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Three Essays on Wartime Markets and Production in Economic History

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Three Essays on Wartime Markets and Production in Economic History

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by

Zhihao Xu

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ABSTRACT OF THE DISSERTATION

Three Essays on Wartime Markets and Production in Economic History

by

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Doctor of Philosophy in Economics
University of California, Los Angeles, 2021
Professor Dora Luisa Costa, Chair

This dissertation contributes to our understanding of commodity markets, financial markets, and production during wartime.

Chapter 1 provides a short introduction to multiple channels through which wars affected an economy studied in Chapter 2 to Chapter 4.

Chapter 2 investigates how financial integration impacts price integration in real sectors. Using hand-collected data from a domestic exchange market during the Chinese Civil War (1945-1949), I model the connection between these two integrations measured respectively by capital flow costs (or domestic exchange rates) and relative commodity prices across cities. I use battle shocks to a financial hub in the exchange network to identify the impact of exchange rates on price convergence between a city pair connected to the hub. I find that (1) city pairs with a direct domestic exchange link exhibited faster commodity price convergence than others; (2) battles around financial hubs tended to raise capital flow costs between a connected city pair, decelerating price convergence by 4% - 8%; (3) a weak form of purchasing power parity holds: a 1% depreciation in the domestic exchange rates was associated with a 0.2-0.3 percentage point reduction in inflation rate differentials; and (4) a

higher inflation rate did not impede or strengthen the price convergence channel via domestic exchanges. These results imply that China's financial development was more sophisticated than expected relative to its status as an agricultural economy in the early 20th century.

Chapter 3 studies how bond traders' extreme beliefs of repayments led to bond market anomalies. The conventional valuation model states that the value of a bond is the sum of the present values of its future cash flows. However, the prices of the consolidated government bonds soared up to thousands of times their face values from 1946 to 1948 during the Chinese Civil War. I find that (1) the bond prices anchored the Shanghai wholesale price index amid hyperinflation; (2) the extreme price pattern was primarily explained by the bond traders' evolving belief that the government would repay the bonds with an appropriate multiplier after implementing the Currency Reform; (3) the belief was significantly affected by relevant news about repayment. On a weekly average basis, one more positive news about the Currency Reform will lead to an 8.8 percentage points increase in bond price growth rate, while one additional negative news about the repayment with multipliers will decelerate the growth rate by 8.2 percentage points; and (4) at least before the eve of the Currency Reform, the Shanghai financial markets were not sensitive to political uncertainties resulting from the Civil War.

Chapter 4 builds a two-layer supply chain framework in a static centralized economy to investigate the propagation of a productivity shock across sectors. I show that a productivity shock can be transmitted downstream (from an intermediate goods sector to a final goods sector), upstream, or horizontally (from a final goods sector to another sector). A negative shock incurred by a sector may hurt another sector if they are linked directly, but will always stimulate the production in an indirectly linked sector. Using detailed bombing data and production indices across armament sectors during the Second World War, this chapter investigates whether a shock caused by the Allies' strategic bombing towards Nazi Germany propagated through the production network. The empirical results fit the theoretical model well.

The dissertation of Zhihao Xu is approved.

Nico Voigtländer

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University of California, Los Angeles

2021

To my grandfather, who will be forever in my heart

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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VITA

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CHAPTER 1

Introduction

This dissertation studies commodity markets, financial markets, and production during wartime, which exhibits multiple channels through which wars could affect an economy.

Chapter 2 shows that battles could undermine commodity market integration by impairing the efficacy of a financial network. Specifically, I study a domestic exchange market in China during the Chinese Civil War from 1945 to 1949. The domestic exchange market enabled cross-regional money transfers. A city pair in the domestic exchange network was connected directly (for bilateral clearings) or indirectly via a financial hub city (for multilateral clearings). Since the financial hub was not necessarily on a transportation route for physical goods between the city pair, negative shocks from battles to the hub city were more likely to affect capital flows than trade flows between them. These unique market and geographic features separated the domestic exchange network from the trade network, which provides a channel to investigate whether dysfunction of multilateral clearings in the financial network would impair cross-regional price integration by impeding capital flows. To implement this research design, I first compile a data set of commodity prices and the domestic exchange rates across leading cities from archives. The domestic exchange rates were bounded by currency shipping costs and are thus a good measure of cross-regional capital flow costs. I also document all major battles in the Civil War. Then, I estimate a commodity price convergence model in which a battle risk measure was used as an instrumental variable for the domestic exchange rates. I show that the domestic exchange market provided an efficient channel for price convergence across regions, even in an underdeveloped economy.

City pairs with a direct domestic exchange connection displayed faster commodity price convergence than others. In the financial network, a weaker connection to a financial hub due to battles decelerated the commodity price convergence between two other cities connected to it by 4%-8%. Finally, 1% depreciation in the domestic exchange rate was associated with a 0.2-0.3 percentage point reduction in inflation rate differential.

From another perspective, Chapter 3 shows a very unusual way in which wartime political uncertainties affected a bond market. A bond price puzzle occurred in Shanghai during the Chinese Civil War. Inconsistent with the conventional pricing model, the Consolidated Bond prices from 1946 to 1948 soared up to many times their face value amid the Chinese hyperinflation. On one hand, the real bond value (as a ratio of the original price to the wholesale price index) was generally stationary, which was a partial hedge against the hyperinflation. On the other hand, the real value fluctuated vastly upon the arrival of information about what multiplier the bond would be repaid with. To disentangle the bond anomaly, I propose a hypothesis: if the bond traders' belief of repayment with multipliers takes the price index as a reference, then the growth rate in the deflated bond price increases (decreases) in the arrivals of positive (negative) news about repayment multipliers. This belief is also related to an expectation for the Currency Reform: it was believed that the Chinese government would use a new currency to retire bonds denominated in the old currency like a repayment multiplier. To test the hypothesis, I collect data by hand with regard to (1) newspaper articles about "repayment with multipliers" and the "Currency Reform", (2) detailed information of battles in the Civil War, and (3) daily prices of various financial assets in Shanghai. I then build an empirical model to examine the effect of news about repayment on the asset price growth rates. I find that one more positive news about the Currency Reform per week will lead to an 8.8 percentage points increase in weekly bond price growth rate while one additional negative news about the repayment with multipliers will decelerate the growth by 8.2 percentage points. I also show that up until the Currency Reform was instated, prices of the Consolidated Bonds and other financial assets were not responsive to the influence from battles in the Civil War, which is very different from other studies concerning the effect of political uncertainties on financial markets. However, note that the expectation for the Currency Reform was closely related to the Nationalist Government's financial distress from increasing military expenses and its efforts to control inflation. In some sense, political uncertainties in the Chinese Civil War indirectly generated the bond price puzzle by advancing the Currency Reform.

Finally, Chapter 4 discusses how wartime productions were affected by undermining the supply chains. I build a two-layer production network model in a static centralized economy to investigate the propagation of a productivity shock across sectors. I show that a productivity shock can be transmitted downstream (from an intermediate goods sector to a final goods sector), upstream, or horizontally (from a final goods sector to another sector). A negative shock incurred by a sector may hurt another sector if they are linked directly, but will always stimulate the production in an indirectly-linked sector. Using detailed bombing data and production indices across armament sectors during the Second World War, this chapter investigates whether a shock caused by the Allies' strategic bombing towards Nazi Germany propagated through the production network. The empirical results fit the theoretical model well.

CHAPTER 2

Price Convergence Through a Financial Network: Does Financial Integration Impact Price Integration in Real Sectors?

2.1 Introduction

Financial development matters for real economic activities (King and Levine, 1993), which furthers economic growth (e.g., Black and Strahan, 2002) and impacts international trade (Manova, 2008; Caballero et al., 2018; and Paravisini et al., 2015). Furthermore, increasing international financial integration may lead to an increase in cross-country correlations in both consumption and GDP (Imbs, 2006), and large welfare gains by risk sharing (Colacito and Croce, 2010) and alleviating capital scarcity (Hoxha et al., 2013).

However, the real effects of domestic financial integration have long been understated. It is long assumed that financial markets have been highly integrated in an advanced economy such as the United States since early times. Only recently has more research attention been cast on US banking integrations between the late 1970s and mid-1990s due to deregulation. These domestic financial integrations expanded interstate trade by 17%-25% (Michalski and Ors, 2012), explained up to one-fourth of the rise in cross-state house price correlation (Landier et al., 2017), and increased output synchronization across states by 13% of its standard deviation (Goetz and Gozzi, 2019). For developing countries where these effects may be greater, a lack of data has discouraged similar investigations.

Using newly hand-collected data, I examine the impact of financial integration on the price co-movement in real sectors in an underdeveloped economy. Specifically, I study a domestic exchange market in China during the Chinese Civil War (hereinafter referred to as "the Civil War") from 1945 to 1949. In this chapter, financial integration is measured by capital flow costs or domestic exchange rates (explained later), and price co-movement/integration is measured by convergence rate in commodity price differentials across regions. The domestic exchange market enabled cross-regional money transfers. Any city pair in the domestic exchange network was connected directly (for bilateral transactions) or indirectly via a financial hub city (for multilateral transactions). Since the financial hub was not necessarily on a transportation route for physical goods between the city pair, negative shocks to the hub city were more likely to affect capital flows than trade flows between them. These unique market and geographic features separated the domestic exchange network from the trade network, which provides a channel to investigate whether dysfunction in the financial network would impair cross-regional price integration by impeding capital flows.

To implement this research design, I first compile a dataset of commodity prices and the domestic exchange rates across leading cities from numerous archives by hand collection and digitization. The domestic exchange rates (or their premium/discount percentages) reflected relative money demand between cities. They were bounded by currency shipping costs and thus a good measure of cross-regional capital flow costs. The commodity prices are further used to construct a cross-city inflation rate panel with a weighted average method. I then document the detailed information of all major battles in the Civil War. Furthermore, the domestic exchange networks are recovered according to Ma (2013) and Ma (2016), and my data collection from historical newspapers. To resolve the simultaneity issue between cross-city price gaps and domestic exchange rates, I create a war risk measure as an instrumental variable for the exchange rates. The war risk measure identifies the network effect: battles around a financial hub undermined the channel of multilateral clearings between the hub and a connected city pair, thus raising the absolute premium in the exchange rates. This change impeded the capital flows between the city pair and decelerated the price convergence accordingly.

The main findings and contributions of this paper are fourfold. First, I show that the domestic exchange market provided an efficient channel for price convergence across regions, even in an underdeveloped economy with political uncertainty. During the Civil War, any pair of cities with a direct domestic exchange connection exhibited faster commodity price convergence (a half-life of 22.17 days) than those making payments only via a financial hub (23.73 days). These half-lives are much smaller than studies on other countries or in other periods, such as approximately 9 years in the United States (Cecchetti et al., 2002), 3-6 weeks in Mexico (Elberg, 2016), and on average 2.35 months in China during the late 1990s (Fan and Wei, 2006). This paper makes quantitative contributions to a strand of literature that investigates the institutional role and efficacy of the domestic exchange market before the introduction of the central banking system (Garbade and Silber, 1979; Bodenhorn, 1992; Phillips and Cutler, 1998; Knodell, 1998; and James and Weiman, 2010).

Second, in the domestic exchange network, a weaker connection to a financial hub due to battles decelerated the commodity price convergence between two other cities connected to it by 4%-8%. This result contributes to the research on market integration (Shiue, 2002; Jacks, 2006; Ejrnæs and Persson, 2010; and Hynes et al., 2012) with the implication that a financial system could play an essential role in leading market integration in addition to the influences from information and transport technology, institutional barriers to trade, geography, and monetary regimes.

Third, this paper applies the classical theory of purchasing power parity (PPP) to a domestic case: I show that 1% depreciation in the domestic exchange rate was associated with a 0.2-0.3 percentage point reduction in inflation rate differential. Numerous studies have tested multiple forms of PPP across countries using different currencies in both long term and short term (Adler and Lehmann, 1983; Krugman, 1978; Abuaf and Jorion, 1990; and

Rogoff, 1996). Other studies have also examined across countries using the same currency like in a monetary union (Rogers, 2007 and Égert, 2007). However, when it turns to an intra-national case, most studies view "nominal exchange rates" as one across regions due to their unawareness of domestic exchange rates. Therefore, this paper is the first to confirm that a weak form of PPP existed between domestic exchange rates and cross-regional prices, to the best of my knowledge.

Finally, this paper is related to studies on China's economy with regard to domestic financial integration (Keller et al., 2015 and Ma and Zhao, 2020) and its integration with the rest of the world (Jacks et al., 2017 and Zhao and Zhao, 2018). While Keller et al. (2015) show that China's capital market was much less efficient than Britain's in the 18th and 19th centuries, my work, similar to Ma and Zhao (2020), reveals that the evolution in China's financial system developed more than expected relative to its status as an agricultural economy no later than the early twentieth century. As noted in Gat (2008), China's world share of GDP (32.9%) in 1820 was much higher than that (8.9%) in 1913. The great contrast between financial advance and economic falling-behind would motivate a revisit on what was the main driving force of China-West divergence.

The remainder of this chapter is organized as follows. Section 2.2 provides the historical background of the domestic exchange market and the Chinese Civil War. Section 2.3 describes the data collection process and provides summary statistics. Section 2.4 describes the research design. Section 2.5 presents the main results of commodity price convergence. Section 2.6 examines whether the classical PPP theory could be applied to the domestic exchange rates scenario. Section 2.7 provides some robustness tests. Section 2.8 concludes my findings.

2.2 Historical Background

This section introduces domestic exchange and domestic exchange market and explains the importance of the Chinese Civil War period for the research setting.

2.2.1 Domestic Exchange

Just as foreign exchange is used to tender payments internationally, domestic exchange was used to transfer money inter-regionally (Garbade and Silber, 1979). Buyers could purchase domestic exchanges in one location to make payments or receive money in another while exchange sellers would take charge of currency shipping after all settlements. The *domestic exchange rate* was quoted as a price (or premium/discount) of each payment in amount of 1000 *yuan* in China (or $1,000 payment in the United States). For example, a rate termed as "1,000.25 *yuan* (25 cents premium) *in* Peiping[1] *on* Tientsin" means that an additional 25 cents must be paid to transfer 1,000 *yuan* from Peiping to Tientsin. Similarly, a rate of "$999.25 (75 cents discount) *in* Boston *on* Philadelphia" was to charge 75 cents below par for a $1,000 payment from Boston to Philadelphia.

The "fluctuations in these rates were influenced by relative differences in economic activity and bounded by the cost of shipping gold (currency)" (Phillips and Cutler, 1998). In other words, the domestic exchange rate or its absolute value measures currency shipping cost, indicating how fast capital flows across regions. Since these statements are relevant to the research idea, I will illustrate them in section 2.4.1.

[1] According with the archives, Chinese places and some old Chinese names frequently used in English in this dissertation are given in Postal Romanization. Other Chinese characters are given in Hanyu Pinyin. For example, *Peiping* rather than *Beiping* refers to the "北平" in Chinese characters.

2.2.2 Domestic Exchange Market

In the domestic exchange network, any two cities were linked to each other directly or indirectly. A direct link between two cities indicates that bilateral payments or trading in domestic exchanges existed, while an indirect link means multilateral payments were formed among these two cities and at least another hub city. Note that for a city pair, an existing direct link did not necessarily exclude in-between indirect links. Illustrative examples are shown in Figure 2.1. Since the indirect links between two cities provided an additional channel of capital flows between two cities besides the direct link (if any), they would affect the domestic exchange rates as well, which will also be explained in subsection 2.4.

Now a historical term in economics, the domestic exchange market once played an important role as an inter-regional payment system in the pre-central banking era. "Exchange rates between cities within the United States[2] existed during the nineteenth century and the first two decades of the twentieth" (Garbade and Silber, 1979). In contrast, as an underdeveloped country, contemporary China developed its domestic exchange market in the early twentieth century. The market prospered in the 1930s and the 1940s and disappeared around 1951 when China began its centrally planned economy. Figure 2.2 and Figure 2.3 display the domestic exchange network in China during the 1920s–1930s and the Civil War period of 1945-1949, respectively. In both figures, each black edge connecting a city pair indicates an in-between direct link. The direct links in the 1920s-1930s are recovered based on two Chinese works, Ma (2016) and Ma (2016), and those links during 1945-1949 are set if corresponding domestic exchange rates were reported in contemporary newspapers. Among all cities, Shanghai, Hankow, Tientsin, and Chungking were the largest financial hubs with the most direct links.

[2] The Federal Reserve System was created on December 23, 1913, in the United States.

2.2.3 The Chinese Civil War Period

The Chinese Civil War was a civil war fought between the Kuomingtang (hereinafter referred to as "KMT")-led government of the Republic of China and forces of the Communist Party of China (hereinafter referred to as "CPC") lasting between 1945 and 1950. Its main phase ended after CPC established the People's Republic of China on October 1, 1949. The Civil War period manifested two main features: hyperinflation and countless battles. Both are crucial to the research design because they provide variations and identification.

2.2.3.1 Hyperinflation

The Civil War was accompanied by enormous hyperinflation in China. Based on price data of 22 kinds of commodities in the Chungking city[3], the general price level rose by 3,092,332,200% from January 1946 to April 1949. According to my calculation (see Table 2.2), 20 leading cities on average experienced a 1.6% daily inflation rate. To fight against inflation, China implemented a currency reform on August 19, 1948[4]. The hyperinflation, however, worsened after the reform. The daily inflation rate was on average 7.14% after August 19, 1948 compared to 1.02% before that day.

The hyperinflation provides an opportunity to observe dramatic and highly frequent changes in both cross-city prices of individual goods and general price levels within a relatively short time (less than four years). These variations are necessary for estimating price convergence rates. Moreover, currency reform can also be used for robustness tests in future work.

There is another subsection 3.2.2 discussing Chinese hyperinflation in more details because it has more relevance in Chapter 3 of this dissertation.

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[3] The temporary capital city of the Republic of China from September 6, 1940 to May 5, 1946.

[4] A new currency, Gold Yuan Certificate, was issued to replace the old currency, Fabi. The replacement rate was 1 unit of Gold Yuan for 3 million units of Fabi.

2.2.3.2 Battles

Since the Civil War first broke out in the north of China, most of the major battles occurred north to the Yangtze River before 1949. Figure 2.4 shows the geographical and temporal distribution of major battles from October 1945 to April 1949. Battles were very heterogeneous: some severely blocked the transportation routes between cities while others took place in rural areas. Due to CPC's military strategy[5], leading cities were not attacked on purpose, so major battles were thereby reviewed as exogenous shocks. In particular, the effect of battles on a hub city was exogenous to the direct economic connection between two other cities in the domestic exchange network. Therefore, I will use some battle measure as an instrumental variable in section 2.4.

2.3 Data

To measure cross-city price convergence and the effect of battles, I hand-collected and digitized sheets from multiple forms of numerous archives. I compiled a novel data set of commodity prices and domestic exchange rates across leading cities in China with information on all major battles during its Civil War period. This section documents the data collection process and describes the data collected.

2.3.1 Cross-City Prices, Exchange Rates, and Battle Information

All sheets containing commodity prices and domestic exchange rates are stored in historical archives. The main sources are the *Financial Weekly*[6] and the *Credit News*[7]. Some of the

[5]The CPC's military strategy: (1) to eliminate KMT's troops was the primary goal; (2) first to occupy rural areas, then to capture small towns, and finally to attack large cities.

[6]An internal periodical published by the Central Bank of the Republic of China, also used as a main source in Section 3.4 of Chapter 3.

[7]A newspaper published by the Agency of the Credit and Statistics

sheets are in the electronic (scanned) version, some of them are in paper version, but most are stored as microfilm slides in the National Library of China. Figure 2.5 and Figure 2.6 show a sample sheet from a microfilm archive and how I used the projector to collect it.

In total, I collected the daily prices of 6 commodities (coal, rice, wheat, oil, cotton, and cotton yarn) and domestic exchange rates across 20 leading cities[8], with the longest span from December 17, 1945 to April 26, 1949. Based on the cross-city commodity prices, I constructed a cross-city daily inflation rate panel, which will be discussed later in subsection 2.3.2. I will use inflation rates across regions to test purchasing power parity within China.

I also collected information on major battles from *The History of the Chinese People's Liberation Army (1945-1949).* The battle information includes battle size, casualty, location (area), and duration. In total, 104 major battles from September 1945 to April 1949 are compiled as a panel based on which I construct two measures of war risk in subsection 2.4.3.

2.3.2 Construction of Cross-City Inflation Rate

Generally, the archives do not include data of cross-regional inflation rates. The contemporary Nationalist government constructed inflation rates (price indices), but only for a few cities such as Shanghai and Chungking. The Research Department, the Central Bank of the Republic of China adopted a *Weighted Average Method* to calculate the inflation rate:

$$\pi_t \approx \log \frac{P_t}{P_{t-1}} \triangleq \frac{\sum_k [w^k \cdot \log(\frac{p_t^k}{p_{t-1}^k})]}{\sum_k w^k} \approx \frac{\sum_k [w^k \cdot \frac{(p_t^k - p_{t-1}^k)}{p_{t-1}^k}]}{\sum_k w^k} = \frac{\sum_k (w^k \cdot \sigma_t^i)}{\sum_k w^k} \tag{2.1}$$

where π represents the inflation rate, P denotes the price index, p^k is the price of commodity k, w^k is a weight assigned to commodity k, and σ^i is the price change rate of commodity k. Table 2.1 shows the weights (add up to 100%) assigned to 22 categories of commodities

[8]They are Canton, Chengtu, Chungking, Foochow, Hankow, Hsuchow, Kaifeng, Kunming, Kweilin, Kweiyang, Lanchow, Nanchang, Nanking, Ningpo, Shanghai, Sian, Peiping, Tientsin, Tsinan, and Tsingtao with 11 in the south and 9 in the north of China.

adopted by the Central Bank. Most of the commodities included in Table 2.1 are agricultural goods, which implies that contemporary China was an underdeveloped agricultural economy.

Accordingly, I apply their method and weights to construct an inflation rate panel of all 20 leading cities. Due to data availability, I can only use the five (coal, rice, wheat, oil, and cotton) of the 22 categories. However, those commodities are all agricultural goods, and as marked in red in Table 2.1, their weights add up to 62.8%, which is a good representation of the general price level.

2.3.3 Descriptive Statistics

The domestic exchange rates and commodity prices varied much across cities and fluctuated dramatically as the war continued. Table 2.2 display the summary statistics of commodity prices and domestic exchange rates, respectively.

To exclude systemic noises from hyperinflation, the price of each commodity is reported as a log difference at the city-pair level, or a log relative price. Intuitively, if it is easy to transport some good, the cross-regional price gap is small. On average, cotton yarn displays the smallest price gap (0.162), while the log relative price of coal was greatest (0.942).

Domestic exchange rates and their absolute values are an indicator of currency shipping costs, which are reported as a premium/discount percentage (hereinafter quoted in this format). A mean of premium (absolute premium) at 3.0% (resp. 5.9%) with a standard deviation of 9.1% (resp. 7.6%) indicates a much higher capital flow cost in China than that in the United States. The United States scarcely experienced a premium over 0.1% and a standard deviation over 0.04% (Garbade and Silber, 1979). Table 2.2 also shows very high (a mean of 1.6%) and volatile (a standard deviation of 7.6%) cross-city daily inflation rates.

The price data features a positive correlation between capital flow costs and commodity relative price. As shown in Figure 2.7, except for the case of coal, a higher capital flow cost between a city pair generally indicates a greater in-between commodity price gap. This basic correlation motivates a formal model regarding the impact of capital flow costs on cross-regional price convergence in the next section.

The battle information is summarized in Table 2.3. A battle of average size lasted around three weeks, with around 36,000 soldiers involved and resulting in 9,300 casualties. The battle influence on each city could be heterogeneous since half of the leading cities were in the south. The average distance to the front was approximately 937 kilometers (with a standard deviation of 483 kilometers).

Another important feature contained in Table 2.2 and Table 2.3 concerns a time trend. Apparently, most price and battle variables display a much larger value in post-reform period than in pre-reform period, indicating that the financial system and real sectors were more sensitive to a high political uncertainty towards the late stage of the Civil War.

2.4 Research Design

This section describes the research design and how to implement it in detail. Two properties of the domestic exchange rates are linked to relevant empirical specification and identification.

2.4.1 Properties of Domestic Exchange Rates

Remark 1 *Fluctuations in domestic exchange rates were influenced by relative differences in economic activity and bounded by the cost of shipping gold (currency).*

This remark was earlier claimed by Phillips and Cutler (1998). I will informally prove the second part of this remark and illustrate the first part by an example.

The second part: consider an exchange buyer who wants to transfer \$1,000 from location A to location B. He can either purchase a domestic exchange on New York at a rate DR, or ship the money by himself at a cost C per \$1,000. Therefore, DR must be no more than

$1,000+C$. Similarly, an exchange seller will never sell it for $DR < 1,000 - C$ since then he would rather fulfill the currency shipping obligation incurring C.

The first part: for a trading period of T, no matter how many transactions occur, there are only two directions of money flows between locations A and B. If the domestic exchanges in A on B add up to x dollars, and the exchanges in B on A sum up to y dollars, suppose $x > y$, then apparently, only $x - y$ dollars of currency will be finally shipped. Thus a price in $[1000 + \frac{x-y}{x} \cdot C, 1000 + C]$ is acceptable for a seller of exchanges in A on B, and similarly, a price in $[1000 - \frac{x-y}{x} \cdot C, 1000]$ is acceptable for a seller of exchanges in B on A. Therefore, more imbalance in domestic exchange transactions will be more likely to generate a high rate in A on B, and a lower rate in B on A.

For more illustration, see another example in Figure 2.8

Remark 2 *For two locations A and B with direct domestic exchange trading, a new location C connecting to them will decrease the fluctuation range of the exchange rates between A and B due to a reduction in shipping costs.*

Since a new location C connecting to A and B will generate multilateral payments among them. After settlement, currency was shipped via the cheapest routes among A, B, and C.

For more illustration, see another example in Figure 2.9

2.4.2 Main specification

Inspired by Elberg (2016), I am interested in how a change in the domestic exchange rate affected the cross-city price convergence. Consider a general specification of convergence:

$$\Delta P_{c,t} = \underbrace{\beta}_{\text{auto convergence trend}} \cdot P_{c,t-1} + \Gamma_0 \cdot X_{c,t} + \underbrace{\Gamma_1 \cdot X_{c,t}}_{\text{shifts in convergence trend}} \cdot P_{c,t-1} + Lags + FEs + \varepsilon_{c,t} \tag{2.2}$$

In the above equation, the output variable is $\Delta P_{c,t} = P_{c,t} - P_{c,t-1}$,where $P_{c,t}$ is the price differential $P_t^i - P_t^j$ between a city pair $c(i,j)$ at time t. $X_{c,t}$ is a vector of controls that may influence convergence rate. FE represents a variety of fixed effect. Finally, $Lags$ represents a bundle of lagged terms[9] of $\Delta P_{c,t}$.

Suppose $P_{c,t}$ is a stationary sequence. Its half-life represents the time it takes $P_{c,t}$ to decay from some initial value $\widehat{P}$ to its half value $\frac{1}{2}\widehat{P}$. In the above equation, without any other factors, $P_{c,t}$ would converge by itself with a convergence rate of $(1+\beta)$. This implies a half-life of $-\ln(2)/\ln(\beta+1)$. Please note that a higher convergence speed is equivalent to a lower convergence rate or a shorter half-life. For the details of the half-life, please check Subsection 2.A.2 in the appendices.

Taking into account all the covariates, $P_{c,t}$ converges with a rate of $(1+\beta+\Gamma_1 \cdot X_{c,t-1})$, or a half life of $-\ln(2)/\ln(\beta+\Gamma_1 \cdot X_{c,t-1}+1)$.

2.4.3 Identification

A simple intuition is that money in the domestic exchange market flowing from one city of high (low) price levels to another city of low (high) price levels would promote (discourage) in-between price convergence. However, according to Remark 1, the domestic exchange rates between a city pair reflected both the relative economic activity (imbalance in capital flows/relative money demand) and currency shipping costs. These two factors influenced the demand and supply in the domestic exchange market, respectively. Since trading volume data is not available, there is an ambiguity of how capital flows changed if a higher domestic exchange rate appeared. Furthermore, a common simultaneity issue also occurs: cross-city price differentials and domestic exchanges of the same period were determined simultaneously.

To resolve these issues, recall that in Remark 2, the currency shipping costs (or absolute value of the premium) in domestic exchange transactions between a city pair $c(i,j)$ would be likely to decrease by connecting to another hub city h, and so would the rate fluctuation

[9] I choose the order of lagged terms based on Elberg (2016) and Cecchetti et al. (2002).

range. In other words, disconnecting from the hub city h was more likely to lead to a higher absolute premium in exchange rate between i and j. Therefore, battles around a hub city, a supply shifter, can be used as an instrumental variable to identify the effect of domestic exchange.

The construction of battle instruments depends on the following logic. First, a threat from battles around a hub h impeded the indirect channel of capital flows between i and j via h. Second, if close to h but far from i and j, a battle was not likely to affect economic activities, especially trade flows within i and j as long as h was not a pivot right on their transportation route between i and j .Third, weakened capital flows decelerate price convergence between i and j. Please note that the second point is a key identifying assumption to be tested afterwards.

Accordingly, I create a measure of indirect war risk. It is the war risk to a city pair $c(i,j)$ indirectly via all connected hub cities. The construction is as follows: (1) for a city pair $c(i,j)$ with domestic exchange rates, find all the hub cities directly connected to both i and j; (2) for any hub $h(c)$, calculate the average influence from ongoing battles at time t as:

$$battle_{h,t} = \sum_{b(t)} \frac{\text{casualty}_{b(t)}}{\text{distance}_{b(t),h}} \tag{2.3}$$

where $b(t)$ represents some ongoing battle, $\text{casualty}_{b(t)}$ represents the casualty in battle $b(t)$, and $\text{distance}_{b(t),h}$ represents the distance between $h(c)$ and $b(t)$; apparently, $battle_{h,t}$ puts more weight on a battle if it was severe or close to h; (3) finally, $IW_{c,t}$ the indirect war risk to $c(i,j)$ at time t via all connected hubs. In other words, $IW_{c,t}$ is the sum of $battle_{h,t}$ over all $h(c)$:

$$IW_{c,t} = \sum_{h(c)} battle_{h,t} \tag{2.4}$$

To test the identifying assumptions stated above, I also create a measure of war risk confronting a city pair directly. For city i in a city pair $c(i,j)$,

$$battle_{i,t} = \sum_{b(t)} \frac{\text{casualty}_{b(t)}}{\text{distance}_{b(t),i}} \tag{2.5}$$

where $b(t)$ represents some ongoing battle, casualty$_{b(t)}$ represents the casualty in battle $b(t)$, and distance$_{b(t),i}$ represents the distance between i and $b(t)$; finally, the direct war risk targeting $c(i,j)$ at time t is $DW_{c,t}$.

$$DW_{c,t} = battle_{i,t} + battle_{j,t} \tag{2.6}$$

Should hypotheses be true, whereby indirect war risks $IW_{c,t}$ affected price convergence but direct war risk $DW_{c,t}$ did not, then the domestic exchange market is indeed a meaningful channel for price integration across regions.

2.5 Commodity Price Convergence

This section focuses cross-city commodity price convergence. Accordingly, the variable $P_{c,t}$ in Equation 2.2 switches to log commodity price differentials (for eliminating hyperinflation noise): $p_{k,c,t} = \log(p^i_{k,t}) - \log(p^j_{k,t})$ for a city pair $c(i,j)$ at time t, where $p^i_{k,t}$ is the (level) price of commodity k in city i. As in subsection 2.4.2, cross-city price gaps had its own convergence pattern, the following results thereby show which factors influenced the pattern.

2.5.1 The Effect of Direct/Indirect Domestic Exchange Links

I first study the effect of direct/indirect links in the domestic exchange network without exchange rate data. The direct link is defined in subsection 2.2.2. The specification is adjusted accordingly:

$$\Delta p_{k,c,t} = \beta p_{k,c,t-1} + \beta_1 \cdot DL_c \cdot p_{k,c,t-1} + \beta_2 \cdot DIS_c \cdot p_{k,c,t-1} + FEs + \varepsilon_{c,t} \tag{2.7}$$

where $DL_c = 1$ if a direct link existed between a city pair c. DIS_c is the distance between a city pair c. FEs represents a variety of fixed effects.

Three hypotheses are (1) cities far from each other exhibited a slower (with a positive coefficient) convergence in commodity prices for a higher trade cost; (2) a direct link between a city pair allowed faster capital flows, and thus, a faster in-between price convergence speed; and (3) the price convergence between two cities was slower if more hubs (links) were needed to connect them.

Table 2.4 shows the effect of direct links during 1945-1949. On average, the convergence rate changed by -0.003 due to a direct domestic exchange link. In other words, city pairs had a shorter half-life of 22.17 days compared to 23.73 days in those only with an indirect link. Table 2.5 shows that if it takes an additional hub/link to connect a city pair then in-between convergence rate would be changed by +0.004. Finally, using the domestic exchange links in the 1920s-1930s as an instrument for those links during the Civil War, Table 2.6 confirms the accelerating impact of direct links.

2.5.2 The Effect of Domestic Exchange Rates

The main results of this chapter are related to the effect of domestic exchange rates on price convergence. As a measure of capital flow costs across cities, the absolute value of domestic exchange rates is the main factor of interest. The specification is as follows:

$$\Delta p_{k,c,t} = \beta p_{k,c,t-1} + \gamma_0 \cdot |DR_{c,t-1}| + \gamma_1 \cdot |DR_{c,t-1}| \cdot p_{k,c,t-1} + Controls + Lags + FEs + \varepsilon_{c,t} \quad (2.8)$$

where $|DR_{c,t}|$ is the absolute value of premium percentage in domestic exchange rate between a city pair c (in city i on city j). $Controls$ represents a vector of control variables that may influence convergence rate. FEs represents a variety of fixed effects. Finally, $Lags$ represents a bundle of lagged terms[10] of $\Delta p_{k,c,t}$.

Two expectations are (1) the linear term $|DR_{c,t-1}|$ would not affect price convergence because it is only an add-on to the price gap; (2) the interaction term $|DR_{c,t-1}| \cdot p_{k,c,t-1}$ should have a decelerating impact (or a positive coefficient) on $\Delta p_{k,c,t}$ since a higher value in $|DR_{c,t-1}|$ indicates a raised currency shipping cost, thus impeding price convergence. The results in Table 2.8 are consistent with these expectations. A coefficient of 0.028-0.041

[10] I choose the order of lagged terms based on Elberg (2016) and Cecchetti et al. (2002).

combined with a mean of 6% in $|DR_{c,t-1}|$ implies that capital flow costs in the domestic exchange market on average decelerated the commodity price convergence across regions by 4%-8%.

To test the identifying assumption that battles surrounding financial hubs did not affect the trade flows between a connected city pair, I add the direct war risks, $DW_{c,t}$, into Equation 2.8, and the results in Table 2.9 almost stay the same as in Table 2.8 except the insignificant coefficients of $DW_{c,t}$ terms as expected.

2.5.3 IV Results

A change in today's domestic exchange reflects a change in capital flows in a city pair, thereby affecting the convergence pattern in price gaps from yesterday to today. However, the simultaneity issue occurs between the rates and gaps in the same period. The solution to endogeneity is to use the war risk instrumental variable described in Equation 2.4 for domestic exchange rates (capital flow costs). Battles around a hub city impeded the capital flows between a city pair by increasing currency shipping costs (thus raising the absolute premium in exchange rates). Since the financial hub was not necessarily a trading pivot, the effect of a financial network in terms of capital flows are separated from that of a trade network in terms of goods flows.

Table 2.10 and Table 2.11 display the IV results without and with exclusion controls for identification, respectively. Generally, the IV results strengthen the impact of domestic exchange rates. With direct war risk measure (exclusion condition) controlled, the effect is more significant.

2.6 The Purchasing Powerful Parity

This section observes from another perspective the association between cross-city price gaps and domestic exchange rates: the Purchasing Power Parity (PPP).

The classical PPP theory links general price levels of two countries to the exchange rate of their currencies without frictions:

$$e_{A/B} = \frac{\text{Price Level in A}}{\text{Price Level in B}} \tag{2.9}$$

where $e_{A/B}$, the nominal exchange rate, represents how many units of A's currency one unit of B's currency switches to.

A similar hypothesis in this research is that the relative price ratio of two regions in a country equals the domestic exchange rates without frictions. Let $DR_{c,t}$ denote domestic exchange rate (in i on j) in terms of city pair $c(i,j)$, and $P_{i,t}$ and $P_{j,t}$ be price levels at city i and j at time t. An absolute form of the (domestic) PPP is thus:

$$DR_{c,t} = \frac{P_{i,t}}{P_{j,t}} \tag{2.10}$$

Remember that I do not directly construct price indices across cities, but base-year basket costs can be absorbed by the city-pair fixed effect so I can turn to a relative form of PPP:

$$\%\Delta \text{ in } DR_{c,t} \approx \log(\frac{DR_{c,t}}{DR_{c,t-1}}) = \log(\frac{P_{i,t}}{P_{i,t-1}}) - \log(\frac{P_{j,t}}{P_{j,t-1}}) \approx \pi_{i,t} - \pi_{j,t} = \Pi_{c,t} \tag{2.11}$$

where $\%\Delta$ means percentage change (change rate), $\pi_{i,t}$ and $\pi_{j,t}$ denote city i and $j's$ inflation rates, and $\Pi_{c,t}$ represents the inflation rate differential between city pair $c(i,j)$.

Alternatively, I will test an even weaker form of PPP, a proportional relationship between the change rates of domestic exchange rate and cross-city inflation rate differentials:

$$\%\Delta \text{ in } DR_{c,t} \propto \Pi_{c,t} \tag{2.12}$$

with the following empirical specification:

$$\Pi_{c,t} = \theta_0 \cdot \Pi_{c,t-1} + \theta_1 \cdot (\%\Delta \text{ in } DR_{c,t}) + \theta_2 \cdot (\%\Delta \text{ in } DR_{c,t-1}) + FEs + \varepsilon_{c,t} \tag{2.13}$$

If this weak form of PPP holds, θ_1 or θ_2 should be significantly positive.Table 2.13 confirms this relationship. Column (1) is the main specification, while column (2), (3), and (4) control for lagged terms. On average, 1% depreciation in the domestic exchange rate is significantly associated with a 0.2-0.3 percentage point reduction in inflation rate differential.

2.7 Robustness Tests

2.7.1 The Effect of the Currency Reform

There is a concern that hyperinflation itself rather than domestic exchange market played a crucial role in promoting cross-regional price convergence. Intuitively, in an economy of highly monetary uncertainty, people may be more risk averse in cross-regional transactions because price changes too frequently for accurate accounting over the goods' transportation time. Therefore, price integration is supposed to be slow during the hyperinflation period. This subsection partially resolves the concern by examining the effect of the Currency Reform on price convergence.

As stated in background section, the Nationalist government implemented the Currency Reform on August 19, 1948 to fight against inflation. However, the Reform failed: the daily inflation rate was on average 7.1% in the post-Reform period compared to 1.0% before August 19, 1948. As people could not anticipate the implementation date, the Reform provided a natural experiment on the impact of raised inflation rates on price convergence.

The interaction terms with a Reform dummy displayed insignificant impacts on both the influence of domestic exchange rates and the distance on price convergence, as shown in

Table 2.14. This result implies that a higher inflation rate did not impede or strengthen the price convergence channel via domestic exchange markets.

2.7.2 Alternative Measures of Capital Flow Costs

Besides the absolute value of premium in domestic exchange rate, the subsection provides three alternative measures of capital flow costs as referenced by Garbade and Silber (1979): (1) a 6-day moving average of the absolute premium in domestic exchange rates, $\underset{\widehat{t}\in[t,t-5]}{mean}|DR_{c,\widehat{t}}|$; (2) the max value of the absolute premium over the past 6 days, $\max_{\widehat{t}\in[t,t-5]}|DR_{c,\widehat{t}}|$; or (3) the standard deviation of the absolute premium over the past 6 days, $\underset{\widehat{t}\in[t,t-5]}{std.}(DR_{c,\widehat{t}})$. Generally, as shown in Table 2.15 and Table 2.16, the effect of domestic exchanges is robust to different measures of capital flow costs.

2.7.3 City-Pair Heterogeneous Convergence

Further robustness concerns are whether with heterogeneous auto-convergence rates across city pairs, capital flow costs in terms of domestic exchanges would still alter convergence trends. In this sense, a specification with heterogeneous auto trend is:

$$\Delta p_{k,c,t} = \beta_c \cdot p_{k,c,t-1} + \gamma_0 \cdot |DR_{c,t-1}| + \gamma_1 \cdot |DR_{c,t-1}| \cdot p_{k,c,t-1} + controls + Lags + FEs + \varepsilon_{c,t} \quad (2.14)$$

where β_c represents a city-pair specific auto-convergence rate. Results in Table 2.17 show that the coefficients of interaction term (of capital flow costs) are comparable to those in Table 2.8 and Table 2.9. This implies the effect of domestic exchange rate is robust to heterogeneous convergence setting.

2.8 Conclusion

This chapter shows that the wartime domestic exchange market provided a meaningful channel for price convergence across regions. First, city pairs with a direct link exhibited faster commodity price convergence (a half-life of 22.17 days) than others (23.73 days). Second, in the domestic exchange network, a weaker connection to a financial hub due to battles decelerated the commodity price convergence between two other cities connected to it by 4%-8%. Since the financial hub was not necessarily a trading pivot, the effect of a financial network in terms of capital flows are separated from that of a trade network in terms of goods flows. It also provides an implication for research in financial networks: impaired connections to a node (like a branch) in the financial system may weaken the communication between two others connected to this node, even if a direct link already exists between them. Furthermore, the weak form of purchasing power parity holds between the change in domestic exchange rates and cross-city inflation rate differentials. On average, a 1% depreciation in the domestic exchange rate was associated with a 0.2-0.3 percentage points reduction in inflation rate differential. In a sense, this paper fills the blank in this classical theory regarding an interregional scenario with the historical domestic exchange rates. Finally, the effect of domestic exchange markets on price convergence is independent of hyperinflation. A higher inflation rate did not impede or strengthen the price convergence channel via domestic exchange markets.

Although China had fallen behind the West for approximately 200 years until recent decades, it contained some development potential, unlike sub-Saharan Africa. The effectiveness of the wartime domestic exchange market reflects such economic sophistication inheriting from its pre-industrialization era. For instance, Wu (2016) characterizes *Piaohao*, a set of regional financial firms developed in Shanxi province in the 19th century which functioned well as modern bank networks. The giant gap between the evolving financial institution and economic stagnation would lead to a revisit on the main driving force of China-West divergence.

2.A Appendices

2.A.1 Details in Inflation Rate Construction

For most of the leading cities, the daily inflation rate of city i at date t is constructed via the weighted average method in Equation 2.1 with the price information of 5 kinds of commodities:

$$\begin{aligned}\pi_{i,t} \quad = \quad & \frac{0.386}{0.628} \cdot \frac{p_{i,t}^{rice} - p_{i,t-1}^{rice}}{p_{i,t-1}^{rice}} + \frac{0.137}{0.628} \cdot \frac{p_{i,t}^{wheat} - p_{i,t-1}^{wheat}}{p_{i,t-1}^{wheat}} \\ & + \frac{0.053}{0.628} \cdot \frac{p_{i,t}^{\text{cotton}} - p_{i,t-1}^{\text{cotton}}}{p_{i,t-1}^{\text{cotton}}} + \frac{0.036}{0.628} \cdot \frac{p_{i,t}^{coal} - p_{i,t-1}^{coal}}{p_{i,t-1}^{coal}} + \frac{0.016}{0.628} \cdot \frac{p_{i,t}^{oil} - p_{i,t-1}^{oil}}{p_{i,t-1}^{oil}} \end{aligned} \tag{2.15}$$

for Ningpo city and Foochow city, coal price data are not available, with a reduced sum of weights 0.592 their inflation rates are thereby constructed as:

$$\begin{aligned}\pi_{i,t} \quad = \quad & \frac{0.386}{0.592} \cdot \frac{p_{i,t}^{rice} - p_{i,t-1}^{rice}}{p_{i,t-1}^{rice}} + \frac{0.137}{0.592} \cdot \frac{p_{i,t}^{wheat} - p_{i,t-1}^{wheat}}{p_{i,t-1}^{wheat}} \\ & + \frac{0.053}{0.592} \cdot \frac{p_{i,t}^{\text{cotton}} - p_{i,t-1}^{\text{cotton}}}{p_{i,t-1}^{\text{cotton}}} + \frac{0.016}{0.592} \cdot \frac{p_{i,t}^{oil} - p_{i,t-1}^{oil}}{p_{i,t-1}^{oil}} \end{aligned} \tag{2.16}$$

for Nanchang city, cotton price data are not available, with a reduced sum of weights 0.575 their inflation rates are thereby constructed as:

$$\begin{aligned}\pi_{i,t} \quad = \quad & \frac{0.386}{0.575} \cdot \frac{p_{i,t}^{rice} - p_{i,t-1}^{rice}}{p_{i,t-1}^{rice}} + \frac{0.137}{0.575} \cdot \frac{p_{i,t}^{wheat} - p_{i,t-1}^{wheat}}{p_{i,t-1}^{wheat}} \\ & + \frac{0.036}{0.575} \cdot \frac{p_{i,t}^{coal} - p_{i,t-1}^{coal}}{p_{i,t-1}^{coal}} + \frac{0.016}{0.575} \cdot \frac{p_{i,t}^{oil} - p_{i,t-1}^{oil}}{p_{i,t-1}^{oil}} \end{aligned} \tag{2.17}$$

2.A.2 Convergence Rate

For a stationary time series $\{P_t\}$, if at $t = t_0$, $P_{t_0} = \widehat{P} > 0$, and at $t = t_0 + T$, $P_{t_0+T} = \frac{1}{2}\widehat{P}$, then T is termed as the half-life of Y_t.

In a simple $AR(1)$ model with a convergence rate δ: $P_t = \delta P_{t-1} + \varepsilon_t$, for $|\delta| < 1$. If

$P_{t+T} = \frac{1}{2}P_t$, since $P_{t+T} \approx \delta^T P_t$, $T = -\ln(2)/\ln(\delta)$. Alternatively, since $P_t - P_{t-1} = \Delta P_t = (\delta - 1)P_{t-1} + \varepsilon_t$, let $\beta = \delta - 1$, then the half-life is $-\ln(2)/\ln(\beta + 1)$.

Tables

Table 2.1: Weights Assigned to 22 Categories of Commodities

Rice	38.6%	Wheat	13.7%	Glutinous Rice	4.4%
Soybean	4.0%	Beef	1.6%	Pork	6.4%
Egg	1.9%	Salt	4.3%	Cooking Oil	1.6%
Sugar	2.4%	Cotton	5.3%	Raw Silk	1.6%
Wool	0.3%	Iron	1.2%	Copper	0.1%
Coal	3.6%	Kerosene	1.4%	Timber&Cement	5.0%
Cowhide	0.2%	Bristles	0.5%	Tung Oil	1.1%
Tea	0.8%				

Notes: This table shows the weights of 22 commodities used by the Central Bank of Republic of China to calculate a city-level price index. In this paper, the data of only 5 commodities, which are marked in red, are available for calculating cross-city daily inflation rates. Source: *The Financial Monthly of the Central Bank*.

Table 2.2: Summary Statistics of Cross-City Commodity Prices, Inflation Rates, and Domestic Exchange Rates

	Mean			Standard Deviation			# of Observations		
	Pre	Post	All	Pre	Post	All	Pre	Post	All
$\lvert \ln p_i^{coal} - \ln p_j^{coal} \rvert$	.927	1.109	.942	.667	.773	.678	56,946	5,049	61,995
$\lvert \ln p_i^{rice} - \ln p_j^{rice} \rvert$	.670	.921	.694	.472	.651	.498	68,329	7,298	75,627
$\lvert \ln p_i^{wheat} - \ln p_j^{wheat} \rvert$	.569	.724	.581	.426	.532	.437	67,044	5,651	72,695
$\lvert \ln p_i^{oil} - \ln p_j^{oil} \rvert$	.387	.827	.425	.307	.633	.369	67,737	6,390	74,127
$\lvert \ln p_i^{cot\,ton} - \ln p_j^{cot\,ton} \rvert$	.319	.666	.343	.249	.499	.288	64,019	4,807	68,826
$\lvert \ln p_i^{yarn} - \ln p_j^{yarn} \rvert$	.150	.321	.162	.133	.235	.150	49,897	3,910	53,807
π_i	1.0%	7.1%	1.6%	5.9%	15.6%	7.6%	8,568	883	9,451
$\lvert \pi_i - \pi_j \rvert$	4.0%	11.6%	4.4%	6.6%	15.2%	7.5%	51,781	2,801	54,582
$DR_{i,j}$	3.5%	0.5%	3.0%	7.7%	14.1%	9.1%	14,656	2,895	17,551
$\lvert DR_{i,j} \rvert$	5.2%	9.1%	5.9%	6.7%	10.7%	7.6%	14,656	2,895	17,551

Notes: "All", "Pre", and "Post" indicate the data samples of the whole Civil War period, the pre-reform period, and the post-reform period. $\ln p_i^k$: log price of commodity k in city i. $\ln p_i^k - \ln p_j^k$: absolute relative price or cross-city price differential in commodity k. π_i: daily inflation rate in city i. $\pi_i - \pi_j$: absolute daily inflation rate differential across cities. $DR_{i,j}$: premium/discount percentage in domestic exchange rate in i on j, $(rate - 1000)/1000 \times 100\%$. $|DR|$: absolute premium/discount percentage, a measure of capital flow/currency shipping cost. Data marked in red indicate that post-reform values were usually much greater than those in pre-reform period.

Table 2.3: Summary Statistics of Major Battles

	Mean			Standard Deviation		
	Pre	Post	All	Pre	Post	All
Duration	22.49	22.71	22.52	23.54	25.69	23.71
Size	20,409	136,538	36,042	23,741	209,620	87,288
Casualty	6,970	24,302	9,303	7,615	45,452	18,606
# of Obs.	90	14	104	90	14	104
Distance	936	941	937	485	469	483
# of Obs.	1,890	294	2,184	1,890	294	2,184

Notes: "All", "Pre", and "Post" indicate the data samples of the whole Civil War period, the pre-reform period, and the post-reform period. Duration, size, casualty, distance are in units of days, soldier numbers, the number of the deaths and the wounded, and kilometers, respectively. Distance means the distance between the centering location of each battle and each city. Data marked in red indicate that though with a comparable average duration, a post-reform battle was usually much more severe than one in pre-reform period.

Table 2.4: OLS Results: the Effect of Direct Links of Domestic Exchange on Commodity Price Convergence

Dependent Variable: $\Delta p_{k,c,t}$						
	OLS Regression					
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.030***	-.044***	-.030***	-.044***	-.031***	-.045***
	(.001)	(.003)	(.001)	(.003)	(.001)	(.003)
$DL_c \times p_{k,c,t-1}$	-.004*	-.004*	-.005*	-.004*	-.005*	-.004*
	(.002)	(.002)	(.002)	(.002)	(.003)	(.002)
$DIS_c \times p_{k,c,t-1}$		.012***		.011***		.012***
		(.002)		(.002)		(.003)
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$week$ FE	N	N	Y	Y	N	N
$k \times week$ FE	N	N	N	N	Y	Y
Obs.	352,576	352,576	352,576	352,576	352,576	352,576
$Adj.R^2$	0.015	0.015	0.020	0.020	0.025	0.026

Notes: This table reports OLS regression results of the specification in Equation 2.7. DLc = 1 if a direct link existed between city pair c during 1945-1949; DISc: the distance between city pair c in units of 1,000 km. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.5: OLS results: the Effect of Indirect Links of Domestic Exchange on Commodity Price Convergence

Dependent Variable: $\Delta p_{k,c,t}$						
	OLS Regression					
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.039***	-.051***	-.039***	-.051***	-.040***	-.052***
	(.004)	(.005)	(.004)	(.005)	(.004)	(.005)
$NL_c \times p_{k,c,t-1}$	.004**	.004*	.004**	.004*	.004**	.004*
	(.002)	(.002)	(.002)	(.002)	(.002)	(.002)
$DIS_c \times p_{k,c,t-1}$		.012***		.011***		.012***
		(.003)		(.003)		(.003)
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$week$ FE	N	N	Y	Y	N	N
$k \times week$ FE	N	N	N	N	Y	Y
Obs.	331,246	331,246	331,246	331,246	331,246	331,246
$Adj.R^2$	0.014	0.015	0.019	0.020	0.025	0.026

Notes: NLc: the number of links/financial hubs needed to connect city pair c in the domestic exchange network of the 1920s-1930s; DISc: the distance between city pair c in units of 1,000 km. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.6: IV Results: the Effect of Direct Links of Domestic Exchange on Commodity Price Convergence

Dependent Variable: $\Delta p_{k,c,t}$						
	IV Regression					
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.026***	-.040***	-.026***	-.039***	-.026***	-.040***
	(.002)	(.004)	(.003)	(.005)	(.003)	(.005)
$DL_c \times p_{k,c,t-1}$	-.013**	-.012*	-.015**	-.013*	-.015**	-.013*
	(.006)	(.007)	(.007)	(.008)	(.007)	(.008)
$DIS_c \times p_{k,c,t-1}$		.011***		.011***		.011***
		(.003)		(.003)		(.003)
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$week$ FE	N	N	Y	Y	N	N
$k \times week$ FE	N	N	N	N	Y	Y
Obs.	331,246	331,246	331,246	331,246	331,246	331,246

Notes: This table reports IV regression results of the specification in Equation 2.7. DLc = 1 if a direct link existed between city pair c during 1945-1949; The number of links/financial hubs needed to connect city pair c in the domestic exchange network of the 1920s-1930s is used as an instrumental variable for DLc in IV regressions; DISc: the distance between city pair c in units of 1,000 km. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.7: The Effect of Domestic Exchange Rates

Dependent Variable: $\Delta p_{k,c,t}$						
	OLS Regression					
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.031***	-.030***	-.035***	-.049***	-.048***	-.048***
	(.003)	(.003)	(.003)	(.006)	(.006)	(.006)
$\lvert DR_{c,t-1}\rvert$	-.013	-.012	-.014	-.015	-.014	-.014
	(.012)	(.012)	(.015)	(.012)	(.012)	(.015)
$\lvert DR_{c,t-1}\rvert \times p_{k,c,t-1}$	.040***	.040***	.041***	.041***	.040***	.041***
	(.013)	(.012)	(.014)	(.012)	(.012)	(.014)
$DIS_c \times p_{k,c,t-1}$				.016***	.016***	.012**
				(.005)	(.004)	(.005)
$Lags(6days)$	Y	Y	Y	Y	Y	Y
day FE	Y	N	N	Y	N	N
$k \times day$ FE	N	Y	Y	N	Y	Y
$c \times year$ FE	N	N	Y	N	N	Y
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$Obs.$	42,038	41,926	41,925	42,038	41,926	41,925
$Adj.R^2$	0.098	0.223	0.226	0.099	0.224	0.226

Notes: This table reports OLS regression results of the specification in Equation 2.8 without battle exclusions. $|DR|$ is absolute premium/discount percentage, representing the capital flow cost. DISc is distance between city pair c in 1,000 km. Lags: Δp lagged for 6 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.8: OLS Results: the Effect of Domestic Exchange Rates without Battle Exclusions

	Dependent Variable: $\Delta p_{k,c,t}$					
	OLS Regression					
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.030***	-.029***	-.033***	-.045***	-.043***	-.043***
	(.003)	(.003)	(.002)	(.006)	(.006)	(.006)
$\lvert DR_{c,t-1}\rvert$	.008	.010	.005	.007	.008	.005
	(.012)	(.012)	(.014)	(.011)	(.011)	(.014)
$\lvert DR_{c,t-1}\rvert \times p_{k,c,t-1}$	.040***	.040***	.028**	.041***	.040***	.028**
	(.012)	(.011)	(.014)	(.012)	(.011)	(.013)
$DIS_c \times p_{k,c,t-1}$				.013**	.012***	.009**
				(.005)	(.004)	(.004)
$Lags(3days)$	Y	Y	Y	Y	Y	Y
day FE	Y	N	N	Y	N	N
$k \times day$ FE	N	Y	Y	N	Y	Y
$c \times year$ FE	N	N	Y	N	N	Y
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$Obs.$	54,865	54,769	54,769	54,865	54,769	54,769
$Adj.R^2$	0.114	0.244	0.246	0.115	0.245	0.247

Notes: This table reports OLS regression results of the specification in Equation 2.8 without battle exclusions. $|DR|$ is the absolute premium/discount percentage in the domestic exchange rate, representing the capital flow cost. DISc is the distance between city pair c in unit of 1,000 km. Lags: Δp lagged for 3 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.9: OLS Results: The Effect of Domestic Exchange Rates with Battle Exclusions

OLS Regression: Dependent Variable, $\Delta p_{k,c,t}$						
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.029***	-.029***	-.032***	-.044***	-.043***	-.043***
	(.003)	(.003)	(.003)	(.006)	(.006)	(.006)
$\lvert DR_{c,t-1}\rvert$	.008	.009	.005	.007	.008	.005
	(.012)	(.012)	(.014)	(.011)	(.011)	(.014)
$\lvert DR_{c,t-1}\rvert \times p_{k,c,t-1}$	.040***	.040***	.028**	.041***	.040***	.028**
	(.012)	(.011)	(.014)	(.012)	(.011)	(.013)
$DIS_c \times p_{k,c,t-1}$				.013**	.012***	.009**
				(.005)	(.004)	(.004)
$DW_{c,t-1}$	-4.8e-6	-2.6e-5	-2.4e-5	-1.1e-5	-3.2e-5	-2.7e-5
	(9.4e-5)	(7.9e-5)	(8.3e-5)	(9.4e-5)	(7.9e-5)	(8.3e-5)
$DW_{c,t-1} \times p_{k,c,t-1}$	-9.6e-5*	-2.4e-5	-2.3e-5	-8.6e-5	-1.6e-5	-1.8e-5
	(5.3e-5)	(5.6e-5)	(5.5e-5)	(5.3e-5)	(5.7e-5)	(5.5e-5)
$Lags(3days)$	Y	Y	Y	Y	Y	Y
day FE	Y	N	N	Y	N	N
$k \times day$ FE	N	Y	Y	N	Y	Y
$c \times year$ FE	N	N	Y	N	N	Y
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$Obs.$	54,865	54,769	54,769	54,865	54,769	54,769
$Adj.R^2$	0.114	0.244	0.246	0.115	0.245	0.247

Notes: This table reports OLS regression results of the specification in Equation 2.8 with battle exclusions. $|DR|$ is the absolute premium/discount percentage in the domestic exchange rate, representing the capital flow cost. DISc is distance between city pair c in 1,000 km. DWc is the measure of war risk directly to city pair c. Lags: Δp lagged for 3 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.10: IV Results: The Effect of Domestic Exchange Rates without Battle Exclusions

Dependent Variable: $\Delta p_{k,c,t}$						
	IV Regression					
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.033***	-.037***	-.040***	-.051***	-.053***	-.051***
	(.006)	(.006)	(.006)	(.008)	(.008)	(.008)
$\lvert DR_{c,t-1}\rvert$	-.116	-.080	-.116	-.140	-.102	-.120
	(.116)	(.115)	(.140)	(.120)	(.118)	(.140)
$\lvert DR_{c,t-1}\rvert \times p_{k,c,t-1}$	.093	.151**	.136*	.114*	.169**	.146**
	(.064)	(.071)	(.074)	(.062)	(.068)	(.073)
$DIS_c \times p_{k,c,t-1}$				.015**	.013**	.010**
				(.006)	(.006)	(.005)
$Lags(3days)$	Y	Y	Y	Y	Y	Y
day FE	Y	N	N	Y	N	N
$k \times day$ FE	N	Y	Y	N	Y	Y
$c \times year$ FE	N	N	Y	N	N	Y
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$Obs.$	54,865	54,769	54,769	54,865	54,769	54,769

Notes: This table reports IV regression results of the specification in Equation 2.8 without battle exclusions. $|DR|$ is the absolute premium/discount percentage in the domestic exchange rate, representing the capital flow cost. DISc is distance between city pair c in 1,000 km. Lags: Δp lagged for 3 days. The indirect war risk to city pair c, IWc, is used as an instrumental variable for $|DR|$. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.11: IV Results: The Effect of Domestic Exchange Rates with Battle Exclusions

IV Regression: Dependent Variable, $\Delta p_{k,c,t}$						
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.039***	-.039***	-.042***	-.056***	-.054***	-.053***
	(.005)	(.005)	(.005)	(.008)	(.007)	(.007)
$\lvert DR_{c,t-1}\rvert$	-.060	-.045	-.063	-.081	-.065	-.070
	(.102)	(.093)	(.108)	(.103)	(.094)	(.109)
$\lvert DR_{c,t-1}\rvert \times p_{k,c,t-1}$	.180***	.177***	.172***	.192***	.187***	.177***
	(.054)	(.054)	(.063)	(.053)	(.053)	(.062)
$DIS_c \times p_{k,c,t-1}$				.015**	.013**	.010**
				(.007)	(.006)	(.005)
$DW_{c,t-1}$	-2.6e-5	-4.9e-5	-3.5e-5	-4e-5	-6.2e-5	-4e-5
	(9.3e-5)	(8.3e-5)	(9.1e-5)	(9.3e-5)	(8.3e-5)	(9.1e-5)
$DW_{c,t-1} \times p_{k,c,t-1}$	-1.0e-4*	-1.8e-5	-2.5e-5	-8.7e-5	-5.4e-6	-1.9e-5
	(5.4e-5)	(5.6e-5)	(5.5e-5)	(5.4e-5)	(5.7e-5)	(5.5e-5)
$Lags(3days)$	Y	Y	Y	Y	Y	Y
day FE	Y	N	N	Y	N	N
$k \times day$ FE	N	Y	Y	N	Y	Y
$c \times year$ FE	N	N	Y	N	N	Y
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$Obs.$	54,865	54,769	54,769	54,865	54,769	54,769

Notes: This table reports IV regression results of the specification in Equation 2.8 with battle exclusions. $|DR|$ is the absolute premium/discount percentage in the domestic exchange rate, representing the capital flow cost. DISc is distance between city pair c in 1,000 km. DWc is the measure of war risk directly to city pair c. The indirect war risk to city pair c, IWc, is used as an instrumental variable for $|DR|$. Lags: the dependent variable is lagged 3 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.12: The Effect of Domestic Exchange Rates

Dependent Variable: $\Delta p_{k,c,t}$						
	OLS Regression		IV Regression			
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.043***	-.043***	-.054***	-.053***	-.053***	-.051***
	(.006)	(.006)	(.007)	(.007)	(.008)	(.008)
$\|DR_{c,t-1}\|$	.008	.005	-.065	-.070	-.102	-.120
	(.011)	(.014)	(.094)	(.109)	(.118)	(.140)
$\|DR_{c,t-1}\| \times p_{k,c,t-1}$	.040***	.028**	.187***	.177***	.169**	.146**
	(.011)	(.013)	(.053)	(.062)	(.068)	(.073)
$DIS_c \times p_{k,c,t-1}$	.012***	.009**	.013**	.010**	.013**	.010**
	(.004)	(.004)	(.006)	(.005)	(.006)	(.005)
$DW_{c,t-1}$	-3.2e-5	-2.7e-5	-6.2e-5	-4e-5		
	(7.9e-5)	(8.3e-5)	(8.3e-5)	(9.1e-5)		
$DW_{c,t-1} \times p_{k,c,t-1}$	-1.6e-5	-1.8e-5	-5.4e-6	-1.9e-5		
	(5.7e-5)	(5.5e-5)	(5.7e-5)	(5.5e-5)		
Lags	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
$k \times day$ FE	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
$c \times year$ FE	*N*	*Y*	*N*	*Y*	*N*	*Y*
$c \times k$ FE	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
Obs.	54,769	54,769	54,769	54,769	54,769	54,769
$Adj.R^2$	0.245	0.247				

Notes: Specifications (1)-(2) are OLS regressions, and (3)-(6) are IV regressions. $|DR|$ is the absolute premium/discount percentage in the domestic exchange rate. DISc is distance between city pair c in 1,000 km. DWc is the direct war risk to city pair c. The indirect war risk to city pair c, IWc, is used as an instrumental variable for $|DR|$. Lags: the dependent variable is lagged 3 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.13: The Purchasing Power Parity: the Relationship between the Change Rates of Domestic Exchange Rate and Cross-City Inflation Rate Differentials

Dependent Variable: $\Pi_{c,t}$	(1)	(2)	(3)	(4)
$\%\Delta$ in $DR_{c,t}$	.224***	.292***	.245***	.302***
	(.039)	(.042)	(.038)	(.043)
$\%\Delta$ in $DR_{c,t-1}$		.170***		.177***
		(.053)		(.052)
$\Pi_{c,t-1}$			.017	.001
			(.018)	(.019)
Constant	-.344***	-.347***	-.341***	-.341***
	(.001)	(.001)	(.004)	(.004)
Obs.	10,222	9,084	9,162	8,565
Adj.R^2	.317	.313	.317	.321

Notes: This table reports OLS regression results of specification in Equation 2.12. Π_c: inflation rate differential between city pair c. $\%\Delta$ in DR_c: percentage change in domestic exchange rate between city pair c. All specifications include city-pair and day FEs. Standard errors are in parentheses and clustered at the city-pair level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.14: The Effect of the Currency Reform

Dependent Variable: $\Delta p_{k,c,t}$						
	OLS Regression					
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.045***	-.043***	-.043***	-.045***	-.043***	-.043***
	(.006)	(.006)	(.006)	(.006)	(.006)	(.006)
$\|DR_{c,t-1}\|$	.007	.008	.005	.008	.008	.006
	(.011)	(.011)	(.014)	(.011)	(.011)	(.014)
$\|DR_{c,t-1}\| \times p_{k,c,t-1}$	.031**	.027*	.033**	.030*	.029*	.030*
	(.015)	(.016)	(.016)	(.012)	(.016)	(.017)
$\|DR_{c,t-1}\| \times p_{k,c,t-1} \times Reform$	.014	.019	-.009	.020	.009	.002
	(.017)	(.018)	(.021)	(.028)	(.025)	(.029)
$DIS_c \times p_{k,c,t-1}$	.013**	.013***	.009**	.014***	.012***	.010**
	(.005)	(.004)	(.004)	(.005)	(.004)	(.004)
$DIS_c \times p_{k,c,t-1} \times Reform$				-.001	.002	-.003
				(.004)	(.003)	(.004)
Lags	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
day FE	*Y*	*N*	*N*	*Y*	*N*	*N*
$k \times$ *day* FE	*N*	*Y*	*Y*	*N*	*Y*	*Y*
$c \times$ *year* FE	*N*	*N*	*Y*	*N*	*N*	*Y*
$c \times k$ FE	*Y*	*Y*	*Y*	*Y*	*Y*	*Y*
Obs.	54,865	54,769	54,769	54,865	54,769	54,769
$Adj.R^2$	0.115	0.245	0.247	0.115	0.245	0.247

Notes: This table reports OLS regression results of the effect of the currency reform. $|DR|$ is the absolute premium/discount percentage in the domestic exchange rate. DISc is distance between city pair c in 1,000 km. Reform=1 if after Aug.19, 1948 (the implementation date). Lags: Δp lagged for 3 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.15: The Effect of Alternative Measures of Capital Flow Costs

OLS Regression: Dependent Variable $\Delta p_{k,c,t}$						
	$Cost_{c,t} = \underset{\hat{t}\in[t,t-5]}{mean}\lvert DR_{c,\hat{t}}\rvert$			$Cost_{c,t} = \max_{\hat{t}\in[t,t-5]}\lvert DR_{c,\hat{t}}\rvert$		
	(1)	(2)	(3)	(4)	(5)	(6)
$p_{k,c,t-1}$	-.028***	-.040***	-.040***	-.028***	-.040***	-.040***
	(.002)	(.006)	(.006)	(.002)	(.006)	(.006)
$Cost_{c,t-1}$	.018*	.017	.017*	.009	.009	.009
	(.011)	(.010)	(.010)	(.010)	(.010)	(.010)
$Cost_{c,t-1} \times p_{k,c,t-1}$	.041***	.040***	.040***	.028***	.028***	.028***
	(.011)	(.011)	(.011)	(.009)	(.009)	(.009)
$DIS_c \times p_{k,c,t-1}$		.011**	.010**		.011**	.011**
		(.004)	(.004)		(.004)	(.004)
$DW_{c,t-1}$			2.1e-6			1.3e-6
			(8.3e-5)			(8.4e-5)
$DW_{c,t-1} \times p_{k,c,t-1}$			-3.2e-5			-3.2e-5
			(6.7e-5)			(6.6e-5)
$Lags(3days)$	Y	Y	Y	Y	Y	Y
$k \times day$ FE	Y	Y	Y	Y	Y	Y
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$Obs.$	63,840	63,840	63,840	63,840	63,840	63,840
$Adj.R^2$	0.220	0.220	0.220	0.220	0.220	0.220

Notes: $Cost_{c,t}$ is some measure of the capital flow cost between city pair c at time t: it is a moving average of the absolute premium percentage in domestic exchange rates over past 6 days from t in specifications (1)-(3); or the max value of the absolute premium percentage over the past 6 days from t in specifications (4)-(6). DISc is the distance between city pair c in 1,000 km. DWc is the measure of war risk directly related to city pair c. Lags: Δp lagged for 3 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 2.16: The Effect of Alternative Measures of Capital Flow Costs (Continued)

OLS Regression: Dependent Variable $\Delta p_{k,c,t}$			
	$Cost_{c,t} = \underset{\hat{t}\in[t,t-5]}{std.}(DR_{c,\hat{t}})$		
	(7)	(8)	(9)
$p_{k,c,t-1}$	-.027***	-.039***	-.039***
	(.002)	(.006)	(.006)
$Cost_{c,t-1}$	.012	.010	.010
	(.035)	(.034)	(.034)
$Cost_{c,t-1} \times p_{k,c,t-1}$	.066	.069*	.070*
	(.042)	(.042)	(.041)
$DIS_c \times p_{k,c,t-1}$		.011***	.011***
		(.004)	(.004)
$DW_{c,t-1}$			-1.7e-5
			(8.5e-5)
$DW_{c,t-1} \times p_{k,c,t-1}$			-2.0e-5
			(6.9e-5)
$Lags(3days)$	Y	Y	Y
$k \times day$ FE	Y	Y	Y
$c \times k$ FE	Y	Y	Y
$Obs.$	60,964	60,964	60,964
$Adj.R^2$	0.222	0.223	0.223

Notes: $Cost_{c,t}$ is some measure of the capital flow cost between city pair c at time t: it is a moving average of the standard deviation of the absolute premium percentage over the past 6 days from t in specifications (7)-(9). DISc is the distance between city pair c in 1,000 km. DWc is the measure of war risk directly related to city pair c. Lags: Δp lagged for 3 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

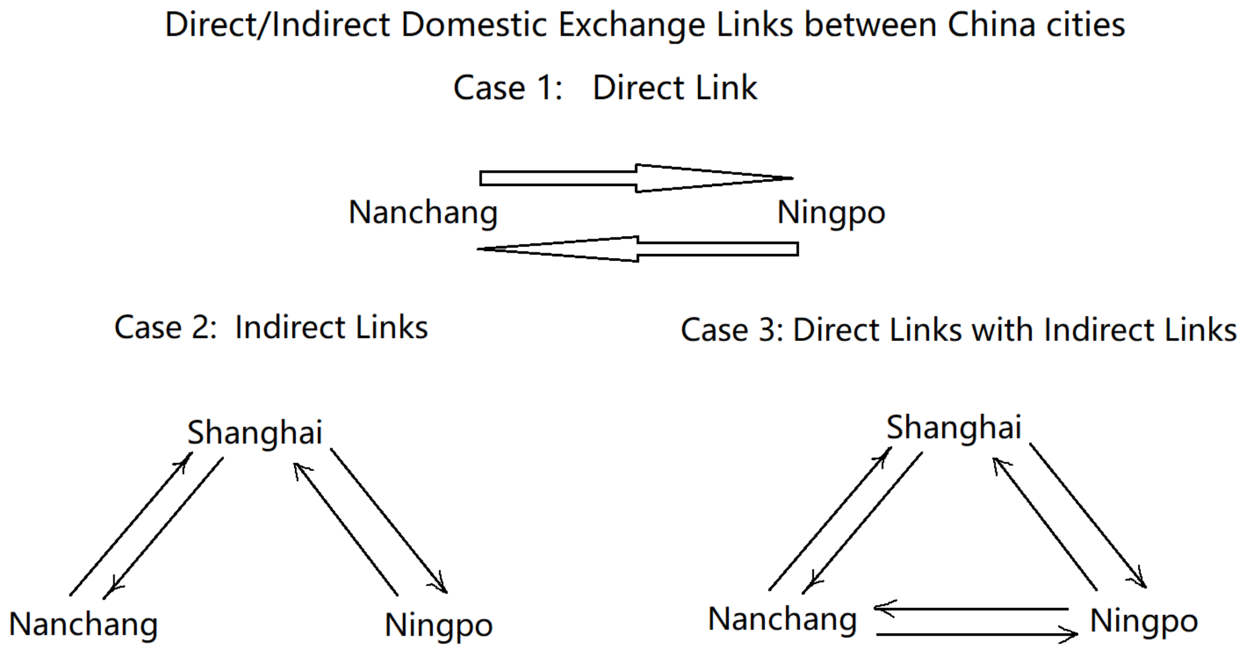
Table 2.17: OLS Results: The Effect of Domestic Exchange Rates with Heterogeneous Auto Convergence Trends

	Dependent Variable: $\Delta p_{k,c,t}$					
	OLS Regression: $\beta_c \cdot p_{k,c,t-1}$					
	(1)	(2)	(3)	(4)	(5)	(6)
$\lvert DR_{c,t-1}\rvert$	.002	.006	.006	.002	.006	.006
	(.012)	(.012)	(.015)	(.012)	(.012)	(.015)
$\lvert DR_{c,t-1}\rvert \times p_{k,c,t-1}$	.047***	.051***	.038***	.047***	.051***	.038***
	(.013)	(.013)	(.014)	(.013)	(.013)	(.014)
$DW_{c,t-1}$				-2.0e-5	-4.8e-5	-4.2e-5
				(9.0e-5)	(7.6e-5)	(7.9e-5)
$DW_{c,t-1} \times p_{k,c,t-1}$				-8.4e-5	-1.9e-5	-2.6e-5
				(5.3e-5)	(5.6e-5)	(5.4e-5)
$Lags(3days)$	Y	Y	Y	Y	Y	Y
day FE	Y	N	N	Y	N	N
$k \times day$ FE	N	Y	Y	N	Y	Y
$c \times year$ FE	N	N	Y	N	N	Y
$c \times k$ FE	Y	Y	Y	Y	Y	Y
$Obs.$	54,865	54,769	54,769	54,865	54,769	54,769
$Adj.R^2$	0.117	0.247	0.249	0.118	0.247	0.249

Notes: This table reports OLS regression results of specification in Equation 2.14. $|DR|$ is the absolute premium/discount percentage in the domestic exchange rate, representing the capital flow cost. DISc is the distance between city pair c in 1,000 km. DWc is the measure of war risk directly to city pair c. Lags: Δp lagged for 3 days. Standard errors are in parentheses and clustered at the city-pair×commodity level. *: p<0.10, **: p<0.05, ***: p<0.01.

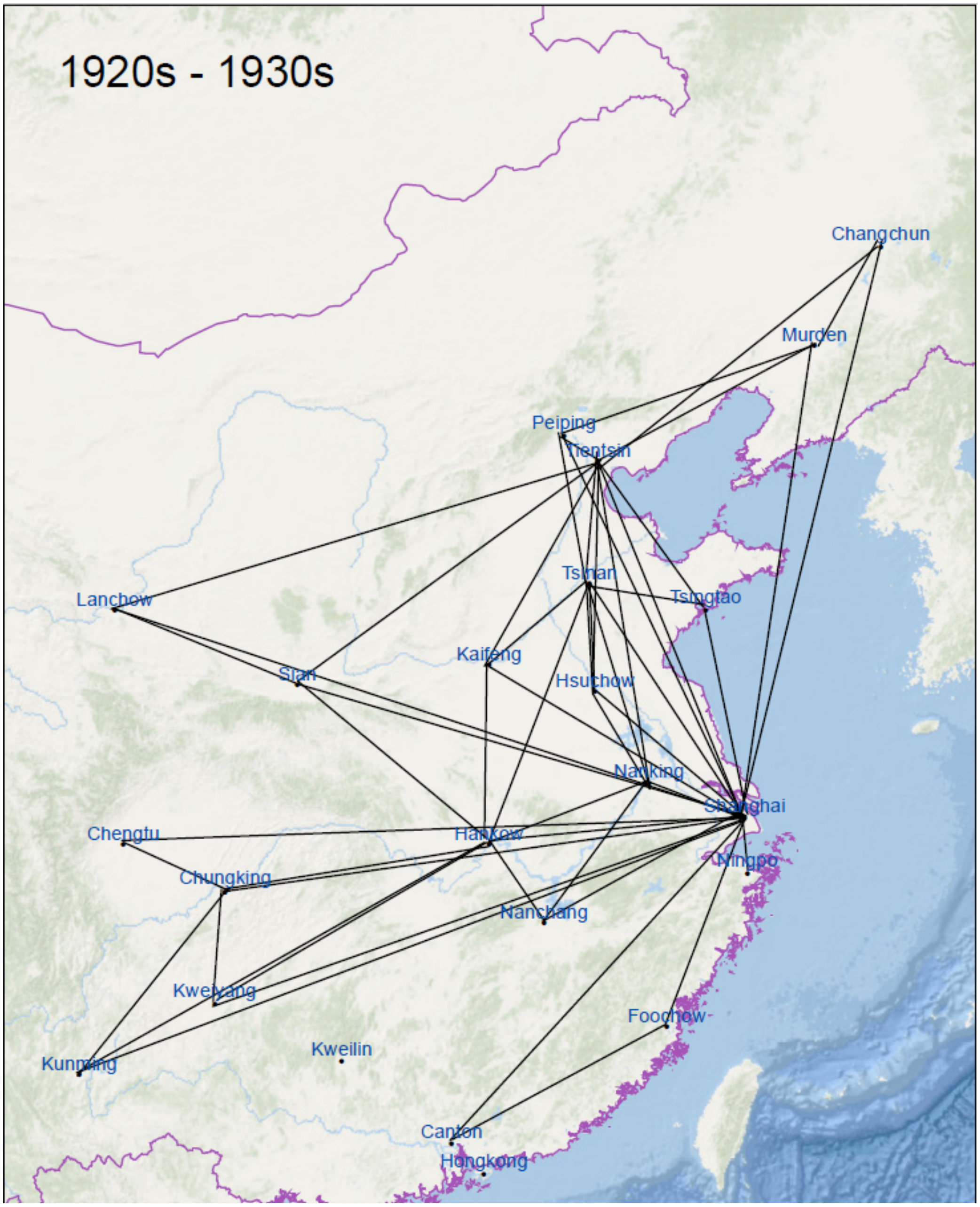
Figures

Figure 2.1: Illustrative Examples of links in a Domestic Exchange Network



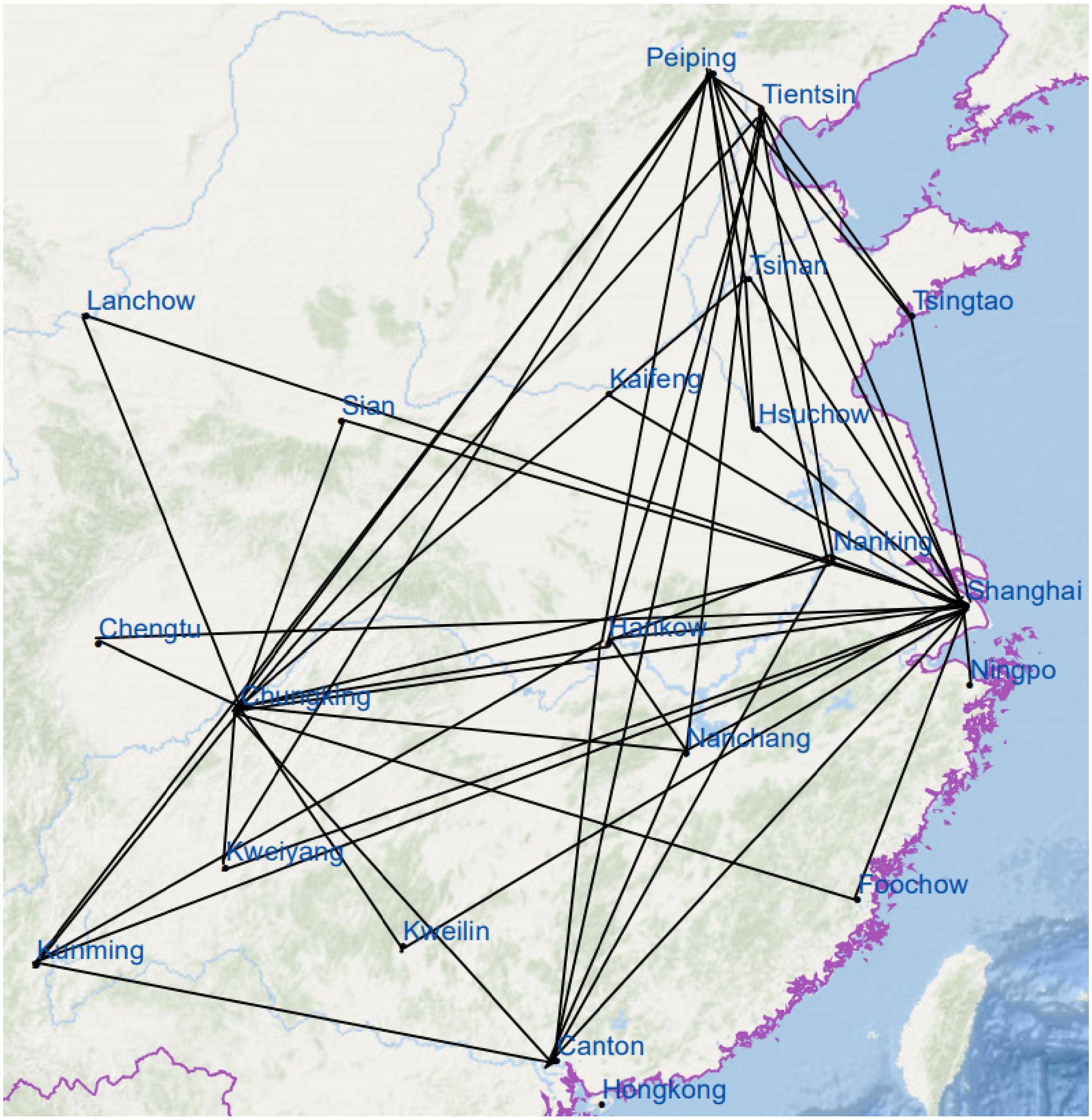
Notes: Case 1 shows a direct domestic exchange link between Nanchang and Ningpo represented by an exchange rate in Nanchang (Ningpo) on Ningpo (Nanchang). Case 2 shows that only an indirect link existed between Nanchang and Ningpo cities; there was no direct trading in exchanges between them; in-between payments had to flow via the hub city, Shanghai. Case 3 shows that both direct and indirect links existed between any city pair; for example, Nanchang's payment to Ningpo could be fulfilled directly by in-between domestic exchange or indirectly via the hub city, Shanghai.

Figure 2.2: The Domestic Exchange Network in China: 1920s-1930s



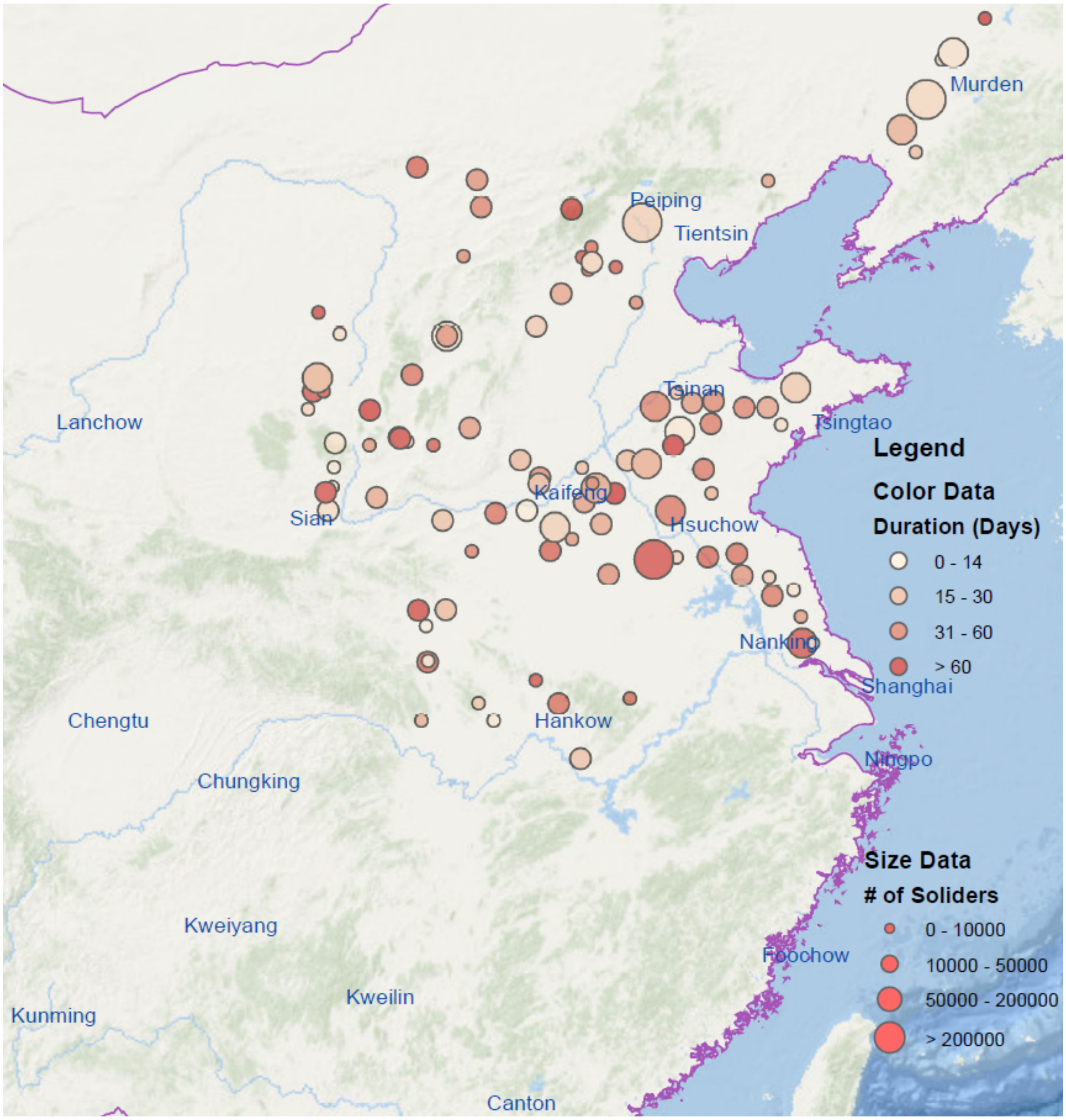
Notes: A black edge indicates that a direct domestic exchange link existed between a city pair. A city with more than two direct links was a hub city. In the 1920s-1930s. Shanghai, Tientsin, and Hankow were the largest hub cities in the domestic exchange network. GIS mapping of the domestic exchange network is based on Ma (2013) and Ma (2016).

Figure 2.3: The Domestic Exchange Network in China: 1945-1949



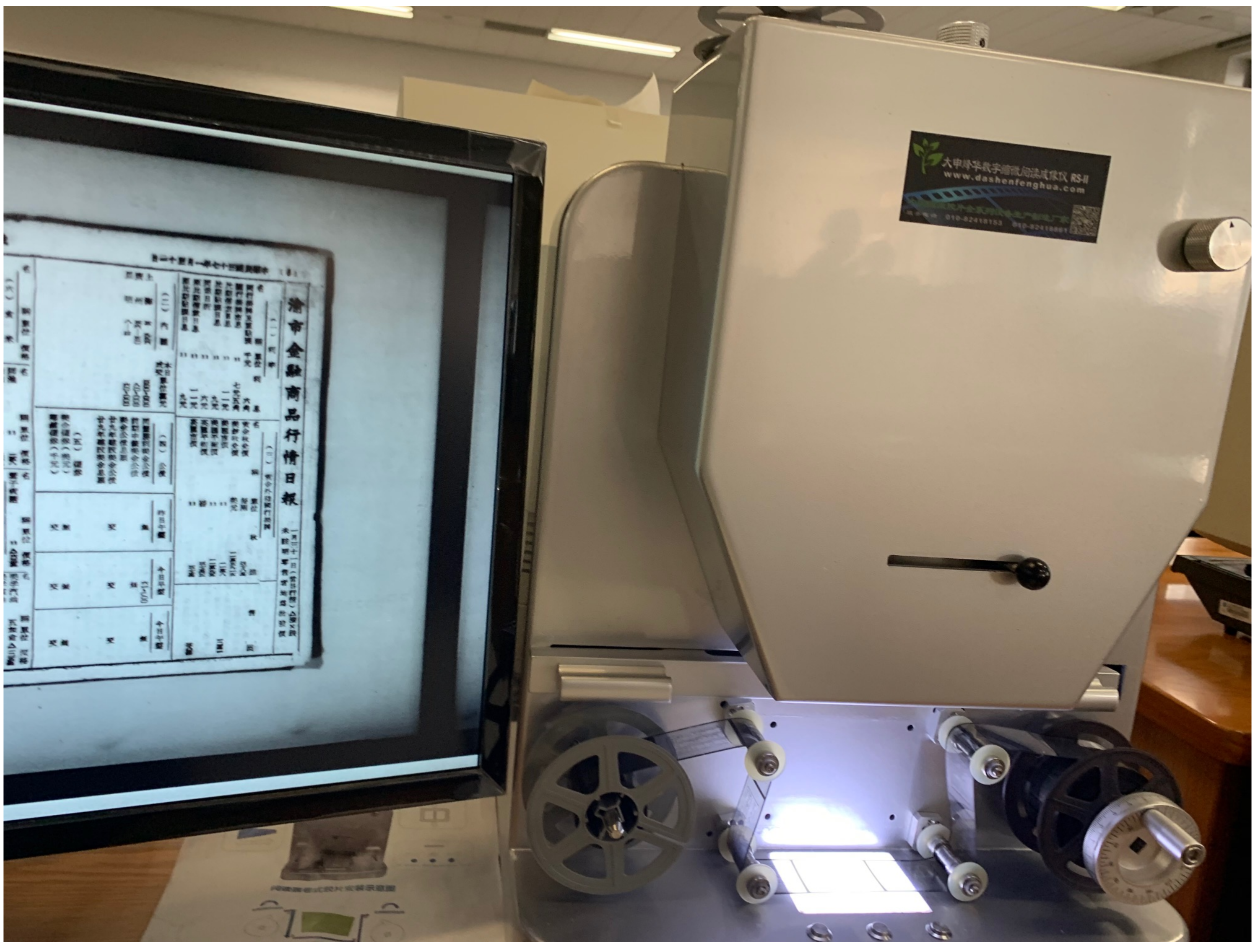
Notes: A black edge indicates that a direct domestic exchange link existed between a city pair. A city with more than two direct links was a hub city. From 1945 to 1949, Shanghai, Chungking, Tientsin, Peiping, and Hankow were the largest hub cities in the domestic exchange network. GIS mapping of the domestic exchange network is based on contemporary newspapers: a direct link is assumed between two cities if a domestic exchange rate was reported in some newspapers.

Figure 2.4: Major Battles in the Chinese Civil War (1945.10-1949.4)



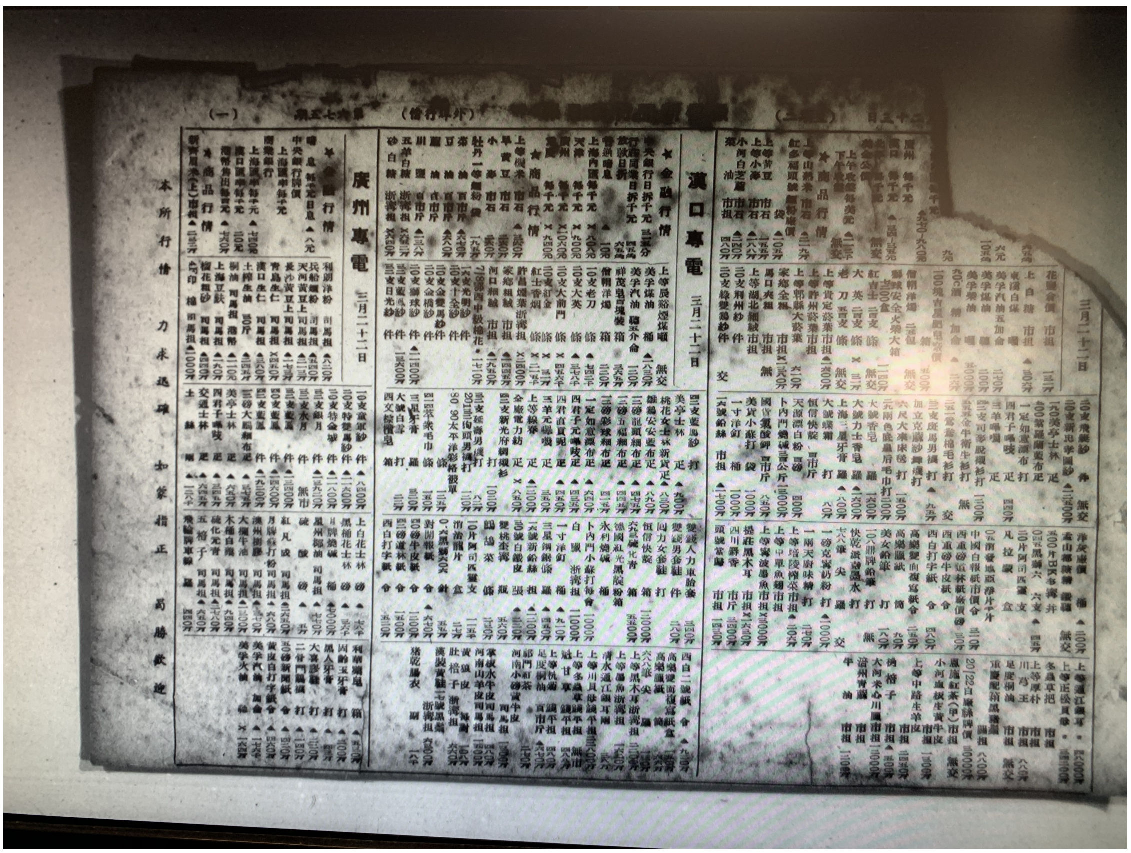
Notes: Each circle represents a major battle occurred in the Chinese Civil War period: the circle size indicates the battle size, measured by the number of soldiers; the circle's opacity indicates the battle duration. GIS mapping relies on the battle information documented in *The History of the Chinese People's Liberation Army (1945-1949)*.

Figure 2.5: Collecting Sheets from a Archive Microfilm with a Film Projector



Notes: I collected thousands of sheets of commodity price data from archived microfilms, and digitized the data using a film projector in the National Library of China in Beijing in December 2019.

Figure 2.6: A Sample Sheet from a Microfilm Archive



Notes: This was a sample datasheet from a microfilm archive. It was projected on a monitor screen with a microfilm projector.

Figure 2.7: Capital Flow Costs v.s. Commodity Relative Prices

Notes: This set of 6 diagrams shows the correlation between commodity relative prices and capital flow costs. From the left top diagram to the right bottom diagram, scattered plots are arranged for cotton yarn, cotton, oil, wheat, rice, and coal, respectively. A fitted line is also added for each plot. The capital flow cost is measured by premium percentage in domestic exchange rates. For a given commodity, the relative price is calculated as the log difference of prices between two cities. Except for the case of coal, a higher capital flow cost is generally associated with a greater cross-city gap in commodity price.

Figure 2.8: Capital Flows in Bilateral and Multilateral Domestic Exchanges

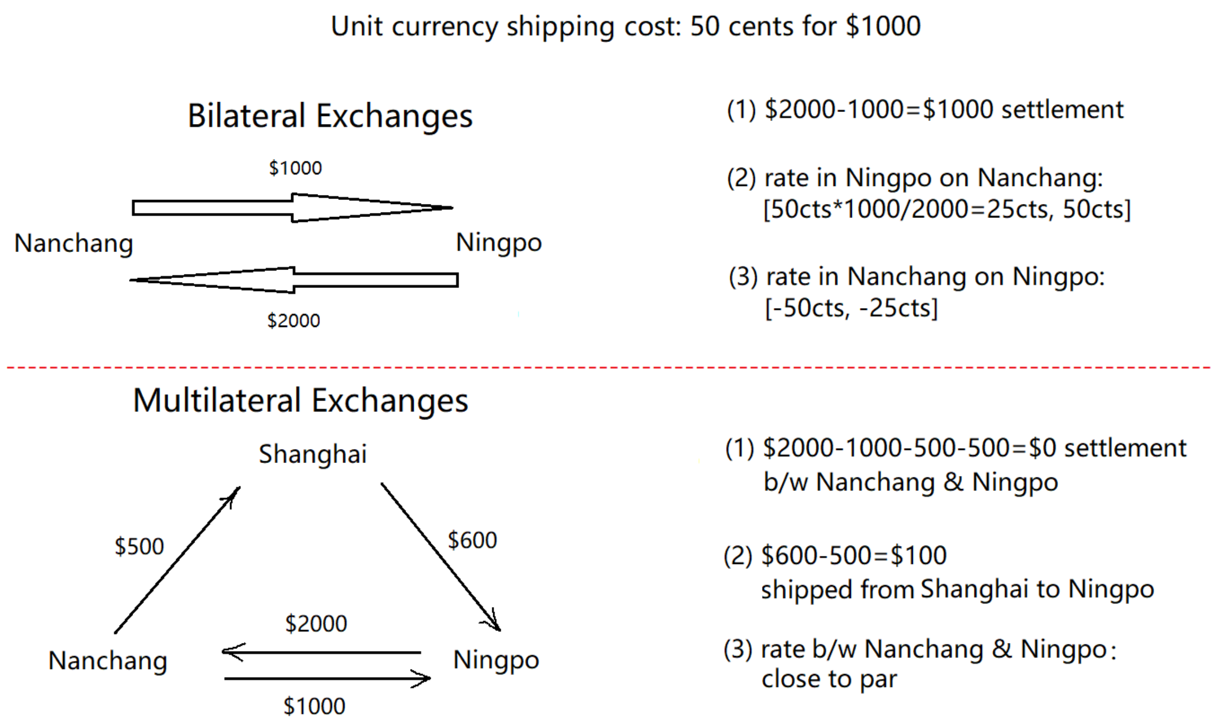
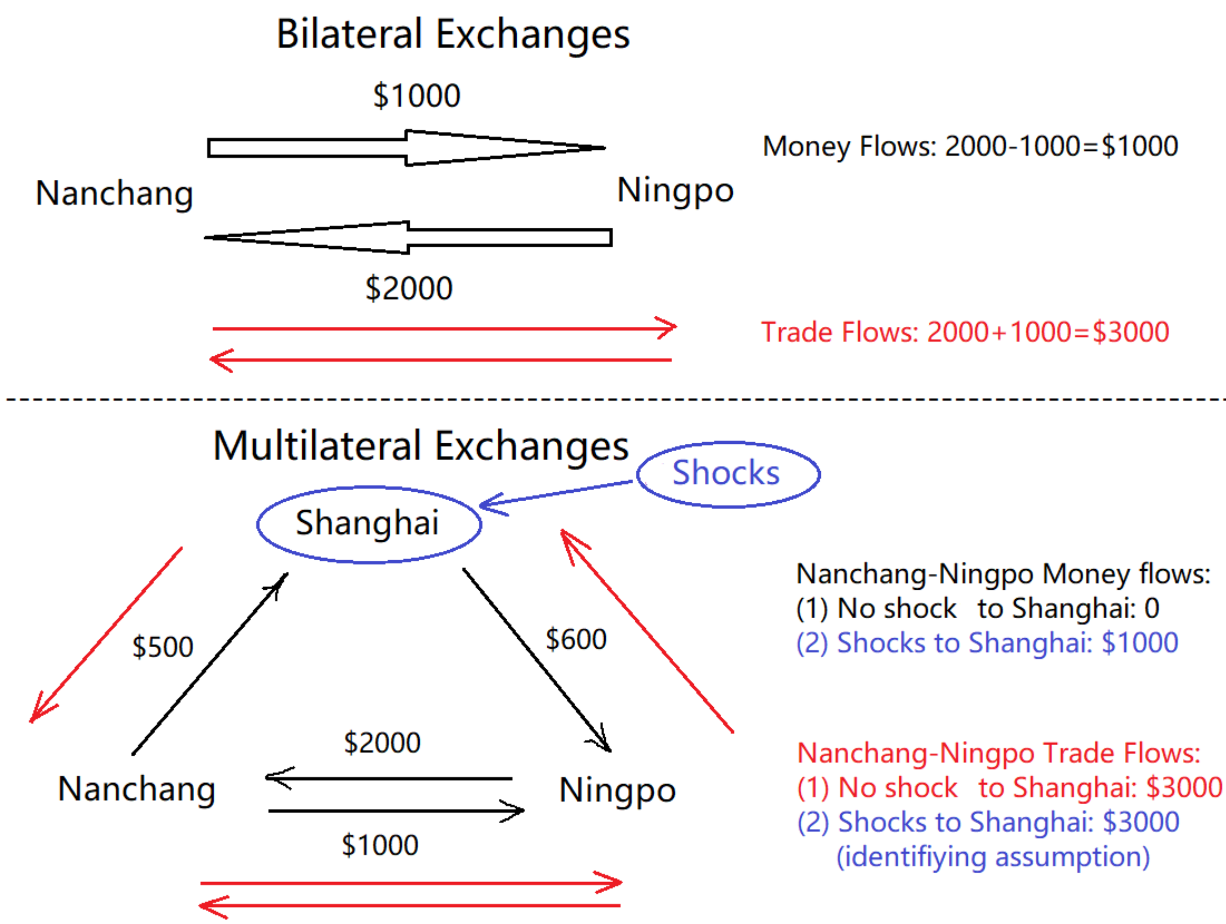


Figure 2.9: How Battle Shocks to a Financial Hub Altered Capital Flows Between a City Pair



CHAPTER 3

A Bond Price Puzzle: A Partial Hedge Against the Chinese Hyperinflation

3.1 Introduction

A pricing anomaly, when some financial asset is priced differently from what a model predicts, has long been studied with many competing theories proposed, such as “behavioral” theories and “rational structural uncertainty” (Brav and Heaton, 2002). The anomalous stock returns attract much of the research attention (Fama and French, 2008; Li et al., 2009; and Stambaugh et al., 2012). However, little is known about bond (especially the government bond) market anomalies partially because, with more certain future cash flows, bond prices exhibit much fewer fluctuations than stock prices.

This chapter investigates a bond market anomaly by adopting a unique setting of a famous government bond collection, the 25th Year Consolidated Bonds[1], in the Shanghai financial market during the Chinese Civil War[2]. The conventional bond pricing model claims that the value of a bond is the sum of the present values of its future cash flows. Under normal circumstances, an associated bond yield rate (or discount rate) is positive. Although negative yield rates exist in many countries' bond markets, the price of bonds rarely deviates far from their face value. The Consolidated Bond prices, however, soared up to many times their face

[1]Hereinafter referred to as the Consolidated Bond.

[2]Hereinafter referred to as the Civil War.

value from 1945 to 1948 amid the Civil War[3]. For example, the Type C Consolidated Bond, maturing in seven and a half years with a 100 yuan[4] principal, was traded at 750 yuan on July 31, 1946, which implies an associated annualized yield rate of -23.6%. Two years later, its price increased to 1,120,000, with the yield rate declining to -81.6%. Although it could not be explained by traditional anomaly variables for corporate bonds such as book-to-market and net issuance (Choi and Kim, 2018; Chordia et al., 2017), the Consolidated Bond price shared a similar exponential pattern with the Shanghai wholesale price index[5]. Instead of being inflated away, the real bond value (as a ratio of the original price to the price index) was generally stationary, which indicates that the bond price anchored the general price level. A preliminary review of the contemporary events shows that the real value fluctuated vastly upon the arrival of information about what multiplier the bond would be repaid with. These phenomena thereby motivate a plausible solution to the bond market anomaly.

To disentangle the soaring bond price puzzle, I propose a hypothesis: if the bond traders' belief of repayment with multipliers takes the price index as a reference, then the growth rate in the deflated bond price increases (decreases) in the arrivals of positive (negative) news about repayment multipliers. This belief is also related to an expectation for an anti-inflationary currency reform[6]: bond investors had long believed that the Chinese government would use a new currency to retire bonds denominated in the old currency, which was equivalent to repayment with a multiplier.

To test the hypothesis, I first collect by hand the information about Shanghai financial markets and factors affecting bond traders' belief of repayment. Then, I compile two novel data sets. One set includes (1) newspaper articles containing information about "repayment with multipliers" and the "Currency Reform" and (2) detailed information of battles in the

[3]See Figure 3.1.

[4]Unit of Fabi, a Chinese currency.

[5]See Figure 3.2.

[6]Hereinafter referred as to the Currency Reform.

Civil War. The other set contains daily Consolidated Bond prices, price indices, and prices of other financial assets in Shanghai, mainly from 1946 to 1948. Finally, I build an empirical model to examine the effect of news about repayment on the asset price growth rates.

The main findings and contributions of this chapter are as follows. First, I show that the Consolidated Bond price puzzle was primarily explained by the evolving beliefs of repayments that were driven by relevant news. On a weekly average basis, one more positive news about the Currency Reform will lead to an 8.8 percentage points increase in bond price growth rate while one additional negative news about the repayment with multipliers will decelerate the growth by 8.2 percentage points. The continuous arrival of favorable news about the Currency Reform predominates, which strengthened investors' belief that the Consolidated Bond would be repaid with an appropriate multiplier after the future reform was implemented. This chapter contributes to the research on signaling and reputation in public/sovereign debt (Cole et al., 1995; Cole and Kehoe, 1995) and on the trade-off between nominal and indexed government debts (Calvo, 1988; Bohn, 1988). While inflating away the public debt might not necessarily lower the fiscal burden significantly (Hilscher et al., 2014), it was the Nationalist Government's motive to maintain its creditworthiness that fulfilled the bond traders' extreme beliefs.

Second, up until the Currency Reform was instated, prices of the Consolidated Bonds and other financial assets in the Shanghai market were not responsive to the influence from battles in the Civil War, which is a very different result from other studies concerning the effect of political uncertainties on financial markets. This strand of literature finds that not only the exchange rate of a domestic currency to gold (Guinnane et al., 1996) but also the yield rates of sovereign bonds issued overseas (Mitchener et al., 2015; Howell and Zhao, 2019) were highly responsive to the progress of respective civil wars. It is worth noting that, however, the expectation for the Currency Reform was closely related to the Nationalist Government's financial distress from increasing military expenses and its efforts to control inflation. As the war proceeded, it became more of common knowledge that the government must maintain its creditworthiness in debt markets for the future reform. Since the Shanghai financial markets were mainly accessible to the wealthy in the early 20th century of China, this chapter, to some extent, indicates that at least the Chinese middle or upper class had not lost trust in the Nationalist Government until the late summer of 1948.

Finally, this research also shows that though not anticipated, the Consolidated Bond resembled modern inflation-indexed securities, which complements the studies of using common stocks, gold, and other financial assets to hedge against inflation(Bodie, 1976; Van Hoang et al., 2016) and even hyperinflation(Zhao and Li, 2015).

The remainder of this chapter is organized as follows. Section 3.2 provides the Consolidated Bond basics and introduces the historical background of the Chinese hyperinflation. Section 3.3 describes the soaring bond price pattern, qualitatively disentangles the bond price puzzle, and proposes the hypothesis. Section 3.4 describes the data used in this chapter. Section 3.5 tests the hypothesis and interprets the results. Section 3.6 concludes the chapter.

3.2 Historical Background

The Consolidated Bond price puzzle stems from the sociopolitical background of the Chinese hyperinflation and how the bonds were issued and repaid during that time.

3.2.1 The Consolidated Bonds

The 25th Year Consolidated Bonds[7] were issued by the Ministry of Finance, the National Government of the Republic of China[8]. The bond issuance began on February 1, 1936. The

[7]In Chinese, the bonds were named as "二十五年统一公债". The Republic of China was established in 1912 and adopted the Republic of China calendar or Mingguo calendar. This calendar calls year 1912 the 1st year (of the Republic), or "(民国)元年" in Chinese, so the 25th year, or "二十五年", means year 1936.

[8]Hereinafter, the National Government of the Republic of China is referred to as the Nationalist Government or the ROC.

Consolidated Bonds worth a total value of 1.46 billion yuan (in Fabi currency) were divided into five types: Type A, Type B, Type C, Type D and Type E[9]. Their terms to maturity were respectively 12 years, 15 years, 18 years, 21 year, and 24 years. With the same annual coupon rate of 6% paid semiannually, each type of the bonds had four kinds of paper bond certificates in face amount of 5,000 yuan, 1,000 yuan, 100 yuan, and 10 yuan, respectively. As an illustration a bond certificate sample with 100 yuan par value and coupon certificates is shown in Figure 3.3.

To mitigate the Nationalist Government's financial distress, the Consolidated Bonds were used to retire a variety of old bonds[10] with the purpose of extending the initial maturities and regulating the bond market. As old bonds, the Consolidated Bond repayment was financed by customs revenue according to the 25th Year Consolidated Bond Regulations published on February 8, 1936[11].

The interest payments of the Consolidated Bonds were scheduled to be on January 31 and July 31 of each year. The principal repayments, however, were more complicated due to a lottery system. There was a serial number on each bond certificate. For each type of bond, the government would conduct a lottery of the last three digits of the serial numbers every six months[12]. The bond certificates with a drawn number would also be repaid with

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[9]In Chinese, "甲种", "乙种", "丙种", "丁种" and "戊种"

[10]Type A Consolidated Bond, worth 0.15 billion yuan, was used to replace or repay for five old bonds, Type B worth 0.15 billion yuan for four old bonds, Type C worth 0.35 billion for nine old bonds, Type D worth 0.55 billion yuan for seven bonds, and Type E worth 0.26 billion yuan for three bonds.

[11]On the afternoon of February 1, 1936, the Finance Minister of China, Kung Hsiang-hsi, made a declaration of the consolidated bond issuance with the government bondholder association in Shanghai. However, the regulations and repayment schedules of consolidated bonds were published later on February 8, 1936.

[12]According to documentation, the first lottery for Type A bond was scheduled on May 10, 1936 and the other lotteries on February 10 and August 10 of each following year until the maturity date. The first lottery for Type B bond was scheduled on May 10, 1936 and the other lotteries on March 10 and September 10 of each following year. The first lottery for Type C bond was scheduled on June 10, 1936 and the other lotteries on April 10 and October 10 of each following year. The first lottery for Type D bond was scheduled on June 10, 1936 and the other lotteries on May 10 and November 10 of each following year. The first lottery for Type E bond was scheduled on July 10, 1936 and the other lotteries on June 10 and December 10 of each following year.

its face value on January 31 and July 31 of each year. The winning probability of each future lottery could be calculated based on repayment schedules.

Since the Second Sino-Japanese War broke out on July 7, 1937, China had gradually lost its customs revenue. The ROC Central Bank advanced funds to the Ministry of Finance for continuing bond repayments. On January 15, 1939 the Ministry of Finance announced that the bond repayment was suspended. However, in order to maintain its credit, the Nationalist Government also stated that future drawn bond certificates could be discounted at the Central Bank. During the Civil War period following the Sino-Japanese War, the Ministry of Finance resumed the bond repayment on July 1, 1946 and retired all the outstanding Consolidated Bonds after implementing the Currency Reform. The timeline in Table 3.1 provides a brief history of the Consolidated Bond.

The Consolidated Bond issuance was an important financial measure the Nationalist Government made in 1936, which was also a popular topic in contemporary newspapers. For example, there were 108 articles regarding the bond in Shen Bao (申报) newspaper[13] issued in 1936. Recall that the Consolidated Bonds were used to retire (or extend the maturity of) old bonds. It was indeed the second check on the Nationalist Government's creditworthiness for which the bond holders held a high expectation.

3.2.2 The Chinese Hyperinflation

Two wars directly led to the unprecedented Chinese hyperinflation. The hyperinflation started as early as 1938 when an increasing number of cities were occupied by Japanese troops during the Sino-Japanese War. The Nationalist Government accelerated printing Fabi currency to finance surging military expenses while losing many tax revenue sources and to offset (by inflation) its loss of Fabi stocks in Japanese occupied areas.

Upon the outbreak of the Civil War at the end of 1945, China's economy was far from

[13] Shen Bao (申报), issued daily, was the most popular newspaper in China before 1949.

recovering from the previous war. The Nationalist Government maintained a very high level of budget deficit as shown in Table 3.4, but roughly filled the gap by asking for advance from state banks as displayed in Table 3.5. Without a committed central bank system, the state banks could not reject the advance request. Additionally, there was no determined monetary policy target for effectively controlling the private credit expansion. Therefore, the currency note was issued at an accelerating speed as displayed in Table 3.3, resulting in a hyperinflationary economy as reflected in Table 3.2 and Figure 3.2.

Among multiple arduous tasks, defeating CPC in the Civil War was the most pressing and difficult for the Nationalist Government. Thus, its military expenditure consistently occupied a dominating proportion of its total expenditure as shown in Table 3.6. This situation got much worse when the war balance turned towards CPC after the fall of 1947. Inability to collect tax revenue (which occurred due to a lack of legitimacy after multiple military failures and loss of territories), and (or unwillingness) to reduce expenditure made it impossible for the government to fight against inflation, regardless of its full awareness of the hyperinflation cost. However, the "anti-inflationary" Currency Reform was mandated on August 19, 1948. According to the decree, a new currency named "Gold Yuan Certificate" was issued to replace the old Fabi, with a exchange rate of 1 Gold Yuan for 3 million Fabi. People were ordered to exchange all their stocks of gold, silver and other foreign currencies with Gold Yuan by September 30th, 1948 or they would be confiscated, and all price and wage were frozen at the level on August 19th. According to the decree, the issued Gold Yuan amount could not exceed 200 million, but this limit was exceeded within just 10 days. Also, the deadline for submitting the precious gold was extended for another month. The Currency Reform collapsed and Gold Yuan thereby lost its public credit very soon, depreciating even faster than the old Fabi (see also Table 3.3).

As Chinese began to accept and use their first fiat money, Fabi, in 1935, they did not anticipate that the hyperinflation would follow and last for more than fourteen years. Neither did the original Consolidated Bond holders in 1936. When the Sino-Japanese War broke out in 1937, most of the Consolidated Bonds were far from maturity: even Type A Bond with the shortest term would be retired in 1948. Since the Consolidated Bond interests and principals were paid in Fabi (nominal terms), the real value of those bonds should be close to zero in the context of hyperinflation. However, Chapter 3.3 displays a puzzle of soaring bond price which was closely related to the bond holders' expectation for the Nationalist Government as briefly mentioned in Subsection 3.2.1.

3.3 The Bond Price Puzzle

The price soaring of the Consolidated Bonds was a puzzle because it constituted a counterexample for the conventional bond valuation. However, the puzzle could partially dissolve in China's socioeconomic environment during the 1940s.

3.3.1 Soaring Bond Prices

According to the conventional bond evaluation model, the value of a bond as shown in Equation 3.1 is the sum of present values of its future coupon and principal payments:

$$Value_{t_0} = \frac{Coupon_{t_1}}{(1+r)^{t_1-t_0}} + \frac{Coupon_{t_2}}{(1+r)^{t_2-t_0}} + ... + \frac{Coupon_{t_{n-1}}}{(1+r)^{t_{n-1}-t_0}} + \frac{Coupon_{t_n}}{(1+r)^{t_n-t_0}} + \frac{Principal}{(1+r)^{T-t_0}} \quad (3.1)$$

where t_0 is the current time the bond is traded, t_i $(i = 1, 2.., n)$ is the time the i^{th} coupon will be paid after t_0, T (maturity time) is time the bond principal will be repaid. Under normal circumstances, the discount rate or yield to maturity r is nonnegative .

Based on Equation 3.1, it is simple to calculate the upper bound price of a bond. As bond value decreases in r:

$$\begin{aligned} Value_{t_0} &\leq Coupon_{t_1} + Coupon_{t_2} + ... + Coupon_{t_{n-1}} + Coupon_{t_n} + Principal \\ &\leq \text{the sum of all Coupons since issuance plus Principal} \end{aligned}$$

Therefore, the upper bound value of, for example, Type C Bond with 100 yuan par, is $100 \times 6\% \times 15 + 100 = 190$ yuan. However, this value is surprisingly far lower than the actual prices of Consolidated Bonds traded during the Civil War as displayed in Table 3.7 and Figure 3.1. As early as October 1945, Type C Bond's price exceeded 300 yuan. It fluctuated much in 1946, reaching its peak of more than 6,000 yuan. After June 1947, the price generally maintained an exponential growth pattern with an average increase rate of 1.5% per day, finalizing its trading history at the level of 12 million yuan on August 26, 1948. It can be also seen from Figure 3.1 that the other four types of bonds with a 100 yuan face value featured almost the same price pattern. Apparently, traditional bond pricing determinants in regular times would fail to explain such an unprecedented puzzle of soaring bond prices. Recalling from Figure 3.2, however, the bond price patterns are similar to wholesale price index patterns around the same period. This "coincidence" motivates a plausible solution to the bond price puzzle.

3.3.2 Disentanglement: An Evolving Belief of Repayment

The similarity between patterns of the Consolidated Bond prices and the wholesale price index motivates a deflation operation even though the bonds were paid in nominal terms. I use the Shanghai wholesale price index to deflate the Type C Bond price. The index is normalized to 1 for average commodity price from January to June 1937. Therefore, the deflated price roughly reflects how much the bond was worth relative to the value when it was initially issued. Figure 3.4 and Table 3.8 both show that the Type C Bond deflated price experienced four major phases. Phase I from late March 1946 to early July 1946 witnessed the largest fluctuations: the deflated price started around 1, quickly climbed to its peak of over 2 in May and plummeted to around 0.2 by the end of June. Phase II starting from July 1946 saw much less volatility until February 1947. Phase III was like a repetition of the first one with a lower peak of around 1.5 but a wider time span of over 4 months. In the last phase after June 1947, the deflated price turned to a stationary pattern. On average, the 100 yuan Type C Consolidated Bond was worth around 0.3-0.5 Fabi yuan in year 1937 price. Though if depreciated greatly, the real value was regularly stable and never continuously declined to near zero, which provides a descriptive evidence that the bond price anchored the general price level.

Why did the bond price anchor the wholesale price index?

The Consolidated Bond issuance in 1936 was an important action the Nationalist Government took to rebuild its creditworthiness in the bond market. Not only in 1936 when the bonds were issued (see the description in Subsection 3.2.1) but also during the Civil War, the public paid much attention to how the government would repay the bonds. Table 3.12 summarizes the number of articles directly discussing the Consolidated Bonds[14] in three important newspapers issued in Shanghai: there were 345, 640, and 521 total counts in 1946, 1947, and 1948, respectively.

Although international conventions and the Consolidated Bond regulations only agreed with repayments in nominal terms (face values on bond and coupon certificates), the bond holders held a high expectation for the Nationalist Government to treat the Consolidated Bonds preferentially. They aimed for bond repayment with a variety of multipliers at different times, taking the price index as a reference. Furthermore, the belief of multipliers evolved according to the arrivals of news, good or bad.

The following are a few important events/news in chronological order which significantly affected the bond traders' belief of repayment with multipliers. On June 15, 1946, the Ministry of Finance released the information that the government would abate the bond discounting method and resume the original repayment method for all bonds issued before 1940. However, this information did not refer to any preferential treatment with the Consolidated Bonds so the belief of multipliers was severely shocked and bond price slumped just as the description of phase I. On August 14, 1946, a judgement was pronounced for the first court case concerning a client's prewar deposit in a commercial bank. The bank was ordered

[14]When searching the relevant news, I counted all the articles containing "统债" or "统一公债" which precisely means the Consolidated Bonds and "公债" which generally means government bonds but in the context specifically refers to the Consolidated Bonds.

to repay the client with a 1,000 multiplier. This judgement severely affected the commercial bank system but strengthen bond traders' belief that the government bond would be repaid in a similar way, which led to a bullish sentiment in the bond market. On June 6, 1947, the Minister of Finance emphasized that the bond would be retired with face value (in nominal terms) which deeply discouraged the bond traders and led to a sharp decline in bond prices as described in Phase III.

A derived form of the belief of bond repayment with multipliers was an expectation for the Currency Reform. There were lasting sentiments in financial markets that if the Currency Reform was implemented, then the Consolidated Bonds would be repaid with a new currency. Since the replacement ratio of new and old currencies would depend on the contemporary price index, the expectation for the Currency Reform was exactly the belief of repayment with multipliers. In fact, the expectations for the Currency Reform and multipliers were to some extent self-fulfilled. Soon after the Currency Reform, the Nationalist Government announced on September 6, 1948 that all the bonds denominated in Fabi currency would be retired with some multiplier[15] of their face values. For all types of Consolidated Bonds, the repayment multiplier is 27,000.

A hypothesis is thereby proposed that there was a belief of bond repayment with multipliers (and/or a belief of the Currency Reform) with reference to the general price level in the Shanghai Consolidated Bond market. The hypothesis will be tested in Section 3.5.

3.4 Data

To disentangle the bond price puzzle, I collected as much relevant information as possible about the bond trader's belief of repayment, the Consolidated Bonds per se, and financial

[15] Adjusted repayment multipliers were announced on February 8, 1949. See Table 3.9 for the initial and adjusted multipliers for all bonds

markets in Shanghai. The data collection and digitization process is similar to the description in Section 2.3, Chapter 2 of this dissertation.

3.4.1 Sociopolitical News

I first compiled sociopolitical events of two dimensions that might affect the Consolidated Bond market. One dimension is about financial and political news and public opinions reported in newspapers. As discussed in Subsection 3.3.2, two types of information might directly or indirectly affect the bond price pattern: "repayment with multipliers" and the "Currency Reform." Therefore, I collected related articles from Shen Bao (申报), mentioned in Subsection 3.2.1, and two other popular Shanghai newspapers, Ta Kung Pao (大公报)[16] and Zheng Xin Suo Bao (征信所报)[17], issued in 1946-1948[18]. The article counts are summarized in Table 3.12: in total, there were 268 articles directly discussing repayment with multipliers and 318 articles about the Currency Reform in these three newspapers in less than 3 years. The other dimension of information relates to battles in the Civil War because wartime political uncertainty might lead to sell-offs and large fluctuations in financial markets. The battle statistics are described in Subsection 2.3.1 and 2.3.3 of Chapter 2.

3.4.2 Shanghai Financial Markets

I then compiled a novel data set of Shanghai financial markets mainly during 1946-1948. Unless otherwise noted, all information was obtained from the *Financial Weekly* (also see Subsection 2.3.1 in Chapter 2). Most data were reported on a daily basis. Note that unlike today, China had six working days (excluding Sundays and holidays) each week in the 1940s. The following is a description of the variables in the data set.

[16]Ta Kung Pao (大公报) was issued daily.

[17]Zheng Xin Suo Bao (征信所报) was issued daily (except Sundays).

[18]Before August 19, 1948.

I collected daily prices of Type A-E Consolidated Bonds traded on the Shanghai bond market from October 1, 1945 to August 28, 1948. In reference to how fast the bond price actually increased, I also collected daily price levels, measured by the wholesale price indices[19] of 23 basic commodities in Shanghai, from March 25, 1946 to August 19, 1948.

I obtained interest rates, prices of precious metals and foreign currencies, bill clearing amounts, and stock price indices in Shanghai, which reflected the financial market fundamentals. The nominal interest rates from March 25, 1946 to August 19, 1948 are measured by the black-market loan rates[20] on the Shanghai money market. Gold, silver, U.S. banknotes and Hong Kong banknotes also had daily quotations but they had generally become buying rates set by the Central Bank rather than regular market prices since March 1947. The amount of bill clearings in Shanghai, an indicator of commercial activeness, was collected from January 4, 1946 to August 19, 1948. The Shanghai stock price index was taken from the *Capital Market* and the *Securities Market*[21]. These two periodicals were issued by the Investigation and Research department of the Shanghai Stock Exchange[22]. They listed prices of many individual stocks and constructed a (general) stock price index as a weighted price average of 7 component stocks[23]. I was able to collect daily stock price indices of the whole year of 1947 and monthly indices from October 1946 to August 1948. I also compiled

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[19]The index normalized the average price from January to June in 1937 to 100. I divide each price index by 100 for convenience.

[20]The rate was daily quoted but calculated as the interest of per yuan loan per month. The nominal interest rates from January 14, 1946 to March 23, 1946 are also available but measured by loan rates on the securities market.

[21]The *Securities Market* published its first issue in November 1946 and changed its name to the *Capital Market* in January, 1948.

[22]The Shanghai Stock Exchange, hereinafter referred to as SSE, was "reestablished" on September 9, 1946 and began trading stocks on September 16, 1946. Its predecessor, Shanghai Chinese Merchants Stock Exchange was founded in May 1920 and shut down on December 8, 1941 due to the Japanese's occupation of the Shanghai International Settlement during the Second Sino-Japanese War.

[23]Those 7 component stocks with respective weights are: Wing On Textiles (永安纱厂, 70%), Hsin Ho Textiles (信和纱厂, 10%), Mayar Silk (美亚织绸, 7%); Standard Shirts (新光内衣, 5%); Ching Foo Knit'g (景福衫袜, 4.5%); Chin Sin Knit'g (勤兴衫袜, 2%) and Wing On Co. (永安公司, 1.5%).

weekly stock price indices from the week of September 23, 1946 to the week of August 16, 1948 using the same weighting method.

As shown in Table 3.8, Table 3.10 and Table 3.11, the Shanghai financial market experienced a rapid growth in all financial assets and the nominal interest rate. Their descriptive statistics are summarized in Table 3.13 in which all variables except *Interest Rate* are deflated by the Shanghai wholesale price index. The coefficient of variation (CV) is used to measure deflated asset price volatility. Generally, the Consolidated Bonds manifested a much higher price volatility (with a more than double CV, marked in red) than other assets, which indicates unusual forces were specifically driving bond trading or arbitrage.

3.5 Research Design

3.5.1 Empirical Specification

To investigate the bond price puzzle in a quantitative way, a hypothesis with regard to repayment belief is formally proposed in this section.

Hypothesis: If the bond traders' belief of repayment with multipliers takes price index as a reference, then the deflated bond price growth rate increases (decreases) in the arrivals of positive (negative) news about repayment multipliers.

A simple empirical specification is constructed as Equation 3.2:

$$\dot{p}_t := log\frac{p_t}{p_{t-1}} = \alpha_0 + \alpha_1 \cdot News_t + \alpha_2 \cdot Interest_t + \Gamma_t \cdot X_t + \epsilon_t \tag{3.2}$$

In the above equation, p_t is the Consolidated Bond price deflated by the Shanghai wholesale price index at time t. As shown in Figure 3.1, the price patterns of all five bond types are similar, so at this stage I only use Type C Bond price. $\dot{p}_t$ is defined as the growth rate of p_t. $News_t$ is the measure of good (bad) news about repayment with multipliers. $Interest_t$ is the interest rate. X_t is a vector of other control variables and Γ_t is its coefficient vector. ϵ_t is an error term.

In this section, I use the number of articles (see a descriptive statistics in Table 3.12) concerning repayment with multipliers as the news measure. Specifically, I collected relevant articles from Shen Bao (申报) newspaper and divided them into four categories: positive news about repayment with multipliers[24], negative news about repayment with multipliers, positive news about the Currency Reform, and negative news about the Currency Reform.

$Interest_t$ is added because it is well known that the interest rate is a primary determinant for bond pricing. If the Consolidated Bond price pattern, however, was irrelevant with the interest rate, it would imply that some irregular factors existed in the bond market.

X_t can include the number of days to the next lottery, deflated stock price index, deflated silver price, deflated U.S. banknotes price [25], the deflated amount of bill clearings, and a Civil War measure. I use prices of other assets and bill clearings amount to control the financial market fundamentals. The number of days to the next lottery matters because in any lottery a drawn bond certificate was expected to be repaid with face value and lost the future opportunity for repayment with multipliers. The Civil War measure is constructed in the same way as Equation 2.3 in Chapter 2. It is an average influence of ongoing battles on Shanghai weighted by distances and casualties.

Time t is of weekly frequency. I calculate and use a 6-day average of daily values for all variables for four reasons. First, this average can eliminate noises within a week for volatile asset prices. Second, currently I only have daily stock price index in 1947 but weekly index of more than 2 years. Furthermore, weekly averages of the discrete and scattered article counts are better for estimation. Lastly, denoting the original bond price as P, $\dot{P}_t$ may be very close to $\dot{p}_t$ in daily data due to a relatively small change in daily price index. In this

[24] All news about multipliers with regard to deposit, rent, employee compensation and bond repayments are included if the payable amount occurred before the Sino-Japanese War and was affected by hyperinflation.

[25] I exclude gold price and Hong Kong banknotes price from X_t because they were highly correlated with silver price and U.S. banknotes price, respectively. Silver was also a more popular precious metal than gold in China in the early 20th century.

case, price level reference becomes meaningless and the puzzle mechanism interpretation, if any, will be entirely different.

3.5.2 Main Results

The effects of positive and negative news about repayment with multipliers and the Currency Reform are estimated separately in each specification of Table 3.14. The controls are added sequentially but none of them has a statistically important impact on the Type C Bond deflated price growth rate.

It is worth noting that the battle measure and the interest rate were not relevant to the bond price growth in all specifications, which implies that (1) the Consolidated Bond market was not sensitive to the Civil War situation and (2) the abnormal bond price was not driven by regular forces.

Most coefficients of the four news measures display anticipated signs. In particular, the positive news about the Currency Reform has a strongly significant influence which is consistent across all empirical specifications. Without any control, the price growth rate will be positively and significantly responsive to the positive news about the repayment multipliers. Furthermore, with all controls added, the negative news about multipliers will also show a significant effect on bond price growth. On average, 1 more positive news per week about the Currency Reform will lead to an 8.8 percentage points increase in weekly price growth rate while 1 additional negative news about the multipliers will decelerate the bond growth by 8.2 percentage points each week. Since there were 192 pieces of Currency Reform positive news and 72 pieces of multipliers negative news in Shen Bao newspaper from 1946 to 1948, the overall effect of relevant news is very likely to be positive. In other words, the continuous arrival of good news about the Currency Reform overwhelmed the negative messages about multipliers, which maintained and strengthened bond traders' belief that the Consolidated Bond would be repaid with an appropriate multipliers after the future reform was implemented.

3.5.3 Mechanism

To check whether the news about the Currency Reform and repayment multipliers also influenced the prices of other financial assets, I implement a similar estimation as Equation 3.3:

$$\dot{q}_t := log\frac{q_t}{q_{t-1}} = \beta_0 + \beta_1 \cdot News_t + \beta_2 \cdot Interest_t + \Theta_t \cdot Y_t + \eta_t \tag{3.3}$$

where q_t is the deflated price of some other financial asset at time t. $\dot{q}_t$ is defined as the growth rate of q_t. $News_t$ is defined the same as in Equation 3.2. Y_t is a vector of other control variables and Θ_t is its coefficient vector. η_t is an error term.

As shown in Table 3.15, I estimate the effect of news on all options of q_t, the amount of bill clearings, gold price, silver price, stock price index, U.S. banknotes price and Hong Kong banknotes price. As anticipated, a higher interest rate strongly depressed the stock market and economic activities as reflected by the bill clearings amount in Shanghai. However, none but only the growth rate of U.S. banknotes price was significantly responsive to the negative news about repayment multipliers. As in the case of the bond market, battles had nearly no impact on other assets' price pattern. In other words, Shanghai financial markets paid little attention to the Civil War progress.

These results generally exclude the possibility that news influenced the bond price by affecting relevant assets. In other words, the effect of news about the Currency Reform and Multipliers was Consolidated Bond specific.

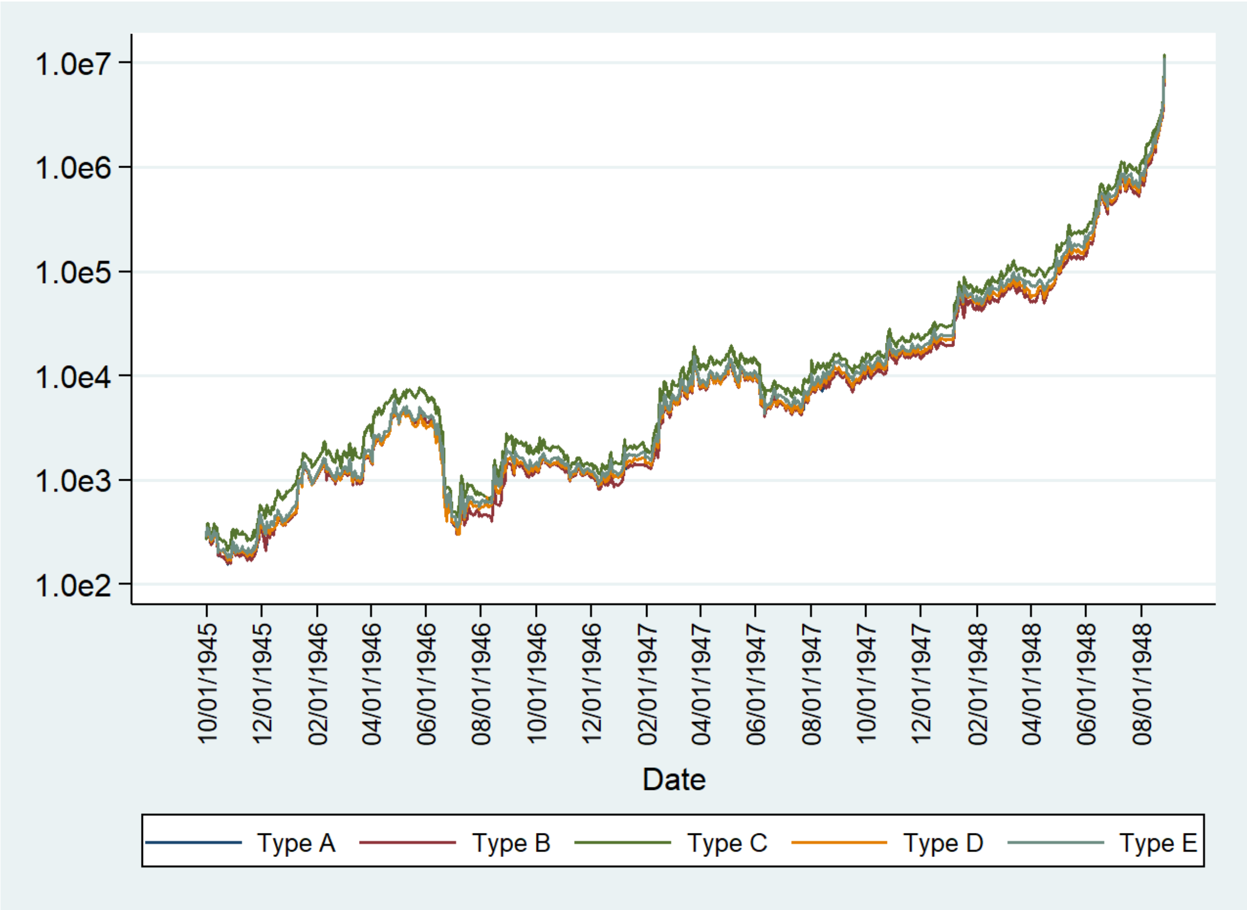
3.6 Conclusion

This chapter provides a solution to the Consolidated Bond price puzzle from 1946 to 1948 during the Chinese Civil War period. In the context of hyperinflation, the bond traders in Shanghai believed that the Nationalist Government would repay the bond far more than its obligation in nominal terms. The belief of repayment with multipliers and the associated expectation for the Currency Reform were strengthened by the continuous arrival of good news, which drove up the bond price. Although the real value of bonds became rather small relative to its initial value in 1936, the soaring bond price kept pace with the price index all the way. The Consolidated Bond thereby provided its investors a partial hedge against the Chinese hyperinflation.

Although the conventional wisdom is that political uncertainties raise financial market volatility, the Civil War had little impact on deflated bond prices. However, the expectation for the Currency Reform was closely related to the Nationalist Government's financial distress from increasing military expenses and its efforts to control inflation. As the war proceeded, it became more of common knowledge that the government must maintain its creditworthiness in debt markets for the future reform. Therefore, rather than inflate away the public debt, the government chose to eventually endorse the bond price bubble on which the bond traders rode for a few years. This case, though in Chinese financial history, may provide a worldwide policy implication that extreme beliefs in financial markets can persist and even be fulfilled in abnormal sociopolitical circumstances.

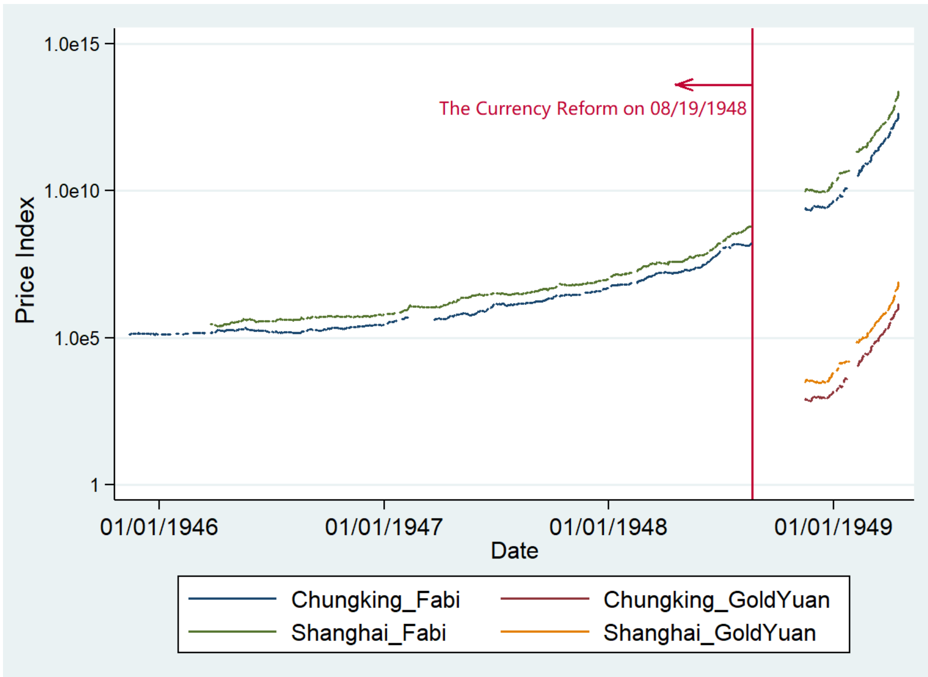
Figures

Figure 3.1: Consolidated Bond Price Patterns, log_{10} Scale



Notes: This figure shows the log_{10} scaled price patterns of the Consolidated Bonds, Type A-E (Par=100 yuan, coupon rate 6%, paid semiannually), from October 1, 1945 to August 28, 1948. Source: *Financial Weekly*.

Figure 3.2: Wholesale Price Indices denominated in Fabi and Gold Yuan Currency in Shanghai and Chungking (log_{10} scale, January-June 1937=100)

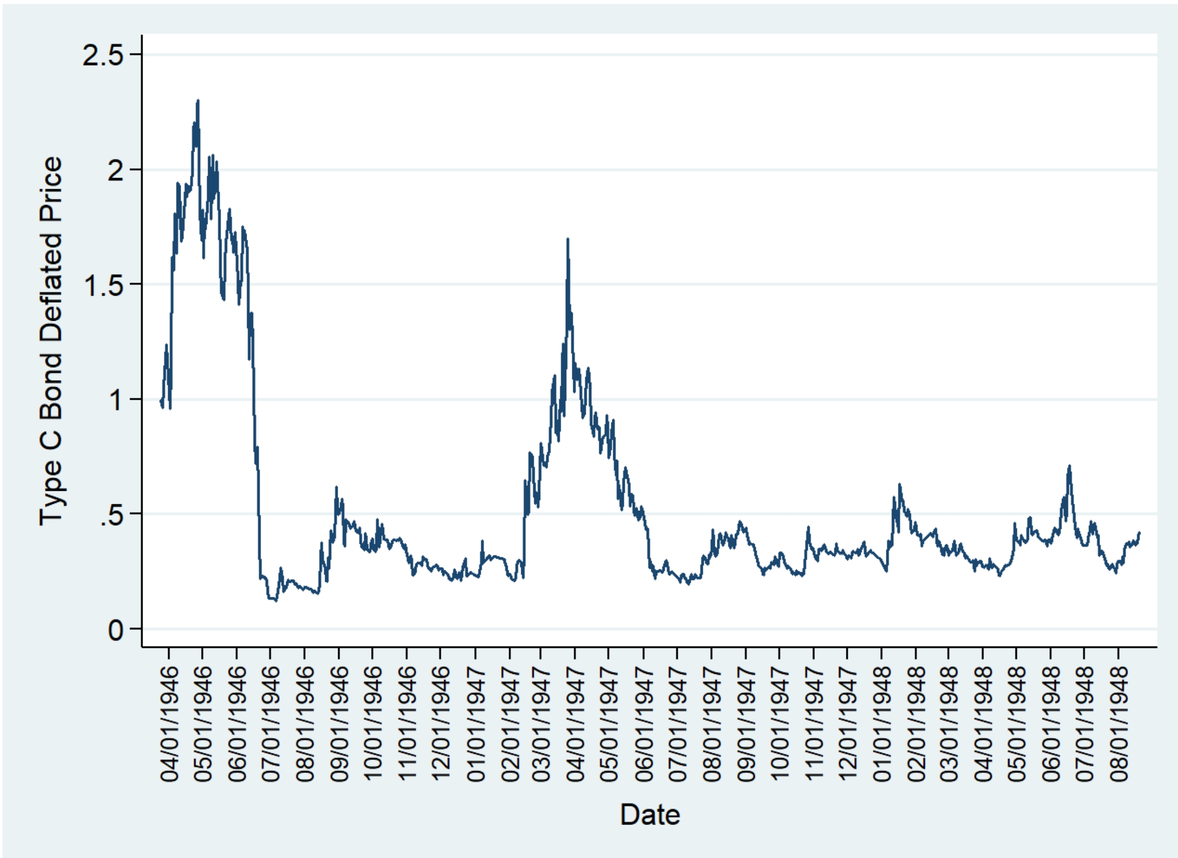


Notes: This figure shows the wholesale price indices (in log_{10} scale) in Shanghai (March 25, 1946 to April 16, 1949) and Chungking (November 13, 1945 to April 16, 1949). The price index normalized the average price from January to June in 1937 to 100. On August 19, 1948, the Currency Reform was implemented and the new currency Gold Yuan Certificate was issued to replace the old currency Fabi in a 1 to 3 million ratio. The red and orange lines indicate the price indices denominated in Gold Yuan. The green and blue lines above them indicate the price indices transferred into Fabi denomination. Source: *Financial Weekly*.

Figure 3.3: A Sample of Type A Consolidated Bond Certificate, Front Side

Notes: This photo shows a Type A Consolidated Bond Certificate with attached coupon certificates on the front side. The face value of this certificate is 100 yuan in Fabi currency. The top half of the paper is the bond certificate with a serial number 024398 printed along the bottom edge. The bottom half of the paper contains 13 coupons (rate 6%, paid semiannually) with the same serial number. Each coupon is worth $100 \times 6\% \times \frac{1}{2} = 3$ yuan. Source: Shanghai Huayu Auction Company website, http://www.huabid.com/auctions/97792.

Figure 3.4: Type C Bond Deflated Price Pattern



Notes: This figure shows the Type C Bond deflated price pattern. I deflate the original bond price by an adjusted Shanghai wholesale index. The index normalized the average commodity price from January to June in 1937 to 1. Therefore, the deflated price reflected the real bond value with a face value of 100 yuan in year 1937 price level. Source: *Financial Weekly*.

Tables

February 1, 1936	Bond Issuance Began.
February 8, 1936	Bond Regulations & Schedules Published.
July 7, 1937	The Second Sino-Japanese War Broke out.
January 15, 1939	Bond Repayment Suspended/Discounting Began.
August 15, 1945	The Second Sino-Japanese War Ended.
July 1, 1946	The First Time the MoF Stated Resumed Original Bond Repayment Method.
July 1, 1946	Bond Repayment Resumed.
August 14, 1946	The First Court Case of Deposit Repayment with Multipliers.
September 9, 1946	SSE Opened.
September 16, 1946	SSE Began Trading Stocks.
December 26, 1947	Deposit Repayment Regulations Published.
August 19, 1948	Gold Yuan Currency Reform Began.
September 6, 1948	Initial Repayment Multipliers Announced.
February 8, 1949	Adjusted Repayment Multipliers Announced.

Table 3.1: Timeline of Events Related to the 25th Year Consolidated Bonds

Table 3.2: Price Index for All China, Shanghai City and Chungking City: 1946.1-1949.4

Year and Month	All China	Shanghai	Chungking
Jan. 1946	182,667	160,315	209,561
Apr. 1946	309,260	325,986	248,296
Jul. 1946	412,908	403,982	273,325
Oct. 1946	547,852	612,071	357,322
Jan. 1947	755,000	817,750	525,300
Apr. 1947	1,390,200	1,669,900	780,567
Jul. 1947	3,122,400	3,359,400	1,986,598
Oct. 1947	5,931,300	7,293,400	3,872,665
Jan. 1948		14,074,200	6,327,700
Apr. 1948		37,764,200	16,678,800
Jul. 1948		287,700,000	132,500,000
Aug. 1948		186.3 (the adoption of Gold Yuan Currency)	
Sep. 1948		197.0	
Oct. 1948		220.4	
Nov. 1948		2,543.1	
Dec. 1948		3,583.7	
Jan. 1949		12,876.2	
Feb. 1949		89,788.0	
Mar. 1949		405,320.0	
Apr. 1949		20,957,009.0	

Source: Chang (1958).

Table 3.3: Note Issue Outstanding (in Billion Yuan) in the Republic of China: 1945.09-1949.03

Period	Note Issue	Ratio	Index	Period	Note Issue	Ratio	Index
Sep. 1945	674.2	1.21	478.01	Oct. 1945	805.9	1.19	500.48
Nov. 1945	901.0	1.11	638.81	Dec. 1945	1,031.9	1.14	731.62
Jan. 1946	1,149.9	1.11	815.28	Feb. 1946	1,261.2	1.09	864.19
Mar. 1946	1,345.6	1.06	954.03	Apr. 1946	1,528.1	1.13	1,083.42
May 1946	1,796.0	1.17	1,273.36	Jun. 1946	2,112.5	1.17	1,497.76
Jul. 1946	2,158.1	1.02	1,530.45	Aug. 1946	2,376.1	1.10	1,684.65
Sep. 1946	2,700.6	1.13	1,914.73	Oct. 1946	2,983.9	1.10	2,115,59
Nov. 1946	3,296.2	1.10	2,337.01	Dec. 1946	3,726.1	1.13	2,641.80
Jan. 1947	4,509.5	1.21	3,197.24	Feb. 1947	4,837.8	1.07	3,430.00
Mar. 1947	5,744.1	1.18	4,072.57	Apr. 1947	6,901.1	1.20	4,892.88
May 1947	8,381.3	1.21	5,942.34	Jun. 1947	9,935.1	1.16	7,096.53
Jul. 1947	11,664.1	1.15	8,455.80	Aug. 1947	13,697.3	1.17	9,714.39
Sep. 1947	16,948.1	1.24	12,019.92	Oct. 1947	20,791.2	1.23	14,745.53
Nov. 1947	26,878.9	1.29	19,063.04	Dec. 1947	33,188.5	1.23	23,537.04
Jan. 1948	40,940.9	1.23	29,036.09	Feb. 1948	53,928.7	1.32	38,247.30
Mar. 1948	69,682.1	1.29	49,419.92	Apr. 1948	97.798.9	1.40	69,360.92
May 1948	137,418.8	1.40	97,460.14	Jun. 1948	196,520.3	1.43	139,376.09
Jul. 1948	374,762.2	1.91	265,788.79	Aug. 21, 1948	663,694.6		
Aug. 31, 1948	0.544	1.00	1.00	Sep. 1948	1.202	2.21	2.21
Oct. 1948	1.850	1.54	3.40	Nov. 1948	3.394	1.83	6.24
Dec. 1948	8.320	2.45	15.29	Jan. 1949	20.822	2.50	38.28
Feb. 1949	59.644	2.87	109.68	Mar. 1949	196.60	3.29	360.40
Apr. 1949	5,161.240	26.32	9,487.57				

Notes: Ratio indicates the month-on-month ratio. From September 1945 to August 21, 1948, the note refers to Fabi, and the Index in June 1937 is normalized to 1. From August 31, 1948 to April 1949, the note refers to the Gold Yuan Certificate, and the index on August 31st, 1948 is normalized to 1 (Source: Wu (1958)).

Table 3.4: Note Issue Outstanding, Government Expenditure, Revenue, and the Deficit, 1946-1948 (January-July), Fabi million Yuan

Year	Note Issue Outstanding	Gov't. Expenditure	Gov't. Revenue	Deficit
1945	1,031,900	2,348,085	1,241,389	1,106,696
1946	3,726,100	7,574,790	2,876,988	4,697,802
1947	33,188,500	43,393,895	14,064,383	29,329,512
1948	374,762,200	655,471,087	220,905,475	434,565,612

Source: Chang (1958).

Table 3.5: Government Bank Loans, Deposits and Increase in Note Issue, 1945-1948 (January-June), Fabi million Yuan

Year	Increase in Deposits	Private Loans	Advances to Gov't.	Increase in Note Issue
1945	431,616	121,661	1,043,257	842,400
1946	4,893,940	1,073,483	5,513,670	2,694,200
1947	20,413,953	16,119,751	27,075,033	29,462,400
1948	161,101,894	156,496,326	166,185,674	163,332,800

Source: Chang (1958).

Table 3.6: Estimated Composition of Central Government Expenditure, 1946-1948 (January-July), in percent of total

Expenditure	Average 1941-44	1946	1947	1948
1. Defense expenditure	60	59.9	54.8	68.5
2. Loan Service	5	0.6	1.2	2.6
3. Development	10	11.0	14.3	5.2
4. Administrative and general expenditure	25	28.5	29.7	23.7
5. Grand Total	100%	100%	100%	100%

Source: Chang (1958).

Table 3.7: Some Daily Prices of Consolidated Bonds (Type A-E) in Shanghai

Date	Type A	Type B	Type C	Type D	Type E
Oct. 1, 1945	280	280	270	290	290
Dec. 1, 1945	320	320	535	350	390
May 1, 1946	4,200	4,200	6,050	4,200	4,350
Aug. 1, 1946	470	470	750	540	610
Oct. 1, 1946	1,250	1,250	2,080	1,300	1,500
Nov. 1, 1946	1,300	1,300	1,750	1,350	1,450
Feb. 1, 1947	1,380	1,380	1,980	1,480	1,680
Apr. 1, 1947	8,000	8,000	12,800	8,000	9,000
Aug. 1, 1947	7,300	7,300	10,900	7,500	8,200
Oct. 1, 1947	11,200	11,200	16,500	12,000	13,800
Dec. 1, 1947	14,600	14600	22,000	16,000	18,000
Apr. 1, 1948	52,000	52,000	94,000	57,000	75,000
Jun. 1, 1948	139,000	139,000	240,000	164,000	193,000
Aug. 19, 1948	1,880,000	1,880,000	2,550,000	1,970,000	2,150,000

Notes: Terms of bonds of type A-E : 12 years, 15 years, 18 years, 21 years and 24 years, par value: 100 *yuan* in Fabi currency, coupon rate: 6%, paid semiannually. Before 1947, there was a single daily price record for each bond, after 1947 the daily price referred to buying price. (Source: *Financial Weekly*).

Table 3.8: Consolidated Bond Prices v.s Stock Price Indices (SPI), Wholesale Price Indices (WPI) and Interest Rates in Shanghai

Month	Bond Price	WPI	$\frac{BondPrice}{WPI}$	SPI	$\frac{BondPrice}{SPI}$	$\frac{SPI}{WPI}$
Apr. 1946	4,998	2,582	1.94			
May 1946	6,772	3,807	1.78			
Jun. 1946	2,715	3,724	0.73			
Jul. 1946	751	4,072	0.18			
Aug. 1946	1,069	4,286	0.25			
Sep. 1946	2,130	5,092	0.42			
Oct. 1946	2,038	5,363	0.38	110	18.5	0.021
Dec. 1946	1,365	5,713	0.24	74	18.4	0.013
Feb. 1947	4,272	10,665	0.40	213	20.1	
Apr. 1947	13,469	14,253	0.94	511	26.4	0.036
Jun. 1947	8,345	29,931	0.28	965	8.6	0.032
Aug. 1947	12,833	32,980	0.39	1,399	9.2	0.042
Oct. 1947	17,343	59,879	0.29	1,816	9.6	0.030
Dec. 1947	27,446	83,796	0.33	2,581	10.6	0.031
Feb. 1948	76,957	201,552	0.38	5,041	15.3	0.025
Apr. 1948	106,292	377,642	0.28	11,915	8.9	0.032
Jun. 1948	443,818	976,900	0.45	23,714	18.7	0.024
Aug. 1948	1,708,985	4,839,764	0.35	86,165	19.8	0.018

Notes: Bond Price: monthly geometric mean of the daily buying price of the type C (18-year term, par=100 *yuan*) bond. WPI: monthly geometric mean of the daily adjusted wholesale price index of 23 basic commodities in Shanghai. The adjusted index takes the average price from January to June in 1937 as 1. The data of these three variables in Aug. 1948 are only up to Aug. 19th (Source: *Financial Weekly*). SPI: monthly arithmetic mean of stock price index constructed by the daily prices of 7 stocks traded in Shanghai Stock Exchange (Source: *Securities Markets* and *Credit Markets*).

Table 3.9: Repayment Multipliers of Central Government's Bond Denominated in Fabi

Bond Name	Multipliers
17th Year Long Term Financial Bond (十七年金融长期公债)	27,000/1,350,000
25th Year Consolidated Bonds, Type B-E (二十五年统一公债乙丙丁戊种债票)	27,000/1,350,000
25th Year Recovery Bond (二十五年复兴公债)	27,000/1,350,000
25th Year Szechwan Relief Bond (二十五年四川善后公债)	27,000/1,350,000
25th Year Kwangtung Consolidated Financial Bond (二十五年整理广东金融公债)	27,000/1,350,000
26th Year National Salvation Bond (二十六年救国公债)	13,000/650,000
26th Year Kwanghsi Consolidated Financial Bond (二十六年整理广西金融公债)	13,000/650,000
27th Year National Defense Bond (二十七年国防公债)	12,000/600,000
27th Year Customs Gold Bond (二十七年金公债关金债票)	12,000/600,000
27th Year Rescue Bond (二十七年振济公债)	12,000/600,000
28th Year Munition Bond, the 2nd Issue (二十八年军需公债第二期债票)	10,000/500,000
29th Year Munition Bond, 1st Issue (二十九年军需公债第一期债票)	9,000/450,000
30th Year Munition Bond, 1st Issuance (三十年军需公债第一期债票)	7,000/350,000
31st Year Allies' Victory Bond (三十一年同盟胜利公债)	5,000/250,000
32nd Year Allies' Victory Bond (三十二年同盟胜利公债)	3,000/150,000
32nd Year Consolidated Bonds of Provincial Debts (三十二年整理省债公债)	3,000/150,000
33rd Year Allies' Victory Bond (三十三年同盟胜利公债)	1,000/50,000

Notes: The first column lists the English and Chinese names of 17 bonds denominated in Fabi currency issued by the central government of the Republic of China before 1945. The second column lists multipliers applied to the principal and interest repayments of these bonds after the implementation of the currency reform on August 19, 1948. For each bond, the first number was the original multiplier announced on September 4, 1948, and the second number was the adjusted multiplier announced on February 8, 1949. The bonds marked in red, the *25th Year Consolidated Bonds*, are discussed in detail in Chapter 2 of this dissertation. Source: *SHAC (2000)*.

Table 3.10: Monthly Average Prices of Consolidated Bond, Gold and Silver and Monthly Average Interest Rate in Shanghai, in Unit of Fabi Yuan

Year & Month	Bond	Gold	Silver	$\frac{Bond}{Gold}$	$\frac{Bond}{Silver}$	Interest Rate
Apr. 1946	4,998	155,043	1,572	3.2×10^{-2}	3.18	0.140
Jun. 1946	2,715	189,881	2,160	1.4×10^{-2}	1.26	0.148
Aug. 1946	1,069	202,711	2,068	5.3×10^{-3}	0.52	0.141
Oct. 1946	2,038	223,065	3,294	9.1×10^{-3}	0.62	0.172
Dec. 1946	1,365	315,468	4,116	4.3×10^{-3}	0.33	0.170
Feb. 1947	2,066	478,936	6,551	4.3×10^{-3}	0.32	0.167
Apr. 1947	13,469	4,800,000	12,610	2.8×10^{-3}	1.07	0.114
Jun. 1947	8,345	4,800,000	21,339	1.7×10^{-3}	0.39	0.183
Aug. 1947	12,833	4,800,000	32,000	2.7×10^{-3}	0.40	0.146
Oct. 1947	17,343	21,438,466	57,809	8.1×10^{-4}	0.30	0.205
Dec. 1947	27,446	30,752,448	96,670	8.9×10^{-4}	0.28	0.231
Feb. 1948	76,957	55,353,407	158,850	1.4×10^{-3}	0.48	0.220
Apr. 1948	106,292	124,912,028	362,487	8.5×10^{-4}	0.29	0.265
Jun. 1948	443,818	189,600,000	678,971	2.3×10^{-3}	0.65	0.298

Notes: Bond: monthly geometric mean of the daily buying price of Type C Consolidated Bond (18-year term, par=100 *yuan*). Gold: monthly geometric mean of the daily price of gold with 0.992 fineness per shih-liang (1 shih-liang=31.25 gram). Silver: monthly geometric mean of the daily price of silver with 0.970 fineness per shih-liang. The price of gold refers to the closing price before Mar. 1947 and then central bank buying prices. $\frac{Bond}{Gold}$: ratio of monthly average bond price over monthly average gold price. $\frac{Bond}{Silver}$: ratio of monthly average bond price over monthly average silver price. Interest Rate: monthly arithmetic mean of daily black market loan rate (in units of *yuan* per *yuan* per month) in Shanghai. For the month of February, 1947, the date range is up to February 8. Source: *Financial Weekly*.

Table 3.11: Monthly Average Prices of U.S. Banknotes and HK Banknotes and Monthly Average Amount of Bill Clearings in Shanghai, in Unit of Fabi Yuan

Year & Month	Clearings	U.S. Notes	H.K. Notes	$\frac{Bond}{Clearings}$	$\frac{Bond}{U.S.Notes}$	$\frac{Bond}{H.K.Notes}$
Apr. 1946	75 Billion	2,089	408	6.66×10^{-8}	2.39	12.3
Jun. 1946	156 Billion	2,575	469	1.74×10^{-8}	1.05	5.79
Aug. 1946	171 Billion	2,880	635	6.25×10^{-9}	0.37	1.68
Oct. 1946	243 Billion	4,229	891	8.39×10^{-9}	0.48	2.29
Dec. 1946	325 Billion	5,846	1,161	4.20×10^{-9}	0.23	1.18
Feb. 1947	384 Billion	9,153	1,746	5.38×10^{-9}	0.23	1.18
Apr. 1947	708 Billion	11,640	2,450	1.90×10^{-8}	1.16	5.50
Jun. 1947	1.2 Trillion	11,640	2,450	6.95×10^{-9}	0.72	3.41
Aug. 1947	1.5 Trillion	11,640	2,450	8.56×10^{-9}	1.10	5.24
Oct. 1947	2.9 Trillion	53,596		5.98×10^{-9}	0.32	
Dec. 1947	4.3 Trillion	76,986		6.38×10^{-9}	0.36	
Feb. 1948	6.2 Trillion	134,232		1.24×10^{-8}	0.57	
Apr. 1948	17 Trillion	302,912		6.25×10^{-9}	0.35	
Jun. 1948	32 Trillion	459,780		1.39×10^{-8}	0.97	
Aug. 1948	164 Trillion			1.04×10^{-8}		

Notes: Clearings: monthly arithmetic mean of the amount of bill clearings. U.S. Notes: monthly geometric mean of the daily price per U.S. dollar/banknote. H.K. banknotes price: monthly geometric mean of the daily price per Hong Kong dollar/banknote. The prices of gold and U.S. banknotes refer to their closing prices before Mar. 1947 and then central bank buying prices. The prices of H.K. banknotes refer to its market buying prices before Mar. 1947 and then central bank buying prices. For the month of February, 1947, the date range is up to February 8. For the month of August 1948, the date is up to August 19. Source: *Financial Weekly*.

Table 3.12: Article Counts in Newspaper Issued in Shanghai

Newspaper	Year	Counts of Articles Directly Related to Consolidated Bond (“公债”/“统债”)	Repayment with Multipliers (“多倍还本”)	Currency Reform (“币制改革”)
Ta Kung Pao	1946	90	49	10
Ta Kung Pao	1947	153	59	19
Ta Kung Pao	1948	183	11	43
Shen Bao	1946	134	43	8
Shen Bao	1947	326	77	78
Shen Bao	1948	215	10	135
Zheng Xin Suo Bao	1946	121	8	3
Zheng Xin Suo Bao	1947	161	11	15
Zheng Xin Suo Bao	1948	123	0	7

Notes: This table summarizes the numbers of articles containing keywords of “Consolidated Bond”, “Repayment with Multipliers”, and “Currency Reform” which were published respectively in three contemporary newspapers from 1946 to 1948. For “Repayment with Multipliers” and “Currency Reform”, the year 1948 means the period before August 19, 1948. Ta Kung Pao (大公报) was daily issued. Shen Bao (申报), daily issued, was the most popular newspaper in China before 1949. Zheng Xin Suo Bao (征信所报) was issued daily, except on Sundays.

Table 3.13: (Deflated) Financial Asset Prices (1946-1948): Summary Statistics

	Observation	Mean	Std.	CV	Min	Max
Interest Rate	744	0.208	0.092	0.443	0.080	0.750
Type A Bond Price	701	0.334	0.268	0.803	0.081	1.760
Type B Bond Price	701	0.335	0.268	0.802	0.081	1.760
Type C Bond Price	705	0.527	0.447	0.849	0.122	2.301
Type D Bond Price	700	0.350	0.257	0.734	0.081	1.745
Type E Bond Price	701	0.387	0.281	0.726	0.095	1.822
Stock Price Index	96	0.027	0.008	0.314	0.011	0.044
Bill Clearings	675	4.20e+07	1.07e+07	0.255	1.07e+07	8.08e+07
Gold Price	623	186.31	133.95	0.719	39.58	433.60
Silver Price	599	0.767	0.209	0.273	0.381	1.301
U.S. Banknotes Price	621	0.725	0.198	0.274	0.308	1.246
H.K. Banknotes Price	391	0.138	0.042	0.303	0.065	0.251

Notes: All variables except *Interest Rate* are deflated by Shanghai wholesale price index. Daily data for all variables except weekly *Shanghai Price Index*. Coefficient of Variation (CV) represents the ratio of the standard deviation (Std.) to the mean. Source: *Financial Weekly*.

Table 3.14: The Effect of News of the Currency Reform and Repayment Multipliers

Dependent Variable: Type C Bond Price Growth Rate, $\dot{p}_t$						
	(1)	(2)	(3)	(4)	(5)	(6)
Positive $Multipliers_t$	.170*	.076	.077	.083	.052	.091
	(.094)	(.068)	(.070)	(.069)	(.061)	(.062)
Negative $Multipliers_t$	-.036	-.040	-.032	-.046	-.080	-.082*
	(.073)	(.073)	(.069)	(.066)	(.056)	(.047)
Positive $Reform_t$	.089***	.101***	.098***	.098***	.108***	.088***
	(.027)	(.027)	(.027)	(.027)	(.023)	(.028)
Negative $Reform_t$	-.042	-.037	-.049	-.054	.027	7.8e-4
	(.055)	(.061)	(.062)	(.064)	(.051)	(.046)
$Interest_t$		.008	.027	.009	.124	-.256
		(.199)	(.211)	(.213)	(.198)	(.363)
$Battles_t$			3.5e-4	3.3e-4	-7.0e-5	4.9e-6
			(2.2e-4)	(2.2e-4)	(2.4e-4)	(2.5e-4)
Controls	*N*	*N*	*N*	*Y*	*Y*	*Y*
Obs.	123	117	117	117	89	75
R^2	0.068	0.062	0.091	0.097	0.217	0.313

Notes: This table reports OLS regression results of the specification in Equation 3.2. The complete set of controls include (a) the number of days to next lottery, (b) deflated amount of bill clearings, (c) deflated stock price index, (d) deflated silver price, (e) deflated U.S. banknotes price. In specification (4), control is (a); in specification (5), controls include (a), (b) and (c); in specification (6), controls include (a), (b), (c), (d) and (e). Standard errors are in parentheses. *: p<0.10, **: p<0.05, ***: p<0.01.

Table 3.15: The Effect of News of the Currency Reform and Repayment Multipliers on Other Asset Prices

Dependent Variable: Other Asset Price Growth Rate, $\dot{q}_t$						
	Clearings	Gold	Silver	Stocks	U.S. Notes	HK Notes
Positive $Multipliers_t$	-.028	-7e-4	-.025	.061	-.001	-.019
	(.062)	(.051)	(.029)	(.056)	(.055)	(.048)
Negative $Multipliers_t$	-.084	-.040	.016	-.068	-.054*	-.045
	(.058)	(.032)	(.041)	(.056)	(.032)	(.032)
Positive $Reform_t$	.008	-.021	-.003	.014	-.021	-.021
	(.045)	(.037)	(.017)	(.017)	(.038)	(.048)
Negative $Reform_t$	.068	-.047	-.019	.004	-.054	-.086
	(.231)	(.038)	(.023)	(.030)	(.039)	(.080)
$Interest_t$	-.295*	.180	.067	-.150*	.080	-.194
	(.170)	(.267)	(.154)	(.083)	(.273)	(.392)
$Battles_t$	-1.4e-4	-1.1e-4	9.6e-7	5.5e-5	-7.5e-5	3.4e-5
	(1.2e-4)	(9.0e-5)	(8.7e-5)	(1.2e-4)	(1.0e-4)	(7.7e-5)
Constant	.068**	-.023	-.003	.012	.008	.032
	(.032)	(.056)	(.032)	(.031)	(.057)	(.066)
Obs.	112	106	102	90	106	66
R^2	0.033	0.037	0.012	0.077	0.035	0.089

Notes: This table reports OLS regression results of the specification in Equation 3.3. Standard errors are in parentheses. *: p<0.10, **: p<0.05, ***: p<0.01.

CHAPTER 4

Shock Propagation Through a Production Network: The Effect of Bombings on Germany's Production

4.1 Introduction

The complex production network has obtained increasing interests from economists and policymakers, as they have recently noticed that an idiosyncratic shock on one firm can propagate throughout the supply chain to other decentralized production units, which may lead to an aggregate risk unexpectedly.

Despite multiple theoretical explanations for propagation channels, identifying an exogenous shock at firm or regional levels appears challenging. To find an approach, a collection of recent papers made use of natural disasters and their aftermath. Barrot and Sauvagnat (2016) combined the U.S. county-level data on the frequency of natural disasters with the firm's identity information of its customers.They found that shocks to suppliers cause their direct customers to reduce output sharply. Similarly, Boehm et al. (2019) documented that American affiliates of Japanese multinationals incurred significant loss in output for months after the Great East Japan Earthquake of 2011. This provided evidence for cross-country transmission of shocks. Another study on the same earthquake was conducted by Carvalho et al. (2021). They showed that the disruption caused by the earthquake and its aftermath propagated upstream and downstream production networks, and these influenced the direct and indirect suppliers and customers of disaster-stricken firms.

Inspired by those papers on natural disasters, I started to make use of a newly established dataset of the Allied strategic bombings during the Second World War (hereinafter referred to as WWII). During WWII, the Allied strategic bombing was used to destroy the Axis' industrial capacity and political infrastructure, rather than purely military targets. It has been long believed that strategic bombing played a crucial role in defeating the Axis powers in late period of WWII (Biddle, 1995). Since strategic bombing directly aims at production units, and its magnitude can be easily measured by tonnage or frequency, it provides a good entry to examining the impact of a negative shock caused by bombing on production network in Nazi Germany.

My theoretical framework most closely relates to a recent collection of works such as Baqaee (2018), Bigio et al. (2016) and Carvalho et al. (2021) that concentrate on how input-output linkages play as a mechanism for propagation and amplification of shocks. They regard each goods as an input for producing every other goods, thereby building input-output linkage. However, in order to get an explicit solution I simplify the setting: each intermediate product is made by labor only, and a final good can not be used as an input. This simple supply chain structure allows me to derive upstream, downstream and horizontal propagation of a negative productivity shock. I will also show that some propagation depends on the input-output linkage. Generally, the empirical test verifies the predictions from the theoretical model.

Using bombing data as an exogenous variable is of long-standing interest to academics. For instance, Davis and Weinstein (2002) (Weinstein and Schell (2012)) consider the distribution of economic activity in Japan from the Stone Age to the modern era. In their work, the Allied bombing of Japanese cities in WWII is regarded as a shock to relative city sizes. However, to the best of my knowledge, my current research is the first one to investigate the propagation mechanism of the supply chain through bombing data.

The remainder of this chapter is organized as follows. Section 4.2 provides a brief description of the Allied strategic bombing towards Germany and Germany armament production. Section 4.3 introduces the theoretical model of supply chain in a wartime economy context, and derives multiple predictions which can be tested. Section 4.4 describes the data and present empirical specifications. Section 4.5 illustrates all the estimation results. Section 6 concludes.

4.2 Historical Background

Soon after WWII, the United States Strategic Bombing Survey (Survey, 1945) produced assessments on the effects of Anglo-American strategic bombing of Nazi Germany and Imperial Japan, of which the session towards Germany was named “The Effects of Strategic Bombing on the German War Economy”. The report viewed the contributions of Allied bombing as “decisive” towards victory. The Survey pointed out multiple successes against crucial industries (such as bombings against oil plants, ammunition plants, vehicle MFG., and submarine production). It also mentions several failures (ex. the attack on aviation, tanks and armored vehicles, ball bearings, V-weapons, steel and consumer Goods).

According to a newly digitized resource named Theater History of Operations (hereinafter referred to as THOR (1945)) Data: World War II , established by the Defense Digital Service, the Allied air force had operated a total of 178,281 bombing missions throughout WWII. Among these missions, 95,827 were targeted towards locations in the European theatre, and 61,742 were directly aimed at Germany. The total tonnage of bombs dropped over Germany was 1,993,336, constituting 64% and 47% of the total amount of bombs dropped on Europe and of the whole world, respectively.

As is shown in Figure 4.1, although Nazi Germany incurred air attacks as early as mid-1940, the Allied strategic bombing had not reached such a large scale until 1943. After July 1944, the Allied sped up bombing operation until the war ended.

I analyzed the target characteristics which is summarized in Table 4.3 and Table 4.4 in the appendix, and found that three types of targets had incurred air attack the most: (1) transportation infrastructure (mainly on bridges), (2) important intermediate input plants, such as chemical plants and oil refineries facilities, and (3) some final armament production units like tank plants and aircraft MFG.s.

In sum, since German war economy manifests itself as a supply chain framework, and the Allied had chosen to attack the crucial nodes in the supply-chain, the case of strategic bombing provides a good opportunity to examine how a negative shock propagated through this production network during war time. In the next section, I will set up a simple supply-chain model and illustrate its nature.

4.3 Theoretical Framework: Supply Chain in a Wartime Economy

4.3.1 Model Setting

At this stage, I will only focus on the effect of strategic bombing on armament production and military production itself. The civilian production/consumption side is not taken into account and neither is the trade-off between "Butter and Gun". Also as known, Nazi Germany war economy is highly centralized, and therefore only a social planner problem matters. However, in the light of the standard context of the welfare theorem, I will still use "implicit price" terms for analysis.

As an initial step, consider a static war economy consisting of two types of goods: m distinct intermediate goods (such as raw chemicals for producing explosives, and parts and components used for weapon assembly), denoted by $j \in \{1, 2, ..., m\}$ and n final goods (such as tanks, airplanes, and trucks) denoted by $i \in \{m + 1, ..., m + n\}$. Each goods is uniquely produced by one firm, thus I will use i and j to refer to a firm or a product interchangeably.

There is 1 unit of labor employed. To make the model simple, assume that each intermediate goods is produced only by labor, with a constant return to scale:

$$X_j = \varepsilon_j L_j \tag{4.1}$$

where l_j is the labor employed by firm j, and $\varepsilon_j \in [0,1]$ is the productivity shock incurred by an intermediate goods firm. $\varepsilon_j = 1$ represents the productivity level of intermediate sector j without being bombed.

Each final goods is made only by intermediate goods:

$$Y_i = (M_i)^{z_i} \tag{4.2}$$

where $z_i \in [0, \bar{z}_i]$ is the corresponding productivity shock faced by a final goods firm. $\bar{z}_i$ denotes the productivity level if final goods sector i does not incurs bombing. M_i is the intermediate goods bundle, given by:

$$M_i = [\sum\nolimits_{j=1}^{m} A_{ij}^{\sigma} X_{ij}^{1-\sigma}]^{\frac{1}{1-\sigma}} \tag{4.3}$$

where $\sigma \geq 0$ is the elasticity of substitution between different intermediate goods x_{ij} used the by firm i. A larger coefficient $A_{ij} \geq 0$ assigns more weight of an intermediate goods j as an input for producing the final goods i. If $A_{ij} = 0$ then producing i does not need any j. Assume for some final sector i all weights sum to: $\sum_{j=1}^{m} A_{ij} = A_i$. Let matrix $\Lambda = [A_{ij}]$ be the inter-firm input-output linkage. Note that A_i is not normalized to 1 since each support of ε_j has been normalized to be [0,1].

Market clearing requires:

$$\sum_j L_j = 1 \tag{4.4}$$

and

$$\sum_i X_{ij} = X_j \tag{4.5}$$

There are two reasons for excluding labor in production of final goods: (1) for producing technology-specific armament final goods such as tanks and aircrafts, it seems infeasible to arbitrarily allocate labor across distinct sectors. Thus, in this case, it seems less important to discuss substitution between labor and intermediate goods in the production of final goods; (2) the absence of labor input in the production function leads to a simple and closed solution.

Let's assume that the dictator of this war economy only cares about its safety brought by defense power, which is constituted by the defense utilities from consuming armament final goods:

$$U(Y_{m+1}, Y_{m+2}, ..., Y_{m+n}) = \sum_{i=m+1}^{m+n} log(Y_i) \tag{4.6}$$

Note that here all final weapon goods are perishable and thereby consumed at once as established.

Current model characterizes the supply chain as consisting of two layers, one layer of upstream firms (interchangeably for intermediate sectors/firms), and one layer of downstream firms (interchangeably for final goods firms), as shown in Figure 4.2. This simplification of the production network will help me make more use of the existing production data with regard to the following empirical work, because it predominantly covers those armament sectors that only produce a final product.

4.3.2 Downstream Propagation in a Supply Chain

Thereafter, I turn to analyze the supply chain and all calculations and proof details are put into the appendix in the end.

Before presenting my main results, I put here some explicit solutions:

$$\frac{X_{ik}}{X_{ij}} = \frac{A_{ik}}{A_{ij}} (\frac{\varepsilon_k}{\varepsilon_j})^{\frac{1}{\sigma}} \tag{4.7}$$

$$X_{ij} = \frac{A_{ij} \varepsilon_j^{\frac{1}{\sigma}} z_i}{[\sum_p z_p] \cdot [\sum_k A_{ik} (\varepsilon_k)^{\frac{1-\sigma}{\sigma}}]} \tag{4.8}$$

$$L_j = \frac{\varepsilon_j^{\frac{1-\sigma}{\sigma}} \sum_i A_{ij} z_i}{[\sum_i z_i] \cdot [\sum_k A_{ik} (\varepsilon_k)^{\frac{1-\sigma}{\sigma}}]} \tag{4.9}$$

It is easy to show that $\frac{\partial X_{ij}}{\partial \varepsilon_j} > 0$, $\frac{\partial L_j}{\partial \varepsilon_j} > 0$, and $\frac{\partial X_{ij}}{\partial \varepsilon_k} < 0$, $\frac{\partial L_j}{\partial \varepsilon_k} < 0$ for any $k \neq j$. These imply that a higher productivity level in certain upstream sector allows its downstream firm to substitute its input for other inputs, and more labor will be employed in this intermediate sector accordingly. Although in a social planner context, this can be derived from the standard analysis of a supply shock with "implicit prices".

Based on these basic steps, the following proposition answers the main question of this chapter: under which conditions will a negative shock be propagated from an upstream firm to a downstream one?

Proposition 1 *A negative productivity shock (from bombing) on the production of an intermediate input j will lower its final output i.*

The above proposition describes the basic channel of how a bombing towards an upstream (intermediate) sector affects its downstream (final) production. A negative shock on ε_j suppresses supply of j. Its "implicit price" goes up, thereby its user i employs less of i input. Notice from equation (7), constant elasticity of substitution in final goods i's production yields a "homothetic preference" across intermediate inputs $\{X_{ij}\}$, which implies that usage of other inputs increases proportionately. However, this substitution can not fully compensate for the effect of decline in supply of i. In other words, the income effect due to "expensive" i exceeds the substitution effect in a standard CES function.

Therefore, Proposition 1 provides a simple hypothesis to be tested: given other factors fixed, more destruction towards an upstream firm leads to lower output in a downstream firm. An illustration is as shown in Figure 4.3.

From Proposition 1, we can also get three simple corollaries:

Corollary 1 *If $A_{ij} = A_i$, then $\frac{\partial^2 Y_i}{\partial \varepsilon_j^2} \lesseqgtr 0$, for $z_i \lesseqgtr 1$.*

Corollary 1 provides an opportunity to check the range of productivity level z_i of some specific final sector i in my theoretical framework: just to see whether the marginal effect on a single-input firm from bombing is supplier will vary as bombing continues. We call i a productive final goods firm if $z_i > 1$. Then Corollary implies that a single-input downstream firm can resist more negative shocks from its upstream supplier if it is a productive firm.

Corollary 2 *For any two intermediate sectors j and k, $\frac{\partial Y_i/\partial \varepsilon_j}{\partial Y_i/\partial \varepsilon_k} = \frac{A_{ij}\varepsilon_j^{\frac{1-2\sigma}{\sigma}}}{A_{ik}\varepsilon_k^{\frac{1-2\sigma}{\sigma}}}$.*

Corollary 2 says that when around a similar productivity level, a negative shock on a more important input will impede production of final goods more severely than that on a less important one. Practically, we can believe that two intermediate sectors j and k without any destruction at some point, share the same productivity level as $\varepsilon_k = \varepsilon_j = 1$. Then a larger decline in production of final goods due to the shock on one input relative to another implies the former input plays a more important role in producing this final goods.

4.3.3 Upstream and Horizontal Propagation

Since under the conditions stated in Proposition 1, a negative shock can propagate from an upstream sector to a downstream one, it is natural to ask whether a shock can be transmitted in other directions. The following proposition shows that not only can a shock on a final sector spread to its upstream suppliers, but also it can be passed to a horizontal firm which produces another kind of final goods.

Proposition 2 *A negative productivity shock (from bombing) on the production of final goods i*

(a) will certainly increase the output in every other intermediate sector which is not its upstream supplier;

(b) will certainly stimulate the production of other final goods p;

but

(c) will lower the output of its supplier j, only if on average j plays a relatively more important role in i's production than in production of other sector k, especially for those k with a higher productivity level. Mathematically, $\frac{\partial X_j}{\partial z_i} > 0$ *if* $\sum_{k \neq i} z_k [\frac{A_{ij}}{\sum_t A_{it}(\varepsilon_t)^{\frac{1-\sigma}{\sigma}}} - \frac{A_{kj}}{\sum_t A_{kt}(\varepsilon_t)^{\frac{1-\sigma}{\sigma}}}] > 0$.

The explanation for part (a) is similar to (b).

The intuition of part (b) is that as bombing destroys some capacity in final sector i, its "demand" for the input from its suppliers (such as j) decreases, which also suppresses the "implicit price" of these inputs relative to other intermediate goods. There are two cases here:

Case 1: Some final sector p also uses some of these inputs, as displayed in Figure 4.4.

A lower "implicit price" of these inputs encourages sector p to employ more of them, according to the "homothetic preference" shown in equation (7), p will simultaneously employ more of other inputs even though their "prices" don't change, thereby expanding production.

Case 2: Some final sector p does not use any of these inputs, as displayed in Figure 4.5.

Although p is not directly linked to these suppliers, it can be indirectly affected by connecting to some other final sector t. As t partly shares the inputs with the original final sector i, and partly shares the inputs with p, the decrease in price will propagate from beginning to the end (ex. in Figure 4.5. The channel is $i \to j \to t \to j+1 \to p$). Eventually, p will also employ more of all inputs, and production will increase.

Figure 6: Upstream/horizontal shock propagation when p is not directly linked to i

The test for part (a) is limited, because I only have the production information of one intermediate good, "Explosives". More details of testing will be presented in the next two sections.

Part (b) in Proposition 2 can be easily tested.

The mathematical statement for part (c) is troublesome, but the intuition is that in order to significantly influence one of its upstream suppliers, one final sector must be the major customer of this supplier among all the other firms that produce final goods. Since it is very difficult to check the condition in part (c), I may do it in an opposite way: to select two inputs for one final goods, and to pick out which one weighs more in producing this final output.

4.3.4 Potential Extensions to the Model

The dataset of Germany armament production also includes the information of "Anti-aircraft Gun" and "Fighter" sectors. As known, these two types of weapons can effectively protect civilian and military units from air strikes. Therefore, the production of anti-aircraft guns and fighters can endogenously affect productivities of other sectors, which leaves an interesting but a more complicated context for me. To put it simply, I plan to incorporate some endogeneity element into productivity shocks faced by the intermediate sector and the final sector, writing them as $\varepsilon_j(Y_a, Y_f)$ and $z_i(Y_a, Y_f)$, where Y_a and Y_f denote the output in anti-aircraft gun and fighter production units, respectively. Basically, it is similar to the R&D sector in a growth model.

Another direction for extending this paper is to rebuild a dynamic model, because in reality Nazi Germany might have restored parts and components or even finished weapons underground as an response to bombing.

Finally, when I have access to more data of labor and capital stocks, I may rewrite my final goods production function and also examine the effect of supply-chain on labor and capital reallocation.

4.4 Empirical Specification

4.4.1 Data

The data of Nazi Germany armament production comes from statistics tables in the book "*Die Deutsche Industrie im Kriege 1939-1945*" (Wagenführ, 1968). It dates monthly from January 1942 to January 1945 and covers 1 aggregation series, 15 group series, and 34 sector series. Most series contain 37 data points of production index (some contain 35 or 36), representing the trend of production in each sector. Most sectors set its production index in January 1942 to around 100. At its peak of production, each sector on average reached an index as 4-6 times as large as its initial level.

A statistics summary of this production data is displayed in Table 4.1 and Table 4.2 in appendix.

It is unknown whether those index only represent the armament production units in Germany mainland, or also cover those in its vassal countries (such as Romania and Bulgaria) or its occupied countries (such as France). The production data I have are aggregated without any geographic distribution information.

On the other hand, the bombing data from THOR (1945) mentioned in section 4.2, is in every detail. It covers ten thousands of air bombing missions throughout World War II, with information of date, target country, target industry, code, bombing location, tonnage of bombs, etc.

To match these two data sets, I presume that all the armament production units were located in Germany mainland, and thereby I focused on the bombings that were targeted for Germany territory. I sorted the bombing data by "target industry", deleted some irrelevant points, and then obtained 33,800 effective bombing observations which are summarized in Table 4.3 and Table 4.4. Furthermore, for these observations, I summed all the tonnage of bombs on each target industry within each month from January 1942 to January 1945.

Eventually, I created a data set of 496 observations with a positive bomb tonnage, and 1,206 observations with a 0 bomb tonnage, completely matching the production index panel.

4.4.2 Assumptions and Hypotheses

In the current model, multiple assumptions need to be restated or clarified before testing:

Assumption 1 *Tonnage of bombs dropped on each target industry is viewed as exogenous*

Assumption 2 *The total amount of labor was not reduced by bombings*

Assumption 3 *In each period, the negative shock from bombing is measured by total bomb tonnage of the same period*

Due to data availability, I can only test the propagation of the negative shock caused by bombing across industries rather than across firms as stated in Section 4.3. In addition, as all my production data are related to final weapon goods, only two of the propagation channels stated previously can be tested: (1) from an upstream intermediate industry to a downstream weapon industry, and (2) from one weapon industry to another weapon industry.

Notice that although in theoretical model, all final goods share the same inputs pool linked by the matrix $\Lambda = [A_{ij}]$, regressing each output on all inputs (or the shock to each input) is infeasible due to collinearity. Therefore, I will not put all final sectors together, but concentrate on those that are similar to each other.

Based on current datasets and the results in the previous section, three shock propagation channels/hypotheses can be tested:

The downstream channel:

(A) Given other factors fixed, more destruction towards an upstream firm leads to lower output in a downstream firm; in Figure 4.3, it refers to channel $j \to i$.

The upstream and horizontal channels:

(B) A negative productivity shock from bombing to the production of final goods i will increase the production of another final goods p; in Figure 4.4 or 4.5, it refers to channel $i \to j \to ... \to p$,

and

(C) it will certainly increase the output in each of the other intermediate sectors which are not its upstream suppliers; in Figure 4.5, it refers to channel $i \to j \to t \to j+1$.

Note that in all 50 series, there are only 2 final goods sectors that employ one unique input for production: "Powder Group" and "Explosive Group". They both only use an input from "Chemical Plants" (Target ID: 43, i.e., ID^{43} thereafter). Also note that in all 46 types of targets, there are only 5 final goods sectors: "Aircraft Factories and Assembly Plants" (ID^{11}), "Tank Factories" (ID^{21}), "Vehicle MFG. Plants" (ID^{22}), "Explosives MFG. Plants" (ID^{23}), and "Ship Building" (ID^{75}).

As an initial step, I will test (1) and(2) together with a specification as below:

$$Final_{it} = \alpha_i + \beta_i ID_t^{43} + \gamma_i ID_t^{43} \cdot AID_t^{43} + \delta_i ID_t^{23} + \lambda_i' Other_t + \theta_i t + \varepsilon_{it} \tag{4.10}$$

where i="Powder" or "Explosive"; ID_t^k denotes the tonnage of bombs dropped on the sector with ID k in month t, which is a measure for negative productivity shock; $Other_t = [ID_t^{11}, ID_t^{21}, ID_t^{22}, ID_t^{75}]'$; AID_t^{43} means the accumulated tonnages of bombs dropped on the sector with ID 43 before month t.

If the above hypothesis (A) is true, I expect to see a significantly negative β_i; if hypothesis (B) is true, I will find a positive coefficient vector λ. The coefficient of cross-term between ID_t^{23} and AID_t^{23} is used to quantify the additional marginal impact from current bombing which relates to current productivity level, i.e., the bombing history. If γ_i turns out to be significantly positive, i is a productive firm according to Corollary 1. δ_i measures how bombing towards an Explosive Plant directly affects the production by itself, and its reasonable value should be negative. Finally, θ_i measures the time trend.

It is interesting to find that Explosive Plant ID^{23} is the only sector which can produce both intermediate goods (ex. provided as an input for producing ammunition) and final goods. This allows me to test hypothesis (C) by finding its unique downstream firm V-weapon Plants (ID^{16}) in my dataset. The estimation equation is written as:

$$Intermediate_{jt} = \phi_j + \varphi_j \cdot ID_t^{16} + \mu_j' \cdot Other_t + \zeta_j \cdot ID_t^{23} + \psi_j \cdot t + \epsilon_{jt} \tag{4.11}$$

where j="Powder" or "Explosive" are both intermediate goods produced by the Explosive Plant, except for ID^{16} all the other variables are defined as the same as in equation (10). If hypothesis (C) is true, then μ_j is a positive vector. According to equation (21) in the appendix, ζ_j should be negative. If φ_j is significantly negative, then this means that j is a relatively important input for producing V-weapon according to part (c) of Proposition 2.

4.5 Empirical Results

The estimation results for equation (10) and (11) are summarized in Table 4.5 and Table 4.6.

As can be seen in Table 4.5, if the "Explosive" is regarded as a final goods, its production in month t is significantly hurt by the propagation of a negative shock (which is measured by the current tonnage of bombs) incurred by its unique upstream supplier "Chemical Plant" during the same month. The weak correlation between the cross-term and output implies that the marginal effect of bombing towards intermediate goods is constant, not depending on previous damages. In this case, the "Explosive" is a regular sector, neither productive nor unproductive. In addition to a positive time trend, its production is significantly harmed by the direct bombing towards the "Explosive Plant" itself. Also, a bombing shock is propagated horizontally from another sector "Vehicle Plants", and its positive coefficient verifies what hypothesis (B) predicts.

On one hand, the production of "Powder", however, manifests itself differently. Firstly, bombing on its supplier in the current period has little impact. Instead, the damage of bombing accumulates, and comes into effect, which displays the unproductive profile of the "Powder" sector. An expected horizontal propagation is also found from "Vehicle Plants", while performance of other variables is not as expected.

On the other hand, Table 4.6 shows "Explosive" is an important input for its downstream final sector V-weapon relative to "Powder" with a significantly negative coefficient φ_j. The upstream and horizontal propagation of shock as displayed in Figure 4.5 is partly confirmed by positively significant coefficients of ID_t^{11} (Aircraft Factories) and ID_t^{22} (Vehicle Plants). In other words, Hypothesis (C) is partially confirmed.

4.6 Conclusion

The preliminary model in this chapter consists of a two-layer supply chain in a static and closed economy: upstream firms employ labor to make intermediate products, and then supply them to downstream firms for production of final goods. Within the production network, a negative productivity shock like bombing can be transmitted from a sector to another by altering the relative "implicit prices" among goods. The propagation of shock may proceed downstream, upstream or horizontally. It derives from my simple setting that (1) a negative shock incurred by a sector may also adversely affect the production of another sector if they are directly connected to each other; (2) if there is no direct connection between two sectors, then bad news to one will in turn stimulate the other's production. The bombing and production dataset allows me to empirically test these propagation channels. The estimations on "Powder" and "Explosive" basically admit the propagation effect through the production network, and partly support my results derived from the baseline model.

Certainly, some mismatch between the production data and bombing data limits the test on upstream propagation. For downstream shock transmission, I only test two sectors, not only because currently I focus on those final sectors that use only one input, but also due to my limited knowledge of the composition of intermediate goods. These limitations in turn shed light on the directions of my future research. On one hand, I will investigate the current data set more deeply to fully comprehend its cross-sectional and time trend characteristics. For example, as bombing not only affects the production of an intermediate product, but also influences its transportation and storage, controls like bombs on bridges, rail tracks and Supply Dumps need to be taken into account further. Furthermore, German's investment in air defense also has an impact on the supply chain by producing more anti-aircraft facilities. On the other hand, as new data sources are discovered, I may extend the baseline model to a more complicated framework in which a final product can be also used as an input for another sector.

The strategic bombing records provide abundant information for researching the nature of the supply chain, thereby encouraging more interesting and challenging studies.

4.A Appendices

4.A.1 Proof of Propositions

4.A.1.1 Proof of Proposition 1:

Set Lagrangian function for the social planner problem:

$$\underset{\{L_j\},\{X_{ij}\},\{\lambda_j\},\mu}{Max} L = \sum\nolimits_{i=m+1}^{m+n} log(Y_i) + \sum_j \lambda_j [X_j - \sum_i X_{ij}] + \mu(1 - \sum_j L_j) \tag{4.12}$$

The first-order conditions imply that

$$\lambda_j \varepsilon_j = \mu \tag{4.13}$$

$$\frac{z_i A_{ij}^{\sigma} X_{ij}^{-\sigma}}{\sum_j A_{ij}^{\sigma} X_{ij}^{1-\sigma}} = \lambda_j. \tag{4.14}$$

Combined with (4) and (5), we have

$$\frac{X_{ik}}{X_{ij}} = \frac{A_{ik}}{A_{ij}} (\frac{\varepsilon_k}{\varepsilon_j})^{\frac{1}{\sigma}} \tag{4.15}$$

$$\mu = \sum_i z_i \tag{4.16}$$

These imply that

$$X_{ij} = \frac{A_{ij} \varepsilon_j^{\frac{1}{\sigma}} z_i}{[\sum_p z_p] \cdot [\sum_k A_{ik} (\varepsilon_k)^{\frac{1-\sigma}{\sigma}}]} \tag{4.17}$$

$$L_j = \frac{\varepsilon_j^{\frac{1-\sigma}{\sigma}} \sum_i A_{ij} z_i}{[\sum_i z_i] \cdot [\sum_k A_{ik} (\varepsilon_k)^{\frac{1-\sigma}{\sigma}}]} \tag{4.18}$$

These allow us to explicitly figure out the effect of intermediate goods productivity shock on final goods:

$$\frac{\partial Y_i}{\partial \varepsilon_j} = \frac{\partial Y_i}{\partial M_i} \cdot [\frac{\partial M_i}{\partial X_{ij}} \frac{\partial X_{ij}}{\partial \varepsilon_j} + \sum_{k \neq j} \frac{\partial M_i}{\partial X_{ik}} \frac{\partial X_{ik}}{\partial \varepsilon_j}] \tag{4.19}$$

where $\frac{\partial Y_i}{\partial M_i} = z_i M_i^{z_i - 1} \geq 0$, and $\frac{\partial M_i}{\partial X_{ik}} = \frac{M_i^\sigma}{\varepsilon_k z_i^\sigma}([\sum_i z_i] \cdot [\sum_k A_{ik}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}])^\sigma > 0$, $\forall k$.

$\frac{\partial X_{ij}}{\partial \varepsilon_j} = -\frac{A_{ik}A_{ij}\frac{1-\sigma}{\sigma}\varepsilon_k^{\frac{1}{\sigma}} z_i(\varepsilon_j)^{\frac{1-2\sigma}{\sigma}}}{[\sum_i z_i] \cdot [\sum_k A_{ik}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}]^2} < 0$ for $k \neq j$, and

$$\frac{\partial X_{ij}}{\partial \varepsilon_j} = \kappa \cdot \{\sum_k [A_{ik}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}] - A_{ij}(1-\sigma)\varepsilon_j^{\frac{1-\sigma}{\sigma}}\} \tag{4.20}$$

where $\kappa = \frac{A_{ij} \cdot z_i \cdot \varepsilon_j^{\frac{1-\sigma}{\sigma}}}{\sigma[\sum_i z_i] \cdot \{\sum_k [A_{ik}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}]\}^2} > 0$. Since $\sum_k [A_{ik}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}] \geq A_{ij}\varepsilon_j^{\frac{1-\sigma}{\sigma}} > A_{ij}(1-\sigma)\varepsilon_j^{\frac{1-\sigma}{\sigma}}$, we have $\frac{\partial X_{ij}}{\partial \varepsilon_j} > 0$, and

$$\frac{\partial X_j}{\partial \varepsilon_j} = \sum_i \frac{\partial X_{ij}}{\partial \varepsilon_j} > 0 \tag{4.21}$$

Therefore, the sign of $\frac{\partial Y_i}{\partial \varepsilon_j}$ is determined by

$$\left[\sum_k [A_{ik}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}] - A_{ij}(1-\sigma)\varepsilon_j^{\frac{1-\sigma}{\sigma}}\right] - \sum_{k \neq j} \varepsilon_k^{\frac{1-\sigma}{\sigma}} A_{ik}(1-\sigma) = \sigma \sum_k \varepsilon_k^{\frac{1-\sigma}{\sigma}} A_{ik} > 0 \tag{4.22}$$

4.A.1.2 Proof of Proposition 2:

Part (a): As $\frac{\partial X_{pj}}{\partial z_i} = -\frac{A_{pj}\varepsilon_j^{\frac{1}{\sigma}} z_p}{[\sum_t z_t]^2 \cdot [\sum_k A_{pk}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}]} < 0$ for any $i \neq p$, $\frac{\partial \sum_{p \neq i} X_{pj}}{\partial z_i} < 0$, which means the negative productivity shock to the production of final goods increases the output in each of other intermediate sectors which are not its upstream suppliers.

Part (b): $\frac{\partial Y_p}{\partial z_i} = \frac{\partial Y_p}{\partial M_p} \cdot [\sum_j \frac{\partial M_p}{\partial X_{pj}} \frac{\partial X_{pj}}{\partial z_i}]$, since $\frac{\partial Y_p}{\partial M_p} > 0$, $\frac{\partial M_p}{\partial X_{pj}} > 0$, and $\frac{\partial X_{pj}}{\partial z_i} < 0$, we have $\frac{\partial Y_p}{\partial z_i} < 0$.

Part (c): As $\frac{\partial X_{ij}}{\partial z_i} = \frac{A_{ij}\varepsilon_j^{\frac{1}{\sigma}}}{\sum_k A_{ik}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}} \frac{\sum_{k \neq i} z_k}{[\sum_k z_k]^2} > 0$, and $X_j = \sum_i X_{ij} = \frac{\varepsilon_j^{\frac{1}{\sigma}}}{\sum_k z_k} \sum_i \frac{A_{ij} z_i}{\sum_k A_{ik}(\varepsilon_k)^{\frac{1-\sigma}{\sigma}}}$, $\frac{\partial X_j}{\partial z_i} = \frac{\varepsilon_j^{\frac{1}{\sigma}}}{[\sum_k z_k]^2} \sum_{k \neq i} z_k [\frac{A_{ij}}{\sum_t A_{it}(\varepsilon_t)^{\frac{1-\sigma}{\sigma}}} - \frac{A_{kj}}{\sum_t A_{kt}(\varepsilon_t)^{\frac{1-\sigma}{\sigma}}}] > 0$ iff the last term in bracket is positive.

4.A.2 Proofs of Corollaries

4.A.2.1 Proof of Corollary 1:

If $A_{ij} = A_i$, then $A_{ik} = 0$ for any $k \neq j$, thus $X_{ij} = \frac{\varepsilon_j z_i}{\sum_p z_p}$, and $Y_i = [A_{ij}^{\frac{\sigma}{1-\sigma}} \frac{\varepsilon_j z_i}{\sum_p z_p}]^{z_i}$. Therefore, $\frac{\partial^2 Y_i}{\partial \varepsilon_j^2} \lesseqgtr 0$, if $z_i \lesseqgtr 1$.

4.A.2.2 Proof of Corollary2:

$\frac{\partial Y_i}{\partial \varepsilon_j} = \frac{\partial Y_i}{\partial M_i} \frac{M_i^\sigma}{z_i^{\sigma-1}} (\sum_i z_i)^{\sigma-1} \cdot [\sum_k A_{ik} (\varepsilon_k)^{\frac{1-\sigma}{\sigma}}]^{\sigma-1} A_{ij} \cdot \varepsilon_j^{\frac{1-2\sigma}{\sigma}}$ for any j, so $\frac{\partial Y_i / \partial \varepsilon_j}{\partial Y_i / \partial \varepsilon_k} = \frac{A_{ij} \cdot \varepsilon_j^{\frac{1-2\sigma}{\sigma}}}{A_{ik} \cdot \varepsilon_k^{\frac{1-2\sigma}{\sigma}}}$.

Tables

Table 4.1: German Armament Production Indices, 1942.1-1945.1

Sector	Obs.	Mean	Std.	Max	Min
Total	37	213.8	59.4	322	97
Weapons Group	37	240.7	93.1	408	98
Light Weapons	37	197.5	70.6	331	90
Heavy Weapons	37	372.5	136.2	582	97
Fighting Vehicles	37	371	228	779	96
Artillery (in total)	37	303.4	173.3	609	73
Light Artillery	37	574.5	404.8	1282	62
Heavy Artillery	37	203.5	91.5	371	77
Smoke Mortar	37	197.2	193.3	835	38
Anti-aircraft Gun (in total)	37	260	99.3	451	88
Light Anti-aircraft Gun	37	240	99.1	416	89
Heavy Anti-aircraft Gun	37	283	105	530	87
Board Weapons	37	366	203	765	93
Marine Guns	36	144	29.8	204	94
Torpedo Weapons	37	105	16.5	137	79
Tank Group Index	37	338	182	598	80
Armored Car	37	220	105	402	90
Tanker Hunter	37	907	829	2866	7
Motor Vehicles Group Index	37	121	24.1	168	60
Passenger Cars	37	112	34.9	178	29
Truck	37	154	34.2	217	69
Traction Vehicle Group Index	37	185	55	281	96
Traction Vehicle with Track	37	342	183	675	83
Traction Vehicle without Track	37	148	34.5	227	97

Notes: This table and the next table display the descriptive statistics of the monthly aggregate German production index and the monthly indices of 34 sectors and 14 groups. Obs: the number of monthly observations. Mean: the monthly average of observations. Std: the standard deviation of observations. Max: the maximum value of observations. Min: the minimum value of observations. Source: Wagenführ (1968)

Table 4.2: German Armament Production Index, 1942.1-1945.1 (Continued)

Sector	Obs.	Mean	Std.	Max	Min
Aircraft Group Index	37	209	66.5	367	88
Military Aircraft	37	443	321	1130	99
Attack Aircraft	37	123	43.5	179	21
Fighter	37	353	164	731	98
Transport Aircraft	37	182	122	443	0
Transportsegler	37	43	41.2	191	0
Shipbuilding Group	37	159	36.3	233	90
Ammunition Group	36	238	65.2	335	98
Light Ammunition	36	465	238	861	92
Heavy Ammunition	36	804	332	1319	70
KWK Ammunition	36	543	323	944	66
Artillery and Thrower Ammunition	36	554	186	773	74
Mines and Handgranate	36	988	589	2249	52
Anti-Aircraft Gun Ammunition	36	131	35.2	194	90
Board Weapon Ammunition	35	143	31.8	213	82
Throwing Ammunition	35	110	32.5	160	16
Marine Artillery Ammunition	35	88.2	23.1	168	52
Powder Group	37	179	41.4	242	97
Explosives Group	37	182	47.5	276	99

Notes: Continuing from the previous table, this table displays the descriptive statistics of the monthly aggregate German production index and the monthly indices of 34 sectors and 14 groups. Obs: the number of monthly observations. Mean: the monthly average of observations. Std: the standard deviation of observations. Max: the maximum value of observations. Min: the minimum value of observations. Source: Wagenführ (1968)

Table 4.3: Tonnages in Allied Strategic Bombing by Targets, 1942.1-1945.1

Target Industry	Target ID	Obs.	Mean	Std.	Min	Max
Cities Towns and Urban Areas	2	10,168	53.9	126.2	1	999
Public Utilities	3	125	29.4	50.3	1	518
Manufacturing Installations	9	254	35.8	72.1	1	778
Aircraft Factories and Assembly Plants	11	1,436	38.4	26.8	1	164
Engine Plants	13	535	34.2	27.6	1	110
A/C Component Plants	15	336	41.7	28.2	1	112
V-Weapon Factories	16	220	33.2	13.2	3	66
Armament and Ordnance Plants	20	380	25.4	30.0	2	399
Tank Factories	21	1,481	32.7	18.8	1	132
Vehicle MFG. Plants	22	862	31.0	20.9	1	118
Explosives MFG. Plants	23	49	41.4	37.2	1	105
Machinery & Equipment Mfg. Plants	30	26	46.0	29.4	1	102
Bearings MFG. Plants	32	252	33.9	17.4	1	85
Electrical Products MFG. Plants	33	10	32.5	39.1	1	90
Optical Products MFG. Plants	35	12	19.8	16.2	3	40
Precision Instrument MFG. Plants	36	4	43.5	1.7	42	45
Iron and Steel Production Facilities	39	207	27.8	50.0	1	407
Light Metal Plants	40	32	17.9	16.4	1	48
Aluminum Production Facilities	41	30	19.1	7.4	1	28
Chemical Plants	43	1,105	41.0	76.1	1	804
R.R. manufacturing works and roundhouses	45	246	52.3	119.7	1	999
Rubber and Tire Manufacturing Facilities	46	16	27.3	4.3	20	33

Notes: This table and the next table display tonnages in Allied strategic bombing missions across different targets. Obs: the number of missions. Mean: the average tonnage. Std: the standard deviation of tonnages. Max: the maximum value of tonnages. Min: the minimum value of tonnages. Source: THOR.

Table 4.4: Tonnages in Allied Strategic Bombing by Targets, 1942.1-1945.1 (Continued)

Target Industry	Target ID	Obs.	Mean	Std.	Min	Max
Synthetic Rubber MFG.	48	94	13.9	9.4	2	53
Oil Refineries	50	272	39.0	40.1	1	408
Natural Oil Refineries	51	936	34.8	27.8	1	150
Synthetic Oil Refineries	52	2,625	45.0	88.0	1	997
Oil Storage Facilities and Other Oil Installations	53	215	43.8	30.9	2	290
Transportation Facilities	60	99	40.1	96.8	1	591
Bridges	61	1,184	24.9	20.6	1	110
Tunnels	62	1	17	0	17	17
R.R. Installations, Tracks, Marshalling Yards	63	4,231	35.6	57.4	1	925
Moving Trains & Rolling Stock	64	4	6.5	6.4	1	12
Highways and Vehicles	65	68	24.6	21.5	1	65
Waterways and Boats	66	68	100.7	200.2	1	972
Naval Installations	70	305	21.0	22.9	1	204
Ports and Harbors	71	286	29.2	24.3	1	117
Submarine Pens and Yards	72	458	25.0	21.9	1	179
Ships	73	7	2.1	0.7	1	3
Tugs, Barges, and Sampans	74	4	35.5	0.6	35	36
Ship Building	75	143	39.6	29.9	1	108
Air Fields and Airdromes	78	2,908	29.6	28.6	1	702
Supply Dumps and Warehouses	83	675	34.3	34.6	1	752

Notes: Continuing from the previous table, this table displays tonnages in Allied strategic bombing missions across different targets. Obs: the number of missions. Mean: the average tonnage. Std: the standard deviation of tonnages. Max: the maximum value of tonnages. Min: the minimum value of tonnages. Source: THOR.

Table 4.5: Downstream and Horizontal Channel Estimation

	Explosive	Powder
ID_t^{43}	$-1.0e-2$ **	$-1.8e-4$
	$(3.9e-3)$	$(4.1e-3)$
$ID_t^{43} \cdot AID_t^{43}$	$-1.2e-7$	$-2.6e-7$ *
	$(1.3e-7)$	$(2.8e-2)$
ID_t^{23}	$-9.6e-2$ ***	$-2.4e-2$
	$(2.7e-2)$	$(2.8e-2)$
ID_t^{11}	$2.5e-3$	$-1.7e-4$
	$(1.9e-3)$	$(1.9e-3)$
ID_t^{21}	$-3.0e-3$	$-4.3e-3$ *
	$(2.2e-3)$	$(2.3e-3)$
ID_t^{22}	$1.3e-2$ **	$8.9e-3$ *
	$(4.9e-3)$	$(5.1e-3)$
ID_t^{75}	$-1.1e-2$	$5.6e-3$
	$(9.5e-3)$	$(9.8e-3)$
t	4.73 ***	3.95***
	(0.47)	(0.48)
$constant$	104.7	110.4
$Adj.\ R^2$	0.839	0.773
$obs.$	37	37

Notes: This table shows the estimation results of Equation 4.10. Standard errors are in parentheses. *: p<0.10, **: p<0.05, ***: p<0.01.

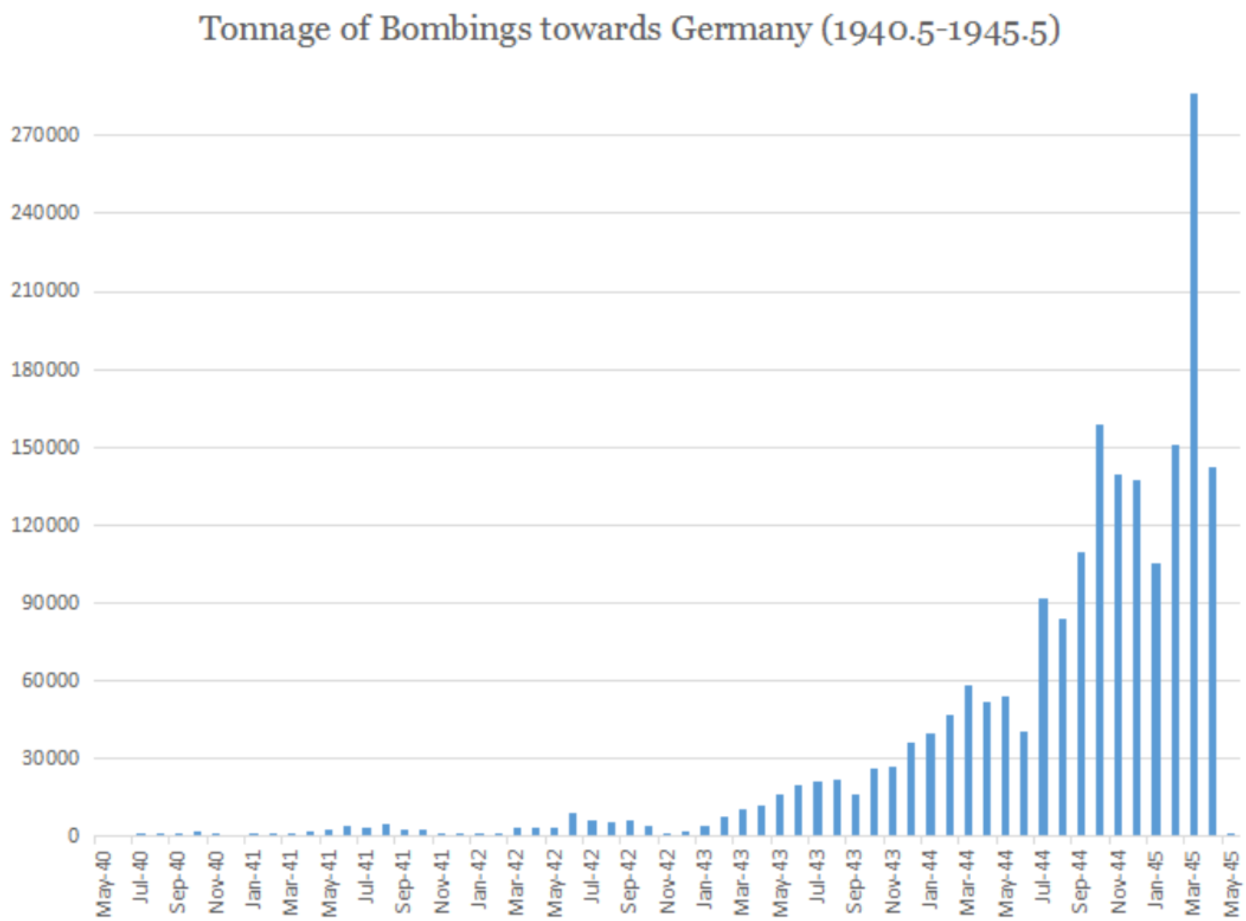
Table 4.6: Upstream and Horizontal Channel Estimation

	Explosive	Powder
ID_t^{16}	$-1.7e-2$ **	$-7.8e-3$
	$(8.3e-3)$	$(6.6e-3)$
ID_t^{23}	$6.6e-3$ ***	$9.1e-3$
	$(3.4e-2)$	$(2.7e-2)$
ID_t^{11}	$7.6e-3$ **	$3.1e-3$
	$(3.0e-3)$	$(2.4e-3)$
ID_t^{21}	$-8.9e-3$ **	$-7.8e-3$ **
	$(3.6e-3)$	$(2.9e-3)$
ID_t^{22}	$1.3e-2$ *	$1.3e-3$ **
	$(6.5e-3)$	$(5.2e-3)$
ID_t^{75}	$-1.5e-2$	$2.7e-3$
	$(1.6e-2)$	$(1.3e-2)$
t	3.10 ***	2.98***
	(0.63)	(0.50)
constant	118.9	119.7
Adj. R^2	0.600	0.661
obs.	37	37

Notes: This table shows the estimation results of Equation 4.11. Standard errors are in parentheses. *: $p<0.10$, **: $p<0.05$, ***: $p<0.01$.

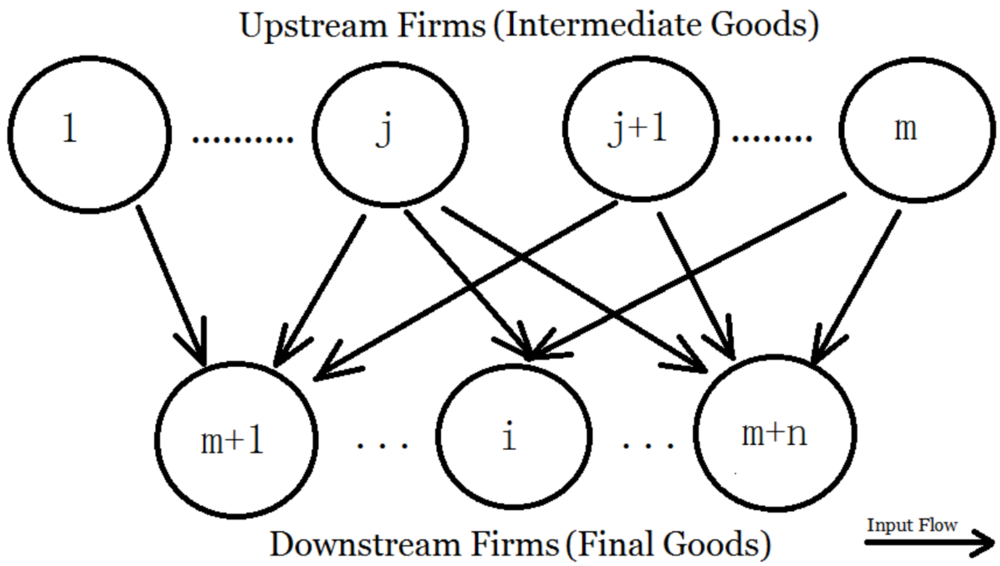
Figures

Figure 4.1: Monthly Tonnages of Bombs Incurred by Nazi Germany (1940.5-1945.5)



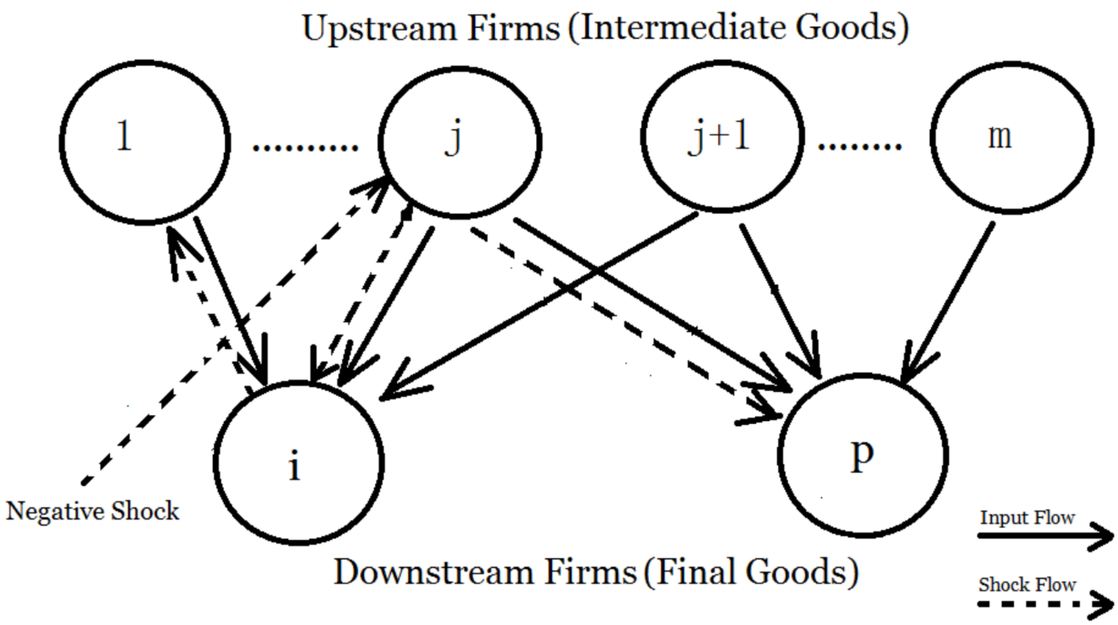
Notes: This figure shows the monthly tonnages of bombs dropped in Nazi Germany from May 1940 to May 1945. Source: THOR.

Figure 4.2: Supply Chain Illustration



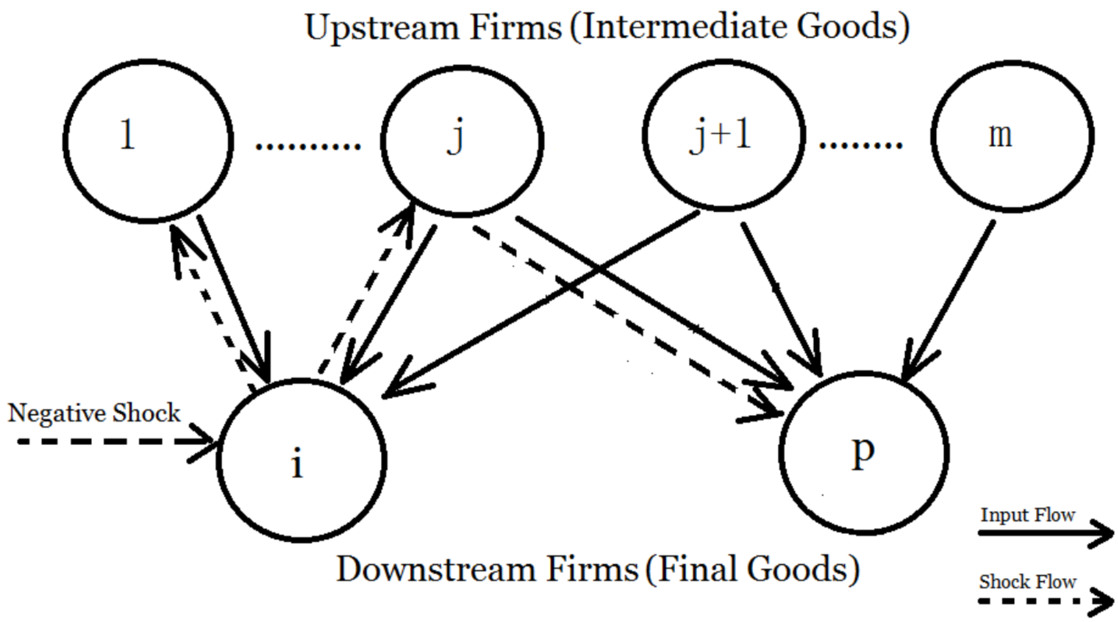
Notes: This figure shows a two-layer supply chain. Here upstream firms produced intermediate goods, which provided inputs for downstream firms. With these intermediate goods, downstream firms then produced the final goods. An upstream firm may provide inputs to one or more downstream firms. Similarly, a downstream firm may use inputs from one or more upstream firms. An arrow mark indicates an input flow direction.

Figure 4.3: Downstream Propagation of a Shock



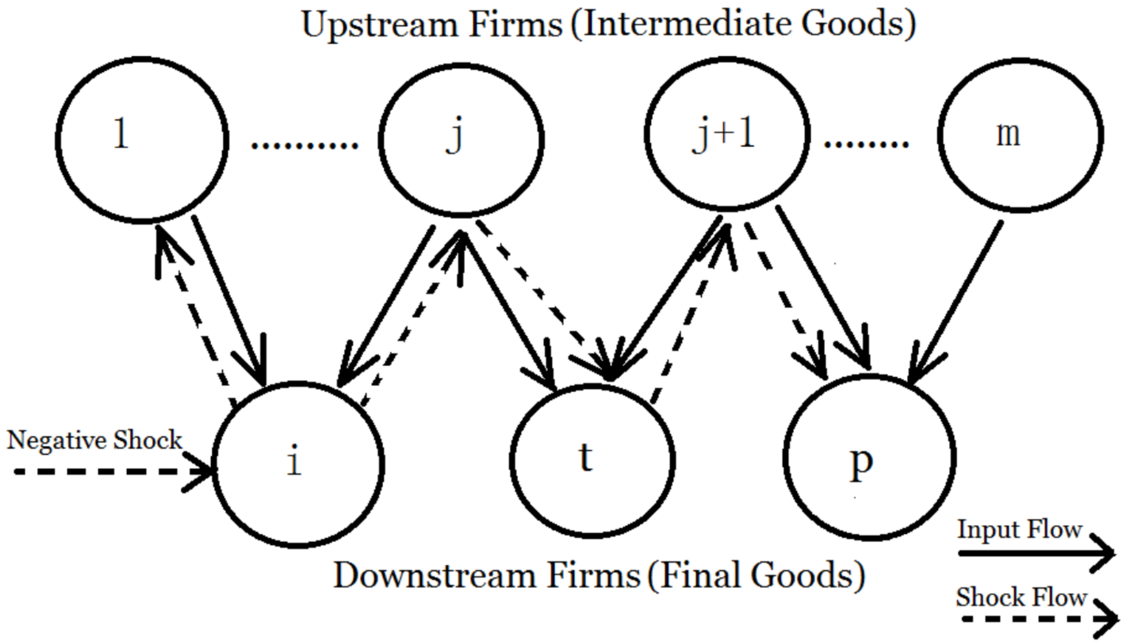
Notes: This figure shows how a negative shock that targets an upstream firm propagates throughout the production network. It can directly affect the downstream firms using the input from the upstream firm or indirectly affect other downstream and upstream firms. A solid arrow mark indicates an input flow direction and a dashed arrow mark indicates the shock's flow direction.

Figure 4.4: Upstream/Horizontal Shock Propagation When p Is Directly Linked to i



Notes: This figure shows how a negative shock that targets a downstream firm propagates throughout the production network. It can directly affect the upstream stream firms offering the input to the downstream firm or indirectly affect another downstream using the same input through a two-step propagation. A solid arrow mark indicates an input flow direction and a dashed arrow mark indicates a shock flow direction.

Figure 4.5: Upstream/Horizontal Shock Propagation When p Is Not Directly Linked to i



Notes: This figure shows how a negative shock that targets a downstream firm propagates throughout the production network. It can directly affect the upstream stream firms offering the input to the downstream firm or indirectly affect another downstream using other inputs through a multiple-step propagation. A solid arrow mark indicates an input flow direction and a dashed arrow mark indicates a shock flow direction.

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