2.5. Corollary 2.4 states this result formally.

Corollary 2.4. Sudden Stop Surge

Sudden stops increase following an unanticipated increase in σ from σ_L to σ_H, i.e.

$$\Pr\left(\psi = 1 \mid \sigma_H, \varphi_R^*\left(\sigma_L\right)\right) > \Pr\left(\psi = 1 \mid \sigma_L, \varphi_R^*\left(\sigma_L\right)\right)$$

The previous corollary indicates that a surge in sudden stops may be an indirect evidence of an increase in the underlying rollover risk. A more direct way to identify the increase in rollover risk is by examining the volatility of gross interim flows. In our model, the gross interim flows in external liabilities is given by $-\varphi D$ during normal times. The next corollary shows that in our model, gross external flows do become more volatile following an increase in rollover risk, consistent with our findings in the empirical section.

Corollary 2.5. Increased Interim Volatility

Gross interim flows are more volatile following an increase in σ from σ_L to σ_H, i.e.,

$$Var(\varphi \mid \sigma_H) > Var(\varphi \mid \sigma_L).$$

2.4 A Multi-Country Dynamic Extension with Learning and Regime Change

The previous section highlighted the main forces determining the optimal foreign reserves: costly sudden stop probabilities and productive capital use. We now propose a dynamic model with N small (emerging) economies to explain the increase in foreign reserves holdings and the transitory outburst in sudden stops.

As shown in the empirical section, gross flows in external liabilities increased after the mid-1990s in emerging economies. In our model, this is consistent with an increase in rollover risk as shown in Corollary 2.5. We showed in Corollary 2.4 that an unexpected increase in the rollover risk will lead to an outburst of sudden stops. This unusual rise in sudden stops prompts governments to update their beliefs and thereby rein in sudden stops.

In fact, using this extension, we can quantitatively account for the increase in reserves and the temporary outburst of sudden stops following an unexpected switch in rollover risk.

2.4.1 Environment

We consider N identical small economies indexed by $j = 1, \ldots, N$. Time is infinite, discrete and indexed by $t = 0, 1, \ldots, \infty$. Each country is populated by an infinitely-lived representative agent and a welfare-maximizing domestic government. The domestic agents in country j order consumption sequences according to $\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t C_t^j \right]$ where

β is the discount factor. There is a continuum of infinitely lived risk-neutral foreign lenders $i \in [0, 1]$.

2.4.2 Timing

Each time period t is divided into three stages, $s = 0, 1, 2$ and encapsulates the three stages of the previous model:

- $s = 0$ is the initial contracting stage
- $s = 1$ is the interim stage when liquidity shocks are realized and rollovers decided
- $s = 2$ is the final production and consumption stage.

2.4.3 Shocks and Information Structure

The aggregate interim liquidity shock in country j at time t is denoted by $\varphi_t^j \in [0, 1]$. The N aggregate shocks $\left\{\varphi_t^j \ : \ j = 1 \dots N\right\}_{t=0}^{\infty}$ are independent and identically distributed across countries and time. These aggregate liquidity shocks follow a common stochastic process with cumulative distribution function F_{σ_t}. As in the basic model, a fraction φ_t^j of foreign lenders lending to country j receive liquidity shocks and must call the debt in the interim. We assume $\sigma_t \in \{\sigma_L, \sigma_H\}$ with $\sigma_L < \sigma_H$. This regime parameter σ_t is unobserved and unknown to the agents. However, all agents share a common belief ρ_t at time t:

$$\rho_t \triangleq \Pr\left(\sigma_t = \sigma_L\right)$$

At the end of each period t, agents observe the sudden stop occurrences in the N countries. Using these sudden stop occurrences and the endogenous sudden stop probabilities, agents update their beliefs according to Bayes' rule, detailed in section 2.4.5.

2.4.4 Technologies

Within each period t, the technologies available at a stage s are identical to those in the previous section.[10] We now allow for partial liquidation in the interim: $L_t^j\left(\varphi_t^j\right) \in \left[0,\ K_t^j\right]$. Also, at the end of each period, the government can save $R_{0,t+1}^j\left(\varphi_t^j\right)$ reserves for the next period. These saved reserves are available at the initial stage ($s = 0$) during the next period. These inter-temporal reserves are allocated from the reserves remaining in the final stage ($s = 2$) of the current period t:

$$R_{0,t+1}^j\left(\varphi_t^j\right) \in \left[0\ ,\ R_{2,t}^j\left(\varphi_t^j\right)\right]$$

2.4.5 Optimal Recursive Debt Contracts

An important difference with the basic model is the endogeneity of reserve endowments. In the basic model, the reserve endowment was zero; in the dynamic model, governments will face a consumption/savings decision and will choose the reserve endowments of the following period. Another difference is the relaxation of the full liquidation constraint; this implies that sudden stops need not necessarily occur as soon as reserves are depleted.

Given an incoming level of reserves R_0 and a belief ρ, a debt contract is defined to be:

- five scalars $\{R_1,\ K,\ r_N,\ r_S,\ \varphi_S\}$, representing the initial reserves, the normal interest rate, the sudden stop interest rate, and the sudden stop cutoff; and
- five state-contingent functions $\{C\left(\varphi\right),\ R_2\left(\varphi\right),\ L\left(\varphi\right),\ R_0'\left(\varphi\right),\ \psi_i\left(\varphi, \varphi_i\right)\}$, which denote the consumption, the interim reserves, the interim liquidation, the inter-temporal reserves savings, and the individual rollover policies, respectively.

As before, let

[10] The superscript j and the subscript t are therefore added to the variables from the previous model to denote the country and the period. We keep the subscripts indicating the stage s when necessary.

$$
\begin{aligned}
\psi(\varphi) &= \int \psi_j(\varphi) dj \\
P_1(\varphi) &= \begin{cases} D & \text{if } \psi(\varphi) < 1 \\ (1+r_S)\, D & \text{otherwise} \end{cases} \\
P_2(\varphi) &= \begin{cases} (1+r_N)\, D & \text{if } \psi(\varphi) < 1 \\ 0 & \text{otherwise} \end{cases}
\end{aligned}
$$

Resource Feasibility A debt contract is *resource feasible* if it satisfies the following constraints:

$$R_1 + K \leq D + R_0 \tag{2.9}$$

$$R_2(\varphi) + \psi(\varphi) P_1(\psi(\varphi)) \leq R_1 + \lambda L(\varphi) \quad \forall \varphi \tag{2.10}$$

$$C(\varphi) + (1 - \psi(\varphi)) P_2(\psi(\varphi)) \leq R_2(\varphi) - R_0'(\varphi) + A(K - L(\varphi)) \quad \forall \varphi \tag{2.11}$$

$$L(\varphi) \in [0,\ K] \quad \forall \varphi \tag{2.12}$$

$$R_0'(\varphi) \in [0,\ R_2(\varphi)] \quad \forall \varphi \tag{2.13}$$

$$0 \leq R_1,\ R_2(\varphi),\ C(\varphi) \quad \forall \varphi \tag{2.14}$$

Individual Rationality A debt contract is *individually rational* if it satisfies the following constraints:

$$\psi_i^*(\varphi, \varphi_i) \in \arg\max V(\cdot) \tag{2.15}$$

$$\text{where} \qquad V(\psi_i \,|\, \varphi, \varphi_i) = \begin{cases} P_1(\psi(\varphi)) & \text{if } \psi_i = 1 \\ \mathbb{1}_{\varphi_i = 0} \cdot P_2(\psi(\varphi)) & \text{if } \psi_i = 0 \end{cases}$$

$$\psi_i^*(\varphi, \varphi_i) = \begin{cases} 0 & \text{if } \varphi < \varphi_S \\ 1 & \text{otherwise} \end{cases} \tag{2.16}$$

The first condition, which requires an individual to roll over the loan if and only if this yields a higher payoff than calling the loan, is identical to the basic model. The second condition requires an individual to roll over the loan if and only if the aggregate liquidity shock, φ, is larger than the sudden stop cutoff, φ_S.

Participation Constraint A debt contract satisfies the *participation constraint* if ex ante the debt contract is as profitable as investing at the world interest rate r_W:

$$\mathbf{E}_{\varphi}\left[V\left(\psi_i \,|\, \varphi, \varphi_i\right)\right] \;\geq\; (1+r_W)D \tag{2.17}$$

Renegotiation Proofness Finally, a debt contract is *renegotiation-proof* if it satisfies the following constraints:

$$(1+r_S)\,D \geq \min\left\{(1+r_N)\,D, \theta\left(R_1+\lambda K\right)\right\} \tag{2.18}$$

Recursive Problem and Beliefs Given a belief ρ about the liquidity shock regime, we define the optimal recursive contracts as the solution to the following recursive problem:

$$\begin{aligned} W\left(R_0;\ \rho\right) = \quad & \max_B \quad \mathbf{E}_{\varphi|\,\rho}\left[u\left(C\left(\varphi\right)\right) + \beta W\left(R_0'\left(\varphi\right);\ \rho\right)\right] \\ & \text{subject to} \qquad (2.9)-(2.18) \end{aligned}$$

The common belief is dynamically updated using the sudden stop occurrences and sudden stop probabilities in the N countries. Let us denote $\chi_t \in \{0,1\}^N$ as the vector of sudden stops. Bayes' Rule implies that:

$$\rho_{t+1} = \frac{\rho_t \Pr\left(\chi_t \mid \sigma_L\right)}{\rho_t \Pr\left(\chi_t \mid \sigma_L\right) + \left(1-\rho_t\right)\Pr\left(\chi_t \mid \sigma_H\right)}$$

with

$$\begin{cases} \Pr\left(\chi_t \mid \sigma_L\right) & \triangleq \prod_{j=1}^{N}\left\{\left[1-F_{\sigma_L}\left(\underline{\varphi_{s,t}^j}\right)\right]\cdot\chi_t^j + F_{\sigma_L}\left(\underline{\varphi_{s,t}^j}\right)\cdot\left(1-\chi_t^j\right)\right\} \\ \Pr\left(\chi_t \mid \sigma_H\right) & \triangleq \prod_{j=1}^{N}\left\{\left[1-F_{\sigma_H}\left(\overline{\varphi_{s,t}^j}\right)\right]\cdot\chi_t^j + F_{\sigma_H}\left(\overline{\varphi_{s,t}^j}\right)\cdot\left(1-\chi_t^j\right)\right\} \end{cases}$$

where $\underline{\varphi^j_{S,t}}$ is the sudden stop cutoff for$(R_0;\ \rho) = \left(R^j_{0,t},;\ \rho_t = 1\right)$ and $\overline{\varphi^j_{S,t}}$ is the sudden stop cutoff for $(R_0;\ \rho) = \left(R^j_{0,t},;\ \rho_t = 0\right)$. Hence, given a sequence of sudden stop occurrences $\{\chi_t\}_t$, an initial belief ρ_0, and initial reserve endowments $\left\{R^j_-\right\}^N_{j=1}$, the realized sequence of optimal contracts is well-defined using the functional equation solutions and Bayes' rule.

2.4.6 Quantitative Analysis

In this section, we discuss the quantitative results of a carefully parametrized model. Our simulations show that our extended model can account for the stylized facts we documented.

In particular, we simulate the following thought experiment. We assume that the period of 1990-1996 was an era of relatively low volatility in international capital movements, i.e. a σ_L regime. By 1997, globalization and widespread financial liberalization allowed less restrictive capital movements but governments and investors underestimated the increase in capital mobility, i.e. there is an unexpected change to a σ_H regime. Based on our theory, this will cause an underinvestment in reserve holdings which increases the probability of sudden stops. Governments and investors, seeing the rise in sudden stops, update their common belief about the prevailing regime. By 2002, agents have fully learned the new regime; as a result, reserves-to-debt is higher and sudden stops decrease.

Parametrization and Functional Forms A period in the model is assumed to be a quarter. We choose $N = 23$ as we have 23 emerging economies in our dataset. The liquidity shock process is an important element of the model. We assume the aggregate liquidity shock distributions $(F_{\sigma_L}, F_{\sigma_H})$ belong to the class of Generalized Bounded

Pareto distributions on $[0, 1]$:

$$F_\sigma(\varphi) \triangleq 1 - (1 - \varphi)^{\frac{1}{\sigma}}$$

An increase in σ shifts the cumulative distribution function F_σ to the right. The switch from σ_L to σ_H therefore reflects the increase in interim capital mobility. The parameters β, r_W, σ_L, and σ_H are then set to match some facts regarding international liquidity. In particular, we set β to match average interest rates of 2% in emerging economies over 1990-2007, r_W to match the risk-free rate of 1%, while σ_L and σ_H are set to match median reserves-to-debt ratios in the emerging economies for the periods of 1990-1996 and 2002-2007 respectively. We follow Ennis and Keister (2003) to set the divestment cost $1 - \lambda$ to be 30%. We assign an arbitrary value of A to 1.2. The parameters are summarized in table 2.3.

Table 2.3: Parameter values

Name	Symbol	Value	Target
Discount factor	β	0.98	average interest rates in emerging economies over 1990-2007
World interest rate	r_W	0.01	risk-free rate
Low rollover risk parameter	σ_L	0.06	average reserves-to-external debt liabilities median among emerging economies 1990-1996
High rollover risk parameter	σ_H	0.16	average reserves-to-external debt liabilities median among emerging economies 2002-2007
Divestment parameter	λ	0.7	Ennis and Keister (2003)
Productivity	A	1.2	-
Bargaining parameter	θ	1	-
Number of economies	N	23	number of emerging countries studied

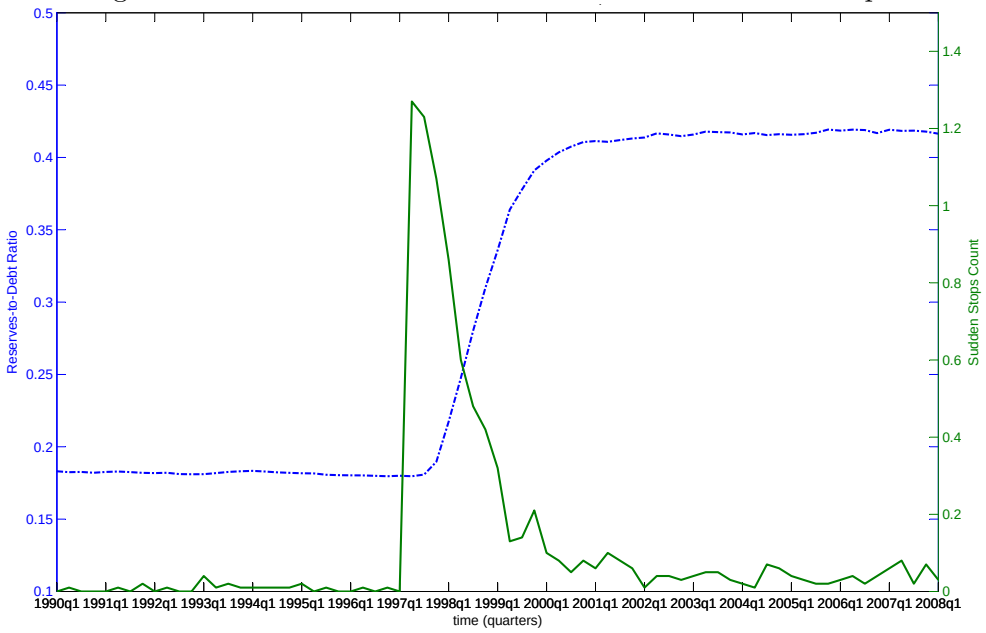
Quantitative Results We consider $N = 23$ identical economies starting with different initial foreign reserves.[11] As the N economies experience different aggregate liquidity paths, their reserves holdings and sudden stops paths also evolve differently. The results shown are the average across a large number of simulated paths for the N countries.

As can be seen in figure 2.6, our model is able to replicate the pattern of low

[11] The initial levels of foreign reserves were generated by simulating, for a few periods, the model with initial zero foreign reserves.

frequency sudden stops during 1990-1996, high frequency sudden stops in the transition (1997-2001), and low frequency after the transition (2002-2007). During the transition, governments under-invest in reserves, thereby increasing the probability of sudden stops. Once the governments have learned of the regime change to higher liquidity shocks, they choose to hold a higher level of reserves, thus returning sudden stop probabilities to lower levels.

Figure 2.6: Model results - Reserves-to-Debt and Sudden Stops



In our theory, misaligned beliefs beget "abnormal" sudden stop occurrences. As sudden stops occurrences increase, reserves dry up more often but governments keep building up their foreign holdings as a result of updated beliefs. In this model, model reserves do not serve as a *post*-sudden stop insurance. Instead, in contrast to most consumption smoothing theories of reserves allocation, reserves play an active role of

preventing sudden stop occurrences and they do not help increase consumption after sudden stops.

Table 2.4 summarizes our key results. One drawback of the results is that the speed at which agents learn the true process is quite fast: this leads to governments increasing reserves faster and sudden stops ceasing sooner than 2002 as seen in the data. Also, since $\sigma_L < \sigma_H$, the post-crisis era is characterized by slightly more sudden stops than the pre-crisis era. Of course, both periods feature much less sudden stops than the crisis/adjustment era.

Table 2.4: Summary of Numerical Results

	1990-1996	1997-2001	2002-2007
Data			
Reserves-to External Debt Liabilities	0.167	0.282	0.409
Sudden Stops	2	10	0
Model			
Reserves-to External Debt Liabilities	0.177	0.326	0.416
Sudden Stops	0.32	7.19	0.95

2.5 Conclusion

In this paper, we have studied empirically and theoretically the joint dynamics foreign reserves and sudden stops in emerging economies. Using international liquidity data for 23 emerging economies, we document that foreign reserve shave dramatically increased in emerging countries from 1990 to 2007. We also present the time series of sudden stops in these emerging economies: there were virtually no sudden stops except during 1997-2001.

We then develop a small open economy model where reserves endogenously affect

the probability of sudden stops. In our model, "patient" foreign lenders choose to roll over their loans as long as their returns are not undermined by the divestment made to repay lenders calling in the interim. Sudden stops occur when all foreign lenders choose to call the loans. On one hand, reserves protect domestic projects from liquidation and make foreign lenders calmer as the country is solvent in more states of the world. On the other hand, foreign reserves reduce the capital used in the productive sector. Consequently, the model yields an endogenous probability of sudden stop and an optimal reserves-to-debt ratio. Furthermore, we show that foreign reserve holdings increase with the rollover risk.

We then extend our model to explain the accumulation of foreign reserves and the transitory surge in sudden stops in emerging economies. In our model, any underestimation of the underlying rollover risk will temporarily induce an outburst of sudden stops. We present a dynamic multi-country model with Bayesian learning and a regime switch in the rollover risk. With the gradual learning of the true regime, we obtain a transition path during which sudden stops surge. The optimal reserves-to-debt ratios are higher at the end of the transition, and sudden stops subside, as seen in the data.

This paper therefore provides a useful theory of reserves, rollover risk, and sudden stops. Our model however is highly stylized. It does not include many potentially relevant features. For instance, Cole and Kehoe (2000) indicate that the composition of a country's debt portfolio matters for sudden stops and Obstfeld, Shambaugh, and Taylor (2010) highlighted other relevant dimensions of financial stability. We leave these directions for future research.

Chapter 3

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Appendix A

Appendix to Chapter 1

A.1 Empirical Appendix

A.1.1 Descriptive Statistics

Table 1: TAA certified workers by state per thousand of w.a.p.

(1983-2009)

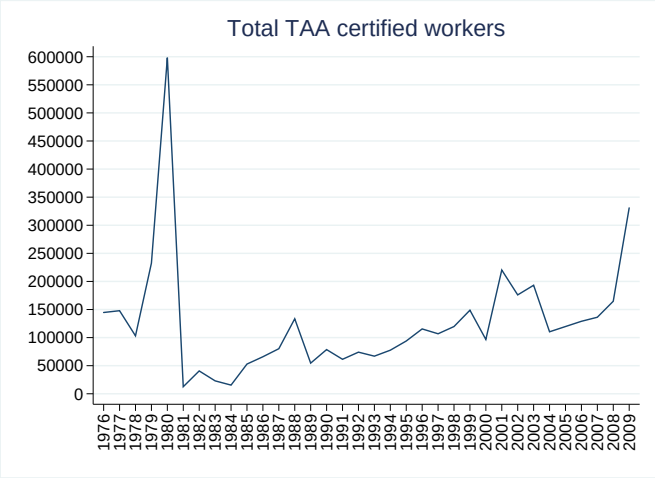
State	Average	Minimum	Maximum	IQR
AL	1.23	0.07	2.68	1.43
AK	0.93	0.00	6.02	1.07
AZ	0.33	0.03	1.47	0.27
AR	1.08	0.06	2.37	1.21
CA	0.25	0.03	0.74	0.23
CO	0.57	0.01	2.98	0.47
CT	0.44	0.04	1.01	0.47
DE	0.25	0.00	3.38	0.30
FL	0.13	0.04	0.29	0.13
GA	0.70	0.01	1.56	0.60
HI	0.06	0.00	0.70	0.08
ID	0.67	0.00	1.86	0.63
IL	0.45	0.02	1.87	0.38
IN	0.84	0.02	3.23	0.86
IA	0.38	0.00	2.10	0.49
KS	0.57	0.00	3.01	0.60
KY	0.91	0.02	2.56	0.84
LA	0.59	0.00	4.50	0.61
Overall	0.67	0.00	7.35	0.71

State	Average	Minimum	Maximum	IQR
ME	1.32	0.43	2.66	1.09
MD	0.23	0.01	0.60	0.24
MA	0.58	0.05	1.63	0.34
MI	1.00	0.03	6.89	0.98
MN	0.47	0.01	2.05	0.33
MS	1.19	0.02	3.00	1.20
MO	0.74	0.06	1.33	0.46
MT	0.63	0.00	4.03	0.63
NE	0.24	0.00	0.94	0.47
NV	0.13	0.00	1.13	0.13
NH	0.59	0.00	1.88	0.65
NJ	0.54	0.13	1.07	0.41
NM	0.61	0.00	3.00	0.69
NY	0.39	0.07	0.74	0.20
NC	1.37	0.07	3.77	2.18
ND	0.57	0.00	5.66	0.48
OH	0.80	0.18	3.71	0.76
OK	0.74	0.01	2.14	0.47
OR	0.90	0.00	4.40	0.82
PA	0.95	0.14	2.44	0.44
RI	0.89	0.00	1.95	0.87
SC	1.10	0.02	2.78	1.65
SD	0.46	0.00	2.86	0.33
Overall	0.67	0.00	7.35	0.71

State	Average	Minimum	Maximum	IQR
TN	1.31	0.22	2.68	1.03
TX	0.61	0.07	2.55	0.41
UT	0.64	0.07	3.43	0.53
VT	0.53	0.00	1.85	0.82
VA	0.63	0.10	1.97	0.36
WA	0.63	0.02	5.42	0.35
WV	0.62	0.05	2.06	0.61
WI	0.78	0.10	2.68	0.77
WY	0.87	0.00	7.35	1.12
Overall	0.67	0.00	7.35	0.71

A.1.2 U.S. TAA series

Figure A.1: Total number of TAA-certified workers in the US



I only use data post-1983 due to the unusual spike in the the data pre-1983. Significant changes in the program pre-1983 are documented in Rosen (2006). In particular, the auto-workers misused the program and the Reagan administration ultimately revamped it.

A.1.3 Population dynamics

To see how population dynamics respond to trade shocks I run the following lagged dependent regression:

$$\text{US pop. share}^{i}_{t+1} = \alpha + \beta \times \text{import pressure}^{i}_{t} + \gamma \times \text{US pop. share}^{i}_{t} + \text{controls}^{i}_{t} + \text{error}^{i}_{t}$$

Using OLS, I obtain the following estimates:

$$\underset{}{\text{US pop. share}^{i}_{t+1} =} \quad \underset{}{\alpha +} \quad \underset{(0.149)}{-0.003 \times \text{import pressure}^{i}_{t}} \quad \underset{(0.007)}{+0.937 \times \text{US pop. share}^{i}_{t}}$$

$$R^2 = \ 0.9997 \qquad\qquad N = 1350$$

A.1.4 Government transfers

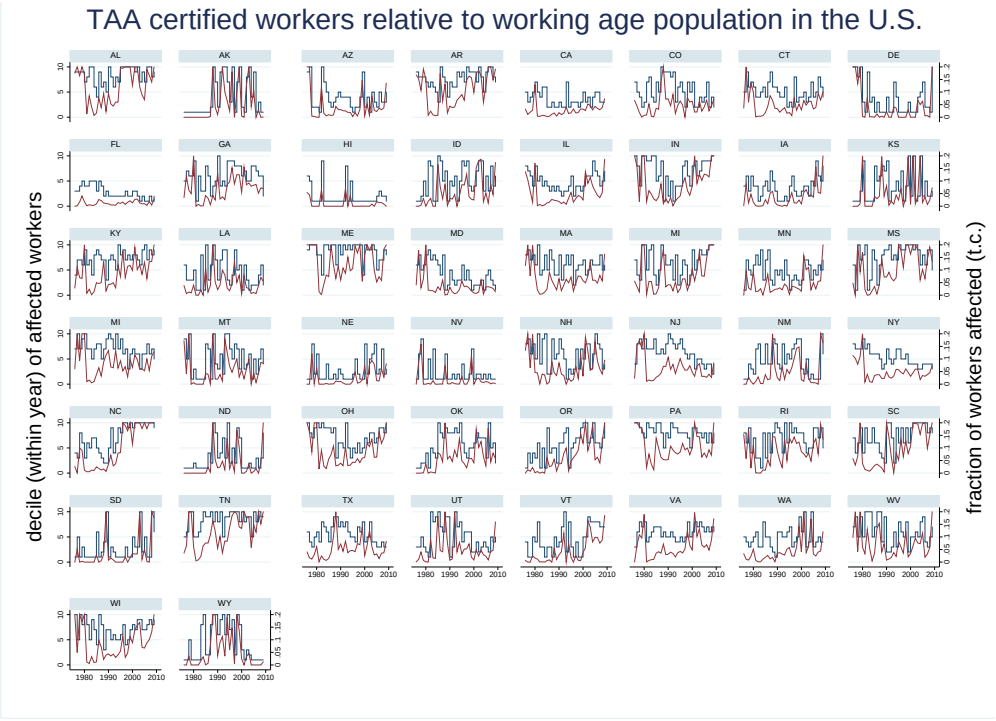
$$\underset{}{\text{govt. transfers}^{i}_{t} =} \quad \underset{}{\alpha +} \quad \underset{(4.715)}{17.52 \times \text{import pressure}^{i}_{t}} \quad + \gamma \cdot \ \text{controls}^{i}_{t} + \ \text{error}^{i}_{t}$$

$$R^2 = \ 0.6658 \qquad\qquad N = 1350$$

In the government transfers regression above, the import pressure was rescaled by 1,000 and therefore expressed in numbers of TAA certified workers displaced per thousand w.a.p. The government transfers variable is the average yearly income received from the government (in 2005$).

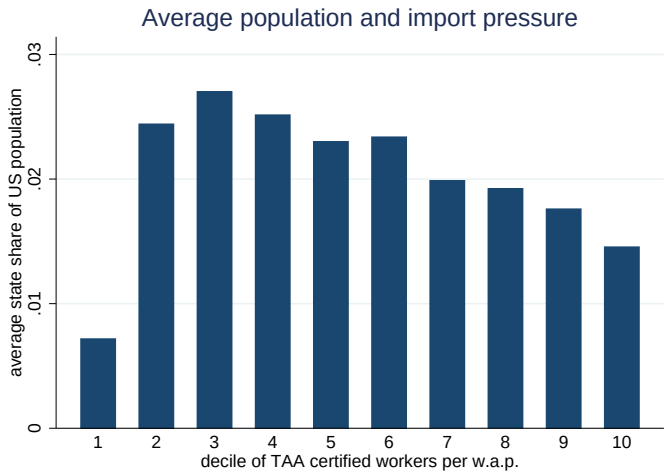
A.1.5 State-level variations in TAA certifications

Figure A.2: Within-year deciles across states of TAA import pressure



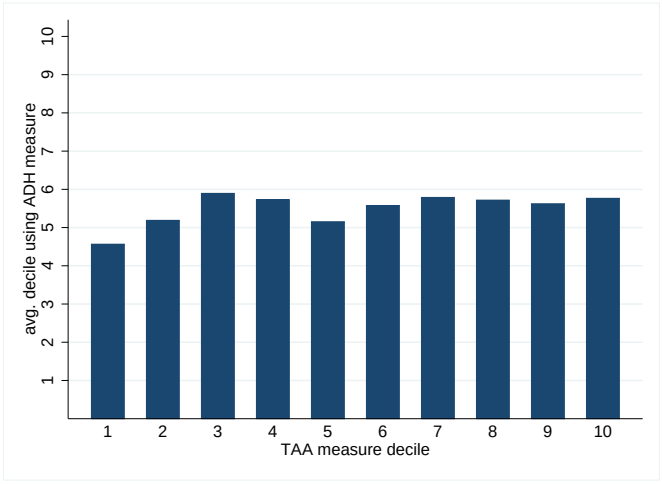
A.1.6 State population and import competition

Figure A.3: State population and import competition



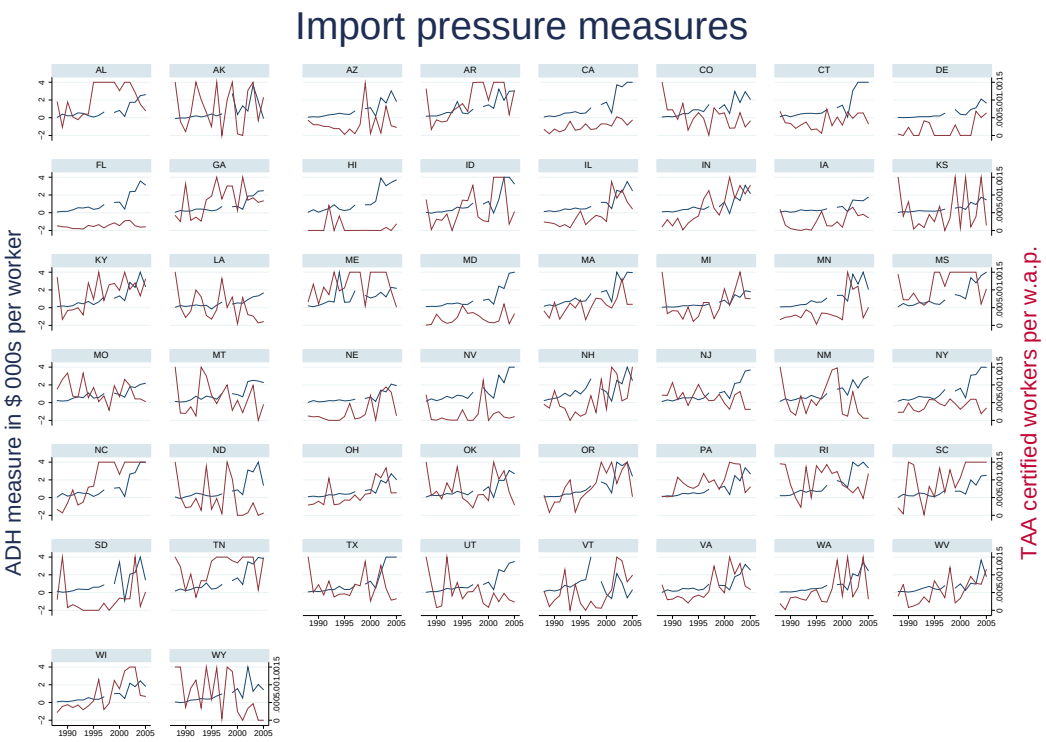
A.1.7 Limited variation in the standard import penetration

Figure A.4: Limited variation in standard import penetration at the state-level



A.1.8 Comparing different measures of import pressure

Figure A.5: Time series of import pressure (1988-1997;1999-2005)



Appendix B

Appendix to Chapter 2

B.1 Table of average ratios by country

Table B.1: Detailed Foreign Reserves

	Average Foreign Reserves to GDP		Average Foreign Reserves to External Debt Liabilities	
	1990-1996	2002-2007	1990-1996	2002-2007
Emerging				
Argentina	4.9	13.5	14.3	21.4
Brazil	4.9	8.6	19.5	35.3
Chile	20.4	16.5	50.9	39.0
China	8.4	33.2	54.3	271.4
Colombia	9.9	10.8	35.6	35.1
Czech Republic	17.4	25.3	57.2	77.5
Egypt	20.9	19.8	35.2	65.5
Hungary	15.5	16.6	26.6	26.2
India	3.5	18.4	11.8	101.0
Indonesia	6.5	12.4	11.7	25.2
Korea	5.4	24.6	28.0	97.4
Malaysia	28.5	47.1	77.0	125.6
Mexico	4.6	8.2	12.2	40.9
Morocco	10.4	28.6	15.9	99.1
Pakistan	1.8	10.4	4.3	28.2
Peru	11.2	18.4	16.7	49.1
Philippines	8.0	17.3	13.3	28.4
Poland	6.9	14.2	15.9	35.8
Romania	4.2	18.5	22.7	53.9
Russia	3.0	23.2	7.3	68.5
South Africa	1.0	7.1	4.7	34.9
Thailand	19.3	30.6	41.8	112.1
Turkey	3.9	10.9	13.0	25.5
Advanced				
France	2.1	1.7	3.9	1.3
Germany	3.8	1.8	8.7	1.5
United Kingdom	3.6	1.9	2.4	0.7
United States	1.0	0.5	3.2	0.8

B.2 Proofs

Proof of Proposition 2.1. The proof involves guessing and verifying an equilibrium that is characterized by the cutoff conditions specified in Proposition 2.1(i) and 2.1(ii). We then derive a condition under which the equilibrium is unique.

The cutoff conditions imply that the state-contingent policy and payment functions can be written as:

$$\begin{aligned}
L(\varphi) &= \begin{cases} 0 & \text{if } \varphi < \varphi_R \\ K & \text{otherwise} \end{cases} \\
R_2(\varphi) &= \begin{cases} R_1 - \varphi D & \text{if } \varphi < \varphi_R \\ 0 & \text{otherwise} \end{cases} \\
\psi_i(\varphi, \varphi_i) &= \begin{cases} 0 & \text{if } \varphi < \varphi_R \text{ and } \varphi_i = 0 \\ 1 & \text{otherwise} \end{cases} \\
P_1(\varphi) &= \begin{cases} D & \text{if } \varphi < \varphi_R \\ (1 + r_S) D & \text{otherwise} \end{cases} \\
P_2(\varphi) &= \begin{cases} (1 + r_N) D & \text{if } \varphi < \varphi_R \\ 0 & \text{otherwise} \end{cases}
\end{aligned}$$

Individual rationality implies that $1 + r_N \geq 1$. Since $\lambda < 1$, we know that $1 + r_N > \frac{R_1 + \lambda K}{D}$. Combining (2.2) and (2.8), we get that $1 + r_S = \frac{R_1 + \lambda K}{D}$.

The participation constraint, holding with equality, can be written as $(1 + r_W) = G(\varphi_R) + (1 + r_N)(F(\varphi_R) - G(\varphi_R)) + (1 - F(\varphi_R))(1 + r_S)$ where $G(x) = \int_0^x \varphi dF(\varphi)$.

Substituting the resource constraints and the condition $\varphi_R = \dfrac{R_1}{D}$, the optimal debt contract problem can be written as:

$$\max_{\varphi_R} D \int_0^{\varphi_R} \left[A(1 - \varphi_R) + \varphi_R - \varphi + (1 - \varphi) \frac{G(\varphi_R) + (1 - F(\varphi_R))(\lambda + (1 - \lambda)\varphi_R) - (1 + r_W)}{F(\varphi_R) - G(\varphi_R)} \right] dF(\varphi)$$

The first order condition is given by:

$$(1 - \varphi_R) f(\varphi_R) + 1 - F(\varphi_R) = \frac{A - 1}{A - \lambda}$$

Using the bounded Pareto distribution, we get:

$$\varphi_R^* = 1 - \left[\frac{A - 1}{A - \lambda} \left(\frac{\sigma}{\sigma + 1} \right) \right]^{\sigma}$$

To verify the equilibrium, it suffices to show that $C^*(\varphi) \geq 0 \ \forall \varphi \in [0, \varphi_R)$. Since $C^*(\varphi)$ is strictly increasing in φ, it suffices to show $C^*(0) \geq 0$.

$$
\begin{aligned}
C^*(0) &= A(1-\varphi_R)+\varphi_R+\left(\frac{G(\varphi_R)+(1-F(\varphi_R))(\lambda+(1-\lambda)\varphi_R)-(1+r_W)}{F(\varphi_R)-G(\varphi_R)}\right)\\
&= \frac{((A(1-\varphi_R)+\varphi_R)(F(\varphi_R)-G(\varphi_R))+G(\varphi_R)+(1-F(\varphi_R))(\lambda+(1-\lambda)\varphi_R)-(1+r_W))}{F(\varphi_R)-G(\varphi_R)}\\
&= \frac{((A-1)(1-\varphi_R)(F(\varphi_R)-G(\varphi_R))+F(\varphi_R)+(1-F(\varphi_R))(\lambda+(1-\lambda)\varphi_R)-(1+r_W))}{F(\varphi_R)-G(\varphi_R)}\\
&= \frac{1}{F(\varphi_R)-G(\varphi_R)}((A-1)(1-\varphi_R)(F(\varphi_R)-G(\varphi_R))-(1-\lambda)(1-\varphi_R)(1-F(\varphi_R))-r_W)\\
&= (A-1)(1-\varphi_R)-\frac{1}{F(\varphi_R)-G(\varphi_R)}((1-\lambda)(1-\varphi_R)(1-F(\varphi_R))+r_W)\\
&= (A-1)(1-\varphi_R)-\frac{\sigma+1}{1-(1-\varphi_R)^{\frac{1}{\sigma}+1}}\left((1-\lambda)(1-\varphi_R)(1-\varphi_R)^{\frac{1}{\sigma}}+r_W\right)\\
&= (A-1)(1-\varphi_R)-\frac{\sigma+1}{1-(1-\varphi_R)^{\frac{1}{\sigma}+1}}\left((1-\lambda)(1-\varphi_R)^{\frac{1}{\sigma}+1}+r_W\right)\\
&= (A-1)\left[\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right]^{\sigma}-\frac{\sigma+1}{1-\left(\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right)^{\sigma+1}}\left((1-\lambda)\left(\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right)^{\sigma+1}+r_W\right)
\end{aligned}
$$

Note that

$$
\lim_{A\to\infty}\left[(A-1)\left[\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right]^{\sigma}-\frac{\sigma+1}{1-\left(\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right)^{\sigma+1}}\left((1-\lambda)\left(\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right)^{\sigma+1}+r_W\right)\right]=+\infty
$$

Hence $\exists A^*(\lambda,\sigma,r_W)$ such that $\forall A\geq A^*$, $C^*(0)\geq 0$. □

Proof of Proposition 2.3. (i) From Proposition 1, we know that

$$
\varphi_R^*=1-\left[\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right]^{\sigma}.
$$

Then,

$$
\begin{aligned}
\frac{\partial\varphi_R^*}{\partial\sigma} &> 0\\
-\left\{\log\left[\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right]+\frac{1}{\sigma+1}\right\}\left[\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right]^{\sigma} &> 0\\
\log\left[\frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)\right]+\frac{1}{\sigma+1} &< 0\\
\log\left[\frac{A-1}{A-\lambda}\right] &< -\left[\log\left(\frac{\sigma}{\sigma+1}\right)+\frac{1}{\sigma+1}\right]
\end{aligned}
$$

It suffices to show $0<-\left[\log\left(\frac{\sigma}{\sigma+1}\right)+\frac{1}{\sigma+1}\right]$, which is true since $h(\sigma)\equiv\log\left(\frac{\sigma}{\sigma+1}\right)+\frac{1}{\sigma+1}$ is increasing in σ, $\lim_{\sigma\to+\infty}h(\sigma)=0^+$, and $\lim_{\sigma\to 0^+}h(\sigma)=-\infty$, which implies that $h(\sigma)<0$ for all $\sigma>0$.

(ii) From Corollary 2.2, we know that

$$\Pr(\psi = 1) = 1 - F(\varphi_R^*)$$

Substituting for φ_R^*, we get

$$\Pr(\psi = 1) = \frac{A-1}{A-\lambda}\left(\frac{\sigma}{\sigma+1}\right)$$

The result is obvious. □

Proof of Corollary 2.4. That $\Pr(\psi = 1 \mid \sigma_H, \varphi_R^*(\sigma_H)) > \Pr(\psi = 1 \mid \sigma_L, \varphi_R^*(\sigma_L))$ follows from Proposition 2.3(ii). That $\Pr(\psi = 1 \mid \sigma_H, \varphi_R^*(\sigma_L)) > \Pr(\psi = 1 \mid \sigma_H, \varphi_R^*(\sigma_H))$ follows from Proposition 2.3(i). □